Readme Supplement

for

CAEPIPE Version 5.15

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Annexure A

ANSI B31.x Code Compliance

B31.3 (2004)

Allowable Internal Pressure

For straight pipes and bends, the allowable pressure is calculated using Eq. (3a) for straight pipes and Eq. (3c) with I = 1.0 for bends from paras 304.1.2. and 304.2.1. respectively.

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

where

P = allowable pressure

S = allowable stress

E = joint factor (input as material property) from Table A-1A or A-1B from para. 302.3.3. and para 302.3.4.

W = Weld Joint Strength Reduction Factor from para. 302.3.5 (e)

W = 1.0 for all materials with Tempreature <= 950^0 F (or 510^0 C)

W = 0.5 for all materials with Tempreature >= 1500^0 F (or 815^0 C) and the value of W is linearly interpolated between 950^0 F and 1500^0 F or 510^0 C and 815^0 C.

t_a = available thickness for pressure design

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

(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 from Table 304.1.1, valid for t_a < D/6, and

$Y = \frac{d + 2c}{D + d + 2c}$, valid for $t_a \geq D/6$

For closely spaced miter bends, the allowable pressure is calculated using Eq. (4b) from para 304.2.3.

$$P = \frac{SEWt_a(R-r)}{r(R-r/2)}$$

where

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

R = effective bend radius of the miter (see para. 304.2.3 of code for definition)

For widely spaced miter bends, the allowable pressure is calculated using Eq. (4c) from para 304.2.3 as

$$P = \frac{SEWt_a^2}{r(t_a + 1.25\tan\theta\sqrt{rt_a})}$$

where

θ = miter half angle

Sustained Stress

The stress (S_L) due to sustained loads (pressure, weight and other sustained mechanical loads) is calculated from para 302.3.5(c).

$$S_L = \frac{PD}{4t_s} + \frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z_m} \le S_h W$$

where

P = maximum pressure

D = outside diameter

t_s = wall thickness used for sustained stress calculation after deducting corrosion allowance from the nominal thickness

= nominal thickness – corrosion allowance

$i_i =$ 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_m = corroded section modulus; for reduced outlets, effective section modulus

S_h = hot allowable stress

W = defined above under "Allowable Internal Pressure"

Sustained plus Occasional Stress

The stress (S_{Lo}) due to sustained and 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. 302.3.6).

For temp <= 427^0 C or 800^0 F

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

For temp > 427^0 C or 800^0 F

$$S_{Lo} = \frac{P_{peak} D}{4t_a} + \left[\frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z_m}\right]_{sust} + \left[\frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z_m}\right]_{occasional} \leq 0.9 W S_y$$

where

Z_m = corroded section modulus; for reduced outlets, effective section modulus

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

S_y = yield strength at maximum temperature and

W = 1.0 for Austenetic stainless steel and 0.8 for all other materials

Expansion Stress

The stress (S_E) due to thermal expansion is calculated using Eq. 17 from para. 319.4.4

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

where

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

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

M_t = torsional moment

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

$S_A = f(1.25 S_C + 0.25 S_h)$, Eq. (1a) of para. 302.3.5(d)

$f =$ stress range reduction factor from Eq. (1c) of para. 302.3.5 (d) = $6N^{-0.2}$

where f >= 0.15 and f <= 1.0

S_c = allowable stress at cold temperature

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

$S_A = f[1.25(S_C + S_h) - S_L]$, Eq. (1b) of para. 302.3.5(d).

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

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), 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

$$S_L = \frac{PD}{4t_n} + \frac{R}{A} + \frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z}$$

For other Fittings or Components.

$$S_{L(fc)} = \frac{PD}{4t_n} + \frac{R}{A} + \frac{\sqrt{(0.75 i_i M_i)^2 + (0.75 i_o M_o)^2 + (M_t)^2}}{Z}$$

Sustained + Occasional Stress S_{LO}:

For Pipes and Long Radius Bends

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

For Fittings or Components

$$S_{Lo} = S_{L(fc)} + \frac{(P_{peak} - P)D}{4t_n} + \left[\frac{R}{A} + \frac{\sqrt{(0.75 i_i M_i)^2 + (0.75 i_o M_o)^2 + (M_t)^2}}{Z}\right]_{occasional} \leq 0.75ST$$

where

P = maximum 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 $0.75 i_i$ 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

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)

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

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 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)).

$S_c = 0.33 S_u T$ at the minimum installed or operating temperature

$S_h = 0.33 S_u T$ at the maximum installed or operating temperature

where

S_u = specified minimum ultimate 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)

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.

$$S_L = \left|S_p + S_x\right| + \left|S_T\right| + S_B \leq 0.9ST$$

where

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

Thermal expansion stress = $S_T = E\alpha(T_1 - T_2)$

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

For Pipes and Long Radius Bends

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

For other Fittings or Components.

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

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

Where

P = maximum operating pressure

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 temperature

T_1 = installation temperature

T_2 = warmest or coldest operating temperature

$\alpha =$ coefficient of thermal expansion at T_2 defined above