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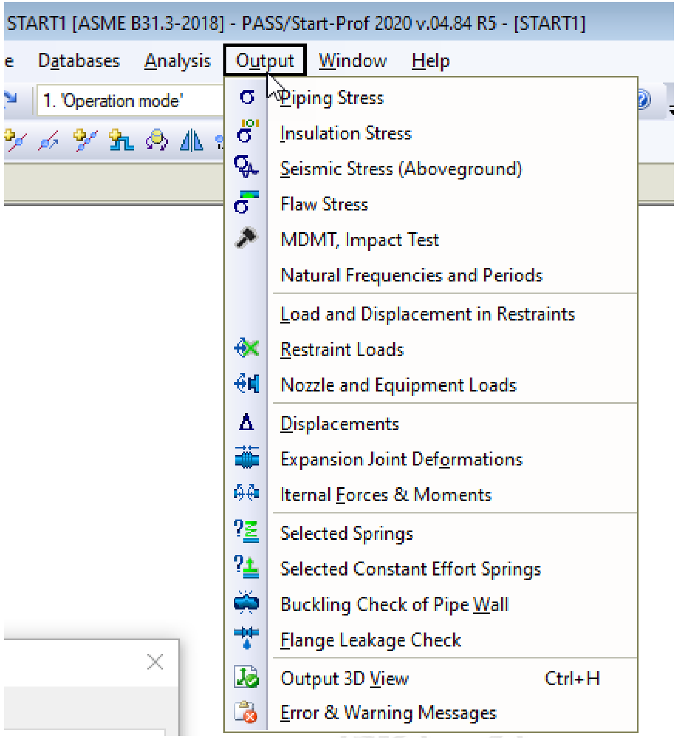
Pipe Stress Analysis with PASS/START-PROF Software

Piping Stress analysis involves examining the flexibility of a stress critical piping system under different loading conditions.
Piping stress analysis determines the

- Stresses in Pipes and Fittings
- Stresses in Insulation
- Stresses in Flaws
- Displacements
- Forces, and Moments at Restraints and Equipment
- Longitudinal Buckling Check
- Buckling Check under External Pressure
- Flange Leakage Check
- Expansion Joint Deformations
- Spring Hangers and Supports Selection
- Natural Frequencies

And it suggests necessary modifications for satisfying the ASME Code requirements for limits of sustained, displacement & occasional load allowable stresses.



PASS
PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Pipe Stress Analysis with PASS/START-PROF Software

Loads on Piping System

- Primary Loads: Internal Pressure, Weight of Pipe, Piping component, Insulation, Fluid, etc.
- Secondary Loads: Pipe expansion and contraction
- Occasional Loads: Wind, Snow, Ice, Seismic, Discharge Reaction Loads (Relief valve, PSV, etc.), Slug Flow Loads, Water Hammer Loads, etc.

Pipe Stress Analysis with PASS/START-PROF Software

When do pipe stress analysis required?

There are rules for when pipe stress analysis is required. Different industries or companies use own guidelines. Here are the most common rules

- If the operating temperature exceeds 150F and the pipe size is 4″ or above
- If the system temperature exceeds 300F need to analyze lines smaller than 4″ also
- If any line size is above 8″
- If the line >2 ½” is connected to rotating equipment
- If the line >6″ is connected to pressure vessels
- If the piping is cryogenic
- If the piping system carries hazardous chemicals
- If the piping system is located in a high seismic zone
- etc.

When not required?

- If the exactly the same piping has been previously analyzed
- If there is no thermal growth in the piping system and the line is small

319.4 Flexibility Analysis

319.4.1 Formal Analysis Not Required. No formal analysis of adequate flexibility is required for a piping system that

(a) duplicates, or replaces without significant change, a system operating with a successful service record

(b) can readily be judged adequate by comparison with previously analyzed systems

(c) is of uniform size, has no more than two points of fixation, no intermediate restraints, and falls within the limitations of empirical eq. (16)[8]

$$\frac{Dy}{(L-U)^2} \le K_1 \qquad (16)$$

where

D = outside diameter of pipe, mm (in.)

E_a = reference modulus of elasticity at 21°C (70°F), MPa (ksi)

K_1 = 208 000 S_A/E_a, (mm/m)^2

= 30 S_A/E_a, (in./ft)^2

[8] *WARNING*: No general proof can be offered that this equation will yield accurate or consistently conservative results. It is not applicable to systems used under severe cyclic conditions. It should be used with caution in configurations such as unequal leg U-bends or near-straight "sawtooth" runs, or for large thin-wall pipe ($i \ge 5$), or where extraneous displacements (not in the direction connecting anchor points) constitute a large part of the total displacement. There is no assurance that terminal reactions will be acceptably low, even if a piping system falls within the limitations of eq. (16).

L = developed length of piping between anchors, m (ft)

S_A = allowable displacement stress range in accordance with eq. (1a), MPa (ksi)

U = anchor distance, straight line between anchors, m (ft)

y = resultant of total displacement strains, mm (in.), to be absorbed by the piping system

PASS PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Wall Thickness Calculation using PASS/START-PROF

ASME B31.1:

$$t \geq t_m = \left(\frac{PD_o}{2(SW_l + Py)} + C\right)/(1 - mt\%)$$

$$\frac{P_t(D_o - 2t)}{2t} \leq 0.9S_y$$

ASME B31.3:

Low Pressure

$$t \geq t_m = \left(\frac{PD_o}{2(SEW_l + Py)} + C\right)/(1 - mt\%)$$

$$\frac{P_t(D_o - 2t)}{2t} \leq 1.0S_y$$

High Pressure (Chapter IX)

$$t \geq t_m = \left(\frac{D_o}{2}\left[1 - exp\left(\frac{-P}{S}\right)\right] + C\right)/(1 - mt\%)$$

$$\frac{P_t}{ln\left(\frac{D_o}{D_o - 2t}\right)} \leq 1.0S_y$$

ASME B31.9:

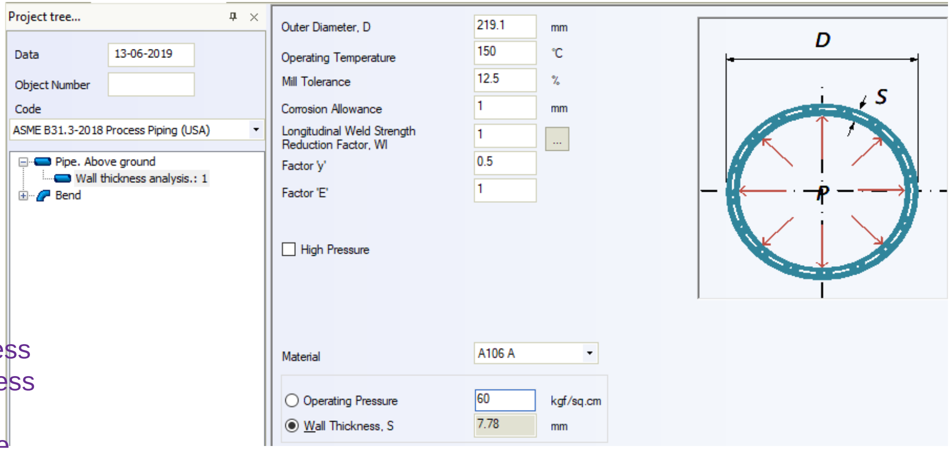
$$t \geq t_m = \left(\frac{PD_o}{2SE} + C\right)/(1 - mt\%)$$

$$\frac{P_t(D_o - 2t)}{2t} \leq 0.9S_y$$

ASME B31.5:

$$t \geq t_m = \left(\frac{PD_o}{2(S + Py)} + C\right)/(1 - mt\%)$$

Test pressure is not checked



t – Nominal wall thickness

t_m – Design wall thickness

$mt\%$ – Mill tolerance

C – Corrosion allowance

D_o – Outside Diameter

S – Allowable stress from database

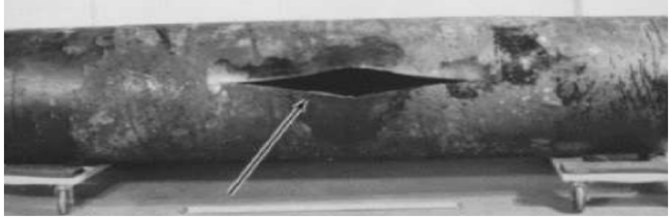
E – Longitudinal weld joint efficiency factor. Specified by user in pipe properties. For ASME B31.1 and B31.5 used E=1, because it is already added to database values.

S_y – Yield stress

W_l – Longitudinal weld strength reduction factor. Specified by user in pipe properties

P – Design Pressure

Pt – Test Pressure



PASS PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

ASME B31.4:

If $D_o/t \geq 20$ then

Pipeline:

$$t \geq t_m = \left(\frac{PD_o}{2E \cdot 0.72S_y} + C\right)/(1 - mt\%)$$

Riser and Platform for Inland Waterways:

$$t \geq t_m = \left(\frac{PD_o}{2E \cdot 0.6S_y} + C\right)/(1 - mt\%)$$

Test:

$$\frac{P_t D_o}{2t} \leq 0.9S_y$$

If $D_o/t < 20$ then

Pipeline:

$$t \geq t_m = \left(\frac{P(D_o - t)}{2E \cdot 0.72S_y} + C\right)/(1 - mt\%)$$

Riser and Platform for Inland Waterways:

$$t \geq t_m = \left(\frac{P(D_o - t)}{2E \cdot 0.6S_y} + C\right)/(1 - mt\%)$$

Test:

$$\frac{P_t(D_o - t)}{2t} \leq 0.9S_y$$

ASME B31.4 Chapter IX (Offshore pipelines):

If $D_o/t \geq 20$ then

Pipeline:

$$t \geq t_m = \left(\frac{PD_o}{2 \cdot 0.72S_y} + C\right)/(1 - mt\%)$$

Riser and Platform piping:

$$t \geq t_m = \left(\frac{PD_o}{2 \cdot 0.6S_y} + C\right)/(1 - mt\%)$$

Test:

$$\frac{P_t D_o}{2t} \leq 0.9S_y$$

If $D_o/t < 20$ then

Pipeline:

$$t \geq t_m = \left(\frac{P(D_o - t)}{2 \cdot 0.72S_y} + C\right)/(1 - mt\%)$$

Riser and Platform piping:

$$t \geq t_m = \left(\frac{P(D_o - t)}{2 \cdot 0.6S_y} + C\right)/(1 - mt\%)$$

Test:

$$\frac{P_t(D_o - t)}{2t} \leq 0.9S_y$$

ASME B31.4 Chapter XI (Slurry Pipes):

If $D_o/t \geq 20$ then

$$t \geq t_m = \left(\frac{PD_o}{2 \cdot 0.8ES_y} + C\right)/(1 - mt\%)$$

Test:

$$\frac{P_t D_o}{2t} \leq 0.9S_y$$

If $D_o/t < 20$ then

$$t \geq t_m = \left(\frac{P(D_o - t)}{2 \cdot 0.8ES_y} + C\right)/(1 - mt\%)$$

Test:

$$\frac{P_t(D_o - t)}{2t} \leq 0.9S_y$$

ASME B31.8:

$$t \geq t_m = \left(\frac{PD_o}{2EFS_y} + C\right)/(1 - mt\%)$$

$$\frac{P_t D_o}{2t} \leq FS_y$$

Offshore: F=0.72 for Pipeline and F=0.5 for platform piping and risers

Onshore: F – specified by user

If option "Use alternative formula 841.1.1 (b)" activated and $D_o/t < 30$, then

$$t \geq t_m = \left(\frac{PD_o}{2EFS_y + P} + C\right)/(1 - mt\%)$$

B31.4, B31.8, B31.5:
Bends are not checked.
Bend wall thickness should not be less than pipe wall thickness.
B31.9:

$$t_{bend} = \left(\frac{PD_o}{2SE}k + C\right)/(1 - mt\%)$$

B31.1, B31.3:

$$t_m = \left(\frac{PD_o}{2(SEW/I + Py)} + C\right)/(1 - mt\%)$$

ASME B31.1: E=1
GBT 20801: W=1
Centerline:

$$I = 1$$

Intrados:

$$I = \frac{4(R/D_o) - 1}{4(R/D_o) - 2}$$

Extrados:

$$I = \frac{4(R/D_o) + 1}{4(R/D_o) + 2}$$

EN 13480:
For $D_o/(D_o - 2t) \leq 1.7$

$$t \geq \left(\frac{PD_o}{2(fE + 0.5P)}\frac{R/D_o - 0.25}{R/D_o - 0.5} + C\right)/(1 - mt\%)$$

For $D_o/(D_o - 2t) > 1.7$

$$t \geq \left(\frac{D_o}{2}\left(1 - \sqrt{\frac{fE - P}{fE + P}}\right)\frac{R/D_o - 0.25}{R/D_o - 0.5} + C\right)/(1 - mt\%)$$

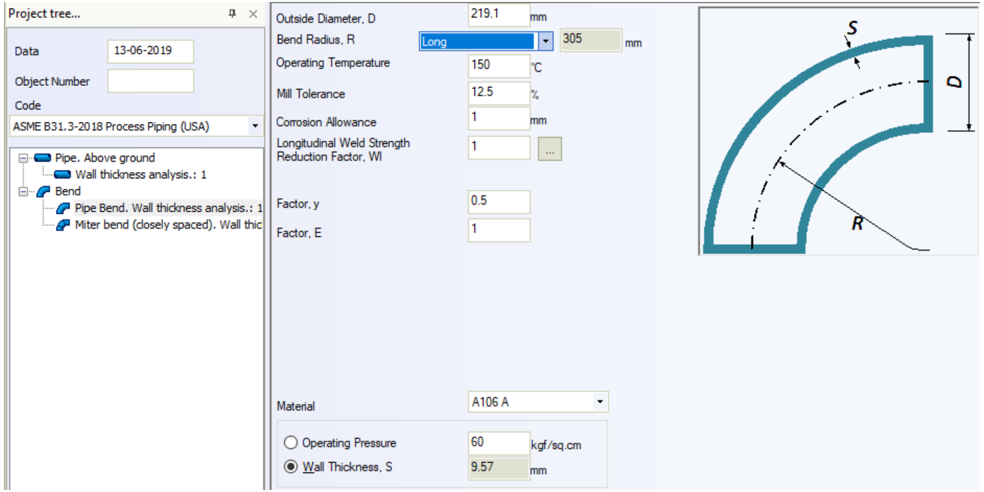
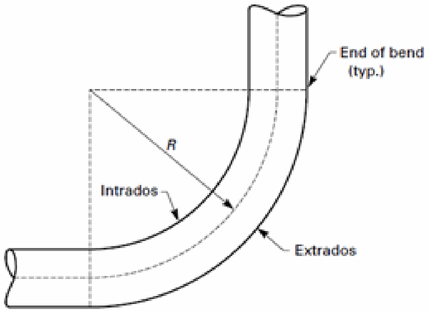


Fig. 102.4.5 Nomenclature for Pipe Bends

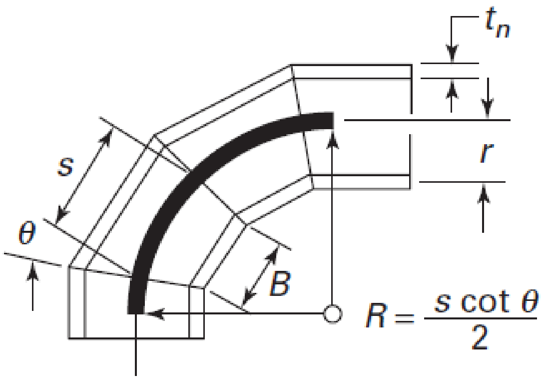


ASME B31.4, B31.5, B31.8:
Miter bends are not checked.
Bend wall thickness should not be less than pipe wall thickness.
ASME B31.1:
If $\theta > 22.5°$ or $B < 6t_m$ then allowable pressure is 0.07 MPa.
If $\theta \le 22.5°$ and $B \ge 6t_m$ then allowable pressure is 0.7 MPa.
Wall thickness should be not less than

$$t_s \ge t_m = \left(\frac{PD_o}{2(SW + Py)} + \mathrm{C}\right)/(1 - mt\%)$$

$$t_s = \left(t_m \frac{2 - r/R}{2(1 - r/R)} + \mathrm{C}\right)/(1 - mt\%)$$

$$r = \frac{D_o - t_s}{2}$$



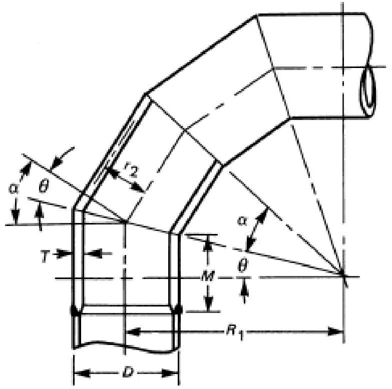
ASME B31.3, B31.9, EN 13480:
For ASME B31.9, EN 13480: W=1
Allowable pressure for miter bends with $\theta \le 22.5°$ (minimum of 2 equations):

$$P_m = \frac{S \cdot E \cdot W \cdot tc^2}{r_2[tc + 0.643tan(\theta)\sqrt{r_2 tc}]}$$

$$P_m = \frac{S \cdot E \cdot W \cdot tc[R_1 - r_2]}{r_2[R_1 - 0.5r_2]}$$

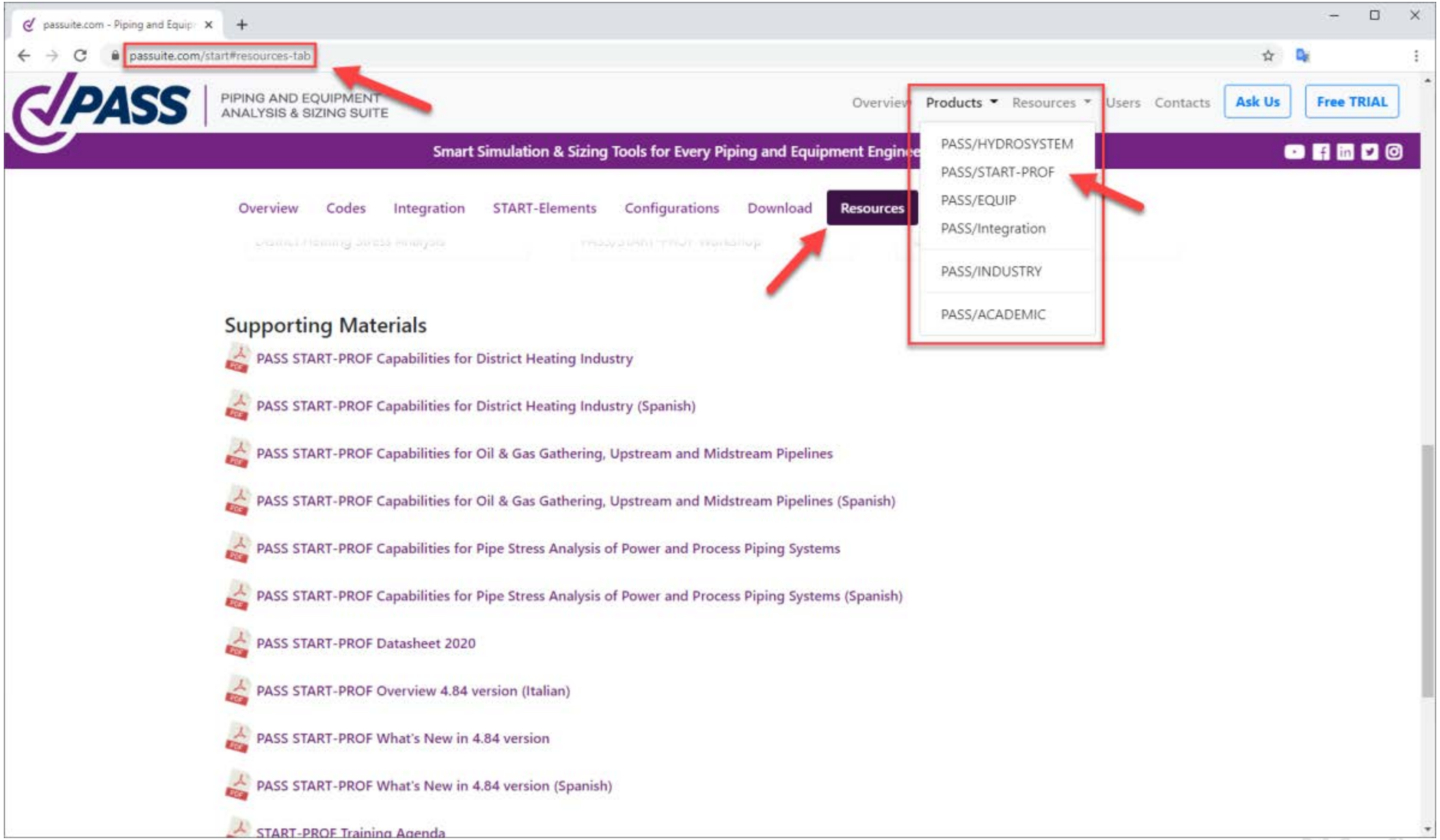
$$tc = (T - C) \cdot (1 - mt\%)$$

$$r_2 = \frac{D_o - T}{2}$$



Error message if $\theta > 22.5°$
T – Miter bend wall thickness,
C – Corrosion allowance

