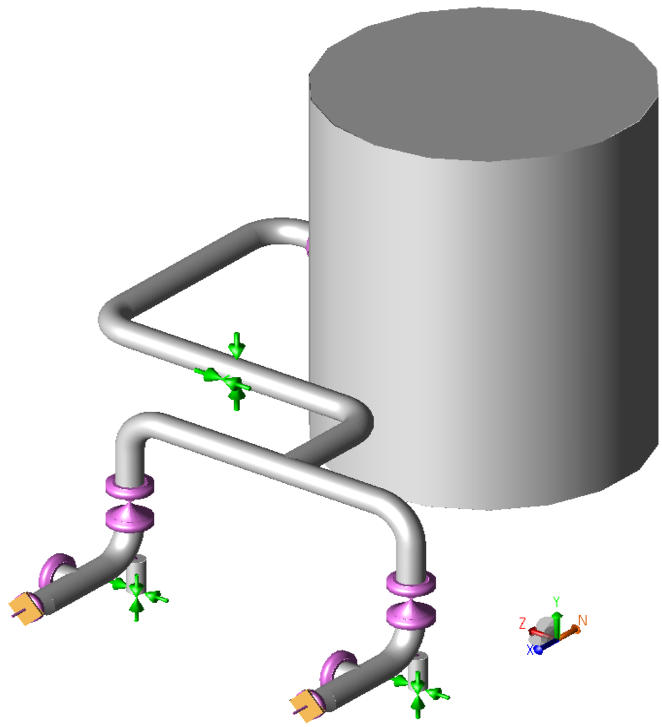
Design Conditions:

Code: **ASME B31.3**
Year: **2016**
Addenda: **-**

Piping Flexibility Analysis Report

Cust: **PVEng**
File: **12755f-1 R0**
Desc: **Piping Stress Analysis Report Sample**
Dwg: **General Arrangement Drawing**
Date: **May 10, 2018**



Author: **Arman Haydarian**
Reviewer: **Cameron Moore, P.Eng.**

Conclusion:
The Piping Stress Analysis Report Sample has been analyzed to ASME B31.3, 2016 edition rules and is found acceptable.

Engineering Notes

Notes:

This analysis does not guarantee leak tightness of the gasketed joint

This calculation was performed based on the received data from client:

- Design and operating temperatures
- System cycling <7000 (Low cycle)
- Isometric drawings

All the recommendations must be accommodated and no change in any part of the layout and supports (types and locations) can be made so that results of calculation remains valid.

This analysis only includes design calculations based on the received data and has no part in the fabrication and construction activities to control they will be inline with the calculations and assumptions made.

Reference Drawings: P&ID, Line List, Piping isometrics, Material specifications, Equipment general arrangements

301 Loads Considered:

(301.2) Design Pressure: **Yes**
(301.3) Design Temperature: **Yes**
(301.4) Ambient Effects: **Yes**
(301.5) Dynamic Effects: **Yes**
(301.6) Weight Effects: **Yes**
(301.7) Thermal Expansion Effects: **Yes**
(301.8) Support Effects: **Yes**
(301.9) Reduced Ductility Effects: **Yes**
(301.10) Cyclic Effects: **No**
(301.11) Air Condensation Effects: **No**

Revisions:

Rev	Description	Date	Initials
0	Release	2018-05-10	Arman

Contents

Methodology

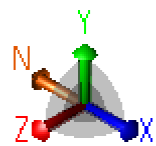
Piping flexibility analysis was performed on this job using CAESAR II 2018 build 180215 software, based on the following input data:

Pprocess data ===>> P&ID drawings used.
Piping geometry ===>> Isometric drawings received electronically.
Material Data ===>> Piping material specification supplied by client
Equipment Data ===>> Equipment vendor drawings received from client.
3D Model ===>> Electronic file received showing piping, equipment, and surrounding structures.

The stress model was built accordingly to analyze the system and meet all the necessary requirements.
We used metric unit system to perform this calculation.

Seismic data was considered based on NBC code 2015 of the installation site as advised by client.
Wind load was considered based on NBC code 2015 of the installation site as advised by client.

Coordinate system in CAESAR: N direction shows north as per the isometric drawings.



Elements and node numbering: Beam elements used based on the differential length between nodes.
Each element has two nodes, FROM and TO.
Node numbers are refered as N- # where required.

Load case nomenclature:
OPE ===>> Operating
EXP ===>> Expansion
SUS ===>> Sustained
OCC ===>> Occasional

