Burns Engineering, Inc.

Selection and Application
How to choose an RTD with confidence

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

Today's Discussion

- Selecting an RTD
  - Placement
    - Surface mount
    - Immersion
  - Protection
    - Hazardous atmosphere
    - Ambient temperature
    - Water
    - Corrosive/erosive
    - Sunlight
  - Performance
    - Accuracy
    - Durability
    - Long term stability
  - Price
  - Service life

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.

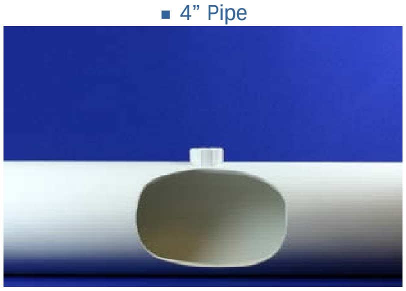
The Application

Start with the Basics & Build from there . . . tell me about your application.

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.

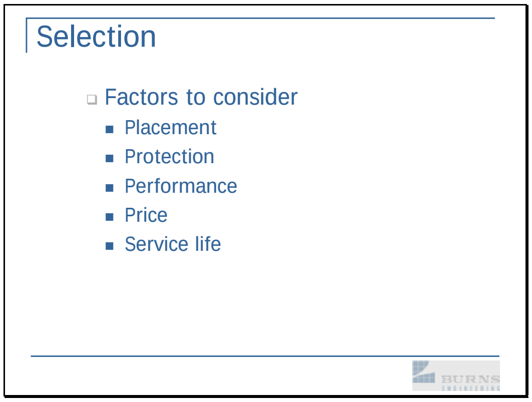
The Application

- 4" Pipe

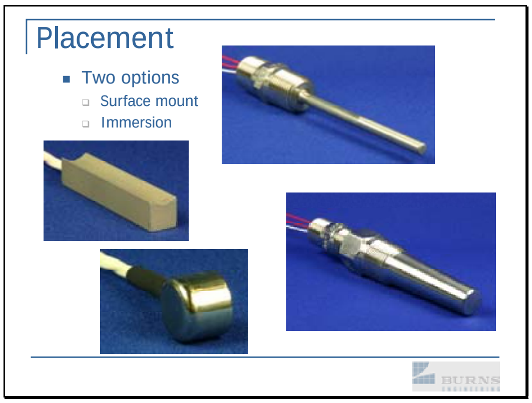


The application is a proprietary fluid flowing in a 4" pipe at 100 feet/second. Temperature is maintained at 150° F to maintain a viscosity near that of water. There is very little vibration in the pipe and there is a 3/4" NPT process connection for the sensor installation.

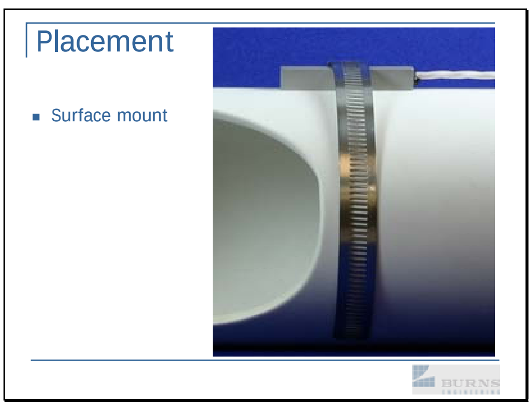
We will be selecting a platinum resistance thermometer to install in the pipe to maintain a measurement accuracy of +/- 1° F.



First we'll look at where to place the sensor for the best measurement accuracy.

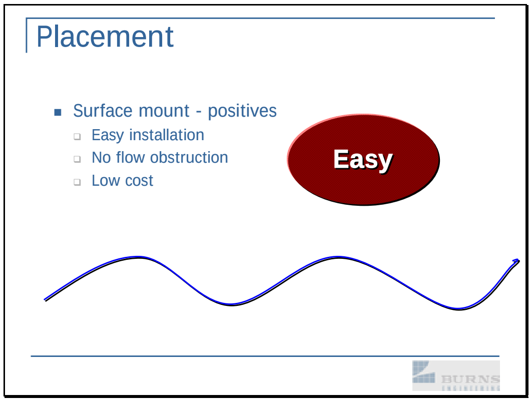


For a pipe there are two options, surface mounted or immersion. The two parts on the left are just two of a wide variety of surface mount sensors available and the two on the right are examples of the two most common styles of immersion sensors (direct – top photo and thermowell – bottom photo).

