Sizing Thermowell according to ASME PTC 19.3

AIS 2015 – 17th September – Endress+Hauser
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SUMMARY

- Why is stress thermowell calculation necessary?
- Loading system description
- Basic frequency calculation theory:
  - Natural frequency
  - Wake frequency: dynamic loading system
- Methods for thermowell sizing
- ASME PTC 19.3 – 2010
- Used Standards – ASME vs DIN
- Example: minimum needed data

Why is a Thermowell Calculation necessary?

Thermowells are exposed to various stresses: mechanical, fluid dynamical, chemical, thermal.
Effects from these stresses can be:

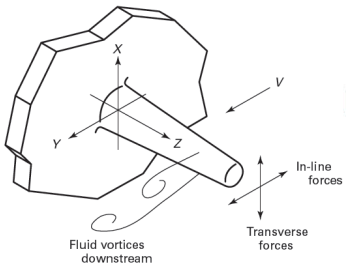
- Thermowell leakage due to microcracks without collapse
- Thermowell collapse
- Delayed failure through material fatigue, caused by crack growth rate

If the thermowell is damaged the process medium can leak under high pressure and high temperatures leading to risky conditions for persons and environment.
A thermowell calculation according to standards enables a safe dimensioning and is often the basis for the system acceptance by approval Parties (e.g. Notified Bodies).

The calculation includes the most important and clearly calculable strains and thus leads to higher plant safety.

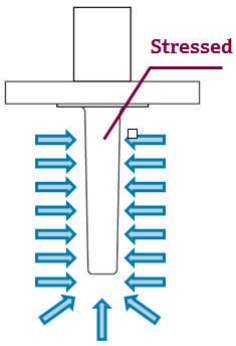
Loading System description

Fluid dynamic loads



Schematic example of fluid dynamic loading forces: both the drag and lift forces are considered

Static loads



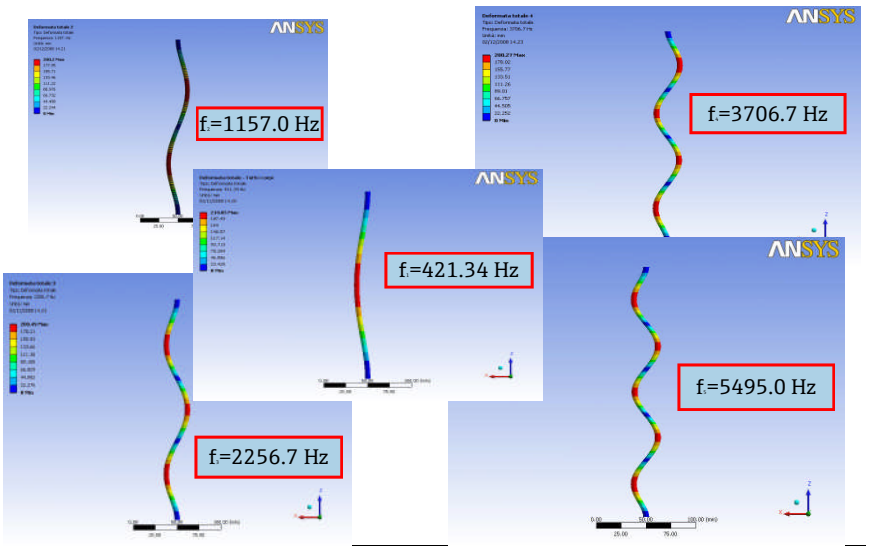
Process fluids

Fluid effects: chemical composition, concentration, viscosity, phases

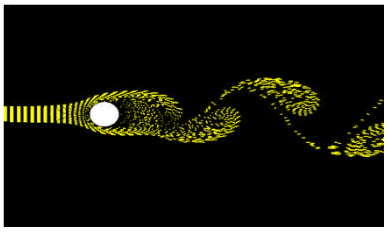
Thermowell's natural frequencies

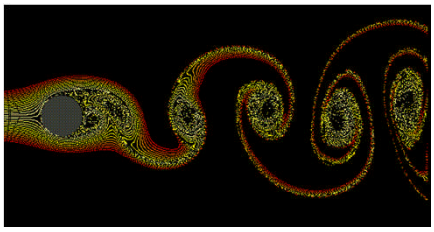
- A thermowell is a system with its own mass and stiffness: it can vibrate under dynamic loads
- Like every system equipped with mass and stiffness, a thermowell has its own natural frequencies
- Natural frequency: frequency at which a body naturally vibrates once it has been set up into motion.
  - Vibration = oscillation around body's static equilibrium position
- A real body has infinite natural frequencies.