Process Overview

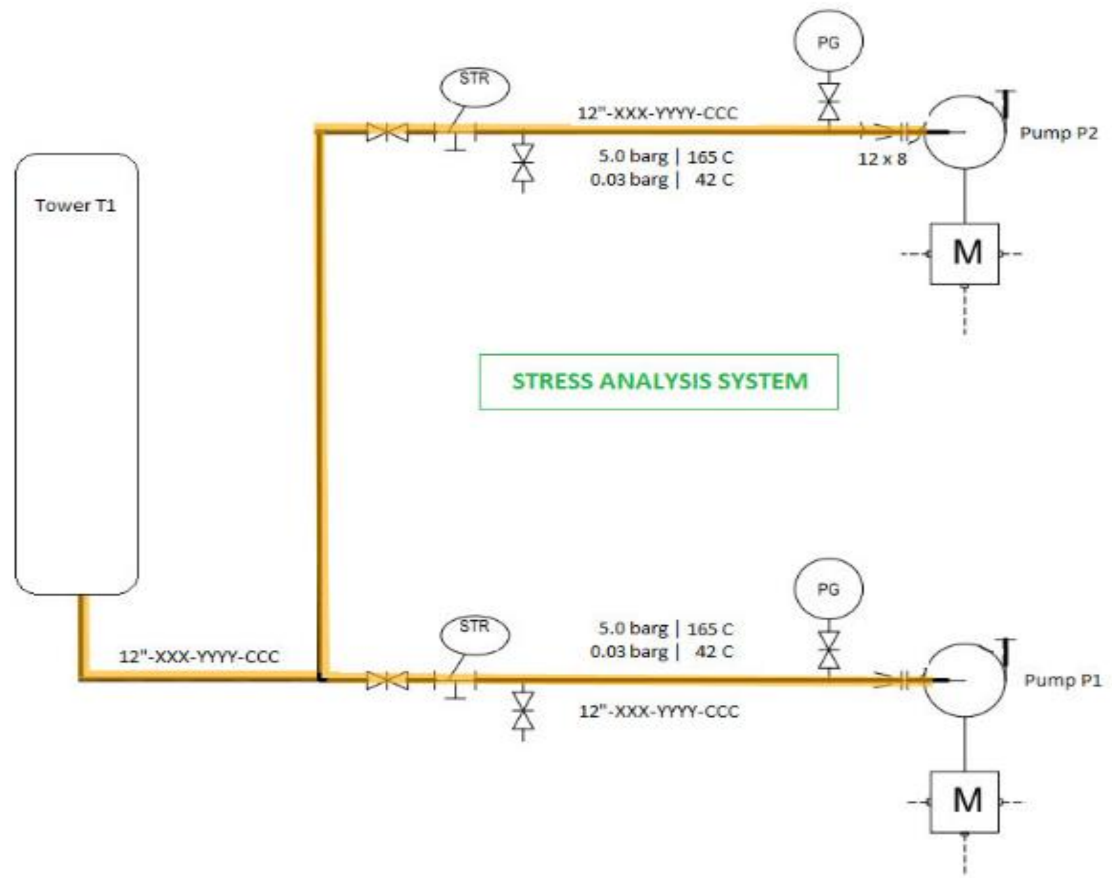


Fig-1

Process Overview

The system P&ID showing pumps P1 and P2 suction lines transferring fluid from tower T1.
Based on P&ID notes each pump can run individually while the other is on stand-by. We will consider three operating cases as follows:

- OPE 1 ==>> Both pumps are hot
- OPE 2 ==>> Pump-A is hot, and Pump-B is cold
- OPE 3 ==>> Pump-A is cold, and Pump-B is hot

Input Data

Line List

Table below is showing the lines in the stress analysis system:

LINE DESCRIPTION								OPER. CONDITION		DES. CONDITION		FIELD TEST		INS. & PAINTING	
CALC. NO.	LINE NO.	SIZE (in)	PIPING SPEC	PHASE	FROM	TO	Fluid Density KG/m^3	NORMAL TEMP. °C	PRESS. Bar(G)	TEMP. °C	PRESS. Bar(G)	MED.	PRESS. Bar(G)	INSU. CLASS	INS. THK mm
SAMPLE-01	XXX-YYY-001	12"	CS-1	L	T1-N1	P1-SUC	980	42	0.03	165	5.0	WATER	7.5	H	30
SAMPLE-01	XXX-YYY-002	12"	CS-1	L	T1-N1	P2-SUC	980	42	0.03	165	5.0	WATER	7.5	H	30

Material Data

Piping material data from material specification (Piping Class CS-1) was used to enter into CAESAR.

