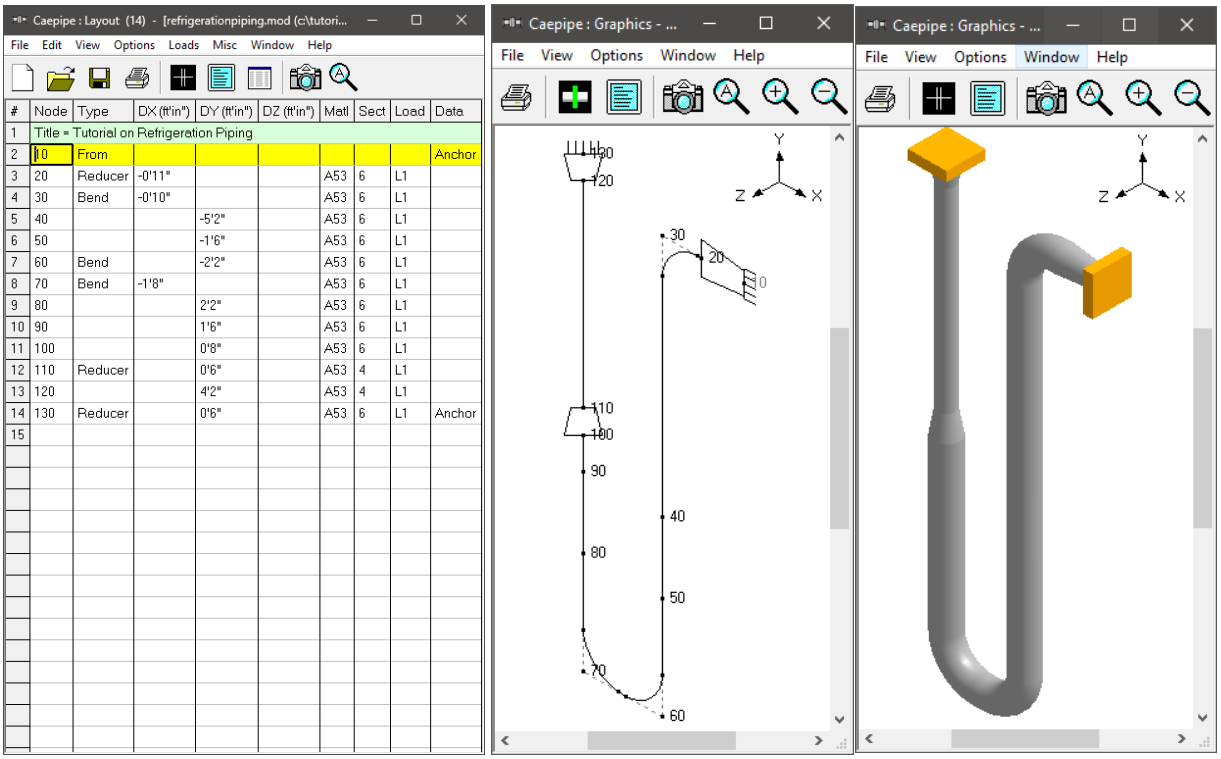
Tutorial on Refrigeration Piping using CAEPIPE

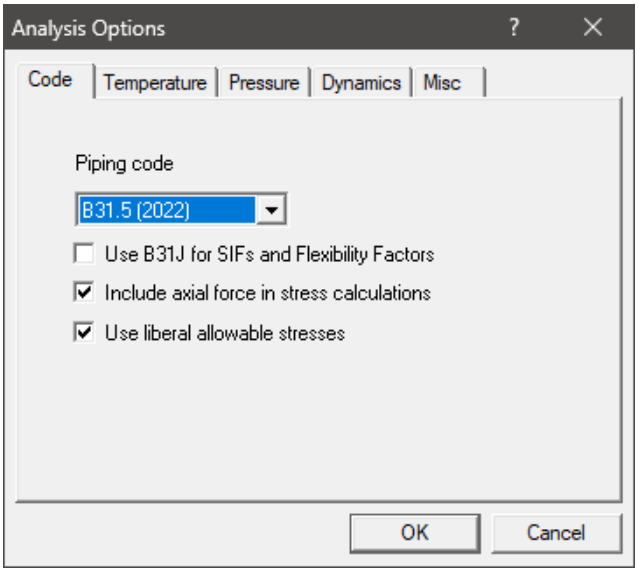
Steps to perform Analysis of Refrigeration Piping with ASME B31.5 Code using CAEPIPE:

The snap shot below shows the sample layout of a refrigeration piping system. The system experiences two (2) different temperatures during its operation (from -50 deg. F to 200 deg. F) with installation temperature as 70 deg. F. Being refrigeration piping, the analysis code is selected as ASME B31.5 for this system.



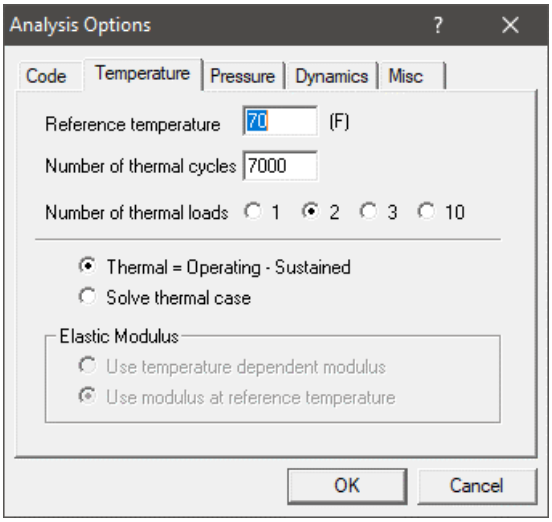
Step 1:

Select the Analysis code as ASME B31.5 through Layout Window > Options > Analysis as shown below.



Step 2:

As the piping layout involves two (2) operating temperatures, “Number of Thermal Loads” needs to be set as “2”. This can be done through Layout Window > Analysis > Temperature as shown below. In addition, the installation temperature (same as “Reference temperature”) can be input as shown below.

