

## Basics of thermowell design and selection

*Do not underestimate the importance of thermowells in temperature measurements*

### Fast Forward

- Understanding process conditions that affect performance is essential to selecting the best thermowell.
- Industry standards provide simple calculations that can be performed to ensure optimal thermowell operation.
- Consider relevant factors and standards during the thermowell selection process.

By Ehren Kiker

When planning for a temperature measurement application, a fair amount of consideration is typically given to sensor selection (e.g., thermocouple vs. RTD) and wiring of the output (e.g., transmitter vs. direct wiring), and how these factors will affect the measurement. Often, by comparison, relatively little consideration is given to the mechanical components of the sensor assembly, particularly the thermowell.

Of all the components in a typical temperature assembly, a thermowell would seem to be the simplest and least critical. In reality, the thermowell is fundamentally important because it directly and significantly affects the life span of the sensor and accuracy of the measurement. It also protects the closed process, providing plant and personnel safety.

An understanding of process conditions that affect thermowell performance, basic design, and installation criteria is essential to selecting the best thermowell for the particular application. Industry standards for thermowell design provide simple calculations that can be performed to ensure performance and reliability. Understanding conditions and performing relevant calculations can mean the difference between temperature measurements that perform as expected and measurements that are unreliable, unsafe, and costly.

Temperature measurement is often an invasive procedure because a sensor protected by a thermowell is inserted into a process pipe, tube, or vessel. While the sensor makes the actual temperature measurement, the thermowell does the heavy lifting of taking whatever the process throws at it, while allowing proper operation of the sensor. A properly designed thermowell must be able to withstand all process conditions and phenomena with minimal effect on temperature measurement responsiveness and accuracy.



Many application conditions must be considered when making design decisions for the thermowell. These conditions can be broadly categorized as static loads, fluid dynamic loads, thermal loads imposed by the process, and the corrosion rate – all influenced by the chemical and physical conditions of the process media.

Designing the thermowell for optimal performance begins with defining all the conditions, which may cause thermowell degradation, damage, or failure. Next, determine which features are needed to allow the thermowell to withstand worst-case application conditions.

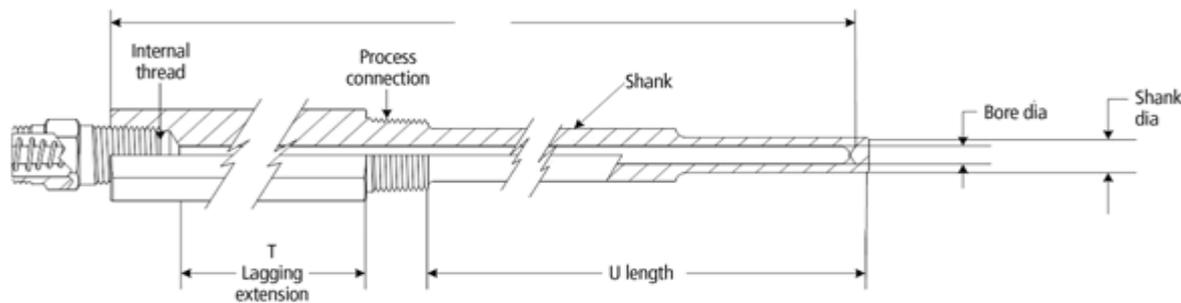


Figure 1: The basic elements of a thermowell include the tubular housing, which is machined from bar stock and welded to a pipe or vessel at the process connection, and the temperature sensor probe, which is threaded into the stem to reach deep into the process.

## Thermowell design considerations

Once the application conditions are defined, the next step is to delineate the basic design of the thermowell. While thermowell design can take many variations, the basic design criteria are the definition of the raw material, the process connection, and the geometry/shape (Figure 1).

One of the most important factors in raw material selection centers on material compatibility with the process media. Also important is the mechanical strength of material when installed in the process. Consider not only to selecting a material that is compatible with the corrosion properties of the specific process fluid, but also the cost of different materials or coatings. Selecting an exotic metal, such as Monel, may provide greater corrosion resistance compared to stainless steel, but may be prohibitively expensive, prompting the use of a coating.

The process connection (i.e., where the thermowell is inserted into the pipe or vessel) is an important variable that defines the physical configuration of the installation. The process connection also affects the thermowell's performance.

