ROMAC
Restraint Calculator for DI & PVC Piping Systems

Welcome
Thrust restraint using mechanical joint restraint fittings instead of thrust blocks can be very economical. When restrained joints are used the pipeline becomes its own thrust block. By restraining certain joints along the pipeline at changes in direction, pipe size or dead end conditions, the resultant force is transferred to the surrounding soil by the pipeline itself. The soil types used in this program are divided into broad categories with varying properties. Care should be used when choosing the soil group to use in the calculation and if at all possible, soil tests should be conducted to ensure the proper soil classification.

This document is not intended to provide background into thrust restraint design or pipe to soil interface theory but to provide the calculations and soil group properties used in the program.

The Romac Restraint Calculator is a design reference guide for use in the restraint of piping joints using Romac products. Results of the calculator should be verified and approved by an engineer prior to use. Particular applications and conditions may not be covered by the formulas and the constants contained within the program. It is the responsibility of the user to understand the program's limitations and apply its results correctly. If there are questions with the use of the program please do not hesitate to contact Romac Engineering.

Getting Started
How to use the RomaCalc restraint calculator

Inputting Variables
There are two methods of inputting variables:

- Pick box – Clicking on the down arrow to the right of each input box drops down a selection box to choose from. Use the scroll bar to see additional values
- Hyperlinked text – Clicking on the underlined text pops up a window with more information about the input. Select from the graphic or use the drop down pick box to input the variable.

Run the Calculation
Once all of the input fields have been entered, press the "Calculate Results" button to run the calculation. The results will display in the top right area of the screen. This result is the required length (in feet) of the pipeline that is to be restrained. **Every joint or fitting that is within this calculated length must be restrained**. On smaller diameter pipelines, the calculated length is often less than a full length of pipe. With planning, only the fitting needs to be restrained for these instances. After the calculation is run, any change to the input variables will dynamically change the result. If a different fitting is selected, the previous result is removed and after the fitting specific information is input is ready to run another calculation.

General Information Inputs

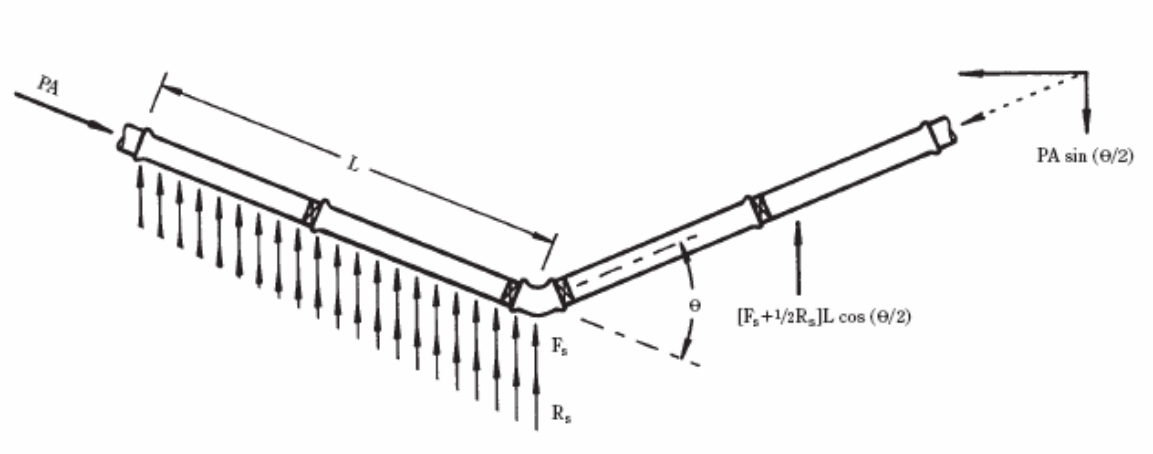
- Pipe Material – Select the pipe material from the drop down pick box or click on the text to select from the pop up dialog box. Options for Ductile Iron, Ductile Iron wrapped in polyethylene encasement (Polywrapped DI) or PVC are provided.
- Soil Type – Select the soil type classification from the drop down pick box or click on the text for the soil classification descriptions and select from there.
- Trench Type – Select the trench type from the drop down pick box or click on the text to open the dialog box for trench type descriptions and select from there.
- Safety Factor- Select the safety factor from the drop down pick box or click on the text to open the dialog box. In the dialog box, either select a safety factor from the drop down pick box or enter your own. When entering your own safety factor just enter the number; e.g. 4 or 2.25.
- Test Pressure – Select the test pressure from the drop down pick box or click on the text to open the dialog box. In the dialog box, either select a test pressure from the drop down pick box or enter your own. When entering your own test pressure just enter the number; e.g. 175.
- Depth of Cover – Select the depth in feet to the top of the pipe from the drop down pick box or click on the text to open the dialog box. In the dialog box, either select a depth from the drop down pick box or enter your own. When entering your own depth just enter the number; e.g. 4.5 or 36. Note: This depth input is for the upper pipe in the case of a Vertical Offset.