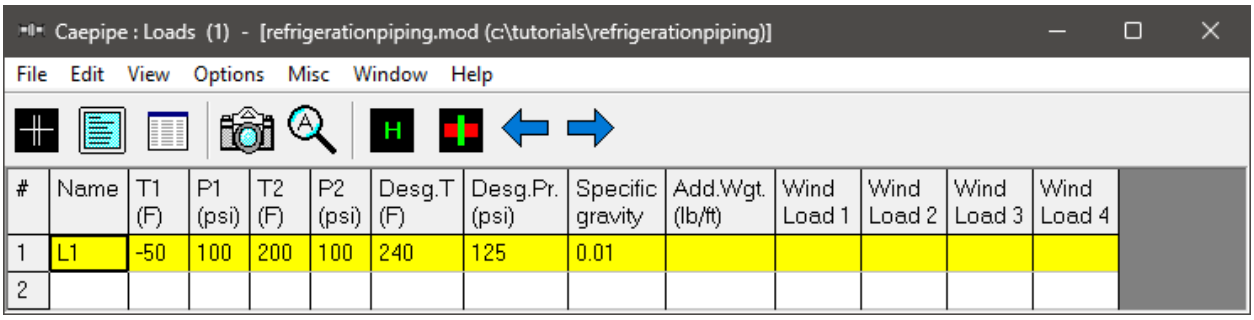


Note:

As per para. 519.4.5(a) of ASME B31.5 (2022), bending and torsional stresses shall be computed using the as-installed modulus of elasticity, i.e., E_c at installation temperature (same as “Reference temperature”). Hence, "Use modulus at reference temperature" is set as "default" and is disabled for user to modify.

Step 3:

Enter the Operating temperatures of the piping layout through “Layout Window > Misc > Loads” as shown below.



#	Name	T1 (F)	P1 (psi)	T2 (F)	P2 (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	L1	-50	100	200	100	240	125	0.01					
2													

Note:

Design Temperature entered will be used to determine the allowable stress for material, which is in turn used to compute the Allowable Pressure as per the piping code selected (B31.5 in this case).

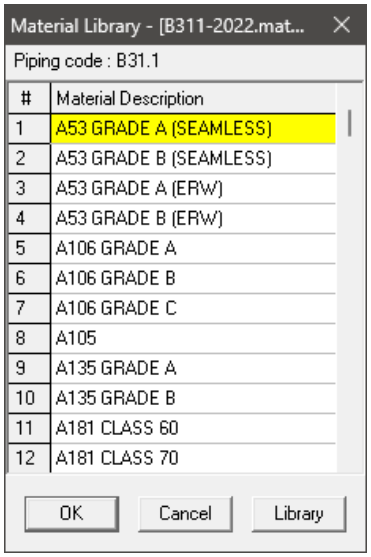
The Allowable Pressure so computed as per the piping code selected is then compared against the Design Pressure entered above and reported in the Code Compliance results.

In addition, starting CAEPIPE Version 10.20, a new load case called “Design (W+PD+TD)” is added. When this load case is selected for Analysis, CAEPIPE will compute and show results for Displacements,

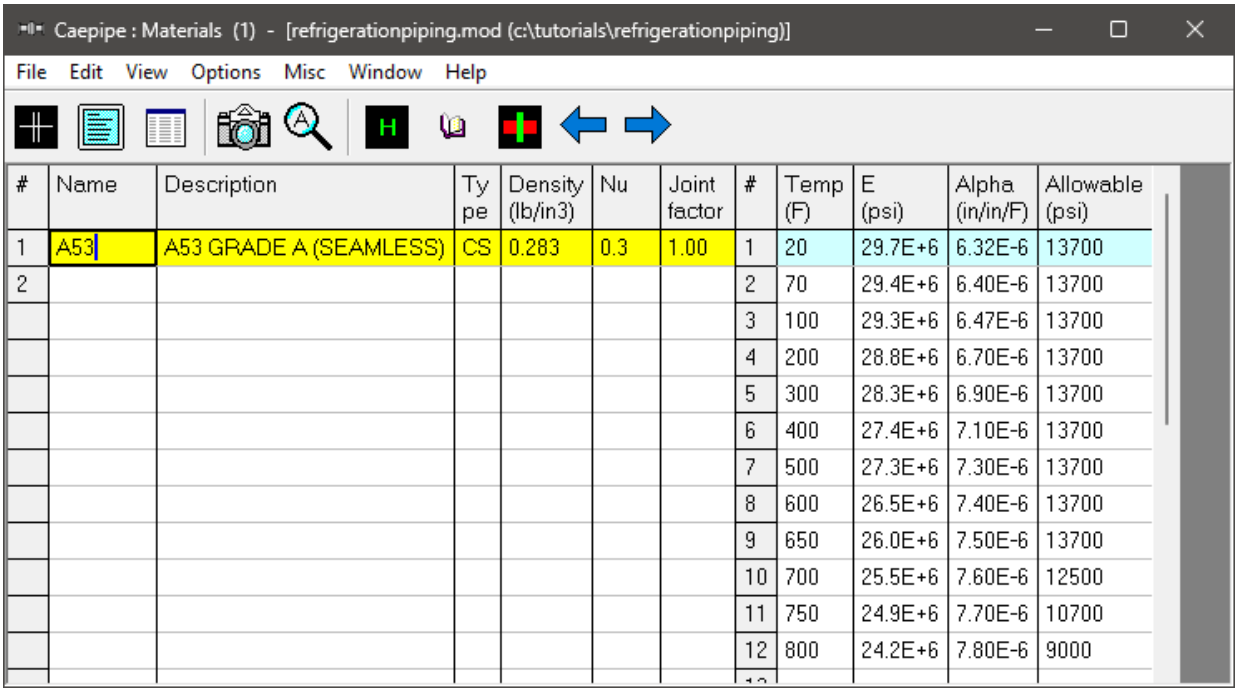
Element Forces & Moments, Support Loads and Support Load Summary. This load cases is NOT included in Stress Calculations, Rotating Equipment Qualifications and Flange Equivalent Pressure Calculations.

Step 4:

Select the material properties corresponding to “A53 Grade A (SEAMLESS)” through “Layout Window > Misc > Materials > File > Library…”.



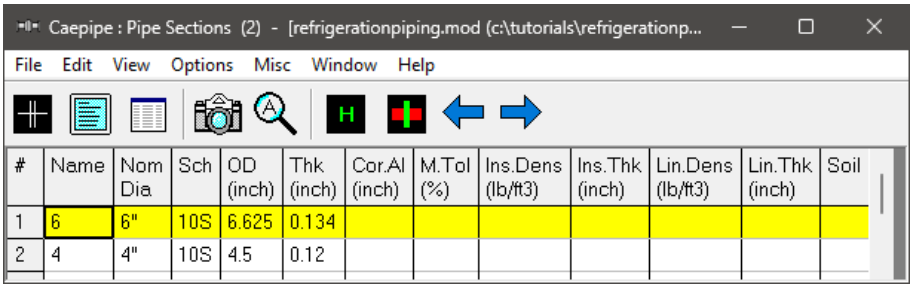
From the dialog box shown, select the Material library as B315-2016 from the folder “Material_Library” available inside the CAEPIPE installation folder. Once selected, highlight the material as shown above and press the button “OK”.



