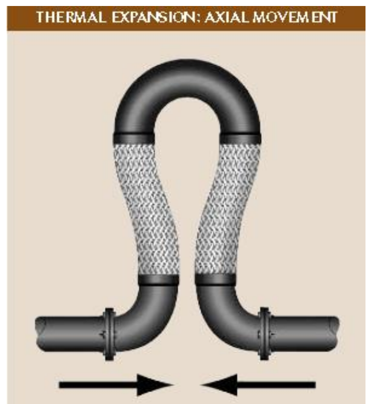
Tutorial for Modeling of MetraLoop using CAEPIPE

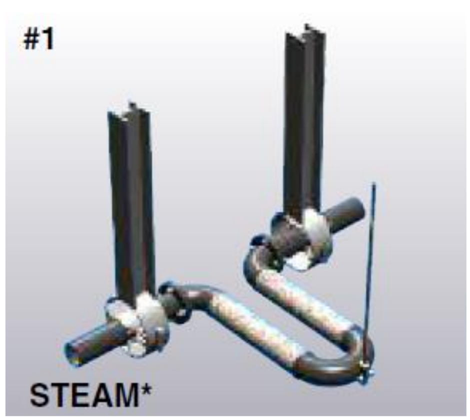
The following are the Steps for modeling and including MetraLoop in CAEPIPE analysis.

General

The MetraLoop is simply a flexible variation of the traditional hard pipe loop. For any given length of pipe and given temperature change, the amount of thermal growth/contraction can be calculated and an appropriate MetraLoop can be designed. When installed in a pipe run, the MetraLoop's legs simply bend as shown in the figure below to compensate for the pipe's expansion or contraction. Unique to the loop is the low amount of force required to bend its legs, minimizing anchor loads, guiding and installation costs.



Illustrated above is a typical MetraLoop. No support is required for the 180° return bend for standard loops 2-1/2" diameter and smaller. However, due to the weight of the return bend and the extreme flexibility of the loop, larger sizes require support (as shown below) to prevent the loop from sagging in all orientations except when installed hanging down. Guides are recommended but not always required.



The Steps provided in this tutorial are applicable for different types of MetraLoop such as SWEAT Ends, Threaded Ends, Flanged Ends, etc. with and without supports at the middle of the U-bend.

MetraLoop without Support at the middle of the U-bend

- As an example, dimensional details and mechanical properties corresponding to 6” 150# FLANGED ENDS • FITTINGS - SCHED. 40 CARBON STEEL • HOSE & BRAID - SERIES 300 STAINLESS STEEL of MetraLoop are referred from http://www.metraflex.com/literature/metraloop/literature/Metraflex-Metraloop.pdf.
- The same is presented below for quick reference. The PDF file downloaded from the link mentioned above is attached herewith for convenience.

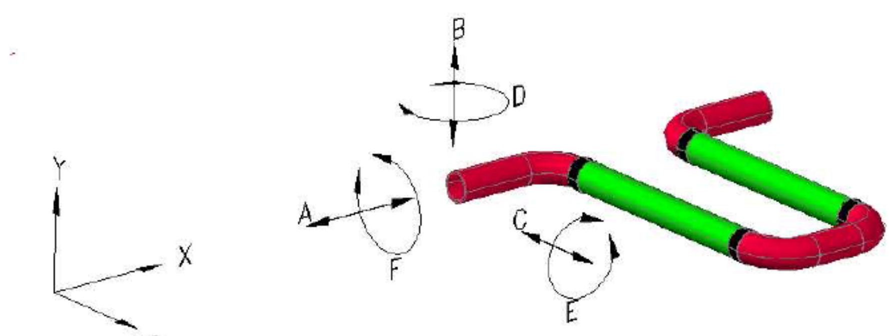
150# FLANGED ENDS • FITTINGS - SCHED. 40 CARBON STEEL • HOSE & BRAID - SERIES 300 STAINLESS STEEL

PIPE SIZE	MODEL #	MOVEMENT	END TO END A	LENGTH B	PSI SINGLE BRAID	†PSI DOUBLE BRAID	MAX STEAM PRESS.	*SPRING FORCE LBS.	WEIGHT LBS.
2” (50mm)	MLF30200	±1.5”	12-1/2”	17-3/8”	500	750	300	78	21
	MLF80200	±4”	14-1/2”	24-1/2”					24
2-1/2” (65mm)	MLF30250	±1.5”	15-1/2”	21”	387	619	300	83	30
	MLF80250	±4”	16”	28-1/4”					36
3” (80mm)	MLF30300	±1.5”	18-1/2”	23-3/8”	288	431	216	90	46
	MLF80300	±4”	18-1/2”	30”					50
4” (100mm)	MLF30400	±1.5”	24-1/2”	28”	232	371	183	120	63
	MLF80400	±4”	24-1/2”	35-3/8”					69
5” (125mm)	MLF30500	±1.5”	30-1/2”	32-1/4”	191	306	153	186	91
	MLF80500	±4”	30-1/2”	40-1/4”					101
6” (150mm)	MLF30600	±1.5”	36-1/2”	36-3/4”	165	264	132	202	148
	MLF80600	±4”	36-1/2”	45-3/8”					163
8” (200mm)	MLF30800	±1.5”	48-1/2”	44-1/2”	212	230	115	260	287
	MLF80800	±4”	48-1/2”	53-1/2”					309
10” (250mm)	MLF31000	±1.5”	60-1/2”	53-1/4”	175	200	100	283	453
	MLF81000	±4”	60-1/2”	63-1/4”					484
12” (300mm)	MLF31200	±1.5”	72-1/2”	61-3/4”	160	188	94	390	636
	MLF81200	±4”	72-1/2”	72-3/4”					666
14” (355mm)	MLF31400	±1.5”	84-1/2”	71”	110	125	63	706	636
	MLF81400	±4”	84-1/2”	80-1/2”					666
16” ** (400mm)	MLF31600	±1.5”	96-1/2”	78-1/2”	110	170	85	900	636
	MLF81600	±4”	96-1/2”	91-1/2”					666
18” ** (455mm)	MLF31800	±1.5”	108-1/2”	86-1/2”	85	150	75	1000	636
	MLF81800	±4”	108-1/2”	100”					666

Spring Rates for NS 6” MetraLoop are received from the manufacturer as given below.