Fitting Information Inputs

- Fitting Type – Select from: Horizontal Bend, Dead End, Reducer, Tee or Vertical Offset from the drop down menu or click on the text to select from the pop up dialog box. After the fitting type has been selected, additional input boxes will be displayed depending on the fitting. Select the appropriate input from the drop down pick box or click on the text to open a dialog box for more information and in some cases, inputting your own custom value.

Equations
The following equations are used in the calculation of the restrained length in this program.

Horizontal Bend:

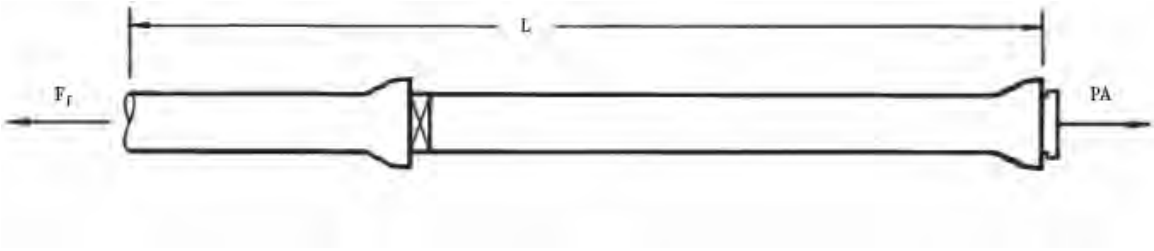


$$L = \frac{S_f PA \tan(½\theta)}{F_s + ½R_s}$$

Where:

L = Length of pipe to be restrained on both sides of the bend (ft)
F_s = Unit frictional force (lb/ft)
S_f = Safety Factor
P = Pressure (psi)
A = Cross sectional area of pipe (in^2)
θ = Angle of bend (^{o})
R_s = Bearing resistance of the soil along the pipeline (lb/ft)

Dead End:



$$L = \frac{S_f PA}{F_s}$$

Where:

L = Restrained Length (ft)

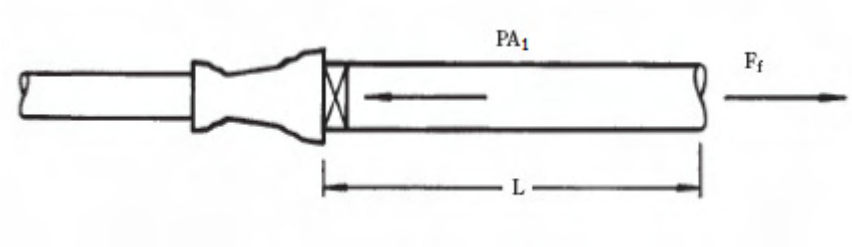
F_s = Unit frictional force (lb/ft)

S_f = Safety Factor

P = Pressure (psi)

A = Cross sectional area of pipe (in^2)

Reducer:



$$L = \frac{S_f P(A_l - A_s)}{F_s}$$

Where:

L = Length of restrained pipe on the large side of the reducer (ft)

F_s = Unit frictional force (lb/ft)

