What is Restrained and Unrestrained Pipes and what is the Strength Criteria

Alex Matveev, September 11, 2018

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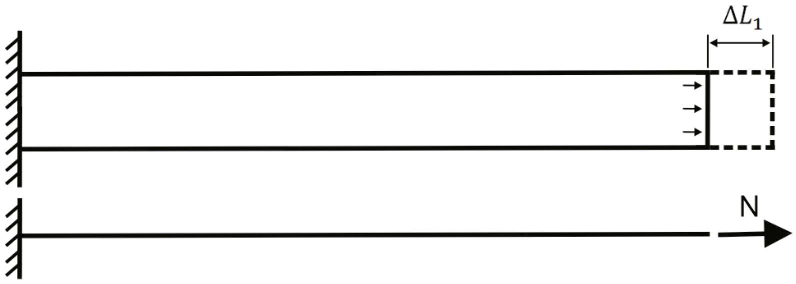
ASME B31.4 and B31.8 codes divide pipes into restrained and unrestrained. Which part of pipe is restrained and which is not? Many engineers have a misconception about this. We will explain the difference and suggest new universal strength criteria, which cover both restrained and unrestrained pipes.

Before we begin, let's say that actually, there are three conditions of pipe behavior instead of two described in ASME B31.4 and B31.8 codes:

- Unrestrained
- Totally Restrained
- Partially Restrained

Unrestrained Pipe



Pipe elongation model due to pressure thrust force on cap

Unrestrained pipe elongation of pipe from pressure consists of two parts. First part is elongation due to pressure load on end cap. The second part is pipe shortening due to Hook's law.

Pipe elongation prom pressure load on end cap is:

$$\Delta L_1 = \frac{NL}{EA}$$

L – Pipe Length

E – Modulus of Elasticity

Pipe cross-section area is

$$A = \pi \frac{D^2 - (D - 2t)^2}{4} = \pi(D - t)t$$

D – Pipe Outer Diameter

t – Pipe Wall Thickness

N – Axial Force in the Pipe

Axial force N is equal to the force acting on cap

$$N = P\pi(D - 2t)^2/4 \approx 0.5S_h \cdot A$$

P – Internal Pressure

Pipe elongation will be

$$\Delta L_1 = \frac{NL}{EA} = \frac{PL}{E}\frac{(D - 2t)^2}{D^2 - (D - 2t)^2} \approx 0.5S_h\frac{L}{E}$$

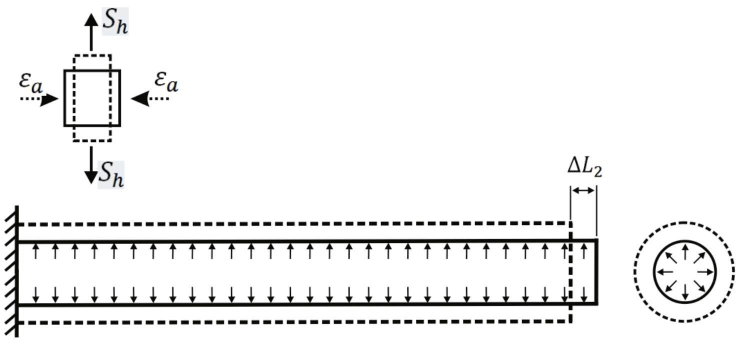
S_h – Hoop Stress in the Pipe

$$S_h = P\frac{(D - t)}{2\text{t}}$$

According to Hooke's law the axial deformation of the pipe under axial stress is:

$$\varepsilon_a = -2\nu \frac{P}{E} \frac{(D-2t)^2}{D^2-(D-2t)^2}$$

ν – Poisson's Ratio



Pipe shortening due to cross-section deformations under internal pressure

Pipe shortening due to internal pressure:

$$\Delta L_2 = \varepsilon_a L = -2\nu \frac{PL}{E} \frac{(D-2t)^2}{D^2-(D-2t)^2} \approx -\nu S_h \frac{L}{E}$$

Total pipe elongation from pressure load is

$$\Delta L = \Delta L_1 + \Delta L_2 = (1-2\nu) \frac{PL}{E} \frac{(D-2t)^2}{D^2-(D-2t)^2} \approx (0.5-\nu) S_h \frac{L}{E}$$

If we add thermal expansion elongation the equation will be:

$$\Delta L = \alpha \Delta T L + (1-2\nu) \frac{PL}{E} \frac{(D-2t)^2}{D^2-(D-2t)^2} \approx \alpha \Delta T L + (0.5-\nu) S_h \frac{L}{E}$$

