

Taking the mysteries out of thermowell selection

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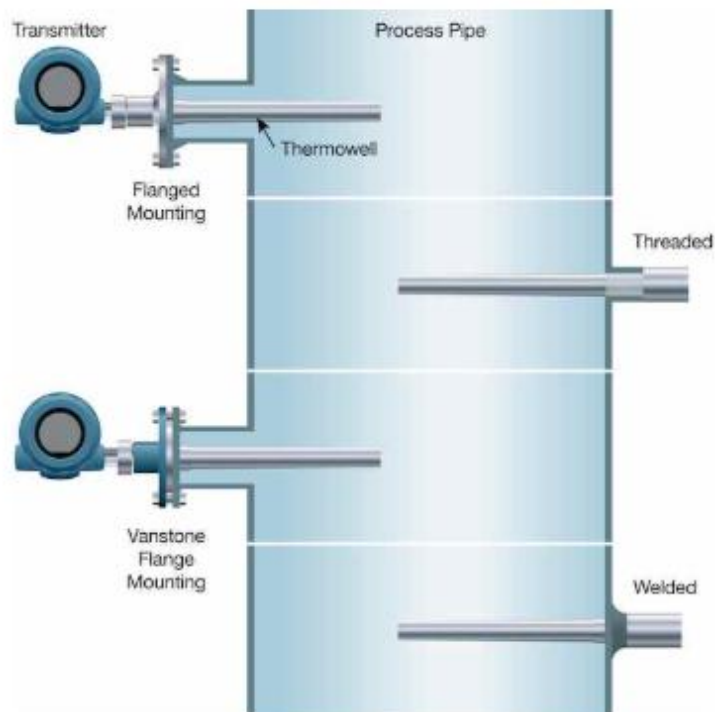
- Control Engineering
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Online Version



Taking the mystery out of thermowell selection

It stands between your process and the sensor element, so understanding thermowell characteristics is key to reliable measurements. Second in the temperature series.



Since it stands between the process and your temperature sensor, a thermowell is critical to accurate, reliable, and safe temperature measurement in most industrial processes. However, selecting the right thermowell can be both a mystery and a challenge. Once you understand the selection criteria, the mystery can be solved, resulting in the best performance of your temperature measurement system. It also ensures a long service life, ease of maintenance, and process integrity.

Why you need a thermowell

Temperature sensors are rarely inserted directly into an industrial process. They are installed in a thermowell to isolate them from the potentially damaging process conditions of flow-induced stresses, high pressures, and corrosive chemical effects. Thermowells are closed-end metal tubes that are installed into the process vessel or piping and become a pressure-tight integral part of the structure. They permit the sensor to be removed from the process quickly and easily for calibration or replacement without requiring a process shutdown and possible drainage of the pipe or vessel.

However, the benefits can only be experienced if the right thermowell is selected and installed. Thermowells are often not specified correctly, leading to gross mechanical failures. They can fail due to weld cracking from fatigue, excessive bending stress, excessive pressure, corrosion, or erosion. Poor thermowell selection and placement can also result in less accurate temperature measurements.

Steps for selection

Proper thermowell selection includes several variables that must be specified appropriately depending on the application for an optimal temperature measurement. A variety of performance criteria and process conditions must be considered when selecting the best design for an application.

1. Connection type—Thermowells are classified according to their connection to the process. The most common types are threaded, socket weld, and flanged. Each of these has a stem or shank that extends into the process that may be straight with constant diameter, tapered all the way from entry point to the tip, partially tapered, or stepped (see Figure 1).

- Threaded thermowells are threaded into process piping or tank, which allows for easy installation and removal when necessary. While this is the most common method, it has the lowest pressure rating of the three options. Threaded connections are also prone to leakage and therefore are not recommended for applications with toxic, explosive, or corrosive materials.
- Welded thermowells are permanently welded to process pipes or tanks. Consequently, removal is difficult and requires cutting the thermowell out of the system. Welding has the highest pressure rating and is generally used in applications with high velocity flow, high temperature, or extreme high pressure. They are necessary where a leak-proof seal is required.
- Flanged thermowells are bolted to a mating flange that is welded onto process pipe or tank. They provide high pressure ratings, easy installation, and simple replacement. Flanged thermowells are used in applications with corrosive environments, high-velocity, high temperature, or high pressure.
- Vanstone / lap joint thermowells are mounted between the mating flange and the lap joint flange. These thermowells allow for use of different materials for the thermowell coming in contact with the process and the overlaying flange, which can save material and manufacturing costs. They are a good choice for corrosive applications, and since there are no welds in this design, weld-joint corrosion is eliminated.

2. Style choices—A second consideration is the thermowell style. Key factors to look at are your pressure and flow rate requirements. Thermowells are most often machined from barstock in a variety of materials and may be coated with other materials for erosion or corrosion protection. Another style is a tubular design also known as a protection tube.