This presentation will be available to download at passuite.com



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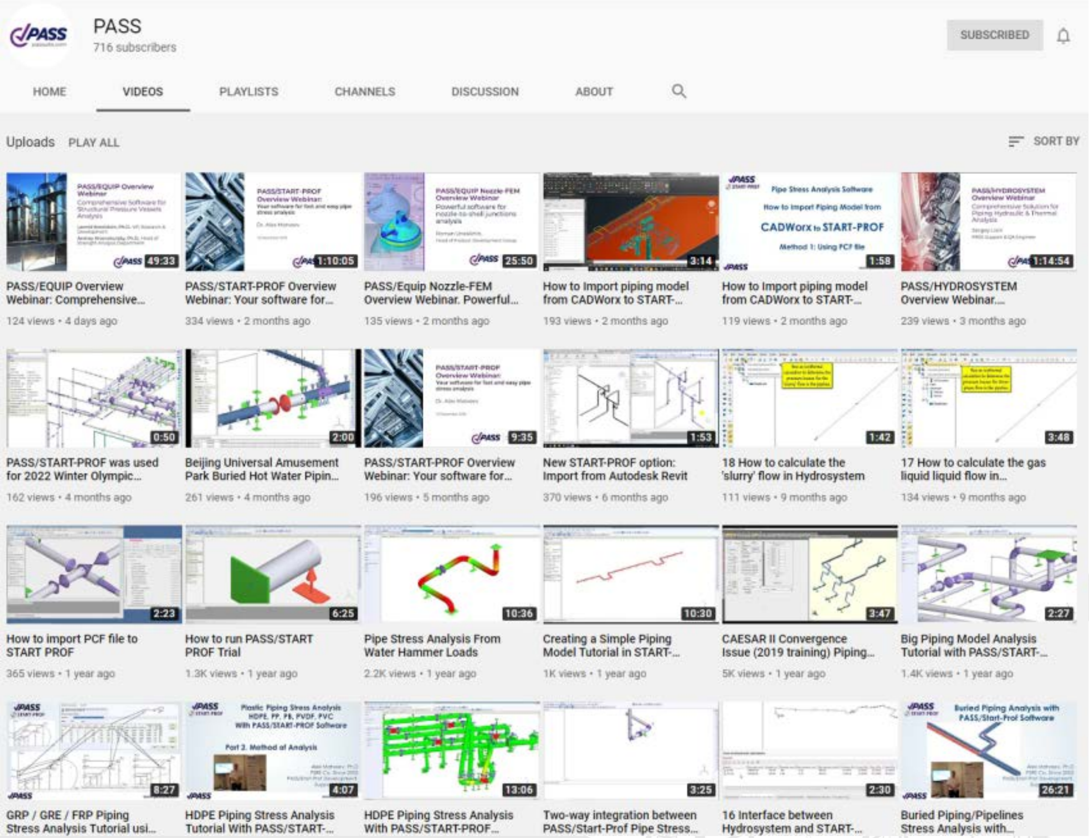


PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Sustained Stress

ASME B31.1, ASME B31.9, DLT 5366 (input: i)

For nonstandard tee, non-standard bend, joint and ASME B31J:

$$S_L = \frac{P(D_o - 2t_n)^2}{D_o^2 - (D_o - 2t_n)^2} \pm \frac{0.75 \cdot max(i_i, i_o, i_t) \cdot \sqrt{M_i^2 + M_o^2 + M_t^2}}{Z}$$

For pipes and other fittings:

$$S_L = \frac{P(D_o - 2t_n)^2}{D_o^2 - (D_o - 2t_n)^2} \pm \frac{(0.75i \geq 1) \cdot \sqrt{M_i^2 + M_o^2 + M_t^2}}{Z}$$

ASME B31.5 (input: i_i, i_o)

F – Axial force without pressure thrust, c – corrosion allowance

$$F = F' + P\left[\frac{\pi(D_o - 2(t_n - c))^2}{4} - \frac{\pi(D_o - 2t_n)^2}{4}\right] - P\frac{\pi(D_o - 2(t_n - c))^2}{4}$$

F with pressure thrust

$$F = F' + P\left[\frac{\pi(D_o - 2(t_n - c))^2}{4} - \frac{\pi(D_o - 2t_n)^2}{4}\right]$$

For pipes and fittings:

$$S_L = \frac{P(D_o - 2(t_n - c))^2}{D_o^2 - (D_o - 2(t_n - c))^2} + \frac{F}{A_p} \pm \frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z}$$

For nonstandard tee, non-standard bend, joint and ASME B31J:

$$S_L = \frac{P(D_o - 2(t_n - c))^2}{D_o^2 - (D_o - 2(t_n - c))^2} + \frac{i_a F}{A_p} \pm \frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z}$$

ASME B31.3 (input: i_i, i_o)

F – Axial force without pressure thrust, c – corrosion allowance

For pipes, bends, reducers, tees:

$$S_L = \sqrt{(|S_a| + S_b)^2 + (2S_t)^2}$$

$$S_a = \frac{F}{A_p}$$

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

$$S_b = \frac{\sqrt{((0.75i_i \geq 1)M_i)^2 + ((0.75i_o \geq 1)M_o)^2}}{Z}$$

For nonstandard tee, non-standard bend, joint and ASME B31J:

$$S_L = \sqrt{(|S_a| + S_b)^2 + (2S_t)^2}$$

$$S_a = \frac{(0.75i_a \geq 1)F}{A_p}$$

$$S_t = \frac{(0.75i_t \geq 1)M_t}{2Z}$$

$$S_b = \frac{\sqrt{((0.75i_i \geq 1)M_i)^2 + ((0.75i_o \geq 1)M_o)^2}}{Z}$$

Allowable Sustained Stress

ASME B31.1

$$S_L \le S_h \cdot W_c/E$$

ASME B31.3

$$S_L \le S_h \cdot W_c$$

ASME B31.5

$$S_L \le S_h/E$$

ASME B31.9

$$S_L \le S_h$$

EN 13480

$$\sigma_1 \le f_f = min(f(T); f_{cr})$$

If $f_{cr} = 0$ Then $\sigma_1 \le f_f = f(T)$

If $R_p = 0$ and t<720 then $R_p = R_m \frac{720-t}{1400}$, t – temperature in Degrees Celsius

R_p, R_m, S_{RTt} – From database at operating (hot) temperature

Not austenitic steel and austenitic with $A < 35\%$

$$f(T) = min\left(\frac{R_p}{1.5}, \frac{R_m}{2.4}\right)$$

Austenitic steel $A \ge 35\%$

If $R_m = 0$ then

$$f(T) = \frac{R_p}{1.5}$$

If $R_m > 0$

$$f(T) = min\left(\frac{R_p}{1.2}, \frac{R_m}{3}\right)$$

Creep allowable:

$$f_{cr} = \frac{S_{RTt}}{S_{fcr}}$$

If temp lower creep limit then $f_{cr} = 0$.

S_{RTt} – from database for specified lifetime (hours).

If "With surveillance of creep exhaustion"=Off (in Project Settings) then

$S_{fcr} = 1.5$

If at specified t $S_{RTt} \ne 0.01$ then

Use S_{RTt}

Else if at specified t $S_{RTt} = 0.01$ then use $S_{RTt} = S_{RT200000h}$

If lifetime> 100'000h then

If $\frac{S_{RT200000}}{S_{RT100000}} < 0.781$ then error message show "SRT20000/SRT1000 is lower than 0.781 see Table 5.3.2-1"

If "With surveillance of creep exhaustion"=On then

If at specified t $S_{RTt} \ne 0.01$ then

Use S_{RTt}, $S_{fcr} = 1.25$

Else if at specified t $S_{RTt} = 0.01$ then

If $S_{RT200000h} \ne 0.01$ use $S_{RTt} = S_{RT200000h}$, $S_{fcr} = 1.25$

If $S_{RT200000h} = 0.01$ use S_{RTt}, for t=150000 $S_{fcr} = 1.35$, for t=100000 $S_{fcr} = 1.5$

$$\sigma_1 \le f_f = min(f(T); f_{cr})$$

If $R_p = 0$ and t<720 then $R_p = R_m \frac{720-t}{1400}$, t – temperature in Degrees Celsius

R_p, R_m, S_{RTt} – From database at operating (hot) temperature

Not austenitic steel and austenitic with $A < 35\%$

$$f(T) = min\left(\frac{R_p}{1.5}, \frac{R_m}{2.4}\right)$$

Austenitic steel $A \ge 35\%$

If $R_m = 0$ then

$$f(T) = \frac{R_p}{1.5}$$

If $R_m > 0$

$$f(T) = min\left(\frac{R_p}{1.2}, \frac{R_m}{3}\right)$$

Creep allowable:

$$f_{cr} = \frac{S_{RTt}}{S_{fcr}}$$

S_{RTt} – from database for specified lifetime (hours).

If "With surveillance of creep exhaustion"=Off (in Project Settings) then

$S_{fcr} = 1.5$

If at specified t $S_{RTt} \ne 0.01$ then

Use S_{RTt}

Else if at specified t $S_{RTt} = 0.01$ then use $S_{RTt} = S_{RT200000h}$

If lifetime> 100'000h then

If $\frac{S_{RT200000}}{S_{RT100000}} < 0.781$ then error message show

"SRT20000/SRT1000 is lower than 0.781 see Table 5.3.2-1"

If "With surveillance of creep exhaustion"=On then

If at specified t $S_{RTt} \ne 0.01$ then

Use S_{RTt}, $S_{fcr} = 1.25$

Else if at specified t $S_{RTt} = 0.01$ then

If $S_{RT200000h} \ne 0.01$ use $S_{RTt} = S_{RT200000h}$, $S_{fcr} = 1.25$

If $S_{RT200000h} = 0.01$ use S_{RTt}, for t=150000 $S_{fcr} = 1.35$, for t=100000 $S_{fcr} = 1.5$

Allowable Occasional Stress

ASME B31.1

$$S_L \le k \cdot S_h / E$$
$$k = 1.15, 1.2$$

ASME B31.9

$$S_L \le k \cdot S_h$$
$$k = 1.15, 1.2$$

ASME B31.5

$$S_L \le k \cdot S_h / E$$
$$k = 1.33$$

ASME B31.3

If $T \le 426.667℃\ (800℉)$ then

$$S_L \le k \cdot S_h$$

Else

$$S_L \le min(k \cdot S_h; 0.9 W_c S_y)$$

For Low Pressure piping $k = 1.33$

For High Pressure piping $k = 1.2$

EN 13480

$$S_L \le k f_f$$

k =1.15, 1.2, 1.3, 1.8

Allowable Test Stress

ASME B31.1, ASME B31.9

$$S_L \le 0.9 S_y$$

ASME B31.3

$$S_L \le 1.0 S_y$$

ASME B31.5

Not calculated

EN 13480

$$\sigma_1 \le 0.95 R_p$$

Expansion Stress

Option “Add axial force and torsion stress” in Project Settings turned ON

$$S_L = \sqrt{(|S_a| + S_b)^2 + (2S_t)^2}$$

$$S_a = \frac{I_a F}{A_p}$$

$$S_t = \frac{I_t M_t}{2Z}$$

$$S_b = \frac{\sqrt{(I_i M_i)^2 + (I_o M_o)^2}}{Z}$$

ASME B31.1, ASME B31.9

$I_a = 1,\ I_t = 0.75i \geq 1,\ I_i = 0.75i \geq 1,\ I_o = 0.75i \geq 1$

For ASME B31J:

$I_a = 1,\ I_t = 0.75max(i_i, i_o, i_t) \geq 1,\ I_i = 0.75max(i_i, i_o, i_t) \geq 1,$
$I_o = 0.75max(i_i, i_o, i_t) \geq 1$

For Non-standard TEE, Non-standard BEND, Joint:

$I_a = 0.75i_a \geq 1,\ I_t = 0.75i_t \geq 1,\ I_i = 0.75i_i \geq 1,\ I_o = 0.75i_o \geq 1$

ASME B31.5

$I_a = 1,\ I_t = 1,\ I_i = i_i,\ I_o = i_o$

For Non-standard TEE, Non-standard BEND, Joint, ASME B31J:

$I_a = i_a,\ I_t = i_t,\ I_i = i_i,\ I_o = i_o$

EN 13480

$$S_a = \frac{I_a F}{A_p} + \frac{P}{2}$$

If **"Use ii/io"=false (input:** i**)**

$I_a = 1,\ I_t = 0.75i \geq 1,\ I_i = 0.75i \geq 1,\ I_o = 0.75i \geq 1$

If **"Use ii/io"=true (input:** i_i, i_o**)**

$I_a = 1,\ I_t = 1,\ I_i = 0.75i_i \geq 1,\ I_o = 0.75i_o \geq 1$

For Non-standard TEE, Non-standard BEND, Joint, ASME B31J:

$I_a = 0.75i_a \geq 1,\ I_t = 0.75i_t \geq 1,\ I_i = 0.75i_i \geq 1,\ I_o = 0.75i_o \geq 1$

Expansion Stress

ASME B31.1, ASME B31.9

For nonstandard tee, non-standard bend, joint and ASME B31J:

$$S_E = max(i_i, i_o, i_t)\frac{\sqrt{M_i^2 + M_o^2 + M_t^2}}{Z} \le S_A$$

For other fittings:

$$S_E = i\frac{\sqrt{M_i^2 + M_o^2 + M_t^2}}{Z} \le S_A$$

ASME B31.5

For other fittings

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

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

$$S_b = \frac{\sqrt{(i_iM_i)^2 + (i_oM_o)^2}}{Z}$$

For nonstandard tee, non-standard bend, joint and ASME B31J:

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

$$S_t = \frac{i_tM_t}{2Z}$$

$$S_b = \frac{\sqrt{(i_iM_i)^2 + (i_oM_o)^2}}{Z}$$

ASME B31.3 (input: i_i, i_o)

For bends:

$$S_E = \sqrt{(|S_a| + S_b)^2 + (2S_t)^2} \le S_A$$

$$S_a = \frac{F}{A_p}$$

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

$$S_b = \frac{\sqrt{(i_iM_i)^2 + (i_oM_o)^2}}{Z}$$

For other fittings:

$$S_E = \sqrt{(|S_a| + S_b)^2 + (2S_t)^2} \le S_A$$

$$S_a = \frac{i_oF}{A_p}$$

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

$$S_b = \frac{\sqrt{(i_iM_i)^2 + (i_oM_o)^2}}{Z}$$

For nonstandard tee, non-standard bend, joint and ASME B31J:

$$S_E = \sqrt{(|S_a| + S_b)^2 + (2S_t)^2} \le S_A$$

$$S_a = \frac{i_aF}{A_p}$$

$$S_t = \frac{i_tM_t}{2Z}$$

$$S_b = \frac{\sqrt{(i_iM_i)^2 + (i_oM_o)^2}}{Z}$$

EN 13480

If **“Liberal Stress Allowable”**=True

$$\sigma_4 = P\left(\frac{(D_o - 2t_n)^2}{D_o^2 - (D_o - 2t_n)^2} + \frac{1}{2}\right) + S_b^{sus} + S_b^{exp}$$

If **“Liberal Stress Allowable”**=False

$$\sigma_3 = S_b^{exp}$$

Creep Check

$$\sigma_5 = P\left(\frac{(D_o - 2t_n)^2}{D_o^2 - (D_o - 2t_n)^2} + \frac{1}{2}\right) + S_b^{sus} + S_b^{exp}\frac{1}{3}$$

S_b^{sus} – From sustained forces (load case L1)

S_b^{exp} - From expansion range forces (load case L9)

If **"Use ii/io"**=false **(input:** i**)**

For nonstandard tee, non-standard bend, joints and ASME B31J:

$$S_b^{sus} = \frac{(0.75max(i_i, i_o) \ge 1)\sqrt{M_i^2 + M_o^2 + M_t^2}}{Z}$$

$$S_b^{exp} = \frac{max(i_i, i_o)\sqrt{M_i^2 + M_o^2 + M_t^2}}{Z}$$

For other fittings:

$$S_b^{sus} = \frac{(0.75i \ge 1)\sqrt{M_i^2 + M_o^2 + M_t^2}}{Z}$$

$$S_b^{exp} = \frac{i\sqrt{M_i^2 + M_o^2 + M_t^2}}{Z}$$

If **"Use ii/io"**=true **(input:** i_i, i_o**)**

For nonstandard tee, non-standard bend, joint and ASME B31J:

$$S_b^{sus} = \frac{\sqrt{((0.75i_i \ge 1)M_i)^2 + ((0.75i_o \ge 1)M_o)^2 + ((0.75i_t \ge 1)M_t)^2}}{Z}$$

$$S_b^{exp} = \frac{\sqrt{(i_iM_i)^2 + (i_oM_o)^2 + (i_tM_t)^2}}{Z}$$

For other fittings:

$$S_b^{sus} = \frac{\sqrt{((0.75i_i \ge 1)M_i)^2 + ((0.75i_o \ge 1)M_o)^2 + (M_t)^2}}{Z}$$

$$S_b^{exp} = \frac{\sqrt{(i_iM_i)^2 + (i_oM_o)^2 + (M_t)^2}}{Z}$$

Allowable Expansion Stress

ASME B31.1

$$S_c \leq 138\ MPa$$
$$S_h \leq 138\ MPa$$

If $S_L \geq S_h$, then

$$S_A = f(1.25S_c/E + 0.25S_h/E)$$

If $S_L < S_h$ and liberal allowable=true then

$$S_A = f(1.25S_c/E + 1.25S_h/E - S_L)$$
$$0.15 \leq f \leq 1.0$$
$$f = 6/N^{0.2}$$

ASME B31.9

$$S_c \leq 138\ MPa$$
$$S_h \leq 138\ MPa$$

If $S_L \geq S_h$, then

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

If $S_L < S_h$ and liberal allowable=true then

$$S_A = f(1.25S_c + 1.25S_h - S_L)$$
$$0.15 \leq f \leq 1.0$$
$$f = 6/N^{0.2}$$

ASME B31.3

$$S_c \leq 138\ MPa$$
$$S_h \leq 138\ MPa$$

For Low Pressure piping

If $S_L \geq S_h$ or liberal allowable=false then

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

If $S_L < S_h$ and liberal allowable=true then

$$S_A = f(1.25S_c + 1.25S_h - maxS_L)$$

For High Pressure piping (Chapter IX)

$$S_A = 1.25S_c + 0.25S_h$$

$maxS_L$ – Maximum S_L stress calculated from **all sustained load cases (L1 and L2) from all available operating modes!**

$$f = 6/N^{0.2}$$

If temperature $T \leq 371℃$ **AND** material (option in database) "Maximum f=1.2"=True then

$0.15 \leq f \leq 1.2$ Else $0.15 \leq f \leq 1.0$

ASME B31.5

$$S_c \geq 0$$
$$S_h \geq 0$$

If $S_L \geq S_h$, then

$$S_A = f(1.25S_c/E + 0.25S_h/E)$$

If $S_L < S_h$ and liberal allowable=true then

$$S_A = f(1.25S_c/E + 1.25S_h/E - S_L)$$
$$0.5 \leq f \leq 1.0$$
$$f = 6/N^{0.2}$$

EN 13480

If **"Liberal Stress Allowable"**=True

$$\sigma_4 \leq f_f + S_A$$
$$f_f = \min(f(T); f_{CR})$$

If $f_{CR} = 0$ then $f_f = f(T)$

If **"Liberal Stress Allowable"**=False

$$\sigma_3 \leq S_A$$

Creep Check

$$\sigma_5 \leq f_{cr}$$

$$f_c \geq 0$$
$$f_h \geq 0$$
$$S_A = U(1.25f_c + 0.25f_h)\frac{E_h}{E_c}$$
$$f_h = \min(f_c; f(T); f_{CR})$$

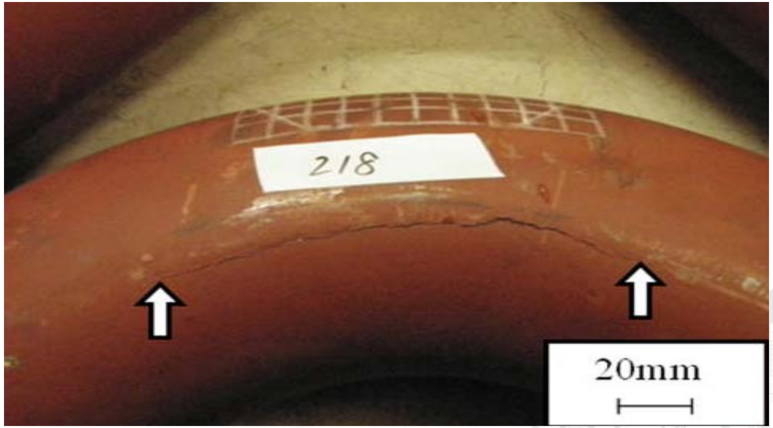
If $f_{CR} = 0$ then $f_h = \min(f_c; f(T))$

$$0.5 \leq U \leq 1.0$$
$$U = 6/N^{0.2}$$
$$f_c = min\left(\frac{R_m}{3}; f(20)\right)$$

R_p, R_m – From database at cold temperature

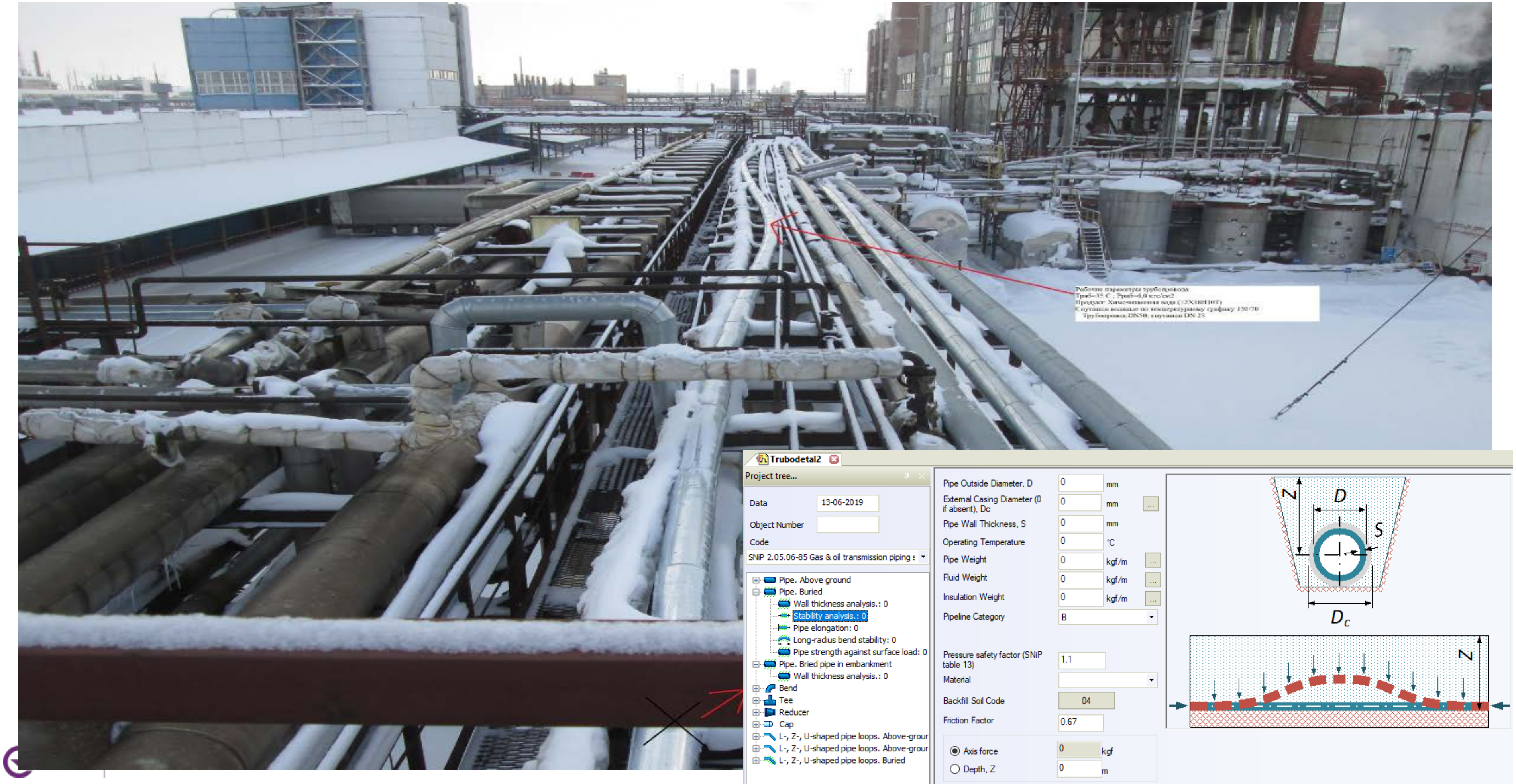
R_p, R_m, S_{RTt} – From database hot temperature