#	Name	Description	Type	Density (lb/in3)	Nu	Joint factor	#	Temp (F)	E (psi)	Alpha (in/in/F)	Allowable (psi)
1	A53	A53 GRADE A (SEAMLESS)	CS	0.283	0.3	1.00	1	20	29.7E+6	6.32E-6	13700
2							2	70	29.4E+6	6.40E-6	13700
							3	100	29.3E+6	6.47E-6	13700
							4	200	28.8E+6	6.70E-6	13700
							5	300	28.3E+6	6.90E-6	13700
							6	400	27.4E+6	7.10E-6	13700
							7	500	27.3E+6	7.30E-6	13700
							8	600	26.5E+6	7.40E-6	13700
							9	650	26.0E+6	7.50E-6	13700
							10	700	25.5E+6	7.60E-6	12500
							11	750	24.9E+6	7.70E-6	10700
							12	800	24.2E+6	7.80E-6	9000

Step 5:

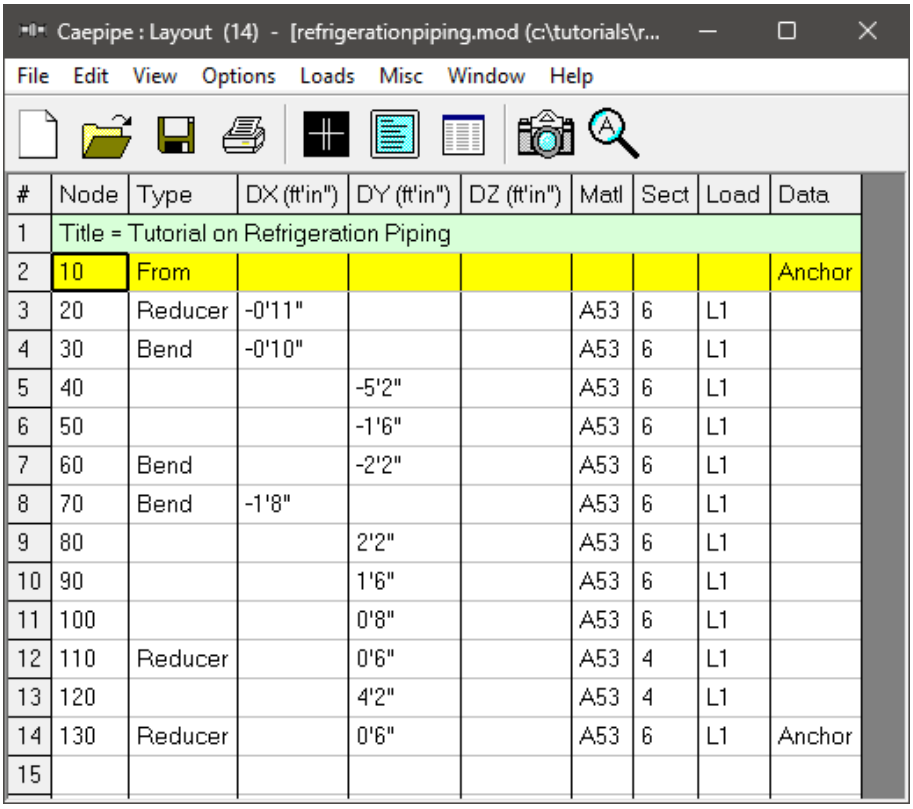
Define the section properties through “Layout Window > Misc > Sections”.



#	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"	10S	6.625	0.134							
2	4	4"	10S	4.5	0.12							

Step 6:

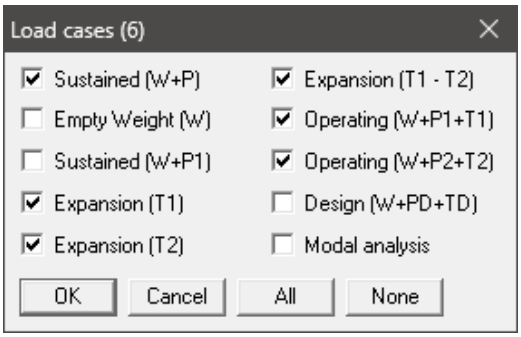
Generate the piping layout as shown below.



#	Node	Type	DX (ft'in")	DY (ft'in")	DZ (ft'in")	Matl	Sect	Load	Data
1	Title = Tutorial on Refrigeration Piping								
2	10	From							Anchor
3	20	Reducer	-0'11"			A53	6	L1	
4	30	Bend	-0'10"			A53	6	L1	
5	40			-5'2"		A53	6	L1	
6	50			-1'6"		A53	6	L1	
7	60	Bend		-2'2"		A53	6	L1	
8	70	Bend	-1'8"			A53	6	L1	
9	80			2'2"		A53	6	L1	
10	90			1'6"		A53	6	L1	
11	100			0'8"		A53	6	L1	
12	110	Reducer		0'6"		A53	4	L1	
13	120			4'2"		A53	4	L1	
14	130	Reducer		0'6"		A53	6	L1	Anchor
15									

Step 7:

After creating the stress model, turn ON load cases through “Layout Window > Loads > Load cases as follows: Expansion (T1) {which is the same as the range (T1 – Tref)}, Expansion (T2) {which is the same as the range (T2 – Tref)}, and Expansion (T1 – T2) [= (T1 – Tref) - (T2 – Tref)].



