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VIBRATIONS AND ROTATING EQUIPMENT

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Acoustical and Mechanical Study Report

Husky 12517 & 31833

Prepared for:

Enerflex Systems Ltd.
David Campbell

APD Project ID:	APD-10-825-EFX-AM
Document No.:	R825-003 Rev 0
Date Issued:	October 18 2010

Equipment Summary

CLIENT:	Enerflex
PROJECT NAME:	Husky 12517 & 31833
APD PROJECT ID:	APD-10-825-EFL-AM
CLIENT PROJECT ID:	Husky 12517 & 31833
COMPRESSOR FRAME:	Ariel JGJ/2
NUMBER OF STAGES:	1 or 2
NUMBER OF CYLINDER:	2
THROW 1:	7-3/8RJ (7.375" bore)
THROW 2:	6-3/8RJ (6" bore)
SUCTION PRESSURE:	765 - 1265 kPa
SUCTION TEMP.:	124 - 127 °F
DISCHARGE PRESSURE:	1600 – 3500 kPa
DISCHARGE TEMP.:	120 °F
FLOW RATE:	2.845 – 5.092 MMSCFD
DRIVER:	Waukesha F18GL nat. gas
POWER:	298 kW
SPEED:	1400 – 1800 RPM

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AP DYNAMICS INC.
Signature
Date OCT 26 2010
PERMIT NUMBER: P 8133
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

PROFESSIONAL ENGINEER
MATTHEW FERGUSON
ALBERTA

Reviewed and Approved By: Matthew Ferguson, P.Eng.	Acoustical Analysis By: Christopher Kowalski	Mechanical Analysis By: Christopher Kowalski

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1. SUMMARY AND RECOMMENDATIONS

1.1 SCOPE OF WORK

Enerflex Ltd. commissioned AP Dynamics Inc. to conduct an acoustical and mechanical study on a set of reciprocating air compressors operating in parallel for the Husky Project as shown in Figure 1.1 and Figure 1.2. The studies were performed as per API 618 4^{th} edition M2-M5. Implementing the recommendations listed in section 1.2 and 1.3 will reduce pulsations and acoustical shaking forces to acceptable levels and ensure that no mechanical natural frequencies will be excited in the main process piping.

