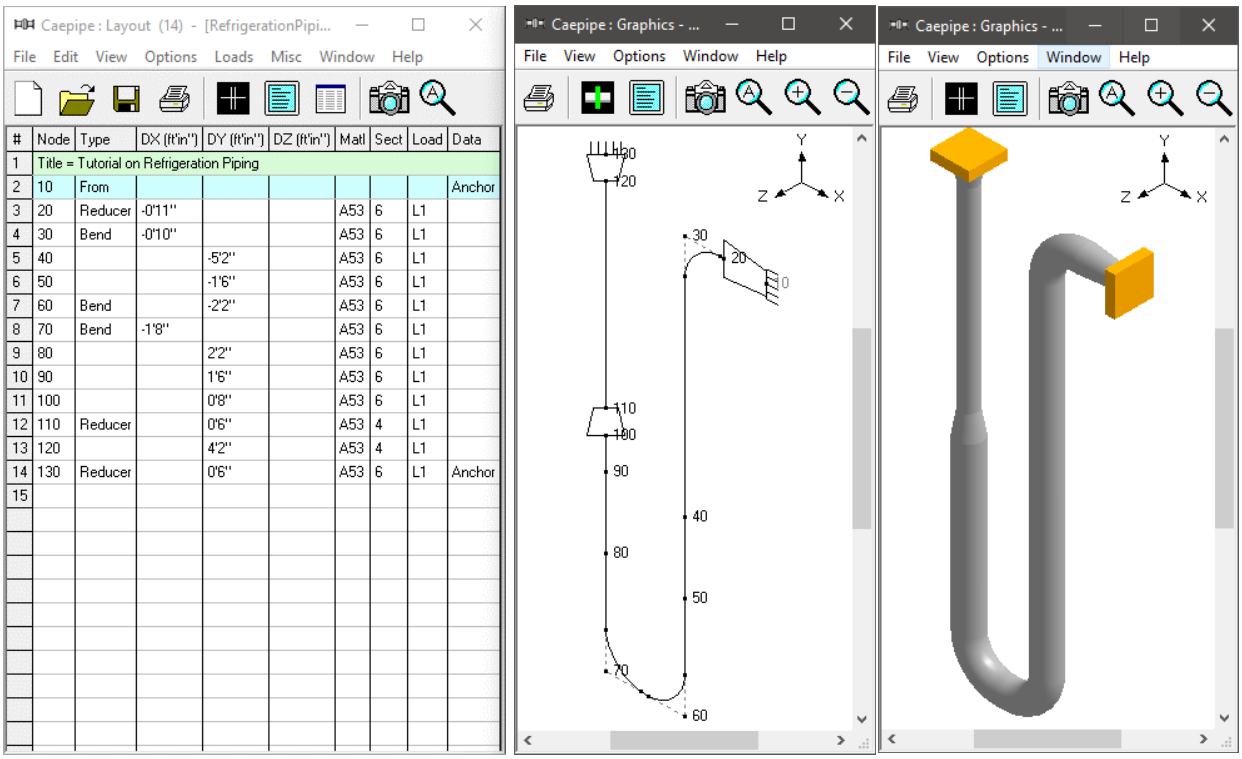
Tutorial on Refrigeration Piping using CAEPIPE

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

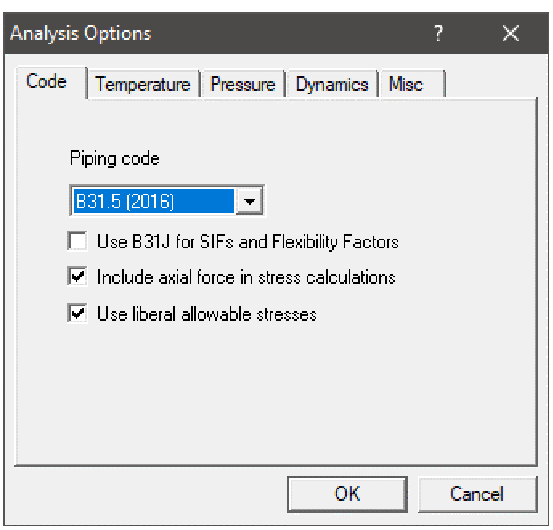
The snap shot below shows the sample layout of a refrigeration piping system. The system experiences two (2) different temperatures during its operation (from -50 deg. F to 200 deg. F) with installation temperature as 70 deg. F. Being refrigeration piping, the analysis code is selected as ASME B31.5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



#	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									

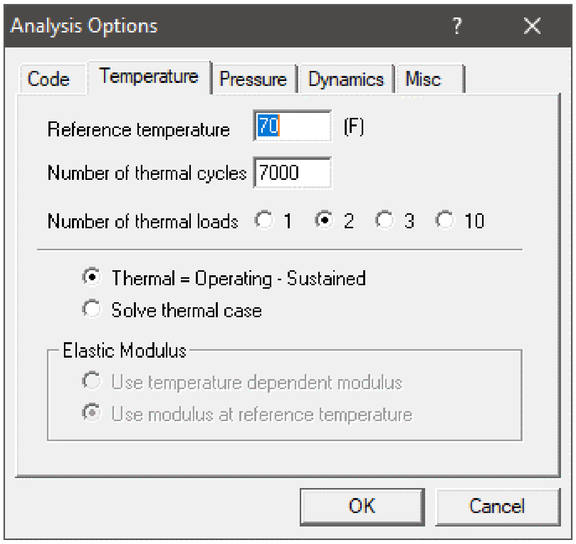
Step 1:

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.