Importance of Expansion Stress Check (Cow Cycle Fatigue Failure)



Importance of Buckling Check

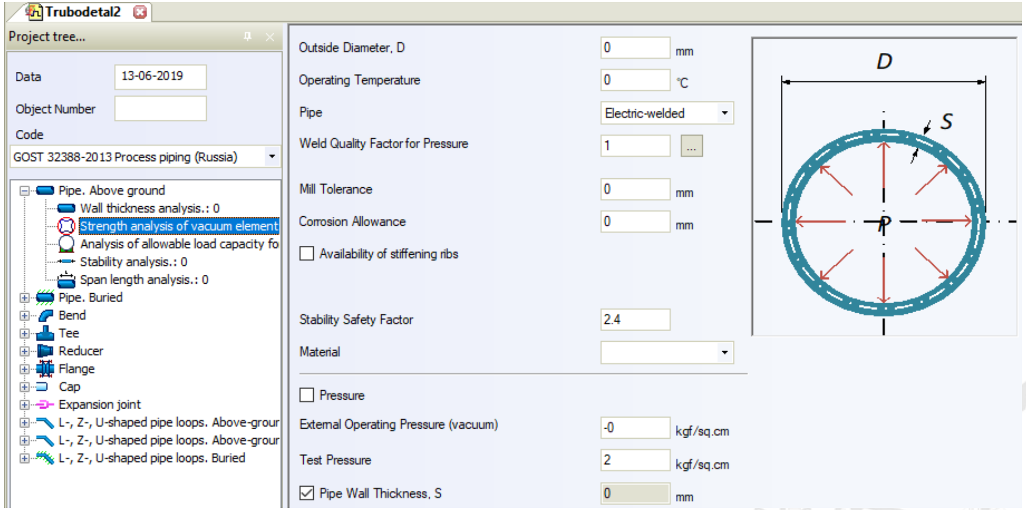
Importance of Buckling Check



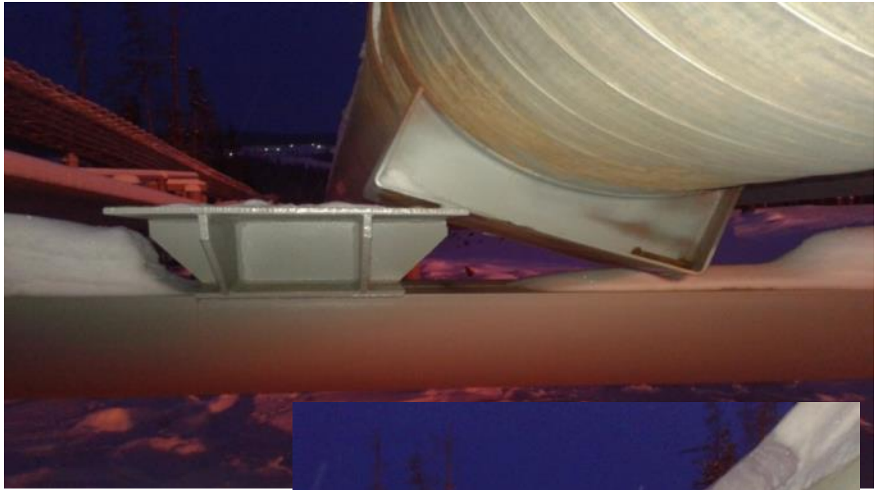
Importance of Checking of Pipeline Upheaval Buckling

Importance of Checking of Local Buckling from External Pressure

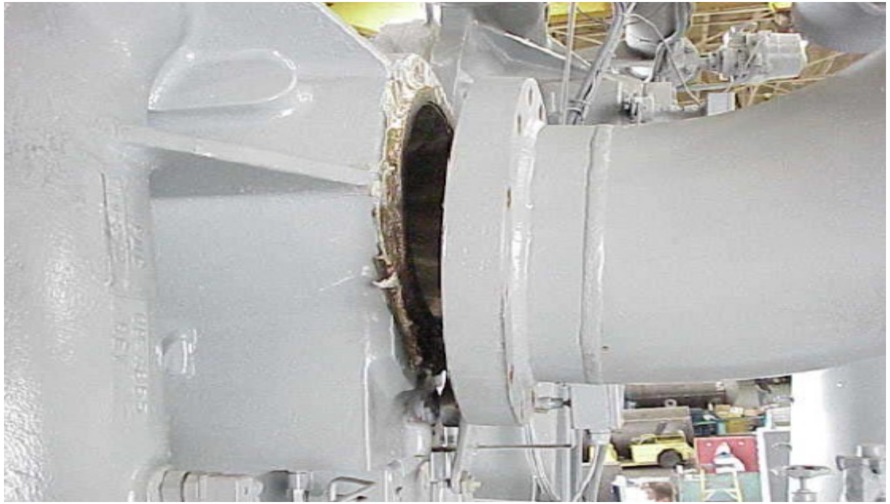
Importance of Checking of Local Buckling from External Pressure



Importance of Checking of Piping Displacements



Importance if Checking of Supports and Equipment loads



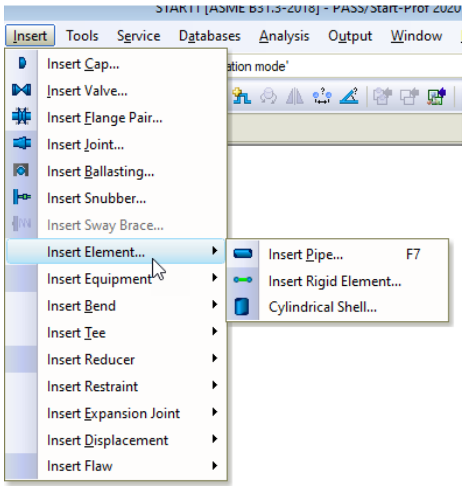
- Option 1. The equipment manufacturer provides allowable loads. It is necessary that the calculated loads from START-PROF be less than those allowed by the manufacturer.
- Option 2. Loads are determined using START-PROF are transferred to equipment manufacturers or steel structure engineers for the subsequent evaluation of the strength of the structure or equipment
- Option 3. The loads are determined with the START-PROF and then checked by a special methods API 610, API 617, NEMA SM 23, API 650, Nozzle-FEM, etc.

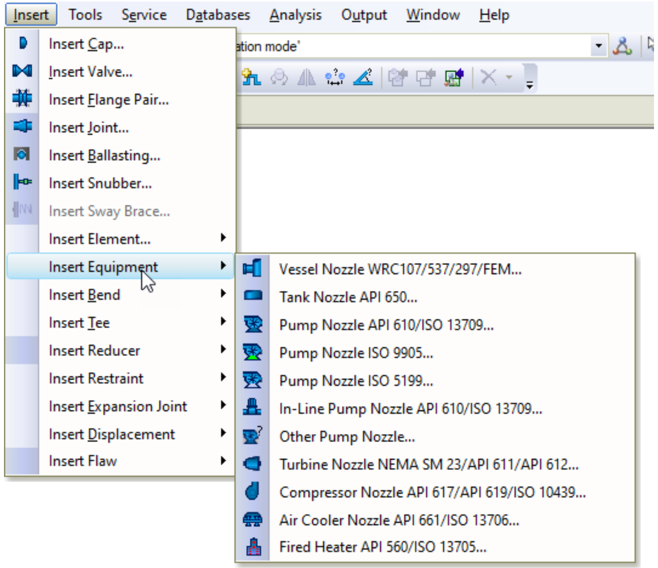
Importance of Checking of Allowable Deformations of Expansion Joints

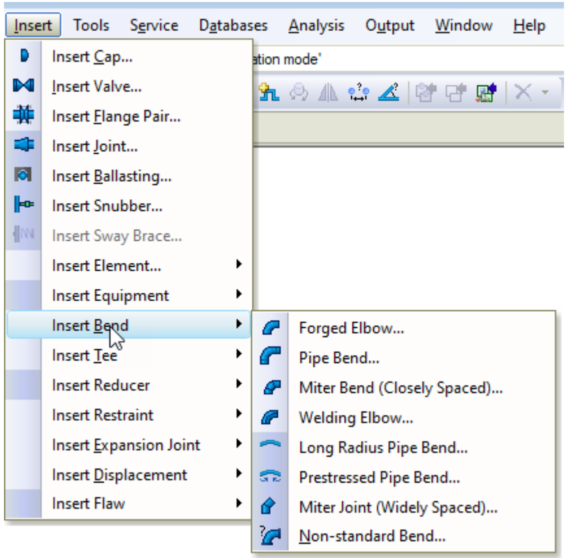
PASS/Start-Prof | Broad Applicability

- Developed since 1965
- 3000+ Active users (companies). Licenses 8000+
- User interface and documentation languages: English, Chinese, Russian
- Piping codes: 32
- Wind, Seismic, Snow, Ice codes: 18

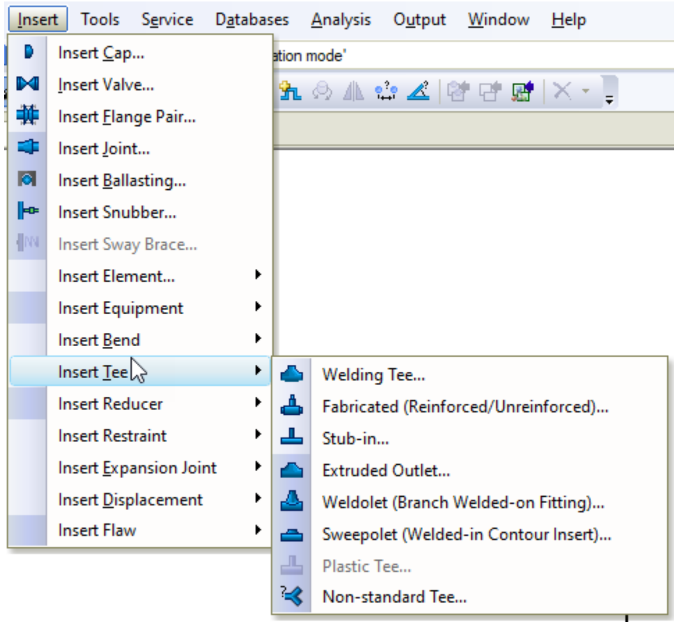
PASS/START-PROF Object-Oriented Piping Model

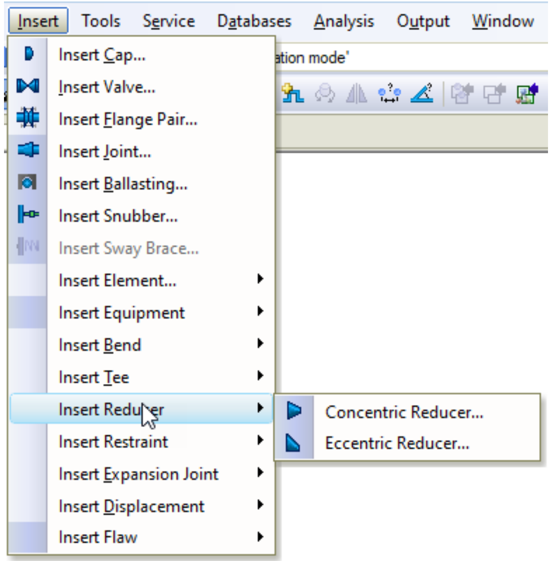


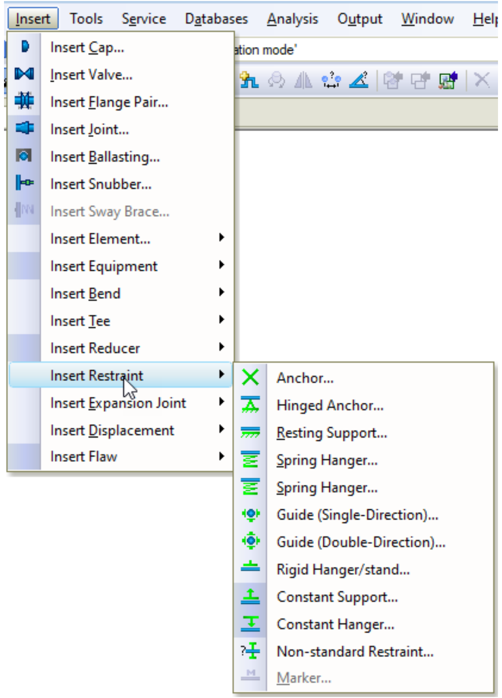




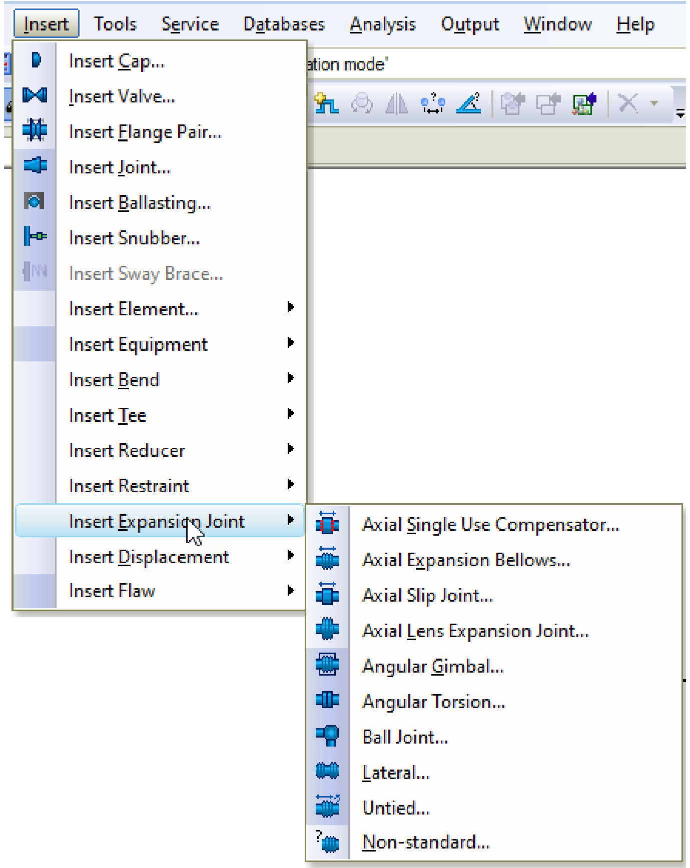
PASS/START-PROF Object-Oriented Piping Model

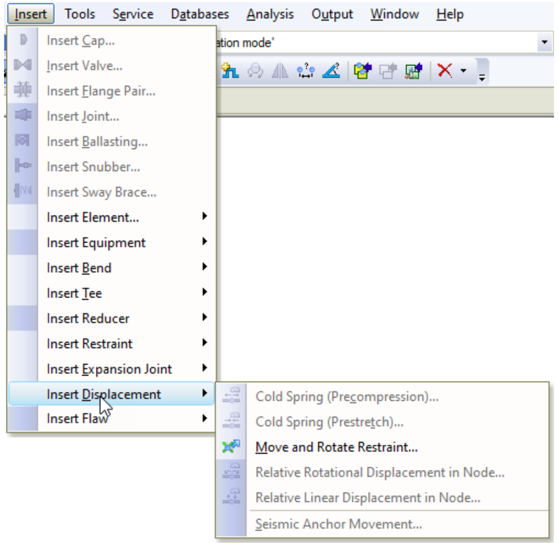


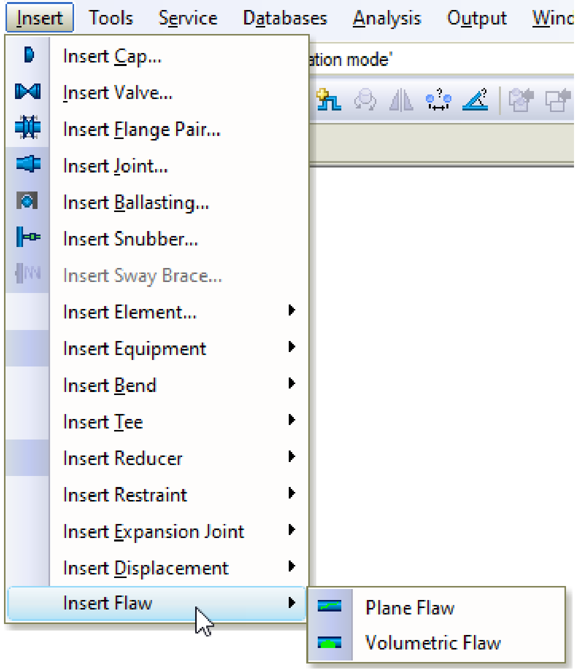




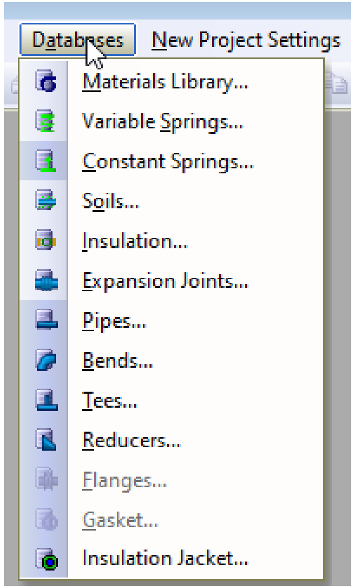
PASS/START-PROF Object-Oriented Piping Model



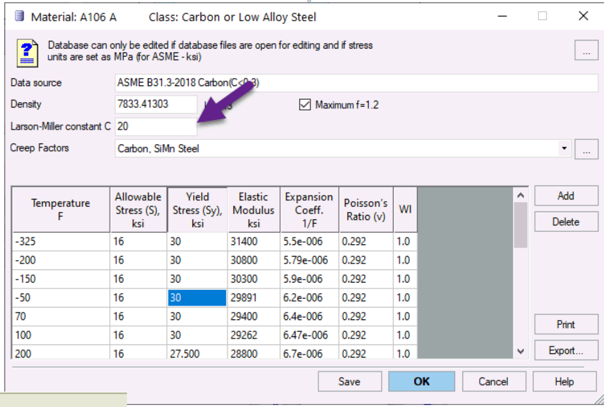




Databases


Databases
New Project Settings
Materials Library...
Variable Springs...
Constant Springs...
Soils...
Insulation...
Expansion Joints...
Pipes...
Bends...
Tees...
Reducers...
Flanges...
Gasket...
Insulation Jacket...

Occasional allowable calculation for elevated temperature fluid service 302.3.6 (2) ASME B31.3-2018 appendix V.



include same or like material, weld metal composition, and welding process under equivalent, or more severe, sustained operating conditions.

302.3.6 Limits of Calculated Stresses Due to Occasional Loads

(a) Operation. Stresses due to occasional loads may be calculated using the equations for stress due to sustained loads in para. 320.2.

(1) Subject to the limits of para. 302.2.4, the sum of the stresses due to sustained loads, such as pressure and weight, S_L, and of the stresses produced by occasional loads, such as wind and earthquake, may be as much as 1.33 times the basic allowable stress provided in Table A-1 or Table A-1M at the metal temperature for the occasional condition being considered. Wind and earthquake forces need not be considered as acting concurrently.

(2) For Elevated Temperature Fluid Service (see definition in para. 300.2) of materials having ductile behavior, as an alternative to the use of 1.33 times the basic allowable stress provided in Table A-1 or Table A-1M, the allowable stress for occasional loads of short duration, e.g., surge, extreme wind, or earthquake, may be taken as the lowest of the following:

(-a) the weld strength reduction factor times 90% of the yield strength at the metal temperature for the occasional condition being considered

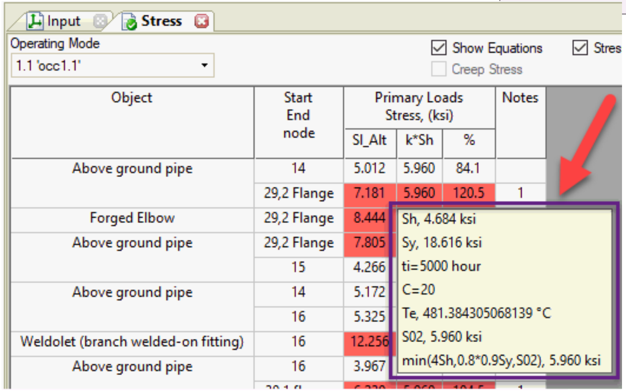
(-b) four times the basic allowable stress provided in Appendix A

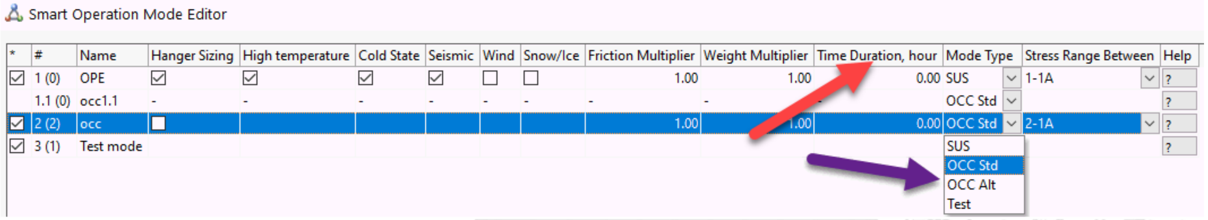
(-c) for occasional loads that exceed 10 h over the life of the piping system, the stress resulting in a 20% creep usage factor in accordance with Appendix V

For (-a), the yield strength shall be as listed in ASME BPVC, Section II, Part D, Table Y-1 or determined in accordance with para. 302.3.2. The strength reduction factor represents the reduction in yield strength with long-term exposure of the material to elevated temperatures and, in the absence of more-applicable data, shall be taken as 1.0 for austenitic stainless steel and 0.8 for other materials.