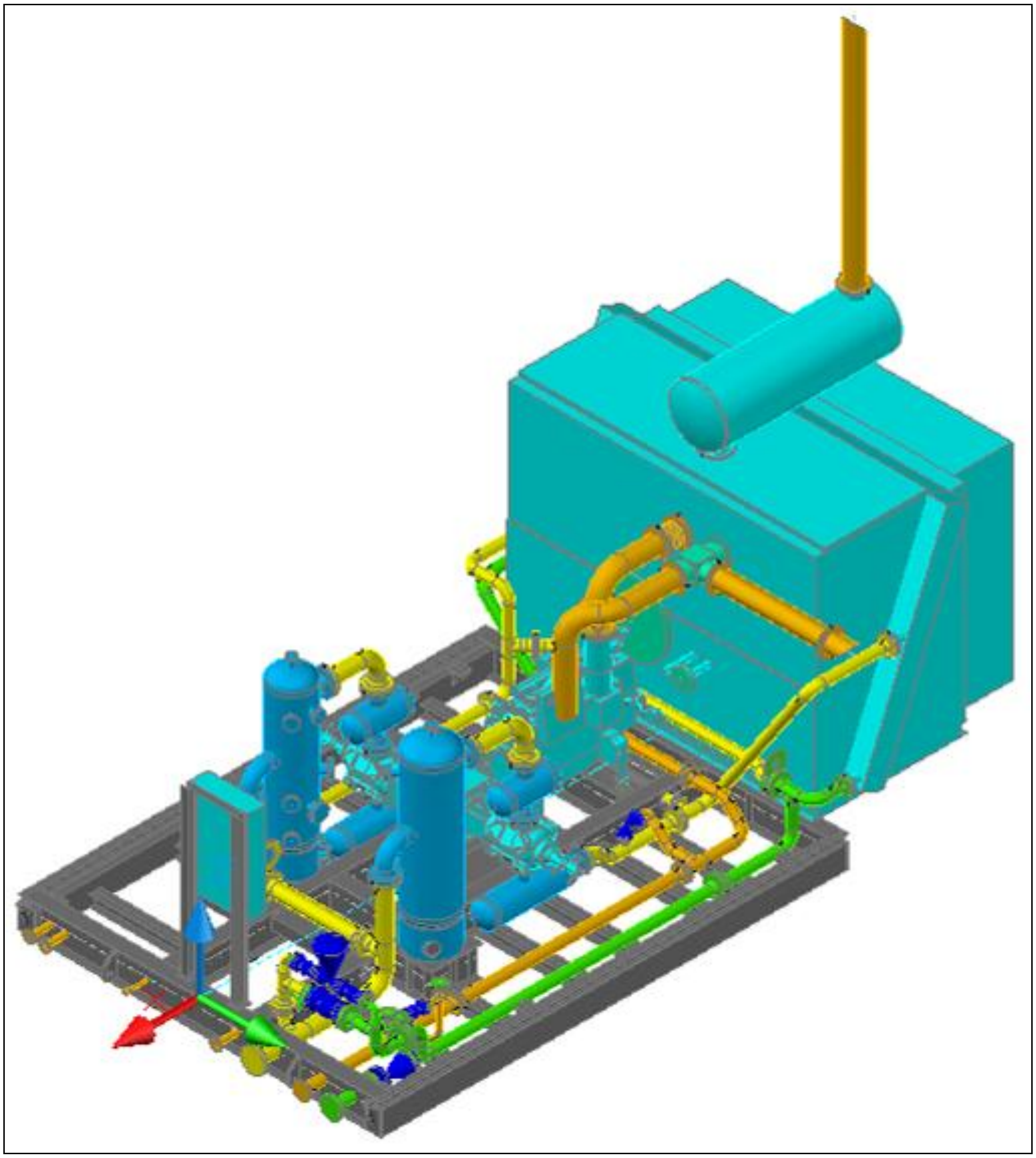


Figure 1.1 Isometric View of Proposed Unit

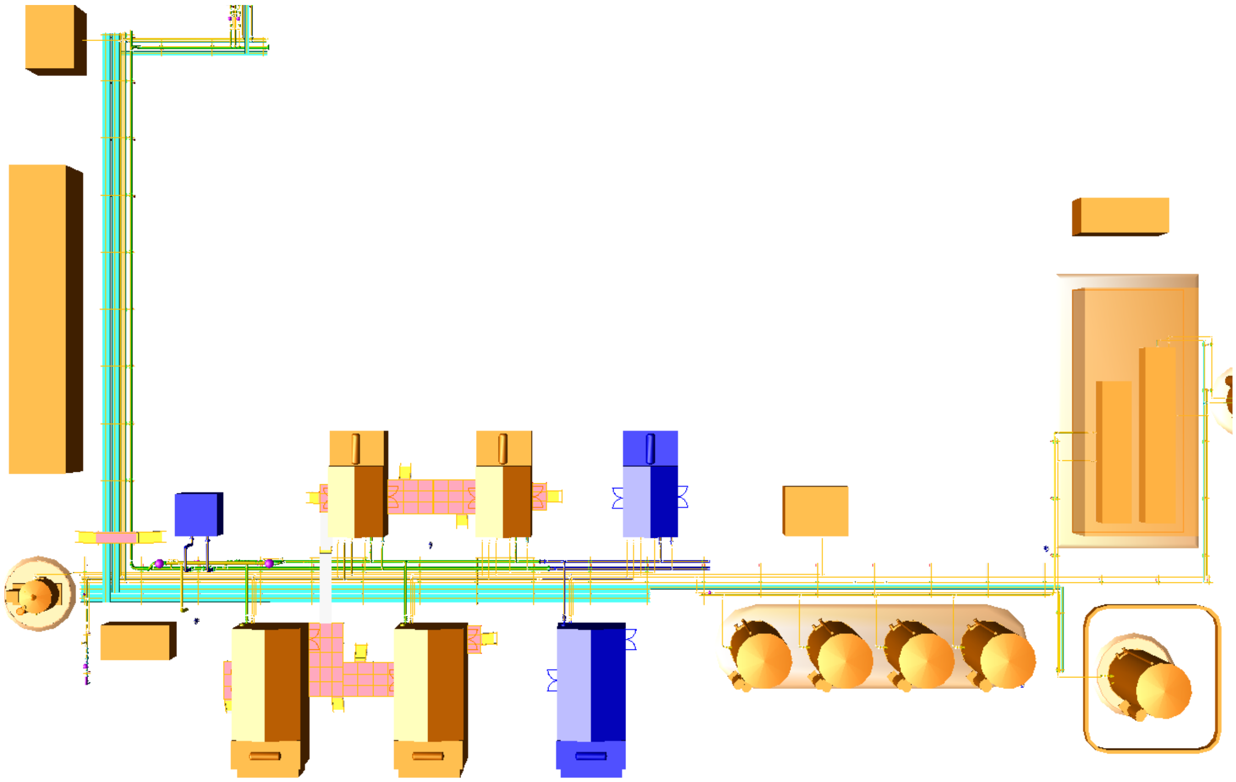


Figure 1.2 Plant Layout

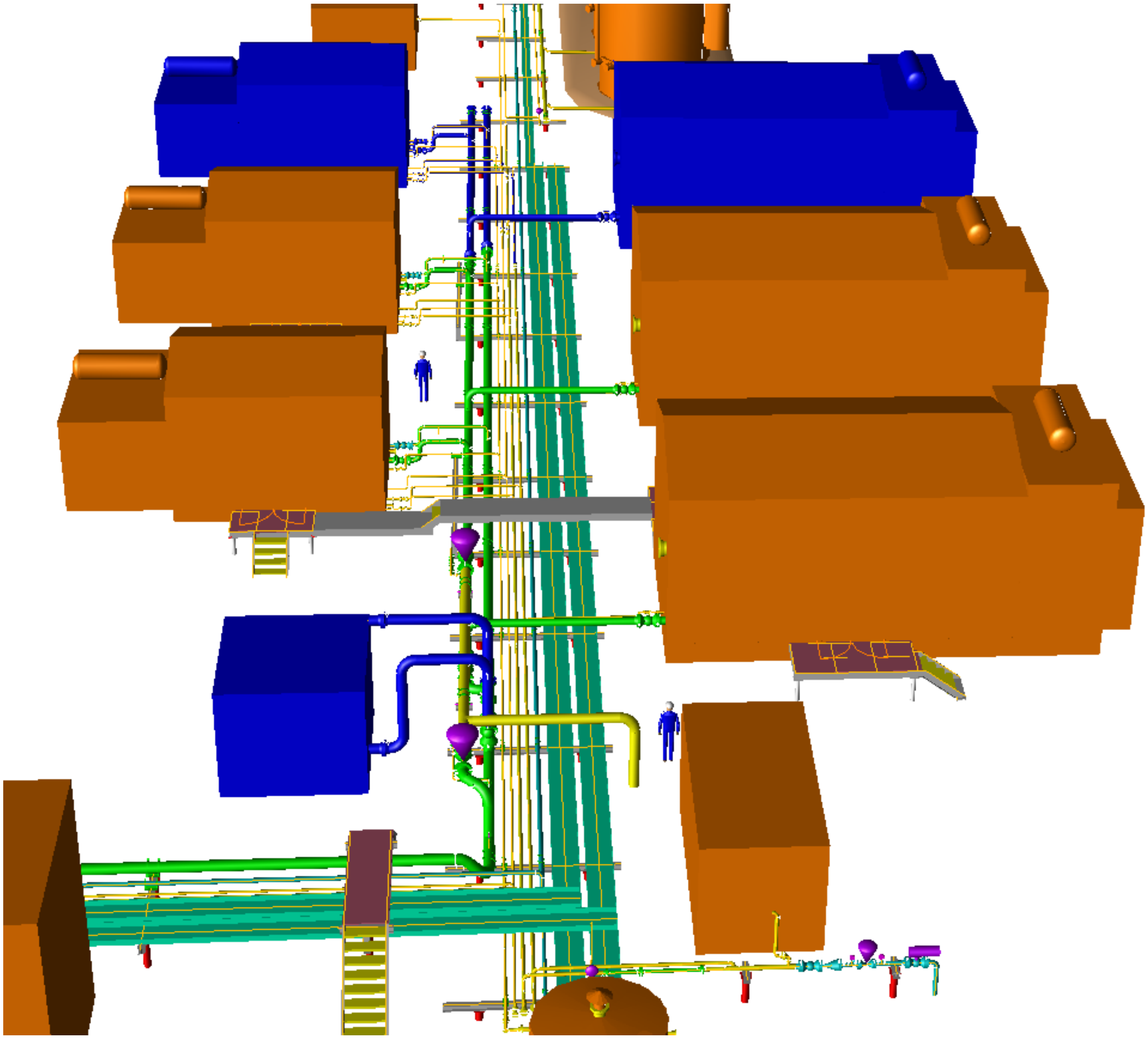


Figure 1.3 Pipe Rack layout 1

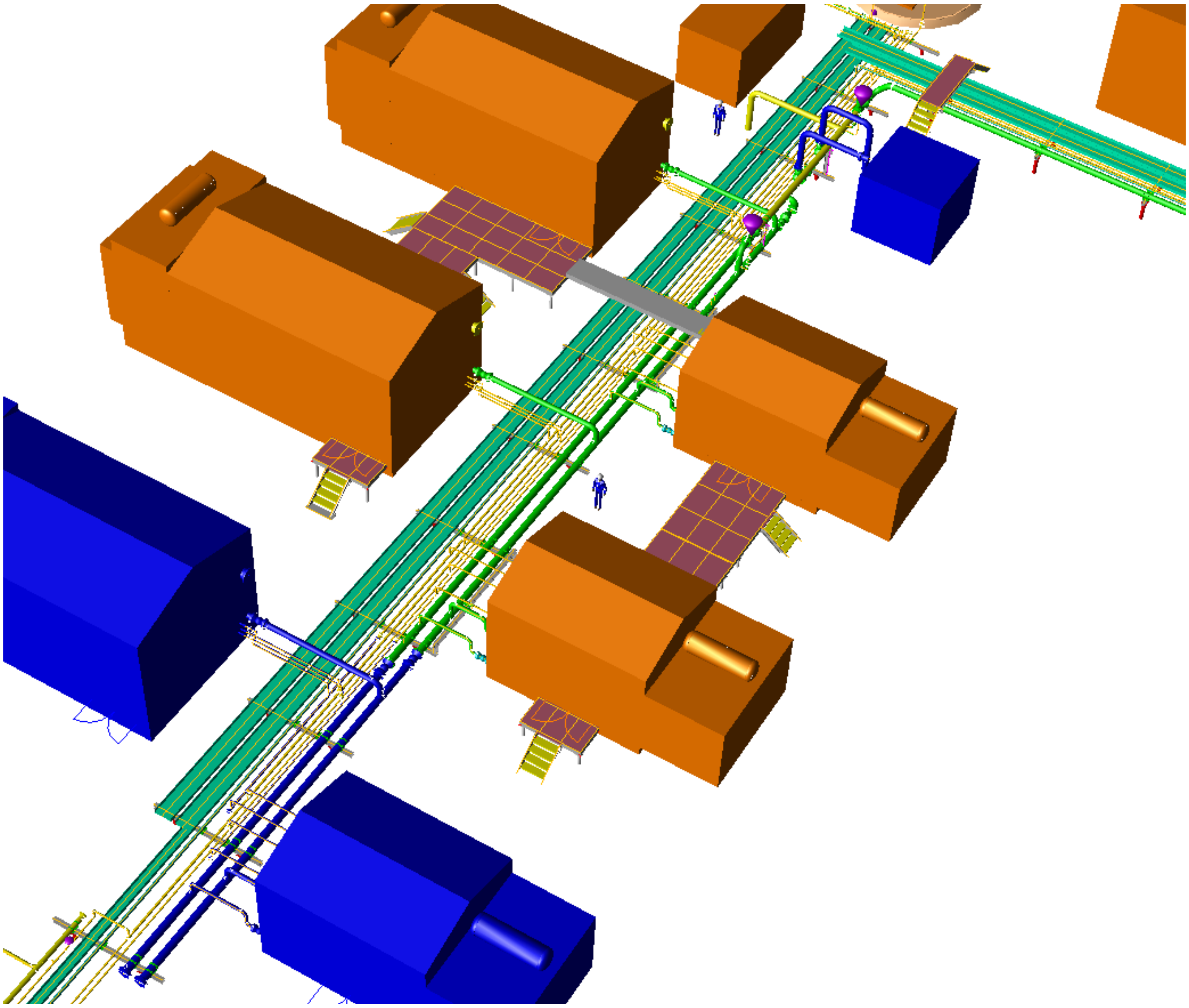


Figure 1.4 Pipe rack layout 2

1.2 ACOUSTICAL RECOMMENDATIONS

The recommended pulsation bottles seam to seam and outer diameters are given in Table 1.1 with corresponding drawing shown in Figure 1.5. Recommended orifice plate locations and inner diameters are given in Table 1.2. In addition to the bottle and orifice recommendations, the Stage 1 Cooler (IC-1) cooler outlet piping should be modified with expanded piping as shown in Figure 1.6. An additional set of flanges and orifice plates should be added at all 3 compressor discharge header tie-in spools as shown in Figure 1.7.