Thermowell's natural frequencies

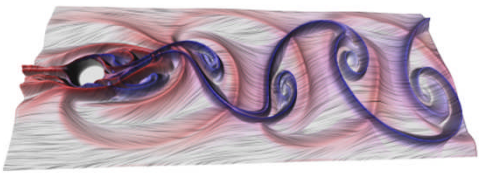


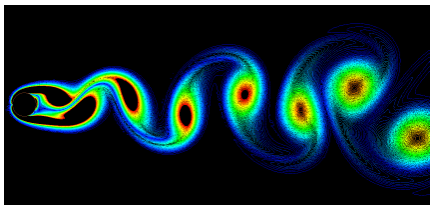
Wake frequencies: dynamic loads





Vortex Shedding





Resonance problem description

- If a solid body is subjected to a force/load with a frequency not equal to a natural frequency, it starts to vibrate at load frequency, and the amplitude of the vibration is “contained”
- If the load/force frequency is near/equal to a natural frequency of the body, the vibration amplitude can be:
  - Very high (when damping is considered)
  - Time-dependent (when damping is neglected): the amplitude increases as time passes – Resonance Phenomena
- PTC 19.3 does not consider the damping contribute

Method for thermowell sizing

Optimization of thermowell design to withstand combination of static and dynamic loads

Stress analysis calculation must be performed according to specific methods

Mechanical strength factors and thermal performance factors are optimized

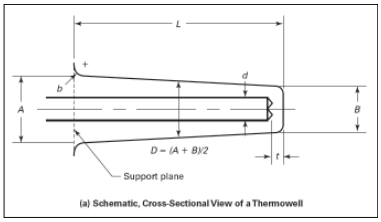
Limits on pressure and velocities acting on the thermowell in order to avoid catastrophic failure

ASME PTC 19.3 - 2010

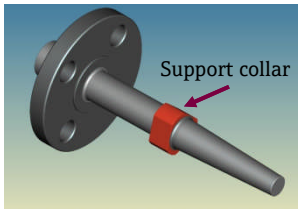
ASME PTC 19.3 TW 2010

- Establishes a mechanical design standard for reliable service of **tapered, straight and step-shank thermowells**
- Applies to thermowell machined **from bar stock**. Thermowells manufactured from **pipe are outside the scope** of this standard
- **Support collars or other means of support are outside the scope** of this standard:
  - E+H doesn't provide any calculation or certification that implies verification of support collars;
  - E+H will provide only suggestions or other mechanical analysis based on **alternative simulation methods like FEM** to the customer for possible use of support collars.

Object and Scope



(a) Schematic, Cross-Sectional View of a Thermowell



ASME PTC 19.3 TW 2010 – analysis results

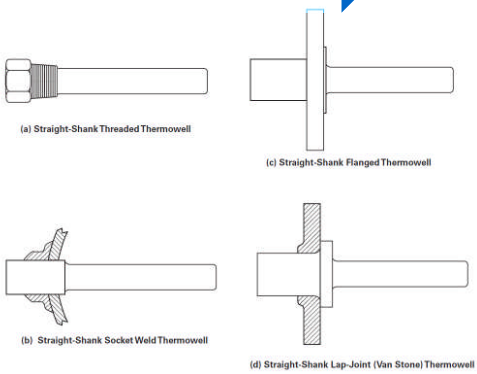
- The thermowell sizing is given satisfactory by comparing the vortex shedding frequency (f_s) to the natural frequency (f_n) .
- Two cases are considered based upon process medium characteristics and conditions:
  - Low density gases:
    - $f_s / f_n < 0,8$
  - General case (high viscosity gases and fluids):
    - Critical condition (steady state drag stress + axial pressure stress > reference allowable working stress) => $f_s / f_n < 0,4$
    - normal case: $f_s / f_n < 0,8$

