Readme Supplement

for

CAEPIPE Version 6.30

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Annexure A

ANSI B31.8 (2007)

Allowable Pressure

For straight pipes and bends (including closely spaced and widely spaced miter bends), the allowable pressure is calculated from para. 841.11.

$$P = \frac{2SEt_aFT}{D}$$

where

P = allowable pressure

S = specified minimum yield strength from para. 841.11(a)

E = longitudinal joint factor (input as material property), obtained from Table 841.115A

t_a = available thickness for pressure design

= t_n × (1 - mill tolerance/100) - corrosion allowance

(Any additional thickness required for threading, grooving, erosion, corrosion, etc., should be included in corrosion allowance.)

t_n = nominal pipe thickness

D = outside diameter

F = construction type design factor, obtained from Tables 841.114A and 841.114B

T = temperature derating factor, obtained from Table 841.116A (also see para 841.116)

Stress due to Sustained and Occasional Loads (Unrestrained Piping)

The sum of longitudinal pressure stress and the bending stress due to external loads, such as weight of the pipe and contents, seismic or wind, etc. is calculated according to paras. 833.6 (a), 833.6 (b), 833.2 (b) along with 805.233, 833.2 (d), 833.2 (e) and 833.2 (f).

Please note, the “include axial force in stress calculations” option is turned ON by default for ANSI B31.8.

Sustained Stress S_L (required to compute Expansion Stress Allowable S_A):

For Pipes and Long Radius Bends

$$S_L = \left|\frac{PD}{4t_n} + \frac{R}{A}\right|_{Sustained} + \left[\frac{\sqrt{(i_iM_i)^2 + (i_oM_o)^2}}{Z}\right]_{Sustained}$$

For other Fittings or Components.

$$S_{L(fc)} = \left|\frac{PD}{4t_n} + \frac{R}{A}\right|_{Sustained} + \left[\frac{\sqrt{(0.75i_iM_i)^2 + (0.75i_oM_o)^2 + (M_t)^2}}{Z}\right]_{Sustained}$$

Sustained + Occasional Stress S_{LO}:

For Pipes and Long Radius Bends

$$S_{Lo} = S_L + \left|\frac{(P_{peak} - P)D}{4t_n} + \frac{R}{A}\right|_{occasional} + \left[\frac{\sqrt{(i_iM_i)^2 + (i_oM_o)^2}}{Z}\right]_{occasional} \leq 0.75ST$$

For Fittings or Components

$$S_{Lo} = S_{L(fc)} + \left|\frac{(P_{peak} - P)D}{4t_n} + \frac{R}{A}\right|_{Occasional} + \left[\frac{\sqrt{(0.75i_iM_i)^2 + (0.75i_oM_o)^2 + (M_t)^2}}{Z}\right]_{occasional} \le 0.75ST$$

where

P = maximum operating pressure = max (P1, P2, P3)

P_{peak} = Peak pressure factor x P

D = outside diameter

t_n = nominal thickness

$i_i =$ in-plane stress intensification factor; the product $0.75i_i$ shall not be less than 1.0

$i_o =$ out-of-plane stress intensification factor; the product $0.75i_o$ shall not be less than 1.0

$M_i =$ in-plane bending moment

$M_o =$ out-of-plane bending moment

M_t = torsional moment

Z = uncorroded section modulus; for reduced outlets, effective section modulus

R = axial force component for external loads

A = corroded cross-section area (i.e., after deducting for corrosion)

S = specified minimum yield strength from para. 841.11(a)

T = temperature derating factor, obtained from Table 841.116A (also see para 841.116)

Note:

Young's modulus of elasticity corresponding to the lowest operating temperature [=min(T1,T2,T3,Tref)] is used to form the stiffness matrix for Sustained and Occasional load calculations.

Expansion Stress (Unrestrained Piping)

The stress (S_E) due to thermal expansion is calculated from para.833.8.

$$S_E = \sqrt{S_b^2 + 4S_t^2} \le S_A$$

where

$S_b =$ resultant bending stress = $\dfrac{\sqrt{(i_iM_i)^2 + (i_oM_o)^2}}{Z}$

$S_t =$ torsional stress = $\dfrac{M_t}{2Z}$

M_t = torsional moment

Z = uncorroded section modulus; for reduced outlets, effective section modulus

Please note, "Liberal allowable" option is always turned ON for ANSI B31.8.