BASIC MATERIAL		KILLED CARBON STEEL		VALVE TRIM	TRIM CN 8
RATING		ASME CL 150		CORROSION ALLOWANCE	1.6mm
PIPING					
SMLS PIPE		8 - 12	SCH10	PIPE;SMLS;CS;API 5L-B;ASME B36.10M;BE	
FITTINGS					
90-DEG ELBOW LR	*3	2 - 14		90-DEG ELBOW LR;CS;ASTM A234-WPB; ASME B16.9;BE	
TEE		2- 14		TEE;CS;ASTM A234-WPB;ASME B16.9;BE	
FLANGES					
FLANGE WN		2 - 24		WELD NECK FLANGE;CS;ASTM A105;CL 150;RF; ASME B16.5	
VALVES					
GATE VALVE		2 - 12		GATE VALVE;OS&Y;FLEXIBLE WEDGE; ASME B16.5 CL 150 RF;CS BODY ASTM A216 WCB; TRIM CN 8;API 600/ASME B16.10;HANDWHEEL OPR; FULL BORE;BLT BNT;FLEX GPH PKG	VA1C02
GLOBE VALVE		8 - 16		GLOBE VALVE;OS&Y;T-BODY;PARABOLIC DISC; ASME B16.5 CL 150 RF;CS BODY ASTM A216 WCB; TRIM CN 8;BS1873/ASME B16.10;GEAR OPR; FULL BORE; BLT BNT;FLEX GPH PKG	VB1C03
BALL VALVE (150°C Max)		6 - 16		BALL VALVE;TRUNNION MOUNTED BALL;FULL BORE; ASME B16.5 CL 150 RF;CS BODY ASTM A216 WCB; 316SS BALL;13CR STEM; REINFORCED PTFE SEAT;API 608/ASME B16.10 LONG PATTERN;GEAR OPR;FIRE-TESTED TRIM;BLOW OUT PROOF STEM;PTFE PKG	VC1C03
CHECK VALVE	H OR V	2 - 24		CHECK VALVE;SWING TYPE;ASME B16.5 CL 150 RF; CS BODY ASTM A216 WCB;TRIM CN 8; API 6D/ASME B16.10;BLT BNT	VD1C02
BUTTERFLY VALVE (150°C Max)		6 - 24		BUTTERFLY VALVE;API 609 CAT B;DOUBLE ECCENTRIC;LUG TYPE;CL 150;FIRE-TESTED TRIM; CS BODY ASTM A216 WCB;304SS SHAFT & DISC;RPTFE SEAT;FLEX GPH PKG;GEAR OPR;CAPSCREWS FOR D&T HOLES ASTM A193 GR B7	VG1C71
BOLTING					
BOLT STUD WITH 2 HEAVY HEX NUTS		1/2 - 60		BLT STUD WITH 2 HEAVY HEX NUTS;ASSEMBLED; COMBINED (INCH SIZE X METRIC LENGTH); ALLOY STL ASTM A193 GR B7/ASTM A194 GR 2H	
GASKETS					
GASKET FLAT RING		1/2 - 24		FLAT RING GASKET;316SS REINFORCED GRAPHITE WITH INNER EYELET;ASME B16.21; ASME B16.5 CL 150 RF;THK=1.5MM	

Equipment Data

Equipment vendor drawings are attched at the end of the calculation.

NBC-2015 G-Factor 7.00

Piping Properties: NBC-2015 - 4.1.8.2

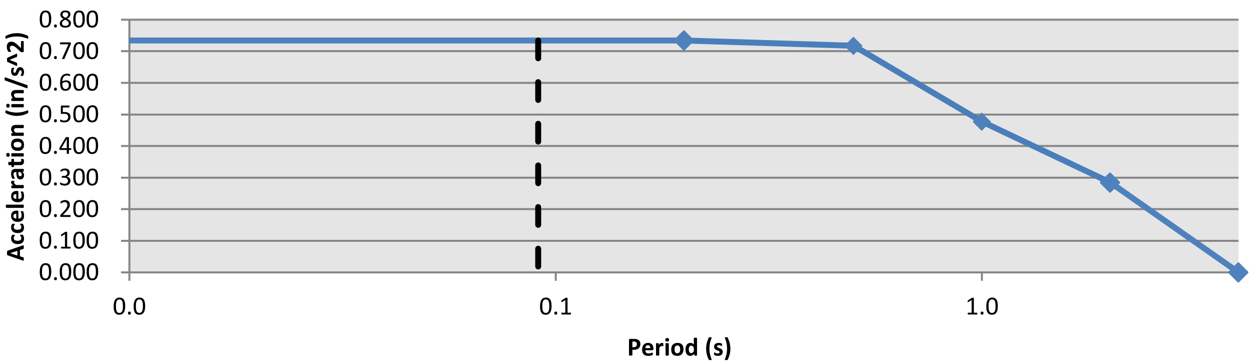
0.091	**Ta** [s] - Lateral period of vibration of piping
1.0	**Ie** [] - Importance factor (4.1.8.5)
1.5	**Rd** [] - Ductility factor (Table 4.1.8.9)
1.3	**Ro** [] - Overstrength factor (Table 4.1.8.9)
1.0	**Mv** [] - Higher mode effect factor (Table 4.1.8.11)

Site Specific Seismic Properties: NBC-2015 - 4.1.8.4 (2% probability of exceedance in 50 years)

0.760	**S_02** [] - S(T=0.2S) spectral acceleration value
0.530	**S_05** [] - S(T=0.5S) spectral acceleration value
0.300	**S_10** [] - S(T=1.0S) spectral acceleration value
0.160	**S_20** [] - S(T=2.0S) spectral acceleration value
0.000	**S_50** [] - S(T=5.0S) spectral acceleration value
0.370	**PGA** - peak ground acceleration
E	**Site_Class**
0.966	**F_02** [] - spectral acceleration site coefficient (Table 4.1.8.4.-B)
1.354	**F_05** [] - spectral acceleration site coefficient (Table 4.1.8.4.-C)
1.593	**F_10** [] - spectral acceleration site coefficient (Table 4.1.8.4.-D)
1.780	**F_20** [] - spectral acceleration site coefficient (Table 4.1.8.4.-E)
2.014	**F_50** [] - spectral acceleration site coefficient (Table 4.1.8.4.-F)

Design Spectral Acceleration: NBC-2015 - 4.1.8.4

SS_02 [in/s^2] =	Max(F_02*S_02,F_05*S_05) *T <= 0.2S*	MAX(0.966*0.76,1.354*0.53) =	0.734
SS_05 [in/s^2] =	F_05*S_05 *T = 0.5S*	1.354*0.53 =	0.718
SS_10 [in/s^2] =	F_10*S_10~~ T = 1.0S	1.593*0.3 =	0.478
SS_20 [in/s^2] =	F_20*S_20 *T = 2.0S*	1.78*0.16 =	0.285
SS_50 [in/s^2] =	F_50*S_50 *T = 5.0S*	2.014*0 =	0.000
STa [in/s^2] =	Interpolated acceleration factor at Ta		**0.734**



