

THERMOWELL CALCULATION

ASME PTC 19.3 TW-2010

The American Society of Mechanical Engineers (ASME) Performance Test Codes (PTC) are used to determine the performance of specific, mechanical equipment, which are designed to meet specified criteria for performance and operability. The results from applying Codes indicate how well the equipment performs its intended function.

The ASME PTC 19.3 is a thermowell stress calculation, which serves as a mathematical proof that the material chosen and the mechanical design will not fail given the effects of the operating conditions. The calculation provides guidance for establishing a comparison between the shedding frequency and the natural frequency of the thermowell.

The ASME standard dates back to 1957 and the 1974 version included a paper authored by J. W. Murdock, which was widely used and accepted by the industry. In 1999, it was discovered that thermowells designed to PTC 19.3-1974 in non-steam services suffer catastrophic failure. Due to this problem, the committee decided to rewrite the entire standard, increasing its size to over forty pages. The 2010 version includes an evaluation of the forces caused by external pressure and the combination of static and dynamic forces. The PTC Standards Committee approved the new standard on January 15, 2010. The Board on Standardization and Testing then approved and adopted the version as the standard practice of the ASME on February 18, 2010. The criterion was also approved as an American Standard by the ANSI Board of Standards Review of April 22, 2010.



Criteria for Thermowells

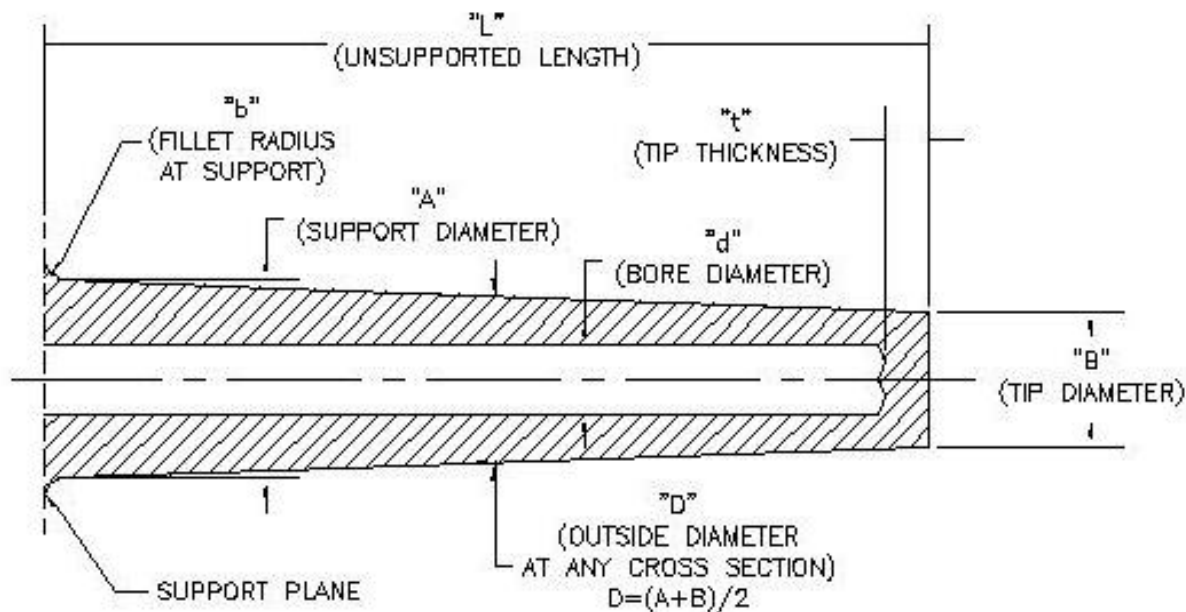
The ASME PTC 19.3 TW-2010 standard applies to thermowells that are:

1. Machined from bar stock.
2. Straight, tapered or step-down shank.
3. Threaded, flanged, van stone or welded process connection.
4. Surface finish of 32 μ in.Ra or better.

Not Within the Scope of This Standard

1. Thermowells manufactured from pipe.
2. Specially designed surface structures, e.g. knurled, spiral.
3. Thermowells fabricated in piece construction (welding of the shank in sections).
4. Shanks that include flame spray or weld overlays.
5. Use of ball joints, spherical unions or packing glands.
6. Ceramic wells or any non-metallic or exotic metals