Selection of the process connection depends on process conditions, such as pressure, temperature, fluid speed/flow rate, and fluid type. Typical process connections for industrial applications are socket weld-in, threaded, and flanged. Other process connections are available for hygienic industries (e.g., Tri-Clamp).

When selecting a flanged process connection, consider the welding procedure used to mate the thermowell to the process connection. The welding procedure must be adapted to the existing or estimated load conditions; it falls into two categories: standard welding and full

penetration welding. Standard welding is mainly suitable for “light-middle” applications (temperature less than 600 °F and pressure up to 1500 psi), while full penetration welding is designed for “heavy” applications.

“Heavy” applications are those where it is necessary to foresee and accommodate thermal and fluid dynamic phenomena combined with the interaction between solid bodies and high-speed fluids.

The thickness, material type, and shape of the thermowell can have significant impact on the responsiveness of the sensor to a change in process temperature. The greater the wall thickness of the thermowell, the slower the response time, as the heat from the process fluid must be conducted through the thermowell to the measuring tip of the sensor. A thinner wall thickness provides quicker response times for temperature measurement, but it also lowers the mechanical strength of the thermowell. The specific thermowell material can also affect responsiveness, and, therefore, must be considered as an important design element.

Thermowell geometry can have a profound effect on the mechanical integrity of the thermowell, as it affects the vibration effects induced by the flow of process fluid past the thermowell. These effects can be quantified and evaluated using industry-standard calculations, such as those found in the ASME PTC 19.3 TW-2010 standard. Typical thermowell geometries are tapered, stepped, or straight.

The thermowell immersion depth (U-length) should be sufficient to eliminate any conduction error from the atmosphere or another process temperature. A general rule is to use an insertion length equal to a minimum of 10 times the diameter of the thermowell. In pipes with a small cross section, the sensor tip should reach – or extend slightly past – the center of the pipe.

The ideal installation for a thermowell is one that minimizes conditions that can compromise the mechanical integrity of the thermowell while making sure that the measuring tip is located in a stable, representative portion of the process temperature profile.

## **Performing thermowell calculations**

When a thermowell is put into service, it is subjected to a variety of stresses. These stresses are typically created by the movement of the process fluid around the thermowell, which causes in-line and transverse vibrations that can induce mechanical failure of the thermowell. Such a failure may not only result in loss of measurement but can also cause significant damage to expensive equipment and create a serious safety risk to plant personnel.

These stresses are the primary cause of thermowell failure in process applications, so it is often necessary to run calculations on the thermowell design to make sure these stresses do not exceed maximum allowable limits.

A variety of methods exist for calculating the failure potential of a specific thermowell design. One of the most commonly accepted methods in the Americas is found in the ASME PTC 19.3 TW-2010 standard. PTC 19.3 looks at the specific thermowell design and considers all dimensions of a thermowell, material properties, and the geometry of the thermowell. The calculation determines many factors having to do with the process application, including the

frequency ratio, dynamic and static stress limits, and the pressure limits. In addition, the standard can also be used to calculate the maximum allowable gauge pressure, as well as the maximum thermowell length.

While these calculations can be time-consuming, there is a variety of free online software, such as Endress+Hauser's Applicator software. These software programs allow an engineer to perform thermo-well calculations per ASME PTC 19.3 and check the suitability of the thermowell design with the specific process conditions (Figure 2).

