Tutorial on Analysis with Multiple Thermal Loads using CAEPIPE

General

The Reference Temperature (can be defined through Layout window > Options > Analysis" is "the ambient temperature at which the pipe is to be/was initially installed". In other words, when the whole piping system is at Reference Temperature, the piping system is "stress free" and the involved pipe supports are "loads free", as long as there are NO cold springs introduced during the installation of the system. There is no need to input Reference Pressure, as at installation the pressure is zero.

T1, T2 etc. (tuned ON through the "Layout window > Loads > Load cases") refer to the temperatures prevailing during different operational states of the piping system. Please note that the value of T1 for the first operational state could be different for different portions of the piping system. In other words, you could input multiple values for T1 (by having at least that many "Loads") corresponding to different portions of the piping. In addition, the same element in the piping system can experience different temperatures T1, T2, T3 etc. during different operational states.

Hence, the Expansion (T1) case in the Results lists the "Range Solution" obtained for the temperature range from Reference Temperature to T1 [i.e., (T1 – Tref)], similarly for Expansion (T2), and so on. The Expansion (T1-T2) case in the Results lists the "Range Solution" obtained for the temperature range from T1 to T2, which is internally computed as [(T1 - Tref) – (T2 – Tref)], similarly for Expansion (T1-T3) and so on.

For the operating (W+P1+T1) case, CAEPIPE considers the weight, the pressure P1 corresponding to T1 and the expansion from Tref to T1.

The following are the Steps for performing Analysis with Multiple Thermal loads in CAEPIPE.

The attached stress system shows the layout of four (4) pipelines. These pipelines are connected to five (5) centrifugal pumps at one end (with one of them being the Spare) and four (4) tanks at the other end. Out of those 5 centrifugal pumps, Pump 2 is the Spare and will turn into operation when one of the other 4 pumps fails. In other words, at any point in time, 4 pumps are operating with 1 pump either on standby or not operational. To represent these, the following thermal load cases are required (see the attached model).

Cases	Description
Case 1	Pump 2 (the Spare) is "OFF" and the remaining Pumps are "ON"
Case 2	Pump 1 is "OFF" and the remaining Pumps (including Spare) are "ON"
Case 3	Pump 3 is "OFF" and the remaining Pumps (including Spare) are "ON"
Case 4	Pump 4 is "OFF" and the remaining Pumps (including Spare) are "ON"
Case 5	Pump 5 is "OFF" and the remaining Pumps (including Spare) are "ON"

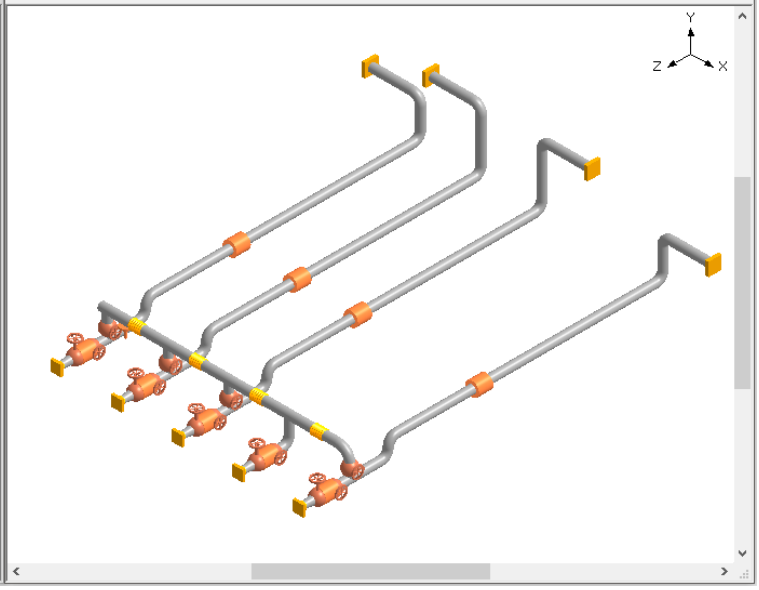
Caepipe : Layout (186) - [MultipleThermalLoads.mod (C:...

File Edit View Options Loads Misc Window Help

#	Node	Type	DX (ft'in")	DY (ft'in")	DZ (ft'in")	Matl	Sect	Load	Data
1	Title = Multiple Thermal Loads								
2									
3	References:								
4	Coordinate System :								
5	X = East = 0 deg; Y = Up ; Z = South = 270 Deg								
6									
7	From Pump 1								
8	10	From		64.9400					Anchor
9	10	Location							Flange
10	20	Bellows			-0'9"	A778	12	C2	Flange
11	25				-0'4-1/2"	A778	12	C2	
12	30	Reducer			-1'2"	A778	16	C2	
13	35				-0.4160	A778	16	C2	
14	35	Location							Flange
15	Dual Disc Wafer Style Check Valve								
16	Weight = 242 lb, Valve Length = 7.5"								
17	40	Valve			-0'7-1/2"	A778	16	C2	Flange
18	Guide Support								
19	50				-1.0900	A778	16	C2	Guide
20	60				-1.0900	A778	16	C2	Flange
21	Wafer Type Butterfly Valve								
22	Weight = 117 lb, Handle Length = 15.75"								
23	70	Valve			-0'3-1/2"	A778	16	CHL	
24	70	Location							Flange
25	80				-2.5570	A778	16	CHL	Welding tee
26	90	Bend			-6.3330	A778	16	CHL	
27	100	Bend		2.6700		A778	16	CHL	

Caepipe : Graphics - [MultipleThermalLoads.mod (C:\Tutorials\MultipleThermalLoads)]

File View Options Window Help



Caepipe : Pipe Sections (3) - [MultipleThermalLoads.mod (C:\Tutorials...

