

This is one formula for interfacial pressure due to thermal expansion. This was derived by a member of the ASME committee. But they could not reach a consensus on it so it was not published in the code. This background material for this derivation was obtained from “Theory and Design of Modern Pressure Vessels” by John Harvey.

$$P_T = \frac{\frac{R_m}{R} E_t \delta}{\left(\frac{R^2}{t} - R_m \right) + R_m \left(2.9 \frac{E_t}{E_{ts}} - 0.3 \right)}$$

Where R_m = mean radius of the tube ($R-t/2$)
 R = Tube OD

$$\delta = \alpha_t R (T - 70) - \alpha_{ts} R (T - 70).$$

Another formula is,

$$P_T = \frac{(T - 70)(\alpha_t - \alpha_{ts}) E_t E_{ts}}{E_t + E_{ts}}$$

Note: these E and alpha are at operating temperature.

Tube pullout force equation from M. H. Jawad's paper¹

Tube Thickness

$$t := 0.065 \text{ in}$$

Inner & outer radii of tube

$$R_i := 0.435 \text{ in}$$

$$R_o := 0.5 \text{ in}$$

$$A_t := \pi \cdot (2 \cdot R_o - t) \cdot t$$

Tube yield stress and allowable stress

$$S_y := 26119.99 \text{ psi}$$

$$S := 15099 \text{ psi}$$

Expanded length of the tube

$$L_e := 1.125 \text{ in}$$

Friction coeff, 0.74 for mild steel-on-mild steel

$$f := 0.74$$

Expanding pressure per reference 2

$$P_e := S_y \cdot \left(1.945 - 1.384 \frac{R_i}{R_o} \right)$$

$$P_e = 19352.823 \text{ psi}$$

Residual Interface pressure by S. Yokell's paper²

$$P_o := P_e \cdot \left[1 - \left(\frac{R_i}{R_o} \right)^2 \right] - \left(\frac{2}{\sqrt{3}} \right) \cdot S_y \cdot \left(\ln \left(\frac{R_o}{R_i} \right) \right)$$

$$P_o = 504.421 \text{ psi}$$

Tube pullout force

$$F := (2 \cdot \pi \cdot R_o \cdot L_e) \cdot f \cdot P_o$$

$$F = 1319.2494 \text{ lbf}$$

Allowable Tube-Tubesheet load per ASME App-A for 'i' joint type (not tested)

$$f_r := 0.7$$

Tube is completely expanded in the Tubesheet

$$f_e := 1$$

$$f_y := 1$$

Assuming $P_t = P_o$,

$$P_t := 0.0 \text{ psi}$$

$$ft_fac := \frac{(Po + Pt)}{Po}$$

$$ft_fac = 1$$

$$Lmax := At \cdot S \cdot fe \cdot fr \cdot fy \cdot ft_fac$$

$$Lmax = 2018 \text{ lbf}$$

References:

1. Jawad, M.H., Clarkin E. J., and Schuessler, R.E., 1987, "Evaluation of Tube-to-Tubesheet Junction," ASME J. Pressure Vessel Technol., 109, pp. 19-26.
2. Yokell, S., 1991, "Expanded and Welded-and-Expanded Tube-to-Tubesheet Joints," TEMA Technical Committee Meeting, San Francisco, CA.