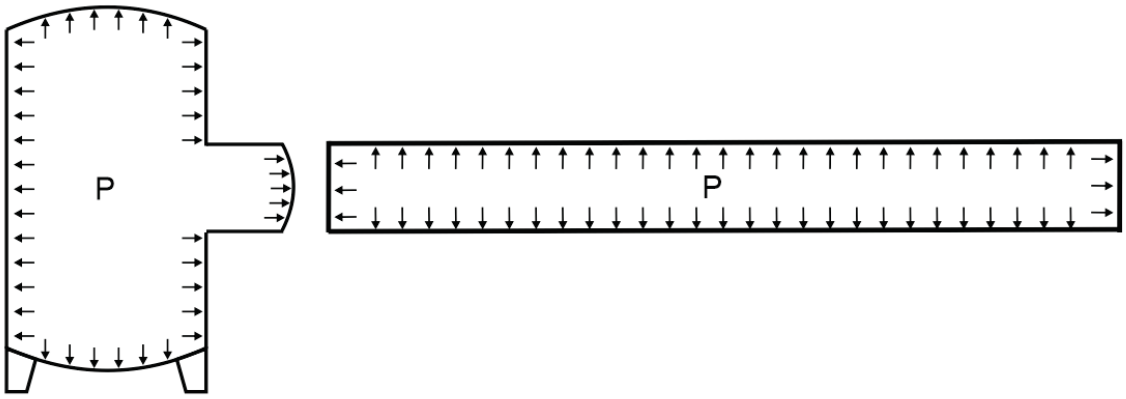
ΔT – Temperature Difference between Installation and Operation temperature

α – Coefficient of thermal expansion

Longitudinal stress caused by internal pressure is

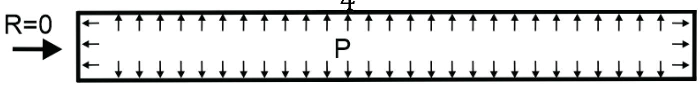
$$S_a = \frac{N}{A} = P \frac{(D-2t)^2}{D^2-(D-2t)^2} \approx 0.5 S_h$$

If the left end is connected to pressure vessel nozzle or rotary equipment, then axial force in the equipment nozzle will be N as calculated above. But when equipment manufacturers calculate allowable loads, they assume that nozzle has end cap and vessel is under pressure. This means that axial stress caused by pressure is already included into allowable loads and should not be considered twice.



This means that we must exclude the pressure thrust load from axial force to calculate the support load that can be compared to allowable load on nozzle. To do this we must assume that pipe has two caps on the both ends. In this case the support load R will be equal to internal force N minus thrust force on the end cap, i.e. zero

$$R = N - P \frac{\pi (D-2t)^2}{4} = 0$$



A strength criterion for unrestrained pipe is:

$$S_a \le S_{Allow}$$

$$S_a = P\frac{(D-2t)^2}{D^2-(D-2t)^2} \approx \frac{P(D-t)}{4t} \approx \frac{PD}{4t}$$

If we add here bending stress M/Z and axial stress N/A from loads other than pressure, we get

$$S_a = \frac{PD}{4t} + \frac{M}{Z} + \frac{N}{A} \leq S_{Allow}$$

If we want to add torsion stress, we should calculate equivalent stress:

$$\sqrt{(S_a)^2 + 2(S_t)^2} \leq S_{Allow}$$

Russian codes add also hoop stress into this equation that is important for high pressure piping:

$$\sqrt{(S_h)^2 - S_a S_h + (S_a)^2 + 3(S_t)^2} \leq S_{Allow}$$

S_{Allow} - Allowable stress. Its value depends on the code. Usually in most codes it is allowable stress Sh at operating temperature, 0.9Sy or Sy for test state, and $k \cdot Sh$ for occasional loads. Where k is occasional load factor from 1.15 to 1.8 depending on selected code.

Thermal expansion has no effect on unrestrained piping systems, i.e. this equation usually used for sustained and occasional stress check in piping systems from pressure, weight and other force-based loads.

The code equations were created for manual calculation. But now most of pipe stress analysis software can consider Bourdon effect. This means that code equations should be modified to match the current level of technology.

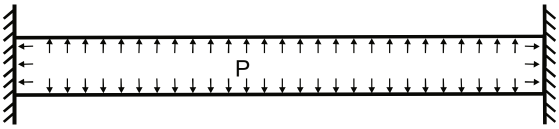
If axial force N is calculated using software that considers Bourdon effect, then we should subtract $(PD/4t)A$ value from axial force otherwise it will be included twice:

$$S_a = \frac{PD}{4t} + \frac{M}{Z} + \frac{N - (PD/4t)A}{A} \leq S_{Allow}$$

This was already done many years ago in Russian codes GOST 32388 Process Piping, GOST 55596 District Heating Networks, SNiP 2.05.06-85 Gas and Oil Pipelines, and ASME B31.3, but still not fixed in all other ASME B31 codes. The criteria for software analysis where M and N calculated with Bourdon effect should be just:

$$S_a = \frac{M}{Z} + \frac{N}{A} \leq S_{Allow}$$

Totally Restrained Pipe



For a restrained pipe with two anchors on both ends, thermal and pressure expansion should be zero

$$\Delta L = 0$$

The axial force required to compress the pipe back to its original length can be calculated from this equation:

$$\Delta L = \frac{RL}{EA}$$

Therefore support load should be:

$$R = \frac{\Delta L \cdot EA}{L}$$

After substitution the ΔL equation we got final support load for restrained pipe:

$$R = \alpha \Delta T E A + (1-2\nu) A \frac{P(D-2t)^2}{D^2-(D-2t)^2} \approx \alpha \Delta T E A + (0.5-\nu) S_h \cdot A$$

