**PTC Code Case #12-02**

**PTC 19.3 TW – 2010**

This Code Case addresses several changes to the PTC 19.3TW, the Thermowell design standard, including tip thickness \((t)\), frequency limits, in-line resonance, cyclic stress conditions.

**Question 1:** In Tables 4-1-1 and 4-1-2, on dimensional limits, include Tip Diameters, \(B\). Why was Tip Thickness excluded from these tables?

**Reply 1:** It is the opinion of the Committee that tip thickness should have been included. Both tables will be revised to include Tip Thickness, \(t\), as shown below. Also, the fourth paragraph of subsection 4-2, on dimensional limits will be revised to include \(t\) and the allowable manufacturing tolerances.

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

<table>
<thead>
<tr>
<th>Description</th>
<th>Symbol</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsupported length</td>
<td>(L)</td>
<td>6.35 cm (2.5 in.)</td>
<td>60.96 cm (24 in.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[Note (1)]</td>
<td>[Note (2)]</td>
</tr>
<tr>
<td>Bore diameter</td>
<td>(d)</td>
<td>0.3175 cm (0.125 in.)</td>
<td>2.0955 cm (0.825 in.)</td>
</tr>
<tr>
<td>Tip diameter</td>
<td>(B)</td>
<td>0.92 cm (0.36 in.)</td>
<td>4.65 cm (1.83 in.)</td>
</tr>
<tr>
<td>Taper ratio</td>
<td>(B/A)</td>
<td>0.58</td>
<td>1</td>
</tr>
<tr>
<td>Bore ratio</td>
<td>(d/B)</td>
<td>0.16</td>
<td>0.71</td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>(L/B)</td>
<td>2</td>
<td>–</td>
</tr>
<tr>
<td><strong>Minimum wall thickness</strong></td>
<td>((B - d)/2)</td>
<td>0.30 cm (0.12 in.)</td>
<td>–</td>
</tr>
<tr>
<td><strong>Tip thickness</strong></td>
<td>(t)</td>
<td>0.30 cm (0.12 in.)</td>
<td>–</td>
</tr>
</tbody>
</table>

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 equation in this standard are valid for themowells longer than the maximum indicated; however, only single piece, drilled bar-stock shanks are covered in this standard.

**4-2 Dimensional Limits**

Calculations may be made using the nominal dimensions provided that a corrosion allowance is not used (see subsection 6-2) and that the thermowell is fabricated with manufacturing tolerances of ±1% for lengths \(L\) and \(L_S\) and ±3% for diameters \(b, A,\) and \(B A, B\) or \(d\) and -0% with no upper limit for \(t\). If tolerances for \(b, A,\) or \(B A, B\) or \(d\) are not met, calculations shall be made according to Section 6.2, using as the corrosion allowance the linear sum of the actual tolerance and any corrosion allowance. If tolerances for \(L\) or \(L_S\) are not met, calculations shall be made assuming that the lengths \(L\) and \(L_S\) each equal the nominal length plus the respective manufacturing tolerance. External pressure calculations shall be made based on the minimum material condition, as discussed in Section 6.13.
**Question 2:** In Note 1 of Table 4-2-1, what is the correlation for natural frequency for other tip diameters?

**Reply 2:** It is the opinion of the Committee that Note 1 needs to be revised to clarify the correlation. See revised Note 1 in Table 4-2-1.

**Table 4-2-1 Dimensional Limits for Step-Shank Thermowells within the Scope of this Standard**

<table>
<thead>
<tr>
<th>Description</th>
<th>Symbol</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsupported length</td>
<td>$L$</td>
<td>12.7 cm (5 in.)</td>
<td>60.96 cm (24 in.)</td>
</tr>
<tr>
<td>Bore diameter</td>
<td>$d$</td>
<td>0.61 cm (0.24 in.)</td>
<td>0.67 cm (0.265 in.)</td>
</tr>
<tr>
<td>Step diameter ratio, for $B = 1.270$ cm (0.5 in.)</td>
<td>$B/A$</td>
<td>0.5</td>
<td>0.8</td>
</tr>
<tr>
<td>Step diameter ratio, for $B = 2.223$ cm (0.875 in.)</td>
<td>$B/A$</td>
<td>0.583</td>
<td>0.875</td>
</tr>
<tr>
<td>Length ratio</td>
<td>$L_s/L$</td>
<td>0</td>
<td>0.6</td>
</tr>
<tr>
<td>Minimum wall thickness</td>
<td>$(B - d)/2$</td>
<td>0.30 cm (0.12 in.)</td>
<td>0.6</td>
</tr>
<tr>
<td>Tip thickness</td>
<td>$t$</td>
<td>0.30 cm (0.12 in.)</td>
<td>-</td>
</tr>
</tbody>
</table>

**Allowable Dimensions [Note (1)]**

| Tip diameter | $B$ | 1.270 cm (0.5 in.) and 2.223 cm (0.875 in.) |

**GENERAL NOTE:** Limits in this table apply to the nominal dimensions of the thermowell.

**NOTE:** (1) The methods presented in this standard apply for other tip diameters than those specified, but the correlation for natural frequency is supplied only for the given tip diameters. For step-shank thermowells, the natural frequency correlation presented in this standard applies for tip diameters (B dimensions) that satisfy Table 4-2-1. The machining tolerance for B specified in section 4-2 may be applied in addition to the dimensional limits specified on Table 4-2-1. The other methods in this standard (not related to natural frequency) may be applied to tip diameters outside those specified in table 4-2-1.
Question 3: Para. 6-8.2, states that the in-line resonance is suppressed if the Scruton number ($N_{Sc}$) > 2.5 and the Reynolds number ($Re$) < $10^5$, then the installed natural frequency shall satisfy Eq. 6-8.2. This is not clear. Please clarify.

