

Tutorial on Analysis with Multiple Thermal Loads using CAEPIPE

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"

The screenshot displays the CAEPIPE software interface. On the left, a table lists the components of the piping system, including nodes, types, dimensions, materials, and sections. On the right, a 3D model of the piping system is shown, featuring four parallel pipelines with various fittings and connections.

#	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							Flange	
11	25				-0.9"	A778	12	C2		
12	30	Reducer			-0.4-1/2"	A778	12	C2		
13	35				-1.2"	A778	16	C2		
14	35	Location			-0.4160	A778	16	C2	Flange	
15	Dual Disc Water Style Check Valve									
16	Weight = 242 lb, Valve Length = 7.5"									
17	40	Valve				-0.7-1/2"	A778	16	C2	
18	Guide Support									
19	50					-1.0900	A778	16	C2	
20	60					-1.0900	A778	16	C2	
21	Water 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	
26	90	Bend				-6.3330	A778	16	CHL	
27	100	Bend				2.6700	A778	16	CHL	
28	Guide Support									
29	105					-15.0"	A778	16	CHL	
30	110	Bend				-30.3600	A778	16	CHL	
31	120	Bend				6.1300	A778	16	CHL	
32	Anchor at Tank 1									
33	130					6.4"			Anchor	
34	-----									
35	From Pump 2									
36	1010	From				-10.0"	64.9400		Anchor	
37	1010	Location							Flange	
38	1020	Bellows							Flange	
39	1025					-0.9"	A778	12	C1	
40	1030	Reducer				-0.4-1/2"	A778	12	C1	
						-1.2"	A778	16	C1	

Caepipe : Pipe Sections (3) - [MultipleThermalLoads.mod (D:\KPD...]

File Edit View Options Misc Window Help

#	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.Tr (inch)
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 (D:\KPDDevelopment\Documents\Tutorial...]

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

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.

Analysis Options

Code | Temperature | Pressure | Dynamics | Misc

Reference temperature: 70 (F)

Number of thermal cycles: 7000

Number of thermal loads: 1 2 3 10

Thermal = Operating - Sustained
 Solve thermal case

Elastic Modulus:
 Use temperature dependent modulus
 Use modulus at reference temperature

OK Cancel

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.

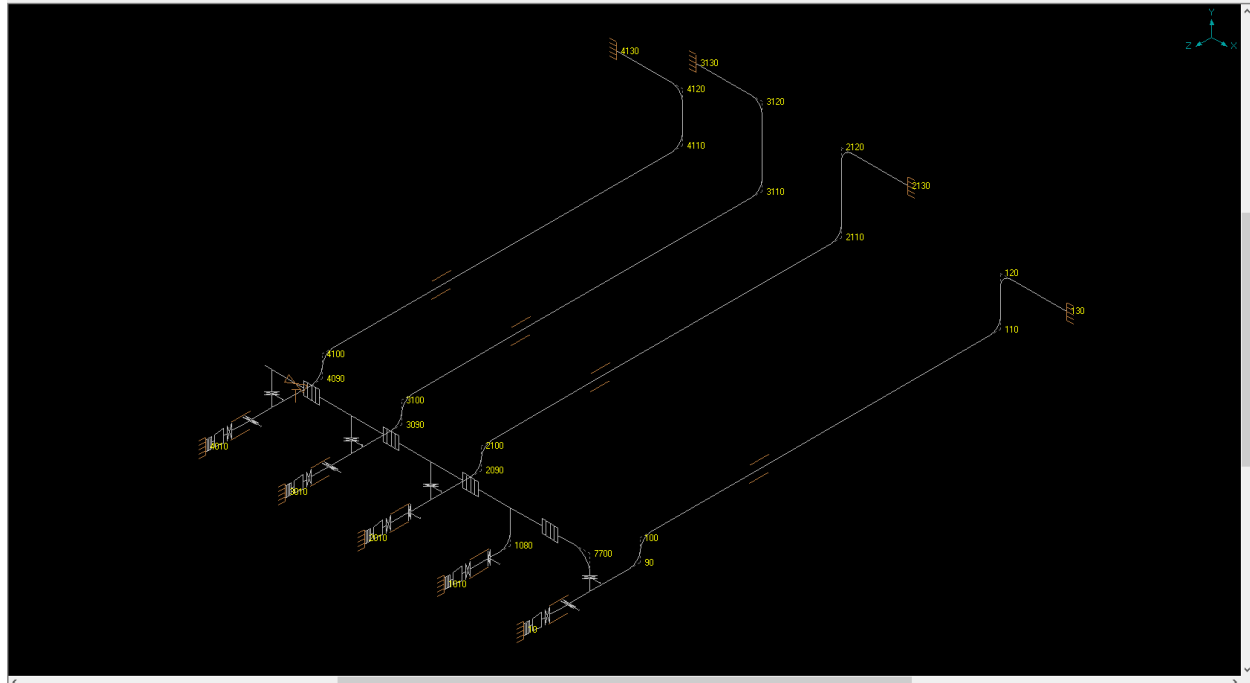
Define the loads C1 through CHL as shown in the snap shot below.