Seismic Base Shear: NBC-2015 - 4.1.8.7

VTa [lb] =	STa*Mv*Ie/(Rd*Ro) *base shear at Ta*	0.734*1*1/(1.5*1.3) =	0.38
Vmin [lb] =	SS_20*Mv*Ie/(Rd*Ro) *min shear*	0.2848*1*1/(1.5*1.3) =	0.15
Vi [lb] =	Max(VTa,Vmin)	MAX(0,0) =	0.38
VmaxRd [lb] =	(2/3)*SS_02*Ie/(Rd*Ro) *V if Rd >= 1.5*	(2/3)*0.734*1/(1.5*1.3) =	0.25
g-factor =	if(Rd>=1.5,Min(VmaxRd,Vi),Vi)	IF(1.5>=1.5,MIN(0,0),0) =	**0.25**

Site Specific Wind Properties: NBC-2015 - 4.1.7 (2% probability of exceedance in 50 years)

0.35	**q** [kPa] - Reference velocity pressure (Table C-1)
1.0	**Iw** [] - Importance factor (Table 4.1.7.3)
B	**Exposure_Category**
1.0	**Ct** [] - Topographic factor, as provided in Article 4.1.7.4
1.0	**Cp** [] - Shape factor, as provided in Articles 4.1.7.5 and 4.1.7.6

Piping System Parameters

1.000	**El1** [m] - Elevation of base above grade
15.000	**El2** [m] - Elevation of highest piping element from grade
0.019	**Beta** [] - Structure damping coef.
0.7078	**Fn** [Hz] - Natural frequency
1.6068	**B** [] - Background turbulence factor
0.1000	**K** [] Terrain roughness factor
1.2929	**ro** [kg/m3] Air density
0.607	**W** [m] - Effective width

C_eH [] = if(0.5*((El2-El1)/12.7)^0.5<0.5,0.5,if(0.5*((El2-El1)/12.7)^0.5>2.5,2.5,0.5*((El2-El1)/12.7)^0.5))
IF(0.5*((15-1)/12.7)^0.5<0.5,0.5,IF(0.5*((15-1)/12.7)^0.5>2.5,2.5,0.5*((15-1)/12.7)^0.5)) = 0.5250

V_10m [m/s] = SQRT(2*Iw*q*1000*C_eH/ro) SQRT(2*1*0.35*1000*0.525/1.2929) = 16.8590

V_H [m/s] = V_10m*SQRT(C_eH) mean wind speed at top 16.859*SQRT(0.525) = 12.2151

S [] = pi()/(3*(1+8*Fn*(El2-El1)/(3*V_H))*(1+10*Fn*W/V_H)) size reduction factor
PI()/(3*(1+8*0.7078*(15-1)/(3*12.2151))*(1+10*0.7078*0.607/12.2151)) = 0.2449

X_o [] = 1220*Fn/V_H 1220*0.7078/12.2151 = 70.6922

F [] = X_o^2/(1+X_o^2)^(4/3) Gust energy ratio 70.6922^2/(1+70.6922^2)^(4/3) = 0.0585

smu [] = SQRT((K/C_eH)*(B+S*F/Beta)) sigma/mu
SQRT((0.1/0.525)*(1.6068+0.2449*0.0585/0.019)) = 0.6706

nu = Fn*SQRT(S*F/(S*F+Beta*B))
0.7078*SQRT(0.2449*0.0585/(0.2449*0.0585+0.019*1.6068)) = 0.3999

g_p = SQRT(2*ln(3600*nu))+0.577/SQRT(2*ln(3600*nu))
SQRT(2*LN(3600*0.3999))+0.577/SQRT(2*LN(3600*0.3999)) = 3.9650

Cg = 1+g_p*smu Gust fctor 1+3.965*0.6706 = 3.6588

Wind Pressure Profile **WP = Iw * q * Ce * Ct * Cg * Cp**

Height Z (m)	Iw	q	Ce	Ct	Cg	Cp	WP (kPa)
2.40	1.0	0.35	0.5000	1.0	3.6588	1.0	**0.6403**
3.80	1.0	0.35	0.5000	1.0	3.6588	1.0	**0.6403**
5.20	1.0	0.35	0.5000	1.0	3.6588	1.0	**0.6403**
6.60	1.0	0.35	0.5000	1.0	3.6588	1.0	**0.6403**
8.00	1.0	0.35	0.5000	1.0	3.6588	1.0	**0.6403**
9.40	1.0	0.35	0.5000	1.0	3.6588	1.0	**0.6403**
10.80	1.0	0.35	0.5000	1.0	3.6588	1.0	**0.6403**
12.20	1.0	0.35	0.5000	1.0	3.6588	1.0	**0.6403**
13.60	1.0	0.35	0.5174	1.0	3.6588	1.0	**0.6626**
15.00	1.0	0.35	0.5434	1.0	3.6588	1.0	**0.6959**

Assumptions

Flange and valve weight is imported into the model based on values from the CAESAR II database.
Connected equipment is modelled to mimic realistic boundary conditions.