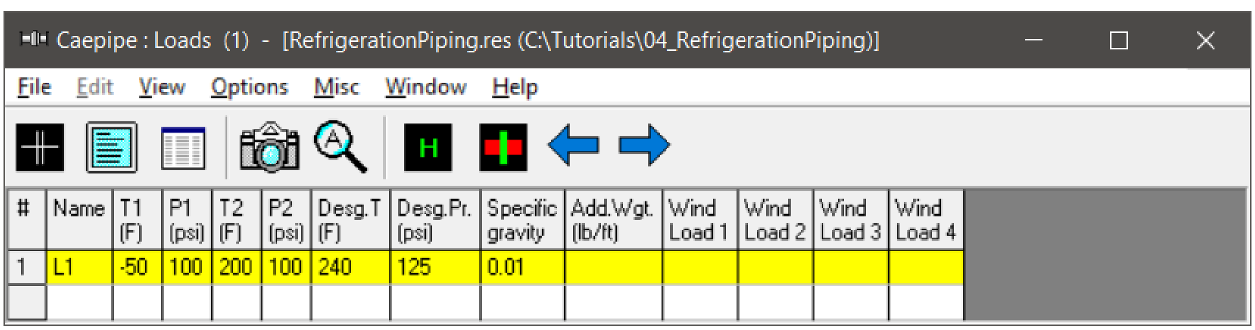


Note:

As per para. 519.4.5(a) of ASME B31.5 (2016), 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.



Note:

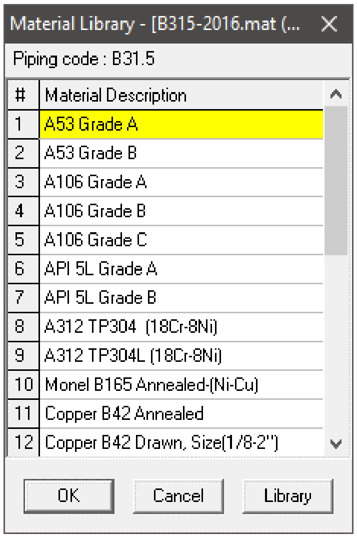
Design Temperature entered will be used to determine the allowable stress for material, which is in turn used to compute the Allowable Pressure as per the piping code selected (B31.5 in this case).

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.

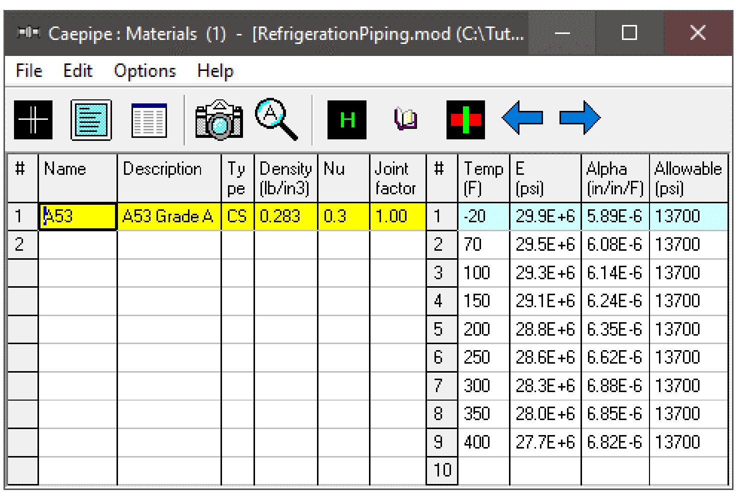
In addition, starting CAEPIPE Version 10.20, a new load case called "Design (W+PD+TD)" is added. When this load case is selected for Analysis, CAEPIPE will compute and show results for Displacements, Element Forces & Moments, Support Loads and Support Load Summary. This load cases is NOT included in Stress Calculations, Rotating Equipment Qualifications and Flange Equivalent Pressure Calculations.

Step 4:

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

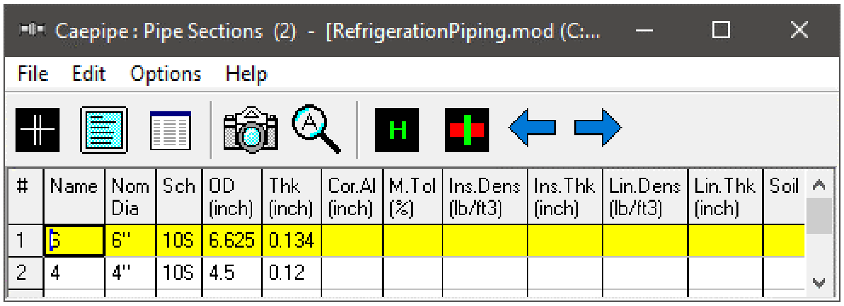


From the dialog box shown, select the Material library as B315-2016 from the folder “Material_Library” available inside the CAEPIPE installation folder. Once selected, highlight the material as shown above and press the button “OK”.



Step 5:

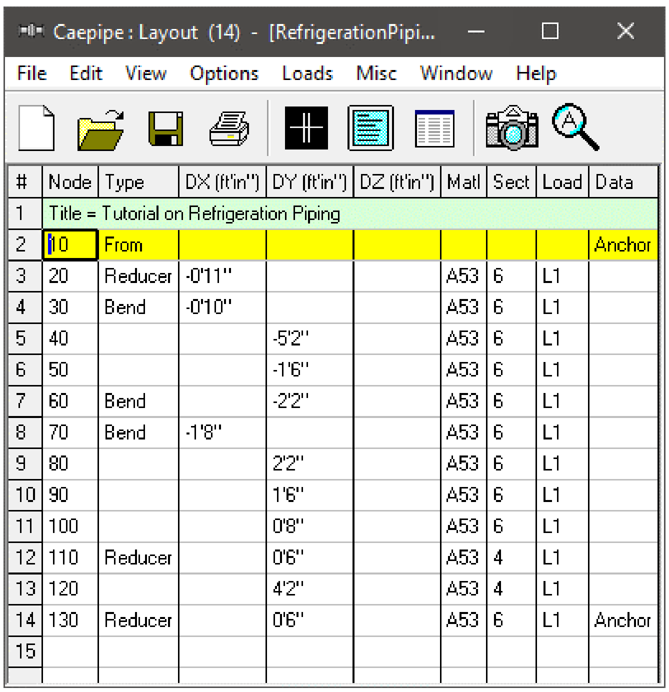
Define the section properties through “Layout Window > Misc > Sections”.