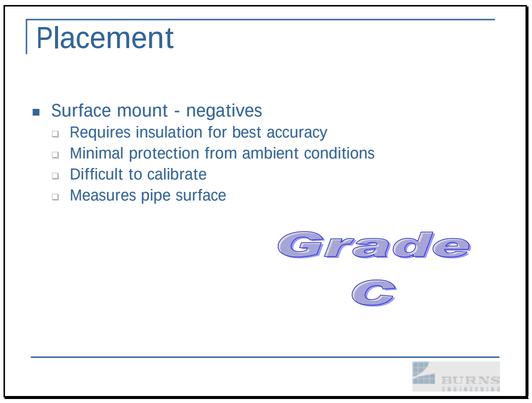


Installation of a surface mount sensor can be accomplished with a hose clamp, tape, or even adhesive.

A few additional styles of surface mount sensors.

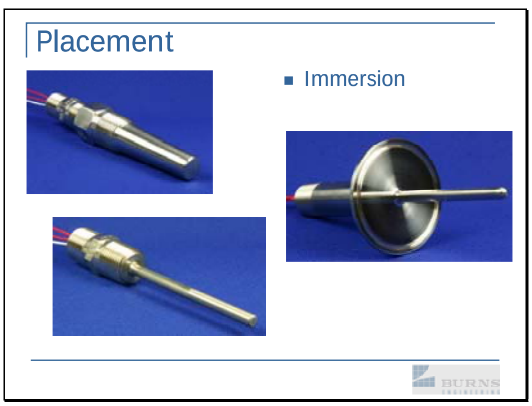


Installation is simple and the sensor is low cost. Accuracy suffers however, and we likely will not achieve the 1° F measurement accuracy requirement relative to the actual fluid temperature since the sensor is measuring the temperature of the pipe, not the fluid.

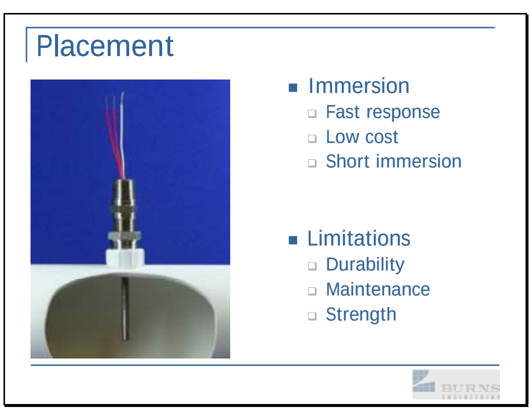


Adding insulation over the sensor will improve accuracy by shielding the sensor from ambient conditions. Calibration can be difficult because the configuration (odd shape) does not match up with most calibration baths or hot blocks.

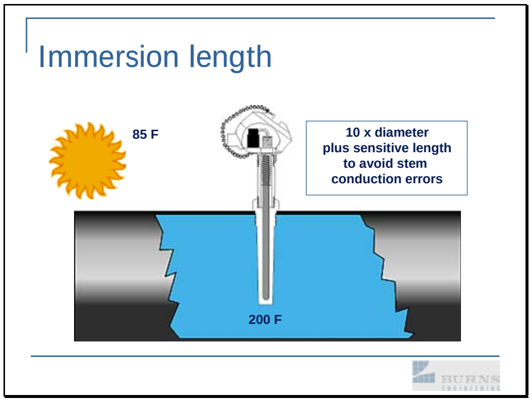
Based on the application requirements this option receives a grade of “C”.



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.