Metraloop Spring Rate Data (use same rates for stainless steel & copper)

Nominal Size (in)	Spring Rate "A" Axial (+ or - x) (lb/in)	Spring Rate "B" Lateral (transverse) 'y' (lb/in)	Spring Rate 'C' Lateral (transverse) 'z' (lb/in)	Spring Rate 'D' Angular (rotation) 'y' (in-lb/deg)	Spring Rate 'E' Angular (rotation) 'z' (in-lb/deg)	Spring Rate 'F' Torsion 'x' (in-lb/deg)
6	50.5	50.5	32.9	32.9	8663	50.5



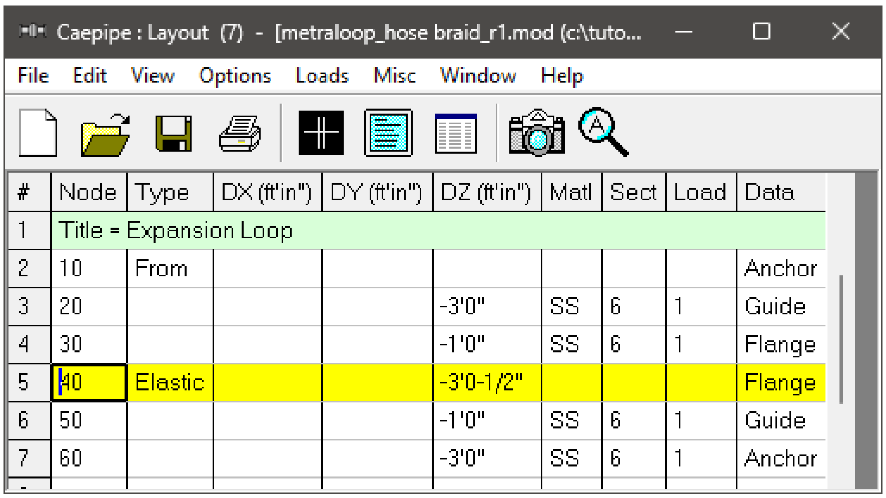
Notes
1. Movements at the ends of the loop in directions 'A', 'B' and 'F' induce lateral offset in the loop legs.
2. Movements in directions 'C' and 'D' induce angular rotation in the loop legs.
4. Movement in direction 'E' will induce torsion on the hose legs.

The Spring Rates provided in the above Table are for the whole loop (End to End) and NOT for the Braided Hose.

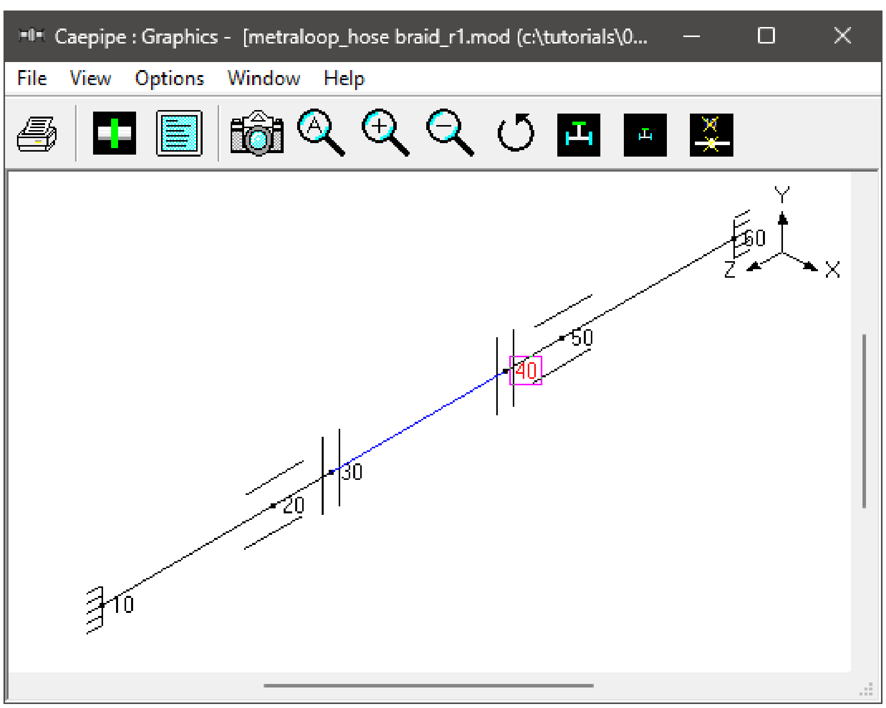
Hence, the whole loop (End to End) is modeled as an Elastic element between Nodes 30 and 40 with its Spring Rates taken from the above Table. The lengths of the various elements of this “MetraLoop” are derived using the overall dimensions A and B given in the catalog. Weight of the flanged “MetraLoop” including the weight of the single flange at each end is included in the two (2) flange weights (= 27 + 148 + 27 = 202 lbs for 2 flanges or 101 lbs for each flange).

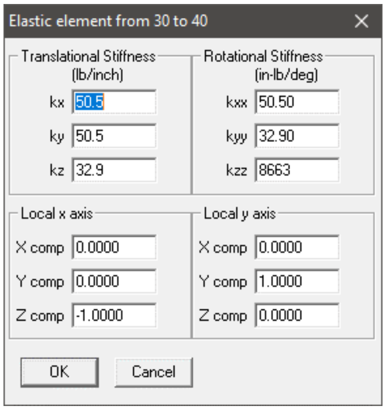
Step 1:

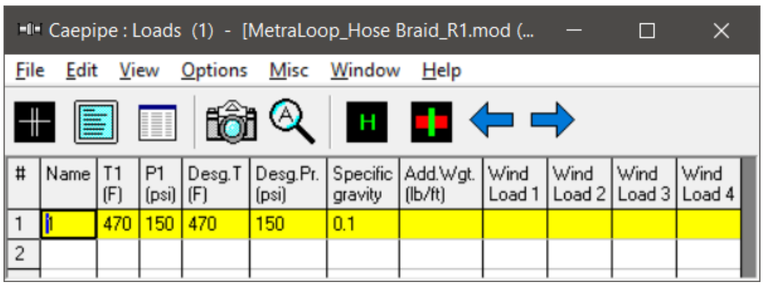
Snap shots shown below are from the CAEPIPE model input file wherein the “MetraLoop” is modeled as an Elastic Element as mentioned above.