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#	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	16	16"	10S	16	0.188	0.04	12.5					
2	12	12"	10S	12.75	0.18	0.04	12.5					
3	6	6"	10S	6.625	0.134	0.04	12.5					
4												

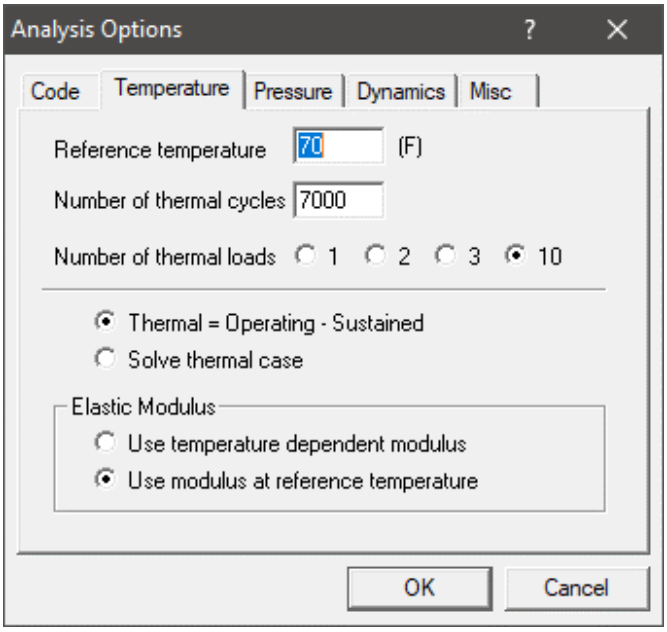
Caepipe : Materials (1) - [MultipleThermalLoads.mod (C:\Tu...

File Edit View Options Misc Window Help

#	Name	Description	Type	Density (lb/in3)	Nu	Joint factor	#	Temp (F)	E (psi)	Alpha (in/in/F)	Allowable (psi)
1	A778	A312 TP316L	AS	0.290	0.3	1.00	1	-20	28.7E+6	8.27E-6	16700
2							2	100	28.1E+6	8.59E-6	16700
							3	200	27.5E+6	8.90E-6	14200
							4	300	27.0E+6	9.20E-6	12700
							5	400	26.4E+6	9.50E-6	11700
							6	500	25.9E+6	9.70E-6	10900
							7	600	25.3E+6	9.90E-6	10400
							8	650	25.0E+6	9.90E-6	10200
							9	700	24.8E+6	10.00E-6	10000
							10	750	24.5E+6	10.05E-6	9800
							11	800	24.1E+6	10.10E-6	9600
							12	850	23.8E+6	10.15E-6	9400
							13	900	23.5E+6	10.20E-6	9200
							14	950	23.1E+6	10.25E-6	9000
							15	1000	22.8E+6	10.30E-6	8800
							16	1050	22.4E+6	10.35E-6	8600
							17	1100	22.0E+6	10.40E-6	8400
							18	1150	21.6E+6	10.50E-6	8300
							19	1200	21.2E+6	10.60E-6	6400
							20				

Step 1:

The above cases can be defined in CAEPIPE by defining the "Number of Thermal loads" as 10 through Layout window > Options > Analysis > Temperature.



Step 2:

Define the Pressures and Temperatures for different operating cases described above through CAEPIPE Layout window > Misc > Loads. Description corresponding to Loads C1 through CHL is given in the table below for clarity.

Cases	Description	Pressures and Temperatures
Case 1	Spare Pump at Node 1010 is "OFF" and the remaining Pumps are "ON"	For C1, T1 = 70 degF; P1 = 0 psi. For others (C2 through C5), T1 = 250 degF and P1 = 10.1 psi
Case 2	Pump 1 at Node 10 is "OFF" and the remaining Pumps are "ON"	For C2, T2 = 70 degF; P2 = 0 psi. For others, T2 = 250 degF and P2 = 10.1 psi
Case 3	Pump 2 at Node 2010 is "OFF" and the remaining Pumps are "ON"	For C3, T3 = 70 degF; P3 = 0 psi. For others, T3 = 250 degF and P3 = 10.1 psi
Case 4	Pump 3 at Node 3010 is "OFF" and the remaining Pumps are "ON"	For C4, T4 = 70 degF; P4 = 0 psi. For others, T4 = 250 degF and P4 = 10.1 psi
Case 5	Pump 4 at Node 4010 is "OFF" and the remaining Pumps are "ON"	For C5, T5 = 70 degF; P5 = 0 psi. For others, T5 = 250 degF and P5 = 10.1 psi
Load with name "CHL" is defined to represent the portion of the piping that are always HOT irrespective of which pump is OFF. Hence, the T1 through T5 is 250 deg F and P1 through P5 is 10.1 psi. The Load cases and Load combinations defined in the model can be seen using Layout window > Misc > Loads and Layout Window > Loads > Load cases respectively.		