The value of axial force can be obtained from the equilibrium conditions near the anchor. Axial force is equal to reaction in anchor subtract the pressure thrust force that is received by anchor and doesn't acting on the pipe:

$$N = -\mathrm{R} + \frac{\pi P(D-2t)^2}{4}$$

Final equation for axial force in restrained pipe is

$$N = -\alpha \Delta T E A + 2\nu \frac{\pi P(D-2t)^2}{4} \approx -\alpha \Delta T E A + \nu S_h \cdot A$$

Axial stress in the restrained pipe will be

$$S_a = \frac{N}{A} = -\alpha \Delta T E + 2\nu \frac{P(D-2t)^2}{D^2-(D-2t)^2} \approx -\alpha \Delta T E + \nu S_h$$

A strength criterion for totally restrained pipe is:

$$S_a = -\alpha \Delta T E + \nu S_h \leq S_{Allow}$$

If we add here bending stress M/Z and axial stress N/A from loads other than pressure, we get

$$S_a = -\alpha \Delta T E + \nu S_h + \frac{M}{Z} + \frac{N}{A} \leq S_{Allow}$$

If we want also consider torsion and hoop stress, we should use the equivalent stress equations like described for unrestraint pipes.

If axial force N is calculated using software that considers Bourdon effect, then we should subtract $\nu S_h A$ value:

$$S_a = -\alpha \Delta T E + \nu S_h + \frac{M}{Z} + \frac{N - \nu S_h A}{A} \leq S_{Allow}$$

The criteria for software where M and N calculated with Bourdon effect and thermal expansion should be:

$$S_a = \frac{M}{Z} + \frac{N}{A} \leq S_{Allow}$$

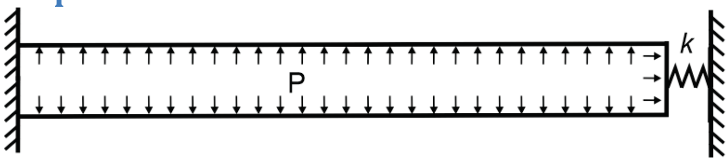
A criterion is the same as for unrestrained pipes, but allowable stress is usually $0.8Sy \dots 1.0Sy$ to prevent the Yielding through all pipe length. Sy – is yield strength of pipe material.

The maximum temperature difference for fully restrained pipe, ignoring longitudinal buckling effect, can be found by equation:

$$\Delta T \leq \frac{S_{Allow} - \nu S_h}{\alpha E}$$

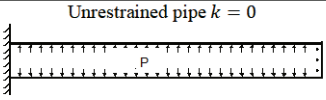
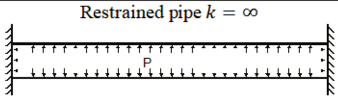
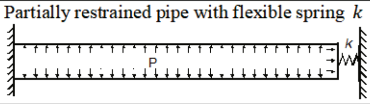
If pressure is zero, this value is about $\Delta T \leq 80°C \dots 110°C$.

Partially Restrained Pipe



If we add flexible spring instead of rigid anchor on the right end of the pipe, we will get the third pipe condition – partially restrained.

We will pass the derivation of equations process and just show the final equations in table below.