Table 1.1 Pulsation Bottles Summary

Bottle Location	OD	S/S	Notes
Suction Bottles	12-3/4"	20"	LWNF outlet nozzles
Cylinder 1 Discharge Bottle	12-3/4"	36"	2.5” XS choke tubes per Figure 1.5
Cylinder 2 Discharge Bottle	12-3/4"	36"	2.5” XS choke tubes per Figure 1.5

Table 1.2 Orifice Plate ID Summary

Location	ID
Cylinder 1 Suction Bottle Inlet Flange	3-1/4"
Cylinder 1 Discharge Flange	3"
Cylinder 2 Scrubber Inlet Flange	3-3/8"
Cylinder 2 Scrubber Outlet Flange	3-11/16"
Cylinder 2 Discharge Flange	2-3/4"
Compressor 1, 2 and 3 Discharge Header Tie-In Spools (see Figure 1.7)	3"

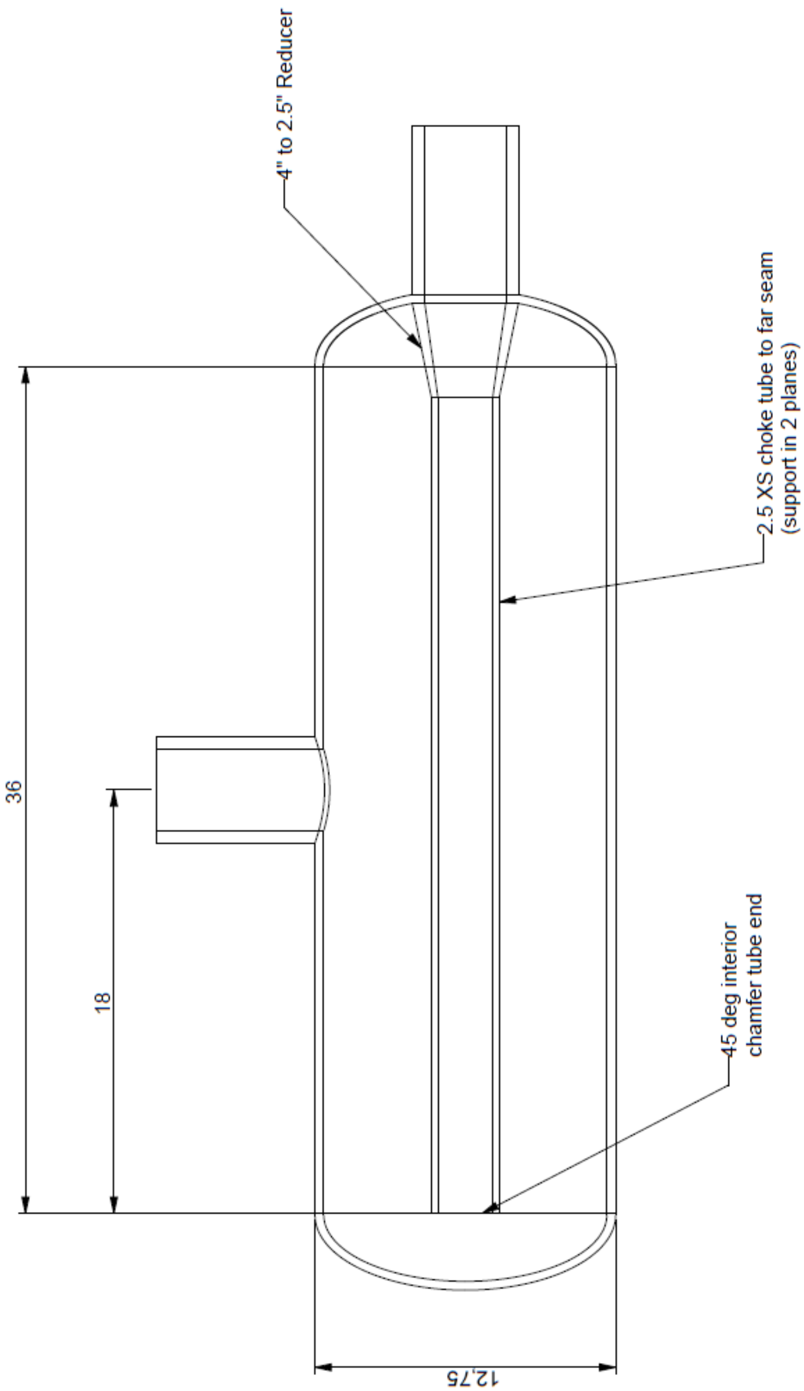


Figure 1.5 Stage 2 Discharge Bottle (see D825-002)

The stage one cooler (IC-1) outlet piping must be altered to minimize pulsations within the piping. The changes are shown below in Figure 1.6. Piping geometry (length) remains unchanged, only pipe diameter is altered.