Define the loads C1 through CHL as shown in the snap shot below.

Caepipe : Loads (6) - [MultipleThermalLoads.mod (C:\Tutorials\03_MultipleThermalLoads)]

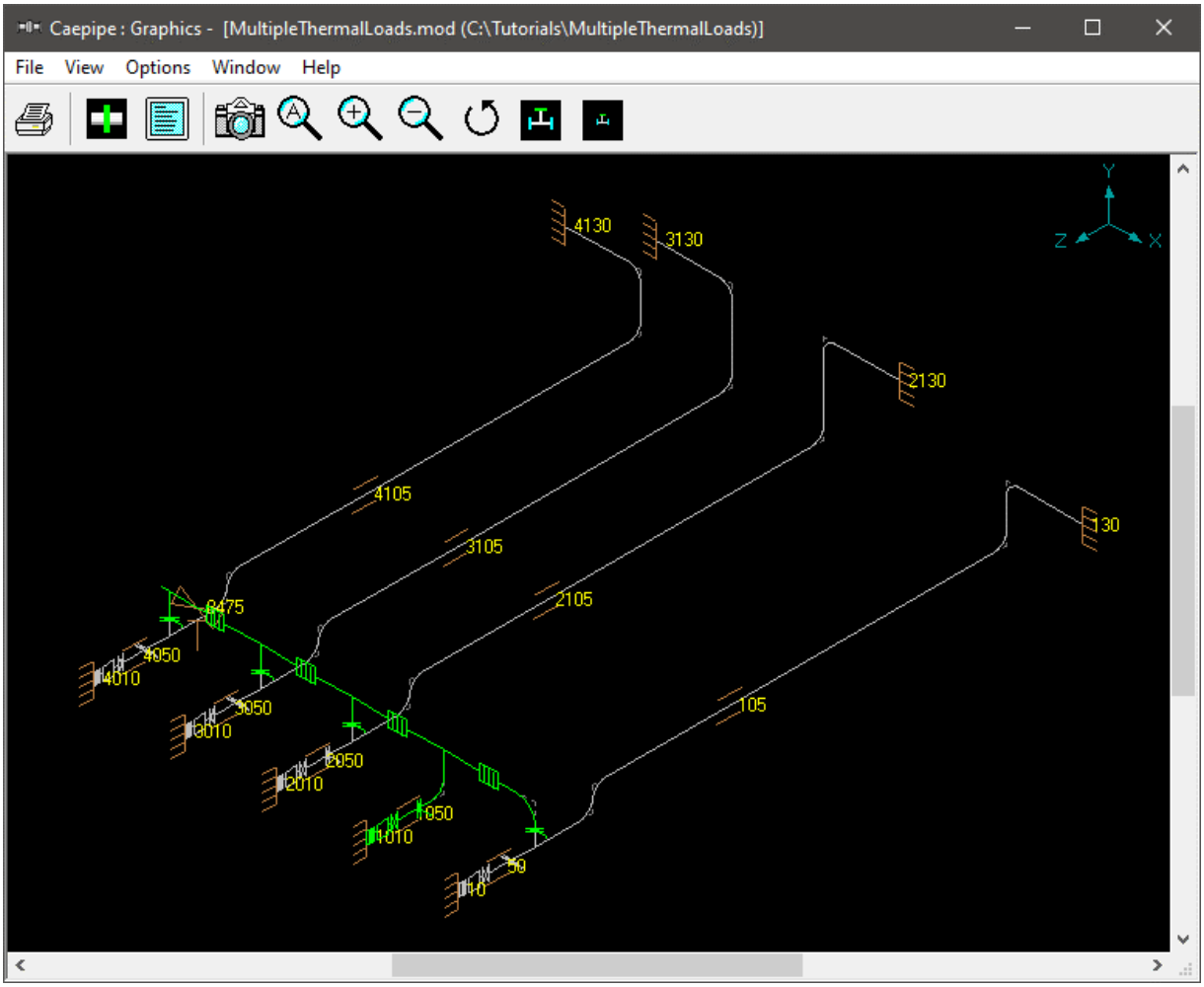
File Edit View Options Misc Window Help

#	Name	T1 (F)	P1 (psi)	T2 (F)	P2 (psi)	T3 (F)	P3 (psi)	T4 (F)	P4 (psi)	T5 (F)	P5 (psi)	T6 (F)	P6 (psi)	T7 (F)	P7 (psi)	T8 (F)	P8 (psi)	T9 (F)	P9 (psi)	T10 (F)	P10 (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	C1	70	0	250	10.1	250	10.1	250	10.1	250	10.1	70	0	70	0	70	0	70	0	70	0	250	10.1	0.01					
2	C2	250	10.1	70	0	250	10.1	250	10.1	250	10.1	70	0	70	0	70	0	70	0	70	0	250	10.1	0.01					
3	C3	250	10.1	250	10.1	70	0	250	10.1	250	10.1	70	0	70	0	70	0	70	0	70	0	250	10.1	0.01					
4	C4	250	10.1	250	10.1	250	10.1	70	0	250	10.1	70	0	70	0	70	0	70	0	70	0	250	10.1	0.01					
5	C5	250	10.1	250	10.1	250	10.1	250	10.1	70	0	70	0	70	0	70	0	70	0	70	0	250	10.1	0.01					
6	CHL	250	10.1	250	10.1	250	10.1	250	10.1	250	10.1	70	0	70	0	70	0	70	0	70	0	250	10.1	0.01					
7																													