#	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.

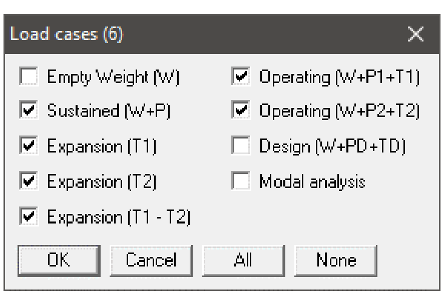


#	Node	Type	DX (ft'in")	DY (ft'in")	DZ (ft'in")	Matl	Sect	Load	Data
1	Title = Tutorial on Refrigeration Piping								
2	10	From							Anchor
3	20	Reducer	-0'11"			A53	6	L1	
4	30	Bend	-0'10"			A53	6	L1	
5	40			-5'2"		A53	6	L1	
6	50			-1'6"		A53	6	L1	
7	60	Bend		-2'2"		A53	6	L1	
8	70	Bend	-1'8"			A53	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 shown below.

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)].



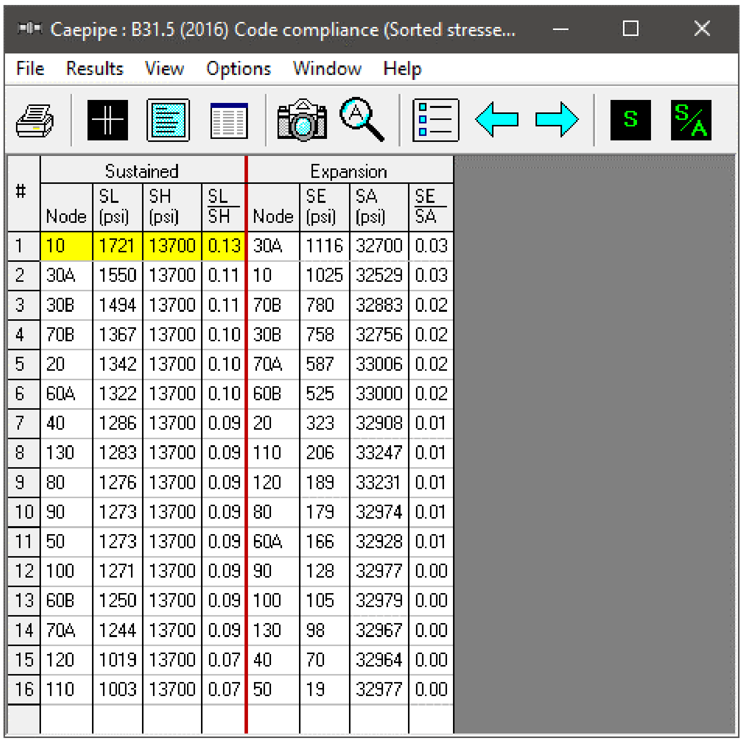
After analysis, Expansion Stress (SE) value given at any node in Results Window > Sorted stresses and Results Window > Code compliance is the highest thermal stress range at that node among the three thermal ranges (T1 – Tref), (T2 – Tref) and (T1 – T2).

Step 8:

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

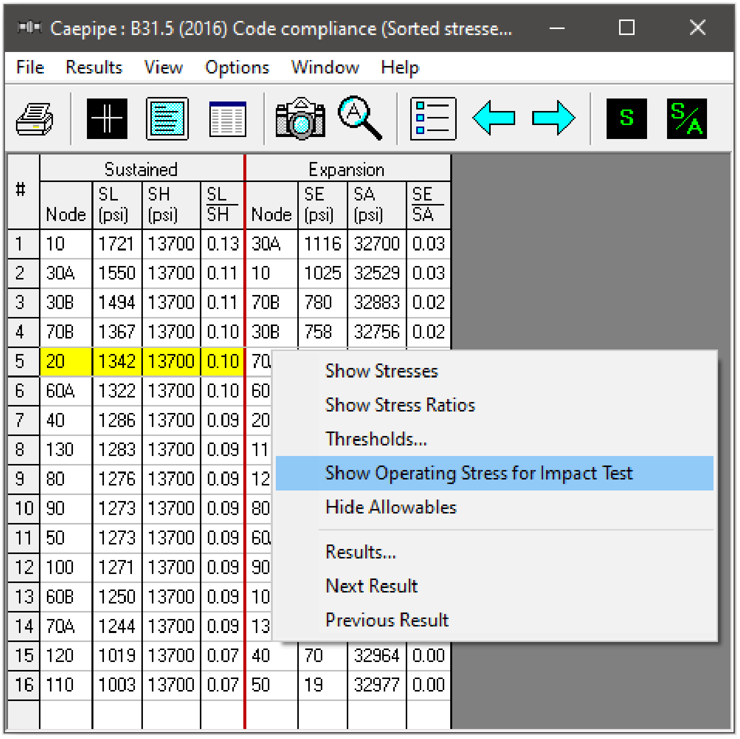
In order to understand the loads and load combinations used for analysis, review the CAEPIPE results file for Sorted Stress, Code Compliance, Displacements, Support Loads (loads acting on the supports by the piping for each load case), Element Forces & Moments (local/global forces and moments on each 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.

