The *FASTEST* Solutions for Piping Design and Analysis.

Readme Supplement

CAEPIPE

Version 6.4

Disclaimer

Please read the following carefully:

This software and this document have been developed and checked for correctness and accuracy by SST Systems, Inc. (SST) and InfoPlant Technologies Pvt. Ltd. (InfoPlant). However, no warranty, expressed or implied, is made by SST and InfoPlant as to the accuracy and correctness of this document or the functioning of the software and the accuracy, correctness and utilization of its calculations.

Users must carry out all necessary tests to assure the proper functioning of the software and the applicability of its results. All information presented by the software is for review, interpretation, approval and application by a Registered Professional Engineer.

CAEPIPE is a trademark of SST and InfoPlant.

SST Systems, Inc.
1798 Technology Drive, Suite 236
San Jose, California 95110
USA

Tel: (408) 452-8111
Fax: (408) 452-8388
Email: info@sstusa.com
www.sstusa.com

InfoPlant Technologies Pvt. Ltd.
7, Crescent Road
Bangalore – 560001
India

Tel: +91-80-40336999
Fax: +91-80-41494967
Email: iplant@vsnl.com
www.infoplantindia.com

Annexure A

ANSI B31.x Code Compliance

Allowable Pressure

For straight pipes and bends (including closely spaced and widely spaced miter bends), the allowable pressure is calculated from para. 403.2.1.

$$P_i = \frac{2SEt_a}{D}$$

where

P_i = allowable pressure

S = allowable stress = 0.72 S_y

S_y = specified minimum yield strength of pipe

E = weld joint factor as defined in Table 403.2.1-1

t_a = available thickness for pressure design

= t_n × (1 - mill tolerance/100) - sum of allowances, as per para 403.2.1, for corrosion, threading, grooving and erosion.

D = outside diameter

Stress due to Sustained Loads (Unrestrained Piping)

For Pipes (as per para 402.6.2)

$$S_L = \left|\frac{PD}{4t_n} + \frac{F_a}{A}\right|_{Sustained} + \left[\frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2 + (M_t)^2}}{Z}\right]_{Sustained} \leq 0.54Sy$$ as per Table 403.3.1-1

where

$i_i =$ in-plane stress intensification factor = 1.0 for pipes

$i_o =$ out-of-plane stress intensification factor = 1.0 for pipes

For Fittings & Components.(as per para 402.6.2)

$$S_{L(fc)} = \left|\frac{PD}{4t_n} + \frac{F_a}{A}\right|_{Sustained} + \left[\frac{\sqrt{(0.75 i_i M_i)^2 + (0.75 i_o M_o)^2 + (M_t)^2}}{Z}\right]_{Sustained} \leq 0.54Sy$$ as per Table 403.3.1-1

where

P = maximum operating pressure = max of CAEPIPE input pressures (P1, P2, P3). Due considerations shall be given as per para 401.2.2.2 while inputting pressure values in CAEPIPE.

D = outside diameter

t_n = nominal thickness as per para 402.1

$i_i =$ 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

F_a = axial force component for external loads

A = <u>nominal</u> cross-section area

S_y = specified minimum yield strength of pipe

Stress due to Sustained Loads + Occasional Loads (Unrestrained Piping)

For Pipes (as per para 402.6.2)

$$S_{Lo} = S_L + \left| \frac{(P_{peak} - P)D}{4t_n} + \frac{F_a}{A} \right|_{occasional} + \left[\frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2 + (M_t)^2}}{Z} \right]_{occasional} \leq 0.8 S_y$$ as per Table 403.3.1-1

For Fittings & Components (as per para 402.6.2)

$$S_{Lo} = S_{L(fc)} + \left| \frac{(P_{peak} - P)D}{4t_n} + \frac{F_a}{A} \right|_{occasional} + \left[\frac{\sqrt{(0.75 i_i M_i)^2 + (0.75 i_o M_o)^2 + (M_t)^2}}{Z} \right]_{occasional} \leq 0.8 S_y$$ as per Table 403.3.1-1

where

P_{peak} = peak pressure = (peak pressure factor x P) where P = maximum operating pressure, as defined above with 1.0 <= peak pressure factor <= 1.1 as per para 403.3.4