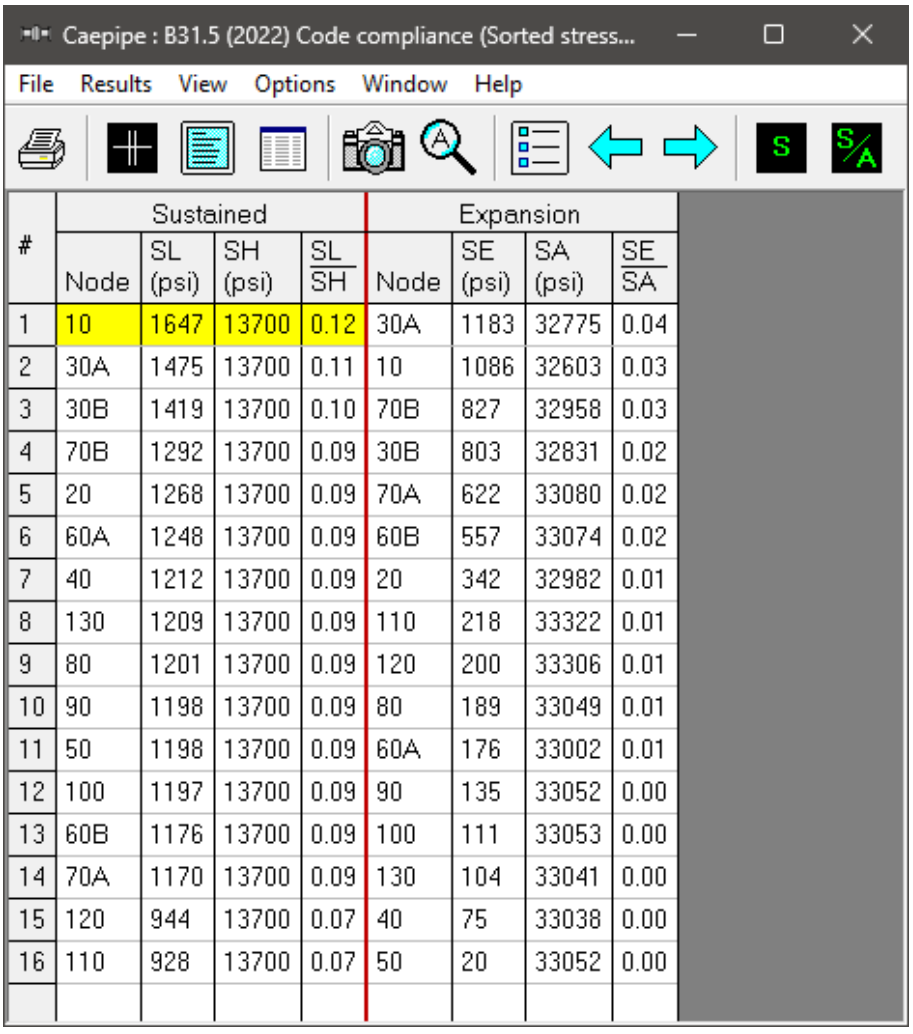
After analysis, Expansion Stress (SE) value given at any node in Results Window > Sorted stresses and Results Window > Code compliance is the highest thermal stress range at that node among the three thermal ranges (T1 – Tref), (T2 – Tref) and (T1 – T2).

Step 8:

Save the model and perform analysis through Layout window > File > Analyze.

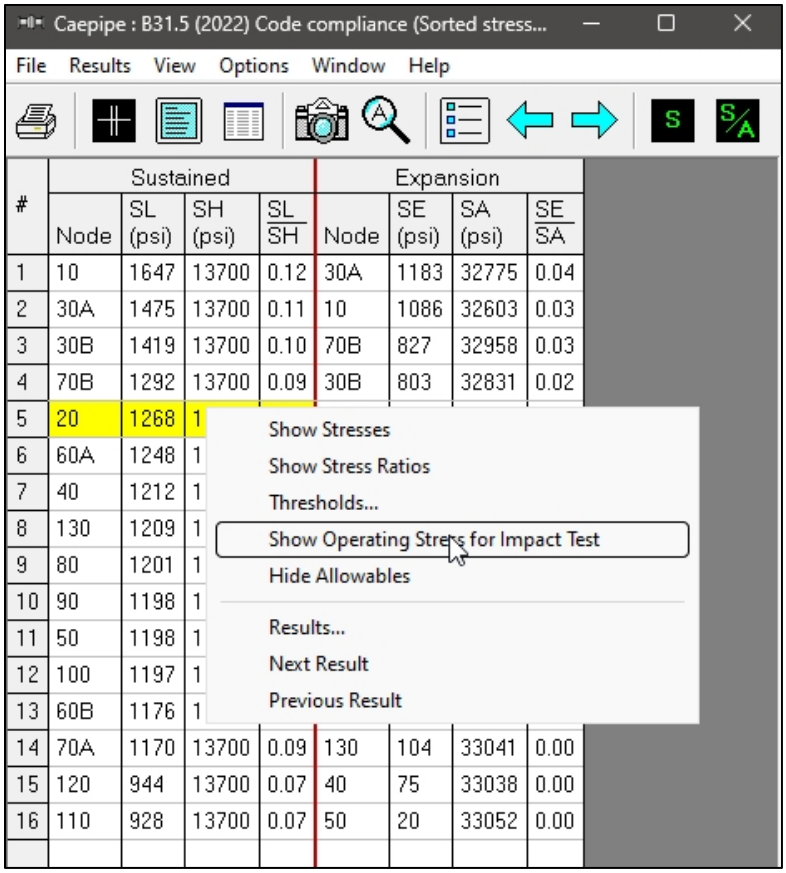
In order to understand the loads and load combinations used for analysis, review the CAEPIPE results file for Sorted Stress, Code Compliance, Displacements, Support Loads (loads acting on the supports by the piping for each load case), Element Forces & Moments (local/global forces and moments on each element for each load case) and Support Load Summary (listing support loads at a particular support for all relevant load cases and load combinations).

As stated above, Sorted Stresses in CAEPIPE lists the maximum of Expansion stresses for all thermal range cases at each node. On the other hand, for Sustained case, it always uses the maximum pressure among the input pressures (P1 and P2 in this case) while computing Sustained Stress at each node.