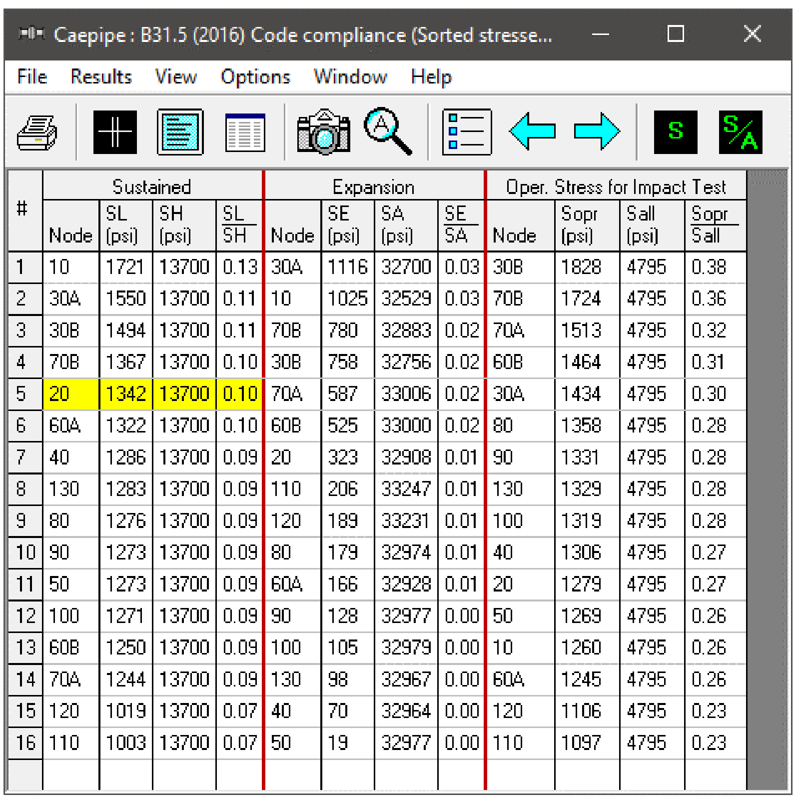


#	Sustained				Expansion			
	Node	SL (psi)	SH (psi)	SL/SH	Node	SE (psi)	SA (psi)	SE/SA
1	10	1721	13700	0.13	30A	1116	32700	0.03
2	30A	1550	13700	0.11	10	1025	32529	0.03
3	30B	1494	13700	0.11	70B	780	32883	0.02
4	70B	1367	13700	0.10	30B	758	32756	0.02
5	20	1342	13700	0.10	70A	587	33006	0.02
6	60A	1322	13700	0.10	60B	525	33000	0.02
7	40	1286	13700	0.09	20	323	32908	0.01
8	130	1283	13700	0.09	110	206	33247	0.01
9	80	1276	13700	0.09	120	189	33231	0.01
10	90	1273	13700	0.09	80	179	32974	0.01
11	50	1273	13700	0.09	60A	166	32928	0.01
12	100	1271	13700	0.09	90	128	32977	0.00
13	60B	1250	13700	0.09	100	105	32979	0.00
14	70A	1244	13700	0.09	130	98	32967	0.00
15	120	1019	13700	0.07	40	70	32964	0.00
16	110	1003	13700	0.07	50	19	32977	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	1721	13700	0.13	30A	1116	32700	0.03
2	30A	1550	13700	0.11	10	1025	32529	0.03
3	30B	1494	13700	0.11	70B	780	32883	0.02
4	70B	1367	13700	0.10	30B	758	32756	0.02
5	20	1342	13700	0.10	70			
6	60A	1322	13700	0.10	60			
7	40	1286	13700	0.09	20			
8	130	1283	13700	0.09	11			
9	80	1276	13700	0.09	12			
10	90	1273	13700	0.09	80			
11	50	1273	13700	0.09	60			
12	100	1271	13700	0.09	90			
13	60B	1250	13700	0.09	10			
14	70A	1244	13700	0.09	13			
15	120	1019	13700	0.07	40	70	32964	0.00
16	110	1003	13700	0.07	50	19	32977	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	1721	13700	0.13	30A	1116	32700	0.03	30B	1828	4795	0.38
2	30A	1550	13700	0.11	10	1025	32529	0.03	70B	1724	4795	0.36
3	30B	1494	13700	0.11	70B	780	32883	0.02	70A	1513	4795	0.32
4	70B	1367	13700	0.10	30B	758	32756	0.02	60B	1464	4795	0.31
5	20	1342	13700	0.10	70A	587	33006	0.02	30A	1434	4795	0.30
6	60A	1322	13700	0.10	60B	525	33000	0.02	80	1358	4795	0.28
7	40	1286	13700	0.09	20	323	32908	0.01	90	1331	4795	0.28
8	130	1283	13700	0.09	110	206	33247	0.01	130	1329	4795	0.28
9	80	1276	13700	0.09	120	189	33231	0.01	100	1319	4795	0.28
10	90	1273	13700	0.09	80	179	32974	0.01	40	1306	4795	0.27
11	50	1273	13700	0.09	60A	166	32928	0.01	20	1279	4795	0.27
12	100	1271	13700	0.09	90	128	32977	0.00	50	1269	4795	0.26
13	60B	1250	13700	0.09	100	105	32979	0.00	10	1260	4795	0.26
14	70A	1244	13700	0.09	130	98	32967	0.00	60A	1245	4795	0.26
15	120	1019	13700	0.07	40	70	32964	0.00	120	1106	4795	0.23
16	110	1003	13700	0.07	50	19	32977	0.00	110	1097	4795	0.23

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

Caepipe : B31.5 (2016) Code Compliance - [Refrigeratio...