Expansion Stress (Unrestrained Piping)

The stress (S_E) due to thermal expansion is calculated from para.402.5.2

$$S_E = \sqrt{S_b^2 + 4S_t^2} \leq S_A$$ as per Table 403.3.1-1 and para 403.3.2

where

S_b = resultant bending stress = $\frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z}$

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

M_t = torsional moment

Z = <u>uncorroded</u> section modulus; for reduced outlets, effective section modulus

Please note, "Liberal allowable" option is always turned ON for ANSI B31.4.

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

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

where f <= 1.2 (from para 403.3.2).

$S_c = 0.67 S_y$ at the lower of the installed temperature or minimum operating temperature

= $0.67 S_y$ at min(T_{ref}, T_1, T_2, T_3)

$S_h = 0.67 S_y$ at the higher of the installed temperature or maximum operating temperature

= $0.67 S_y$ at max((T_{ref}, T_1, T_2, T_3)

where

S_{y} = specified minimum yield strength of pipe

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. 402.6.1

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

where

Pressure stress = $S_p = \gamma \dfrac{PD}{2t_n}$ where $\gamma = 0.3$ as per 402.2.3 and can be either positive <u>or</u> negative

Thermal expansion stress = $S_T = E\alpha(T_i - T_o)$, which can be either positive <u>or</u> negative

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

<u>For Pipes</u>

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

<u>For Fittings & 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) = $S_x = \dfrac{F_a}{A}$

where

P = maximum operating pressure = max (P_1,P_2,P_3)

D = outside diameter

t_n = nominal thickness

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

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

$M_i =$ in-plane bending moment

$M_o =$ out-of-plane bending moment

M_t = torsional moment

F_a = axial force component for external loads

A = <u>nominal</u> cross-section area

Z = <u>uncorroded</u> section modulus; for reduced outlets, effective section modulus

S_y = specified minimum yield strength of pipe

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

E = young’s modulus at ambient (reference) temperature

Note:

1. Para 402.6.2 of B31.4 (2009) states that “Longitudinal stress from pressure in an unrestrained line should include consideration of bending stress or axial stress that may be caused by elongation of the pipe due to internal pressure and result in stress at bends and at connections and produce additional loads on equipment and on supports”

   The above statement seems to imply that “elongation of pipe and opening of bends due to Bourdon effect” are to be included in the Sustained load case (and hence in Operating case and Sustained plus Occasional load case).

   On the other hand, since the deformation due to Bourdon effect is being constrained by piping supports, CAEPIPE includes the Bourdon effect as part of the results for Thermal Expansion (when “Solve Thermal Case” is opted) or as part of the Operating Case (when “Thermal = Operating – Sustained is opted).
2. Young’s modulus of elasticity corresponding to reference temperature (T_{ref}) is used to form the stiffness matrix.
3. Refer Annexure B for the details of “Thickness” and the “Section Modulus” used for weight, pressure and stress calculations.