For (-b), the basic allowable stress for castings shall also be multiplied by the casting quality factor, E_c. Where the allowable stress value exceeds two-thirds of yield strength at temperature, the allowable stress value must be reduced as specified in para. 302.3.2(e).

(b) Test. Stresses due to test conditions are not subject to the limitations in para. 302.3. It is not necessary to consider other occasional loads, e.g., wind and earthquake, as occurring concurrently with test loads.





Automatic creep-rupture usage factor calculation according to ASME B31.3-2018 Appendix V (V303.1-V303.3).

V303.2 Determine Creep-Rupture Usage Factor

The usage factor, u, is the summation of individual usage factors, t_i / t_{ri}, for all service conditions considered in para. V303.1. See eq. (V4).

$$u = \sum (t_i / t_{ri}) \quad \text{(V4)}$$

where

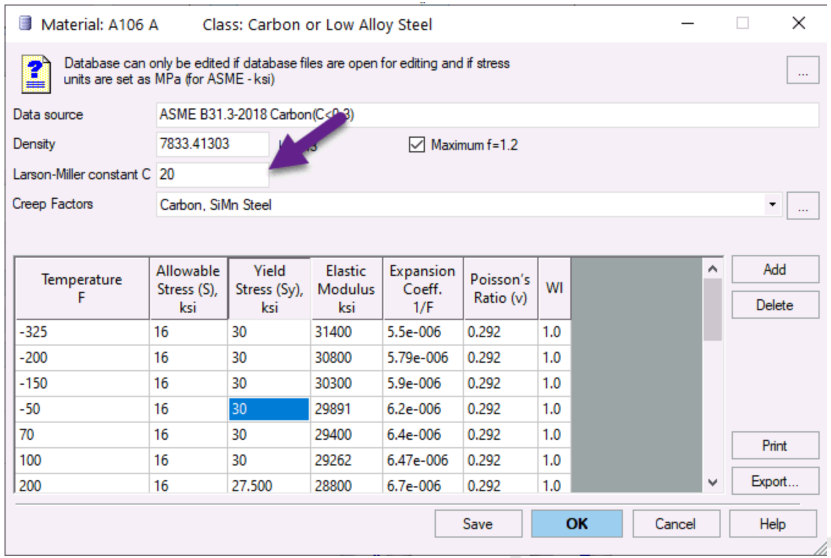
i = as a subscript, 1 for the prevalent operating condition; i = 2, 3, etc., for each of the other service conditions considered

t_i = total duration, h, associated with any service condition, i, at pressure, P_i, and temperature, T_i

t_{ri} = as defined in para. V303.1.4

V303.3 Evaluation

The calculated value of u indicates the nominal amount of creep-rupture life expended during the service life of the piping system. If $u \le 1.0$, the usage factor is acceptable including excursions. If $u > 1.0$, the designer shall either increase the design conditions (selecting piping system components of a higher allowable working pressure if necessary) or reduce the number and/or severity of excursions until the usage factor is acceptable.



Temperature F	Allowable Stress (S), ksi	Yield Stress (Sy), ksi	Elastic Modulus ksi	Expansion Coeff. 1/F	Poisson's Ratio (v)	WI
-325	16	30	31400	5.5e-006	0.292	1.0
-200	16	30	30800	5.79e-006	0.292	1.0
-150	16	30	30300	5.9e-006	0.292	1.0
-50	16	30	29891	6.2e-006	0.292	1.0
70	16	30	29400	6.4e-006	0.292	1.0
100	16	30	29262	6.47e-006	0.292	1.0
200	16	27.500	28800	6.7e-006	0.292	1.0

PASS PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Minimum Design Metal Temperature (MDMT) calculation according to 323.2.2 (a), (b), (d), (e), (f), (g), (h), (i), (j) of ASME B31.3-2018. Added into material database. START-PROF calculates the MDMT according to figure 323.2.2A and figure 323.2.2B depending on the calculated stress ratio if user select appropriate option in project settings, taking into account the code requirements 323.2.2 (g), (h), (i).

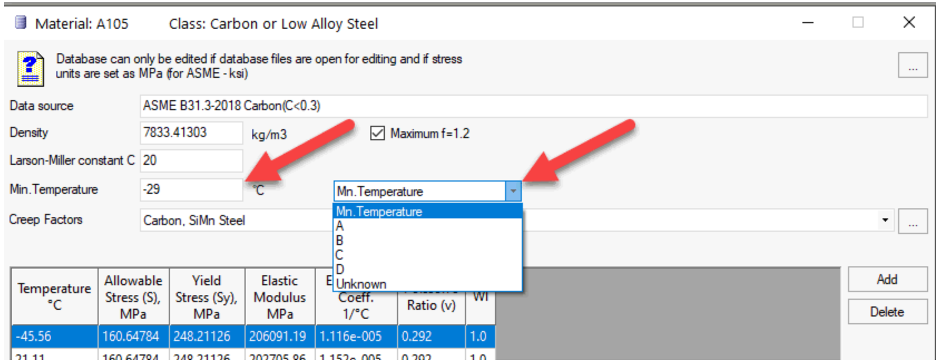


Figure 323.2.2A Minimum Temperatures Without Impact Testing for Carbon Steel Materials
(See Table A-1 or Table A-1M for Designated Curve for a Listed Material; see Table 323.2.2A for Tabular Values)

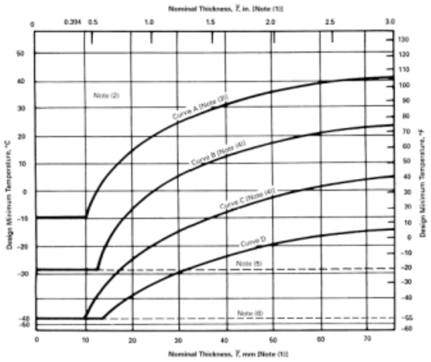
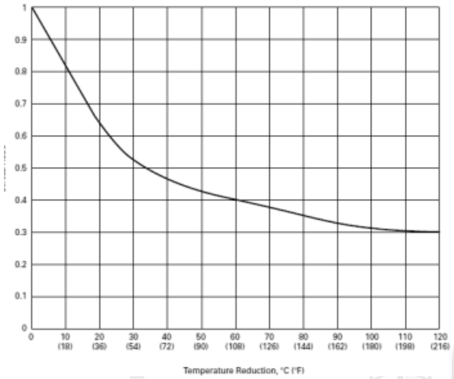
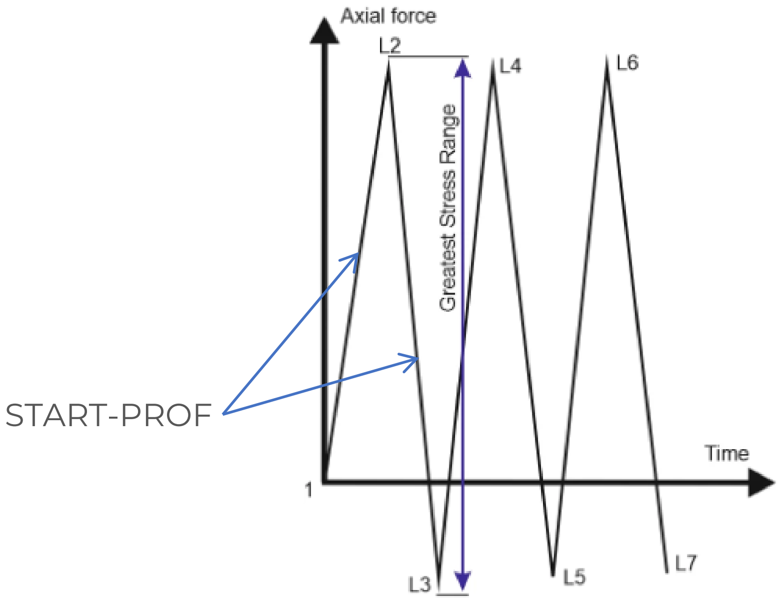
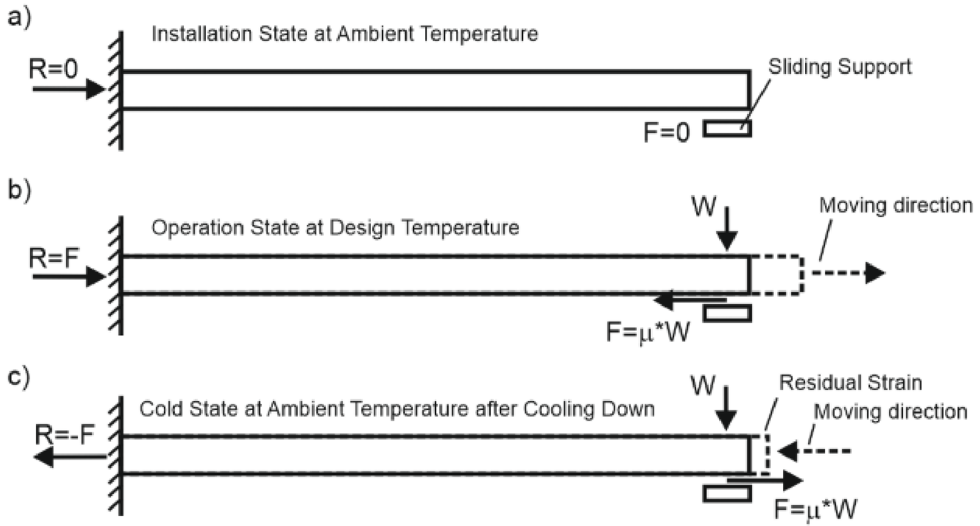


Figure 323.2.2B Reduction in Lowest Exemption Temperature for Steels Without Impact Testing
(See Table 323.2.2B for Tabular Values)



START-PROF calculates the cold state after cooling down from the hot state. It allows to get more realistic expansion stress range.





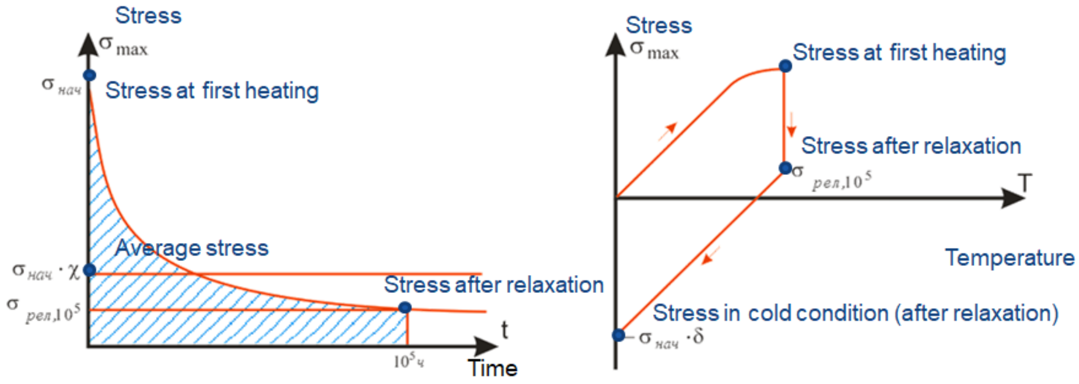
ASME B31.3 319.2.3 (a) code requires to analyze self-springing after creep relaxation, but doesn't give a detailed analysis method for this. CAESAR II can consider creep stress relaxation effect in hot state according to EN 13480 code, but can’t consider self-springing in cold state.

- Can consider creep stress relaxation effect in hot state according to EN 13480 code like CAESAR II.
- Can consider creep stress relaxation and creep self-springing effect in the cold state using Russian RD 10-249-98 code method. It is available for ASME B31.3, B31.1 and some other codes.

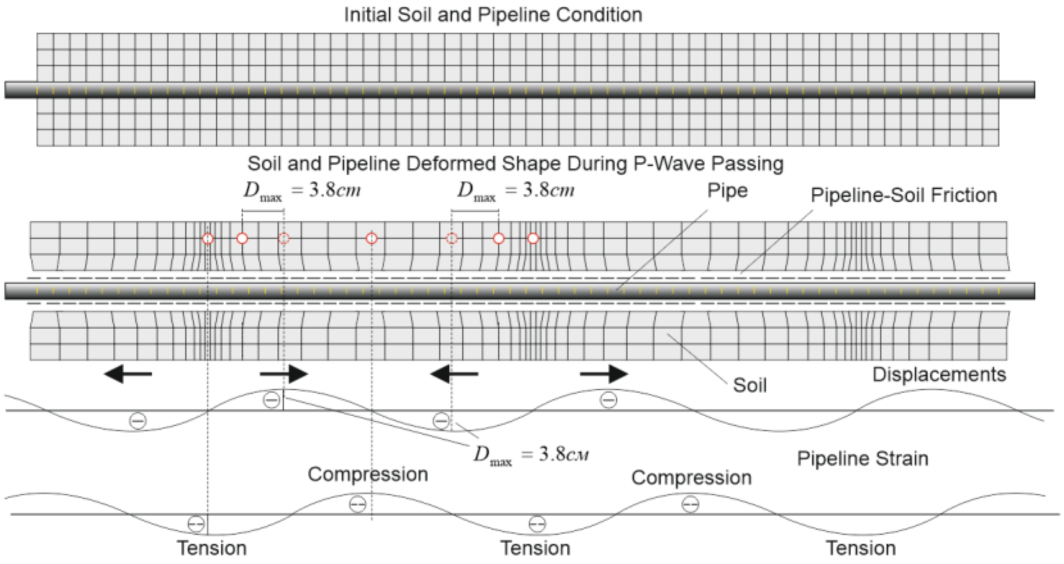
319.2.3 Displacement Stress Range

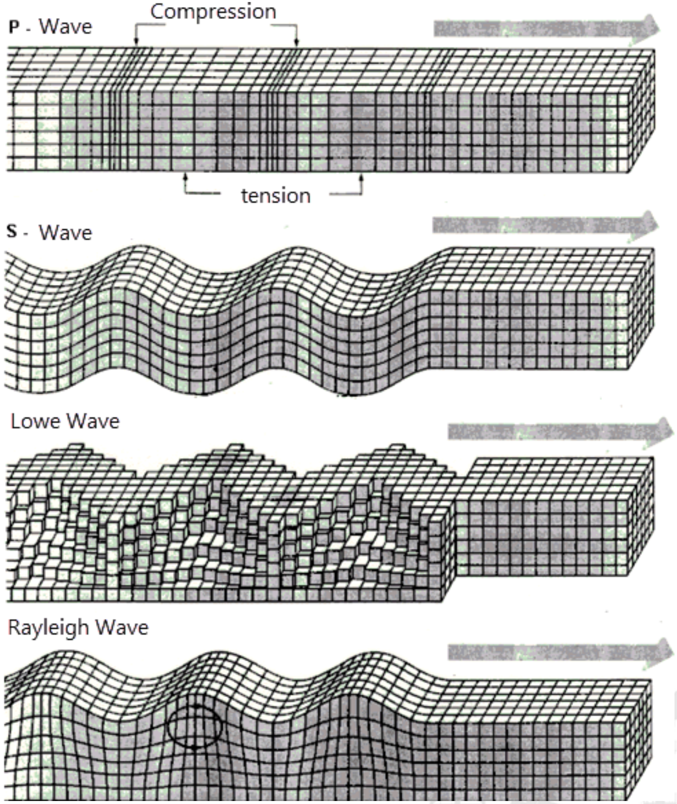
(a) In contrast with stresses from sustained loads, such as internal pressure or weight, displacement stresses may be permitted to attain sufficient magnitude to cause local yielding in various portions of a piping system. When the system is initially operated at the condition of greatest displacement (highest or lowest temperature, or greatest imposed movement) from its installed condition, any yielding or creep brings about a reduction or relaxation of stress. When the system is later returned to its original condition (or a condition of opposite displacement), a reversal and redistribution of stresses occurs that is referred to as self-springing. It is similar to cold springing in its effects.

Creep lead to piping self cold-spring in cold condition

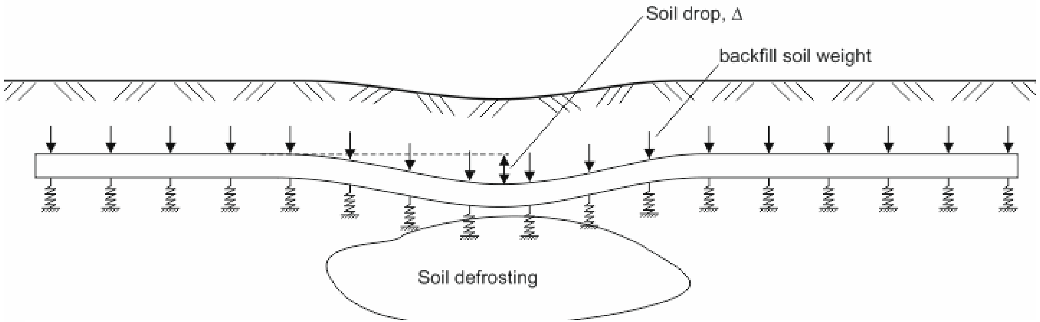


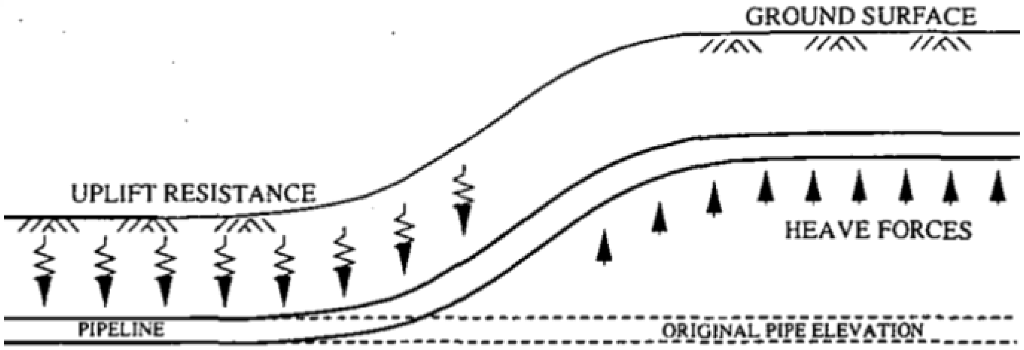
Seismic wave propagation analysis for underground pipelines. START-PROF calculates stress and strain in buried pipeline caused by seismic wave propagation, and checks the stress and strain limits according to ASCE 2001 Guidelines for the Design of Buried Steel Pipe (American Lifelines Alliance).

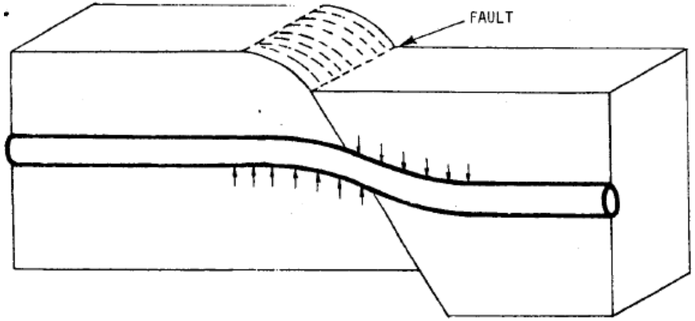




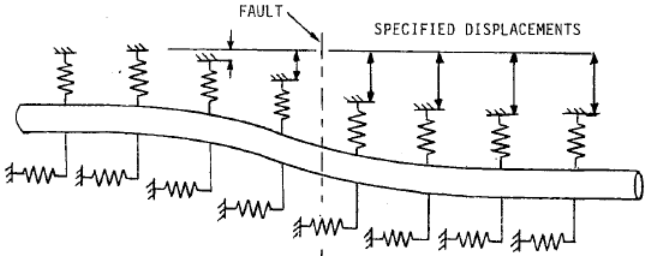
Landslide, Soil subsidence, frost heaving, Permanent ground deformation (seismic fault crossing) can also be modeled. The pipeline strain check is made according to ASCE 2001 (ALA) and GB 50470.

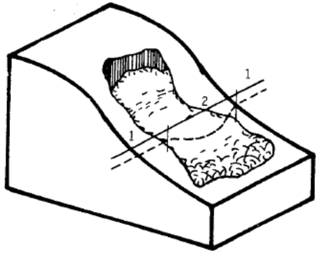




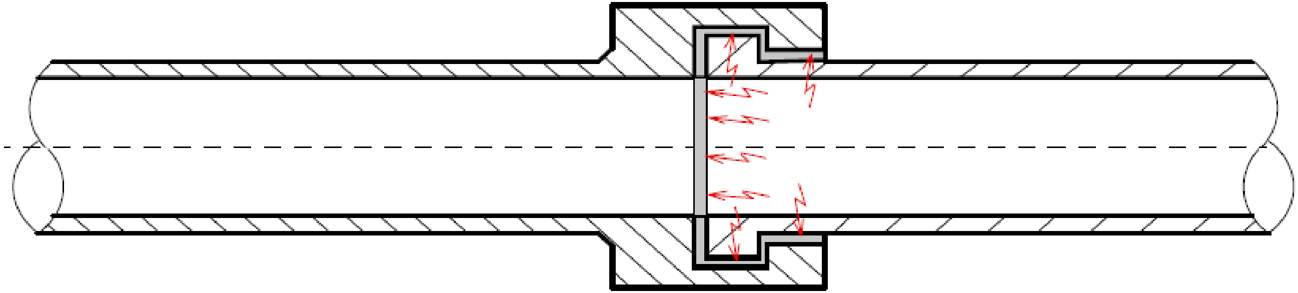


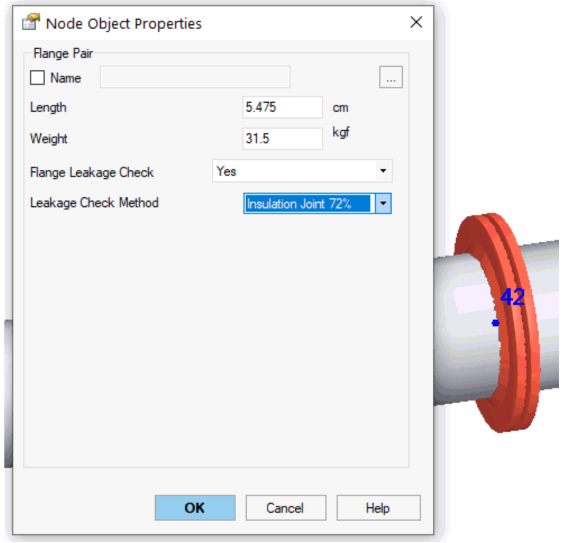
(A) ACTUAL GEOMETRY



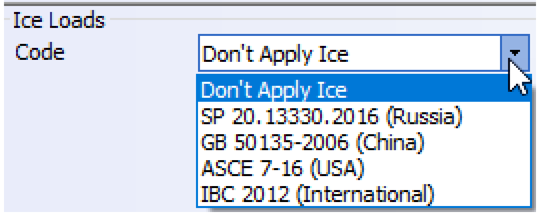


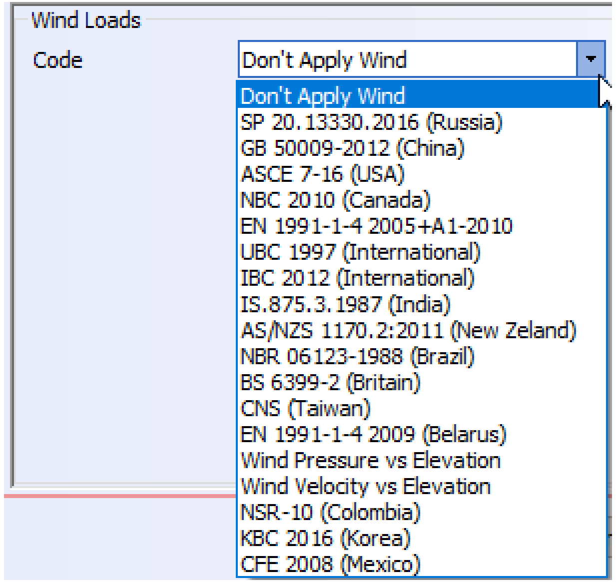
Insulation Joint (Insulation Kit) stress analysis. The axial stress and stress from torsion moment is checked automatically.