File Results View Options Window Help

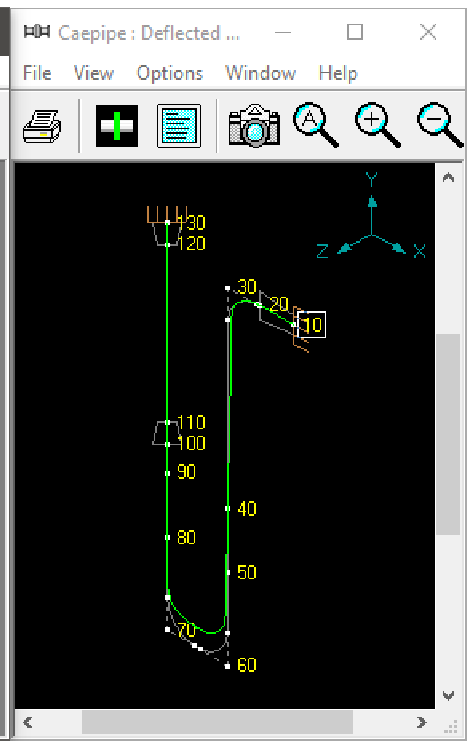
#	Node	Press. Allow. (psi)	Sustained SL (psi)	Sustained SH (psi)	Sustained SL/SH	Expansion SE (psi)	Expansion SA (psi)	Expansion SE/SA
1	10 20	125	1721 1342	13700 13700	0.13 0.10	1025 323	32529 32908	0.03 0.01
2	20 30A	125 563	1342 1324	13700 13700	0.10 0.10	323 314	32908 32926	0.01 0.01
3	30A 30B	125 563	1550 1494	13700 13700	0.11 0.11	1116 758	32700 32756	0.03 0.02
4	30B 40	125 563	1326 1286	13700 13700	0.10 0.09	221 70	32924 32964	0.01 0.00
5	40 50	125 563	1286 1273	13700 13700	0.09 0.09	70 19	32964 32977	0.00 0.00
6	50 60A	125 563	1273 1260	13700 13700	0.09 0.09	19 56	32977 32990	0.00 0.00
7	60A 60B	125 563	1322 1250	13700 13700	0.10 0.09	166 525	32928 33000	0.01 0.02
8	60B 70A	125 563	1240 1239	13700 13700	0.09 0.09	149 167	33010 33011	0.00 0.01
9	70A 70B	125 563	1244 1367	13700 13700	0.09 0.10	587 780	33006 32883	0.02 0.02
10	70B 80	125 563	1279 1276	13700 13700	0.09 0.09	227 179	32971 32974	0.01 0.01

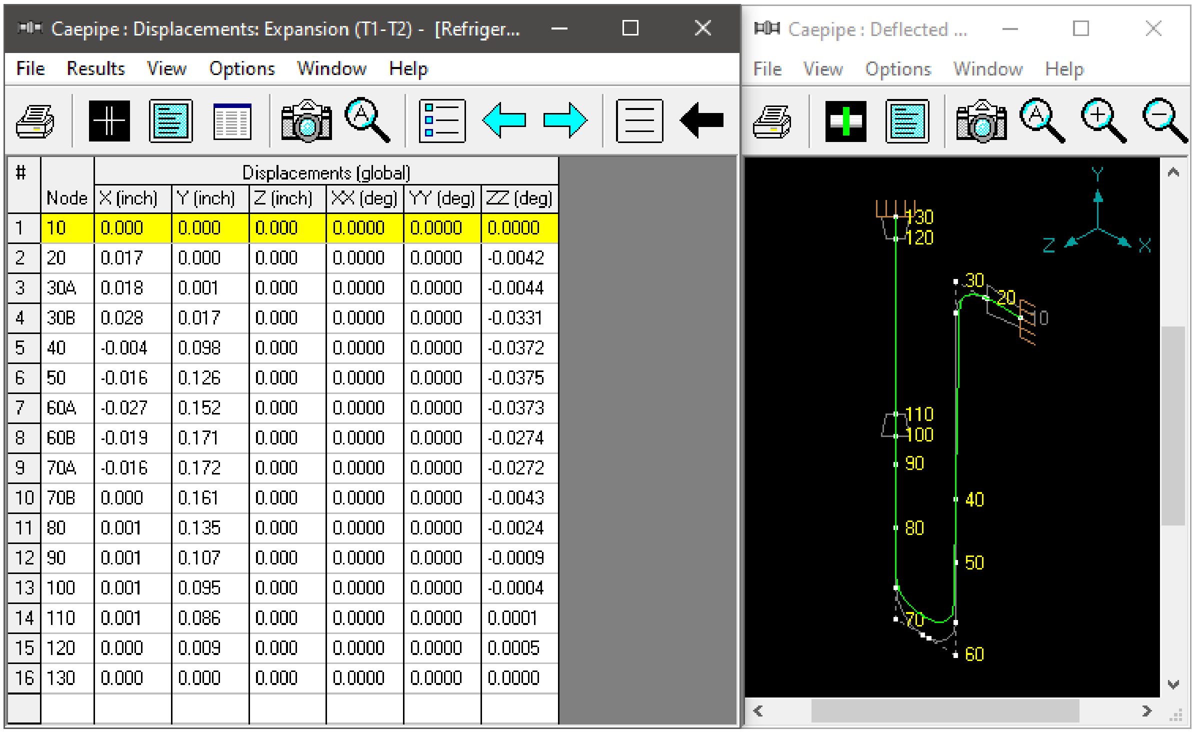
From the Displacement results for Expansion (T1) and Expansion (T1-T2), it is observed that the Displacements are +ve in Global Y direction confirming that the piping is shrinking due to temperature decrease for both expansion cases.