Table 402.1-1 Flexibility Factor, *k*, and Stress Intensification Factor, *i*

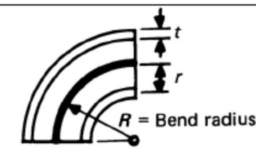
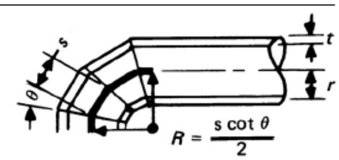
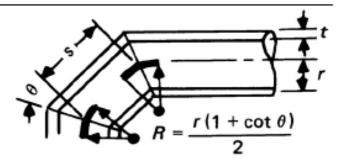
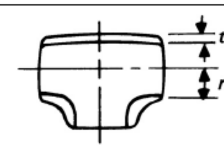
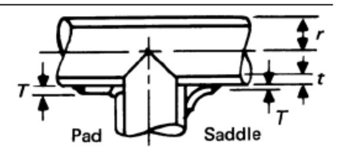
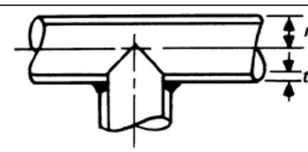
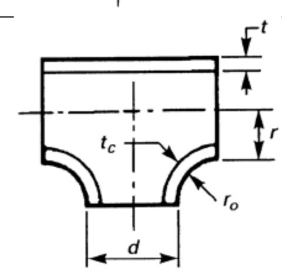
Description	Flexibility Factor, k	Stress Intensification Factor i_i [Note (1)]	Stress Intensification Factor i_o [Note (2)]	Flexibility Characteristic, h	Sketch
Welding elbow, or pipe bend [Notes (3)–(7)]	$\frac{1.65}{h}$	$\frac{0.9}{h^{2/3}}$	$\frac{0.75}{h^{2/3}}$	$\frac{tR}{r^2}$	
Closely spaced miter bend, [Notes (3)–(5), and (7)] $s < r(1 + \tan\theta)$	$\frac{1.52}{h^{5/6}}$	$\frac{0.9}{h^{2/3}}$	$\frac{0.75}{h^{2/3}}$	$\frac{\cot\theta}{2}\,\frac{ts}{r^2}$	
Widely spaced miter bend, [Notes (3),(4), (7), and (8)] $s \geq r(1 + \tan\theta)$	$\frac{1.52}{h^{5/6}}$	$\frac{0.9}{h^{2/3}}$	$\frac{0.75}{h^{2/3}}$	$\frac{1 + \cot\theta}{2}\,\frac{t}{r}$	
Welding tee [Notes (3) and (4)] per ASME B16.9	1	$0.75i_o + 0.25$	$\frac{0.9}{h^{2/3}}$	$4.4\,\frac{t}{r}$	
Reinforced tee [Notes (3),(4), and (9)] with pad or saddle	1	$0.75i_o + 0.25$	$\frac{0.9}{h^{2/3}}$	$\frac{(t + 1/2\,T)^{5/2}}{t^{3/2}\,r}$	
Unreinforced fabricated tee [Notes (3) and (4)]	1	$0.75i_o + 0.25$	$\frac{0.9}{h^{2/3}}$	$\frac{t}{r}$	
Extruded welding tee [Notes (3),(4), and (10)] $r_o \geq 0.05d$ $t_c < 1.5t$	1	$0.75i_o + 0.25$	$\frac{0.9}{h^{2/3}}$	$\left(1 + \frac{r_o}{r}\right)\frac{t}{r}$	
Butt welded joint, reducer, or welding neck flange	1	1.0		. . .	. . .
Double welded slip-on flange	1	1.2		. . .	. . .
Fillet welded joint (single welded), or single welded slip-on flange	1	1.3		. . .	. . .

Table 402.1-1 Flexibility Factor, k, and Stress Intensification Factor, i (Cont'd)

Description	Flexibility Factor, k	Stress Intensification Factor i_i [Note (1)]	Stress Intensification Factor i_o [Note (2)]	Flexibility Characteristic, h	Sketch
Lapped flange (with ANSI B16.9 lap-joint stub)	1	1.6		. . .	. . .
Threaded pipe joint, or threaded flange	1	2.3		. . .	. . .
Corrugated straight pipe, or corrugated or creased bend [Note (11)]	5	2.5		. . .	. . .

NOTES:

(1) In-plane.

(2) Out-of-plane.

(3) For fittings and miter bends, the flexibility factors, k, and stress intensification factors, i, in the Table apply to bending in any plane and shall not be less than unity; factors for torsion equal unity. Both factors apply over the effective arc length (shown by heavy center lines in the sketches) for curved and miter elbows, and to the intersection point for tees.