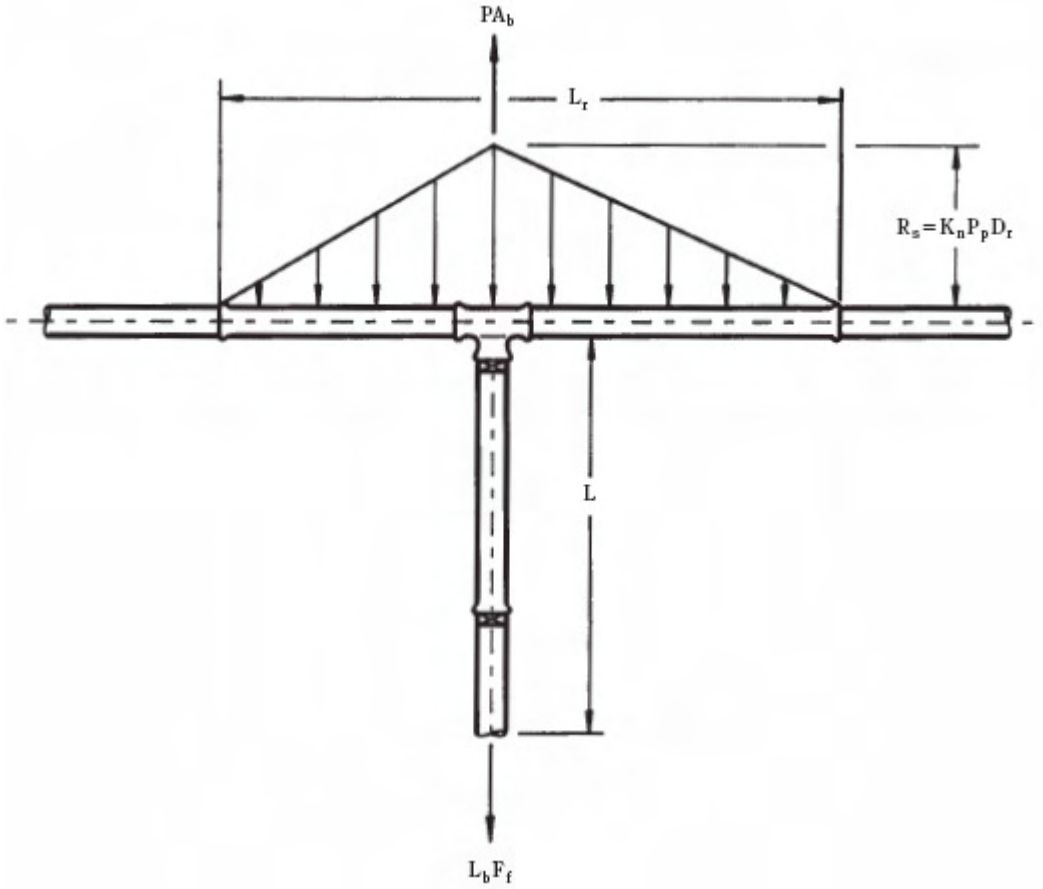
S_f = Safety Factor

P = Pressure (psi)

A_l = Cross sectional area of large pipe (in^2)

A_s = Cross sectional area of small pipe (in^2)

Tee:



$$L = \frac{S_f P A_b - ½ R_s L_r}{F_s}$$

Where:

L = Length of restrained pipe on the branch (ft)

F_s = Unit frictional force (lb/ft)

S_f = Safety Factor

P = Pressure (psi)

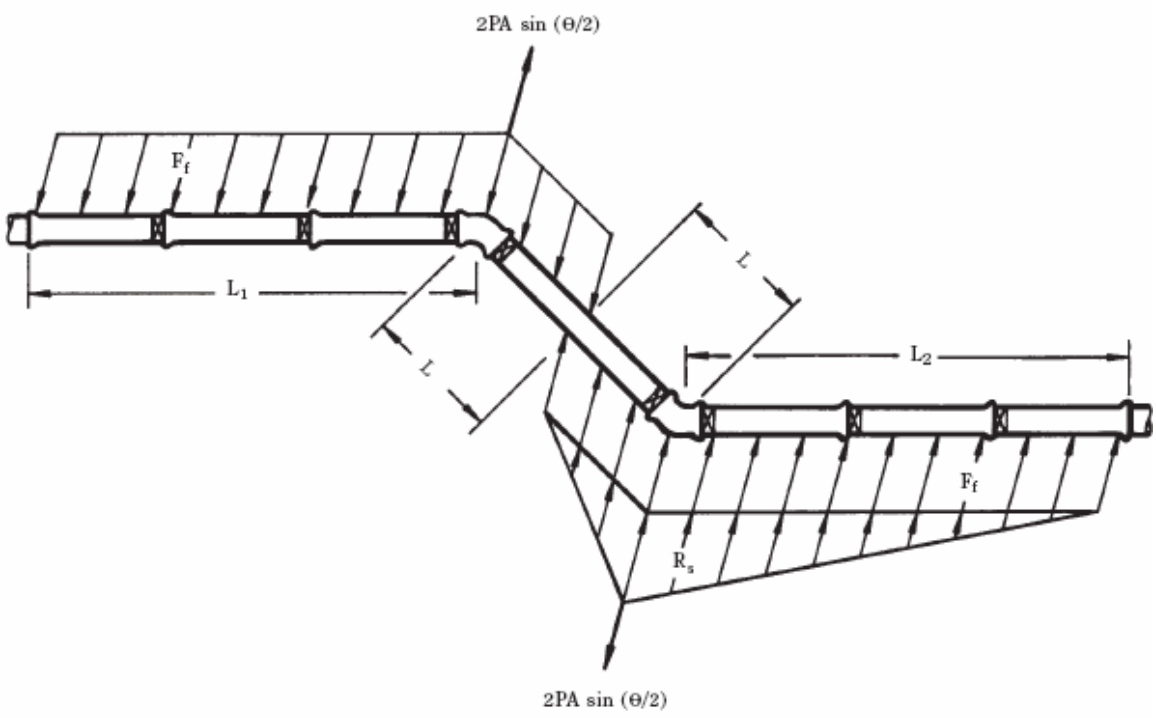
A_l = Cross sectional area of large pipe (in^2)