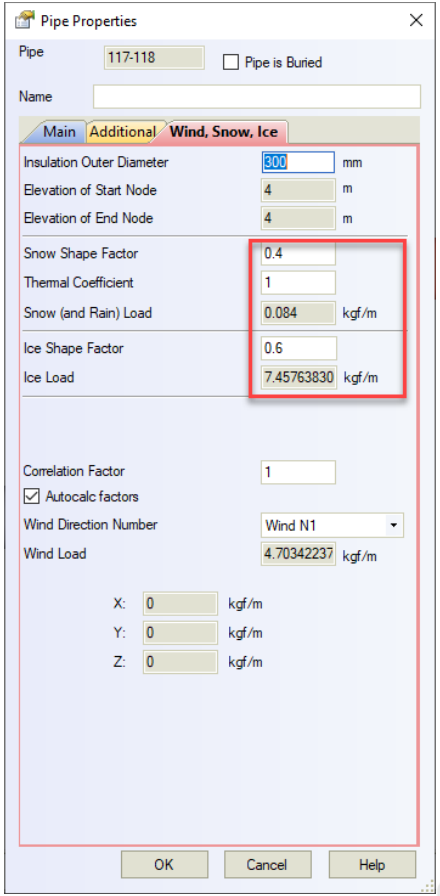


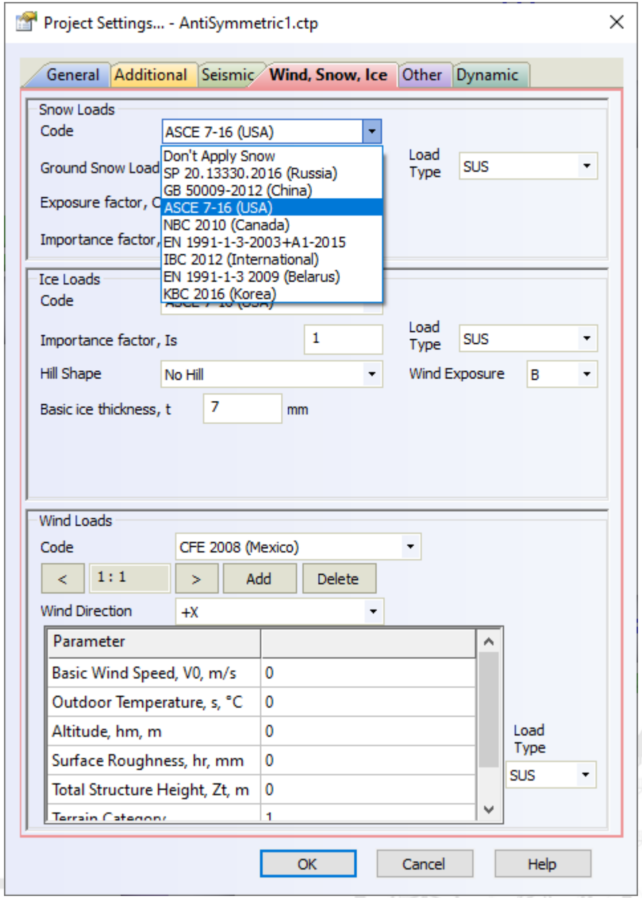


Automatic snow and ice load generation according to national codes.

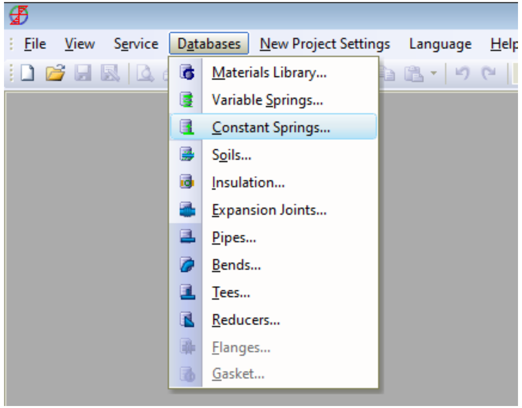


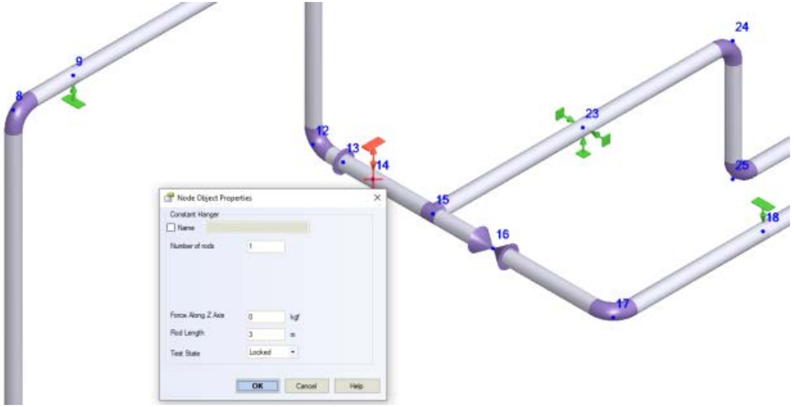


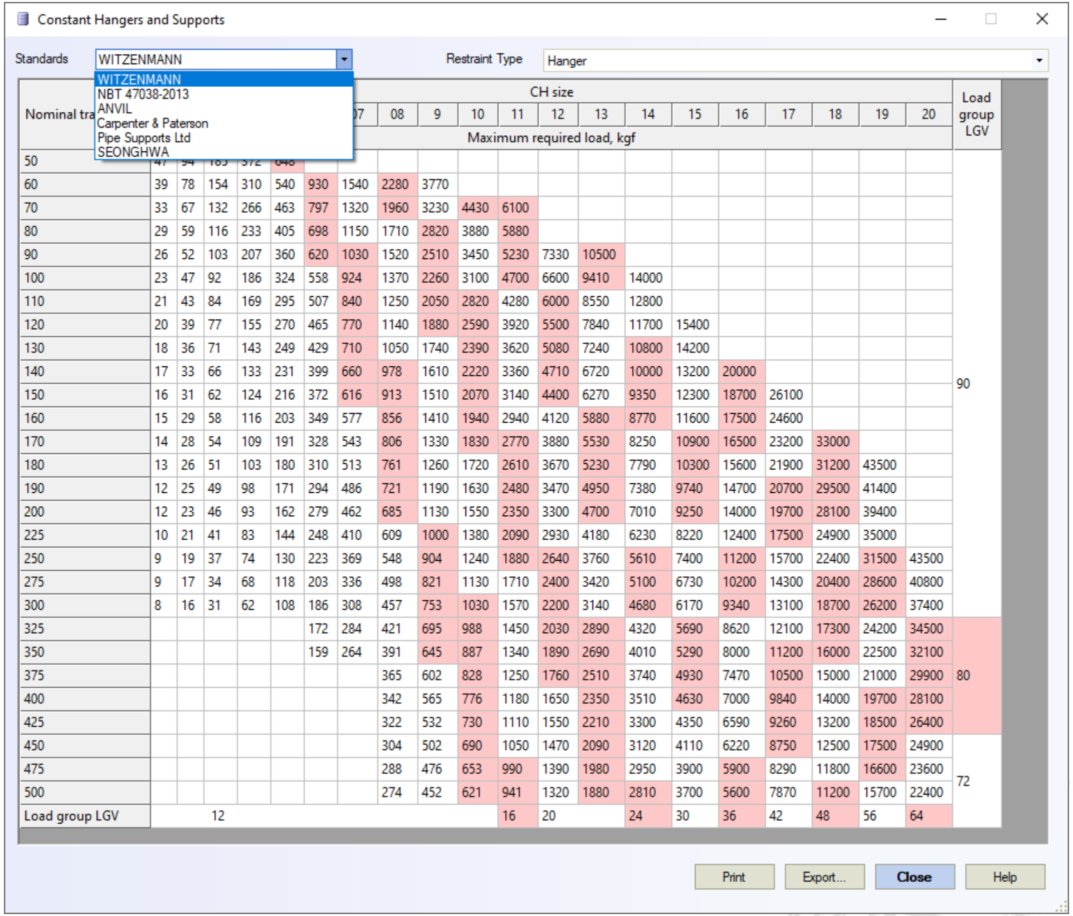




Automatic selection of constant effort hangers and supports.

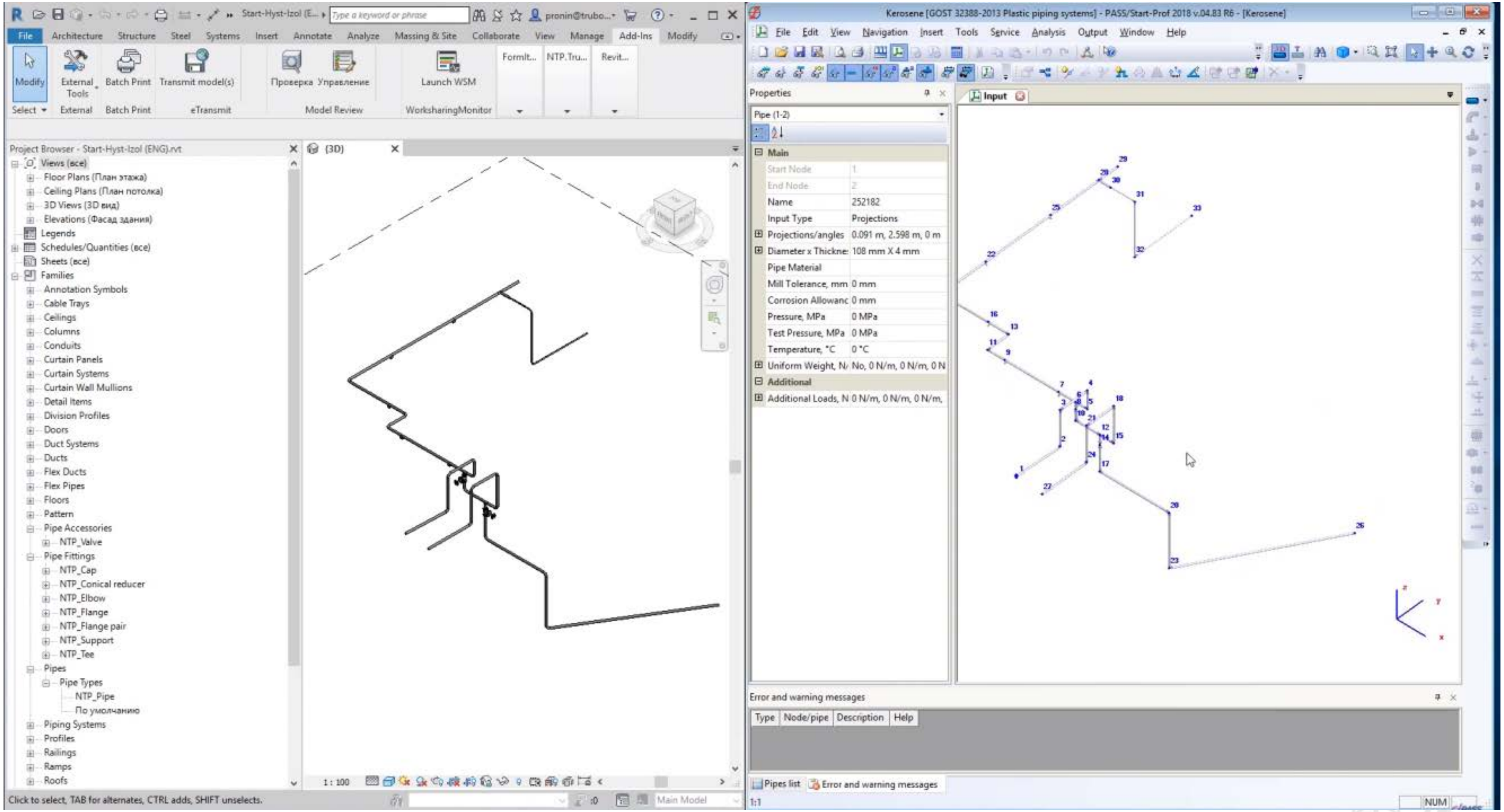




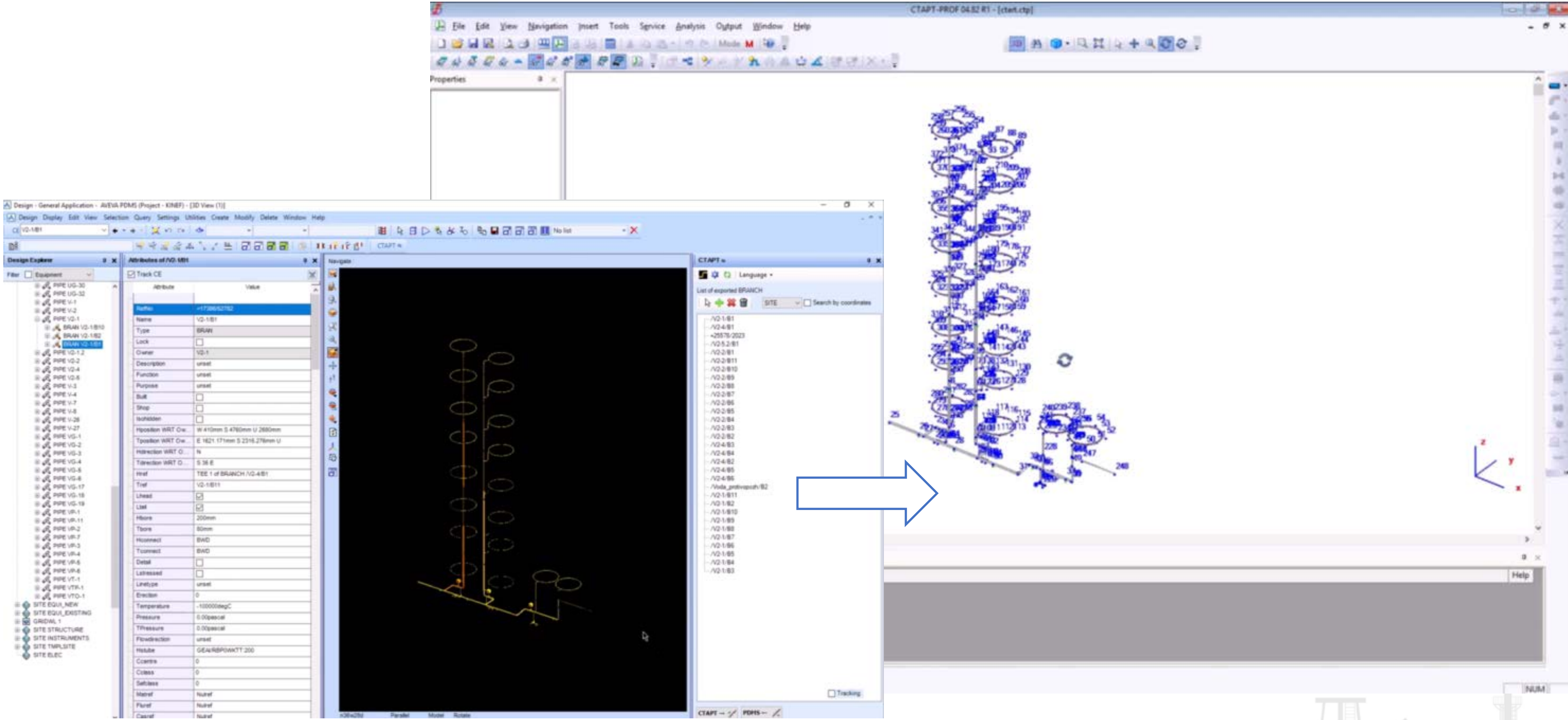


Nominal tra	CH size																				Load group LGV
							07	08	9	10	11	12	13	14	15	16	17	18	19	20	
	Maximum required load, kgf																				
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																
60	39	78	154	310	540	930	1540	2280	3770												
70	33	67	132	266	463	797	1320	1960	3230	4430	6100										
80	29	59	116	233	405	698	1150	1710	2820	3880	5880										
90	26	52	103	207	360	620	1030	1520	2510	3450	5230	7330	10500								
100	23	47	92	186	324	558	924	1370	2260	3100	4700	6600	9410	14000							
110	21	43	84	169	295	507	840	1250	2050	2820	4280	6000	8550	12800							
120	20	39	77	155	270	465	770	1140	1880	2590	3920	5500	7840	11700	15400						
130	18	36	71	143	249	429	710	1050	1740	2390	3620	5080	7240	10800	14200						
140	17	33	66	133	231	399	660	978	1610	2220	3360	4710	6720	10000	13200	20000					
150	16	31	62	124	216	372	616	913	1510	2070	3140	4400	6270	9350	12300	18700	26100				90
160	15	29	58	116	203	349	577	856	1410	1940	2940	4120	5880	8770	11600	17500	24600				
170	14	28	54	109	191	328	543	806	1330	1830	2770	3880	5530	8250	10900	16500	23200	33000			
180	13	26	51	103	180	310	513	761	1260	1720	2610	3670	5230	7790	10300	15600	21900	31200	43500		
190	12	25	49	98	171	294	486	721	1190	1630	2480	3470	4950	7380	9740	14700	20700	29500	41400		
200	12	23	46	93	162	279	462	685	1130	1550	2350	3300	4700	7010	9250	14000	19700	28100	39400		
225	10	21	41	83	144	248	410	609	1000	1380	2090	2930	4180	6230	8220	12400	17500	24900	35000		
250	9	19	37	74	130	223	369	548	904	1240	1880	2640	3760	5610	7400	11200	15700	22400	31500	43500	
275	9	17	34	68	118	203	336	498	821	1130	1710	2400	3420	5100	6730	10200	14300	20400	28600	40800	
300	8	16	31	62	108	186	308	457	753	1030	1570	2200	3140	4680	6170	9340	13100	18700	26200	37400	
325						172	284	421	695	988	1450	2030	2890	4320	5690	8620	12100	17300	24200	34500	
350						159	264	391	645	887	1340	1890	2690	4010	5290	8000	11200	16000	22500	32100	
375								365	602	828	1250	1760	2510	3740	4930	7470	10500	15000	21000	29900	80
400								342	565	776	1180	1650	2350	3510	4630	7000	9840	14000	19700	28100	
425								322	532	730	1110	1550	2210	3300	4350	6590	9260	13200	18500	26400	
450								304	502	690	1050	1470	2090	3120	4110	6220	8750	12500	17500	24900	
475								288	476	653	990	1390	1980	2950	3900	5900	8290	11800	16600	23600	72
500								274	452	621	941	1320	1880	2810	3700	5600	7870	11200	15700	22400	
Load group LGV			12								16	20		24	30	36	42	48	56	64	

Integration with Autodesk Revit is supported.