(4) The values of k and i can be read directly from Chart A by entering with the characteristic, h, computed from the equations given, where

d = outside diameter of branch
R = bend radius of welding elbow or pipe bend, in. (mm)
r = mean radius of matching pipe, in. (mm)
r_o = see Note (10)
s = miter spacing at center line
T = pad or saddle thickness, in. (mm)
t = nominal wall thickness of: part itself, for elbows and curved or mited bends; matching pipe, for welding tees; run or header, for fabricated tees (provided that if thickness is greater than that of matching pipe, increased thickness must be maintained for at least one run O.D. to each side of the branch O.D.)
t_c = the crotch thickness of tees
θ = one-half angle between adjacent miter axes, deg

(5) Where flanges are attached to one or both ends, the values of k and i in this Table shall be corrected by the factors C_1 given below, which can be read directly from Chart B, entering with the computed h: one end flanged, $h^{1/6} \geq 1$; both ends flanged, $h^{1/3} \geq 1$.

(6) The engineer is cautioned that cast butt welding elbows 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.

(7) In large diameter thin wall elbows and bends, pressure can significantly affect the magnitude of flexibility and stress intensification factors. To correct values obtained from this Table for the pressure effect, divide

Flexibility factor, k, by $$1 + 6\frac{P}{E_c}\left(\frac{r}{t}\right)^{7/3}\left(\frac{R}{r}\right)^{1/3}$$

Stress intensification factor, i, by $$1 + 3.25\frac{P}{E_c}\left(\frac{r}{t}\right)^{5/2}\left(\frac{R}{r}\right)^{2/3}$$

where

E_c = cold modulus of elasticity
P = gage pressure

(8) Also includes single miter joint.

(9) When $T > 1\frac{1}{2}t$, use $h = 4.05\ t/r$.

(10) Radius of curvature of external contoured portion of outlet measured in the plane containing the axes of the run and branch. This is subject to the following limitations:

(a) minimum radius, r_o: the lesser of $0.05d$ or 38 mm (1.5 in.)

(b) maximum radius, r_o shall not exceed

(1) for branches DN 200 (NPS 8) and larger, $0.10d$ + 13 mm (0.50 in.)

(2) for branches less than DN 200 (NPS 8), 32 mm (1.25 in.)

(c) when the external contour contains more than one radius, the radius on any arc sector of approximately 45 deg shall meet the requirements of (a) and (b) above

(d) machining shall not be employed in order to meet the above requirements

(11) Factors shown apply to bending; flexibility factor for torsion equals 0.9.

Allowable Pressure

For straight pipes and bends (including closely spaced and widely spaced miter bends), the allowable pressure is calculated from para. 504.1.2.

$$P = \frac{2SEt_a}{D - 2Yt_a}$$

where

P = allowable pressure

S = basic allowable stress at maximum of CAEPIPE input temperatures T_1, T_2 and T_3

E = longitudinal or spiral joint factor (input as material property) from para. 502.3.1 and Table 502.3.1

Table 502.3.1 provides maximum allowable hoop stress values (SE) as a function of metal temperature and Longitudinal or Spiral Joint Factor (E) for various materials. Divide SE value by E value provided in Table 502.3.1 to obtain basic allowable stress S. For materials where E is not given explicitly in Table 502.3.1, use E=1.0.

Hence, SE in the above formula for allowable pressure P is the allowable hoop stress as per para 502.3.1

t_a = available thickness for pressure design (as per para 504.1.1)

= 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

d = inside diameter

Y = pressure coefficient

For ductile non-ferrous materials and ferritic and austenitic steels,

Y = 0.4 for $D/t_a \geq 6$ and Y = $\dfrac{d}{d+D}$, for $4 \leq D/t_a < 6$

Sustained Stress (in corroded condition)

The stress (S_L) due to sustained loads (pressure, weight and other sustained mechanical loads) is calculated from para 502.3.2(d).

$$S_L = \frac{PD}{4t_c} + \frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z_c} \leq S_h$$

where

P = maximum of CAEPIPE input pressures P_1, P_2 and P_3

D = outside diameter

t_c = nominal thickness – corrosion allowance, as per para 502.3.2 (d)

i_i = in-plane stress intensification factor

i_o = out-of-plane stress intensification factor

M_i = in-plane bending moment

M_o = out-of-plane bending moment

Z_c = corroded section modulus as per para 502.3.2 (d)