A_s = Cross sectional area of small pipe (in^2)

R_s = Bearing resistance of the soil along the pipeline (lb/ft)

L_r = Total length between the first joints on either side of the tee (ft)

Vertical Offset:



Upper side - $L = \dfrac{S_f PA \tan(½\theta)}{F_s}$

Lower side - $L = \dfrac{S_f PA \tan(½\theta)}{F_s + ½R_s}$

Where:

L = Length of pipe to be restrained on both sides of the bend (ft)
F_s = Unit frictional force (lb/ft)
S_f = Safety Factor
P = Pressure (psi)
A = Cross sectional area of pipe (in²)
θ = Angle of bend (º)
R_s = Bearing resistance of the soil along the pipeline (lb/ft)

Note: As the bend angle approaches 90º, lateral movement of the outer legs approaches zero. For this condition, restrain all fittings between the bends and calculate the outer leg restraint as dead ends.

Unit Frictional Force:

$$F_s = A_p C + W \tan \delta$$

Where:

$C = f_c C_s$ From soil classification tables (psf)

A_p = Surface area of pipe bearing on the soil (ft²/ft)

$\delta = f_\phi \phi$ From soil classification tables (º)

$A_p = ½\pi D$ For bends. Assume half the pipe circumference bears against the soil.

$A_p = \pi D$ For Tees, Dead Ends and Reducers. Assume the full pipe circumference bears against the soil.

And:

$W = 2W_e + W_p + W_w$ Unit normal force (lb/ft)

Where:

$2W_e$ = Vertical load on top and bottom surfaces of the pipe taken as the prism load (lb/ft)

W_p = Weight of the pipe (lb/ft)

W_w = Weight of the water (lb/ft)

$W_e = H\gamma D$

H = Depth of bury to the top of the pipe (ft)

γ = Backfill soil density (psf)

D = Pipe diameter (ft)

Unit Bearing Resistance:

$$R_s = K_n P_p D$$

Where:

K_n = Trench compaction factor

D = Pipe diameter (ft)

And:

$$P_p = \gamma H_c N_\phi + 2C_s \sqrt{N_\phi}$$

Where:

P_p = Passive soil pressure (psf)

γ = Backfill soil density (psf)

H_c = Mean depth from surface to centerline of pipe (ft)

$N_\phi = \tan^2(45° + ½\phi)$

ϕ = Internal friction of the soil (^{o})

C_s = Soil cohesion (psf)

Soil Parameters:

Properties of soils for use with Ductile Iron pipe:

Soil Group**	ϕ	f_ϕ	C_s*	f_c	γ	K_n Laying Condition (Trench Type)		
						3	4	5
GW & SW	35	0.76	0	0.0	110	0.60	0.85	1.00
GP & SP	31	0.80	0	0.0	110	0.60	0.85	1.00
GM & SM	30	0.76	0	0.0	110	0.60	0.85	1.00
GC & SC	25	0.65	225	0.4	100	0.60	0.85	1.00
CL	20	0.50	250	0.8	100	0.60	0.85	1.00
ML	29	0.75	0	0.0	100	0.60	0.85	1.00
CL, GP & SP	31	0.80	450	0.0	100	0.60	0.85	1.00
ML, GP & SP	31	0.80	300	0.0	100	0.60	0.85	1.00
CH, GP & SP	31	0.80	400	0.0	100	0.40	0.60	0.85
MH, GP & SP	31	0.80	250	0.0	100	0.40	0.60	0.85