Two-way integration with AVEVA PDMS, AVEVA E3D



PIPING AND EQUIPMENT
ANALYSIS & SIZING SUITE

Code	START-PROF
ASME B31.1 Power piping USA	+
ASME B31.3+Ch IX USA Process piping	+
ASME B31.4 + Ch IX&XI USA Fluid Pipelines	+
ASME B31.5 USA Refrigeration Piping and Heat Transfer	+
ASME B31.8 + Ch VIII USA Gas Pipelines	+
ASME B31.9 Building Services Piping	+
ASME B31.12-2014 Hydrogen piping and pipelines	+
ASME B31J-2017 New SIF	+
EN 13480 Europe Industrial Piping	+
EN 13941 Europe District heating	+
CSA Z662 Canada 2015	+
BS PD 8010-1 (2016) Pipeline systems. Steel pipelines on land, UK	+
BS PD 8010-2 (2016) Pipeline systems. Subsea pipelines, UK	+
ISO 14692 International, FRP	+
Plastic piping	+
DLT 5366-2006 Power piping China	+
GB 20801-2006 Process Piping China	+
GB 50316-2008 Process Piping China	+
GB 50251-2015 Gas Pipeline China	+
GB 50253-2014 Oil Pipeline China	+
CJJ/T 81-2013 District heating China	+
11 Russian codes for all industries	+

Feature	START-PROF
Wind load codes	
SP 20.13330.2011, Russia	+
ASCE 7, USA	+
GB 50009, China	+
Wind pressure vs elevation	+
Wind velocity vs elevation	+
IBC 2012 International	+
NBC 2010, Canada	+
EN 1991-1-4 2005, Europe	+
NBR 6123-1998, Brazil	+
IS 875.3.1987, India	+
As/Nz 1170:2002, New Zeland	+
BS 6399-2, UK	+
UBC 1997, International	+
CNS, Taiwan	+
NSR-10, Colombia	+
KBC 2016, Korea	+
CFE 2008 Mexico	+
Snow load codes	
СП 20.13330.2011	+
ASCE 7, USA	+
IBC 2012 International	+
GB 50009, China	+
NBC 2010, Canada	+
EN 1991-1-3 2003, Europe	+
KBC 2016, Korea	+
Ice load codes	
СП 20.13330.2011	+
ASCE 7, USA	+
IBC 2012 International	+
GB 50135-2006, China	+

PASS PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

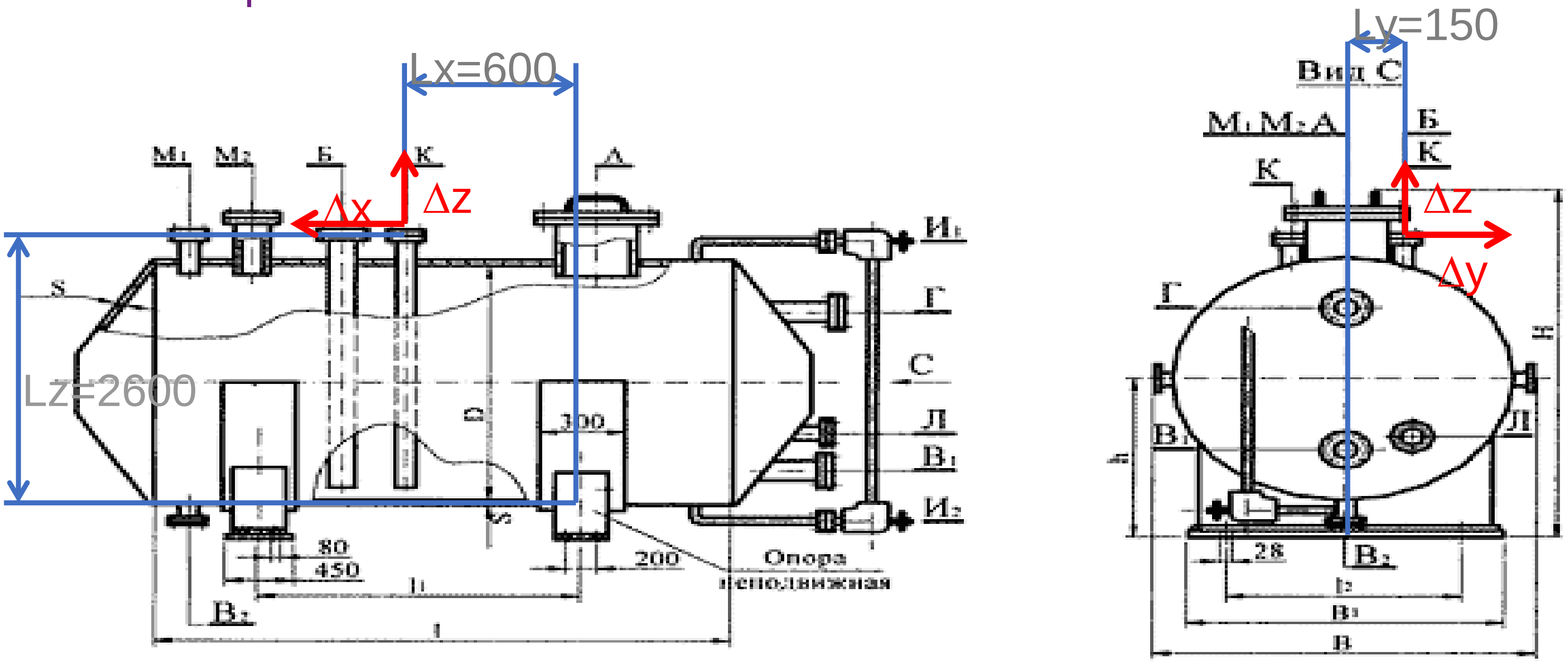
Feature	START-PROF
Equipment Connection	
Insulation Joint (Insulation Kit) stress analysis	+
WRC 297 Nozzle Flexibility	+
PD 5500 Nozzle Flexibility	+
ASME NB-3630 Tee Flexibility	+
API 610 Centrifugal Pump load check / ISO 13709	+
API 617 Centrifugal Compressor load check / API 619 / ISO 10440 / ISO 10439	+
API 650 Tank Nozzle Flexibility	+
API 650 Tank Nozzle Allowable Loads Check	+
NEMA SM 23 Steam Turbine Allowable Loads/API 611/API 612/ISO 10437	+
WRC 107/537	+
API 560 Allowable loads fired heaters	+
API 661 Allowable loads	+
ISO 5199 Centrifugal Pump load check	+
ISO 9905 Centrifugal Pump load check	+
Flange check	
NC 3658.3 Method	+
Equivalent pressure method / Kellogg	+
PVP / Code Case 2901	+
DNV	+

Stress Analysis Features	START-PROF
Load Case Editor / Operation Mode Editor (Many Pressures, Temperatures, Loads, etc.)	+
Seismic Analysis (Static method)	+
Seismic Anchor Movements	+
Pipe and Bend Wall Thickness Check	+
Translation Bourdon Effect	+
Rotational Bourdon Effect for Bends	+
Friction, Gap, One-way, Rotation Rod Restraints Nonlinear Analysis	+
Thermal Bowing (Stratification)	+
Insulation Weight Calculation by Diameter and Density	+
MDMT Minimum Design Temperature, Impact Test	+
MDMT Minimum Design Temperature, Impact Test with Reduction Depending on Stress Ratio	+
Built-in Calculator in Fields	+
SIF Scratchpad	+
Creep Rupture Factor Calculation ASME B31.3 app. V	+
Friction at Cold State (Follow up load case)	+
Automatic Water Hammer Loads Analysis	+
Expansion Joint Deformation Check	+
Tee and Reducer Wall Thickness Check	+
Pipe, Bend, Reducer, Tee Wall Thickness Calculation	+

Feature	START-PROF
CAD Interfaces	
Import and Export to Own Neutral Format	INI
Export/Import Displacements Using File (.csv)	CSV
Export to TXT	+
PCF	+
Hydrosystem Import Dynamic Forces	TXT
Caesar II (.CII) Import/Export	CII
AutoCAD Export	DXF
Autopipe Import and Export	CII
AutoPlant Import	PCF
CADISON	PCF
CadWorx	PCF
I-Sketch	PCF
Marine Import and Export	API
Microstation Export	DXF
ModelStudioCS	PCF
OpenPlant	PCF
PDMS Import and Export	API
Plant3D Import	PCF
Plant4D	PCF
PlantSpace	PCF
Revit	INI
Smart3D	PCF
SmartPlant3D	PCF

- Affordable price ~ $6’000 - $7’800 Permanent License, $2’400 - $3’120 Annual License
- Technical support for the 1st year is provided for free (!)
- Different configurations based on customer needs are available

Nozzle Displacements

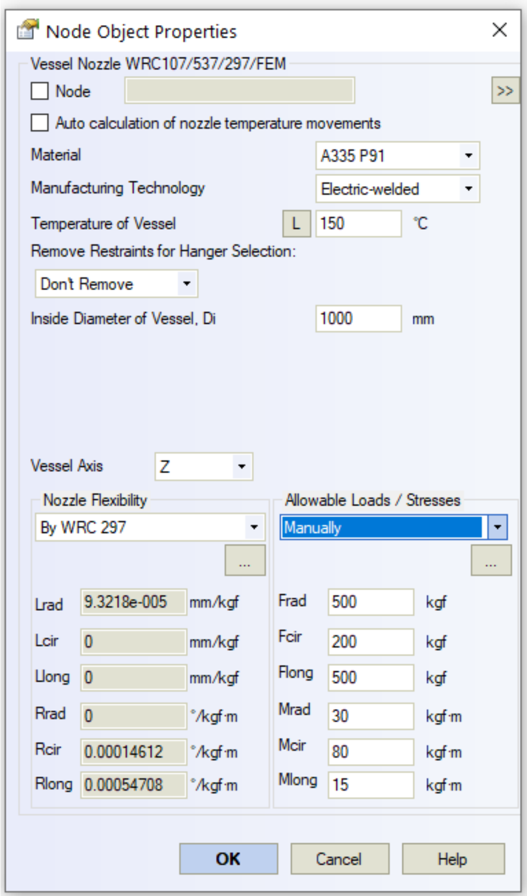


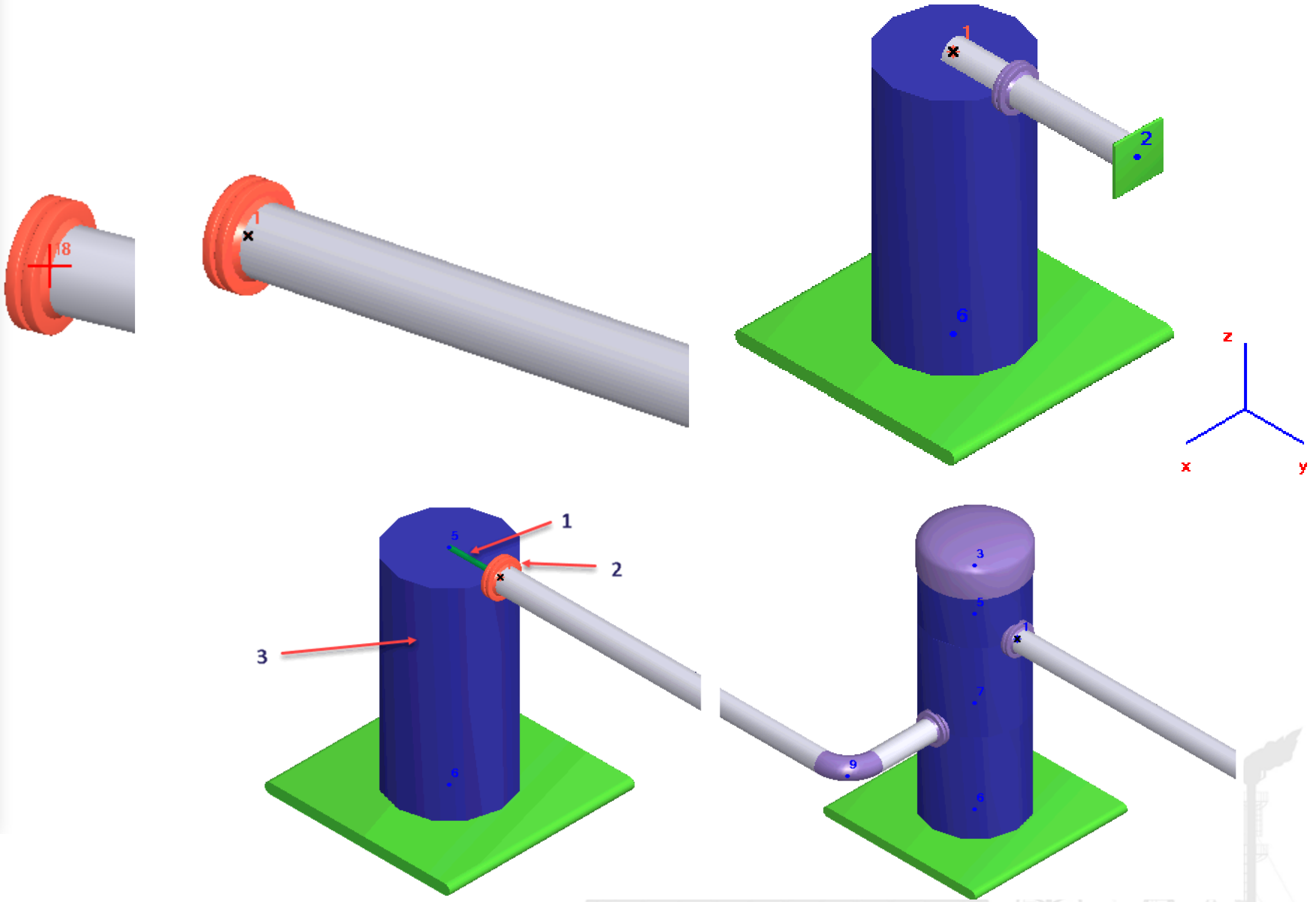
$$\Delta x = Lx \cdot \propto \cdot \Delta T = 600\text{мм} \cdot 1.2 \cdot 10^{-5} \cdot \left(250° - (-20°)\right) = 1.94\text{мм}$$

$$\Delta y = Ly \cdot \propto \cdot \Delta T = 150\text{мм} \cdot 1.2 \cdot 10^{-5} \cdot \left(250° - (-20°)\right) = 0.49\text{мм}$$

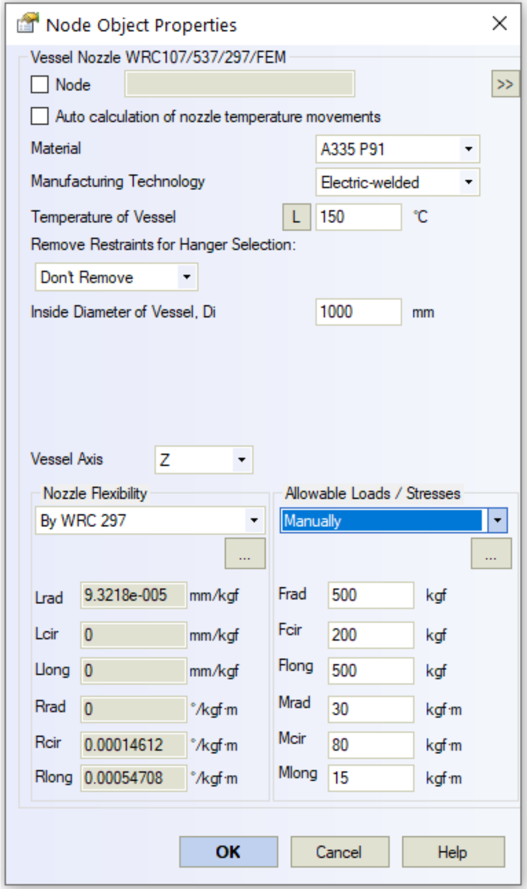
$$\Delta z = Lz \cdot \propto \cdot \Delta T = 2600\text{мм} \cdot 1.2 \cdot 10^{-5} \cdot \left(250° - (-20°)\right) = 8.42\text{мм}$$

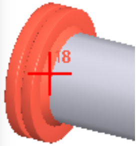
Nozzle Object

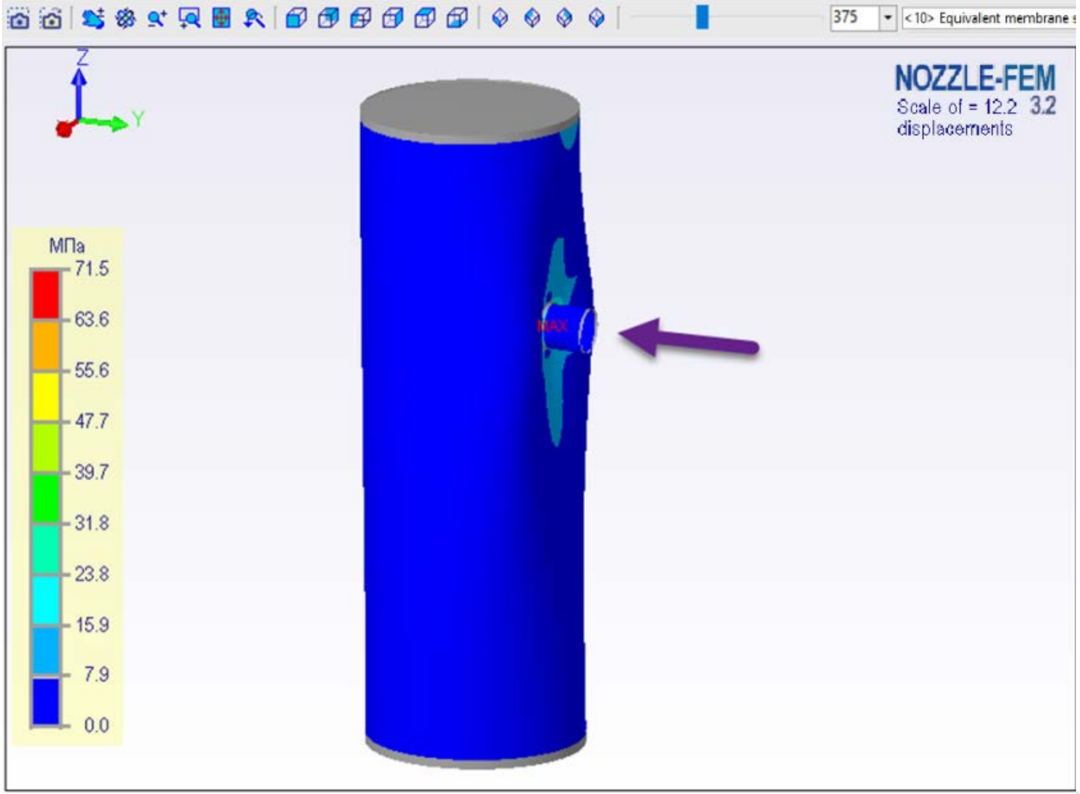




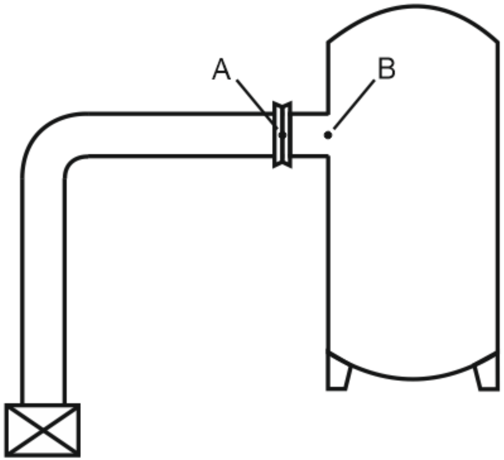
Nozzle Flexibility Using WRC 297, PD 5500





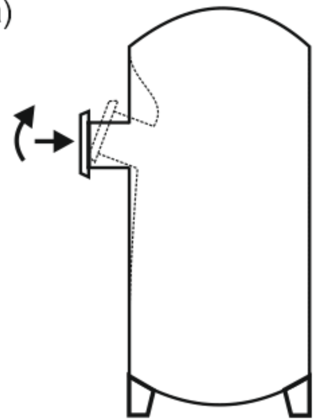


Local and Global Nozzle Flexibility



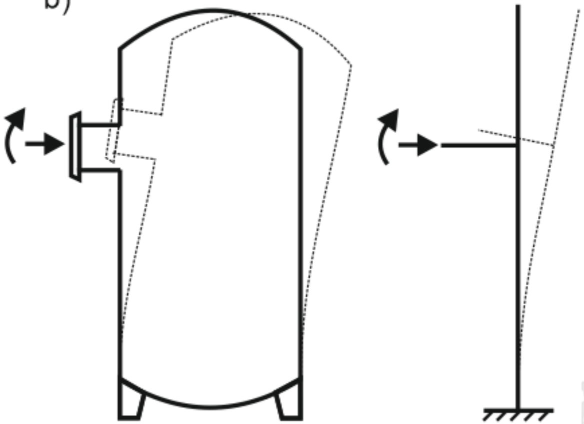
Local Flexibility
Vessel Shell Deformations

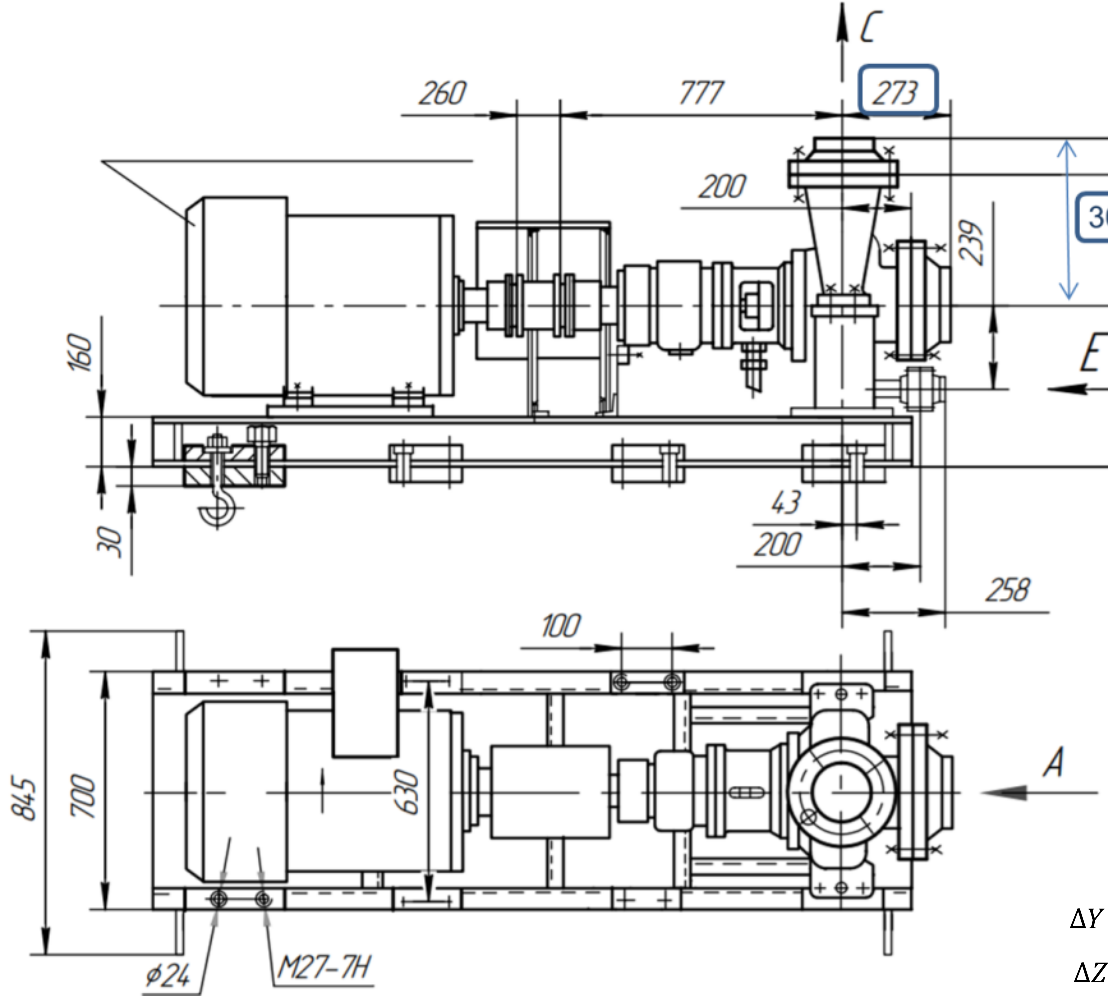
a)