S_h = basic allowable stress at maximum of CAEPIPE input temperatures T_1, T_2 and T_3

Occasional Stress (in corroded condition)

The stress (S_{Lo}) due to occasional loads is calculated as the sum of stress due to sustained loads (S_L) and stress due to occasional loads (S_o) such as earthquake or wind. Wind and earthquake are not considered concurrently (see para. 502.3.3 (a)).

$$S_{Lo} = \frac{P_{peak} D}{4t_c} + \left[\frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z_c}\right]_{sustained} + \left[\frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z_c}\right]_{occasional} \leq 1.33 S_h$$

where

P_{peak} = peak pressure = (peak pressure factor) x P, where P is defined above

Expansion Stress (in uncorroded condition)

The stress (S_E) due to thermal expansion is calculated from para 519.4.5 and para 519.3.5.

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

where

S_b = resultant bending stress = $\frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z}$

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

M_t = torsional moment

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

$S_A = f(1.25 S_{Cold} + 0.25 S_{hot})$

f = stress range reduction factor from Figure 502.3.2

S_{cold} = basic allowable stress at minimum of CAEPIPE input temperatures T_1, T_2, T_3 and T_{ref}

S_{hot} = basic allowable stress at maximum of CAEPIPE input temperatures T_1, T_2, T_3 and T_{ref}

When S_h is greater than S_L, the allowable stress range may be calculated as

$S_A = S_A + f(S_h - S_L)$

where, S_h = basic allowable stress at maximum of CAEPIPE input temperatures T_1, T_2 and T_3

This is specified as an analysis option: “Use liberal allowable stresses”, in the CAEPIPE menu Options->Analysis on the Code tab.

Note:

Refer Annexure B for the details of “Thickness” and the “Section Modulus” used for weight, pressure and stress calculations.

Table 519.3.6 Flexibility Factor, *k*, and Stress Intensification Factor, *i*

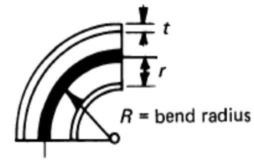
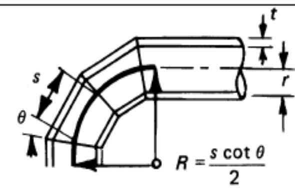
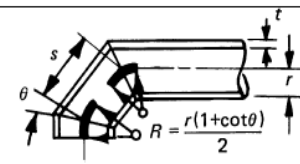
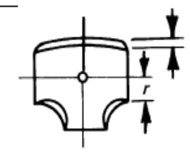
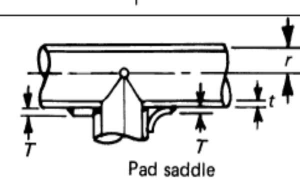
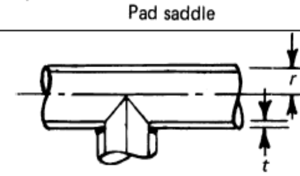
Description	Flexibility Characteristic, *h*	Flexibility Factor, *k*	Stress Intensification Factor i_i [Note (1)]	Stress Intensification Factor i_o [Note (2)]	Illustration
Welding elbow or pipe bend [Notes (3), (4), (5), (6), and (7)]	$\frac{tR}{r^2}$	$\frac{1.65}{h}$	$\frac{0.9}{h^{2/3}}$	$\frac{0.75}{h^{2/3}}$	
Closely spaced miter bend [Notes (3), (4), (5), and (7)], $s < r(1 + \tan\theta)$	$\frac{ts}{r^2}\left(\frac{\cot\theta}{2}\right)$	$\frac{1.52}{h^{5/6}}$	$\frac{0.9}{h^{2/3}}$	$\frac{0.75}{h^{2/3}}$	
Widely spaced miter bend [Notes (3), (4), (7), and (8)], $s \geq r(1 + \tan\theta)$	$\frac{t}{r}\left(\frac{1+\cot\theta}{2}\right)$	$\frac{1.52}{h^{5/6}}$	$\frac{0.9}{h^{2/3}}$	$\frac{0.75}{h^{2/3}}$	
Welding tee ASME B16.9 [Notes (3) and (4)]	$4.4\frac{t}{r}$	1	$0.75i_o + 0.25$	$\frac{0.9}{h^{2/3}}$	
Reinforced fabricated tee with pad or saddle [Notes (3), (4), and (9)]	$\frac{(t + \frac{1}{2}T)^{5/2}}{t^{3/2}r}$	1	$0.75i_o + 0.25$	$\frac{0.9}{h^{2/3}}$	
Unreinforced fabricated tee [Notes (3) and (4)]	$\frac{t}{r}$	1	$0.75i_o + 0.25$	$\frac{0.9}{h^{2/3}}$	
Butt welded joint, reducer, or welding neck flange	...	1	1.0	1.0	...
Double-welded slip-on flange	...	1	1.2	1.2	...