$S_A = f[1.25(S_C + S_h) - S_L]$

$f =$ stress range reduction factor = $6/N^{0.2}$, where N = number of equivalent full range cycles

where f <= 1.0 (from para 833.8 (b)).

S_c = 0.33S_uT at the minimum installed or operating temperature

S_h = 0.33S_uT at the maximum installed or operating temperature

where

S_u = specified minimum <u>ultimate</u> tensile strength = **1.5 S_y (assumed),** and

$S_{y\,=}$ specified minimum yield strength as per para. 841.11(a)

T = temperature derating factor, obtained from Table 841.116A (also see para 841.116)

Note:

Young's modulus of elasticity corresponding to the lowest operating temperature [=min(T1,T2,T3,Tref)] is used to form the stiffness matrix for Expansion load calculations.

Stress due to Sustained, Thermal and Occasional Loads (Restrained Piping)

The Net longitudinal stress (S_L) due to sustained, thermal expansion and occasional loads for restrained piping is calculated from para. 833.3.

$$\begin{aligned} S_L = \quad & \max(\left|S_p + S_x + S_B\right|, \left|S_p + S_x - S_B\right|)_{sustained} + \\ & \max(\left|S_p + S_x + S_B\right|, \left|S_p + S_x - S_B\right|)_{Occasional} + \\ & \max(\left|S_T\right|_{warmest}, \left|S_T\right|_{coldest}) \le 0.9ST \end{aligned}$$

where

Internal pressure stress = $S_p = 0.3\dfrac{PD}{2t_n}$

Thermal expansion stress = $S_T = E\alpha(T_i - T_o)$

Nominal bending stress S_B from Weight and / or other External loads for

<u>For Pipes and Long Radius Bends</u>

$$S_B = \frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z}$$

<u>For other Fittings or Components.</u>

$$S_B = \frac{\sqrt{(0.75 i_i M_i)^2 + (0.75 i_o M_o)^2 + (M_t)^2}}{Z}$$

Stress due to axial loading (other than temperature and pressure) = $S_X = \dfrac{R}{A}$

Where

P = maximum operating pressure = max(P1,P2,P3)

D = outside diameter

t_n = nominal thickness

$i_i =$ in-plane stress intensification factor; the product $0.75i_i$ shall not be less than 1.0

$i_o =$ out-of-plane stress intensification factor; the product $0.75i_o$ shall not be less than 1.0

$M_i =$ in-plane bending moment

$M_o =$ out-of-plane bending moment

M_t = torsional moment

R = axial force component for external loads

A = corroded cross-sectional area

Z = uncorroded section modulus; for reduced outlets, effective section modulus

S = Specified Minimum Yield Strength (SMYS) from para 841.11 (a)