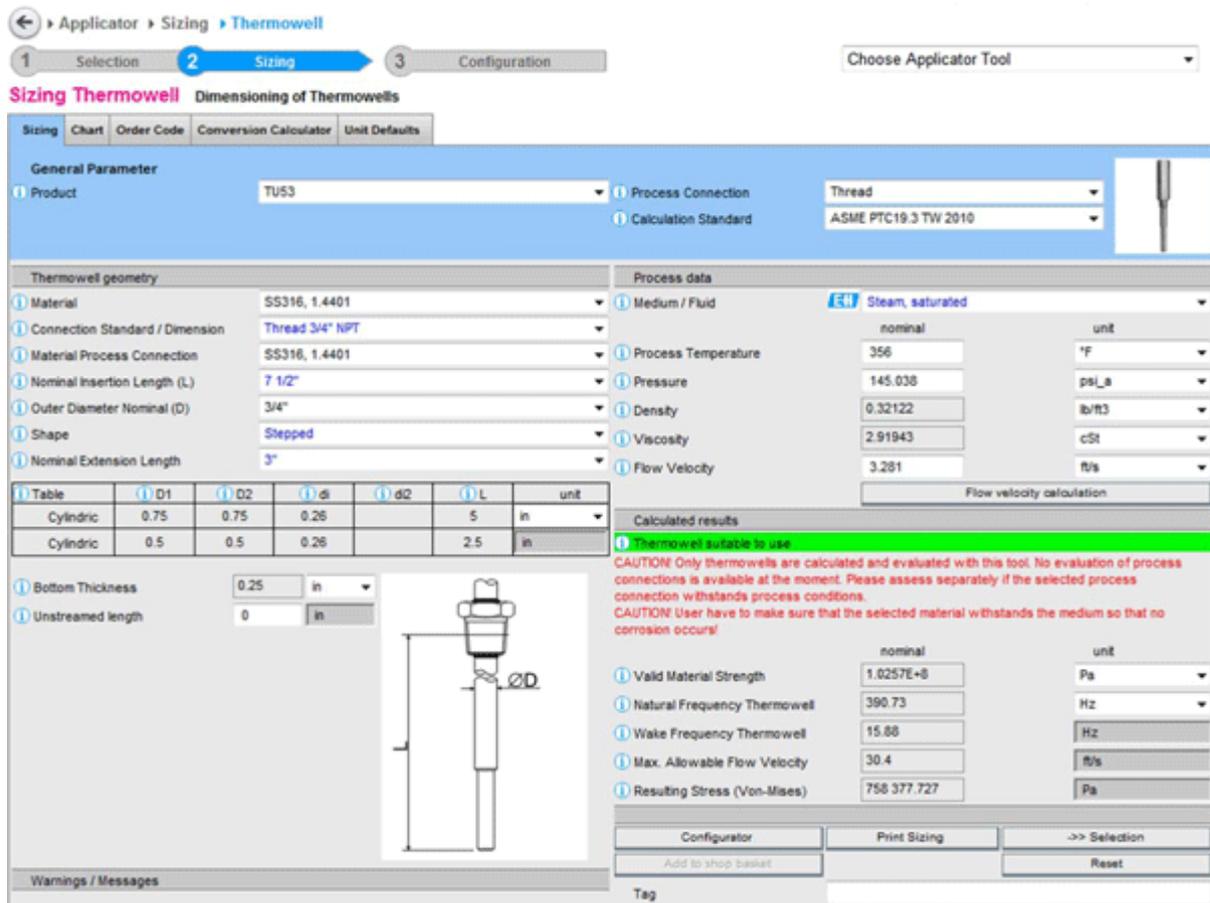


Figure 2: Software for sizing, designing, and specifying a thermowell is available from several sources, including Endress+Hauser.

## Selecting thermowell options

Sometimes, according to the ASME PTC 19.3 calculations, a thermowell cannot withstand the operating conditions for which it is being designed. In these cases, it may be necessary to modify the thermowell geometry. The two most common modifications are shortening and widening. Another modification that is sometimes used is a velocity collar.

*Shortening:* A shorter thermowell has a higher natural frequency and a higher compression load strength, resulting in the ability to withstand greater vibration forces. The drawback of shortening is that the sensor tip will be farther from the center line of the pipe or the desired temperature region in the vessel, which could have an adverse effect on the measurement.

*Widening:* A thermowell with a larger diameter will have a bigger tip, resulting in a lower wake frequency, which results in a lower ratio to the natural frequency. The drawback of widening is that a thicker thermowell causes a slower response time of the measurement.

An effective temperature measurement is characterized by high accuracy, long-term stability, reproducibility, reliability, adequate response time, ease of maintenance, noise immunity, and minimal disturbance to the process temperature that is being measured.

A thermowell may seem like nothing more than a hunk of metal that exists to protect the temperature sensor from damage, but, in many ways, it is the one component in a temperature assembly that has the greatest influence on the overall efficiency of the temperature measurement. Understanding a few basic rules for good thermowell design and using industry standard calculations, such as ASME PTC 19.3 TW-2010, can result in temperature measurements that provide improved sensor performance and increased plant safety.

#### ABOUT THE AUTHOR

**Ehren Kiker** ([ehren.kiker@us.endress.com](mailto:ehren.kiker@us.endress.com)) is a product manager with Endress+Hauser with more than 15 years of experience in process control instrumentation.

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