Table 519.3.6 Flexibility Factor, *k*, and Stress Intensification Factor, *i* (Cont'd)

Description	Flexibility Characteristic, *h*	Flexibility Factor, *k*	Stress Intensification Factor i_i [Note (1)]	Stress Intensification Factor i_o [Note (2)]	Illustration
Fillet welded joint (single-welded), socket welded flange, or single-welded slip-on flange	...	1	1.3	1.3	...
Lap flange (with ASME B16.9 lap-joint stub)	...	1	1.6	1.6	...
Threaded pipe joint or threaded flange	...	1	2.3	2.3	...
Corrugated straight pipe, or corrugated or creased bend [Note (10)]	...	5	2.5	2.5	...

GENERAL NOTE: For reference, see Table 519.3.6 Illustration beginning on page 40.

NOTES:

(1) In-plane.

(2) Out-of-plane.

(3) For fittings and miter bends the flexibility factors, *k*, and stress intensification factors, *i*, in the Table apply to bending in any plane and shall not be less than unity; factors for torsion equal unity.

(4) Both factors apply over the effective arc length (shown by heavy center lines in the sketches) for curved and miter elbows and to the intersection point for tees. The values of *k* and *i* can be read directly from Chart A by entering with the characteristic, *h*, computed from the equations given where

- R = bend radius of welding elbow or pipe bend, in. (mm)
- r = mean radius of matching pipe, in. (mm)
- s = miter spacing at center line, in. (mm)
- T = pad or saddle thickness, in. (mm)
- t = nominal wall thickness, in. (mm), of: part itself for elbows and curved or miter bends; mathing pipe for welding tees; run or header for fabricated tees (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).
- θ = one-half angle between adjacent miter axes, deg

(5) Where flanges are attached to one or both ends, the values of *k* and *T* in the Table shall be corrected by the factors C_1 given below, which can be read directly from Chart B; entering with the computed *h*: one end flanged, $h^{1/6} \geq 1$; both ends flanged, $h^{1/3} \geq 1$.

(6) The engineer is cautioned that cast butt welding elbows 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.

(7) In large-diameter thin-wall elbows and bends, pressure can significantly affect the magnitude of flexibility and stress intensification factors. To correct values obtained from the Table for the pressure effect, divide:

(a) flexibility factor, *k*, by

$$1 + 6\frac{P}{E_c}\left(\frac{r}{t}\right)^{7/3}\left(\frac{R}{r}\right)^{1/3}$$

(b) stress intensification factor, *i*, by

$$1 + 3.25\frac{P}{E_c}\left(\frac{r}{t}\right)^{5/2}\left(\frac{R}{r}\right)^{2/3}$$

where

- E_c = cold modulus of elasticity, ksi (MPa)
- P = gage pressure, psi gage (kPa gage)

(8) Also includes single-miter joint.

(9) When $T > 1.5t$, use $h = 4.05\ t/r$.

(10) Factors shown apply to bending; flexibility factor for torsion equals 0.9.