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

File Results 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	0.008	0.000	0.000	0.0000	0.0000	-0.0019
3	30A	0.008	0.000	0.000	0.0000	0.0000	-0.0020
4	30B	0.013	0.008	0.000	0.0000	0.0000	-0.0151
5	40	-0.002	0.044	0.000	0.0000	0.0000	-0.0170
6	50	-0.007	0.057	0.000	0.0000	0.0000	-0.0171
7	60A	-0.013	0.069	0.000	0.0000	0.0000	-0.0171
8	60B	-0.009	0.077	0.000	0.0000	0.0000	-0.0125
9	70A	-0.007	0.078	0.000	0.0000	0.0000	-0.0124
10	70B	0.000	0.073	0.000	0.0000	0.0000	-0.0019
11	80	0.000	0.061	0.000	0.0000	0.0000	-0.0011
12	90	0.001	0.049	0.000	0.0000	0.0000	-0.0004
13	100	0.001	0.043	0.000	0.0000	0.0000	-0.0001
14	110	0.001	0.039	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

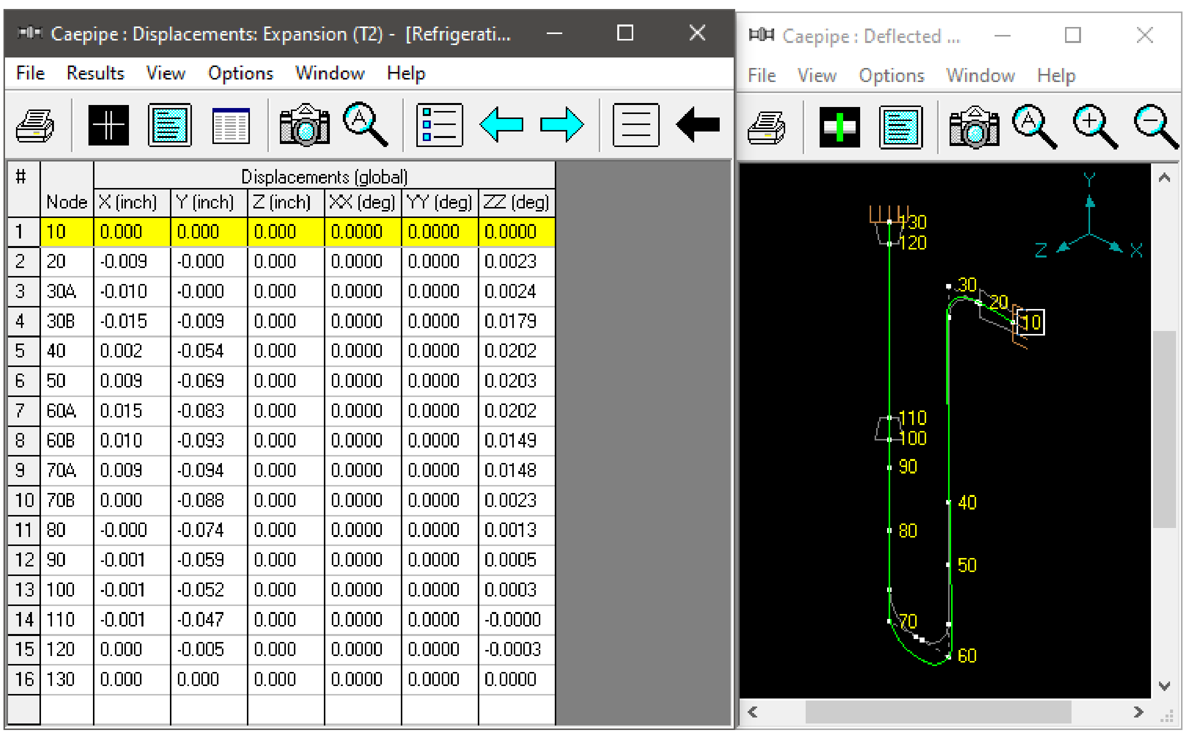




Caepipe : Displacements: Expansion (T1-T2) - [Refriger...

#	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	0.017	0.000	0.000	0.0000	0.0000	-0.0042
3	30A	0.018	0.001	0.000	0.0000	0.0000	-0.0044
4	30B	0.028	0.017	0.000	0.0000	0.0000	-0.0331
5	40	-0.004	0.098	0.000	0.0000	0.0000	-0.0372
6	50	-0.016	0.126	0.000	0.0000	0.0000	-0.0375
7	60A	-0.027	0.152	0.000	0.0000	0.0000	-0.0373
8	60B	-0.019	0.171	0.000	0.0000	0.0000	-0.0274
9	70A	-0.016	0.172	0.000	0.0000	0.0000	-0.0272
10	70B	0.000	0.161	0.000	0.0000	0.0000	-0.0043
11	80	0.001	0.135	0.000	0.0000	0.0000	-0.0024
12	90	0.001	0.107	0.000	0.0000	0.0000	-0.0009
13	100	0.001	0.095	0.000	0.0000	0.0000	-0.0004
14	110	0.001	0.086	0.000	0.0000	0.0000	0.0001
15	120	0.000	0.009	0.000	0.0000	0.0000	0.0005
16	130	0.000	0.000	0.000	0.0000	0.0000	0.0000

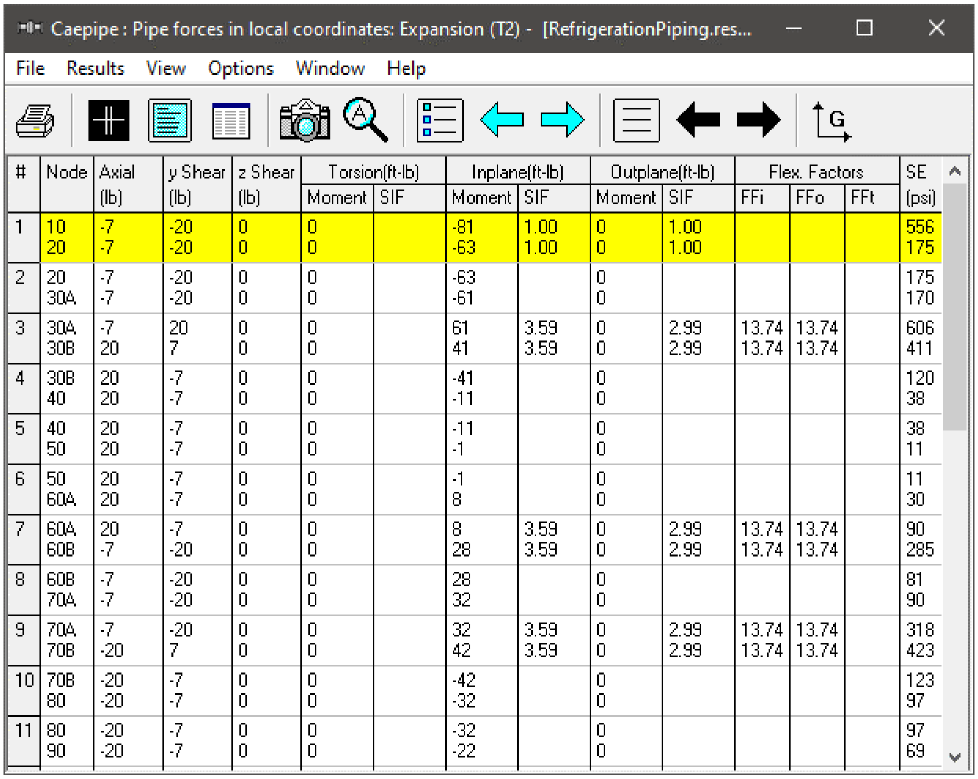
Similarly, from the Displacement results for Expansion (T2), it is observed that the Displacements are -ve in Global Y direction confirming that the piping is expanding downward due to temperature increase.