Each style has pros and cons. Barstock thermowells can withstand higher pressures and faster flow rates than protection tubes can. They have more material options and can be mounted in various ways to meet different process pressure requirements. In contrast, tubular thermowells have a much lower pressure rating and a limited choice of materials. For temperatures up to about 1,200 °C, they are often made from exotic alloys like Inconel. For higher temperatures up to 1,800 °C, the protection tubes are ceramic.

3. Material of construction—The material of construction is an important consideration in choosing a thermowell for any given application. Use of the wrong material often leads to premature failure.

Although there are many choices of thermowell materials, the most commonly used are 316 stainless steel, 304 stainless steel, Monel, Inconel, and Hastelloy. There are also some exotic alloys for very demanding applications.

Three primary factors affect material choice:

- Chemical compatibility with the process media to which the thermowell will be exposed
- Temperature limits, and
- Compatibility with the process piping material to ensure solid, noncorroding welds and junctions.

A word of caution is appropriate here to remind users that it is important that the thermowell conform to the design specs of the pipe or vessel into which it will be inserted to ensure structural and material compatibility.

Choosing a thermowell stem profile

The stem or shank is the part of a thermowell that is inserted into the process piping. Common stem profiles are straight, stepped, and tapered (see Figure 2).

Factors to consider when selecting a stem style include:

- Process pressure
- Required speed of response of the measurement
- Drag force of the fluid flow on the well, and
- Vortex shedding induced vibration effects.

Straight profile thermowells have the same diameter along the entire immersion length. They present the largest profile to the process medium and therefore have the highest drag force as compared to other well styles with the same root diameter. The large tip diameter also adds more mass to heat, which slows the thermal response of the measurement assembly. However, this profile has the best mechanical strength properties.

Stepped profile thermowells have two straight sections with the smaller diameter straight section at the tip. For the same root diameter as a straight profile thermowell, this design has less profile exposure to the flowing process and therefore exhibits less drag force and quicker response time due to lower mass at the tip.

Tapered profile thermowells have an outside diameter that decreases uniformly from root to tip. For the same root diameter, this profile represents a good compromise between straight and stepped configurations. Its drag will be less than a straight type well but typically greater than a stepped type. Also, the response time will be faster than a straight type and slower than a stepped type. The two general forms of a tapered stem are uniform (tapered from root to tip) and non-uniform (straight portion followed by tapered portion). Because of its profile shape, it is a good compromise for strength between the two other styles. It is the common choice for high-velocity flow applications where the flow forces typically are too great to use a stepped well and the tapered design has faster response than the straight type, thus offering an optimal balance of strength and response factors.

Failure considerations

Thermowell failures are often associated with one or more of the following: high drag forces, excessive static pressure, high temperature, corrosion, and fluid induced vibration.

Most thermowell failures are caused by fluid induced vibration. When fluid flows past a thermowell inserted into a pipe or duct, high and low pressure vortices form at both sides of the well. These vortices detach, first from one side and then from the other in an alternating pattern (see Figure 3).

This phenomenon is commonly known as vortex shedding. The differential pressure due to the alternating vortices produces alternating forces on the thermowell resulting in stresses that cause transverse and axial deflection, which can ultimately lead to fracture. The frequency of the oscillations is referred to as the wake frequency. Thermowell manufacturers should provide thermowell calculations to predict the probability of a thermowell failing. The best standard for thermowell calculations is ASME PTC 19.3TW-2010.

Response time considerations

The speed of response of the sensor itself is virtually immediate when compared to the much slower response of the measurement system when using a thermowell. The mass of the thermowell far exceeds that of the sensor and will always be the dominant factor of measurement response.

There are many factors associated with choosing the proper sensor and thermowell components and their proper installation in an effort to optimize the overall response time and accuracy of temperature measurements. Many suggestions are provided in the handbook mentioned in the online references. Emerson also offers a free online tool for conducting preliminary thermowell calculations.

Choosing well yields the best results

There are many considerations involved in selecting a proper thermowell for your temperature measurement system. Like any effective instrumentation deployment, the system design engineer must gather all available process information and performance expectations at the outset of the project. For a system with optimal performance and the lowest cost of ownership, the design engineer must use this information for selecting not only the proper thermowell but also the proper sensor and transmitter. The selection of each component follows a similar path of making educated choices.

Print Version

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Steps for selection

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1. **Connection type**—Thermowells are classified according to their connection to the process. The most common types are threaded, socket weld, and flanged. Each of these has a stem or shank that extends into the process that may be straight with constant diameter, tapered all the way from entry point to the tip, partially tapered, or stepped (see Figure 1).

2. **Threaded thermowells** are threaded into process piping or tank, which allows for easy installation and removal when necessary. While this is the most common method, it has the lowest pressure rating of the three options. Threaded connections are also prone to leakage and therefore are not recommended for applications with toxic, explosive, or corrosive materials.

3. **Welded thermowells** are permanently welded to process pipes or tanks. Consequently, removal is difficult and requires cutting the thermowell out of the system. Welding has the highest pressure rating and is generally used in applications with high velocity flow, high temperature, or extreme high pressure. They are necessary where a leak-proof seal is required.