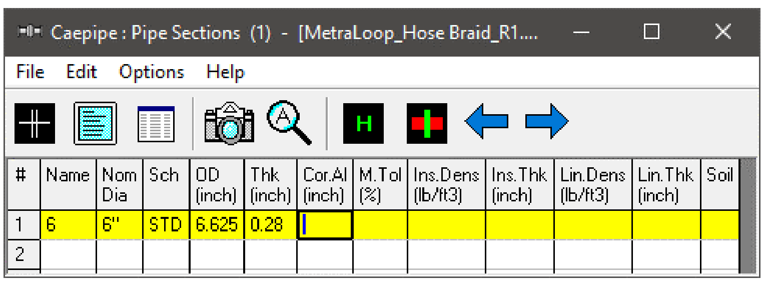
#	Node	Type	DX (ft'in")	DY (ft'in")	DZ (ft'in")	Matl	Sect	Load	Data
1	Title = Expansion Loop								
2	10	From							Anchor
3	20				-3'0"	SS	6	1	Guide
4	30				-1'0"	SS	6	1	Flange
5	40	Elastic			-3'0-1/2"				Flange
6	50				-1'0"	SS	6	1	Guide
7	60				-3'0"	SS	6	1	Anchor



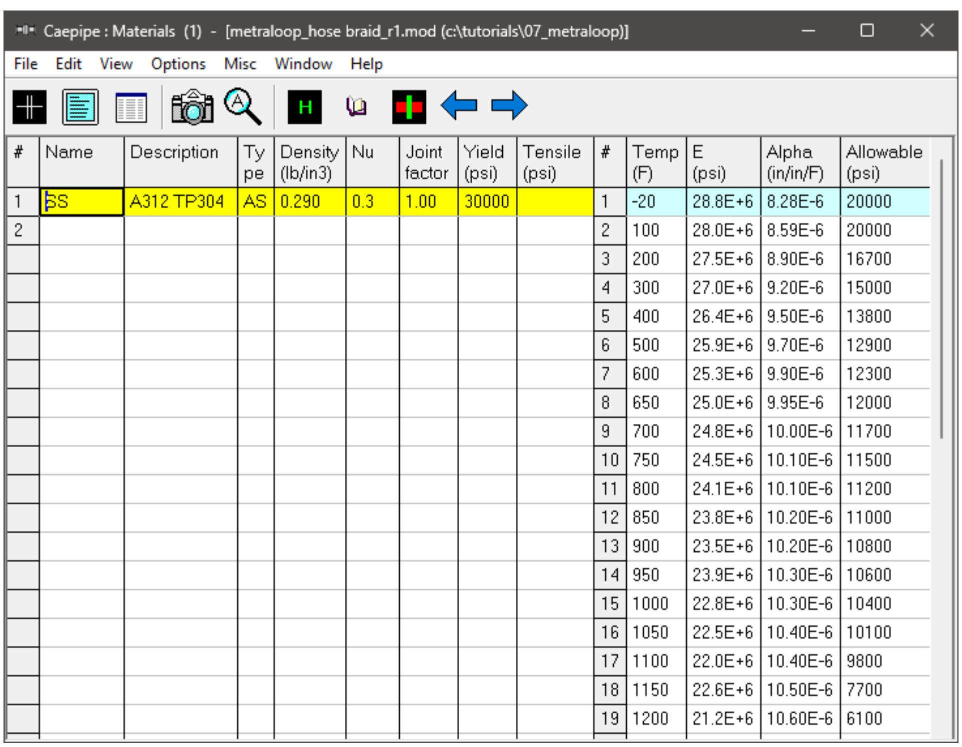




#	Name	T1 (F)	P1 (psi)	Desg.T (F)	Desg.Pr. (psi)	Specific gravity	Add.Wgt. (lb/ft)	Wind Load 1	Wind Load 2	Wind Load 3	Wind Load 4
1	1	470	150	470	150	0.1					
2											



#	Name	Nom Dia	Sch	OD (inch)	Thk (inch)	Cor.Al (inch)	M.Tol (%)	Ins.Dens (lb/ft3)	Ins.Thk (inch)	Lin.Dens (lb/ft3)	Lin.Thk (inch)	Soil
1	6	6"	STD	6.625	0.28							
2												

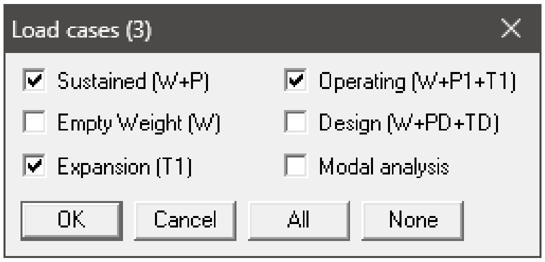


#	Name	Description	Type	Density (lb/in3)	Nu	Joint factor	Yield (psi)	Tensile (psi)
1	SS	A312 TP304	AS	0.290	0.3	1.00	30000	
2								

#	Temp (F)	E (psi)	Alpha (in/in/F)	Allowable (psi)
1	-20	28.8E+6	8.28E-6	20000
2	100	28.0E+6	8.59E-6	20000
3	200	27.5E+6	8.90E-6	16700
4	300	27.0E+6	9.20E-6	15000
5	400	26.4E+6	9.50E-6	13800
6	500	25.9E+6	9.70E-6	12900
7	600	25.3E+6	9.90E-6	12300
8	650	25.0E+6	9.95E-6	12000
9	700	24.8E+6	10.00E-6	11700
10	750	24.5E+6	10.10E-6	11500
11	800	24.1E+6	10.10E-6	11200
12	850	23.8E+6	10.20E-6	11000
13	900	23.5E+6	10.20E-6	10800
14	950	23.9E+6	10.30E-6	10600
15	1000	22.8E+6	10.30E-6	10400
16	1050	22.5E+6	10.40E-6	10100
17	1100	22.0E+6	10.40E-6	9800
18	1150	22.6E+6	10.50E-6	7700
19	1200	21.2E+6	10.60E-6	6100