T = Temperature derating factor from Table 841.116A

E = Young's modulus at ambient (reference) temperature

T_i = installation temperature = T_{ref} in CAEPIPE

T_o = warmest or coldest operating temperature

$\alpha =$ coefficient of thermal expansion at T_o defined above

Table E-1 Flexibility Factor, k, and Stress Intensification Factor, i

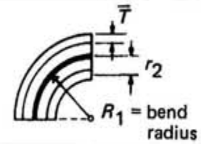
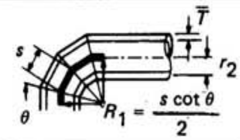
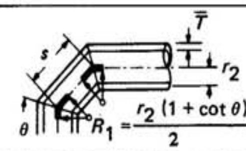
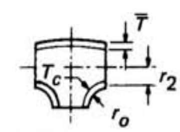
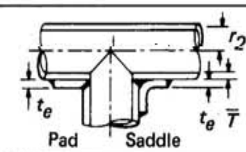
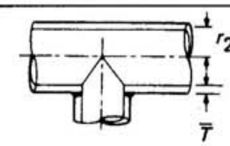
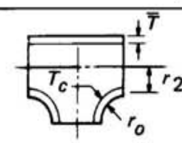
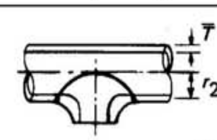
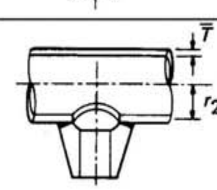
Description	Flexibility Factor, k	Stress Intensification Factor, i [Notes (1) and (2)] Out-plane, i_o	In-plane, i_i	Flexibility Characteristic, h	Sketch
Welding elbow or pipe bend [Notes (1)–(5)]	$\frac{1.65}{h}$	$\frac{0.75}{h^{2/3}}$	$\frac{0.9}{h^{2/3}}$	$\frac{\bar{T} R_1}{r_2^2}$	
Closely spaced miter bend [Notes (1), (2), (3), and (5)] $s < r_2 (1 + \tan \theta)$	$\frac{1.52}{h^{5/6}}$	$\frac{0.9}{h^{2/3}}$	$\frac{0.9}{h^{2/3}}$	$\frac{\cot \theta}{2} \frac{\bar{T}s}{r_2^2}$	
Single miter bend or widely spaced miter bend $s \geq r_2 (1 + \tan \theta)$ [Notes (1), (2), and (5)]	$\frac{1.52}{h^{5/6}}$	$\frac{0.9}{h^{2/3}}$	$\frac{0.9}{h^{2/3}}$	$\frac{1 + \cot \theta}{2} \frac{\bar{T}}{r_2}$	
Welding tee per ASME B16.9 with $r_o \geq d/8$ $T_c \geq 1.5 \bar{T}$ [Notes (1), (2), and (6)]	1	$\frac{0.9}{h^{2/3}}$	$\frac{3}{4} i_o + \frac{1}{4}$	$4.4 \frac{\bar{T}}{r_2}$	
Reinforced fabricated tee with pad or saddle [Notes (1), (2), (7)–(9)]	1	$\frac{0.9}{h^{2/3}}$	$\frac{3}{4} i_o + \frac{1}{4}$	$\frac{(\bar{T} + \frac{1}{2} t_e)^{5/2}}{\bar{T}^{3/2} r_2}$	
Unreinforced fabricated tee [Notes (1), (2), and (9)]	1	$\frac{0.9}{h^{2/3}}$	$\frac{3}{4} i_o + \frac{1}{4}$	$\frac{\bar{T}}{r_2}$	
Extruded outlet $r_o \geq 0.05d$ $T_c < 1.5 \bar{T}$ [Notes (1), (2), and (6)]	1	$\frac{0.9}{h^{2/3}}$	$\frac{3}{4} i_o + \frac{1}{4}$	$\left(1 + \frac{r_o}{r_2}\right) \frac{\bar{T}}{r_2}$	
Welded-in contour insert $r_o \geq d/8$ $T_c \geq 1.5 \bar{T}$ [Notes (1), (2), and (10)]	1	$\frac{0.9}{h^{2/3}}$	$\frac{3}{4} i_o + \frac{1}{4}$	$4.4 \frac{\bar{T}}{r_2}$	
Branch welded-on fitting (integrally reinforced) [Notes (1), (2), (9), and (11)]	1	$\frac{0.9}{h^{2/3}}$	$\frac{0.9}{h^{2/3}}$	$3.3 \frac{\bar{T}}{r_2}$	

Table E-1 Flexibility Factor, *k*, and Stress Intensification Factor, *i* (Cont'd)

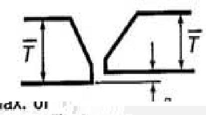
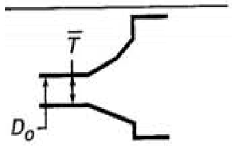
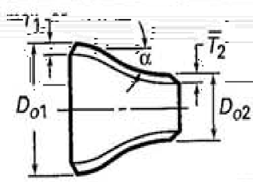
Description	Flexibility Factor, k	Stress Intensification Factor, i	Sketch
Buttweld [Notes (1) and (12)] $\bar{T} \ge 0.237$ in., $\delta_{max.} \le 1/16$ in., and $\delta_{avg}/\bar{T} \le 0.13$	1	1.0	
Buttweld [Notes (1) and (12)] $\bar{T} \ge 0.237$ in., $\delta_{max.} \le 1/8$ in., and $\delta_{avg}/\bar{T}$ = any value	1	1.9 max. or $[0.9 + 2.7(\delta_{avg}/\bar{T})]$, but not less than 1.0	
Buttweld [Notes (1) and (12)] $\bar{T} \le 0.237$ in., $\delta_{max.} \le 1/16$ in., and $\delta_{avg}/\bar{T} \le 0.33$	1	1.9 max. or $1.3 + 0.0036\frac{D_o}{\bar{T}} + 3.6\frac{\delta}{\bar{T}}$	
Tapered transition per ASME B16.25 [Note (1)]			
entric reducer per SME B16.9 [Notes (1) and 3)]	1	2.0 max. or $0.5 + 0.01\alpha\left(\frac{D_{o2}}{\bar{T}_2}\right)^{1/2}$	
ble-welded slip-on flange lote (14)]	1	1.2	
ket welding flange or fit- ng [Notes (14) and (15)]	1	2.1 max or 2.1 $\bar{T}/C_x$ but not less than 1.3	
joint flange (with ASME 16.9 lap joint stub) lote (14)]	1	1.6	
eaded pipe joint or ireaded flange [Note (14)]	1	2.3	
ugated straight pipe, or orrugated or creased bend Note (16)]	5	2.5	