4. **Flanged thermowells** are bolted to a mating flange that is welded onto process pipe or tank. They provide high pressure ratings, easy installation, and simple replacement. Flanged thermowells are used in applications with corrosive environments, high velocity, high temperature, or high pressure.

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inside process

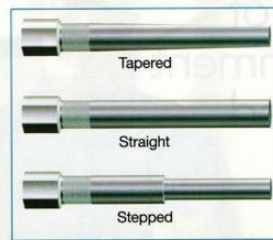


Figure 2: Thermowell profiles offer trade-offs between physical strength and response time. Adding metal increases durability but slows response.

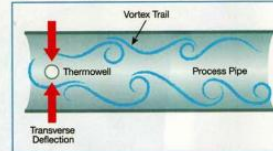


Figure 3: Metal fatigue caused by fluid induced vibration can eventually result in a failure of the thermowell.

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inside process

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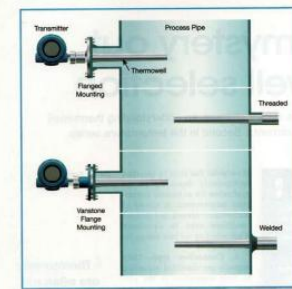


Figure 1: Selecting a thermowell involves specific process conditions and maintainability. At graphics courtesy Emerson Process Management.

Vanstone / lap joint thermowells are mounted between the mating flange and the lap joint flange. These thermowells allow for use of different materials for the thermowell containing in contact with the process and the overlying flange, which can save material and manufacturing costs. They are a good choice for corrosive applications, and since there are no welds in this design, weld-joint corrosion is eliminated.

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inside process

A system design engineer must gather all available process information and performance expectations at the outset of the project.



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Danjin Zalic is a temperature marketing engineer for Emerson Process Management.

Go Online

Emerson offers a free online tool for preliminary thermowell calculations at www.processm.com/ThermowellCalc. Order a free copy of the Engineer's Guide to Industrial Temperature Measurement at www.processm.com/TempGuide.

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Attribute	RTD	Thermocouple
Accuracy	<ul style="list-style-type: none"> • Class A: $\pm 0.15 + 0.002 (t)$ • Class B: $\pm 0.30 + 0.005 (t)$ • Per IEC 60751 	<ul style="list-style-type: none"> • Typical is $\pm 1.1^\circ\text{C}$ or $\pm 0.4\%$ of measured temperature (greater). • Depends on type and range. • Degraded by extension wire.
Stability	<ul style="list-style-type: none"> • Better long-term stability than thermocouples 	<ul style="list-style-type: none"> • Dependent upon thermocouple type, quality of wire and temperatures
Calibration	<ul style="list-style-type: none"> • Easy recalibration for long service life • Best accuracy with sensor and transmitter matching 	<ul style="list-style-type: none"> • Limited when compared to standard thermocouple
Vibration Tolerance	<ul style="list-style-type: none"> • Good in the thin film design 	<ul style="list-style-type: none"> • Good in the larger wire diameters
Temperature Range	<ul style="list-style-type: none"> • -200°C to 850°C 	<ul style="list-style-type: none"> • -270°C to 2300°C
Installation	<ul style="list-style-type: none"> • Requires standard copper wire (less expensive) 	<ul style="list-style-type: none"> • Requires matching extension wire (more expensive)
Purchase Cost	<ul style="list-style-type: none"> • This film design is comparable • Wire rounded is more expensive 	<ul style="list-style-type: none"> • R and S types are most expensive
Life Cycle Costs	<ul style="list-style-type: none"> • Lower 	<ul style="list-style-type: none"> • Higher
Life Span	<ul style="list-style-type: none"> • Many years • Shorter at high temperatures 	<ul style="list-style-type: none"> • Degradation calls for frequent replacement • Shorter at high temperatures • Higher lifecycle costs

ature measurement for kilns, gas turbine exhaust, diesel engines, other industrial processes, and fog machines. They can be made smaller in size than most RTDs, so they can be formed to fit a particular application. As for disadvantages, one is decreased accuracy, particularly at elevated temperatures. Thermocouples are also difficult to recalibrate, depending upon the environmental conditions. They may also be expensive if long lead wires are needed, especially for the precious metal thermocouple types.

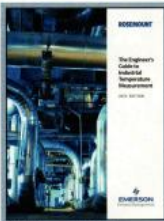
Comparing RTD & Thermocouple Attributes
Now that you know some of the advantages and disadvantages of both, consider a side-by-side comparison of their attributes.

In general, thermocouples are better than RTDs when it comes to overall cost, durability, measurement speed, and temperature range. RTDs provide readings that are both more accurate and repeatable.

Things to Keep in Mind
When selecting between an RTD and thermocouple, keep in mind the temperature range you want to measure. Thermocouples are capable of handling a higher range than RTDs. Second, consider the level of measurement accuracy

you want to gain. In general, RTDs are more accurate than thermocouples, and optimal accuracy can be achieved by utilizing transmitter and sensor matching with RTDs. A third consideration is process vibration. Thermocouples have the highest vibration resistance. 

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