ASME PTC 19.3 TW 2010

ASME PTC 19.3 1974 → ASME PTC 19.3 TW 2010

Improvements

- Larger variety of process connections:
  - Threaded
  - Welded (Socket Weld, Weld in)
  - Flanged



ASME PTC 19.3 TW 2010

ASME PTC 19.3 1974 → ASME PTC 19.3 TW 2010

Improvements

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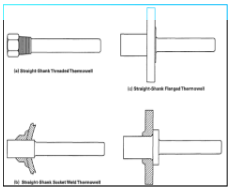
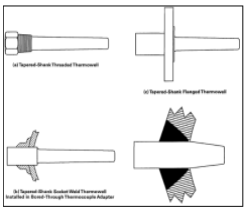
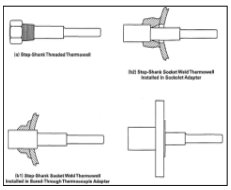
- Larger range of dimensions and shapes



straight



tapered



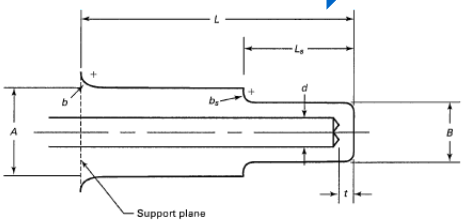
stepped

ASME PTC 19.3 - 2010

ASME PTC 19.3 1974 → ASME PTC 19.3 TW 2010

Improvements

- Larger variety of process connections:
  - Threaded
  - Welded (Socket Weld, Weld in)
  - Flanged
- Larger range of dimensions and shapes
- Step shanks are evaluated separately
- Value of natural frequency is more accurate
  → **more optimized design** (e.g. less thermal inertia)



(b) Schematic, Cross-Sectional View of a Step-Shank Thermowell

BUT still only bar stock no pipes allowed

Used Standards – ASME vs DIN

DIN 43772 ⟵ Standards ⟶ ASME PTC 19.3 TW 2010

Variance

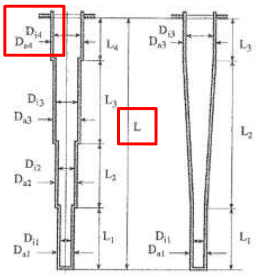


Table 4-1-1 Dimensional Limits for Straight and Tapered Thermowells Within the Scope of This Standard

Description	Symbol	Minimum	Maximum
Unsupported length	L	6.35 cm (2.5 in.) [Note (1)]	60.96 cm (24 in.) [Note (2)]
Bore diameter	d	0.3175 cm (0.125 in.)	2.0955 cm (0.825 in.)
Tip diameter	B	0.92 cm (0.36 in.)	4.65 cm (1.83 in.)
Taper ratio	B/A	0.58	1
Bore ratio	d/B	0.16	0.71
Aspect ratio	L/B	2	...
Minimum wall thickness	$(B - d)/2$	0.30 cm (0.12 in.)	...

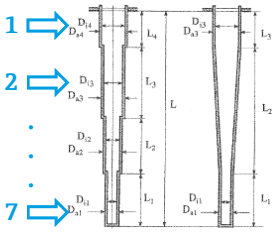
GENERAL NOTE: Limits in this table apply to the nominal dimensions of the thermowell.
NOTES:
(1) Thermowells of length less than the minimum specified require design methods outside the scope of this Standard.
(2) The equations in this Standard are valid for thermowells longer than the maximum indicated; however, only single-piece, drilled bar-stock shanks are covered by this Standard.