Stress Model Overview

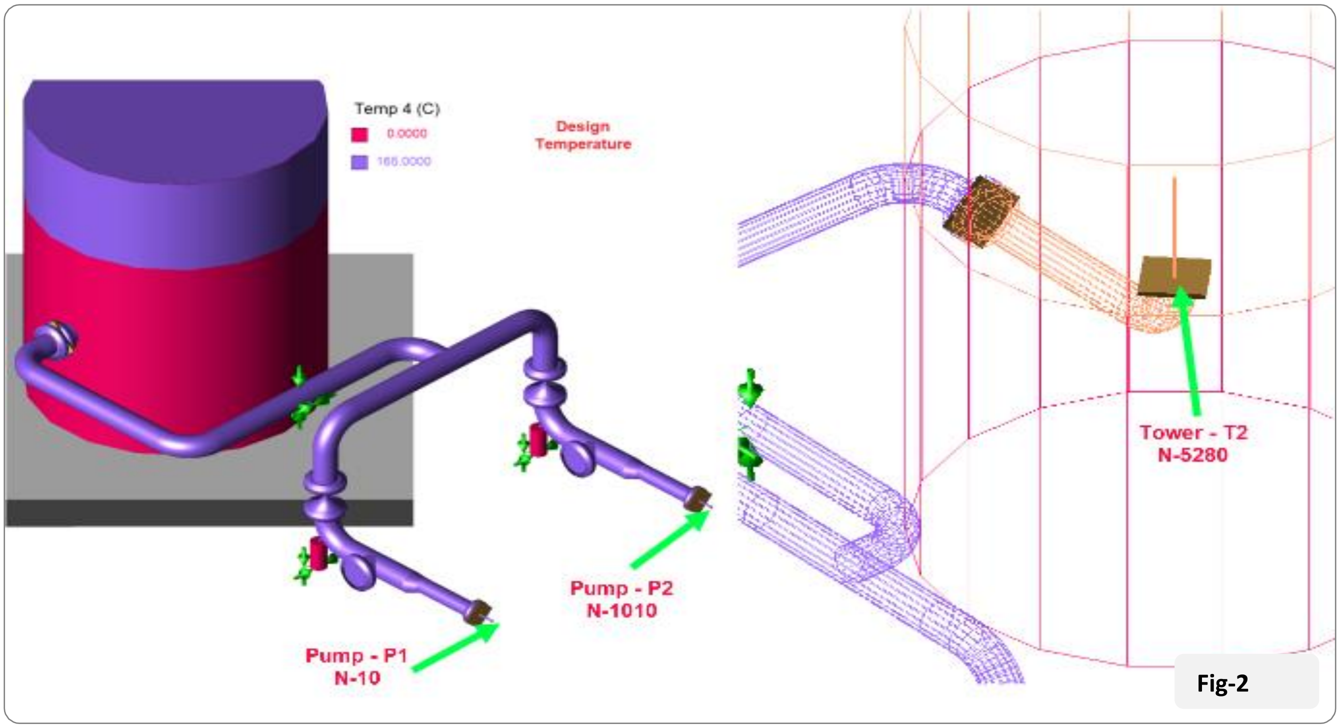


Fig-2

Design temperature and nozzle node numbers

The stress model was created based on the mentioned input data. Rigid elements were introduced to include the pump casing.

The equipment node numbers are shown below as they are referenced when nozzle loads are reported.