	Unrestrained pipe $k = 0$ 	Restrained pipe $k = \infty$ 	Partially restrained pipe with flexible spring k 
Support Load	$R = 0$	$R = \alpha \Delta T E A + (1 - 2\nu) A \frac{P(D-2t)^2}{D^2 - (D-2t)^2} \approx \alpha \Delta T E A + (0.5 - \nu) S_h \cdot A$	$R = \frac{\alpha \Delta T E A + (1-2\nu) A \frac{P(D-2t)^2}{D^2-(D-2t)^2}}{\frac{EA}{kL} + 1} \approx \frac{\alpha \Delta T E A + (0.5 - \nu) S_h \cdot A}{\frac{EA}{kL} + 1}$
Axial Force	$N = P \frac{\pi (D-2t)^2}{4} \approx 0.5 S_h \cdot A$	$N = -\alpha \Delta T E A + 2\nu \frac{P\pi (D-2t)^2}{4} \approx -\alpha \Delta T E A + \nu S_h \cdot A$	$N = \frac{-\alpha \Delta T E A - 2\nu \frac{P\pi (D-2t)^2}{4}}{\frac{EA}{kL} + 1} + \frac{P\pi (D-2t)^2}{4} \approx \frac{-\alpha \Delta T E A - (0.5 - \nu) S_h \cdot A}{\frac{EA}{kL} + 1} + 0.5 S_h \cdot A$
Axial Stress	$S_a = \frac{P(D-2t)^2}{D^2 - (D-2t)^2} \approx 0.5 S_h$	$S_a = -\alpha \Delta T E + 2\nu \frac{P(D-2t)^2}{D^2 - (D-2t)^2} \approx -\alpha \Delta T E + \nu S_h$	$S_a = \frac{-\alpha \Delta T E - 2\nu \frac{P(D-2t)^2}{D^2-(D-2t)^2}}{\frac{EA}{kL} + 1} + \frac{P(D-2t)^2}{D^2 - (D-2t)^2} \approx \frac{-\alpha \Delta T E - (0.5 - \nu) S_h}{\frac{EA}{kL} + 1} + 0.5 S_h$
Elongation	$\Delta L = \alpha \Delta T L + (1 - 2\nu) \frac{P(D-2t)^2}{D^2 - (D-2t)^2} \frac{L}{E} \approx \alpha \Delta T L + (0.5 - \nu) S_h \frac{L}{E}$	$\Delta L = 0$	$\Delta L = \left(\alpha \Delta T L + (1-2\nu) \frac{P(D-2t)^2}{D^2-(D-2t)^2} \frac{L}{E} \right) \left(\frac{1}{\frac{EA}{kL} + 1} \right) \approx \left(\alpha \Delta T L + (0.5 - \nu) S_h \frac{L}{E} \right) \left(\frac{1}{\frac{EA}{kL} + 1} \right)$

The strength criteria for partially restrained pipes should be from sustained primary loads:

$$S_a \leq Sh$$

From occasional primary loads

$$S_a \leq kSh$$

From both primary and secondary loads acting simultaneously

$$S_a \leq 0.8Sy \dots 1.0Sy$$

Primary - are force driven not self-limiting loads like weight, pressure, relief valve thrust, wind, etc.

Secondary – are displacement driven self-limiting loads like thermal expansion, anchor movements, support or soil settlement, etc.

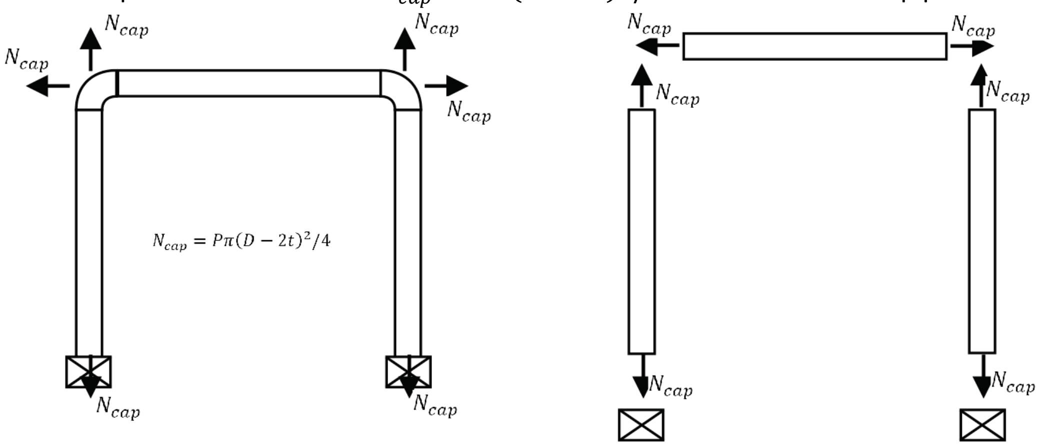
Unrestrained and fully restrained pipe conditions can be easily calculated manually, but third condition require using of pipe stress analysis software, because spring stiffness k depends on connected pipes.

Bourdon Effect Modeling in PASS/Start-Prof

Now I will explain how PASS/Start-Prof software considers pressure Bourdon effect in arbitrary piping model.

Start-Prof model the pressure loads consist of two parts.

Firstly, Start-Prof adds pressure thrust force $N_{cap} = P\pi(D-2t)^2/4$ on each end of the pipe.



Secondly, Start-Prof adds axial deformation for each pipe. It equal to pipe thermal elongation minus pressure shortening, also known as Bourdon effect. Pipe total axial expansion will be

$$\Delta L = \alpha \Delta T L - 2\nu \frac{PL}{E} \frac{(D-2t)^2}{D^2-(D-2t)^2} \approx \alpha \Delta T L - \nu S_h \frac{L}{E}$$

The combination of these two loads allows correct modeling any type of piping: unrestrained, restrained, and partially restrained.