Step 3:

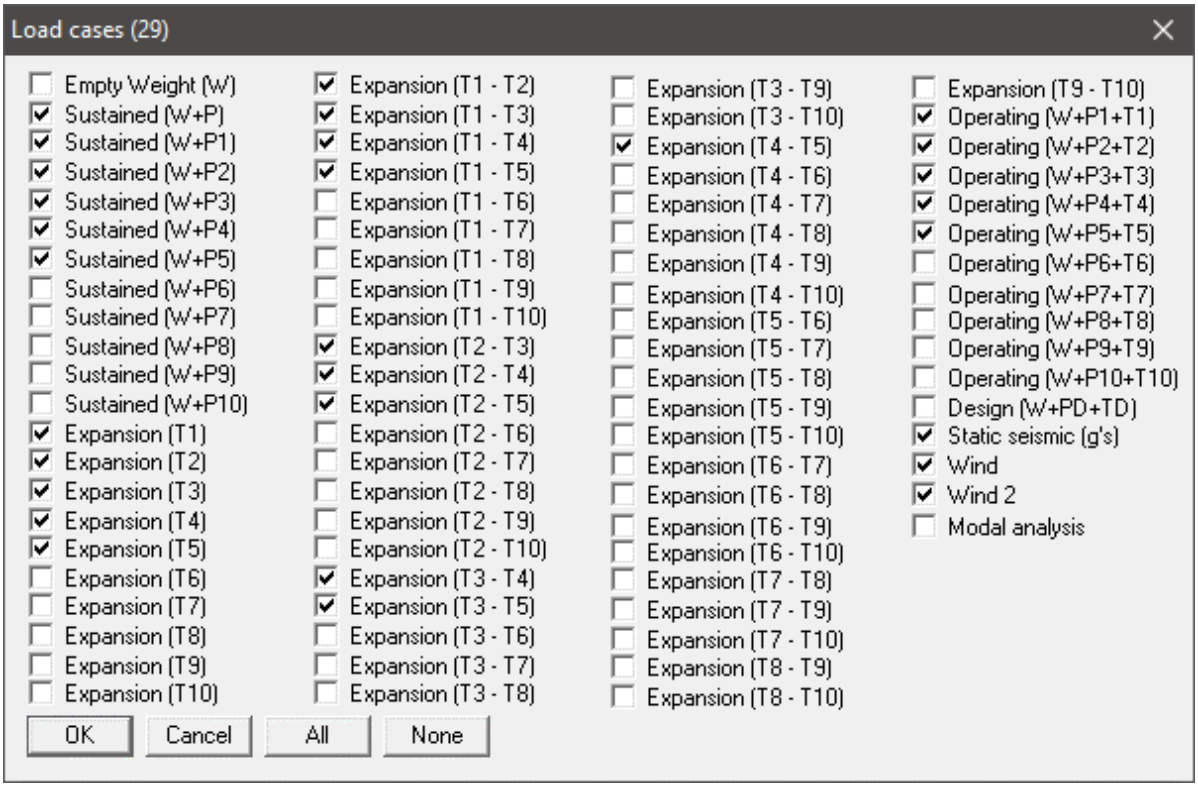
Assign the Loads C1 through CHL to different portions of stress system as required while creating the stress layout. After modeling the stress system, one can review the loads assigned to different portions using the Highlight feature through “Loads List window”.

From the attached model, to review the loads assigned, place the highlight on each load (C1 through CHL) and press “Ctrl+H” or select option “Highlight” under List window >View to highlight only that portion of the model that is using that specific load. The snap shot below highlight only that portion of the model that is using the Load C1.



Step 4:

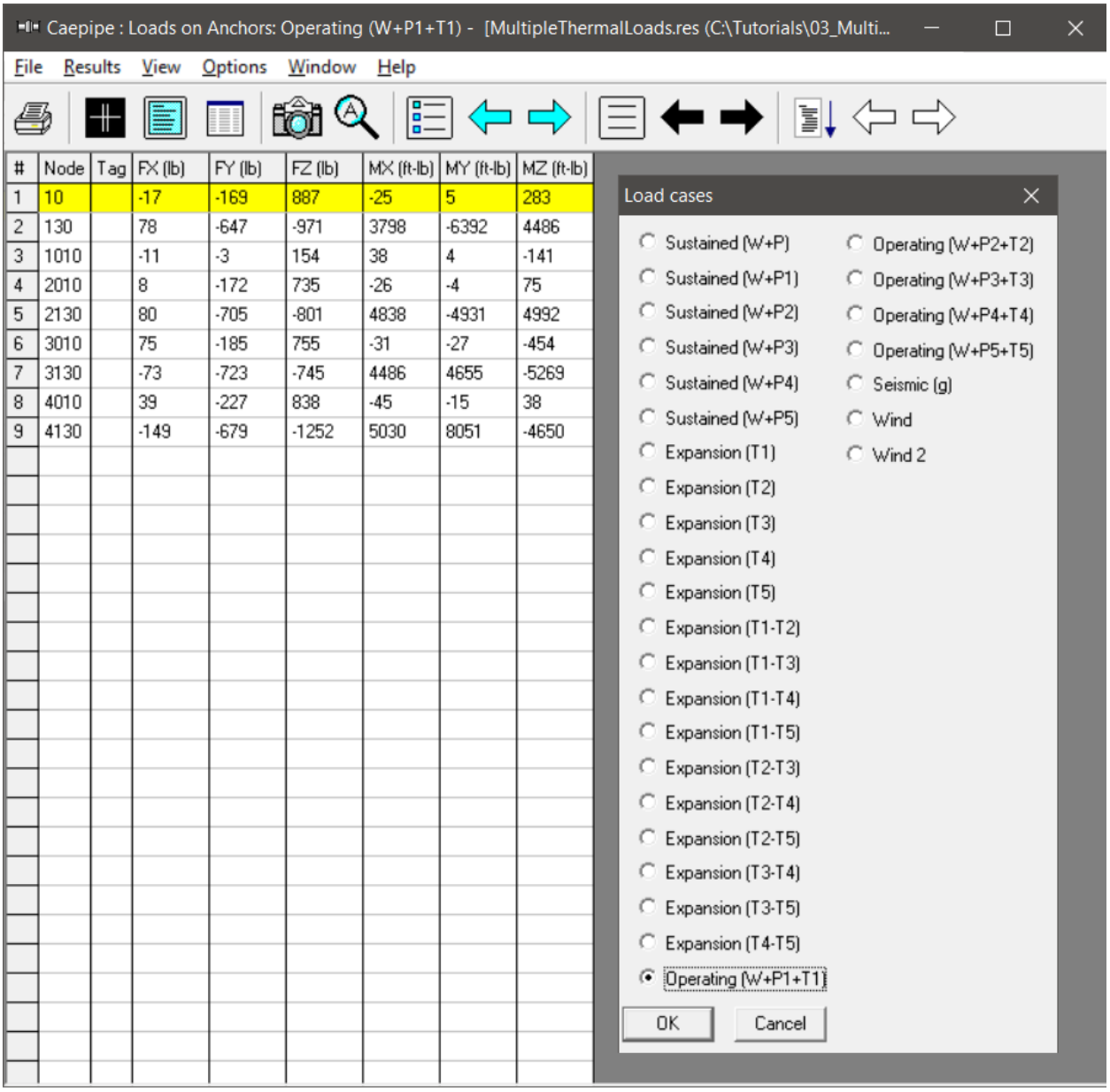
Select the load cases and load combinations required for analysis through Layout window > Loads > Load cases.

