Tutorial for Thermoplastic Piping Analysis as per ASME NM.1 using CAEPIPE

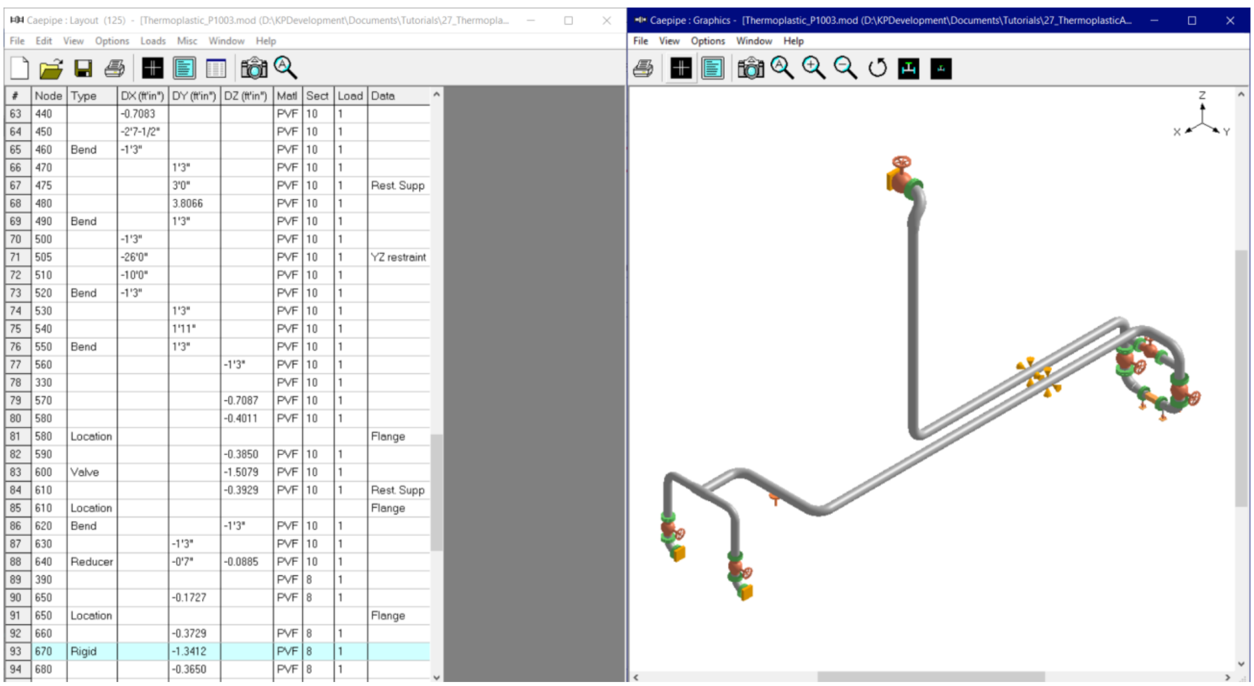
General

Plastic piping has gained wide acceptance in many industries due to its lightweight, superior corrosion resistance, moderate temperature capabilities and mechanical strength. Several manufacturers produce different types of plastic pipes and fittings and provide technical assistance to their customers from design through installation.

Thermoplastic piping systems can be modeled and analyzed using CAEPIPE.

Tutorial

Snapshot shown below is a sample model for Thermoplastic Piping Analysis. Dimensions of the fittings used in this tutorial are only for representation and do not reflect the actual dimensions of Plastic Fittings. Weight of Valves and Flanges are approximated and input just to represent the Plastic Valves and Flanges available.



Step 1:

Select the Piping Code for Analysis as “ASME NM.1” through Layout Window > Options > Analysis > Code.

When done, define the material properties required for piping system through Layout window > Misc > Materials. In the Material List window shown on the screen, double click on an empty row to input a new material or double click on a material description to edit the material properties already input.

Step 2:

ASME NM.3.3 provides tables and data sheets for allowable stresses, mechanical properties (e.g., tensile and yield strength), and physical properties (e.g., coefficient of thermal expansion and modulus of elasticity) for nonmetallic materials such as chlorinated polyvinyl chloride (CPVC); polyvinyl chloride (PVC), polyvinylidene fluoride (PVDF), etc.

In this tutorial, material properties corresponding to PVDF Extruded pipe SF-1673 Grade 2025 (highlighted in RED below) have been referred from ASME NM.3.3 as this material has better corrosion resistance, higher yield and temperature capabilities compared to other Thermoplastics. The material properties thus obtained are entered into CAEPIPE material properties dialog as shown below.

Allowable stress values “S_h” and “S_A” in CAEPIPE material properties are entered by referring to Table 1-1-1 for S and Table 1-1-3 for “S_A“ respectively for PVDF material highlighted in RED below from ASME NM.3.3. From the snapshots shown below, you will observe that the Allowable Secondary Stress Range (S_A) values vary based on the number of equivalent thermal cycles and temperatures. Hence, for this tutorial, the number of equivalent thermal cycles is assumed to be 7000 (= 2 cycles / day * 350 days approx. in a year x 10 years) to obtain the value of “S_A”.

Table 1-1-1 Maximum Allowable Stress Values, *S*, for Thermoplastic Materials (Cont'd)

Line No.	Nominal Composition	Product Form	ASME Spec. No.	Type/Grade	Construction Code Notes	Minimum Yield Strength, ksi	Maximum Temperature Limit, °F	Design Factor
232	PVC	Extruded pipe	SF-1483	PVCO 1135	C01	11.1	130	D01
233	PVC	Extruded pipe	SF-1483	PVCO 1135	C01	11.1	130	D02
234	PVC	Extruded pipe	SF-1483	PVCO 1135	C01	11.1	130	D03
235	PVDF	Extruded pipe	SF-1673	PVDF 2020	...	6.5	200	D02
236	PVDF	Extruded pipe	SF-1673	PVDF 2020	...	6.5	200	D03
237	PVDF	Extruded pipe	SF-1673	PVDF 2025	...	7.7	200	D02
238	PVDF	Extruded pipe	SF-1673	PVDF 2025	...	7.7	200	D03

Table 1-1-1 Maximum Allowable Stress Values, *S*, for Thermoplastic Materials (Cont'd)