Dimensional Limits for Straight and Tapered Thermowells

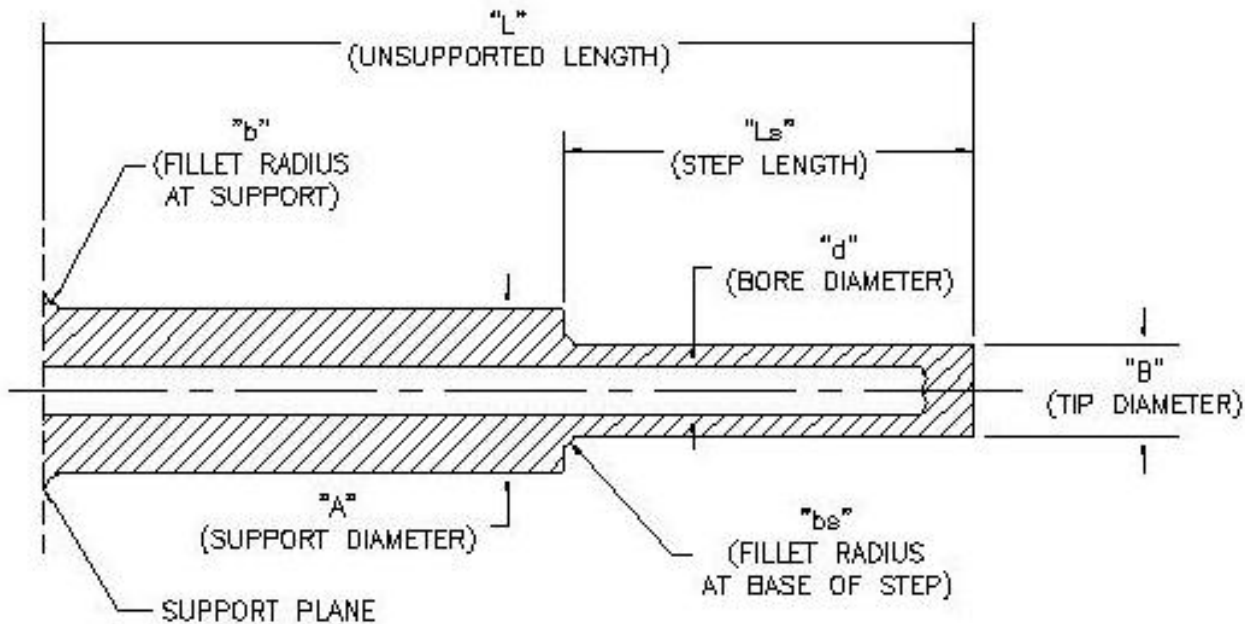


Dimension	Mark	Minimum	Maximum
Unsupported Length	L	2.5"(Note 1)	24"(Note 2)
Bore Diameter	d	0.125"	0.825"
Tip Diameter	B	0.36"	1.83"
Taper Ratio	B/A	0.58"	1.0"
Bore Ratio	d/B	0.16"	0.71"
Aspect Ratio	L/B	2.0"	
Minimum Wall Thk,	(B-d)/2	0.12"	

Notes:

1. Lengths less than the minimum specified are not covered by this standard.
2. Maximum length may be exceeded providing drilled bar stock is of one-piece construction.

Dimensional Limits for Step Down Thermowells



Dimension	Mark	Minimum	Maximum
Unsupported Length	L	5"	24"
Bore Diameter	d	0.24"	0.265"
Step Diameter Ratio, for B=0.5"	B/A	0.5"	0.8"
Step Diameter Ratio, for B=0.875"	B/A	0.583"	0.875"
Length Ratio	L _s /L	0	0.6"
Minimum Wall Thickness	(B-d)/2	0.12"	

Notes:

1. The methods presented in this standard apply for tip diameters other than those specified. However, the correlation for natural frequency is supplied only for the given tip diameters.

Allowable Dimension(Note 1)	Mark	Minimum
Tip Diameter	B	0.5" and 0.875"

Selection of Thermowell Materials

The selection of thermowell material is usually governed by corrosion resistance, strength requirements, temperature limits and welding compatibility to the process piping in the case of socket and weld-in thermowells.

Materials should be certified to meet the requirements of recognized codes (ASTM, ANSI or ASME). Other materials may be used, providing they conform to published specifications covering chemical, physical and mechanical properties as required by this standard.

Available Materials

The table below provides the current materials covered and the upper temperature limit. Lower temperature limit is set at -49°F for all materials.

Note: Upper temperature limits are primarily established using the tables found in the ASME code for pressure piping B31.1. For temperatures, which exceed the upper temperature limit, please consult Thermo Electric.