Reply 3: It is the opinion of the Committee that a clarification is necessary, follows: $N_{Sc} > 2.5$ and $Re < 10^5$, in-line resonance is suppressed, and the installed natural frequency of the thermowell shall satisfy and the following condition shall apply:

Question 4: Please clarify Steps 3 & 4 of para 6-8.3 on the frequency limits.

Reply 4: It is the opinion of the Committee that Steps 3 and 4 should be revised as follows:

Step 3 If the thermowell passes the cyclic stress condition [Eq. 6-12.1] for operation at the in-line resonance condition, the installed natural frequency, $f_n^c$, shall satisfy the following condition shall apply:

$$f_s < 0.8f_n^c$$

(6-8-6)

The conditions of 6-8.4 shall also apply.

Step 4 If the thermowell fails the cyclic stress condition for operation at the in-line resonance condition, the installed natural frequency $f_n^c$ must be high enough to limit excitation of the in-line resonance, as shown in Figs. 6-8-1 and 6-8-2. In this case, $f_n^c$ shall satisfy the following condition shall apply:

$$f_s < 0.4f_n^c$$

(6-8-7)

Exceptions to [eq. (6-8-7)] may be considered pursuant to methods subject to the conditions established by in subsection 6-8.5.

Question 5: Clarify para. 6-8.4, Frequency Limit When the In-Line Resonance Does Not Limit Operation

Reply 5: It is the opinion of the Committee, that para. 6-8.4 shall be revised as follows:

In cases where the thermowell passes the cyclic stress condition for operation at the in-line resonance condition, care shall still be taken that in steady state the flow condition will not coincide with the thermowell resonance. Dwelling within the in-line resonance region may cause a severe vibration of the thermowell tip. This could result in fatigue related failure to the thermowell or unacceptable sensor damage or drift. To avoid this, the steady-state fluid velocity should meet one of the following conditions:
Question 6: Please clarify para. 6-8.5, to indicate what happens when the thermowell design fails the cyclic stress condition for steady-state operation.

Reply 6: In the opinion of the Committee that a substantial revision of para. 6-8.5 was necessary.

6-8.5 Passing Through the In-Line Critical 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 intermediate between the steady-state Strouhal frequency (which excites transverse vibrations) and twice the Strouhal frequency (which excites in-line vibrations) is subjected to large-amplitude significant vibration only for limited periods on start-up or shutdown, as 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 only 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.
(c) The sustained or steady state peak stress is less than the fatigue limit for the number of cycles. The cumulative number of cycles incurred during passage through in-line resonance lock-in region is below $10^{11}$ 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 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 for a range of forcing frequencies equal to 20% of the natural frequency. If the criteria above are met, the designer shall evaluate the maximum stresses when the thermowell is excited.
at its natural frequency, in accordance with subsection 6.12, and determine whether the thermowell has sufficient fatigue strength 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 $0.4f_n^c$ and $0.6f_n^c$.

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.
**Question 7:** Is the first sentence of Step 2 in subsection 6-13, Pressure Limit, necessary?

**Reply 7:** It is the opinion of the Committee that the first sentence was unnecessary and that Step 2 should be revised as follows:

**Step 2** The minimum tip thickness $t$ (see Fig. 4-1-1) shall always be equal to or greater than the minimum wall thickness of the shank. (Refer to Tables 4-1-1 and 4-2-1 for minimum allowed wall thickness.) Calculate the allowable pressure $P_t$ for the tip thickness $t$, using

**Question 8:** Para. 8-1.1.2, is this a weld-in thermowell?

**Reply 8:** In the opinion of the Committee, this paragraph refers to weld-in thermowells and that para. 8-1.1.2 should be revised as follows:

**8-1.1.2 Thermowell Dimensions:** The weld-in thermowell has a tapered shank, with a machined fillet at the root of the shank, which is also the support plane.

**Question 9:** Para. 8-1.1.4, please clarify the use of Eq. 6-6-5

**Reply 9** It is the opinion of the Committee that Eq. (6-6-5) is used to calculate $H_c$. The para. will be revised as follows:

**8-1.1.4 Installation Details.** For the rotational stiffness of the thermowell support, $K_M$, we will assume the thermowell is mounted to a thick-wall pipe [subsection 6-6] and will use eq. (6-6-5) to calculate $H_c$. 