Line No.	Notes	Maximum Allowable Stress, ksi [Note (1)], for Material Temperature, °F, Not Exceeding													
		73	80	90	100	110	120	130	140	150	160	170	180	190	200
232	M20, M22	2.84	2.50	2.13	1.76	1.42	1.14	0.852	...	...	...	...	...	...	...
233	M20, M22	3.55	3.12	2.66	2.20	1.78	1.42	1.07	...	...	...	...	...	...	...
234	M20, M22	7.10	6.25	5.33	4.40	3.55	2.84	2.13	...	...	...	...	...	...	...
235	M23	2.00	1.91	1.78	1.66	1.54	1.42	1.31	1.20	1.10	0.997	0.900	0.805	0.714	0.625
236	M23	4.00	3.82	3.56	3.31	3.07	2.84	2.62	2.40	2.20	2.00	1.80	1.61	1.43	1.25
237	M24	2.50	2.40	2.27	2.13	2.01	1.89	1.77	1.65	1.54	1.44	1.33	1.23	1.14	1.04
238	M24	5.00	4.80	4.53	4.27	4.02	3.77	3.53	3.31	3.09	2.87	2.66	2.46	2.27	2.08

Table 1-1-3 Maximum Allowable Secondary Stress Range Values, S_A, for Thermoplastic Materials (Cont'd)

Line No.	Nominal Composition	Product Form	ASME Spec. No.	Type/Grade	Construction Code Notes	Minimum Yield Strength, ksi	Maximum Temperature Limit, °F	Design Factor	Notes
379	PVDF	Extruded pipe	SF-1673	PVDF 2020	...	6.5	200	D01	M22
380	PVDF	Extruded pipe	SF-1673	PVDF 2020	...	6.5	200	D01	M22
381	PVDF	Extruded pipe	SF-1673	PVDF 2020	...	6.5	200	D01	M22
382	PVDF	Extruded pipe	SF-1673	PVDF 2020	...	6.5	200	D01	M22
383	PVDF	Extruded pipe	SF-1673	PVDF 2020	...	6.5	200	D01	M22
384	PVDF	Extruded pipe	SF-1673	PVDF 2020	...	6.5	200	D01	M22
385	PVDF	Extruded pipe	SF-1673	PVDF 2025	...	7.7	200	D01	M23
386	PVDF	Extruded pipe	SF-1673	PVDF 2025	...	7.7	200	D01	M23
387	PVDF	Extruded pipe	SF-1673	PVDF 2025	...	7.7	200	D01	M23
388	PVDF	Extruded pipe	SF-1673	PVDF 2025	...	7.7	200	D01	M23
389	PVDF	Extruded pipe	SF-1673	PVDF 2025	...	7.7	200	D01	M23
390	PVDF	Extruded pipe	SF-1673	PVDF 2025	...	7.7	200	D01	M23

Table 1-1-3 Maximum Allowable Secondary Stress Range Values, S_A, for Thermoplastic Materials (Cont'd)

Line No.	Number of Equivalent Thermal Cycles, N	Maximum Allowable Secondary Stress Range, ksi [Note (1)], for Material Temperature, °F, Not Exceeding													
		73	80	90	100	110	120	130	140	150	160	170	180	190	200
379	$N \le 1{,}000$	6.63	6.43	6.14	5.86	5.58	5.29	5.01	4.72	4.45	4.18	3.91	3.65	3.38	3.11
380	$1{,}000 < N \le 10{,}000$	6.32	6.14	5.88	5.62	5.36	5.10	4.84	4.58	4.32	4.05	3.79	3.53	3.26	3.00
381	$10{,}000 < N \le 25{,}000$	6.20	6.03	5.78	5.53	5.28	5.03	4.78	4.52	4.26	4.00	3.74	3.48	3.22	2.95
382	$25{,}000 < N \le 50{,}000$	6.11	5.94	5.70	5.45	5.21	4.97	4.73	4.48	4.22	3.96	3.70	3.44	3.18	2.92
383	$50{,}000 < N \le 75{,}000$	6.05	5.89	5.65	5.41	5.17	4.93	4.70	4.46	4.20	3.94	3.68	3.42	3.16	2.90
384	$75{,}000 < N \le 100{,}000$	6.02	5.85	5.62	5.38	5.15	4.91	4.68	4.44	4.18	3.92	3.66	3.40	3.15	2.89
385	$N \le 1{,}000$	7.84	7.60	7.27	6.93	6.59	6.25	5.92	5.58	5.26	4.95	4.63	4.31	3.99	3.68
386	$1{,}000 < N \le 10{,}000$	7.48	7.26	6.95	6.65	6.34	6.03	5.72	5.42	5.10	4.79	4.48	4.17	3.86	3.54
387	$10{,}000 < N \le 25{,}000$	7.33	7.12	6.83	6.53	6.24	5.94	5.65	5.35	5.04	4.73	4.42	4.11	3.80	3.49
388	$25{,}000 < N \le 50{,}000$	7.22	7.02	6.73	6.45	6.16	5.87	5.59	5.30	4.99	4.68	4.38	4.07	3.76	3.45
389	$50{,}000 < N \le 75{,}000$	7.16	6.96	6.68	6.40	6.12	5.83	5.55	5.27	4.96	4.66	4.35	4.04	3.74	3.43
390	$75{,}000 < N \le 100{,}000$	7.11	6.92	6.64	6.36	6.08	5.81	5.53	5.25	4.94	4.64	4.33	4.03	3.72	3.41

Table 2-1 Thermal Expansion Coefficients for Thermoplastic Materials

Temperature °F	Polyethylene PE4608 and PE4710			Poly(vinyl Chloride)			Poly(vinylidene Fluoride)		
	A	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*
70	80	80	0.0	30	30	0.0	69	69	0.0
75	80	80	0.5	30	30	0.2	70	69	0.4
80	80	80	1.0	30	30	0.4	70	70	0.8
85	80	80	1.4	30	30	0.5	71	70	1.3
90	80	80	1.9	30	30	0.7	72	70	1.7
95	80	80	2.4	30	30	0.9	73	71	2.1
100	80	80	2.9	30	30	1.1	74	71	2.6
105	80	80	3.4	30	30	1.3	75	72	3.0
110	80	80	3.8	30	30	1.4	76	72	3.5
115	80	80	4.3	30	30	1.6	77	73	3.9
120	80	80	4.8	30	30	1.8	78	73	4.4
125	80	80	5.3	30	30	2.0	79	74	4.9
130	80	80	5.8	30	30	2.2	81	74	5.3
135	80	80	6.2	30	30	2.3	82	75	5.8
140	80	80	6.7	30	30	2.5	84	75	6.3
145	80	80	7.2	...	...	...	86	76	6.8
150	80	80	7.7	...	...	...	88	77	7.4
155	80	80	8.2	...	...	...	90	77	7.9
160	80	80	8.6	...	...	...	92	78	8.4
165	80	80	9.1	...	...	...	94	79	9.0
170	80	80	9.6	...	...	...	97	80	9.6
175	80	80	10.1	...	...	...	100	81	10.2
180	80	80	10.6	...	...	...	103	82	10.8
185	...	...	...	...	...	...	106	83	11.4
190	...	...	...	...	...	...	109	84	12.1
195	...	...	...	...	...	...	113	85	12.7
200	...	...	...	...	...	...	117	86	13.4

GENERAL NOTE: Coefficient *A* is the instantaneous coefficient of thermal expansion × 10^{-6} (in./in./°F). Coefficient *B* is the mean coefficient of thermal expansion × 10^{-6} (in./in./°F) in going from 70°F to indicated temperature. Coefficient *C* is the linear thermal expansion (in./100 ft) in going from 70°F to indicated temperature.