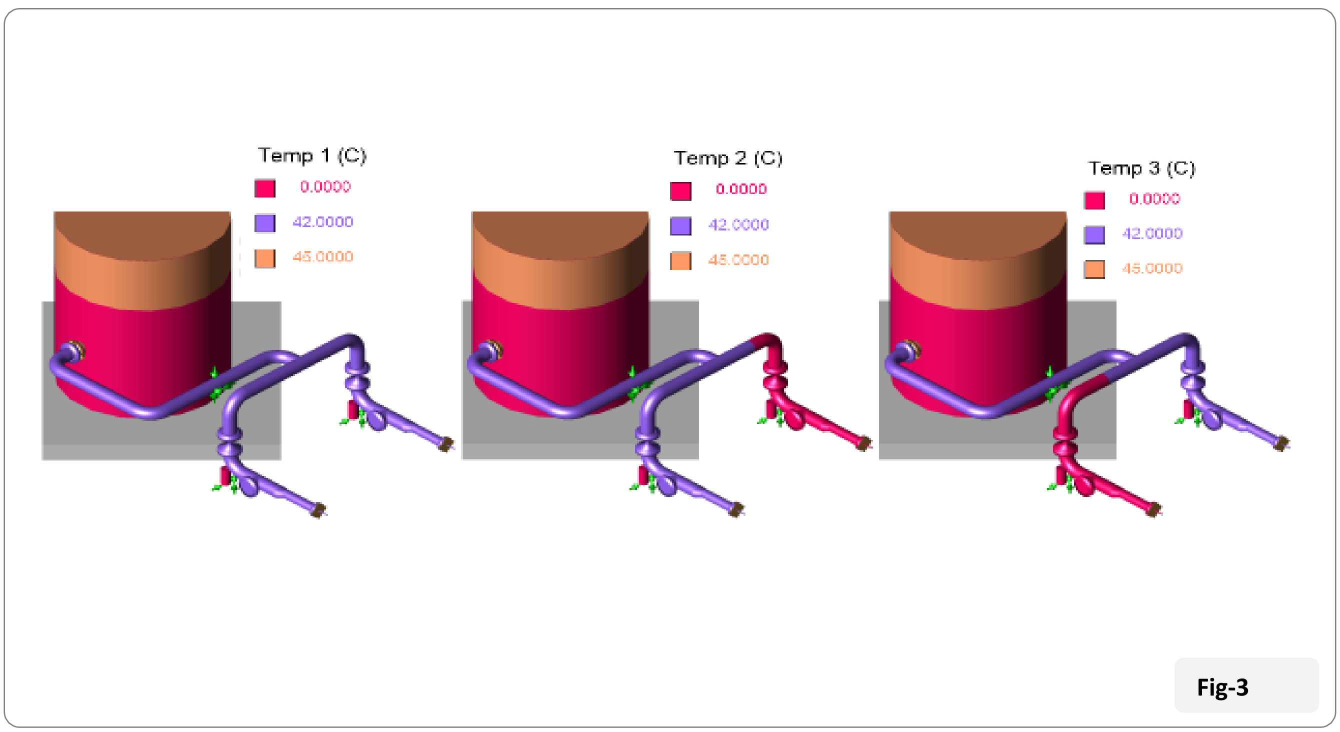


Fig-3

Operation thermal cases

Four different temperatures were considered to cover three operating cases and one design condition.

Wind and seismic data were applied based on the installation site data and NBC code 2015.

Maximum Code Stresses

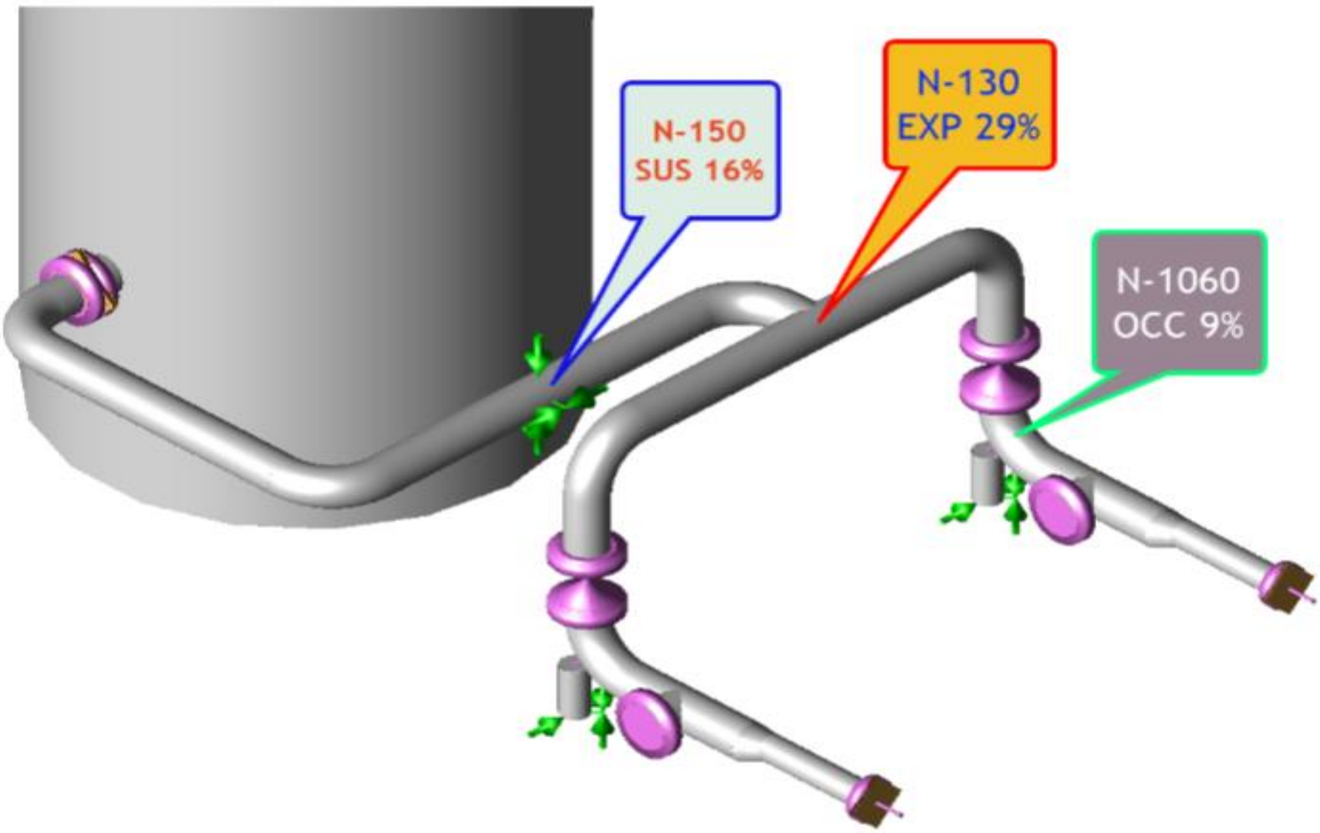


Fig-4

Maximum code stress ratios

The maximum code stress for SUS, EXP, and OCC cases were evaluated.
SUS: Max (L42 ~ L44), EXP: Max(L54 ~ L63), OCC: Max(L64 ~ L72)