Caepipe : Displacements: Expansion (T2) - [Refrigerati...

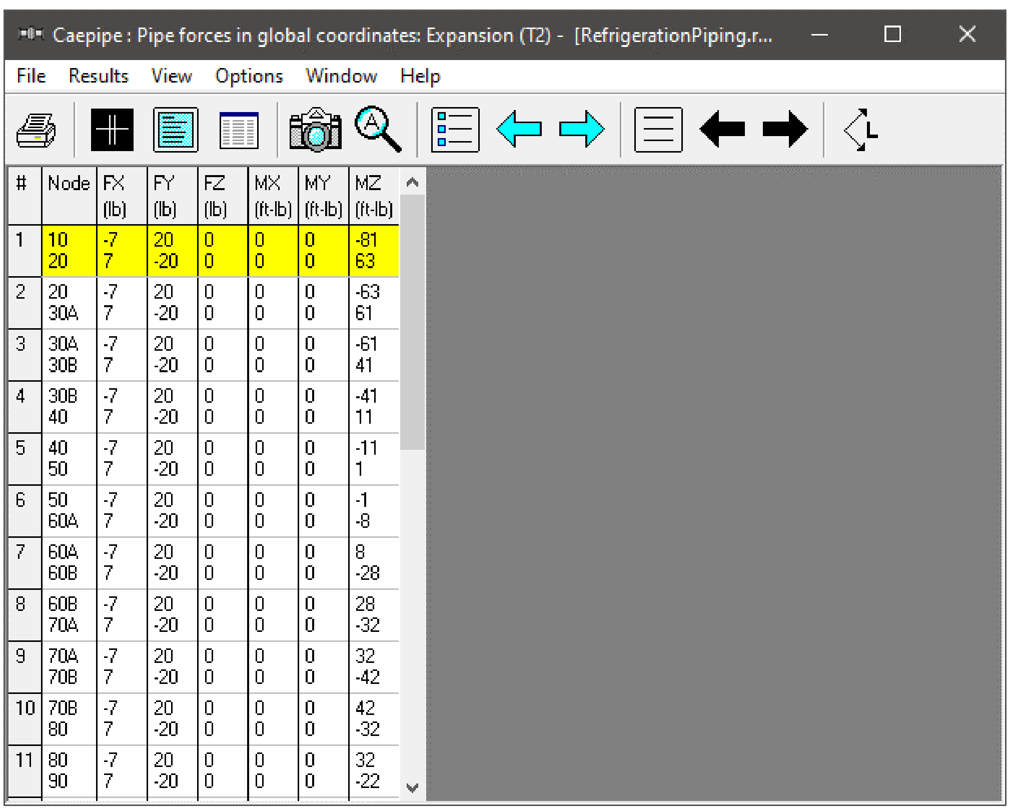
#	Node	Displacements (global)					
		X (inch)	Y (inch)	Z (inch)	XX (deg)	YY (deg)	ZZ (deg)
1	10	0.000	0.000	0.000	0.0000	0.0000	0.0000
2	20	-0.009	-0.000	0.000	0.0000	0.0000	0.0023
3	30A	-0.010	-0.000	0.000	0.0000	0.0000	0.0024
4	30B	-0.015	-0.009	0.000	0.0000	0.0000	0.0179
5	40	0.002	-0.054	0.000	0.0000	0.0000	0.0202
6	50	0.009	-0.069	0.000	0.0000	0.0000	0.0203
7	60A	0.015	-0.083	0.000	0.0000	0.0000	0.0202
8	60B	0.010	-0.093	0.000	0.0000	0.0000	0.0149
9	70A	0.009	-0.094	0.000	0.0000	0.0000	0.0148
10	70B	0.000	-0.088	0.000	0.0000	0.0000	0.0023
11	80	-0.000	-0.074	0.000	0.0000	0.0000	0.0013
12	90	-0.001	-0.059	0.000	0.0000	0.0000	0.0005
13	100	-0.001	-0.052	0.000	0.0000	0.0000	0.0003
14	110	-0.001	-0.047	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.