Table 2-3 Moduli of Elasticity, *E*, of Thermoplastic Materials for Given Temperatures (Cont'd)

Materials	Load Duration	Modulus of Elasticity, E = Value Given × 10^3 psi, for Temperature, °F, of: 73 and Under	80	90	100	110	120	130	140	150	160	170	180	190	200
Poly(vinylidene Fluorides)															
PVDF 2020 [Notes (1) and (3)]	Short term	267.5	252.9	234.1	217.3	202.1	188.2	175.4	163.6	152.6	142.3	132.6	123.5	114.8	106.7
	0.5 hr	237.5	224.6	207.9	192.9	179.4	167.1	155.8	145.3	135.5	126.3	117.7	109.6	102.0	94.7
	1 hr	225.8	213.4	197.6	183.4	170.5	158.8	148.0	138.1	128.8	120.1	111.9	104.2	96.9	90.0
	10 hr	190.7	180.3	166.9	154.9	144.1	134.2	125.1	116.6	108.8	101.4	94.5	88.0	81.9	76.0
	24 hr	178.7	168.9	156.4	145.1	135.0	125.7	117.2	109.3	101.9	95.0	88.6	82.5	76.7	71.2
	100 hr	161.0	152.2	140.9	130.8	121.6	113.3	105.6	98.5	91.8	85.6	79.8	74.3	69.1	64.2
	1,000 hr	142.6	134.8	124.8	115.8	107.7	100.3	93.5	87.2	81.3	75.8	70.7	65.8	61.2	56.8
	1 yr	127.3	120.4	111.4	103.4	96.2	89.6	83.5	77.9	72.6	67.7	63.1	58.8	54.7	50.8
	10 yr	117.2	110.8	102.5	95.2	88.5	82.4	76.8	71.6	66.8	62.3	58.1	54.1	50.3	46.7
	50 yr	110.7	104.7	96.9	90.0	83.7	77.9	72.6	67.7	63.2	58.9	54.9	51.1	47.5	44.2
PVDF 2025 [Notes (1) and (3)]	Short term	255.0	247.5	235.4	221.6	206.3	190.0	173.0	156.0	139.3	123.5	109.0	96.0	84.5	74.7
	0.5 hr	226.4	219.8	209.0	196.8	183.2	168.7	153.6	138.5	123.7	109.7	96.8	85.2	75.1	66.4
	1 hr	215.2	208.9	198.7	187.0	174.2	160.3	146.0	131.6	117.6	104.3	92.0	81.0	71.4	63.1
	10 hr	181.8	176.5	167.8	158.0	147.1	135.5	123.4	111.2	99.3	88.1	77.7	68.4	60.3	53.3
	24 hr	170.3	165.3	157.2	148.0	137.8	126.9	115.6	104.2	93.1	82.5	72.8	64.1	56.5	49.9
	100 hr	153.5	149.0	141.7	133.4	124.2	114.4	104.2	93.9	83.9	74.4	65.6	57.8	50.9	45.0
	1,000 hr	135.9	131.9	125.5	118.1	110.0	101.3	92.2	83.1	74.3	65.8	58.1	51.2	45.1	39.8
	1 yr	121.4	117.8	112.0	105.5	98.2	90.4	82.4	74.2	66.3	58.8	51.9	45.7	40.2	35.6
	10 yr	111.7	108.4	103.1	97.1	90.4	83.2	75.8	68.3	61.0	54.1	47.7	42.0	37.0	32.7
	50 yr	105.6	102.5	97.4	91.7	85.4	78.7	71.6	64.6	57.7	51.1	45.1	39.7	35.0	30.9

NOTES:

(1) These values are applicable to both the condition of sustained and constant loading (under which the resultant strain increases with increased duration of loading) and that of constant strain (under which an initially generated stress gradually relaxes with increased time).

(2) Values of modulus of elasticity for CPVC, PE, and PVC should be used with the understanding that there is an associated ±20% uncertainty. This uncertainty results from compositional variations and variables associated with original data acquisition and analysis.

(3) Values of modulus of elasticity for PA and PVDF should be used with the understanding that there is an associated ±25% uncertainty. This uncertainty results from compositional variations and variables associated with original data acquisition and analysis.

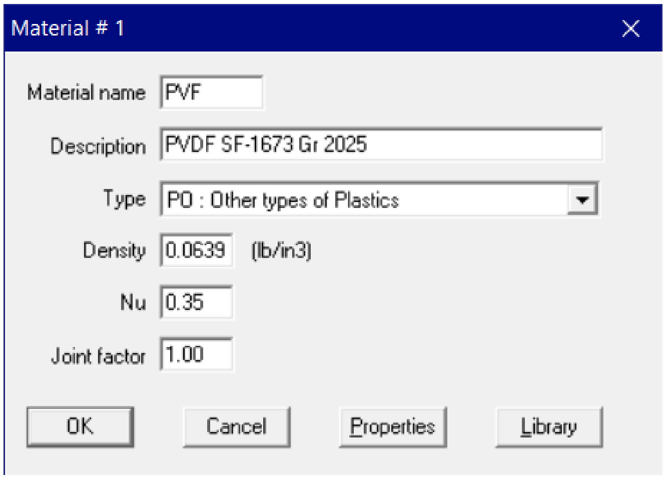
Table 2-4 Poisson's Ratio and Density of Nonmetallic Materials

Material	Poisson's Ratio	Density, lb/in.^{3}
Chlorinated poly(vinyl chlorides) [Note (1)]	0.33	0.0549
Polyamide 11 [Note (1)]	0.41	0.0372
Polyethylene PE2708 [Note (2)]	0.45	0.0337
Polyethylene PE2708 [Note (3)]	0.45	0.0341
Polyethylene PE3608 [Note (2)]	0.45	0.0341
Polyethylene PE3608 [Note (3)]	0.45	0.0345
Polyethylene PE4608 [Note (2)]	0.45	0.0344
Polyethylene PE4608 [Note (3)]	0.45	0.0348
Polyethylene PE4710 [Note (2)]	0.45	0.0344
Polyethylene PE4710 [Note (3)]	0.45	0.0348
Poly(vinyl chloride) [Note (1)]	0.38	0.0509
Poly(vinylidene fluorides) [Note (1)]	0.35	0.0639