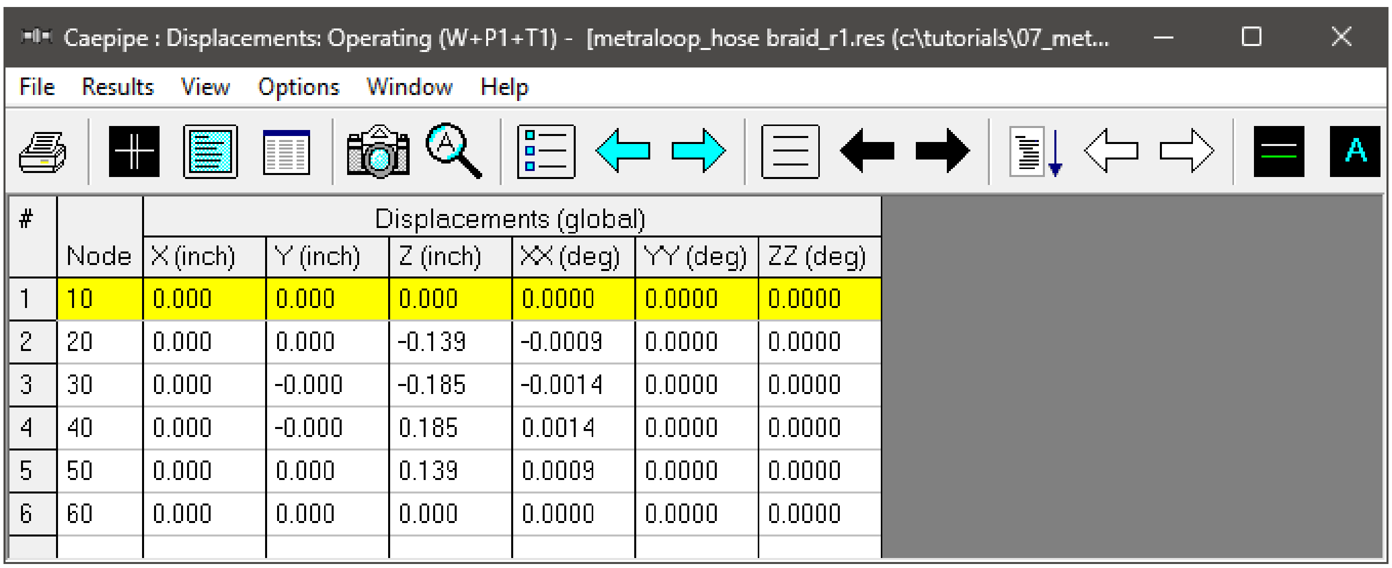
Step 4:

Select the Load Cases shown below for analysis through Layout Window > Loads > Load cases. Save the model and perform the analysis through Layout window > File > Analyze.

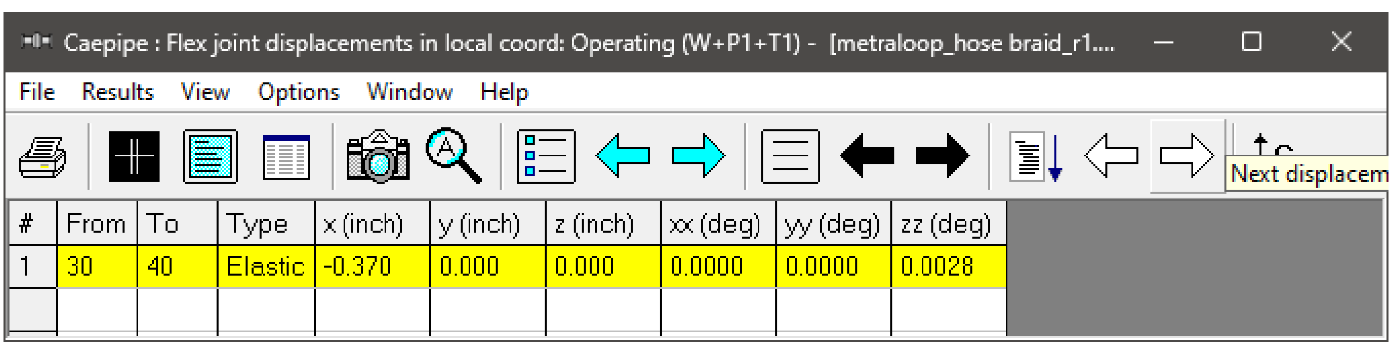


Step 5:

From the Displacements results of CAEPIPE for "Operating (W+P1+T1)" Load case for the model with temperature Increase, note the following.



#		Displacements (global)					
	Node	X (inch)	Y (inch)	Z (inch)	XX (deg)	YY (deg)	ZZ (deg)
1	10	0.000	0.000	0.000	0.0000	0.0000	0.0000
2	20	0.000	0.000	-0.139	-0.0009	0.0000	0.0000
3	30	0.000	-0.000	-0.185	-0.0014	0.0000	0.0000
4	40	0.000	-0.000	0.185	0.0014	0.0000	0.0000
5	50	0.000	0.000	0.139	0.0009	0.0000	0.0000
6	60	0.000	0.000	0.000	0.0000	0.0000	0.0000



#	From	To	Type	x (inch)	y (inch)	z (inch)	xx (deg)	yy (deg)	zz (deg)
1	30	40	Elastic	-0.370	0.000	0.000	0.0000	0.0000	0.0028

The differential **Axial Deflection (local x direction)** between Nodes 30 - 40 = **0.370" < 1.5"** (Allowable Movement specified in the catalog).