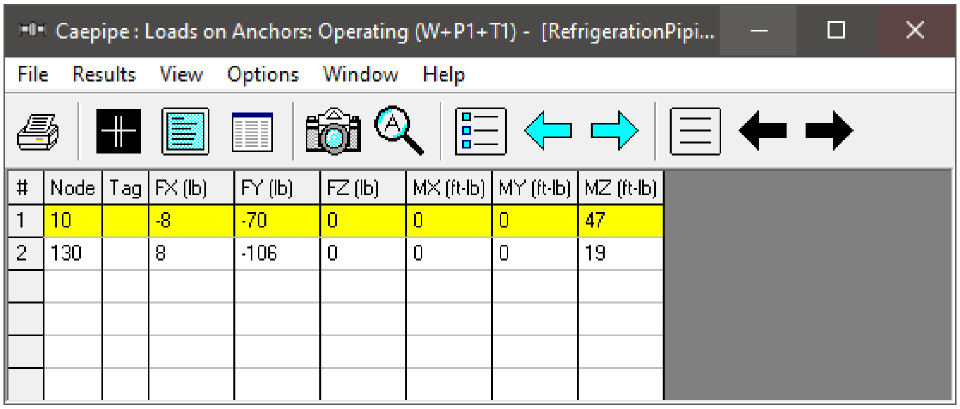
#	Node	Axial (lb)	y Shear (lb)	z Shear (lb)	Torsion(ft-lb) Moment	Torsion(ft-lb) SIF	Inplane(ft-lb) Moment	Inplane(ft-lb) SIF	Outplane(ft-lb) Moment	Outplane(ft-lb) SIF	Flex. Factors FFi	Flex. Factors FFo	Flex. Factors FFt	SE (psi)
1	10 20	-7 -7	-20 -20	0 0	0 0		-81 -63	1.00 1.00	0 0	1.00 1.00				556 175
2	20 30A	-7 -7	-20 -20	0 0	0 0		-63 -61		0 0					175 170
3	30A 30B	-7 20	20 7	0 0	0 0		61 41	3.59 3.59	0 0	2.99 2.99	13.74 13.74	13.74 13.74		606 411
4	30B 40	20 20	-7 -7	0 0	0 0		-41 -11		0 0					120 38
5	40 50	20 20	-7 -7	0 0	0 0		-11 -1		0 0					38 11
6	50 60A	20 20	-7 -7	0 0	0 0		-1 8		0 0					11 30
7	60A 60B	20 -7	-7 -20	0 0	0 0		8 28	3.59 3.59	0 0	2.99 2.99	13.74 13.74	13.74 13.74		90 285
8	60B 70A	-7 -7	-20 -20	0 0	0 0		28 32		0 0					81 90
9	70A 70B	-7 -20	-20 7	0 0	0 0		32 42	3.59 3.59	0 0	2.99 2.99	13.74 13.74	13.74 13.74		318 423
10	70B 80	-20 -20	-7 -7	0 0	0 0		-42 -32		0 0					123 97
11	80 90	-20 -20	-7 -7	0 0	0 0		-32 -22		0 0					97 69

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



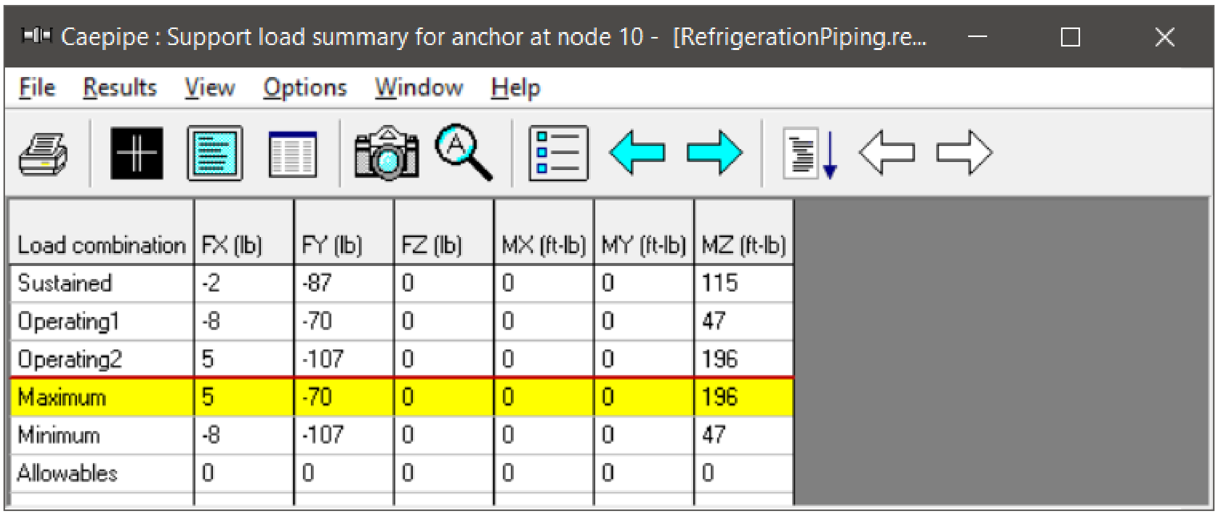
#	Node	FX (lb)	FY (lb)	FZ (lb)	MX (ft-lb)	MY (ft-lb)	MZ (ft-lb)
1	10 20	-7 7	20 -20	0 0	0 0	0 0	-81 63
2	20 30A	-7 7	20 -20	0 0	0 0	0 0	-63 61
3	30A 30B	-7 7	20 -20	0 0	0 0	0 0	-61 41
4	30B 40	-7 7	20 -20	0 0	0 0	0 0	-41 11
5	40 50	-7 7	20 -20	0 0	0 0	0 0	-11 1
6	50 60A	-7 7	20 -20	0 0	0 0	0 0	-1 -8
7	60A 60B	-7 7	20 -20	0 0	0 0	0 0	8 -28
8	60B 70A	-7 7	20 -20	0 0	0 0	0 0	28 -32
9	70A 70B	-7 7	20 -20	0 0	0 0	0 0	32 -42
10	70B 80	-7 7	20 -20	0 0	0 0	0 0	42 -32
11	80 90	-7 7	20 -20	0 0	0 0	0 0	32 -22

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	-70	0	0	0	47
2	130		8	-106	0	0	0	19

Support Load Summary (listing loads on a particular support by the piping) for all <u>relevant</u> 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	-70	0	0	0	47
Operating2	5	-107	0	0	0	196
Maximum	5	-70	0	0	0	196
Minimum	-8	-107	0	0	0	47
Allowables	0	0	0	0	0	0