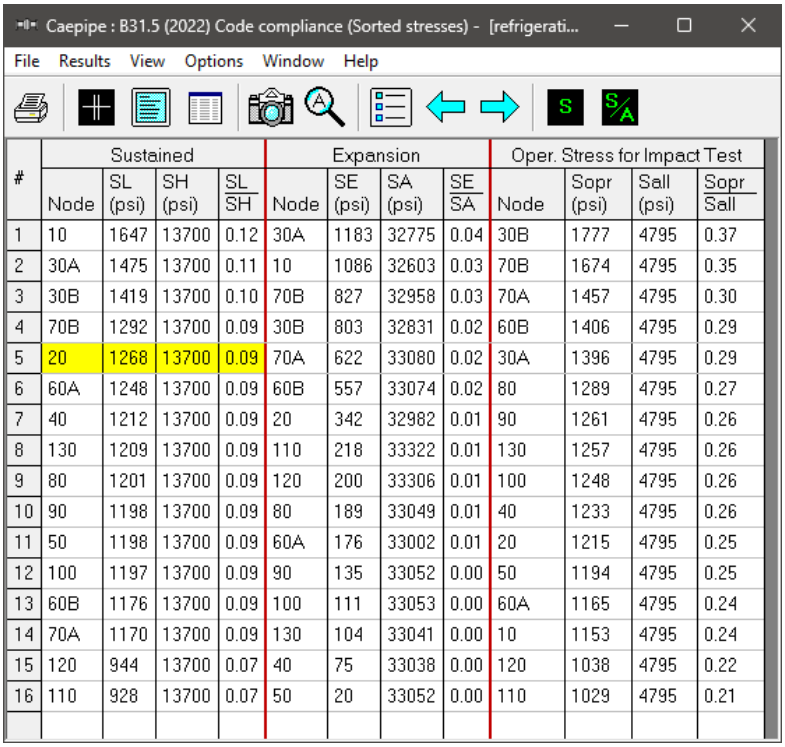


#	Sustained				Expansion			
	Node	SL (psi)	SH (psi)	SL/SH	Node	SE (psi)	SA (psi)	SE/SA
1	10	1647	13700	0.12	30A	1183	32775	0.04
2	30A	1475	13700	0.11	10	1086	32603	0.03
3	30B	1419	13700	0.10	70B	827	32958	0.03
4	70B	1292	13700	0.09	30B	803	32831	0.02
5	20	1268	13700	0.09	70A	622	33080	0.02
6	60A	1248	13700	0.09	60B	557	33074	0.02
7	40	1212	13700	0.09	20	342	32982	0.01
8	130	1209	13700	0.09	110	218	33322	0.01
9	80	1201	13700	0.09	120	200	33306	0.01
10	90	1198	13700	0.09	80	189	33049	0.01
11	50	1198	13700	0.09	60A	176	33002	0.01
12	100	1197	13700	0.09	90	135	33052	0.00
13	60B	1176	13700	0.09	100	111	33053	0.00
14	70A	1170	13700	0.09	130	104	33041	0.00
15	120	944	13700	0.07	40	75	33038	0.00
16	110	928	13700	0.07	50	20	33052	0.00

Operating Stress for Impact Test can be seen by selecting the option “Show Operating Stress for Impact Test” through Mouse Right click.



#	Sustained				Expansion			
	Node	SL (psi)	SH (psi)	SL/SH	Node	SE (psi)	SA (psi)	SE/SA
1	10	1647	13700	0.12	30A	1183	32775	0.04
2	30A	1475	13700	0.11	10	1086	32603	0.03
3	30B	1419	13700	0.10	70B	827	32958	0.03
4	70B	1292	13700	0.09	30B	803	32831	0.02
5	20	1268	1					
6	60A	1248	1					
7	40	1212	1					
8	130	1209	1					
9	80	1201	1					
10	90	1198	1					
11	50	1198	1					
12	100	1197	1					
13	60B	1176	1					
14	70A	1170	13700	0.09	130	104	33041	0.00
15	120	944	13700	0.07	40	75	33038	0.00
16	110	928	13700	0.07	50	20	33052	0.00



#	Sustained				Expansion				Oper. Stress for Impact Test			
	Node	SL (psi)	SH (psi)	SL/SH	Node	SE (psi)	SA (psi)	SE/SA	Node	Sopr (psi)	Sall (psi)	Sopr/Sall
1	10	1647	13700	0.12	30A	1183	32775	0.04	30B	1777	4795	0.37
2	30A	1475	13700	0.11	10	1086	32603	0.03	70B	1674	4795	0.35
3	30B	1419	13700	0.10	70B	827	32958	0.03	70A	1457	4795	0.30
4	70B	1292	13700	0.09	30B	803	32831	0.02	60B	1406	4795	0.29
5	20	1268	13700	0.09	70A	622	33080	0.02	30A	1396	4795	0.29
6	60A	1248	13700	0.09	60B	557	33074	0.02	80	1289	4795	0.27
7	40	1212	13700	0.09	20	342	32982	0.01	90	1261	4795	0.26
8	130	1209	13700	0.09	110	218	33322	0.01	130	1257	4795	0.26
9	80	1201	13700	0.09	120	200	33306	0.01	100	1248	4795	0.26
10	90	1198	13700	0.09	80	189	33049	0.01	40	1233	4795	0.26
11	50	1198	13700	0.09	60A	176	33002	0.01	20	1215	4795	0.25
12	100	1197	13700	0.09	90	135	33052	0.00	50	1194	4795	0.25
13	60B	1176	13700	0.09	100	111	33053	0.00	60A	1165	4795	0.24
14	70A	1170	13700	0.09	130	104	33041	0.00	10	1153	4795	0.24
15	120	944	13700	0.07	40	75	33038	0.00	120	1038	4795	0.22
16	110	928	13700	0.07	50	20	33052	0.00	110	1029	4795	0.21

Similarly, Code Compliance report lists the Stresses element-wise following the same procedure as done for Sorted Stresses.

Caepipe : B31.5 (2022) Code Compliance - [refrigeratio...

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#	Node	Press. Allow. (psi)	Sustained SL (psi)	Sustained SH (psi)	Sustained SL/SH	Expansion SE (psi)	Expansion SA (psi)	Expansion SE/SA
1	10	125	1647	13700	0.12	1086	32603	0.03
	20		1268	13700	0.09	342	32982	0.01
2	20	125	1268	13700	0.09	342	32982	0.01
	30A	563	1249	13700	0.09	333	33001	0.01
3	30A	125	1475	13700	0.11	1183	32775	0.04
	30B	563	1419	13700	0.10	803	32831	0.02
4	30B	125	1251	13700	0.09	234	32999	0.01
	40	563	1212	13700	0.09	75	33038	0.00
5	40	125	1212	13700	0.09	75	33038	0.00
	50	563	1198	13700	0.09	20	33052	0.00
6	50	125	1198	13700	0.09	20	33052	0.00
	60A	563	1185	13700	0.09	60	33065	0.00
7	60A	125	1248	13700	0.09	176	33002	0.01
	60B	563	1176	13700	0.09	557	33074	0.02
8	60B	125	1166	13700	0.09	158	33084	0.00
	70A	563	1164	13700	0.08	177	33086	0.01
9	70A	125	1170	13700	0.09	622	33080	0.02
	70B	563	1292	13700	0.09	827	32958	0.03
10	70B	125	1204	13700	0.09	241	33046	0.01
	80	563	1201	13700	0.09	189	33049	0.01

From the Displacement results for Expansion (T1) and Expansion (T1-T2), it is observed that the Displacements are +ve in Global Y direction confirming that the piping is shrinking due to temperature decrease for both expansion cases.