Maximum Displacements

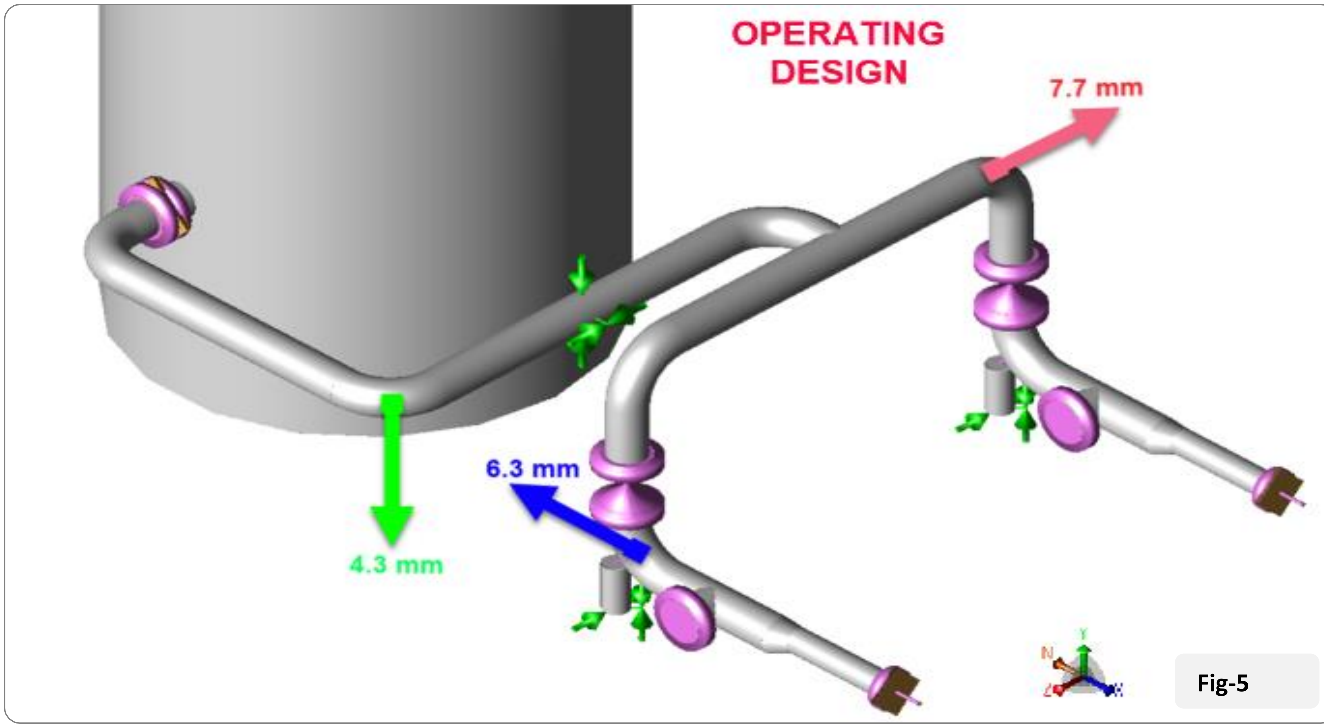


Fig-5

Operating and design maximum displacements

Maximum displacement values were taken from all operating conditions design cases:
L3, L4, L6, L8, L10, L12, L14, L16, L18, L20, L22, L42, L43, L44
The values in the X, Y, and Z directions are shown above.