Table E-1 Flexibility Factor, *k*, and Stress Intensification Factor, *i* (Cont'd)

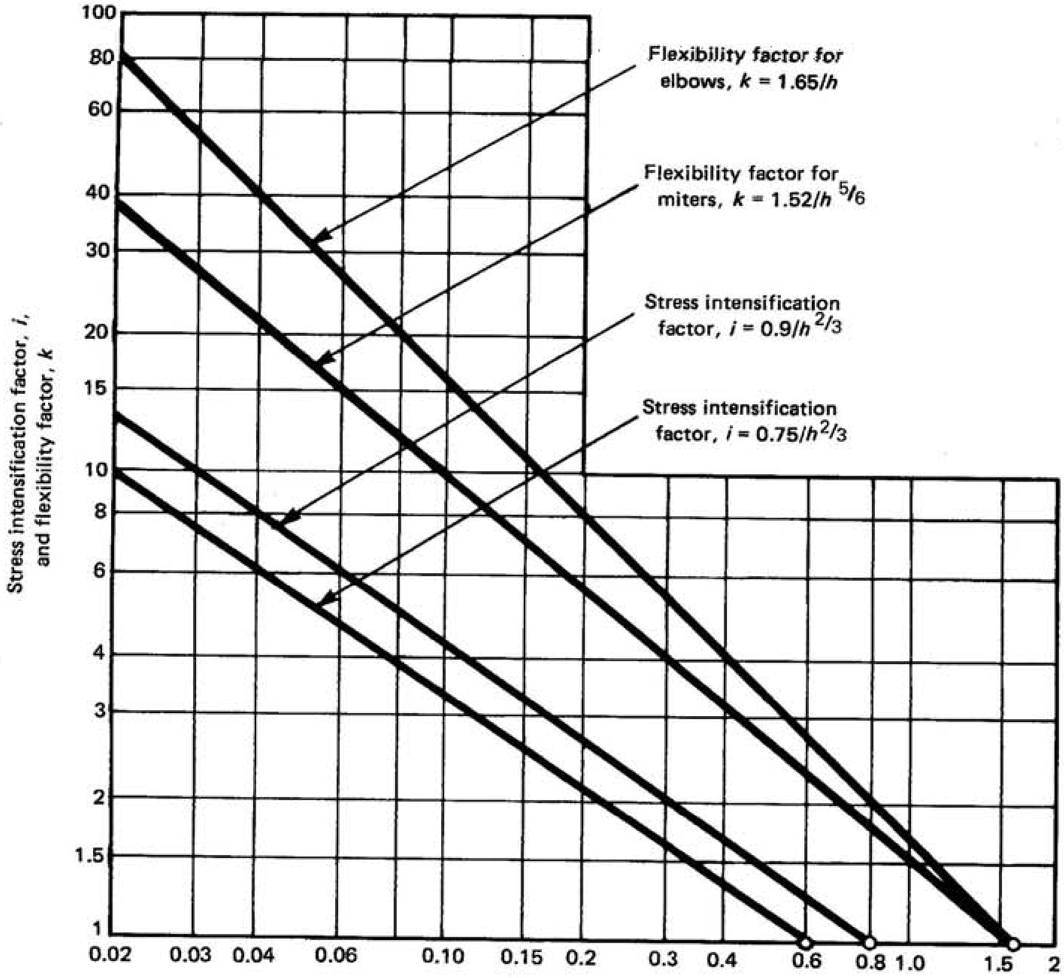


Chart A

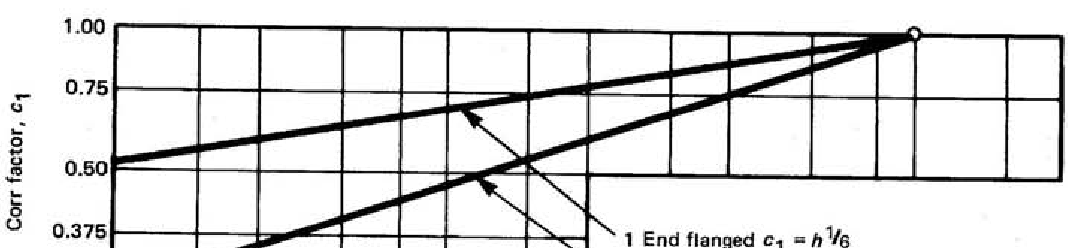


Chart B

Table E-1 Flexibility Factor, *k*, and Stress Intensification Factor, *i* (Cont'd)

NOTES:

(1) The nomenclature is as follows:

R_1 = bend radius of welding elbow or pipe bend, in. (mm)
$\overline{T}$ = nominal wall thickness of piping component, in. (mm)
= for elbows and miter bends, the nominal wall thickness of the fitting, in. (mm)
= for welding tees, the nominal wall thickness of the matching pipe, in. (mm)
= for fabricated tees, the nominal wall thickness of the run or header (provided that if thickness is greater than that of matching pipe, increased thickness must be maintained for at least one run outside diameter to each side of the branch outside diameter), in. (mm)
T_c = the crotch thickness of tees, in. (mm)
d = outside diameter of branch, in. (mm)
r_0 = radius of curvature of external contoured portion of outlet, measured in the plane containing the axes of the header and branch, in. (mm)
r_2 = mean radius of matching pipe, in. (mm)
s = miter spacing at centerline, in. (mm)
t_e = pad or saddle thickness, in. (mm)
α = reducer cone angle, deg
θ = one-half angle between adjacent miter axes, deg

The flexibility factor, *k*, applies to bending in any plane. The flexibility factors, *k*, and stress intensification factors, *i*, shall not be less than unity; factors for torsion equal unity. Both factors apply over the effective arc length (shown by heavy centerlines in the sketches) for curved and miter bends and to the intersection point for tees. (2)

'he values of *k* and *i* can be read directly from Chart A by entering with the characteristic, *h*, computed from the formulas given.