Bourdon effect makes a significant contribution to the support loads, displacements, and stresses for

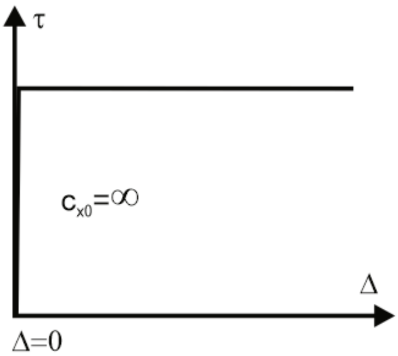
- High pressure piping
- Plastic piping (PE, PP, PB, PVC)
- FRP/GRP/GRE piping

Start-Prof always preforms analysis with Bourdon effect.

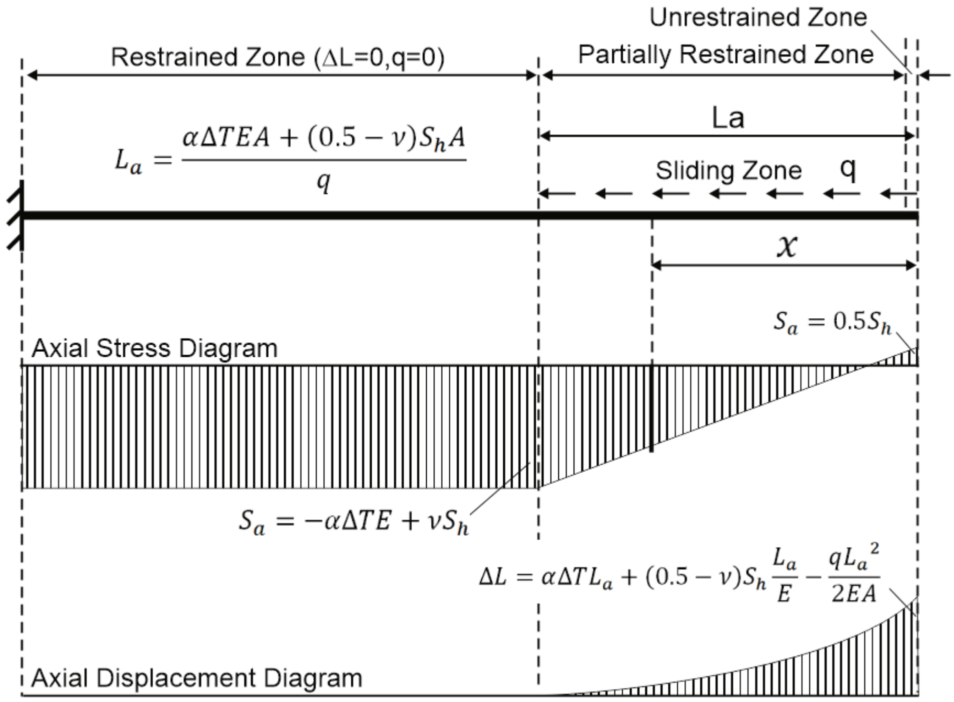
Restrained and Unrestrained Zones in the Buried Pipelines

Buried gas and oil pipelines usually are very long and have a small temperature difference. In this case all three types of pipe condition occur: unrestrained, totally restrained and partially restrained.

Let's assume that soil model is ideal plastic:



In this case the axial stress and axial displacement diagram along the pipeline will be as follows:



As we see unrestrained zone on the right end of the pipe is a very small. The most length of pipeline consists of totally restrained and partially restrained zones.

Anchor load in restrained zone will be:

$$R = \alpha \Delta TEA + (1 - 2\nu)A \frac{P(D - 2t)^2}{D^2 - (D - 2t)^2} \approx \alpha \Delta TEA + (0.5 - \nu)S_h A$$

Axial force at restrained zone is:

$$N_R = -\alpha \Delta TEA + 2\nu \frac{P\pi(D - 2t)^2}{4} \approx -\alpha \Delta TEA + \nu S_h A$$

Stress at restrained zone is:

$$S_a = -\alpha \Delta TE + \nu S_h$$

Axial force at unrestrained zone is:

$$N_U = \frac{P\pi(D - 2t)^2}{4} \approx 0.5 S_h A$$

Stress at unrestrained zone is:

$$S_a = 0.5 S_h$$

Balance equation:

$$N_R = N_U - qL_a$$
$$-\alpha \Delta TEA + \nu S_h A = 0.5 S_h A - qL_a$$

Therefore virtual anchor length is

$$L_a = \frac{\alpha \Delta TEA + (0.5 - \nu)S_h A}{q}$$

Stress function in unrestrained zone is:

$$S_a(x) = -\frac{qx}{A} + 0.5 S_h$$

Displacement function in unrestrained zone is:

$$\Delta L(x) = \int \frac{\left(\alpha \Delta TE - \nu S_h + S_a(x)\right)}{E} dx = C + \alpha \Delta T x - \nu \frac{S_h}{E} x - \frac{qx^2}{2EA} + 0.5 \frac{S_h}{E} x$$
$$= C + \alpha \Delta T x + (0.5 - \nu) \frac{S_h}{E} x - \frac{qx^2}{2EA}$$