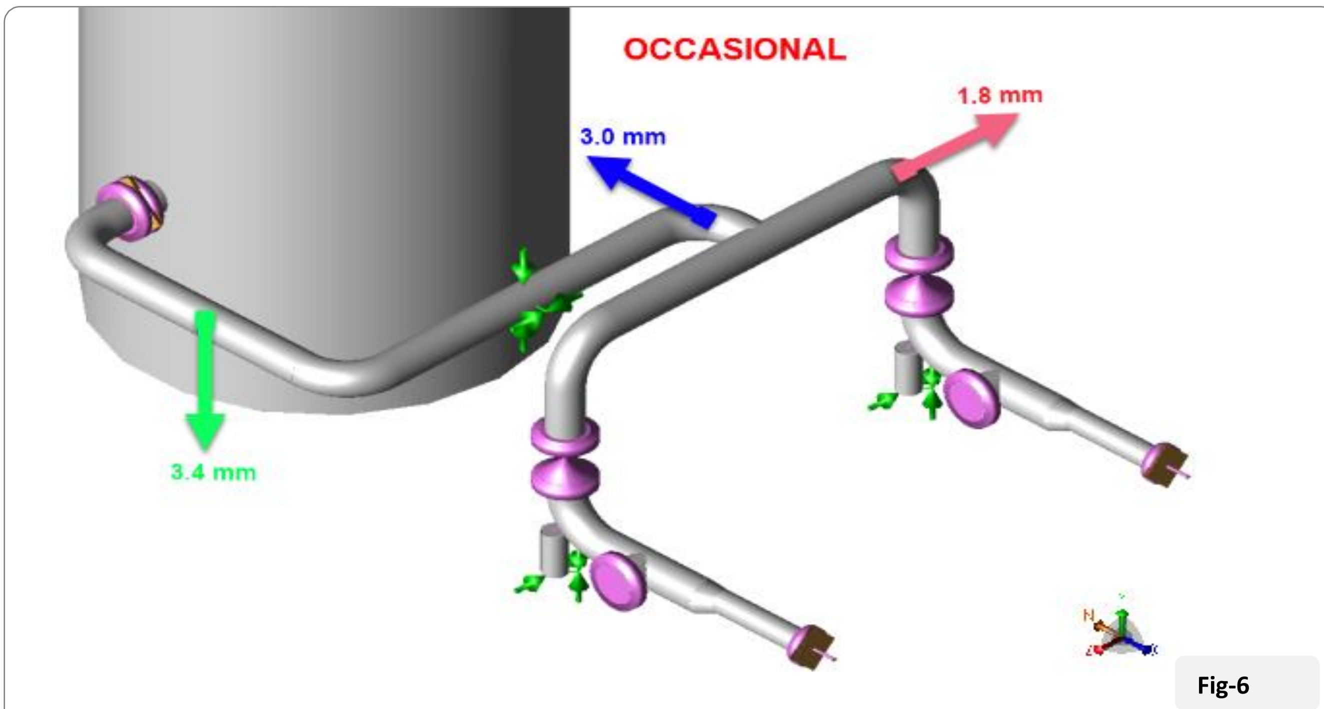


Fig-6

Occasional maximum displacements

Maximum displacement values were taken from all occasional cases:
L64, L65, L66,L67
The values in the X, Y, and Z directions are shown above.

Nozzle Loads

Pump-A and Pump-B nozzle loads were evaluated against 1 x API 610, for operating and sustained conditions.

Node 10	Pump-A	FX [N]	FY [N]	FZ [N]	MX [N.m]	MY [N.m]	MZ [N.m]	FR [N]	MR [N.m]
		4890	**3110**	**3780**	**3530**	**2580**	**1760**	**6919**	**4713**
	1(OPE)	3292	-2079	45	91	53	1101	3894	1106
	2(OPE)	3730	-2054	561	512	576	1084	4295	1330
	3(OPE)	-1223	-1847	-821	-930	-932	890	2362	1589
	4(SUS)	953	-2000	-45	79	-17	1039	2216	1042

Node 1010	Pump-B	FX [N]	FY [N]	FZ [N]	MX [N.m]	MY [N.m]	MZ [N.m]	FR [N]	MR [N.m]
		4890	**3110**	**3780**	**3530**	**2580**	**1760**	**6919**	**4713**
	1(OPE)	3755	-2096	-873	-2180	-1392	1120	4388	2819
	2(OPE)	-176	-1914	-64	-1286	-495	957	1923	1678
	3(OPE)	4272	-2184	-1258	-2413	-1756	1201	4960	3217
	4(SUS)	1171	-2018	56	77	54	1057	2334	1061

Tower T1 nozzle loads were evaluated as per the tower allowable nozzle loads received from client.
Operating, design, and occasional cases were evaluated for the tower, given that it is a stationary equipment.

Node 5280	T1-N	FX [N]	FY [N]	FZ [N]	MX [N.m]	MY [N.m]	MZ [N.m]	FR [N]	MR [N.m]
		10800	**14400**	**10800**	**11230**	**12960**	**8640**	**20991**	**19202**
	4(OPE)	-763	-7810	342	8910	-1713	1199	7855	9152
	6(OPE)	-1437	-7684	113	8488	-3227	1275	7818	9169
	8(OPE)	-1379	-7514	132	8316	-3094	1278	7641	8964
	10(OPE)	-2880	-7907	1312	10632	-6083	474	8517	12259
	24(OPE)	3359	-7689	708	8942	5423	2627	8421	10783
	26(OPE)	-5253	-7874	-168	8894	-9663	-402	9467	13139
	28(OPE)	-947	-7781	270	8918	-2120	1113	7843	9234
	30(OPE)	-947	-7781	270	8918	-2120	1113	7843	9234
	32(OPE)	-855	-7778	273	8920	-1967	1143	7830	9206
	34(OPE)	-1039	-7785	267	8915	-2273	1082	7859	9264
	36(OPE)	-1039	-7785	267	8915	-2273	1082	7859	9264
	38(OPE)	-855	-7778	273	8920	-1967	1143	7830	9206
	42(SUS)	-211	-7794	51	8402	-683	1312	7797	8531
	43(SUS)	40	-7777	51	8413	-87	1385	7777	8527

Recommendations

Use adjustable supports as the first support immediately after each pump nozzle.
The piping alignment has to be carefully controlled before attaching piping to the pump nozzle, so that piping can attached to the pump at zero load without any extra force.
All the directional restraints (guides, stops) have to be installed properly. Typical construction gaps (2mm) are allowed.
The process engineer was consulted in order to agree on relocating the reducers further from pump nozzles and provide flexibility.

Appendices

Appendix I - Output Reports (Electronic File)

a. Listing of Static Load Cases for This Analysis
b. Stress Summary Report: Highest Stresses
c. Restraint Summary Extended Report: Loads on Restraints
d. Displacements Report: Nodal Movements
e. Global Element Forces Report: Forces on Elements
f. Stresses Report: Stresses on Elements
g. Input Listing