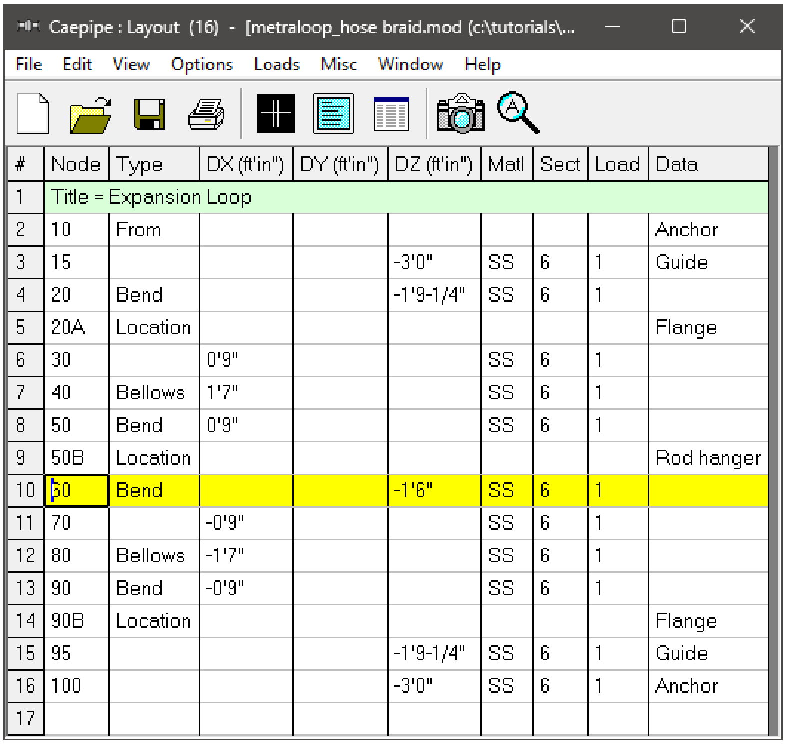
Summary

From the above, it is noted that the differential axial displacement of 0.37" computed by CAEPIPE for Operating Load Case 1 for the Elastic element between Nodes 30 and 40 is less than the Allowable Movement (1.5") provided in the catalog, thereby meeting the criteria.

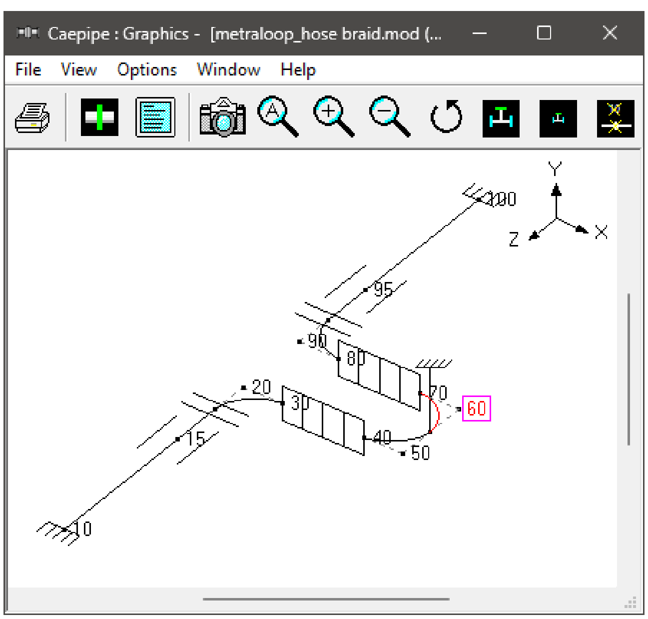
MetraLoop with Support at the middle of the U-bend

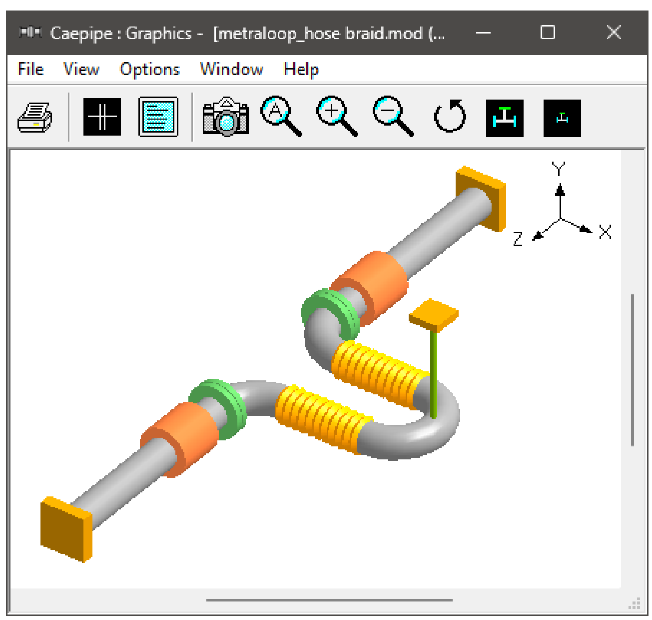
Step 1:

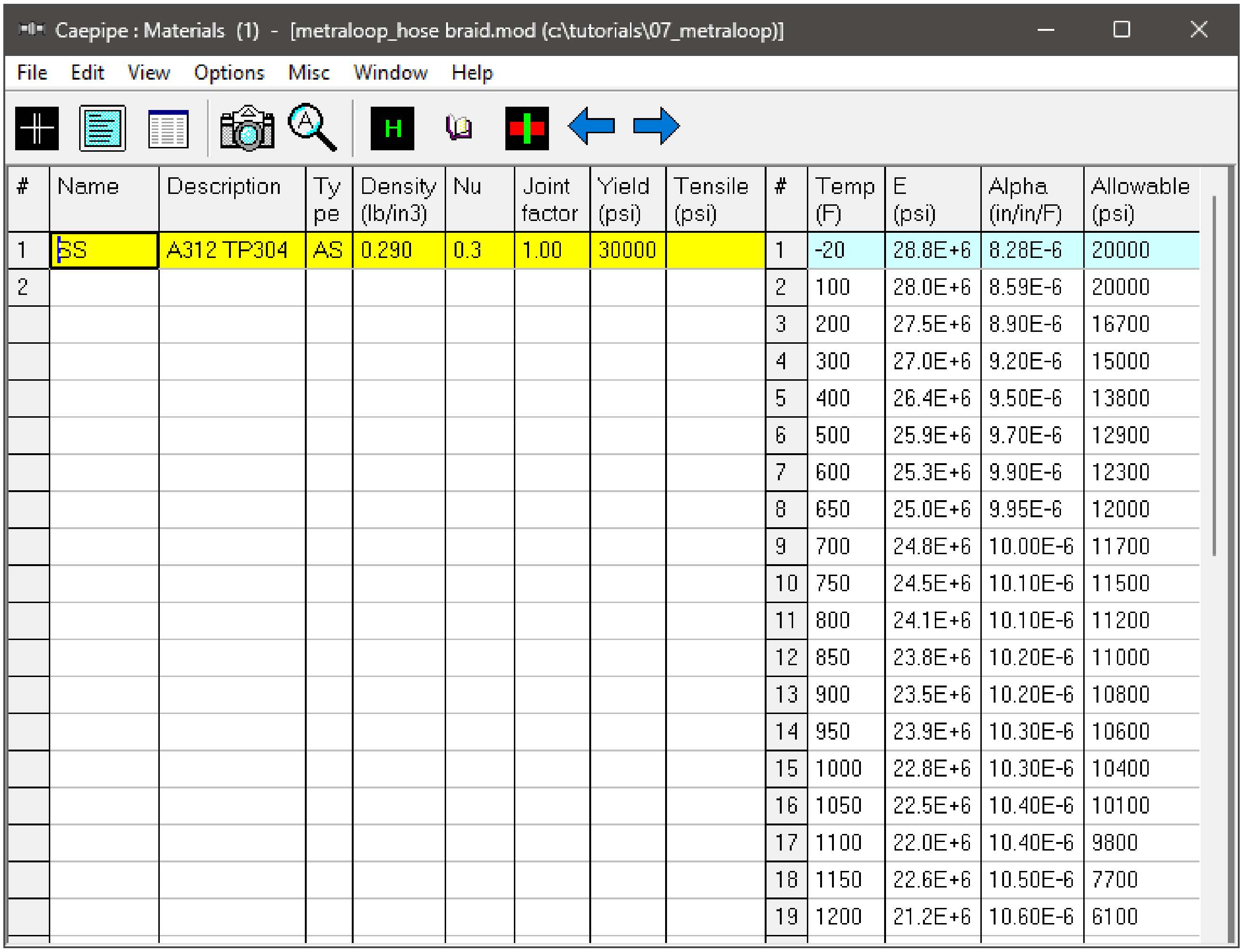
Attached is a sample CAEPIPE input file wherein the two “Hose Braid” Pipes of the Flexible U joint are modeled using CAEPIPE’s Bellow Elements. The lengths of the various elements of this Flexible U joint are derived using the overall dimensions A and B given in the catalog.



#	Node	Type	DX (ft'in")	DY (ft'in")	DZ (ft'in")	Matl	Sect	Load	Data
1	Title = Expansion Loop								
2	10	From							Anchor
3	15				-3'0"	SS	6	1	Guide
4	20	Bend			-1'9-1/4"	SS	6	1	
5	20A	Location							Flange
6	30		0'9"			SS	6	1	
7	40	Bellows	1'7"			SS	6	1	
8	50	Bend	0'9"			SS	6	1	
9	50B	Location							Rod hanger
10	60	Bend			-1'6"	SS	6	1	
11	70		-0'9"			SS	6	1	
12	80	Bellows	-1'7"			SS	6	1	
13	90	Bend	-0'9"			SS	6	1	
14	90B	Location							Flange
15	95				-1'9-1/4"	SS	6	1	Guide
16	100				-3'0"	SS	6	1	Anchor
17									

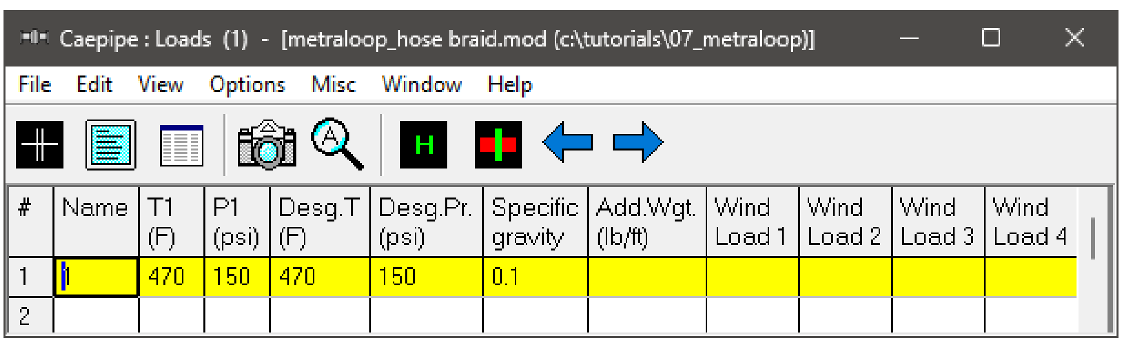




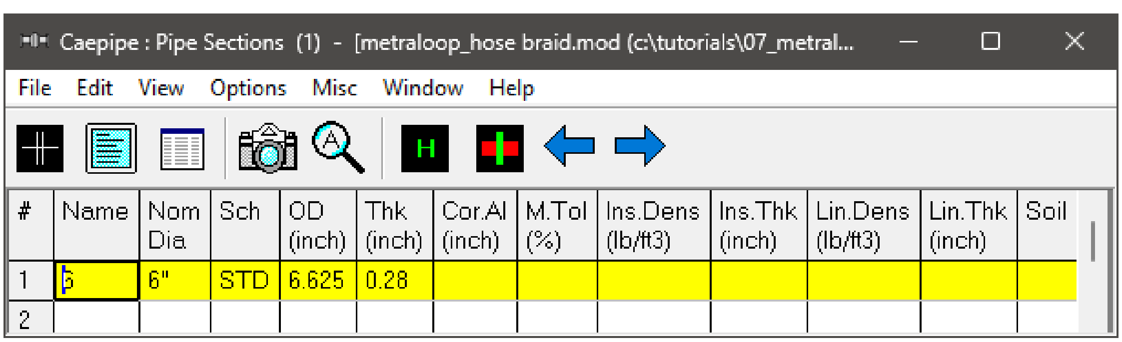


#	Name	Description	Type	Density (lb/in3)	Nu	Joint factor	Yield (psi)	Tensile (psi)
1	SS	A312 TP304	AS	0.290	0.3	1.00	30000	
2								