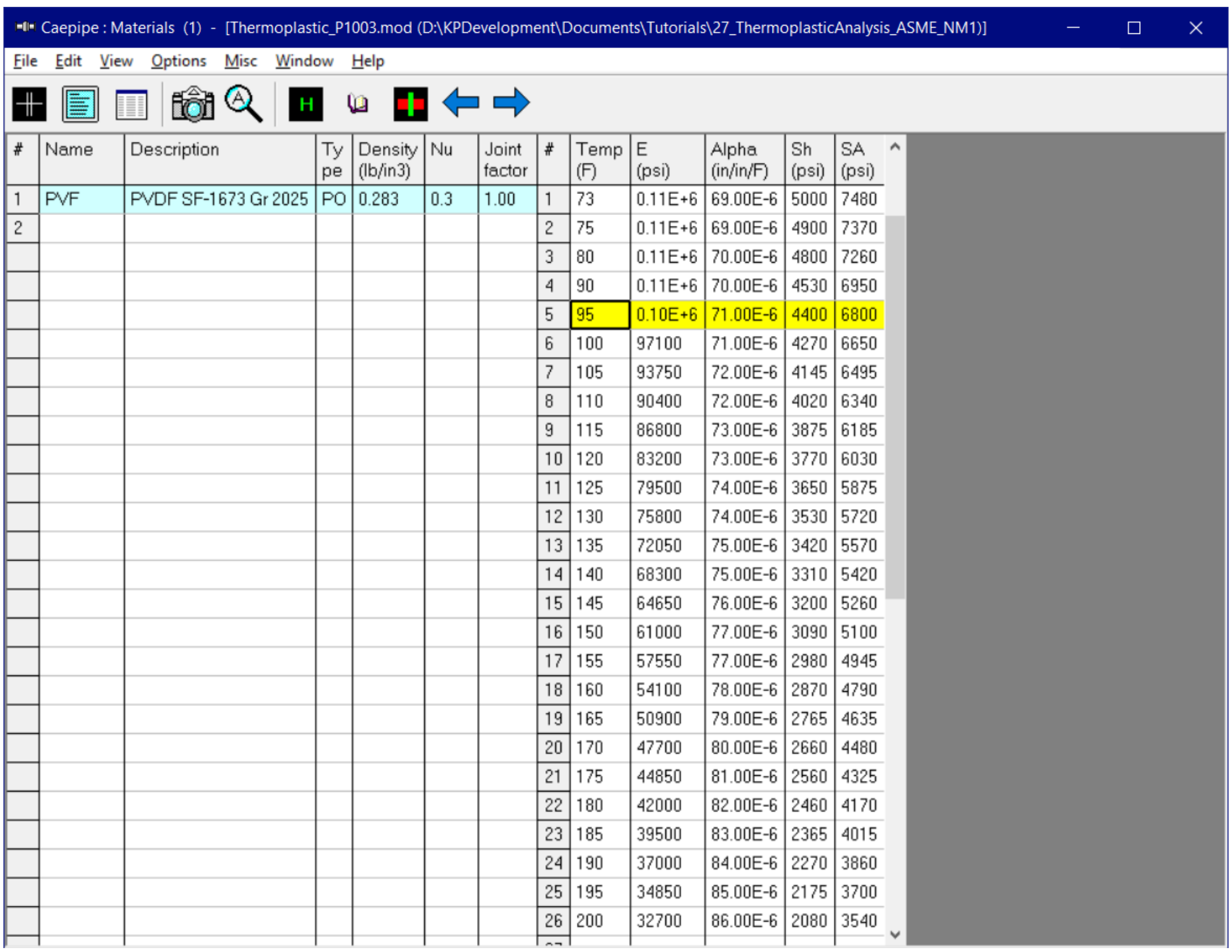
Mean Coefficient of Thermal Expansion data for PVDF material is referred from Table 2-1 corresponding to Column B (highlighted in RED above) for different temperature values and entered into CAEPIPE material properties dialog.

Elastic modulus data for PVDF material is referred from Table 2-3 corresponding to 10 Year (highlighted in RED above) for different temperature values and entered into CAEPIPE material properties dialog.

The material name can be up to five alpha-numeric characters. Enter Material name, Description, Density and Poisson's ratio (Nu) as shown below. Select the type as "PO: Other types of Plastics" from the Type drop-down combo box and press OK.



Input the Temperature related properties into CAEPIPE material properties as shown below by referring to the material properties data given above.



#	Name	Description	Type	Density (lb/in3)	Nu	Joint factor
1	PVF	PVDF SF-1673 Gr 2025	PO	0.283	0.3	1.00
2						

#	Temp (F)	E (psi)	Alpha (in/in/F)	Sh (psi)	SA (psi)
1	73	0.11E+6	69.00E-6	5000	7480
2	75	0.11E+6	69.00E-6	4900	7370
3	80	0.11E+6	70.00E-6	4800	7260
4	90	0.11E+6	70.00E-6	4530	6950
5	95	0.10E+6	71.00E-6	4400	6800
6	100	97100	71.00E-6	4270	6650
7	105	93750	72.00E-6	4145	6495
8	110	90400	72.00E-6	4020	6340
9	115	86800	73.00E-6	3875	6185
10	120	83200	73.00E-6	3770	6030
11	125	79500	74.00E-6	3650	5875
12	130	75800	74.00E-6	3530	5720
13	135	72050	75.00E-6	3420	5570
14	140	68300	75.00E-6	3310	5420
15	145	64650	76.00E-6	3200	5260
16	150	61000	77.00E-6	3090	5100
17	155	57550	77.00E-6	2980	4945
18	160	54100	78.00E-6	2870	4790
19	165	50900	79.00E-6	2765	4635
20	170	47700	80.00E-6	2660	4480
21	175	44850	81.00E-6	2560	4325
22	180	42000	82.00E-6	2460	4170
23	185	39500	83.00E-6	2365	4015
24	190	37000	84.00E-6	2270	3860
25	195	34850	85.00E-6	2175	3700
26	200	32700	86.00E-6	2080	3540

Step 3:

ASME NM.3.1 provides Thermoplastic Material Specifications such as Outside Diameter, Wall Thickness, etc. for different Thermoplastic Materials. See snapshots given below for PVDF materials.