Where flanges are attached to one or both ends, the values of *k* and *i* shall be corrected by the factors, C_u, which can be read directly from Chart B, entering with the computed *h*. (3)

The designer is cautioned that cast buttwelded fittings may have considerably heavier walls than that of the pipe with which they are used. Large errors may be introduced unless the effect of these greater thicknesses is considered. (4)

In large diameter thin-wall elbows and bends, pressure can significantly affect the magnitudes of *k* and *i*. To correct values from the table, divide *k* by (5)

$$\left[1 + 6\left(\frac{P}{E_e}\right)\left(\frac{r_2}{\overline{T}}\right)^{7/3}\left(\frac{R_1}{r_2}\right)^{1/3}\right]$$

de *i* by div

$$\left[1 + 3.25\left(\frac{P}{E_e}\right)\left(\frac{r_2}{\overline{T}}\right)^{5/2}\left(\frac{R_1}{r_2}\right)^{2/3}\right]$$

ere wh

E_e = cold modulus of elasticity
P = gage pressure

If the number of displacement cycles is less than 200, the radius and thickness limits specified need not be met. When the radius and thickness limits are not met and the number of design cycles exceeds 200, the out-plane and in-plane stress intensification factors shall be calculated as $1.12/h^{2/3}$ and $(0.67/h^{2/3}) + 1/4$, respectively. (6)

When $t_e > 1\frac{1}{2}T$, use $h = 4.05T/r_2$. (7)

The minimum value of the stress intensification factor shall be 1.2. (8)

When the branch-to-run diameter ratio exceeds 0.5, but is less than 1.0, and the number of design displacement cycles exceeds 200, the out-plane and in-plane stress intensification factors shall be calculated as $1.8/h^{2/3}$ and $(0.67/h^{2/3}) + 1/4$, respectively, unless the transition weld between the branch and run is blended to a smooth concave contour. If the transition weld is blended to a smooth concave contour, the stress intensification factors in the table still apply. (9)