#	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)	Specific gravity	Add.Wgt. (lb/ft)
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	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	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	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	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	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	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.

Load cases (29) ✕

<input checked="" type="checkbox"/> Sustained (W+P)	<input checked="" type="checkbox"/> Expansion (T1 - T3)	<input type="checkbox"/> Expansion (T3 - T10)	<input checked="" type="checkbox"/> Operating (W+P1+T1)
<input checked="" type="checkbox"/> Sustained (W+P1)	<input checked="" type="checkbox"/> Expansion (T1 - T4)	<input checked="" type="checkbox"/> Expansion (T4 - T5)	<input checked="" type="checkbox"/> Operating (W+P2+T2)
<input checked="" type="checkbox"/> Sustained (W+P2)	<input checked="" type="checkbox"/> Expansion (T1 - T5)	<input type="checkbox"/> Expansion (T4 - T6)	<input checked="" type="checkbox"/> Operating (W+P3+T3)
<input checked="" type="checkbox"/> Sustained (W+P3)	<input type="checkbox"/> Expansion (T1 - T6)	<input type="checkbox"/> Expansion (T4 - T7)	<input checked="" type="checkbox"/> Operating (W+P4+T4)
<input checked="" type="checkbox"/> Sustained (W+P4)	<input type="checkbox"/> Expansion (T1 - T7)	<input type="checkbox"/> Expansion (T4 - T8)	<input checked="" type="checkbox"/> Operating (W+P5+T5)
<input checked="" type="checkbox"/> Sustained (W+P5)	<input type="checkbox"/> Expansion (T1 - T8)	<input type="checkbox"/> Expansion (T4 - T9)	<input type="checkbox"/> Operating (W+P6+T6)
<input type="checkbox"/> Sustained (W+P6)	<input type="checkbox"/> Expansion (T1 - T9)	<input type="checkbox"/> Expansion (T4 - T10)	<input type="checkbox"/> Operating (W+P7+T7)
<input type="checkbox"/> Sustained (W+P7)	<input type="checkbox"/> Expansion (T1 - T10)	<input type="checkbox"/> Expansion (T5 - T6)	<input type="checkbox"/> Operating (W+P8+T8)
<input type="checkbox"/> Sustained (W+P8)	<input checked="" type="checkbox"/> Expansion (T2 - T3)	<input type="checkbox"/> Expansion (T5 - T7)	<input type="checkbox"/> Operating (W+P9+T9)
<input type="checkbox"/> Sustained (W+P9)	<input checked="" type="checkbox"/> Expansion (T2 - T4)	<input type="checkbox"/> Expansion (T5 - T8)	<input type="checkbox"/> Operating (W+P10+T10)
<input type="checkbox"/> Sustained (W+P10)	<input checked="" type="checkbox"/> Expansion (T2 - T5)	<input type="checkbox"/> Expansion (T5 - T9)	<input checked="" type="checkbox"/> Static seismic (g's)
<input checked="" type="checkbox"/> Expansion (T1)	<input type="checkbox"/> Expansion (T2 - T6)	<input type="checkbox"/> Expansion (T5 - T10)	<input checked="" type="checkbox"/> Wind
<input checked="" type="checkbox"/> Expansion (T2)	<input type="checkbox"/> Expansion (T2 - T7)	<input type="checkbox"/> Expansion (T6 - T7)	<input checked="" type="checkbox"/> Wind 2
<input checked="" type="checkbox"/> Expansion (T3)	<input type="checkbox"/> Expansion (T2 - T8)	<input type="checkbox"/> Expansion (T6 - T8)	<input type="checkbox"/> Modal analysis
<input checked="" type="checkbox"/> Expansion (T4)	<input type="checkbox"/> Expansion (T2 - T9)	<input type="checkbox"/> Expansion (T6 - T9)	
<input checked="" type="checkbox"/> Expansion (T5)	<input type="checkbox"/> Expansion (T2 - T10)	<input type="checkbox"/> Expansion (T6 - T10)	
<input type="checkbox"/> Expansion (T6)	<input checked="" type="checkbox"/> Expansion (T3 - T4)	<input type="checkbox"/> Expansion (T7 - T8)	
<input type="checkbox"/> Expansion (T7)	<input checked="" type="checkbox"/> Expansion (T3 - T5)	<input type="checkbox"/> Expansion (T7 - T9)	
<input type="checkbox"/> Expansion (T8)	<input type="checkbox"/> Expansion (T3 - T6)	<input type="checkbox"/> Expansion (T7 - T10)	
<input type="checkbox"/> Expansion (T9)	<input type="checkbox"/> Expansion (T3 - T7)	<input type="checkbox"/> Expansion (T8 - T9)	
<input type="checkbox"/> Expansion (T10)	<input type="checkbox"/> Expansion (T3 - T8)	<input type="checkbox"/> Expansion (T8 - T10)	
<input checked="" type="checkbox"/> Expansion (T1 - T2)	<input type="checkbox"/> Expansion (T3 - T9)	<input type="checkbox"/> Expansion (T9 - T10)	

