PTC 19.3 TW
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1-2 SCOPE

This Standard applies to thermowells machined from bar stock and includes those welded to or threaded into a flange as well as those welded into a process vessel or pipe with or without a weld adaptor. Thermowells manufactured from pipe are outside the scope of this Standard. Thermowells with specially designed surface structures (e.g., a knurled surface or a surface with spiral ridges) are beyond the scope of this Standard, due to the difficulty of providing design rules with broad applicability for these types of thermowells. Thermowell attachment methods, standard dimensions, parasitic vibration of a sensor mounted inside the thermowell, and thermal equilibrium of the sensor relative to the process stream are beyond the scope of this Standard. In addition, thermowells fabricated by welding, including flame spray or weld overlays, at any place along the length of the shank or at the tip are outside the scope of this Standard. The application of the overlay to a barstock thermowell may affect any number of critical attributes such as natural frequency, damping, material properties, or surface finish. These changes are difficult to account for in the calculations, therefore there is risk that an inappropriately designed thermowell could be installed.

3-1 REFERENCE STANDARDS AND GOVERNING CODES

(a) ASME B40.200, Section B40.9, on Thermowells for Thermometers and Elastic Temperature Sensors, discusses the selection, fabrication, and installation of thermowells, as well as providing some standardized designs. Complementing ASME B40.200, Section B40.9, PTC 19.3 TW is limited in scope to mechanical design of thermowells.

(b) ASME Boiler and Pressure Vessel Code (BPVC) Section III Appendices, Appendix N provides guidance on the flow-induced vibration of banks or arrays of tubes and on the excitation of structural vibrations by turbulence. Both of these topics are outside the scope of PTC 19.3 TW, which considers the vibration of single thermowells due to vortex shedding only.

(c) Guidance on minimizing temperature measurement errors in thermowell applications is found in the latest edition of PTC 19.3. Effects considered include heating of the thermowell by fluid impingement, errors due to thermal radiation and conduction along the thermowell, and heat transfer between the thermowell and the surrounding fluid.
6-8.5 Passing Through In-Line Resonance Where the Design Does not Meet the Cyclic Stress Requirements for Continuous Operation at Resonance

In cases where the thermowell design fails the cyclic stress condition for steady-state operation for the entire lifetime of the installation, transient exposure to the in-line resonance condition may be allowable, provided that certain criteria are met. A thermowell with a natural frequency between the steady-state Strouhal frequency (which excites transverse vibrations) and twice the Strouhal frequency (which excites in-line vibrations) is subjected to significant vibration only for limited periods on start-up or shutdown. This is because the in-line vibrations are excited only when twice the Strouhal frequency coincides with the natural frequency of the thermowell. Since this condition is transitory, the design may be acceptable provided that the peak stress does not exceed the fatigue limit for the number of cycles encompassing the total lifetime that installation will be subjected to startup and shutdown cases. Because the specific conditions on startup and shutdown cases cannot always be predicted exactly for the entire lifetime of the installation, additional precautions must be followed to assure the design is conservative.

In summary, where a thermowell design does not meet the cyclic stress requirements for in-line resonance over its lifetime, passage through the in-line resonance condition (as described above) may be allowed if all of the following conditions are met:

(a) The process fluid is a gas.
(b) The thermowell is exposed to the in-line resonance condition only on start-up, shutdown, or other infrequent transient variations in fluid velocity but does not dwell in the in-line resonance condition during steady state operation (see Section 6-8.4).
(c) The cumulative number of cycles incurred during passage through in-line resonance lock-in region is below 10¹¹ cycles.
(d) The process fluid is known to not cause metallurgical changes to the thermowell material that would significantly reduce the fatigue resistance.
(e) The potential consequences of thermowell failure to equipment or personnel are sufficiently limited to be acceptable.
(f) When the thermowell is excited at its natural in-line vibration frequency the maximum stress (refer to section 6-12) shall be less than the fatigue limit for the expected number of start-up and shutdown events encountered by the thermowell in its lifetime.

The number of cycles sustained for each flow velocity transient shall be calculated assuming that lock-in phenomena occurs between 0.4fnc and 0.6 fnc.

Note that the design rules of PTC 19.3 TW ensure only the mechanical integrity of the thermowell. Passage through the in-line resonance may cause a severe vibration of the thermowell tip resulting in unacceptable sensor damage or drift.
6-10.7 Mounting of Thermowells in an Elbow

For thermowells mounted in an elbow and pointing downstream, as shown in Fig. 6-10.7-1, the exact flow path is difficult to model. Thus, the projected area shall be conservatively estimated as the projected area of the thermowell if the flow were to be normal to the thermowell axis along the length of the thermowell exposed to fluid flow. The geometry to be used in the calculation of thermowell ratings is given in Fig. 6-10.7-2.

Thermowells mounted in an elbow with the tip pointing upstream, as shown in Fig. 6-10.7-3, are often preferable to a mounting with the tip pointing downstream. For a conservative justification of a thermowell mounted in this fashion, the thermowell may be evaluated as though it were installed perpendicular to the pipe. Provided that the flow lines in the upstream pipe are closely approximated as lines parallel to the pipe axis, there is minimal transverse fluid flow near the tip of the thermowell, with a consequent reduction of the bending moment. Tip effects are important, and the effective Strouhal number varies with the angle of flow with respect to the thermowell axis [16]. For such an installation, calculation of the bending moment is beyond the scope of this Standard. Predictions of the bending moment and Strouhal number should be made by using computational fluid dynamics or experimental measurements to determine the fluid flow pattern, including the perturbations of upstream piping elements, and consulting reference [16] to determine the forces on the thermowell.

6-10.8 Mounting of Thermowells at an Angle to Flow" and the sentence "Mounting of thermowells at an angle, whether the tip is oriented towards or away from the flow of the process fluid, may be conservatively evaluated as though the thermowell were installed perpendicular to the pipe."

A-2 Other Conversion Factors

(a) Within the U.S. Customary units system, pressures and elastic moduli are commonly given in units of pounds per square inch (psi or lbf/in.²), which is not equivalent to the derived unit of pressure resulting from the combination of pounds, inches, and seconds: lb/(in.-sec²). To convert pounds-force per square inch (psi or lbf/in.²) to lb/(in.-sec²), multiply by 386.088.

(b) Many sources express fluid viscosity in units of centipoise (1 centipoise = 0.01 poise). The centipoise is neither an SI unit nor a U.S. Customary unit, but can be converted using the following conversion factors:

(1) To convert centipoise (cP) to lb/(ft·sec), multiply by 6.714 × 10⁻⁶
(2) To convert centipoise (cP) to pascal second (Pa·s), multiply by 0.001.