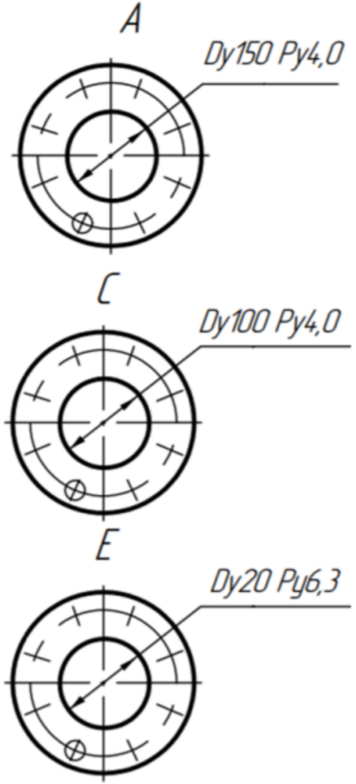


Global Flexibility
(Entire vessel Deformations)

b)







$$\Delta Y = \alpha \cdot \Delta T \cdot L_Y = 1.22 \cdot 10^{-5} \cdot (150+20) \cdot 273 = 0.57 \text{ мм}$$

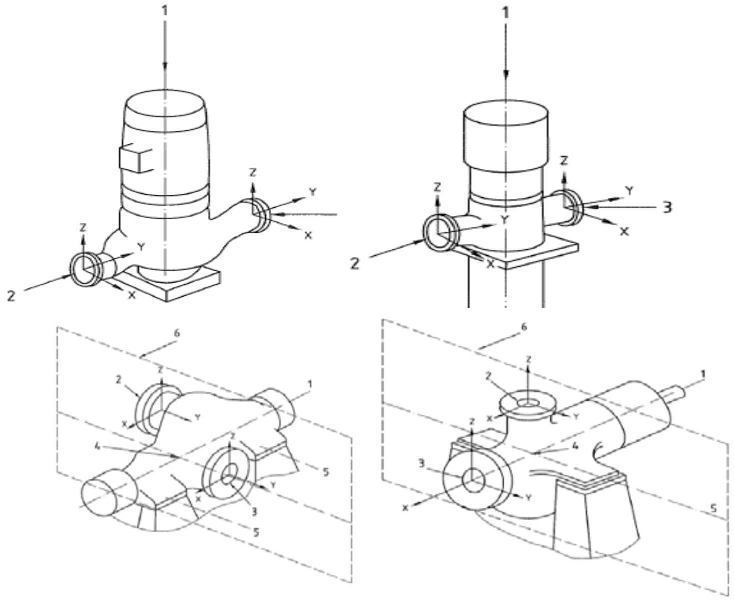
$$\Delta Z = \alpha \cdot \Delta T \cdot L_Z = 1.22 \cdot 10^{-5} \cdot (150+20) \cdot 300 = 0.62 \text{ мм}$$

PASS PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

API 610

Table 4 — Nozzle loadings

	SI units								
	Nominal size of flange (DN)								
	⩽ 50	80	100	150	200	250	300	350	400
	Forces (N)								
Each top nozzle									
F_X	710	1 070	1 420	2 490	3 780	5 340	6 670	7 120	8 450
F_Y	580	890	1 160	2 050	3 110	4 450	5 340	5 780	6 670
F_Z	890	1 330	1 780	3 110	4 890	6 670	8 000	8 900	10 230
F_R	1 280	1 930	2 560	4 480	6 920	9 630	11 700	12 780	14 850
Each side nozzle									
F_X	710	1 070	1 420	2 490	3 780	5 340	6 670	7 120	8 450
F_Y	890	1 330	1 780	3 110	4 890	6 670	8 000	8 900	10 230
F_Z	580	890	1 160	2 050	3 110	4 450	5 340	5 780	6 670
F_R	1 280	1 930	2 560	4 480	6 920	9 630	11 700	12 780	14 850
Each end nozzle									
F_X	890	1 330	1 780	3 110	4 890	6 670	8 000	8 900	10 230
F_Y	710	1 070	1 420	2 490	3 780	5 340	6 670	7 120	8 450
F_Z	580	890	1 160	2 050	3 110	4 450	5 340	5 780	6 670
F_R	1 280	1 930	2 560	4 480	6 920	9 630	11 700	12 780	14 850
	Moments (N m)								
Each nozzle									
M_X	460	950	1 330	2 300	3 530	5 020	6 100	6 370	7 320
M_Y	230	470	680	1 180	1 760	2 440	2 980	3 120	3 660
M_Z	350	720	1 000	1 760	2 580	3 800	4 610	4 750	5 420
M_R	620	1 280	1 800	3 130	4 710	6 750	8 210	8 540	9 820



API 610

F.1 Horizontal pumps

F.1.1 Acceptable piping configurations should not cause excessive misalignment between the pump and driver. Piping configurations that produce component nozzle loads lying within the ranges specified in Table 5 limit casing distortion to one-half the pump vendor's design criterion (see 6.3.3) and ensure pump shaft displacement of less than 250 µm (0,010 in).

F.1.2 Piping configurations that produce loads outside the ranges specified in Table 5 are also acceptable without consultation with the pump vendor if the conditions specified in F.1.2 a) through F.1.2 c) as follows are satisfied. Satisfying these conditions ensures that any pump casing distortion is within the vendor's design criteria (see 6.3.3) and that the displacement of the pump shaft is less than 380 µm (0,015 in).

a) The individual component forces and moments acting on each pump nozzle flange shall not exceed the range specified in Table 5 (T4) by a factor of more than 2.

b) The resultant applied force (F_{RSA}, F_{RDA}) and the resultant applied moment (M_{RSA}, M_{RDA}) acting on each pump-nozzle flange shall satisfy the appropriate interaction equations as given in Equations (F.1) and (F.2):

$$[F_{RSA}/(1{,}5 \times F_{RST4})] + [M_{RSA}/(1{,}5 \times M_{RST4})] < 2 \quad \text{(F.1)}$$

$$[F_{RDA}/(1{,}5 \times F_{RDT4})] + [M_{RDA}/(1{,}5 \times M_{RDT4})] < 2 \quad \text{(F.2)}$$

c) The applied component forces and moments acting on each pump nozzle flange shall be translated to the centre of the pump. The magnitude of the resultant applied force, F_{RCA}, the resultant applied moment, M_{RCA}, and the applied moment shall be limited by Equations (F.3) to (F.5). (The sign convention shown in Figures 21 through 25 and the right-hand rule should be used in evaluating these equations.)

$$F_{RCA} < 1{,}5(F_{RST4} + F_{RDT4}) \quad \text{(F.3)}$$

$$|M_{YCA}| < 2{,}0(M_{YST4} + M_{YDT4}) \quad \text{(F.4)}$$

$$M_{RCA} < 1{,}5(M_{RST4} + M_{RDT4}) \quad \text{(F.5)}$$

where

$$F_{RCA} = [(F_{XCA})^2 + (F_{YCA})^2 + (F_{ZCA})^2]^{0,5}$$

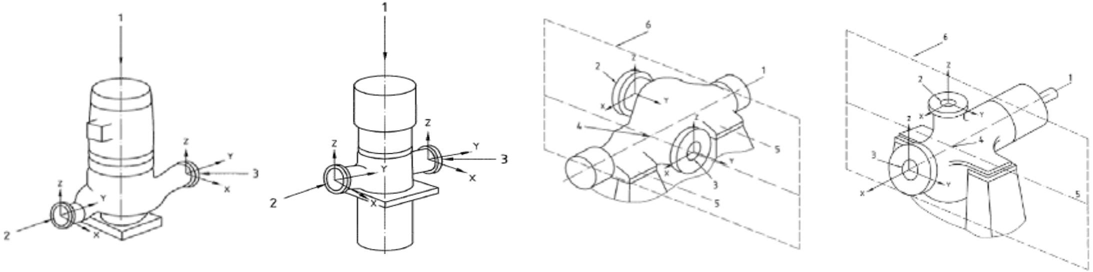
where

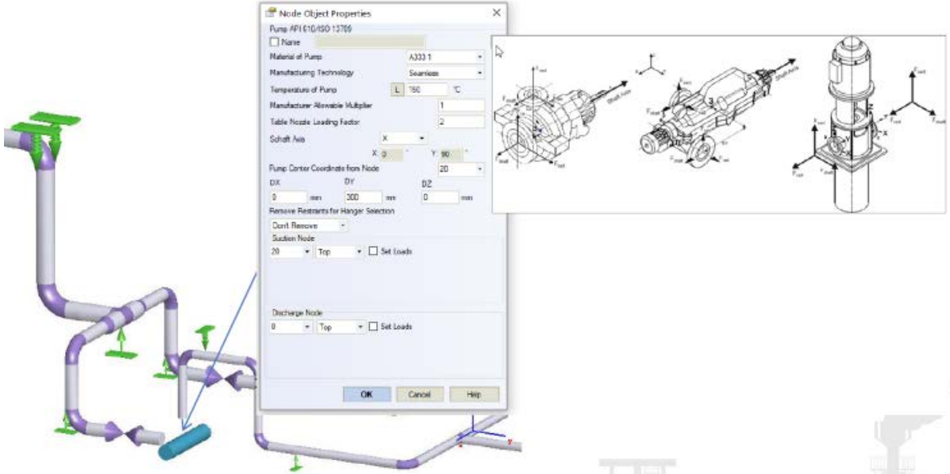
$$F_{XCA} = F_{XSA} + F_{XDA}$$

$$F_{YCA} = F_{YSA} + F_{YDA}$$

$$F_{ZCA} = F_{ZSA} + F_{ZDA}$$

$$M_{RCA} = [(M_{XCA})^2 + (M_{YCA})^2 + (M_{ZCA})^2]^{0,5}$$





where

$$M_{XCA} = M_{XSA} + M_{XDA} - [(F_{YSA})(zS) + (F_{YDA})(zD) - (F_{ZSA})(yS) - (F_{ZDA})(yD)]/1\,000$$

$$M_{YCA} = M_{YSA} + M_{YDA} + [(F_{XSA})(zS) + (F_{XDA})(zD) - (F_{ZSA})(xS) - (F_{ZDA})(xD)]/1\,000$$

$$M_{ZCA} = M_{ZSA} + M_{ZDA} - [(F_{XSA})(yS) + (F_{XDA})(yD) - (F_{YSA})(xS) - (F_{YDA})(xD)]/1\,000$$

In USC units, the constant 1 000 shall be changed to 12. This constant is the conversion factor to change millimetres to metres or inches to feet.

F.1.3 Piping configurations that produce loads greater than those allowed in F.1.2 shall be approved by the purchaser and the vendor.

NOTE In order to evaluate the actual machine distortion (at ambient conditions), the piping alignment checks required in API RP 686, Chapter 6, should be performed. API RP 686 allows only a small fraction of the permitted distortion resulting from use of the values from this annex.

PASS PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Compressor API 617

Node Object Properties

Compressor API 617/ISO 10439

- [ ] Name
- Material of Compressor: 20
- Manufacturing Technology: Seamless
- Temperature of Compressor: L 100 °C
- Factor for Allowable Loads: 1
- Shaft Axis: X
- Center of Compressor Coordinate from Node: 3
- DX 0 mm DY 500 mm DZ 0 mm
- Remove Restraints for Hanger Selection: Don't Remove

Suction Nozzle: 1 — [ ] Set Manual Loads

Discharge Node: 3 — [ ] Set Manual Loads

Additional Nozzle 1: 0 — [ ] Set Manual Loads

Additional Nozzle 2: 0 — [ ] Set Manual Loads

OK | Cancel | Help

In SI units:

$$F_r + 1.09\,M_r \le 54.1\,D_e \quad \text{(F.1a)}$$

In U.S. customary (USC) units:

$$3\,F_r + M_r \le 927\,D_e \quad \text{(F.1b)}$$

F_r is the resultant force, Newtons (lb) (see Figure F.1);

$$F_r = \sqrt{F_x^2 + F_y^2 + F_z^2} \quad \text{(F.2)}$$

M_r resultant moment, in Newton-meters (ft-lb) from Figure F.1;

$$M_r = \sqrt{M_x^2 + M_y^2 + M_z^2}\,. \quad \text{(F.3)}$$

For sizes greater than 200 mm (8 in.), use the following values.

In SI units:

$$D_e = \frac{(400 + D_{nom})}{3}\ \text{(mm)} \quad \text{(F.4a)}$$

In USC units:

$$D_e = \frac{(16 + D_{nom})}{3}\ \text{(in.)} \quad \text{(F.4b)}$$

In SI units:

$$F_c + 1.64 M_c \le 40.4 D_c \quad \text{(F.5a)}$$

In USC units:

$$2F_c + M_c \le 462 D_c \quad \text{(F.5b)}$$

In SI units:

$$F_c + 1.64 M_c \le 40.4 D_c \quad \text{(F.5a)}$$

In USC units:

$$2F_c + M_c \le 462 D_c \quad \text{(F.5b)}$$

where

F_c is the combined resultant of inlet, sidestream, and discharge forces, Newtons (lb);

M_c is the combined resultant of inlet, sidestream, and discharge moments, and moments resulting from forces, Newton-meters (ft-lb);

D_c is the diameter [mm (in.)] of one circular opening equal to the total areas of the inlet, sidestream, and discharge openings. If the equivalent nozzle diameter is greater than 230 mm (9 in.), use a value of D_c equal to the following.

In SI units:

$$D_c \frac{(460 + \text{Equivalent Diameter})}{3}\ \text{(mm)} \quad \text{(F.6a)}$$

In USC units:

$$D_c \frac{(18 + \text{Equivalent Diameter})}{3}\ \text{(in.)} \quad \text{(F.6b)}$$

The absolute value of the individual components (Figure F.1) of these resultants should not exceed the following.

In SI units:

$$F_x = 16.1 D_c \qquad M_x = 24.6 D_c$$

$$F_y = 40.5 D_c \qquad M_y = 12.3 D_c$$

$$F_z = 32.4 D_c \qquad M_z = 12.3 D_c$$

Input | **Equipment**

Operating Mode: 1 'Рабочий режим' (0) — Load Case: Operating W+P+T — [x] Show Equations — ?

Object	Start End node	Type	DN, mm	Frad, N	Fcir, N	Flong N	FR, N	Mrad, N·m	Mcir, N·m	Mlong, N·m	MR, N·m	Sum	Notes
Compressor API 617/API 619/ISO 10439	Node (1)	Suction, Top	200	-15918	12907	-23209	30962	-2577.83	11010.28	8677.81	14253.98	4.30	1
	Node (3)	Discharge, Top	200	1440505	-173	0	1440505	0		28.89	28.89	133.14	1
		ext1											
		ext2											
		Summary Loads	250.91	1424587	12734	-23209	1424833	-2577.83	22615.01	15246.83	27396.16	144.99	
				8130					[illegible]86.24	6172.49			

Dc=250.9141 mm

[Fcir]=k1*40.5Dc=1.00*10162.02=10162.02 N

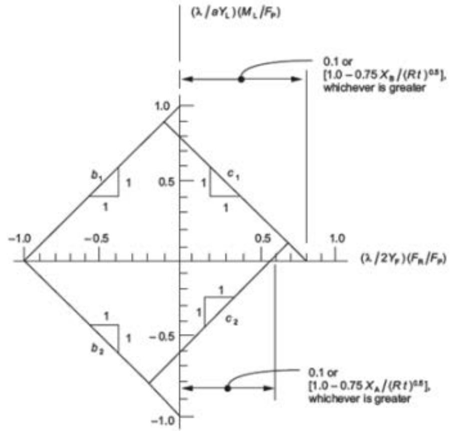


Figure P.3a—Construction of Nomogram for b_1, b_2, c_1, c_2 Boundary

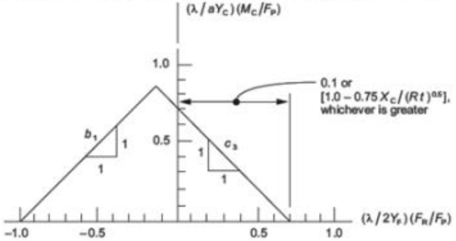
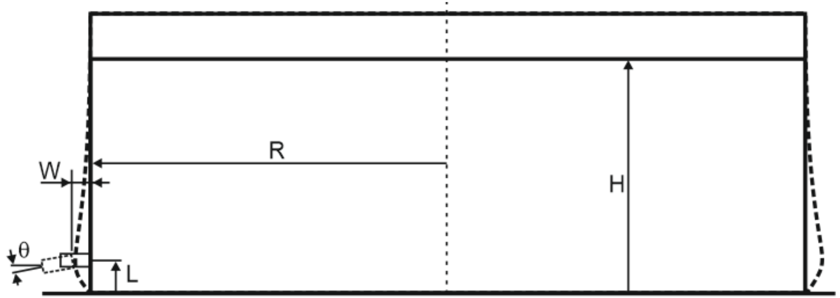
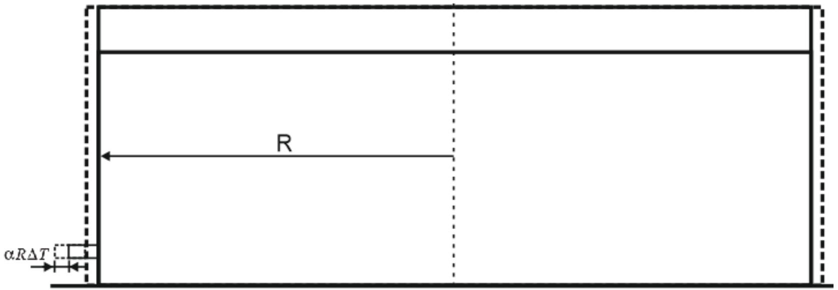


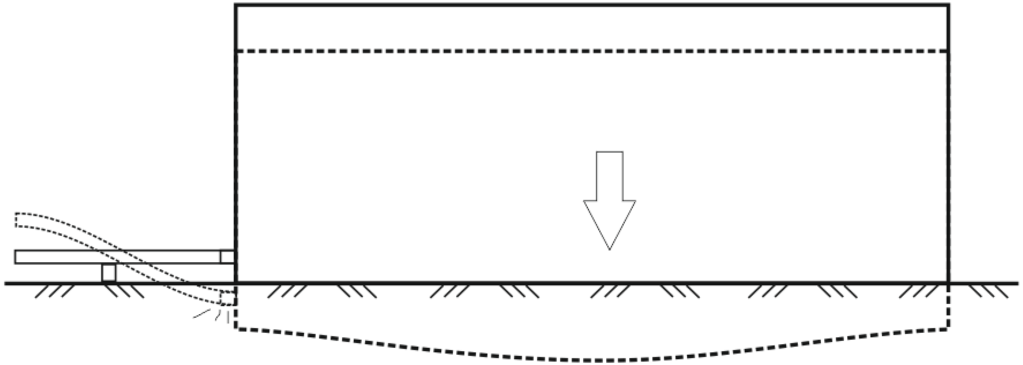
Figure P.3b—Construction of Nomogram for b_1, c_3 Boundary

$$W = \frac{9.8 \times 10^{-6} GHR^2}{Et} \times \left[1 - e^{-\beta L} \cos(\beta L) - \frac{L}{H}\right]$$

$$\theta = \frac{9.8 \times 10^{-6} GHR^2}{Et} \times \left\{\frac{1}{H} - \beta e^{-\beta L}[\cos(\beta L) + \sin(\beta L)]\right\}$$



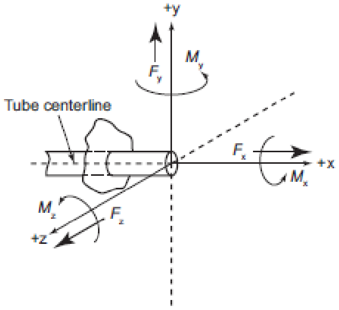




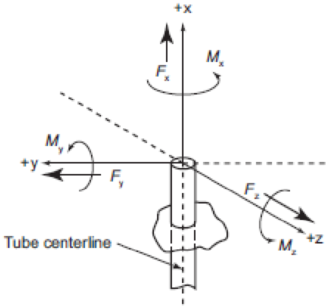
G is the design specific gravity of the liquid;
H is the maximum allowable tank filling height, in mm (in.);
L is the vertical distance from the nozzle center line to the tank bottom, in mm (in.);
R is the nominal tank radius, in mm (in.);
t is the shell thickness at the opening connection, in mm (in.);
β is the characteristic parameter, 1.285/(R*t)^0.5 (1/mm) (1/in.);
E is the modulus of elasticity, in MPa (lbf/in.2);
ΔT is the normal design temperature minus installation temperature, in °C (°F);
α is the thermal expansion coefficient of the shell material, in mm/[mm-°C] (in./[in.-°F])

Fired Heater Modelling

- ❑ Allowable loads calculated according to API 560
- ❑ Method 1: Use an anchor at the point where the piping goes inside the heater. The heater vendor must provide the allowable loads for this anchor point. Or API 560 code may be used