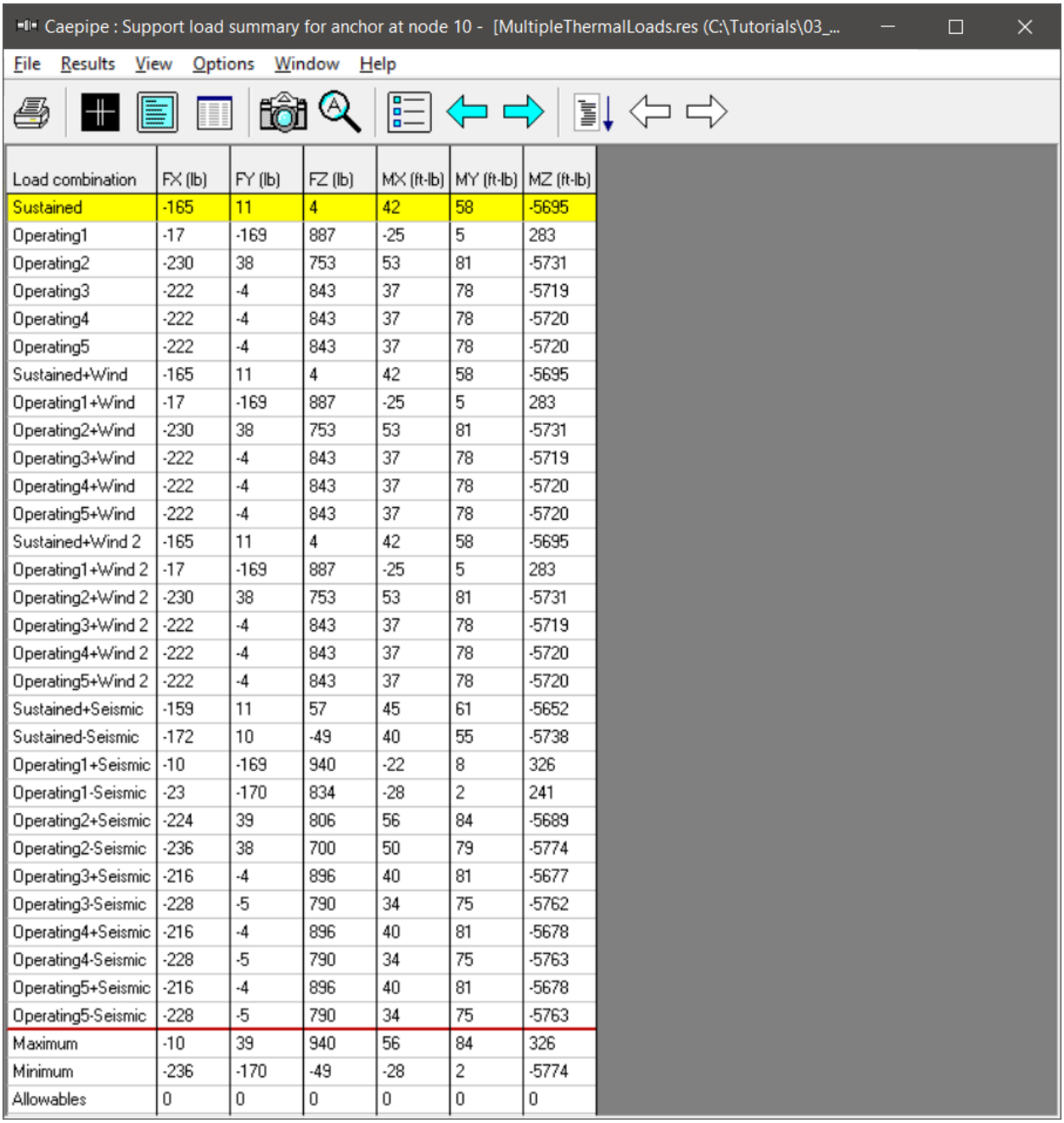


Step 5:

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

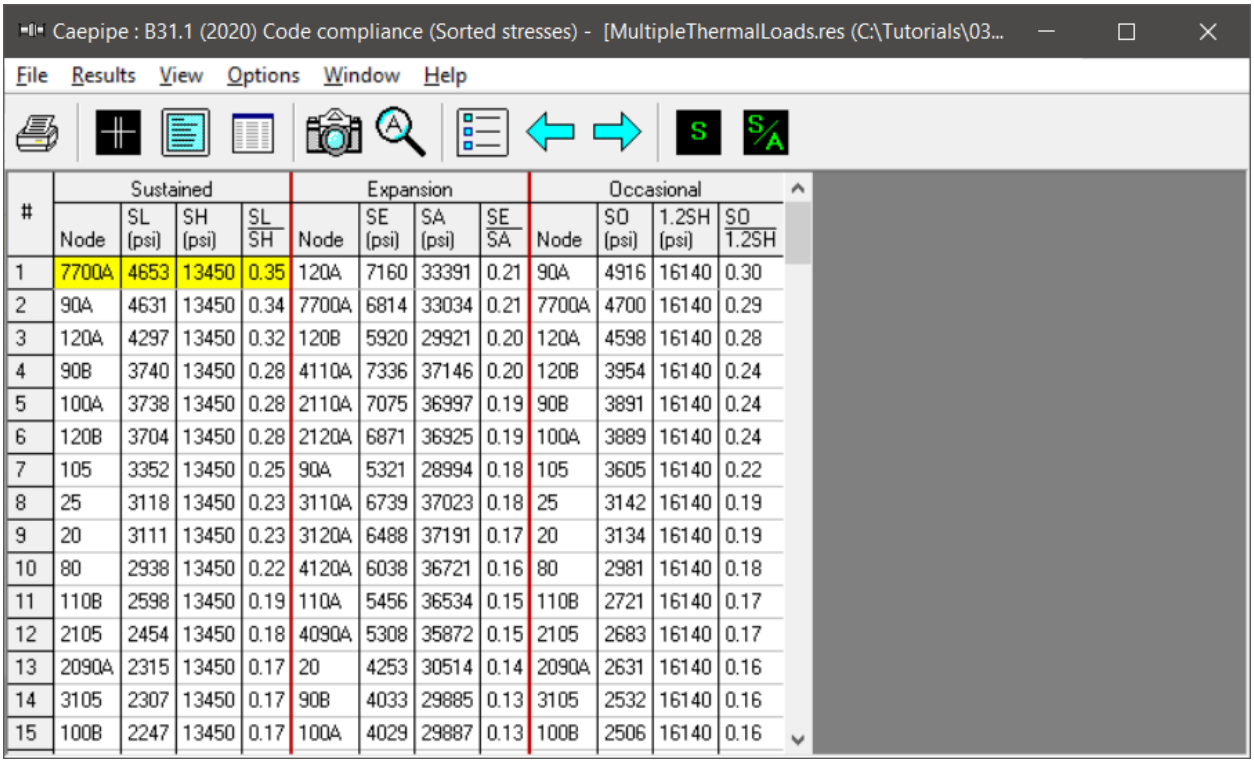
In order to understand the loads and load combinations used for analysis, review the CAEPIPE results file for Support Loads (loads acting on the supports by the piping for each load case), Element Forces & Moments (local/global forces and moments on each element for each load case) and Support Load Summary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