) If the number of displacement cycles is less than 200, the radius and thickness limits specified need not be met. When the radius and thickness limits are not met and the number of design displacement cycles exceeds 200, the out-plane and in-plane stress intensification factors shall be calculated as $1.8/h^{2/3}$ and $(0.67/h^{2/3}) + 1/4$, respectively. (10)

) The designer must be satisfied that this fabrication has a pressure rating equivalent to straight pipe. (11)

) The stress intensification factors apply to girth butt welds between two items for which the wall thicknesses are between $0.875\overline{T}$ and $1.10\overline{T}$ for an axial distance of $\sqrt{D_o\,\overline{T}}$ · D_o and $\overline{T}$ are nominal outside diameter and nominal wall thickness, respectively. δ_{avg} is the average mismatch or offset. (12)

$$M_L = (C/4)(S_b A_b - PA_p)$$

A_b = total area of flange bolts, in.^{2} (mm^3)
A_p = area to outside of gasket contact, in.^{2} (mm^2)
C = bolt circle, in. (mm)
M_L = moment to produce flange leakage, in.-lb (mm·N)
P = internal pressure, psi (MPa)
S_b = bolt stress, psi (MPa)

(15) C_x is the fillet weld length. For unequal lengths, use the smaller leg for C_x.

(16) Factors shown apply to bending. Flexibility factor for torsion equals 0.9.

Annexure B

Thickness and Section Modulus used in Weight, Pressure and Stress Calculations for ANSI B31.x Codes

Particulars	Allowable Pressure	Pipe Weight	Sustained Stress	Expansion Stress	Occasional Stress
B31.1 (2007)					
Pipe Thickness used	Nominal Thk. x (1-mill tolerance/100) – Corrosion allowance	Nominal Thickness	Nominal Thickness	-	Nominal Thickness
Section Modulus used	-	-	Uncorroded Section Modulus; For Branch, effective section modulus	Uncorroded Section Modulus; For Branch, effective section modulus	Uncorroded Section Modulus; For Branch, effective section modulus
B31.3 (2008)					
Pipe Thickness used	Nominal Thk. x (1-mill tolerance/100) – Corrosion allowance	Nominal Thickness	Nominal Thickness - Corrosion allowance	-	Nominal Thickness – Corrosion allowance
Section Modulus used	-	-	*Corroded* Section Modulus; For Branch, effective section modulus	Uncorroded Section Modulus; For Branch, effective section modulus	*Corroded* Section Modulus; For Branch, effective section modulus
B31.4 (2006)					
Pipe Thickness used	Nominal Thk – Corrosion allowance	Nominal Thickness	Nominal Thickness	-	Nominal Thickness
Section Modulus used	-	-	Uncorroded Section Modulus; For Branch, effective section modulus	Uncorroded Section Modulus; For Branch, effective section modulus	Uncorroded Section Modulus; For Branch effective section modulus
B31.5 (2001)					
Pipe Thickness used	Nominal Thk. x (1-mill tolerance/100) – Corrosion	Nominal Thickness	Nominal Thickness	-	Nominal Thickness

Particulars	Allowable Pressure	Pipe Weight	Sustained Stress	Expansion Stress	Occasional Stress
	allowance				
Section Modulus used	-	-	Uncorroded Section Modulus; For Branch, effective section modulus	Uncorroded Section Modulus; For Branch, effective section modulus	Uncorroded Section Modulus; For Branch, effective section modulus
B31.8 (2007)					
Pipe Thickness used	Nominal Thk. x (1-mill tolerance/100) – Corrosion allowance	Nominal Thickness	Nominal Thickness	-	Nominal Thickness
Section Modulus used	-	-	Uncorroded Section Modulus; For Branch, effective section modulus	Uncorroded Section Modulus; For Branch, effective section modulus	Uncorroded Section Modulus; For Branch, effective section modulus

Note:

1. Corrosion allowance includes thickness required for threading, grooving, erosion, corrosion etc.

2. Uncorroded section modulus = section modulus calculated using the nominal thickness.

3. Corroded section modulus = section modulus calculated using the “corroded thickness”
   Corroded thickness = nominal thickness – corrosion allowance

4. Effective section modulus = section modulus calculated using effective branch thickness, which is lesser of $i_i t_b$ or t_h
where, t_b = branch nominal thickness, t_h = header nominal thickness, i_i = in-plane SIF at branch