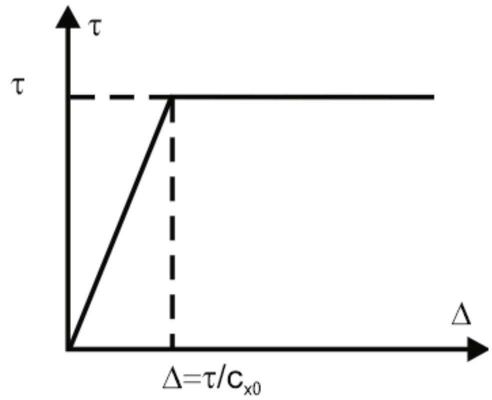
Axial displacement at restrained zone is zero. Therefore:

$$\Delta L(x) = \alpha \Delta T (L_a - x) + (0.5 - \nu) \frac{S_h}{E} (L_a - x) - \frac{q(L_a - x)^2}{2EA}$$

Axial displacement at the right end of the pipe will be

$$\Delta L(0) = \alpha \Delta T L_a + (0.5 - \nu) S_h \frac{L_a}{E} - \frac{q {L_a}^2}{2EA}$$

For more complex and more realistic Elastic-plastic soil model that is used in PASS/Start-Prof pipe stress analysis software the zero displacement (totally restrained) zones is absent:

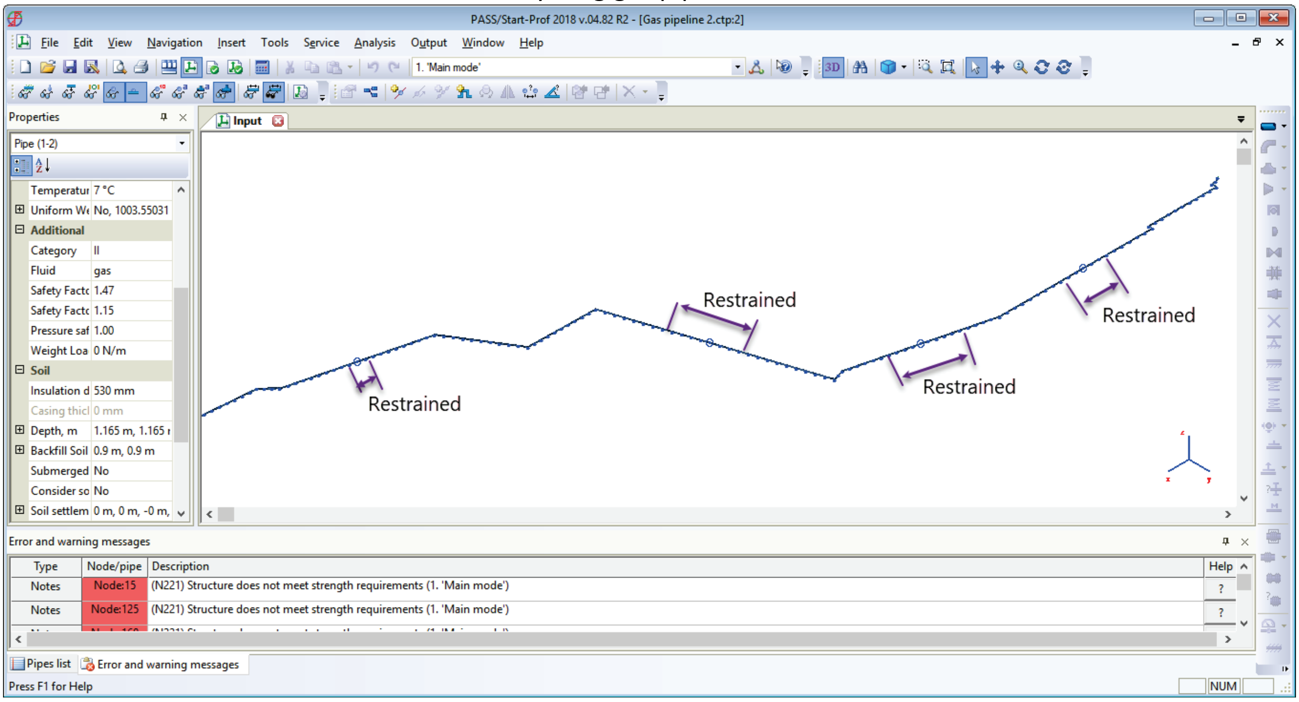


Let's assume that restrained zone begins when axial displacement is very small, for example 1% of maximum displacement. Bypassing complex calculations the sliding zone length that is used in PASS/Start-Prof software is:

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

Strength Criteria in ASME B31.4 and B31.8 Codes

In real design practice the determination where the restrained zones is consume a lot of time. For example on the screenshot below the restrained zones of a very long gas pipeline are shown.