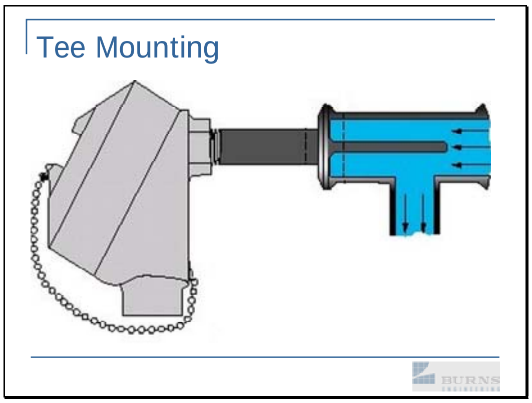


Direct immersion of a small diameter sensor gives an accurate measurement at relatively low cost. It is not always possible or desirable though because of maintenance or durability considerations.

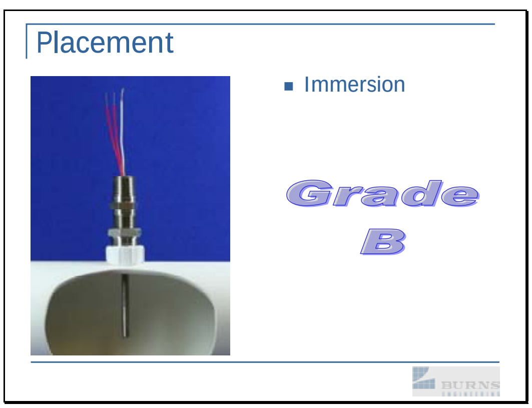


Immersion length is critical to insure an accurate measurement. Conduction error occurs when the ambient conditions affect the measured temperature. Heat conducts from the external portions to the internal and can have an adverse effect on accuracy. Sufficient immersion will nullify this effect.

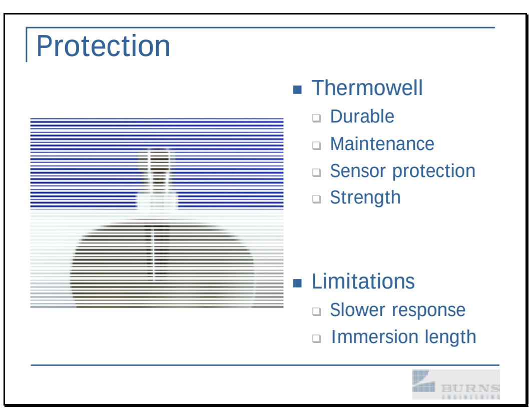
For any thermowell or direct immersion sensor the rule of thumb is 10 x the diameter plus the sensitive length. Most sensors have a 1" sensitive length. A 0.25" diameter direct immersion sensor therefore would need 3.5" of immersion.



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.



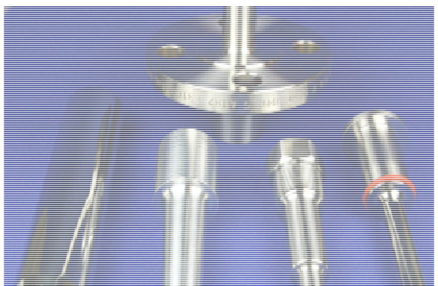
Adding a thermowell provides protection for the sensor and eases the maintenance. Flow induced vibration is resolved with a thermowell in our sample application.

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.

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.

Thermowells

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

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.

Thermowells

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

Corrosion and erosion can quickly destroy a thermowell if not given consideration.

Protection – Corrosion

Chemical	Condition	Material
Hydrogen Sulphide	Dry to 1000 F	316 Stainless Steel
Iodine	to 70 F	Tantalum
Ketones	to B.P.	Aluminum, 316 SS
Kerosene		304 Stainless Steel
Lactic Acid	to 212 F	Tantalum
Magnesium Chloride	to 40% of 212 F	Monel 400
Magnesium Sulphate	to 50% 212 F	Monel 400
Muriatic Acid	to 37% and 150 F	Hastelloy B
Naphtha	70 F	304 Stainless Steel
Natural Gas	to 800 F	304 Stainless Steel
Nickel Chloride	to 80% and 200 F	Hastelloy C
Nickel Sulphate	25% and 125 F	304 Stainless Steel
Nitric Acid	to 40% and 180 F	304 Stainless Steel
	All conc. to 370 F	Tantalum

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Material selection tables are available for numerous chemicals and conditions. This slide shows just a small sample of such a table.