TABLE 1 Outside Diameters and Tolerances for PVDF Pipe Schedules 40 and 80 and SDR 21, in. (mm)

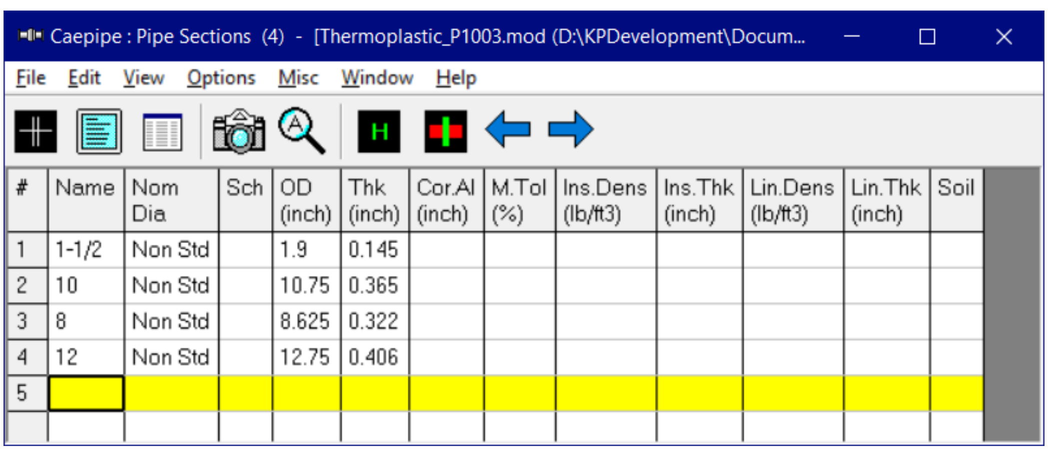
Nominal Pipe Size	Average Outside Diameter	Tolerance	Out-of-Roundness (Maximum Diameter Minus Minimum Diameter)
1¼	1.660 (42.16)	±0.005 (±0.13)	0.050 (1.28)
1½	1.900 (48.26)	±0.006 (±0.15)	0.060 (1.52)
2	2.375 (60.32)	±0.006 (±0.15)	0.070 (1.78)
3	3.500 (88.90)	±0.008 (±0.20)	0.080 (2.04)
4	4.500 (114.30)	±0.009 (±0.23)	0.100 (2.54)
6	6.625 (168.28)	±0.011 (±0.28)	0.100 (2.54)
8	8.625 (219.08)	±0.015 (±0.38)	0.150 (3.80)
10	10.750 (273.05)	±0.015 (±0.38)	0.150 (3.80)
12	12.750 (323.85)	±0.015 (±0.38)	0.150 (3.80)

TABLE 2 Wall Thicknesses and Tolerances for PVDF Pipe Schedules 40 and 80 and SDR 21, in. (mm)

NOTE 1— For fittings, the wall thickness is a minimum value, except that a 10 % variation resulting from core shift is allowable. In such a case, the average of the two opposite wall thickness' shall equal or exceed the value shown in the Schedule 40 table.

Nominal Pipe Sizes	Schedule 40		Schedule 80		SDR 21		SDR 32.5	
	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance
1¼	0.140 (3.56)	+0.020 (+0.51)	0.191 (4.85)	+0.023 (+0.58)	0.079 (2.01)	+0.020 (+0.51)	0.062 (1.57)	+0.020 (0.51)
1½	0.145 (3.68)	+0.020 (+0.51)	0.200 (5.08)	+0.024 (+0.61)	0.090 (2.28)	+0.020 (+0.51)	0.062 (1.57)	+0.020 (0.51)
2	0.154 (3.91)	+0.020 (+0.51)	0.218 (5.54)	+0.026 (+0.66)	0.113 (2.87)	+0.020 (+0.51)	0.073 (1.85)	+0.020 (0.51)
3	0.216 (5.49)	+0.026 (+0.66)	0.300 (7.62)	+0.036 (+0.91)	0.167 (4.22)	+0.020 (+0.51)	0.108 (2.74)	+0.020 (0.51)
4	0.237 (6.02)	+0.028 (+0.71)	0.337 (8.56)	+0.040 (+1.02)	0.214 (5.44)	+0.026 (+0.66)	0.138 (3.51)	+0.020 (0.51)
6	0.280 (7.11)	+0.034 (+0.86)	0.432 (10.97)	+0.052 (+1.32)	0.315 (8.00)	+0.038 (+0.97)	0.204 (5.18)	+0.0241 (0.61)
8	0.322 (8.18)	+0.039 (+0.99)	0.500 (12.70)	+0.060 (+1.52)	0.411 (10.44)	+0.049 (+1.24)	0.265 (6.73)	+0.032 (0.81)
10	0.365 (9.27)	+0.044 (+1.12)	0.593 (15.06)	+0.071 (+1.80)	0.512 (13.00)	+0.061 (+1.55)	0.331 (8.41)	+0.040 (1.02)
12	0.406 (10.31)	+0.049 (+1.24)	0.687 (17.45)	+0.082 (+2.08)	0.607 (15.42)	+0.073 (+1.85)	0.392 (9.96)	+0.047 (+1.19)

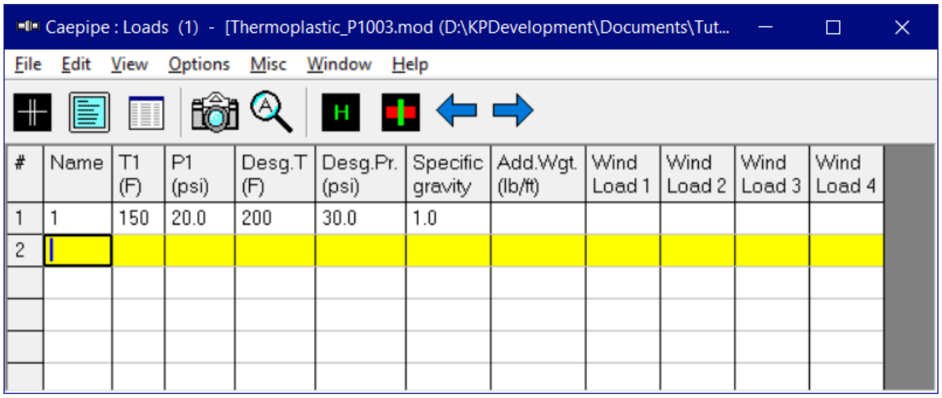
For this tutorial, Section properties such as Outside Diameter and Wall Thicknesses for various Nominal sizes are referred from Table 1 and Table 2 corresponding to PVDF material from ASME NM.3.1 (see the snapshots provided above) and entered into CAEPIPE through Layout Window > Misc > Sections (see the snapshot below).