Caepipe : Displacements: Expansion (T1) - [refrigerationpipin...

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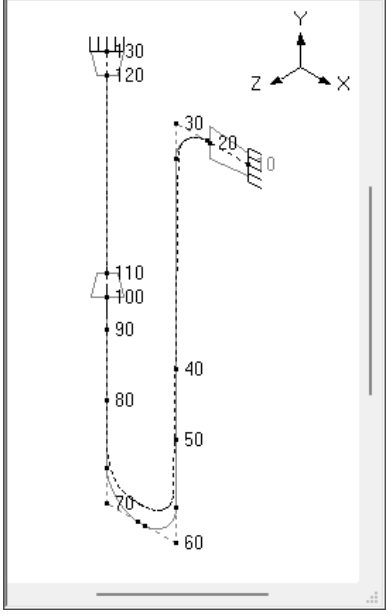
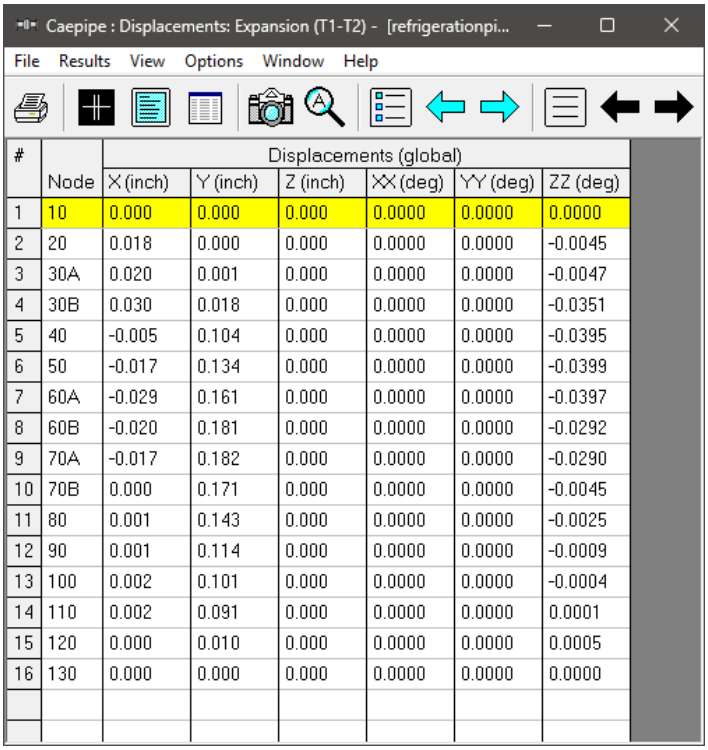
#	Node	Displacements (global) X (inch)	Y (inch)	Z (inch)	XX (deg)	YY (deg)	ZZ (deg)
1	10	0.000	0.000	0.000	0.0000	0.0000	0.0000
2	20	0.008	0.000	0.000	0.0000	0.0000	-0.0021
3	30A	0.009	0.000	0.000	0.0000	0.0000	-0.0022
4	30B	0.014	0.008	0.000	0.0000	0.0000	-0.0162
5	40	-0.002	0.048	0.000	0.0000	0.0000	-0.0182
6	50	-0.008	0.061	0.000	0.0000	0.0000	-0.0184
7	60A	-0.013	0.074	0.000	0.0000	0.0000	-0.0183
8	60B	-0.009	0.083	0.000	0.0000	0.0000	-0.0134
9	70A	-0.008	0.083	0.000	0.0000	0.0000	-0.0134
10	70B	0.000	0.078	0.000	0.0000	0.0000	-0.0021
11	80	0.000	0.065	0.000	0.0000	0.0000	-0.0011
12	90	0.001	0.052	0.000	0.0000	0.0000	-0.0005
13	100	0.001	0.046	0.000	0.0000	0.0000	-0.0001
14	110	0.001	0.042	0.000	0.0000	0.0000	0.0001
15	120	0.000	0.004	0.000	0.0000	0.0000	0.0002
16	130	0.000	0.000	0.000	0.0000	0.0000	0.0000

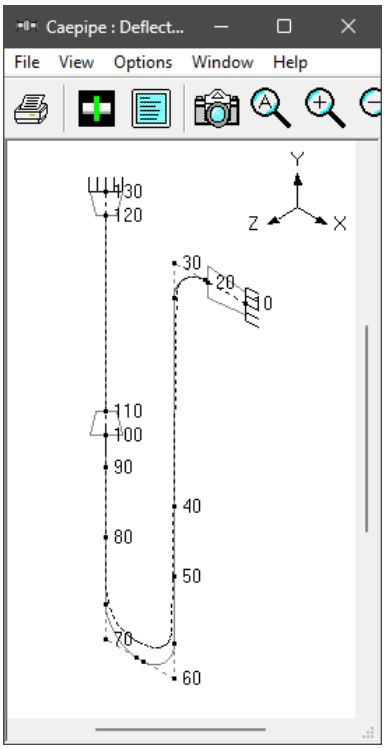
Caepipe : Deflect...