Protection – Erosion

- Materials
  - Stellite
  - Wallex
  - Tungsten Carbide
  - Alumina

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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.

Thermowells

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

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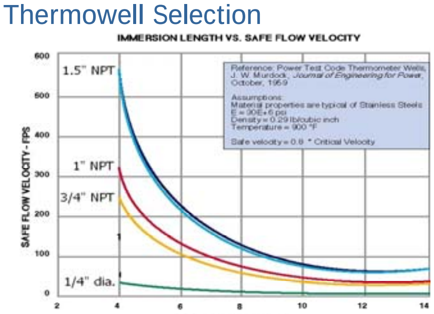
Flow induced vibration is cause by the alternating vortices that form directly downstream of a cylindrical object. They alternate in a rhythmic fashion and if the frequency matches the resonant frequency of the thermowell it will begin to vibrate and will quickly lead to failure.

Thermowell Selection



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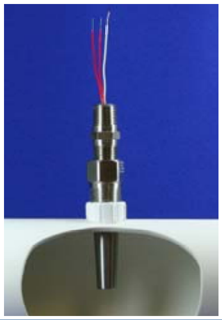
This graph shows that our 0.25” diameter direct immersion sensor will vibrate due to the 100 fps flow rate. Adding the 0.75” NPT thermowell allows a comfortable margin of safety with well over 250 fps capability for the 2.5” immersion length selected.

Protection

- Options
  - Connection head
  - Extension
  - Agency approvals



We’ve protected the internal part of the sensor and now we need to look at the outside.

Protection

- Connection heads
  - Attach extension wires
  - Protect sensor from ambient conditions

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.

Protection

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

Protection

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

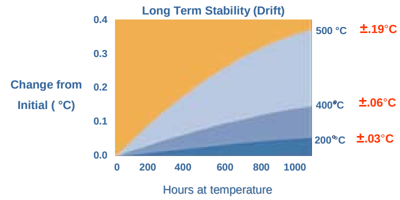
- Error Budget
  - Sensor accuracy
    - Interchangeability
    - Matching to transmitter
    - Thin film or wire wound
    - Repeatable
  - Measurement accuracy
    - Installation
    - Time response
    - Control system
    - Repeatable

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

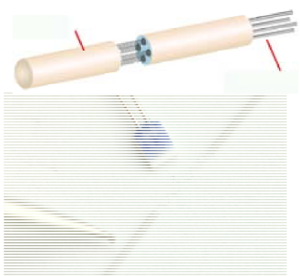
- Definition
  - The state of being resistant to change or deterioration.



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.

Performance – Sensor Type

	Wire Wound	Thin Film
Element Resistance	100 ohms	100, 1000 ohms
Accuracy 0°C/200°C	± 0.13°C/0.5°C	± 0.26°C/1.0°C
Repeatability	0.1°C	0.1°C
Time Response	4.0 Sec.	6.0 Sec.
Temp. Range	-200 to 500°C	-50 to 200°C
Vibration	15 g's	20 g's
Long Term Stability	.1°C	.5°C

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

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

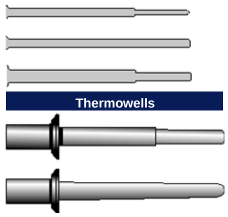
$3693 / year

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 - Time Response

TIME RESPONSE	Direct Immersion RTDs	DIAMETERS
2.5 seconds		1/4" - 1/8"
4 to 6 seconds		1/4"
6 to 8 seconds		1/2" - 1/4"
	Thermowells	
22 seconds		Stepped
26 seconds		Tapered



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

USS Constitution 1797 to present

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.

The Choice

- Features
  - FM Approved
  - High accuracy low drift
  - Maintenance
  - Durable thermowell
  - Corrosion/erosion
  - Immersion depth

Grade A!

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”.

Questions?

Contact us at 800-328-3871 ext 13 or 11
or visit www.burnsengineering.com

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 attending!

Watch for upcoming RTDology™ events

- Open forum Q & A for your temperature topic
- In-depth series on measurement accuracy using RTD’s
- Ins and Outs of Calibration

Burns Engineering, Inc.
Temperature Measurement Experts

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

Join our Temperature Measurement Community

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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