#	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	1-1/2	Non Std		1.9	0.145							
2	10	Non Std		10.75	0.365							
3	8	Non Std		8.625	0.322							
4	12	Non Std		12.75	0.406							
5												

Step 4:

The Operating Temperature (T1), Operating Pressure (P1), Design Temperature (Desg. T) and Design Pressure (Desg. Pr) for the stress analysis are entered as shown below.

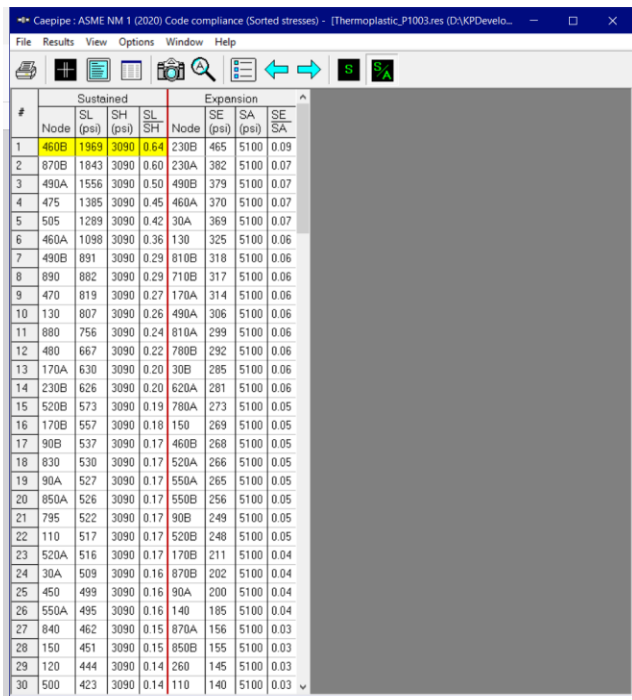


#	Name	T1 (F)	P1 (psi)	Desg.T (F)	Desg.Pr. (psi)	Specific gravity	Add.Wgt. (lb/ft)	Wind Load 1	Wind Load 2	Wind Load 3	Wind Load 4
1	1	150	20.0	200	30.0	1.0					
2											

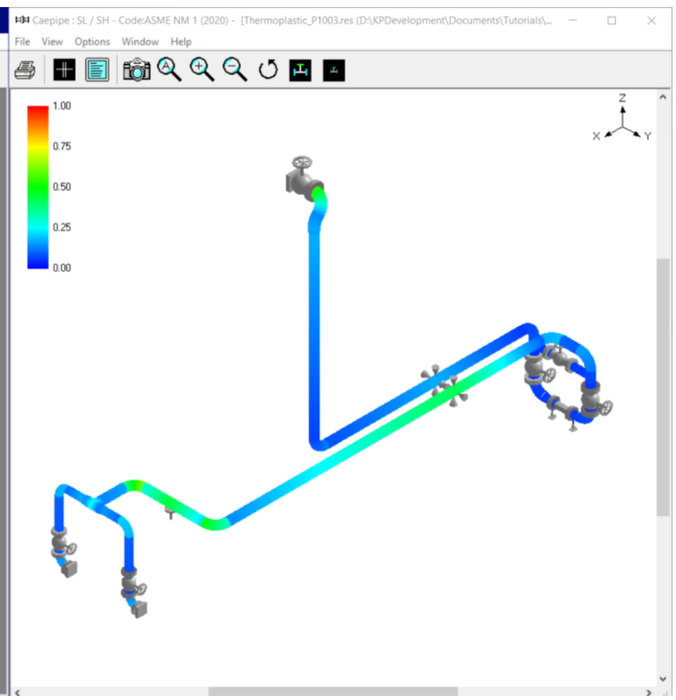
After defining the Material properties, Section properties and Loads required for the stress analysis, complete the stress layout. Save the model and Analyze through Layout window > File > Analyze. Refer to the CAEPIPE model file “Thermoplastic_P1003.mod” included with this tutorial for further details on the layout.

Step 5:

Upon successful analysis, CAEPIPE shows the code compliance as per ASME NM.1 under Sorted stresses and Code Compliance results as shown below.



#	Sustained Node	SL (psi)	SH (psi)	SL/SH	Expansion Node	SE (psi)	SA (psi)	SE/SA
1	460B	1969	3090	0.64	230B	465	5100	0.09
2	870B	1843	3090	0.60	230A	382	5100	0.07
3	490A	1556	3090	0.50	490B	379	5100	0.07
4	475	1385	3090	0.45	460A	370	5100	0.07
5	505	1289	3090	0.42	30A	369	5100	0.07
6	460A	1098	3090	0.36	130	325	5100	0.06
7	490B	891	3090	0.29	810B	318	5100	0.06
8	890	882	3090	0.29	710B	317	5100	0.06
9	470	819	3090	0.27	170A	314	5100	0.06
10	130	807	3090	0.26	490A	306	5100	0.06
11	880	756	3090	0.24	810A	299	5100	0.06
12	480	667	3090	0.22	780B	292	5100	0.06
13	170A	630	3090	0.20	30B	285	5100	0.06
14	230B	626	3090	0.20	620A	281	5100	0.06
15	520B	573	3090	0.19	780A	273	5100	0.05
16	170B	557	3090	0.18	150	269	5100	0.05
17	90B	537	3090	0.17	460B	268	5100	0.05
18	830	530	3090	0.17	520A	266	5100	0.05
19	90A	527	3090	0.17	550A	265	5100	0.05
20	850A	526	3090	0.17	550B	256	5100	0.05
21	795	522	3090	0.17	90B	249	5100	0.05
22	110	517	3090	0.17	520B	248	5100	0.05
23	520A	516	3090	0.17	170B	211	5100	0.04
24	30A	509	3090	0.16	870B	202	5100	0.04
25	450	499	3090	0.16	90A	200	5100	0.04
26	550A	495	3090	0.16	140	185	5100	0.04
27	840	462	3090	0.15	870A	156	5100	0.03
28	150	451	3090	0.15	850B	155	5100	0.03
29	120	444	3090	0.14	260	145	5100	0.03
30	500	423	3090	0.14	110	140	5100	0.03