Caepipe : Support load summary for anchor at node 10 - [MultipleThermalLoads.res (D:\KPDevel... - □ ×

File Results View Options Window Help

Load combination	FX (lb)	FY (lb)	FZ (lb)	MX (ft-lb)	MY (ft-lb)	MZ (ft-lb)	Displacements (global)		
							X (inch)	Y (inch)	Z (inch)
Sustained	-194	18	3	45	69	-5657	0.000	0.000	0.000
Operating1	-18	-156	875	-20	6	273	-0.020	0.084	-0.068
Operating2	-260	49	752	57	92	-5671	0.005	-0.023	0.018
Operating3	-252	7	832	41	89	-5660	0.000	0.000	0.000
Operating4	-252	7	832	41	89	-5661	0.000	0.000	0.000
Operating5	-252	7	832	41	89	-5661	0.000	0.000	0.000
Sustained+Wind	-194	18	3	45	69	-5657	0.000	0.000	0.000
Operating1+Wind	-18	-156	875	-20	6	273	-0.020	0.084	-0.068
Operating2+Wind	-260	49	752	57	92	-5671	0.005	-0.023	0.018
Operating3+Wind	-252	7	832	41	89	-5660	0.000	0.000	0.000
Operating4+Wind	-252	7	832	41	89	-5661	0.000	0.000	0.000
Operating5+Wind	-252	7	832	41	89	-5661	0.000	0.000	0.000
Sustained+Wind 2	-194	18	3	45	69	-5657	0.000	0.000	0.000
Operating1+Wind 2	-18	-156	875	-20	6	273	-0.020	0.084	-0.068
Operating2+Wind 2	-260	49	752	57	92	-5671	0.005	-0.023	0.018
Operating3+Wind 2	-252	7	832	41	89	-5660	0.000	0.000	0.000
Operating4+Wind 2	-252	7	832	41	89	-5661	0.000	0.000	0.000
Operating5+Wind 2	-252	7	832	41	89	-5661	0.000	0.000	0.000
Sustained+Seismic	-188	19	56	48	72	-5615	0.000	0.000	0.000
Sustained-Seismic	-200	18	-50	42	65	-5699	0.000	0.000	0.000
Operating1+Seismic	-12	-155	928	-17	9	315	-0.020	0.084	-0.068
Operating1-Seismic	-25	-157	822	-23	3	231	-0.020	0.084	-0.068
Operating2+Seismic	-254	49	805	60	95	-5628	0.005	-0.023	0.018
Operating2-Seismic	-266	48	699	54	89	-5713	0.005	-0.023	0.018
Operating3+Seismic	-246	8	885	44	92	-5618	0.000	0.000	0.000
Operating3-Seismic	-258	7	779	38	86	-5702	0.000	0.000	0.000
Operating4+Seismic	-246	8	885	44	92	-5619	0.000	0.000	0.000
Operating4-Seismic	-258	7	779	38	86	-5703	0.000	0.000	0.000
Operating5+Seismic	-246	8	885	44	92	-5619	0.000	0.000	0.000
Operating5-Seismic	-258	7	779	38	86	-5703	0.000	0.000	0.000
Maximum	-12	49	928	60	95	315	0.005	0.084	0.018
Minimum	-266	-157	-50	-23	3	-5713	-0.020	-0.023	-0.068