#	Temp (F)	E (psi)	Alpha (in/in/F)	Allowable (psi)
1	-20	28.8E+6	8.28E-6	20000
2	100	28.0E+6	8.59E-6	20000
3	200	27.5E+6	8.90E-6	16700
4	300	27.0E+6	9.20E-6	15000
5	400	26.4E+6	9.50E-6	13800
6	500	25.9E+6	9.70E-6	12900
7	600	25.3E+6	9.90E-6	12300
8	650	25.0E+6	9.95E-6	12000
9	700	24.8E+6	10.00E-6	11700
10	750	24.5E+6	10.10E-6	11500
11	800	24.1E+6	10.10E-6	11200
12	850	23.8E+6	10.20E-6	11000
13	900	23.5E+6	10.20E-6	10800
14	950	23.9E+6	10.30E-6	10600
15	1000	22.8E+6	10.30E-6	10400
16	1050	22.5E+6	10.40E-6	10100
17	1100	22.0E+6	10.40E-6	9800
18	1150	22.6E+6	10.50E-6	7700
19	1200	21.2E+6	10.60E-6	6100



#	Name	T1 (F)	P1 (psi)	Desg.T (F)	Desg.Pr. (psi)	Specific gravity	Add.Wgt. (lb/ft)	Wind Load 1	Wind Load 2	Wind Load 3	Wind Load 4
1	1	470	150	470	150	0.1					
2											



#	Name	Nom Dia	Sch	OD (inch)	Thk (inch)	Cor.Al (inch)	M.Tol (%)	Ins.Dens (lb/ft3)	Ins.Thk (inch)	Lin.Dens (lb/ft3)	Lin.Thk (inch)	Soil
1	6	6"	STD	6.625	0.28							
2												

Step 2:

From the attached model, you may observe that the Bellows are modelled between Nodes 30-40 and Nodes 70-80. The stiffnesses of the bellows are calculated and entered as listed in Step 3 below.

Step 3:

Pipe OD = 6.625”

Pipe Wall Thickness = 0.28”

Length of Braided Pipe = 19”

Elastic Modulus = 28.5E+06 psi

The Braided Hose of the “MetraLoop” is normally “stiff” in axial and torsional directions and “flexible” for lateral and bending directions. Accordingly, the stiffnesses for Braided Hose are **calculated** and **assumed** as given below.

Axial Stiffness = 1% of Adjoining Pipe Stiffness = (1/100) * (AE/L) = 83700 lb/in

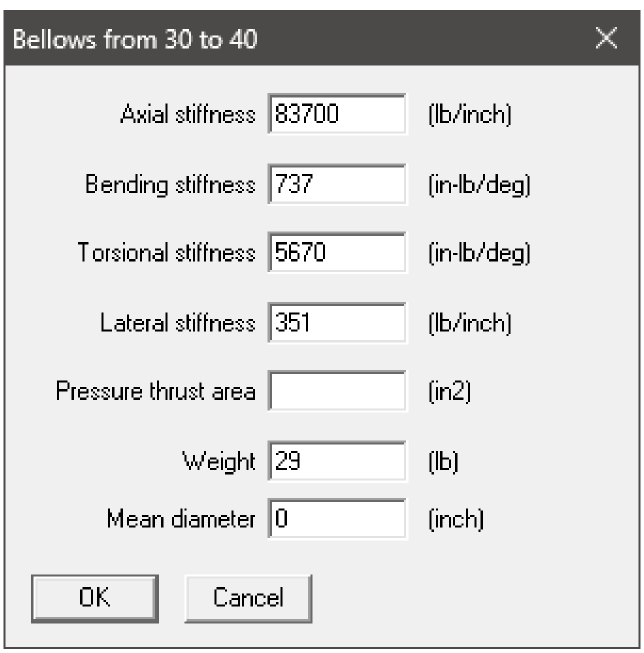
Lateral Stiffness = 0.1% of Adjoining Pipe Stiffness = (0.1/100) * ($3EI/L^3$) = 351 lb/in

Bending Stiffness = 0.1% of Adjoining Pipe Stiffness = (0.1/100) * (EI/L) = 4.22E+04 in-lb/rad = 737 in-lb/deg

Torsional Stiffness = 1% of Adjoining Pipe Stiffness = (1/100) * (GJ/L) = 3.25E+05 in-lb/rad = 5670 in-lb/deg

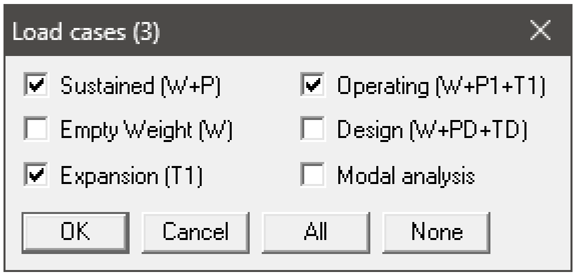
Pressure Thrust is not entered as it is not applicable for Braided Hose.

Lastly, the weight of each bellow is entered as 29 lbs, so that after performing a separate analysis for a stand-alone “MetroLoop”, the total empty weight of 148 lbs for the “MetroLoop” assembly matches with the value given in the catalog.