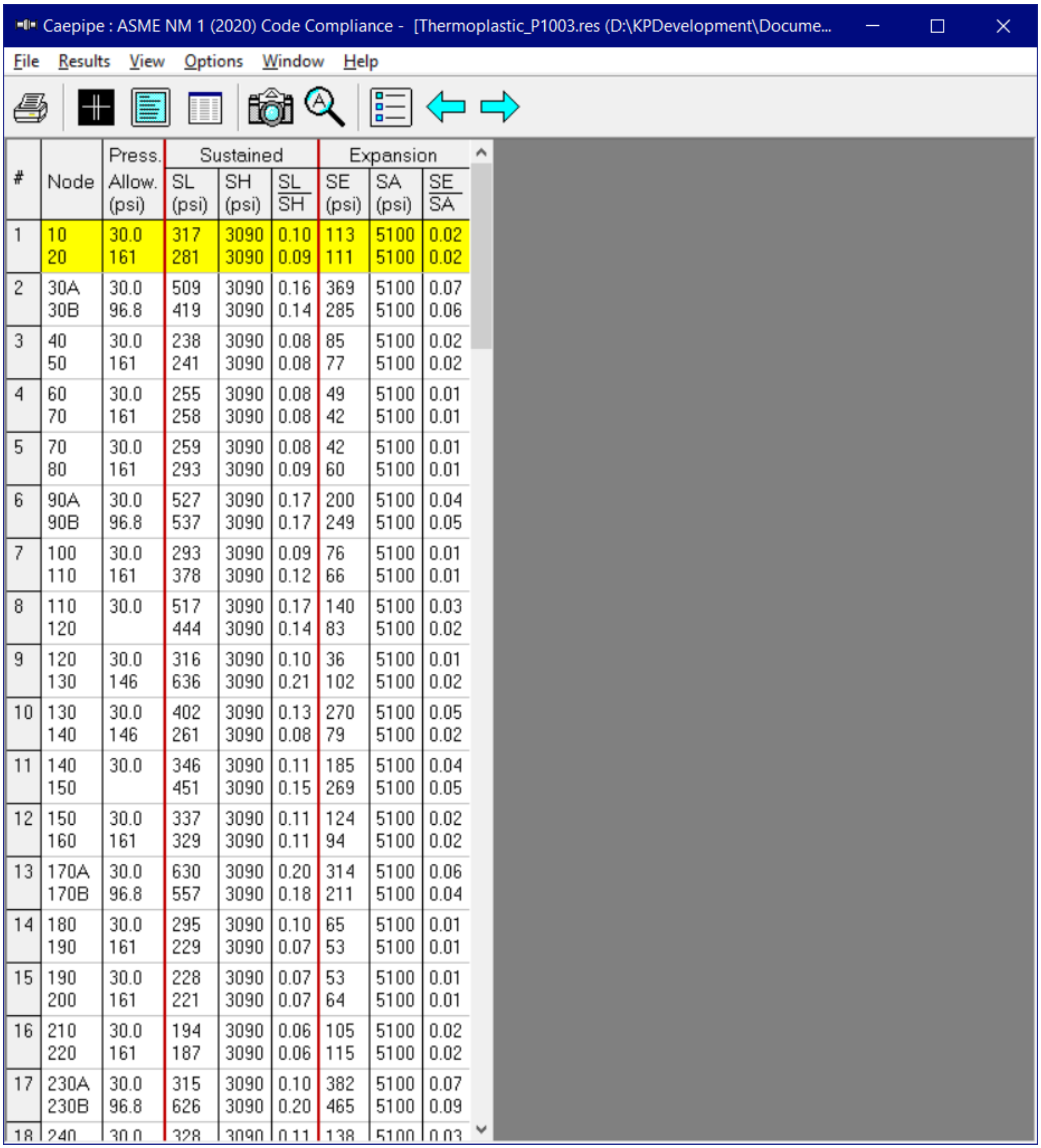


Step 6:

Code Compliance results of CAEPIPE displays the stresses on an element-by-element basis. For the tutorial problem, a snapshot of Code Compliance results is shown below, in which the first element from node 10 to node 20 is highlighted. You will observe that the 2nd Column titled “Press. Allow” output the following for each element.

1. First row outputs the “Design Pressure” input for that element.

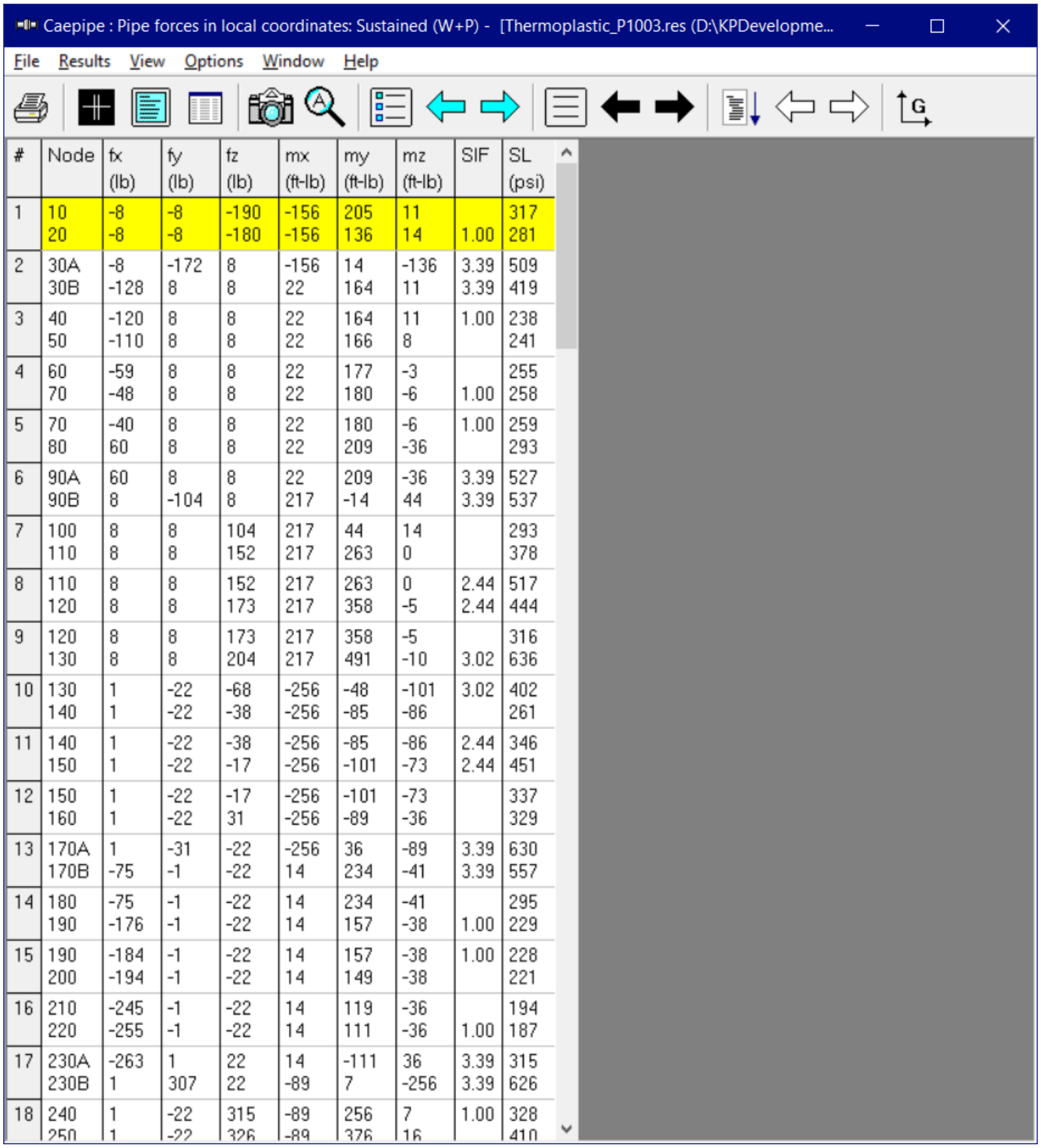
2. Second row outputs the “Calculated Allowable Pressure” for that element as per the equation provided in ASME NM.1. Please note, when the “Design Pressure” input for an element exceeds the “Allowable Pressure” computed for that element, then CAEPIPE will change the display color of Design Pressure to RED.