* For conservatism, soil cohesion (C_s) is at saturated soil conditions

** For more detailed information about soil groups, consult ASTM D2487

Properties of soils for use with PVC pipe:

Soil Group**	ϕ	f_ϕ	C_s*	f_c	γ	K_n Laying Condition (Trench Type)		
						3	4	5
GW & SW	35	0.70	0	0.0	110	0.60	0.85	1.00
GP & SP	31	0.70	0	0.0	110	0.60	0.85	1.00
GM & SM	30	0.60	0	0.0	110	0.60	0.85	1.00
GC & SC	25	0.60	225	0.2	100	0.60	0.85	1.00
CL	20	0.50	250	0.3	100	0.60	0.85	1.00
ML	29	0.50	0	0.0	100	0.60	0.85	1.00
CL, GP & SP	31	0.70	450	0.0	100	0.60	0.85	1.00
ML, GP & SP	31	0.70	300	0.0	100	0.60	0.85	1.00
CH, GP & SP	31	0.70	400	0.0	100	0.40	0.60	0.85
MH, GP & SP	31	0.70	250	0.0	100	0.40	0.60	0.85

* For conservatism, soil cohesion (C_s) is at saturated soil conditions

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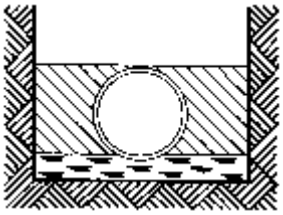
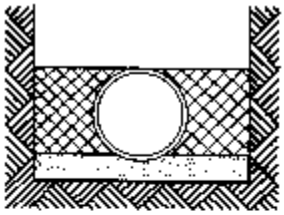
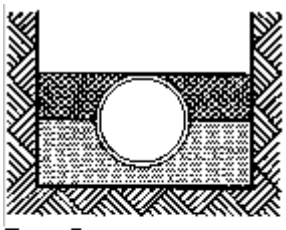
Laying Condition (Trench Type):



Type 3
Pipe bedded in 4-inch minimum loose soil.* Backfill lightly consolidated to top of pipe.



Type 4
Pipe bedded in sand, gravel or crushed stone to a depth of 1/8 pipe diameter, 4-inch minimum. Backfill compacted to top of pipe. (Approximately 80% Standard proctor, AASHTO T-99.)



Type 5
Pipe bedded to its centerline in compacted granular material, 4-inch minimum under pipe. Compacted granular or select material* to top of pipe. (Approximately 90% Standard proctor, AASHTO T-99.)

*"Loose soil" or "select material" is defined as "native soil excavated from the trench, free of rocks, foreign material, and frozen earth."

Dimension and Weight of Pipes:

Nominal Size	Outside Diameter D		DI		PVC	
	Inches	Feet	Weight of Pipe W_p (lbs/ft)	Weight of Water W_w (lbs/ft)	Weight of Pipe W_p (lbs/ft)	Weight of Water W_w (lbs/ft)
3	3.96	0.33	10	4	2	4
4	4.80	0.40	12	6	3	6
6	6.90	0.58	18	13	5	13
8	9.05	0.75	24	24	9	22
10	11.10	0.93	30	37	14	33
12	13.20	1.10	39	53	20	47
14	15.30	1.28	47	72	26	63
16	17.40	1.45	57	94	34	81
18	19.50	1.63	66	119	43	102
20	21.60	1.80	78	147	53	125
24	25.80	2.15	93	212	75	179
30	32.00	2.67	123	329	115	275
36	38.30	3.19	163	473	165	394
42	44.50	3.71	206	642	223	533
48	50.80	4.23	261	838	291	694

References:

DIPRA; "Thrust Restraint Design for Ductile Iron Pipe", Fifth Edition, 2002; Birmingham, Alabama

AWWA M23, PVC Pipe - Design and Installation, Second Edition, 2002; Denver, Colorado

ASTM D 2487; "Classification of Soils for Engineering Purposes."

Uni-Bell Plastic Pipe Association; "Handbook of PVC Pipe, Design and Construction", Second Edition, 1982, Dallas, Texas.

Kennedy, Harold Jr., Shumard, Dennis D., and Meeks, Cary M.; "Investigation of Pipe-To-Soil Friction and Its Affect on Thrust Restraint For PVC and Ductile Iron Pipe", Presented at AWWA Distribution Systems Symposium, September 1989.

Potyondy, J.G.; "Skin Friction Between Various Soils and Construction Materials", Geotechnique, London, England, Volume II, No. 4, December 1961, PP 339-353.