File View Options Window Help

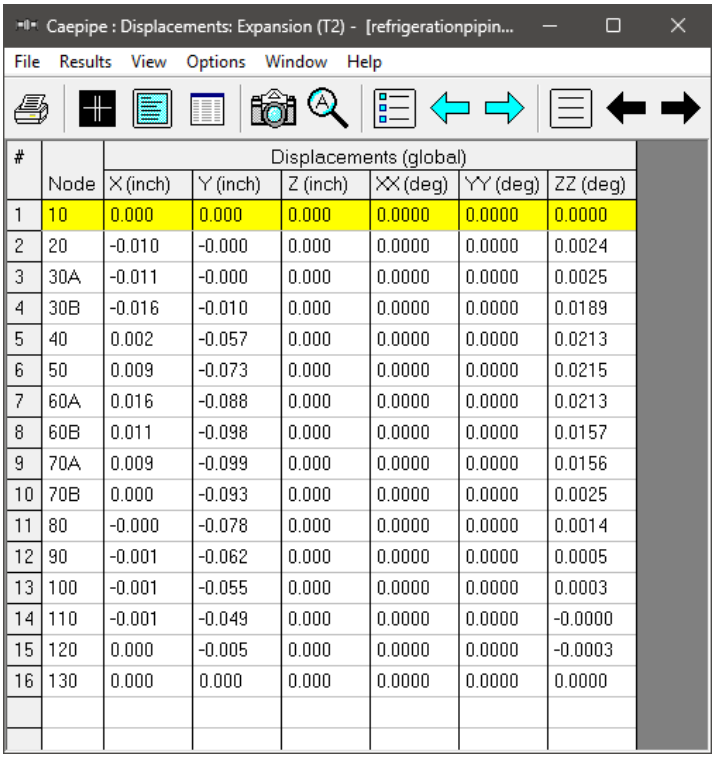




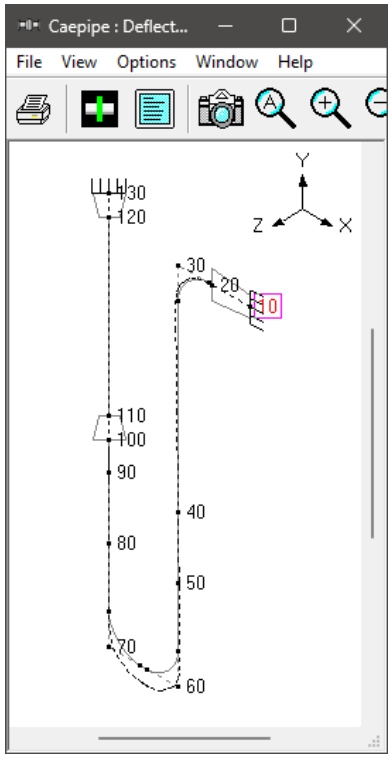
#	Node	Displacements (global) X (inch)	Y (inch)	Z (inch)	XX (deg)	YY (deg)	ZZ (deg)
1	10	0.000	0.000	0.000	0.0000	0.0000	0.0000
2	20	0.018	0.000	0.000	0.0000	0.0000	-0.0045
3	30A	0.020	0.001	0.000	0.0000	0.0000	-0.0047
4	30B	0.030	0.018	0.000	0.0000	0.0000	-0.0351
5	40	-0.005	0.104	0.000	0.0000	0.0000	-0.0395
6	50	-0.017	0.134	0.000	0.0000	0.0000	-0.0399
7	60A	-0.029	0.161	0.000	0.0000	0.0000	-0.0397
8	60B	-0.020	0.181	0.000	0.0000	0.0000	-0.0292
9	70A	-0.017	0.182	0.000	0.0000	0.0000	-0.0290
10	70B	0.000	0.171	0.000	0.0000	0.0000	-0.0045
11	80	0.001	0.143	0.000	0.0000	0.0000	-0.0025
12	90	0.001	0.114	0.000	0.0000	0.0000	-0.0009
13	100	0.002	0.101	0.000	0.0000	0.0000	-0.0004
14	110	0.002	0.091	0.000	0.0000	0.0000	0.0001
15	120	0.000	0.010	0.000	0.0000	0.0000	0.0005
16	130	0.000	0.000	0.000	0.0000	0.0000	0.0000



Similarly, from the Displacement results for Expansion (T2), it is observed that the Displacements are -ve in Global Y direction confirming that the piping is expanding downward due to temperature increase.



#	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	20	-0.010	-0.000	0.000	0.0000	0.0000	0.0024
3	30A	-0.011	-0.000	0.000	0.0000	0.0000	0.0025
4	30B	-0.016	-0.010	0.000	0.0000	0.0000	0.0189
5	40	0.002	-0.057	0.000	0.0000	0.0000	0.0213
6	50	0.009	-0.073	0.000	0.0000	0.0000	0.0215
7	60A	0.016	-0.088	0.000	0.0000	0.0000	0.0213
8	60B	0.011	-0.098	0.000	0.0000	0.0000	0.0157
9	70A	0.009	-0.099	0.000	0.0000	0.0000	0.0156
10	70B	0.000	-0.093	0.000	0.0000	0.0000	0.0025
11	80	-0.000	-0.078	0.000	0.0000	0.0000	0.0014
12	90	-0.001	-0.062	0.000	0.0000	0.0000	0.0005
13	100	-0.001	-0.055	0.000	0.0000	0.0000	0.0003
14	110	-0.001	-0.049	0.000	0.0000	0.0000	-0.0000
15	120	0.000	-0.005	0.000	0.0000	0.0000	-0.0003
16	130	0.000	0.000	0.000	0.0000	0.0000	0.0000



Element Forces & Moments (local forces and moments on each element for Expansion (T2) load case) are shown below.

Caepipe : Pipe forces in local coordinates: Expansion (T2) - [refrigerationpiping.res (c:\tutorials\refrigerationpiping)]

File Results View Options Window Help

#	Node	Axial (lb)	y Shear (lb)	z Shear (lb)	Torsion(ft-lb) Moment	Torsion(ft-lb) SIF	Inplane(ft-lb) Moment	Inplane(ft-lb) SIF	Outplane(ft-lb) Moment	Outplane(ft-lb) SIF	Flex. Factors FFi	Flex. Factors FFo	Flex. Factors FFt	SE (psi)	SA (psi)	SE SA
1	10	-7	-21	0	0		-85	1.00	0	1.00				585	32603	0.02
	20	-7	-21	0	0		-66	1.00	0	1.00				184	32982	0.01
2	20	-7	-21	0	0		-66		0					184	32982	0.01
	30A	-7	-21	0	0		-64		0					179	33001	0.01
3	30A	-7	21	0	0		64	3.59	0	2.99	13.74	13.74		637	32775	0.02
	30B	21	7	0	0		43	3.59	0	2.99	13.74	13.74		432	32831	0.02
4	30B	21	-7	0	0		-43		0					126	32999	0.00
	40	21	-7	0	0		-12		0					40	33038	0.00
5	40	21	-7	0	0		-12		0					40	33038	0.00
	50	21	-7	0	0		-1		0					11	33052	0.00
6	50	21	-7	0	0		-1		0					11	33052	0.00
	60A	21	-7	0	0		9		0					32	33065	0.00
7	60A	21	-7	0	0		9	3.59	0	2.99	13.74	13.74		94	33002	0.00
	60B	-7	-21	0	0		30	3.59	0	2.99	13.74	13.74		299	33074	0.01
8	60B	-7	-21	0	0		30		0					85	33084	0.00
	70A	-7	-21	0	0		33		0					95	33086	0.00
9	70A	-7	-21	0	0		33	3.59	0	2.99	13.74	13.74		334	33080	0.01
	70B	-21	7	0	0		44	3.59	0	2.99	13.74	13.74		445	32958	0.02
10	70B	-21	-7	0	0		-44		0					130	33046	0.00
	80	-21	-7	0	0		-34		0					102	33049	0.00