Caepipe : Loads on Anchors: Operating (W+P1+T1) - [MultipleThermalLoads.res (C:\Tutorials\03_Multi...
File Results View Options Window Help
Node Tag FX (lb) FY (lb) FZ (lb) MX (ft-lb) MY (ft-lb) MZ (ft-lb)
1 10 -17 -169 887 -25 5 283
2 130 78 -647 -971 3798 -6392 4486
3 1010 -11 -3 154 38 4 -141
4 2010 8 -172 735 -26 -4 75
5 2130 80 -705 -801 4838 -4931 4992
6 3010 75 -185 755 -31 -27 -454
7 3130 -73 -723 -745 4486 4655 -5269
8 4010 39 -227 838 -45 -15 38
9 4130 -149 -679 -1252 5030 8051 -4650
Load cases
Sustained (W+P)
Sustained (W+P1)
Sustained (W+P2)
Sustained (W+P3)
Sustained (W+P4)
Sustained (W+P5)
Expansion (T1)
Expansion (T2)
Expansion (T3)
Expansion (T4)
Expansion (T5)
Expansion (T1-T2)
Expansion (T1-T3)
Expansion (T1-T4)
Expansion (T1-T5)
Expansion (T2-T3)
Expansion (T2-T4)
Expansion (T2-T5)
Expansion (T3-T4)
Expansion (T3-T5)
Expansion (T4-T5)
Operating (W+P1+T1)
Operating (W+P2+T2)
Operating (W+P3+T3)
Operating (W+P4+T4)
Operating (W+P5+T5)
Seismic (g)
Wind
Wind 2
OK
Cancel



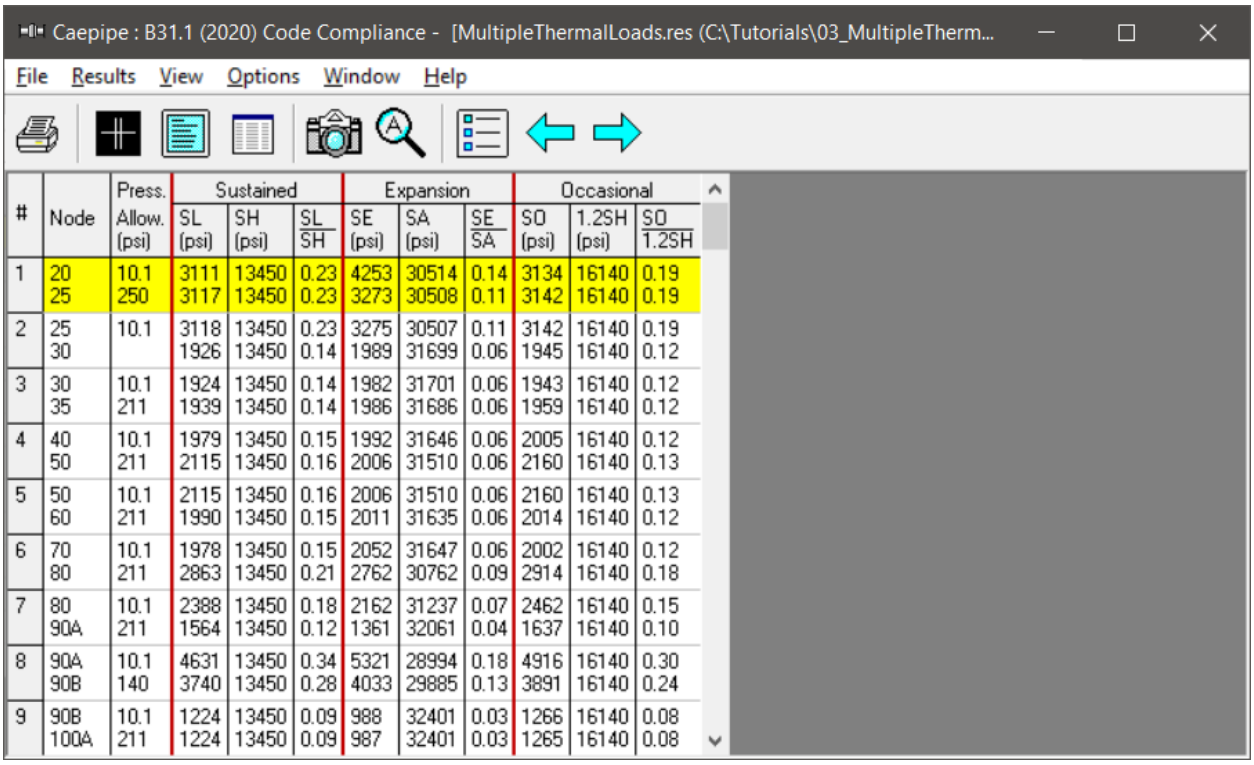
Load combination	FX (lb)	FY (lb)	FZ (lb)	MX (ft-lb)	MY (ft-lb)	MZ (ft-lb)
Sustained	-165	11	4	42	58	-5695
Operating1	-17	-169	887	-25	5	283
Operating2	-230	38	753	53	81	-5731
Operating3	-222	-4	843	37	78	-5719
Operating4	-222	-4	843	37	78	-5720
Operating5	-222	-4	843	37	78	-5720
Sustained+Wind	-165	11	4	42	58	-5695
Operating1+Wind	-17	-169	887	-25	5	283
Operating2+Wind	-230	38	753	53	81	-5731
Operating3+Wind	-222	-4	843	37	78	-5719
Operating4+Wind	-222	-4	843	37	78	-5720
Operating5+Wind	-222	-4	843	37	78	-5720
Sustained+Wind 2	-165	11	4	42	58	-5695
Operating1+Wind 2	-17	-169	887	-25	5	283
Operating2+Wind 2	-230	38	753	53	81	-5731
Operating3+Wind 2	-222	-4	843	37	78	-5719
Operating4+Wind 2	-222	-4	843	37	78	-5720
Operating5+Wind 2	-222	-4	843	37	78	-5720
Sustained+Seismic	-159	11	57	45	61	-5652
Sustained-Seismic	-172	10	-49	40	55	-5738
Operating1+Seismic	-10	-169	940	-22	8	326
Operating1-Seismic	-23	-170	834	-28	2	241
Operating2+Seismic	-224	39	806	56	84	-5689
Operating2-Seismic	-236	38	700	50	79	-5774
Operating3+Seismic	-216	-4	896	40	81	-5677
Operating3-Seismic	-228	-5	790	34	75	-5762
Operating4+Seismic	-216	-4	896	40	81	-5678
Operating4-Seismic	-228	-5	790	34	75	-5763
Operating5+Seismic	-216	-4	896	40	81	-5678
Operating5-Seismic	-228	-5	790	34	75	-5763
Maximum	-10	39	940	56	84	326
Minimum	-236	-170	-49	-28	2	-5774
Allowables	0	0	0	0	0	0

