Welcome to Burns Engineering's RTDology session: RTD Selection and Application.

There are five main areas to consider when selecting an RTD for a particular application. We'll review each of them and select features to properly address each area.

Information is the key to making the correct RTD selection. You need to know the What, Why, Where and How to achieve the best measurement possible. We'll run through a hypothetical application to demonstrate.

The application is a proprietary fluid flowing in a 4" pipe at 100 feet/second. Temperature is maintained at 150° F to maintain a viscosity near that of water. There is very little vibration in the pipe and there is a 3/4" NPT process connection for the sensor installation.

We will be selecting a platinum resistance thermometer to install in the pipe to maintain a measurement accuracy of +/- 1° F.
## Selection

- Factors to consider
  - Placement
  - Protection
  - Performance
  - Price
  - Service life

## Placement

- **Two options**
  - Surface mount
  - Immersion

For a pipe there are two options, surface mounted or immersion. The two parts on the left are just two of a wide variety of surface mount sensors available and the two on the right are examples of the two most common styles of immersion sensors (direct – top photo and thermowell – bottom photo).

Installation of a surface mount sensor can be accomplished with a hose clamp, tape, or even adhesive.

A few additional styles of surface mount sensors.
Installation is simple and the sensor is low cost. Accuracy suffers however, and we likely will not achieve the 1° F measurement accuracy requirement relative to the actual fluid temperature since the sensor is measuring the temperature of the pipe, not the fluid.

Adding insulation over the sensor will improve accuracy by shielding the sensor from ambient conditions. Calibration can be difficult because the configuration (odd shape) does not match up with most calibration baths or hot blocks.

Based on the application requirements this option receives a grade of “C”.

An immersion sensor overcomes the negatives of the surface mount and in most cases dramatically improves the measurement accuracy of the fluid itself in the pipe.

Direct immersion of a small diameter sensor gives an accurate measurement at relatively low cost. It is not always possible or desirable though because of maintenance or durability considerations.
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. A 0.25” diameter direct immersion sensor therefore would need 3.5” of immersion.

To gain additional immersion depth a tee fitting makes an excellent choice. Flow should be directly at the tip of the sensor to minimize vibration and drag effects.

This solution gets a “B” only because maintenance is difficult. The pipe has to be drained first to allow removal of the sensor. Also, the flow rate for our example will cause vibration and probable destruction of the sensor.

Adding a thermowell provides protection for the sensor and eases the maintenance. Flow induced vibration is resolved with a thermowell in our sample application.
Thermowells

- Factors to consider
  - Process connection
  - Pressure
  - Temperature
  - Corrosion/erosion
  - Drag
  - Vibration
  - Wake frequency

There are several factors to consider when selecting a thermowell. First is the process connection.

These are just a few of the several styles of process connections available. Any piping connection has been or can be adapted to a thermowell process connection.

Most metal thermowells will easily handle the temperature range of a RTD. Pressure ratings vary based on material and temperature and need to be carefully considered. Rating tables are available for standard designs.

Corrosion and erosion can quickly destroy a thermowell if not given consideration.
Material selection tables are available for numerous chemicals and conditions. This slide shows just a small sample of such a table.

Particles suspended in a fluid or powdered materials can cause erosion of the well over time. There are several materials available to slow down the erosion. Most are hard materials that are applied through a welding or plasma spraying process.

Most often, just picking the correct thermowell material is sufficient to minimize erosion concerns.

Flow induced vibration is caused by the alternating vortices that form directly downstream of a cylindrical object. They alternate in a rhythmic fashion and if the frequency matches the resonant frequency of the thermowell it will begin to vibrate and will quickly lead to failure.

This graph shows that our 0.25” diameter direct immersion sensor will vibrate due to the 100 fps flow rate. Adding the 0.75” NPT thermowell allows a comfortable margin of safety with well over 250 fps capability for the 2.5” immersion length selected.
We've protected the internal part of the sensor and now we need to look at the outside.

A connection head is the best method for external protection and provides a convenient place to attach lead wires or to house a local transmitter.

Numerous styles and materials from plastic to aluminum are available. Some carry ratings for use in hazardous atmospheres.

Heads provide protection for transmitters and local indicators.
Protection – Hazardous Atmosphere

Hazardous atmospheres require a RTD and connection head assembly that carries an appropriate rating.

Protection - Extensions

Options
- Nipple
- Nipple - coupling
- Union
  - Calibration
  - Replacement

The head is attached to the thermowell and sensor typically with a pipe nipple. The most versatile is the union connection.

Protection - Extension

Union
  - Calibration
  - Replacement
  - Orientation
  - Head temperature

In addition to making sensor removal easier, the union allows the conduit port to be rotated to line up with the facility wiring.

Approximately 3.0” is a good minimum length for an extension. This insures that the temperature in the head does not overheat from the process. Transmitters and the moisture seal on the sensor can be adversely affected by temperatures over 85°C.