That's why we decided to create universal strength criteria that automatically meets the B31.4 and B31.8 code strength requirements, but can be used for any type of piping. The problem is that ASME B31.4-2016 and B31.8-2016 has unclear requirements for stress analysis.

ASME B31.4 code 402.6.2 requires that longitudinal stress in unrestrained pipe should be less than $0.75S_y$ and $0.8S_y$ for occasional loads.

$$S_L = \frac{PD}{4t} \pm \frac{iM}{A} + \frac{F_a}{A} \le 0.75 S_y$$

This requirement can be extended for all pipe conditions, no matter restrained or unrestrained, but for primary loads. Longitudinal stress in any type of piping from sustained primary loads (weight and pressure) should be less than $0.75S_y$:

$$S_L = \pm\frac{iM}{A} + \frac{F_a}{A} \leq 0.75S_y \; or \; 0.8S_y$$

M and F_a should be calculated by software including Bourdon effect.

ASME B31.4 code 402.6.1 requires that longitudinal stress in restrained pipes should be less than $0.9S_y$, the equivalent stress should be less than $0.9S_y$.

$$S_L = S_E + \upsilon S_H \pm \frac{M}{A} + \frac{F_a}{A} \leq 0.9S_y$$
$$S_{eq} \leq 0.9S_y$$

This requirement can also be extended for all pipe conditions, but for primary and secondary loads acting simultaneously (weight, pressure, and thermal expansion).

$$S_L = \pm\frac{M}{A} + \frac{F_a}{A} \leq 0.9S_y$$
$$S_{eq} \leq 0.9S_y$$

M and F_a should also be calculated by software including Bourdon effect.

The expansion stress should be checked for both restrained and unrestrained pipes.

The same way ASME B31.8 strength criteria can be improved.

The summary of strength criteria we show in the following tables.

Table 1. Original ASME B31.4-2016 Strength Criteria

Element	Sustained, L1 SUS				Operation, L2 OPE				Expansion, L9 EXP		Test, L10	
	S_{eq}	allow	S_L	allow	S_{eq}	allow	S_L	allow	S_E	allow	S_L	allow
Onshore Pipeline												
Pipe/R	-	-	-	-	S_{eq}	$0.9S_y$	S_L	$0.9S_y$	S_E	$0.9S_y$	S_L	$0.9S_y$
Fitting/R	-	-	-	-	-	-	-	-	-	-	-	-
Pipe/U	-	-	S_L	$0.75S_y$	-	-	-	-	S_E	S_A	S_L	$0.8S_y$
Fitting/U	-	-	S_L	$0.75S_y$	-	-	-	-	S_E	S_A	S_L	$0.8S_y$
Raiser												
Pipe/W	-	-	S_L	$0.8S_y$	-	-	-	-	S_E	$0.8S_y$	S_L	$0.9S_y$
Fitting/W	-	-	S_L	$0.8S_y$	-	-	-	-	S_E	$0.8S_y$	S_L	$0.9S_y$
Offshore Pipeline (Ch. IX)												
Pipe	S_{eq}	$0.9S_y$	$\lvert S_L \rvert$	$0.8S_y$	S_{eq}	$0.9S_y$	$\lvert S_L \rvert$	$0.8S_y$	-	-	-	-
Fitting	S_{eq}	$0.9S_y$	$\lvert S_L \rvert$	$0.8S_y$	S_{eq}	$0.9S_y$	$\lvert S_L \rvert$	$0.8S_y$	-	-	-	-
Slurry Pipes (Ch. XI)												
Pipe/R	-	-	-	-	S_{eq}	$0.9S_y$	S_L	$0.9S_y$	S_E	$0.9S_y$	S_L	$0.9S_y$
Fitting/R	-	-	-	-	-	-	-	-	-	-	-	-
Pipe/U	-	-	S_L	$0.75S_y$	-	-	-	-	S_E	S_A	S_L	$0.88S_y$
Fitting/U	-	-	S_L	$0.75S_y$	-	-	-	-	S_E	S_A	S_L	$0.88S_y$