- DIN gives a variety of TW geometries (diameters and lengths)
- ASME is applicable in a certain range of parameters

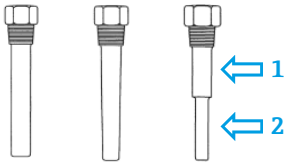
Used Standards – ASME vs DIN

DIN 43772 ⟵ Standards ⟶ ASME PTC 19.3 TW 2010

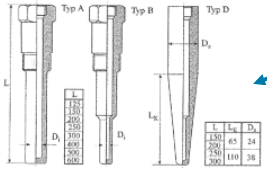
Variance



wide range of segments possible



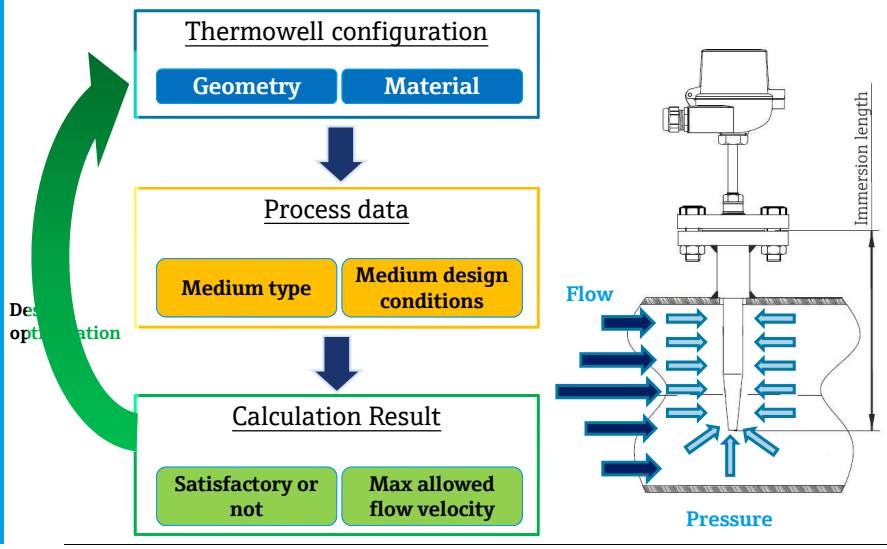
max 2 segments



wide range of TW types

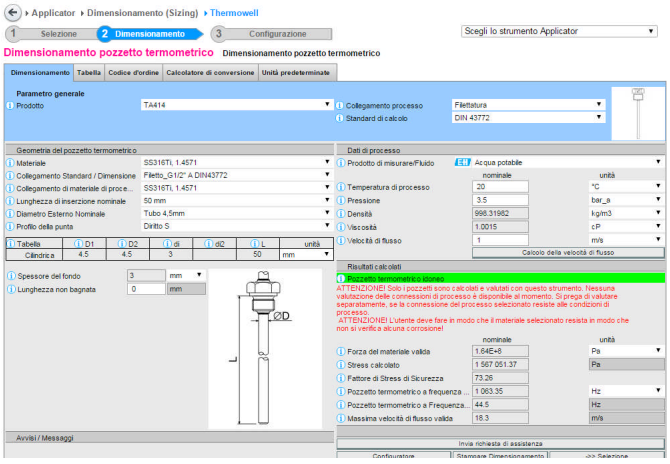
Larger scope of TW types with respect to PTC 19.3 2010

Example



Tool per il dimensionamento del pozzetto termometrico

- Solo per prodotti Endress + Hauser standard



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Tool per il dimensionamento del termometro

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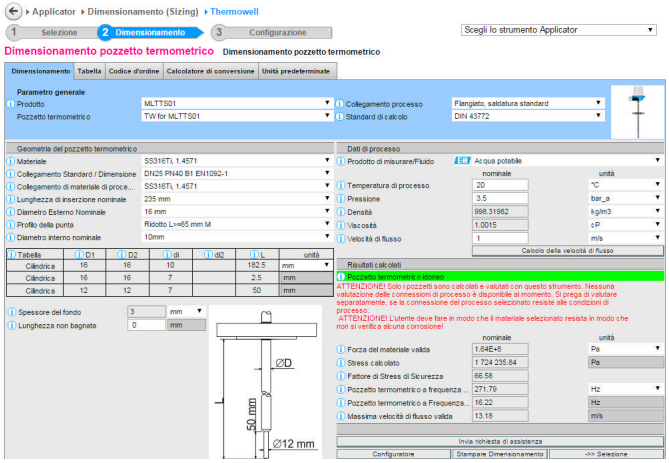

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Any questions?

Products Solutions Services

Thank you very much for your attention

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People for Process Automation