Allowable Pressure

For straight pipes and bends, the calculation of allowable pressure is based on Eq. 2 of para.904.1.

$$P = \frac{2SE(t_m - A)}{D}$$

where

P = allowable pressure

SE = allowable hoop stress, given in Appendix I of B31.9 (2004) Code, where

E = longitudinal or spiral weld joint efficiency factor or casting quality factor

t_m = minimum required pipe thickness as per para.904.1.1(a)

= $t_n \times$ (1 - mill tolerance/100)

t_n = nominal pipe thickness

A = corrosion allowance

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

D = outside diameter

For closely and widely spaced miter bends, the allowable pressure shall be the lower positive value calculated from Eqs. (3A) and (3B) of para 904.2.2 (a)

$$P = \frac{SET}{r}\left(\frac{T}{T + 0.64\tan\theta\sqrt{rT}}\right) \qquad \text{Eq. (3A)}$$

$$P = \frac{SET}{r}\left(\frac{R - r}{R - r/2}\right) \qquad \text{Eq. (3B)}$$

where

r = mean radius of pipe = (D - t_n) / 2

T = t_m – A, where t_m and A are defined above

R = effective bend radius of the miter

θ = miter half angle

Sustained Stress (in uncorroded condition)

The longitudinal stress (S_L) due to sustained loads (pressure, weight and other sustained mechanical loads) is calculated as mentioned in para.902.3.2 (d)

$$S_L = \frac{PD_o}{4t_n} + \frac{0.75iM_A}{Z} \leq S_h$$

where

P = maximum of CAEPIPE pressures P_1, P_2 and P_3

D_o = outside diameter

t_n = nominal wall thickness

i = stress intensification factor. The product 0.75i shall not be less than 1.0.

M_A = resultant bending moment due to weight and other sustained loads

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

S_h = hot allowable stress at maximum of CAEPIPE input temperatures T_1, T_2 and T_3

Occasional Stress (in uncorroded condition)

The longitudinal stress (S_{Lo}) due to occasional loads is calculated as mentioned in para.902.3.3 (a) as the sum of stresses due to pressure, live and dead loads and stress due to occasional loads (S_o) such as earthquake or wind. Wind and earthquake are not considered to occur concurrently.

$$S_{Lo} = \frac{P_{peak} D_o}{4t_n} + \frac{0.75 i M_A}{Z} + \frac{0.75 i M_B}{Z} \leq 1.33 S_h$$

where

M_B = resultant bending moment due to occasional loads

P_{peak} = peak pressure = (peak pressure factor) x P

Expansion Stress (in uncorroded condition)

The stress (S_E) due to thermal expansion is calculated from para.902.3.2 (c), para.919.2.1 and para.919.4.1 (b).

$$S_E = \frac{i M_C}{Z} \leq S_A$$

where

M_C = resultant moment due to thermal expansion

$$S_A = f(1.25 S_C + 0.25 S_h)$$

f = stress range reduction factor = $6/N^{0.2}$, where N being the total number of equivalent reference displacement stress range cycles expected during the service life of the piping. Also $0.15 \leq f \leq 1.0$

S_C = allowable stress at cold temperature, i.e. at minimum of CAEPIPE input temperatures T_1, T_2, T_3 and T_{ref}

When S_h is greater than S_L, the allowable stress range may be calculated as

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

This is specified as an analysis option: “Use liberal allowable stresses”, in the CAEPIPE menu Options->Analysis on the “Code” tab.

Note:

Refer Annexure B for the details of “Thickness” and the “Section Modulus” used for weight, pressure and stress calculations.

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 (2009)					
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
B31.5 (2006)					
Pipe Thickness used	Nominal Thk. x (1-mill tolerance/100) – Corrosion allowance	Nominal Thickness	Nominal Thickness – Corrosion allowance	-	Nominal Thickness – Corrosion allowance
Section Modulus	-	-	Corroded Section Modulus;	Uncorroded Section Modulus;	Corroded Section Modulus;

Particulars	Allowable Pressure	Pipe Weight	Sustained Stress	Expansion Stress	Occasional Stress
used			For Branch, effective section modulus	For Branch, effective 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
B31.9 (2004)					
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