Material	Code	Upper Temperature Limit
316 or 316 Low Carbon Stainless Steel	316/316L	1499.9°F
304 or 304 Low Carbon Stainless Steel	304/304L	1199.9°F
310 Stainless Steel	310SS	999.9°F
321 Stainless Steel	321SS	1199.9°F
347 Stainless Steel	347SS	1199.9°F
Duplex Grade Stainless Steel, F51	Duplex(F51)	599.9°F
Alloy 20, Nickel, Chromium, Molybdenum Stainless Steel Alloy	Alloy 20	799.9°F
Hastelloy® C276	C276	1249.9°F
Inconel® 600	Inconel 600	1199.9°F
Inconel® 625	Inconel 625	1199.9°F
Incoloy® 800	Incoloy 800	1499.9°F
Monel 400, Nickel Copper Alloy	Monel 400	899.9°F
Forge Carbon Steel, ASTM Grade A105	A105	999.9°F
Chromium – Molybdenum Low Alloy Steel containing 4 to 6 % Chromium	F5	1199.9°F
Chromium – Molybdenum Low Alloy Steel containing 8 to 10 % Chromium	F9	1199.9°F
Chromium – Molybdenum Low Alloy Steel containing 1.0 to 1.5 % Chromium	F11	999.9°F
Chromium – Molybdenum Low Alloy Steel containing 2.0 to 2.5 % Chromium	F22	1199.9°F
Chromium – Molybdenum Low Alloy Steel containing 8 to 9.5 % Chromium	F91	1199.9°F
Titanium Grade 2	Tit GR2	599.9°F
F44 (254SMO) 6%Molybdenum Austenitic Stainless Steel Alloy	F44-254SMO	749.9°F

Low Fluid Velocities

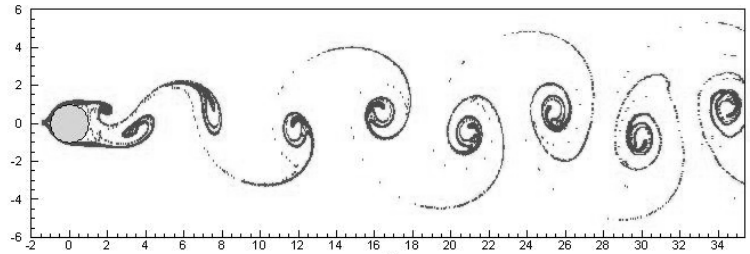
At low velocities, the risk of thermowell failure is minimal and does not usually require frequency calculations. If the following criteria are met, the designer may elect to waive calculation requirements.

1. Maximum fluid velocity is less than 2.1 ft/sec. [0.46 M/s].
2. Wall thickness at "A" support diameter minus "d" bore diameter ≥ 0.376 " [9.55 mm].
3. "L" Unsupported length ≤ 24 " [.61 M]
4. "A" support and "B" tip diameter ≥ 0.5 " [12.7 mm]
5. Thermowell material satisfies "S" maximum allowable working stress ≥ 69 MPa.
6. "Sf" fatigue endurance limit, in the high-cycle limit ≥ 21 MPa.
7. Thermowell material not subject to stress corrosion or embrittlement.

The designer may still elect to have calculations performed in order to establish an external pressure rating and should still be cautious of sensor failure due to high vibration caused by in-line resonance.

Frequency Limits

A thermowell installed in a flowing process fluid (liquid or gas) will produce a shedding of vortices as the fluid passes around the thermowell. This circular flow creates a turbulent wake as vortices emerge from both sides downstream of the thermowell. The circular flow patterns are called von Karman (wake) vortices. These vortices break away periodically in a phenomenon known as vortex shedding and cause a regular change to the thermowell in two types of forces.



Smoke Trail showing von Karman Vortex

1. An oscillating-lift force, transverse to the fluid flow.
2. An oscillating-drag, in-line in the direction of the flow.

The induced vibrations are of critical importance due to the way their frequency corresponds to the resonance frequency of the thermowell. If the natural frequency of the thermowell overlaps the lift force or twice the drag force, the buildup of vibration that can occur could result in failure of the thermowell and/or the sensor contained therein. To prevent thermowell failure, a safety factor or ratio between the vortices' shedding frequency (f_s) and the resonance frequency of the thermowell with compliant support (f_{nc}) must be set.

ASME PTC 19.3 TW-2010 has revised the frequency criteria based on limits set by in-line resonance and passage of static cyclic conditions.

In low density gases with a Scruton Number (N_{sc}) of >2.5 Reynolds Number $<10^5$, the in-line resonance is suppressed and therefore the acceptable ratio will be:

$$f_s < 0.8f_{nc}$$

If a thermowell passes cyclic stress conditions for operation at the in-line resonance condition, the acceptable ratio will be:

$$f_s < 0.8f_{nc}$$

If a thermowell fails the cyclic stress condition for operation at the in-line resonance condition, the thermowell natural frequency will be high enough to limit excitation of the in-line resonance. Therefore, the acceptable ratio will be:

$$f_s < 0.4f_{nc}$$

Ways to Improve Thermowell Performance

Thermowells are an integral part of the piping and process containment system. Thermowell dimensions, material and process mounting is the sole responsibility of the designer and must meet the needs of the end user. Thermowells, which fail to meet pressure, stress or frequency requirements may result in a passable solution with modifications to the dimensions or material.