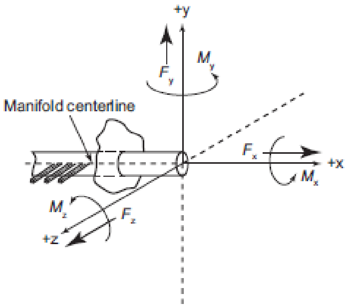
a) Horizontal Tubes



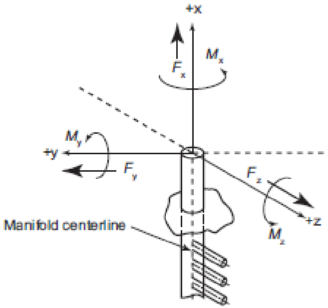
b) Vertical Tubes

Table 6—Allowable Forces and Moments for Tubes

Pipe Size DN (NPS)	Force						Moment					
	F_x		F_y		F_z		M_x		M_y		M_z	
	N	(lbf)	N	(lbf)	N	(lbf)	N·m	(ft·lbf)	N·m	(ft·lbf)	N·m	(ft·lbf)
50 (2)	445	(100)	890	(200)	890	(200)	475	(350)	339	(250)	339	(250)
75 (3)	667	(150)	1334	(300)	1334	(300)	610	(450)	475	(350)	475	(350)
100 (4)	890	(200)	1779	(400)	1779	(400)	813	(600)	610	(450)	610	(450)
125 (5)	1001	(225)	2002	(450)	2002	(450)	895	(660)	678	(500)	678	(500)
150 (6)	1112	(250)	2224	(500)	2224	(500)	990	(730)	746	(550)	746	(550)
200 (8)	1334	(300)	2669	(600)	2669	(600)	1166	(860)	881	(650)	881	(650)
250 (10)	1557	(350)	2891	(650)	2891	(650)	1261	(930)	949	(700)	949	(700)
300 (12)	1779	(400)	3114	(700)	3114	(700)	1356	(1000)	1017	(750)	1017	(750)



a) Horizontal Manifold



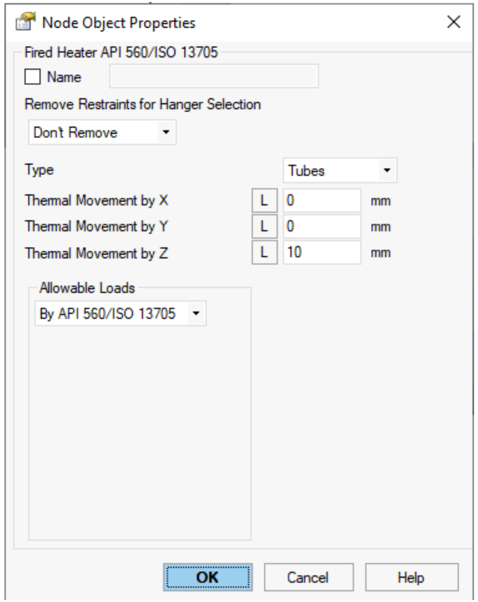
b) Vertical Manifold

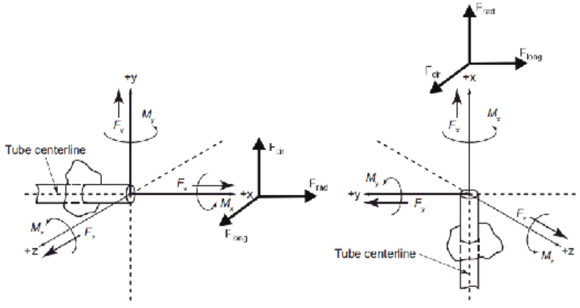
Table 8—Allowable Forces and Moments for Manifolds

Manifold Size DN (NPS)	Force						Moment					
	F_x		F_y		F_z		M_x		M_y		M_z	
	N	(lbf)	N	(lbf)	N	(lbf)	N·m	(ft·lbf)	N·m	(ft·lbf)	N·m	(ft·lbf)
150 (6)	2224	(500)	4448	(1000)	4448	(1000)	1980	(1460)	1492	(1100)	1492	(1100)
200 (8)	2668	(600)	5338	(1200)	5338	(1200)	2332	(1720)	1762	(1300)	1762	(1300)
250 (10)	3114	(700)	5782	(1300)	5782	(1300)	2522	(1860)	1898	(1400)	1898	(1400)
300 (12)	3558	(800)	6228	(1400)	6228	(1400)	2712	(2000)	2034	(1500)	2034	(1500)
350 (14)	4004	(900)	6672	(1500)	6672	(1500)	2902	(2140)	2170	(1600)	2170	(1600)
400 (16)	4448	(1000)	7117	(1600)	7117	(1600)	3092	(2280)	2305	(1700)	2305	(1700)
450 (18)	4893	(1100)	7562	(1700)	7562	(1700)	3282	(2420)	2441	(1800)	2441	(1800)
500 (20)	5338	(1200)	8006	(1800)	8006	(1800)	3471	(2560)	2576	(1900)	2576	(1900)
600 (24)	5782	(1300)	8451	(1900)	8451	(1900)	3661	(2700)	2712	(2000)	2712	(2000)

Fired Heater Modelling

- Allowable loads calculated according to API 560
- Method 1: Use an anchor at the point where the piping goes inside the heater. The heater vendor must provide the allowable loads for this anchor point. Or API 560 code may be used





a) Horizontal Tubes   b) Vertical Tubes

...splayed. In the second row the allowable values are displayed.

Input | Equipment

Operating Mode: 1 'main mode' (0)   Load Case: Operating W+P+T   Show Equations   ?

Object	Start End node	Type	DN, mm	Frad, kgf	Fcir, kgf	Flong kgf	FR, kgf	Mrad, kgf·cm	Mcir, kgf·cm	Mlong, kgf·cm	MR, kgf·cm	Sum	Notes
Fired Heater API 560/ISO 13705	Node (1)	calculated	219	-96033.70		40605.70			-2029708.86				1
		allowable		133.40	266.90	266.90		11660	8810	8810			

- Method 2: Model whole or part of the furnace coil that is inside the heater. Vendor should provide allowable displacements at the point where the pipe goes inside the heater (+dx, -dx, +dy, -dy, +dz, -dz). Usually it's the gap values between the pipe and heater shell

Table 7—Allowable Movements for Tubes

Dimensions in millimeters (inches)

Terminals	Allowable Movement											
	Horizontal Tubes						Vertical Tubes					
	Δ_x		Δ_y		Δ_z		Δ_x		Δ_y		Δ_z	
Radiant	a	a	+25	(+1)	25	(1)	a	a	25	(1)	25	(1)
Convection	a	a	+13	(+0.5)	13	(0.5)	—	—	—	—	—	—

NOTE Except where noted, the above movements are allowable in both directions (±).

[a] To be specified by heater vendor.

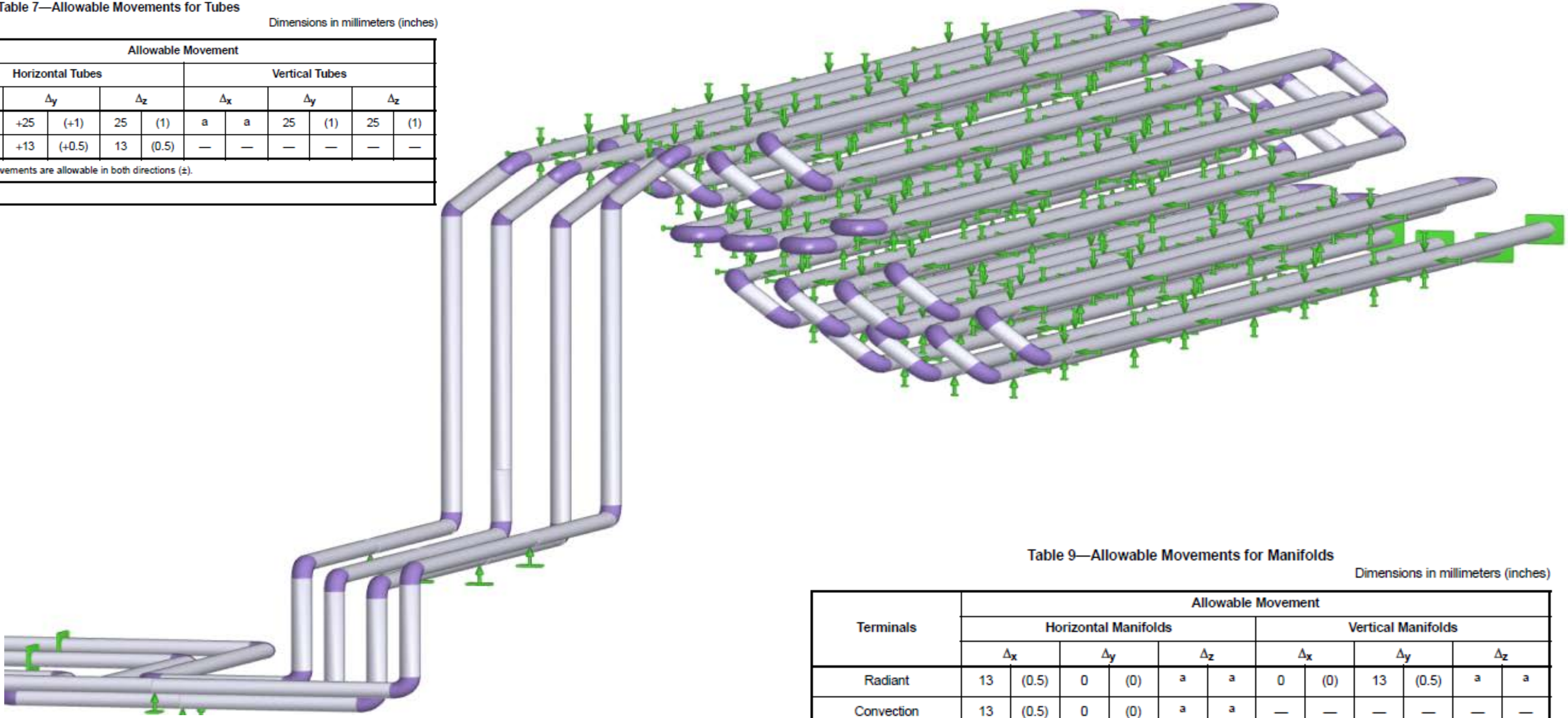


Table 9—Allowable Movements for Manifolds

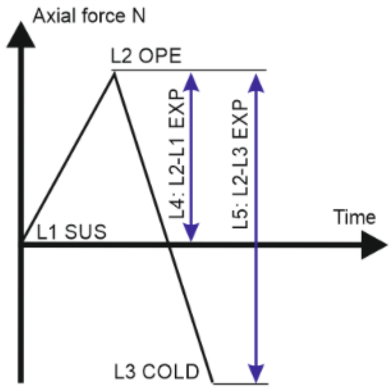
Dimensions in millimeters (inches)

Terminals	Allowable Movement											
	Horizontal Manifolds						Vertical Manifolds					
	Δ_x		Δ_y		Δ_z		Δ_x		Δ_y		Δ_z	
Radiant	13	(0.5)	0	(0)	a	a	0	(0)	13	(0.5)	a	a
Convection	13	(0.5)	0	(0)	a	a	—	—	—	—	—	—

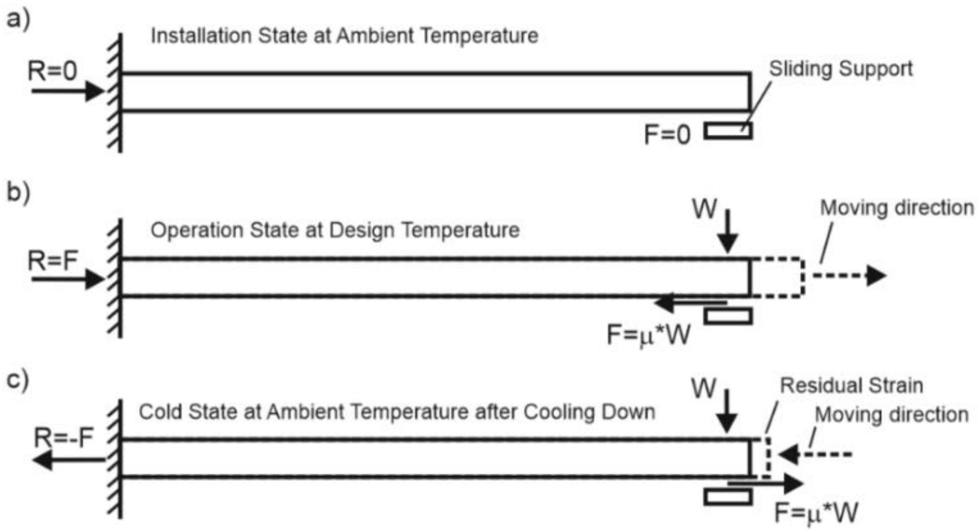
NOTE The above movements are allowable in both directions (±).

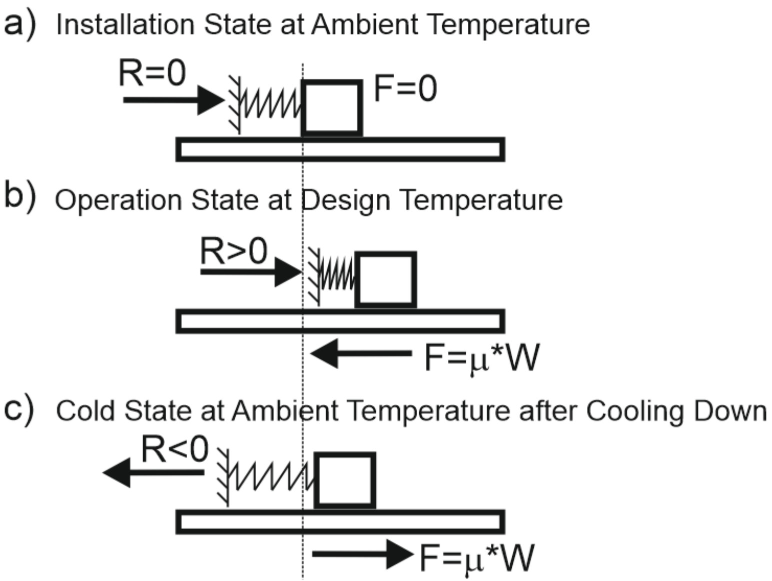
[a] Δ_z is to be specified by heater vendor.

Effect of Friction in Operating and Cold State

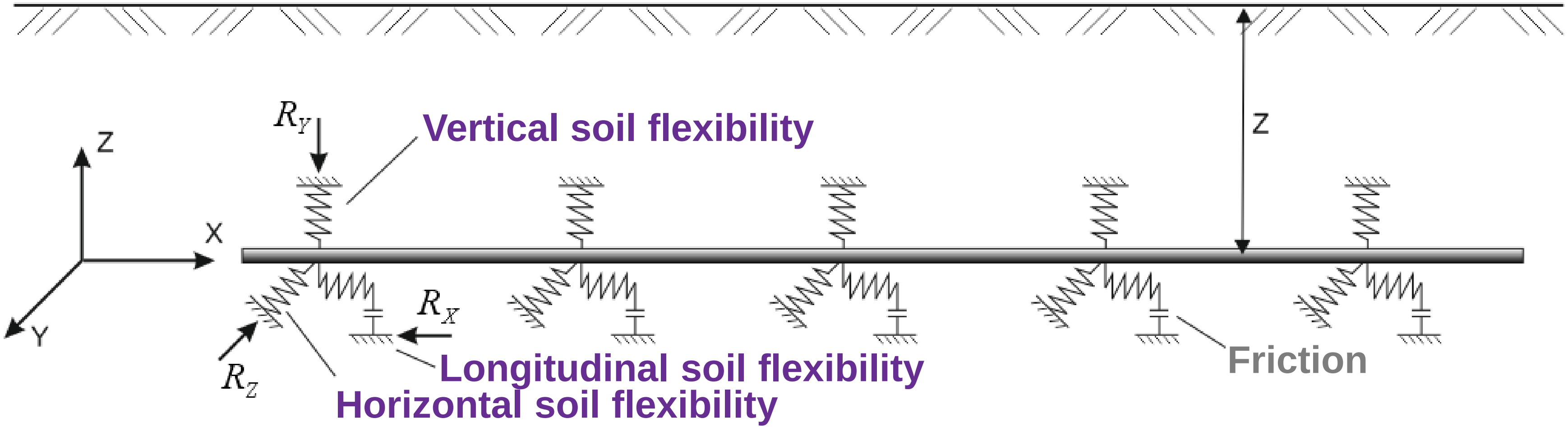


L1: W+P SUS
L2: W+P+T OPE
L3: L2-T COLD (follow up L2)
L4: L2-L1 EXP
L5: L2-L3 EXP

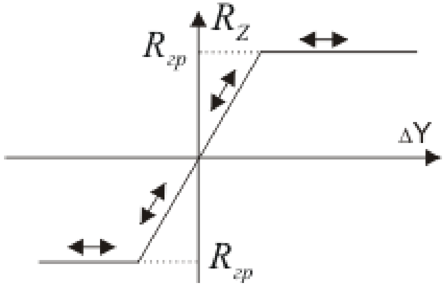




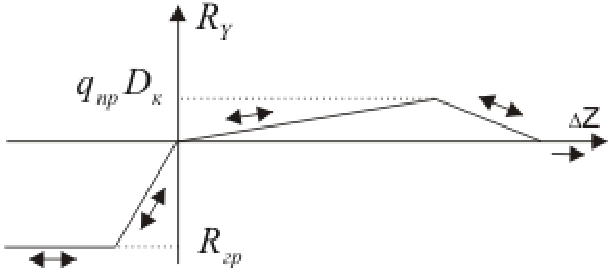
The Pipe and Soil Interaction Model



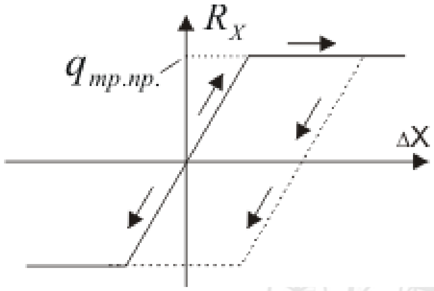
Horizontal soil P-Δ diagram



Vertical soil P-Δ diagram



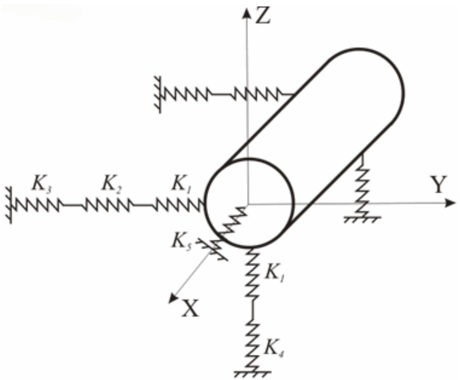
Longitudinal soil P-Δ diagram (friction)

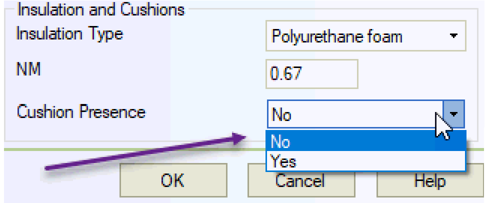


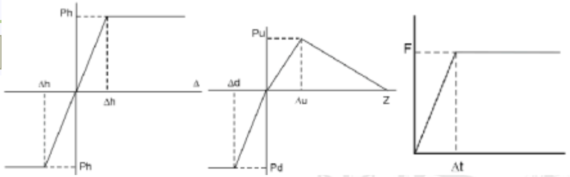
PASS/Start-Prof | Soil Model

Each soil support stiffness consist of vertical, horizontal and longitudinal nonlinear springs

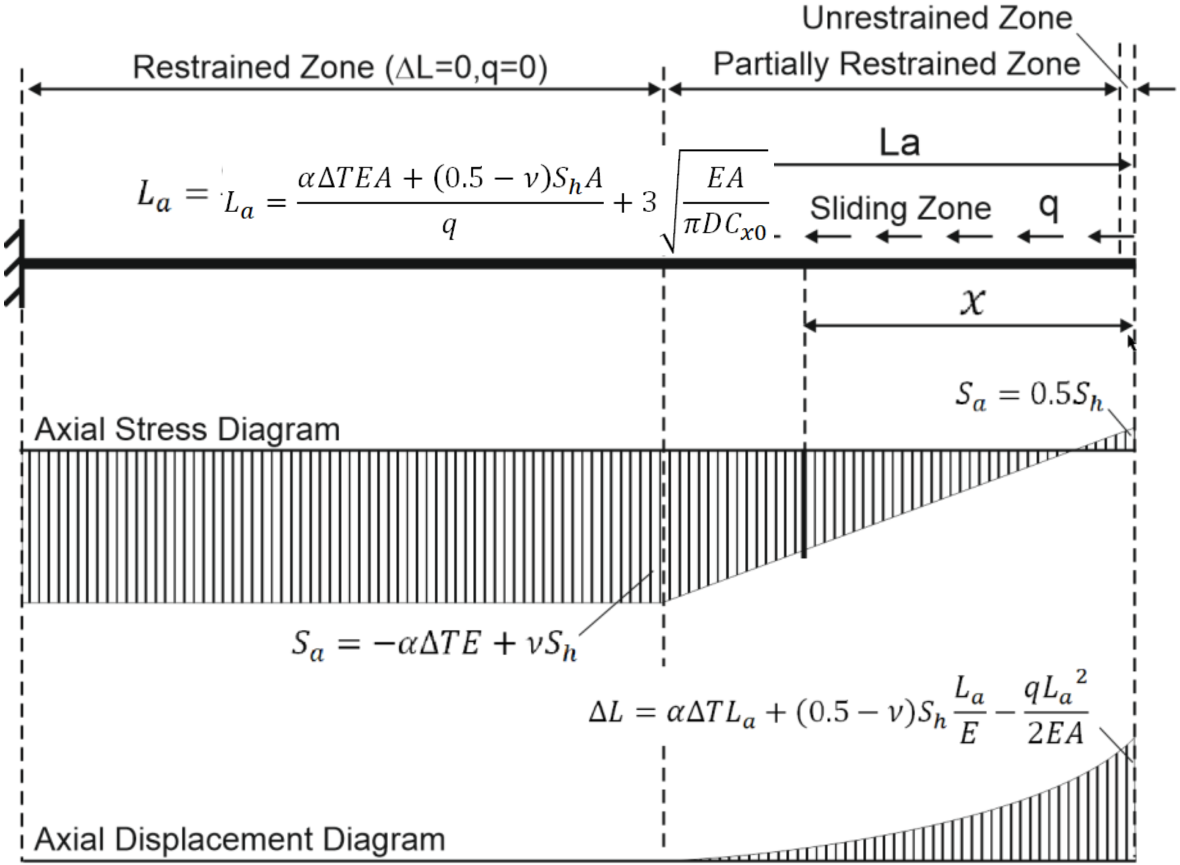
- Horizontal spring consist of 3 springs K1, K2, K3.
- Vertical Spring consist of 2 (or 3) springs K1, K4 (and K2).
- Longitudinal spring K5

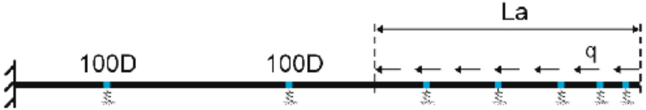






Restrained and Unrestrained Zones





$$L_a = \frac{\alpha \Delta T E A + (0.5 - \nu) S_h A}{q} + 3\sqrt{\frac{EA}{\pi D C_{x0}}}$$

Sh is the ring stress, q is the friction force, E is the modulus of elasticity, A is the area, DT is the temperature difference, a is the linear expansion coefficient, n is the Poisson coefficient

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