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 Sustained case, it always uses the maximum pressure among the input pressures (P1 through P10) while computing Sustained Stress at each node.

Caepipe : B31.1 (2014) Code compliance (Sorted stresses) - [MultipleThermalLoads.res (D:\KPDev...]

File Results View Options Window Help

#	Sustained				Expansion				Occasional			
	Node	SL (psi)	SH (psi)	SL/SH	Node	SE (psi)	SA (psi)	SE/SA	Node	SL+SO (psi)	1.2SH (psi)	SL+SO/1.2SH
1	80	10930	13450	0.81	80	14963	22695	0.66	80	11193	16140	0.69
2	90A	7053	13450	0.52	90A	8771	26572	0.33	90A	7442	16140	0.46
3	90B	5205	13450	0.39	120B	10150	33957	0.30	120A	5596	16140	0.35
4	100A	5203	13450	0.39	4120B	10875	36723	0.30	120B	5439	16140	0.34
5	25	4806	13450	0.36	2120B	10463	36672	0.29	90B	5409	16140	0.34
6	7700A	4649	13450	0.35	3120B	9899	36380	0.27	100A	5406	16140	0.33
7	120A	4301	13450	0.32	4080	7810	31481	0.25	25	4844	16140	0.30
8	8500	4162	13450	0.31	120A	8252	33386	0.25	7700A	4784	16140	0.30
9	120B	3730	13450	0.28	2120A	8934	36989	0.24	8500	4222	16140	0.26
10	105	3383	13450	0.25	4120A	8573	36820	0.23	110B	3820	16140	0.24
11	100B	3302	13450	0.25	3120A	8461	37156	0.23	110A	3807	16140	0.24

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

Caepipe : B31.1 (2014) Code Compliance - [MultipleThermalLoads.res (D:\KPDevelopment\Docu...]

File Results View Options Window Help

#	Node	Press. Allow. (psi)	Sustained			Expansion			Occasional		
			SL (psi)	SH (psi)	SL/SH	SE (psi)	SA (psi)	SE/SA	SL+SO (psi)	1.2SH (psi)	SL+SO/1.2SH
1	20	10.1	3261	13450	0.24	4203	30364	0.14	3285	16140	0.20
	25	250	3264	13450	0.24	3235	30361	0.11	3289	16140	0.20
2	25	10.1	4806	13450	0.36	6470	28819	0.22	4844	16140	0.30
	30		3029	13450	0.23	3920	30596	0.13	3066	16140	0.19
3	30	10.1	2091	13450	0.16	1960	31534	0.06	2116	16140	0.13
	35	211	2100	13450	0.16	1964	31525	0.06	2129	16140	0.13
4	40	10.1	2128	13450	0.16	1971	31497	0.06	2170	16140	0.13
	50	211	2236	13450	0.17	1988	31389	0.06	2313	16140	0.14
5	50	10.1	2236	13450	0.17	1988	31389	0.06	2313	16140	0.14
	60	211	2125	13450	0.16	1981	31500	0.06	2158	16140	0.13
6	70	10.1	2098	13450	0.16	2015	31527	0.06	2125	16140	0.13
	80	211	10426	13450	0.78	13828	23199	0.60	10627	16140	0.66
7	80	10.1	8463	13450	0.63	10748	25162	0.43	8773	16140	0.54