1. Change in material may improve performance, providing the alternate material carries the same corrosive and erosion resistance as the first selected material and is accepted by the end user.
2. Reducing the insertion "U" length will improve the force to natural frequency ratio. However, this change may compromise the thermal effectiveness of the sensor within the flow.
3. Increasing the tip diameter on tapered construction or changing to a straight construction.

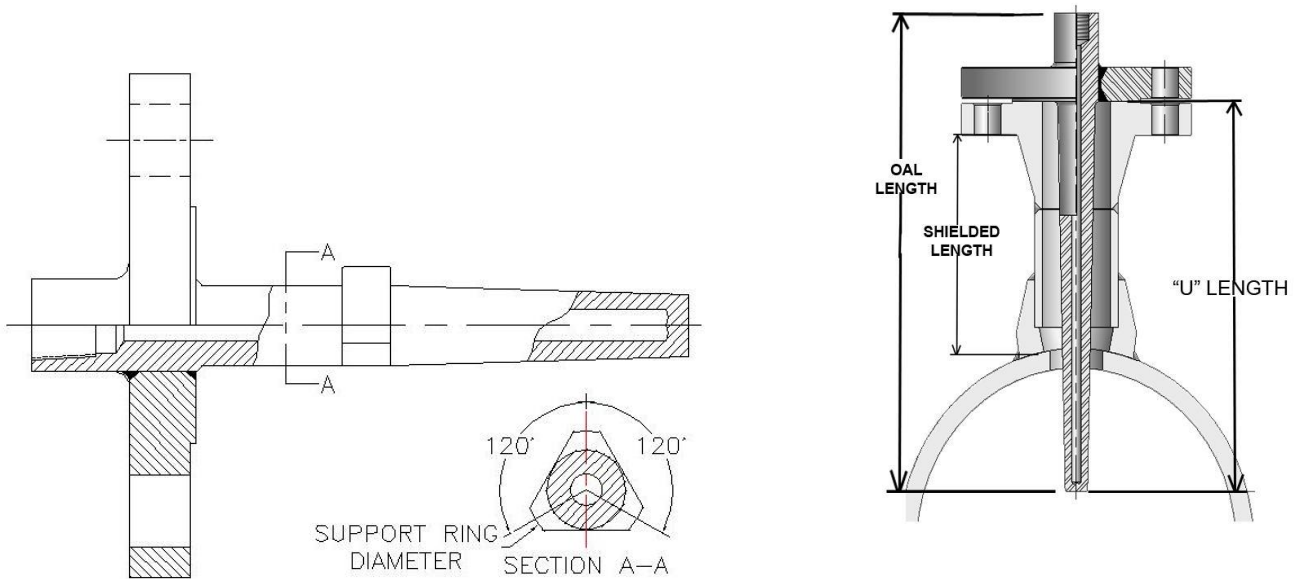
4. Increasing the support diameter. This modification may also require increasing or altering the process mounting connection.
5. Increasing the support fillet radius, which is usually limited to flanged connections.
6. Combination of the above.
7. Changing the location to an area with less velocity.
8. Increasing the tip diameter and/or decreasing the bore size to improve the process pressure rating.

Other Ways to Improve Thermowell Performance not Within the Scope of this Standard

1. Use flanged connections.
2. Attach the thermowell stem to flange using full penetration weld.
3. When mounting the thermowell in an elbow, point the tip upstream on the direction of the flow.

Use of Support Collars

Support collars, also called velocity or frequency collars, provide an anchor within the shielded length of a flanged mounted connection, thereby theoretically reducing the insertion “U” length. Collars are usually triangular in shape and are machined into the shank of the thermowell or a ring welded in place. The diameter must be of a tolerance to assure minimum to zero gap. Surface area may have to be ground at the site to adjust for a tight fit. Support collars are not supported or recommended by the ASME 19.3 TW-2010 standard as the collars do not assure a rigid support plane and are subject to a hammering effect brought on by the constant vibration.



Process Information Required to Run the ASME PTC 19.3-TW-2010 Calculation

- Minimum mandatory information required
1. Maximum or operating temperature.
 2. Maximum or operating pressure.
 3. Fluid (gas or liquid) velocity.
 4. Fluid density.

Additional information if available (recommended)

1. Process Fluid (air, steam, water, etc.).
2. Pipe size and schedule.
3. Fluid flow rate.
4. Fluid viscosity (will use 0.0171 centipoises if not known).
5. Shielded length (flanged thermowells). Knowing this information improves stress resistance.