Table 2. Start Smart Check ASME B31.4-2016 Improved Strength Criteria

Element	Sustained, L1 SUS				Operation L2 OPE				Expansion, L9 EXP		Test, L10	
	S_{eq}	allow	S_L	allow	S_{eq}	allow	S_L	allow	S_E	allow	S_L	allow
Onshore Pipeline												
Pipe	-	-	S_L	$0.75S_y$	S_{eq}	$0.9S_y$	S_L	$0.9S_y$	S_E	$0.9S_y \Vert S_A$	S_L	$0.8S_y$
Fitting	-	-	S_L	$0.75S_y$	-	-	-	-	S_E	S_A	S_L	$0.8S_y$
Raiser												
Pipe	-	-	S_L	$0.8S_y$	S_{eq}	$0.9S_y$	S_L	$0.9S_y$	S_E	$0.8S_y$	S_L	$0.9S_y$
Fitting	-	-	S_L	$0.8S_y$	-	-	-	-	S_E	$0.8S_y$	S_L	$0.9S_y$
Offshore Pipeline (Ch. IX)												
Pipe	S_{eq}	$0.9S_y$	$\lvert S_L \rvert$	$0.8S_y$	S_{eq}	$0.9S_y$	$\lvert S_L \rvert$	$0.8S_y$	-	-	-	-
Fitting	S_{eq}	$0.9S_y$	$\lvert S_L \rvert$	$0.8S_y$	S_{eq}	$0.9S_y$	$\lvert S_L \rvert$	$0.8S_y$	-	-	-	-
Slurry Pipes (Ch. XI)												
Pipe	-	-	S_L	$0.75S_y$	S_{eq}	$0.9S_y$	S_L	$0.9S_y$	S_E	$0.9S_y$	S_L	$0.88S_y$
Fitting	-	-	S_L	$0.75S_y$	-	-	-	-	S_E	S_A	S_L	$0.88S_y$

Table 3. Original ASME B31.8-2016 Strength Criteria

Element	Sustained, L1 SUS				Operation L2 OPE				Expansion, L9 EXP		Test, L10	
	S_{eq}	allow	S_L	allow	S_{eq}	allow	S_L	allow	S_E	allow	S_L	allow
Onshore Pipeline												
Pipe/R	-	-	-	-	S_{eq}	$0.9S_y$	S_L	$0.9S_y$	-	-	S_L	$0.9S_y$
Fitting/R	-	-	-	-	-	-	S_L	$0.9S_y$	-	-	S_L	$0.9S_y$
Pipe/U	-	-	S_L	$0.75S_y$	-	-	-	-	S_E	S_A	S_L	$0.75S_y$
Fitting/U	-	-	S_L	$0.75S_y$	-	-	-	-	S_E	S_A	S_L	$0.75S_y$
Offshore Pipeline (Ch. VIII)												
Pipe	S_{eq}	$0.9S_y$	$\lvert S_L \rvert$	$0.8S_y$	S_{eq}	$0.9S_y$	$\lvert S_L \rvert$	$0.8S_y$	-	-	-	-
Fitting	S_{eq}	$0.9S_y$	$\lvert S_L \rvert$	$0.8S_y$	S_{eq}	$0.9S_y$	$\lvert S_L \rvert$	$0.8S_y$	-	-	-	-

Table 4. Start Smart Check ASME B31.8-2016 Improved Strength Criteria

Element	Sustained, L1 SUS				Operation L2 OPE				Expansion, L9 EXP		Test, L10	
	S_{eq}	allow	S_L	allow	S_{eq}	allow	S_L	allow	S_E	allow	S_L	allow
Onshore Pipeline												
Pipe	-	-	S_L	$0.75S_y$	S_{eq}	$0.9S_y$	S_L	$0.9S_y$	S_E	S_A	S_L	$0.75S_y$
Fitting	-	-	S_L	$0.75S_y$	-	-	-	-	S_E	S_A	S_L	$0.75S_y$
Offshore Pipeline												
Pipe	S_{eq}	$0.9S_y$	$\lvert S_L \rvert$	$0.8S_y$	S_{eq}	$0.9S_y$	$\lvert S_L \rvert$	$0.8S_y$	-	-	-	-
Fitting	S_{eq}	$0.9S_y$	$\lvert S_L \rvert$	$0.8S_y$	S_{eq}	$0.9S_y$	$\lvert S_L \rvert$	$0.8S_y$	-	-	-	-

We already implemented the improved ASME B31.4 and B31.8 strength criteria into PASS/Start-Prof software and call it "Start Smart Check". Every user can select this option and forget about manual selection of restrained and unrestrained pipes in stress analysis software.

Also we add "manual" and "Autodetect" options. Using "manual" option user should select restrained or unrestrained option for each pipe. If "Autodetect" option is selected, Start-Prof automatically use equations for restrained pipe if following condition is truth:

$$\frac{F/A}{-E\alpha\Delta T + \upsilon S_H} > 0.975$$

Manual option is not recommended because it seriously slows down the design process. Autodetect option is not recommended, because the strength criteria will be sometimes too conservative and sometimes less conservative for partially restrained pipes.

We recommend users to select “Start Smart Check” option by default because the similar criteria are already successfully used in Russian codes for buried pipelines for many years and proved their reliability. You can just draw pipeline and run analysis. There’s no need to divide it into restrained and unrestrained.