The Sorted Stresses in CAEPIPE lists the maximum of Expansion stresses for all thermal range cases at each node as well as the maximum of Sustained + Occasional stresses for all Occasional cases at each node. On the other hand, for the Sustained case, it always uses the maximum pressure among the input pressures (P1 through P10) while computing Sustained Stress at each node.



#	Sustained				Expansion				Occasional			
	Node	SL (psi)	SH (psi)	SL/SH	Node	SE (psi)	SA (psi)	SE/SA	Node	SO (psi)	1.2SH (psi)	SO/1.2SH
1	7700A	4653	13450	0.35	120A	7160	33391	0.21	90A	4916	16140	0.30
2	90A	4631	13450	0.34	7700A	6814	33034	0.21	7700A	4700	16140	0.29
3	120A	4297	13450	0.32	120B	5920	29921	0.20	120A	4598	16140	0.28
4	90B	3740	13450	0.28	4110A	7336	37146	0.20	120B	3954	16140	0.24
5	100A	3738	13450	0.28	2110A	7075	36997	0.19	90B	3891	16140	0.24
6	120B	3704	13450	0.28	2120A	6871	36925	0.19	100A	3889	16140	0.24
7	105	3352	13450	0.25	90A	5321	28994	0.18	105	3605	16140	0.22
8	25	3118	13450	0.23	3110A	6739	37023	0.18	25	3142	16140	0.19
9	20	3111	13450	0.23	3120A	6488	37191	0.17	20	3134	16140	0.19
10	80	2938	13450	0.22	4120A	6038	36721	0.16	80	2981	16140	0.18
11	110B	2598	13450	0.19	110A	5456	36534	0.15	110B	2721	16140	0.17
12	2105	2454	13450	0.18	4090A	5308	35872	0.15	2105	2683	16140	0.17
13	2090A	2315	13450	0.17	20	4253	30514	0.14	2090A	2631	16140	0.16
14	3105	2307	13450	0.17	90B	4033	29885	0.13	3105	2532	16140	0.16
15	100B	2247	13450	0.17	100A	4029	29887	0.13	100B	2506	16140	0.16

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



#	Node	Press. Allow. (psi)	Sustained SL (psi)	SH (psi)	SL/SH	Expansion SE (psi)	SA (psi)	SE/SA	Occasional SO (psi)	1.2SH (psi)	SO/1.2SH
1	20	10.1	3111	13450	0.23	4253	30514	0.14	3134	16140	0.19
	25	250	3117	13450	0.23	3273	30508	0.11	3142	16140	0.19
2	25	10.1	3118	13450	0.23	3275	30507	0.11	3142	16140	0.19
	30		1926	13450	0.14	1989	31699	0.06	1945	16140	0.12
3	30	10.1	1924	13450	0.14	1982	31701	0.06	1943	16140	0.12
	35	211	1939	13450	0.14	1986	31686	0.06	1959	16140	0.12
4	40	10.1	1979	13450	0.15	1992	31646	0.06	2005	16140	0.12
	50	211	2115	13450	0.16	2006	31510	0.06	2160	16140	0.13
5	50	10.1	2115	13450	0.16	2006	31510	0.06	2160	16140	0.13
	60	211	1990	13450	0.15	2011	31635	0.06	2014	16140	0.12
6	70	10.1	1978	13450	0.15	2052	31647	0.06	2002	16140	0.12
	80	211	2863	13450	0.21	2762	30762	0.09	2914	16140	0.18
7	80	10.1	2388	13450	0.18	2162	31237	0.07	2462	16140	0.15
	90A	211	1564	13450	0.12	1361	32061	0.04	1637	16140	0.10
8	90A	10.1	4631	13450	0.34	5321	28994	0.18	4916	16140	0.30
	90B	140	3740	13450	0.28	4033	29885	0.13	3891	16140	0.24
9	90B	10.1	1224	13450	0.09	988	32401	0.03	1266	16140	0.08
	100A	211	1224	13450	0.09	987	32401	0.03	1265	16140	0.08