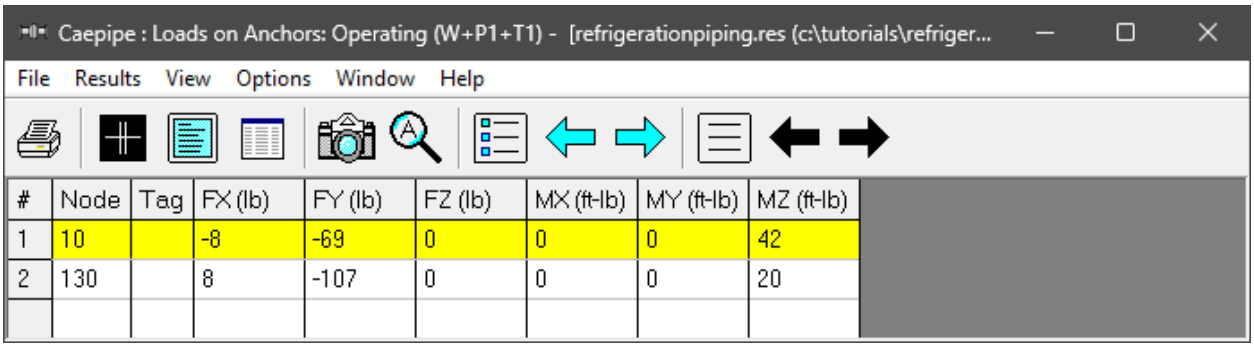
Element Forces & Moments (global forces and moments on each element for Expansion (T2) load case) are shown below.

Caepipe : Pipe forces in global coordinates: Expansion (T2) - [refrigerationpiping.res (c:\tutorials\r...

File Results View Options Window Help

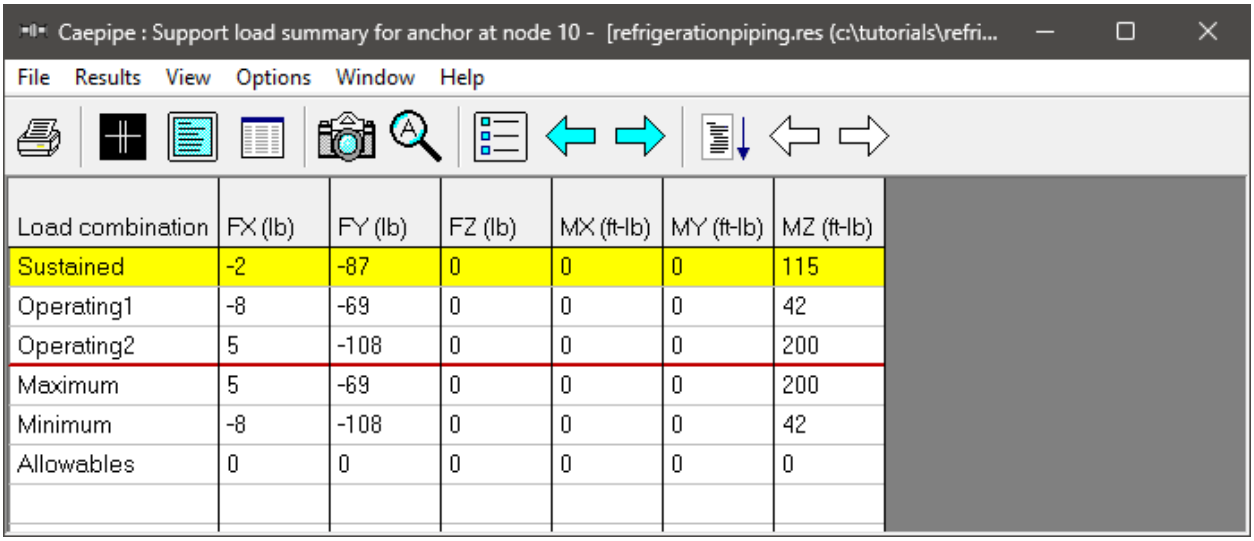
#	Node	FX (lb)	FY (lb)	FZ (lb)	MX (ft-lb)	MY (ft-lb)	MZ (ft-lb)
1	10	-7	21	0	0	0	-85
	20	7	-21	0	0	0	66
2	20	-7	21	0	0	0	-66
	30A	7	-21	0	0	0	64
3	30A	-7	21	0	0	0	-64
	30B	7	-21	0	0	0	43
4	30B	-7	21	0	0	0	-43
	40	7	-21	0	0	0	12
5	40	-7	21	0	0	0	-12
	50	7	-21	0	0	0	1
6	50	-7	21	0	0	0	-1
	60A	7	-21	0	0	0	-9
7	60A	-7	21	0	0	0	9
	60B	7	-21	0	0	0	-30
8	60B	-7	21	0	0	0	30
	70A	7	-21	0	0	0	-33
9	70A	-7	21	0	0	0	33
	70B	7	-21	0	0	0	-44
10	70B	-7	21	0	0	0	44
	80	7	-21	0	0	0	-34

Support Loads on all supports by the piping for Operating Load case 1 are shown below.



#	Node	Tag	FX (lb)	FY (lb)	FZ (lb)	MX (ft-lb)	MY (ft-lb)	MZ (ft-lb)
1	10		-8	-69	0	0	0	42
2	130		8	-107	0	0	0	20

Support Load Summary (listing loads on a particular support by the piping) for all relevant load cases and load combinations) is shown below.



Load combination	FX (lb)	FY (lb)	FZ (lb)	MX (ft-lb)	MY (ft-lb)	MZ (ft-lb)
Sustained	-2	-87	0	0	0	115
Operating1	-8	-69	0	0	0	42
Operating2	5	-108	0	0	0	200
Maximum	5	-69	0	0	0	200
Minimum	-8	-108	0	0	0	42
Allowables	0	0	0	0	0	0