#	Node	Press. Allow. (psi)	Sustained SL (psi)	Sustained SH (psi)	Sustained SL/SH	Expansion SE (psi)	Expansion SA (psi)	Expansion SE/SA
1	10 20	30.0 161	317 281	3090 3090	0.10 0.09	113 111	5100 5100	0.02 0.02
2	30A 30B	30.0 96.8	509 419	3090 3090	0.16 0.14	369 285	5100 5100	0.07 0.06
3	40 50	30.0 161	238 241	3090 3090	0.08 0.08	85 77	5100 5100	0.02 0.02
4	60 70	30.0 161	255 258	3090 3090	0.08 0.08	49 42	5100 5100	0.01 0.01
5	70 80	30.0 161	259 293	3090 3090	0.08 0.09	42 60	5100 5100	0.01 0.01
6	90A 90B	30.0 96.8	527 537	3090 3090	0.17 0.17	200 249	5100 5100	0.04 0.05
7	100 110	30.0 161	293 378	3090 3090	0.09 0.12	76 66	5100 5100	0.01 0.01
8	110 120	30.0	517 444	3090 3090	0.17 0.14	140 83	5100 5100	0.03 0.02
9	120 130	30.0 146	316 636	3090 3090	0.10 0.21	36 102	5100 5100	0.01 0.02
10	130 140	30.0 146	402 261	3090 3090	0.13 0.08	270 79	5100 5100	0.05 0.02
11	140 150	30.0	346 451	3090 3090	0.11 0.15	185 269	5100 5100	0.04 0.05
12	150 160	30.0 161	337 329	3090 3090	0.11 0.11	124 94	5100 5100	0.02 0.02
13	170A 170B	30.0 96.8	630 557	3090 3090	0.20 0.18	314 211	5100 5100	0.06 0.04
14	180 190	30.0 161	295 229	3090 3090	0.10 0.07	65 53	5100 5100	0.01 0.01
15	190 200	30.0 161	228 221	3090 3090	0.07 0.07	53 64	5100 5100	0.01 0.01
16	210 220	30.0 161	194 187	3090 3090	0.06 0.06	105 115	5100 5100	0.02 0.02
17	230A 230B	30.0 96.8	315 626	3090 3090	0.10 0.20	382 465	5100 5100	0.07 0.09
18	240	30.0	328	3090	0.11	138	5100	0.03

Step 7:

Element forces results for each load case (such as Sustained, Expansion, etc.) shows the Element forces and moments in local coordinate system along with Stress Intensification Factors (SIFs) and Stresses computed as per ASME NM.1 for each element as shown below.



#	Node	fx (lb)	fy (lb)	fz (lb)	mx (ft-lb)	my (ft-lb)	mz (ft-lb)	SIF	SL (psi)
1	10	-8	-8	-190	-156	205	11		317
	20	-8	-8	-180	-156	136	14	1.00	281
2	30A	-8	-172	8	-156	14	-136	3.39	509
	30B	-128	8	8	22	164	11	3.39	419
3	40	-120	8	8	22	164	11	1.00	238
	50	-110	8	8	22	166	8		241
4	60	-59	8	8	22	177	-3		255
	70	-48	8	8	22	180	-6	1.00	258
5	70	-40	8	8	22	180	-6	1.00	259
	80	60	8	8	22	209	-36		293
6	90A	60	8	8	22	209	-36	3.39	527
	90B	8	-104	8	217	-14	44	3.39	537
7	100	8	8	104	217	44	14		293
	110	8	8	152	217	263	0		378
8	110	8	8	152	217	263	0	2.44	517
	120	8	8	173	217	358	-5	2.44	444
9	120	8	8	173	217	358	-5		316
	130	8	8	204	217	491	-10	3.02	636
10	130	1	-22	-68	-256	-48	-101	3.02	402
	140	1	-22	-38	-256	-85	-86		261
11	140	1	-22	-38	-256	-85	-86	2.44	346
	150	1	-22	-17	-256	-101	-73	2.44	451
12	150	1	-22	-17	-256	-101	-73		337
	160	1	-22	31	-256	-89	-36		329
13	170A	1	-31	-22	-256	36	-89	3.39	630
	170B	-75	-1	-22	14	234	-41	3.39	557
14	180	-75	-1	-22	14	234	-41		295
	190	-176	-1	-22	14	157	-38	1.00	229
15	190	-184	-1	-22	14	157	-38	1.00	228
	200	-194	-1	-22	14	149	-38		221
16	210	-245	-1	-22	14	119	-36		194
	220	-255	-1	-22	14	111	-36	1.00	187
17	230A	-263	1	22	14	-111	36	3.39	315
	230B	1	307	22	-89	7	-256	3.39	626
18	240	1	-22	315	-89	256	7	1.00	328
	250	1	-22	326	-89	376	16		410

Step 8:

Support Loads and Displacements for each load case can be seen through Support Loads and Displacements results of CAEPIPE respectively. For the design of supports, Support Load Summary of CAEPIPE will show the loads on each support for all load cases selected for analysis.

Note:

Refer to Section titled “ASME NM.1” in CAEPIPE Code Compliance Manual of CAEPIPE for details on how CAEPIPE computes the Flexibility Factors, Stress Intensification Factors and Code Stresses as per ASME NM.1.