Performance – Accuracy

Error Budget
- Sensor accuracy
  - Interchangeability
  - Matching to transmitter
  - Thin film or wire wound
  - Repeatable
- Measurement accuracy
  - Installation
  - Time response
  - Control system
  - Repeatable

Accuracy of the sensor and accuracy of the measurement are most times quite different. Sensor accuracy is determined mostly by the manufacturing interchangeability and the style of sensing element. The wire wound style has the widest temperature range and lowest drift.

Measurement accuracy includes the sensor accuracy and the installation effects. In addition, time response can be a large factor in the measurement accuracy.
**Performance - Stability**

- **Definition**
  - The state of being resistant to change or deterioration.

Stability or long term drift is an important consideration in selecting a RTD for best accuracy. As you can see from the graph as temperature goes up the drift becomes much more significant.

**Performance - Sensor Type**

- **Types**
  - **Elements**
    - Wire wound
    - External wound
    - Coil
    - Thin Film
    - Single or Dual

Wire wound and thin film elements in various configurations are commonly used for RTDs.

Here is a quick comparison of wire wound and thin film elements.

<table>
<thead>
<tr>
<th></th>
<th>Wire Wound</th>
<th>Thin Film</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element Resistance</td>
<td>100 ohms</td>
<td>100-1000 ohms</td>
</tr>
<tr>
<td>Accuracy 0°C/200°C</td>
<td>± 0.13°C/0.5°C</td>
<td>± 0.26°C/1.0°C</td>
</tr>
<tr>
<td>Repeatability</td>
<td>0.1°C</td>
<td>0.1°C</td>
</tr>
<tr>
<td>Time Response</td>
<td>4.0 Sec.</td>
<td>6.0 Sec.</td>
</tr>
<tr>
<td>Temp. Range</td>
<td>-200 to 500°C</td>
<td>-50 to 200°C</td>
</tr>
<tr>
<td>Vibration</td>
<td>15 g's</td>
<td>20 g's</td>
</tr>
<tr>
<td>Long Term Stability</td>
<td>-1°C</td>
<td>-1°C</td>
</tr>
</tbody>
</table>

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

Here’s a conservative example of what heating 1° F higher than necessary can cost you in energy. Accuracy saves you money.

**Performance - Cost of Inaccuracy**

- **Process Fluid:** Water
- **Flow Rate:** 100 GPM
- **Control Temperature:** 100 °F
- **Energy Cost:** 2.9¢ / KW-hour

**Annual Cost of Energy Per °F Error**

$3693 / year
### Performance - Time Response

<table>
<thead>
<tr>
<th>TIME RESPONSE</th>
<th>Direct Immersion RTDs</th>
<th>DIAMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 seconds</td>
<td></td>
<td>1/4&quot; - 1/8&quot;</td>
</tr>
<tr>
<td>4 to 6 seconds</td>
<td></td>
<td>1/4&quot;</td>
</tr>
<tr>
<td>6 to 8 seconds</td>
<td></td>
<td>1/2&quot; - 1/4&quot;</td>
</tr>
<tr>
<td>22 seconds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26 seconds</td>
<td></td>
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</tbody>
</table>

Thermowells

A tapered thermowell used in our example will have a 3 to 4 times slower response than the 0.25" diameter direct immersion sensor. This can be a big factor in accuracy for processes that are changing temperature rapidly. The sensor needs to respond fast enough to keep up with the process.

### Performance - Transmitter

- Lead wire > 250 feet (+0.16°F/100 ft)
- Accuracy
  - Matching
  - Leadwire
- Robust signal
- RFI/EMI

Adding a transmitter can improve accuracy when a long run of lead wire is required. It also provides a more robust signal that is less susceptible to interference from electro-magnetic or radio frequency interference.

### Price – Life Cycle Cost

- Initial cost
- Operating efficiency
- Product quality
- Maintenance costs
- Energy
- Down time
- Troubleshooting
- Product loss
- Overhead and inventory

The goal is to minimize the total life cycle cost of the measurement point while maximizing performance. Numerous costs need to be considered from the initial cost of the sensor to the cost of carrying a spare in inventory.

### Service Life

- Application/Environment
- Construction styles
  - wire wound
  - thin film
  - moisture seals
  - spring loading
- Original specifications
- Calibration cycles

There are many RTDs that have been in service for 20+ years. When giving careful consideration to all the selection factors a long life can be expected and at the lowest life cycle cost.
Our final choice for the application is a FM approved assembly that has a wire wound sensor with high accuracy and low drift. The addition of the thermowell provides the durability and corrosion resistance required. A union style extension will make replacement and calibration easier. We were limited in the immersion depth allowed because of the 4” pipe size. The addition of insulation around the external components of the assembly will help to minimize the affects of ambient temperature conditions on the measured temperature.

This one gets an “A”.

If you have additional questions please give us a call or visit our website. We’re happy to help!

1-800-328-3871   Extension 13 or 11
www.burnsengineering.com

Thank you for joining us for this session. Watch for upcoming RTDology events.

Let’s stay in touch. Join one of our on-line communities, or join them all if you like!

See you next time.

- The Temperature Measurement Experts at Burns Engineering