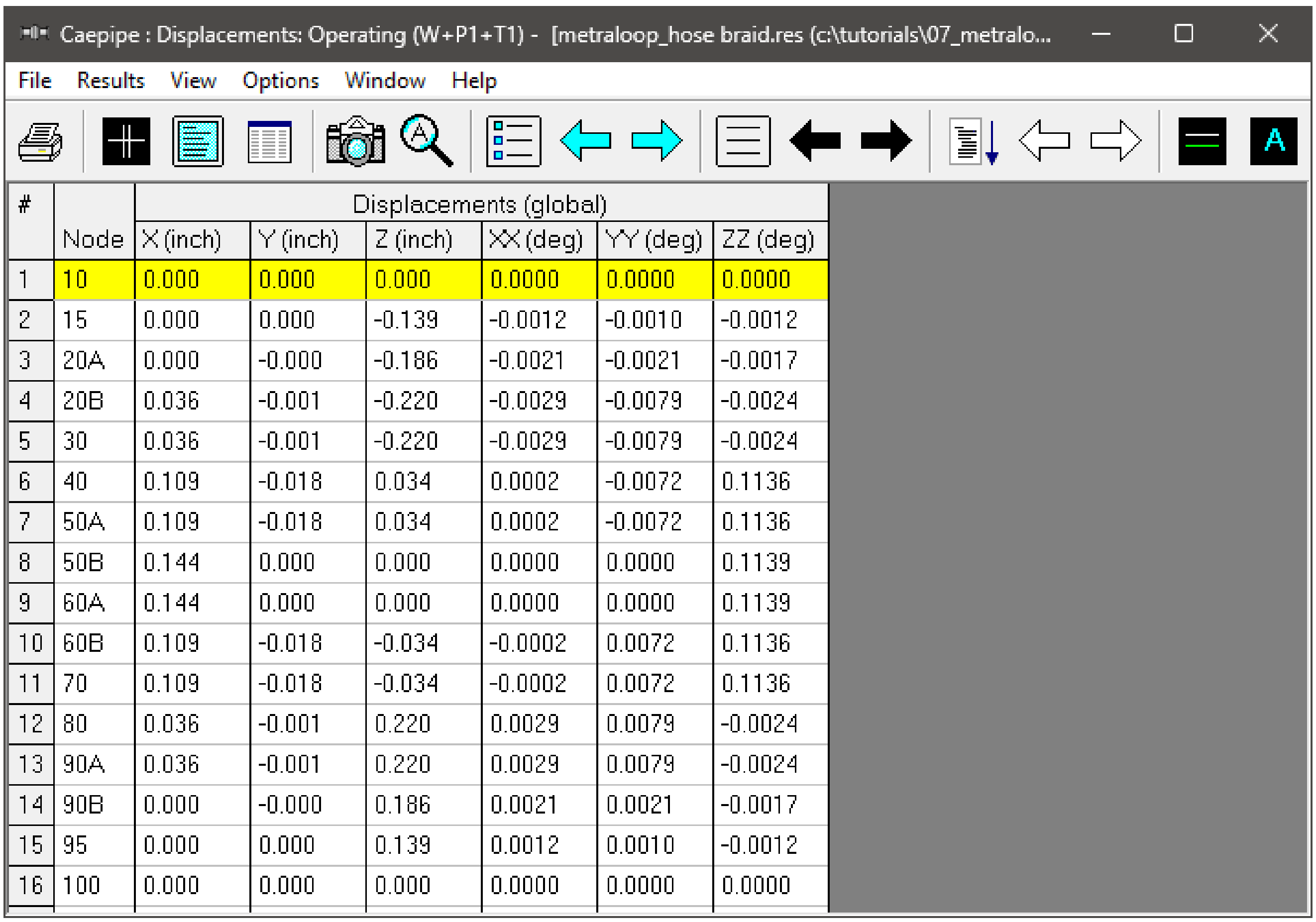
Step 4:

Select the Load Cases shown below for analysis through Layout Window > Loads > Load cases. Save the model and perform the analysis through Layout window > File > Analyze.



Step 5:

From the Displacements results of CAEPIPE for “Operating (W+P1+T1)” Load case for the model with temperature Increase, note the following.



#	Node	Displacements (global)					
		X (inch)	Y (inch)	Z (inch)	XX (deg)	YY (deg)	ZZ (deg)
1	10	0.000	0.000	0.000	0.0000	0.0000	0.0000
2	15	0.000	0.000	-0.139	-0.0012	-0.0010	-0.0012
3	20A	0.000	-0.000	-0.186	-0.0021	-0.0021	-0.0017
4	20B	0.036	-0.001	-0.220	-0.0029	-0.0079	-0.0024
5	30	0.036	-0.001	-0.220	-0.0029	-0.0079	-0.0024
6	40	0.109	-0.018	0.034	0.0002	-0.0072	0.1136
7	50A	0.109	-0.018	0.034	0.0002	-0.0072	0.1136
8	50B	0.144	0.000	0.000	0.0000	0.0000	0.1139
9	60A	0.144	0.000	0.000	0.0000	0.0000	0.1139
10	60B	0.109	-0.018	-0.034	-0.0002	0.0072	0.1136
11	70	0.109	-0.018	-0.034	-0.0002	0.0072	0.1136
12	80	0.036	-0.001	0.220	0.0029	0.0079	-0.0024
13	90A	0.036	-0.001	0.220	0.0029	0.0079	-0.0024
14	90B	0.000	-0.000	0.186	0.0021	0.0021	-0.0017
15	95	0.000	0.000	0.139	0.0012	0.0010	-0.0012
16	100	0.000	0.000	0.000	0.0000	0.0000	0.0000

The differential **Lateral Deflection** (in Z direction) between Nodes 30 and 80 = 2 * **0.22 = 0.44” < 1.5”** (Allowable Movement specified in the catalog).

Summary

From the above, it is noted that the differential lateral displacement computed by CAEPIPE for Operating Load Case between Nodes 30 and 80 are less than the Allowable Movement (1.5”) provided in the catalog, thereby meeting the criteria.

Lastly, the differential displacement of 0.37” computed from the “MetraLoop” model without Support at the middle of U-bend is closer to the differential displacement of 0.44” computed for this model with a vertical support at the middle of U-bend thereby confirming that the stiffnesses assumed for the braided hoses are reasonable.