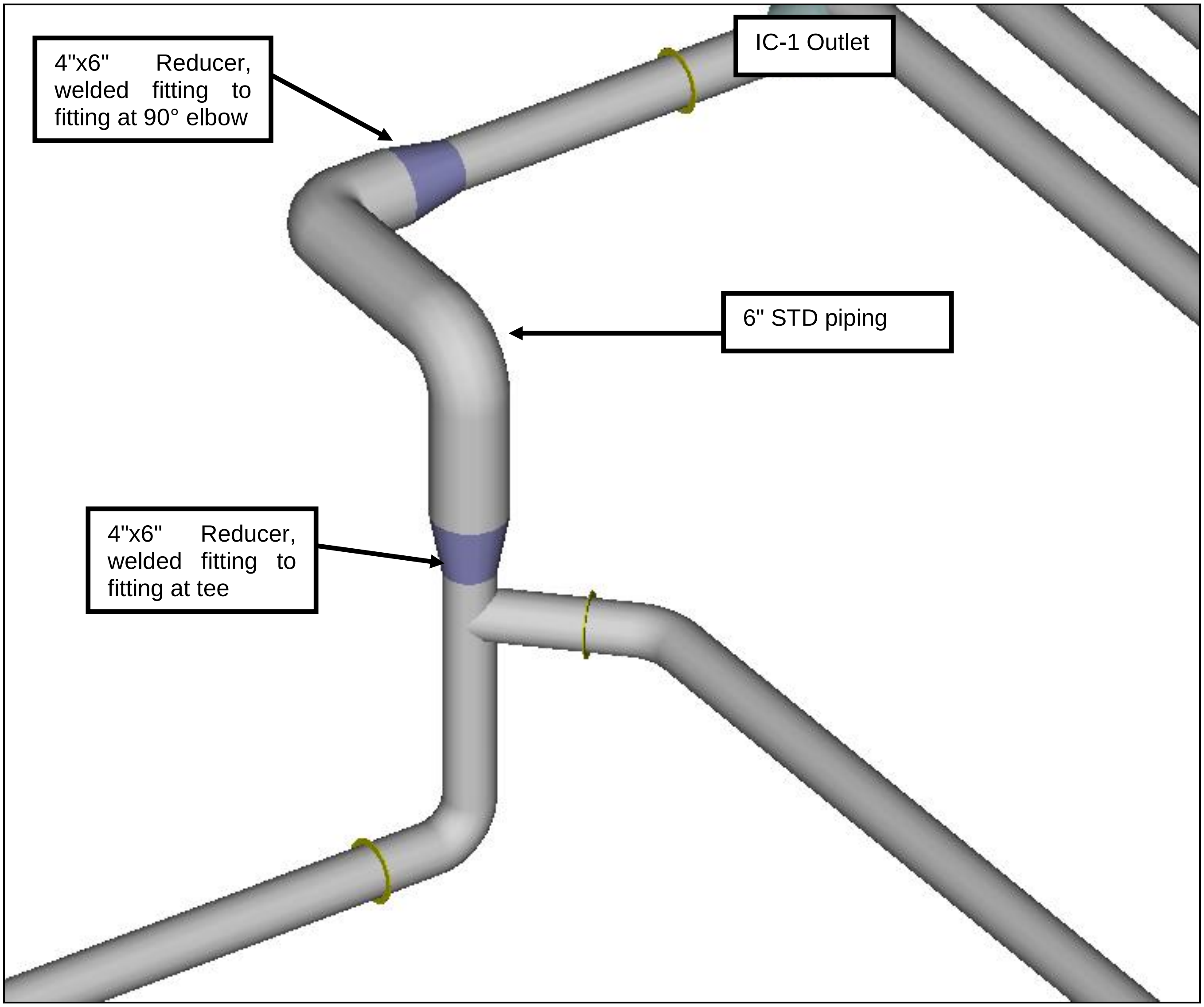


Figure 1.6 Stage 1 Cooler (IC-1) Outlet Piping Changes

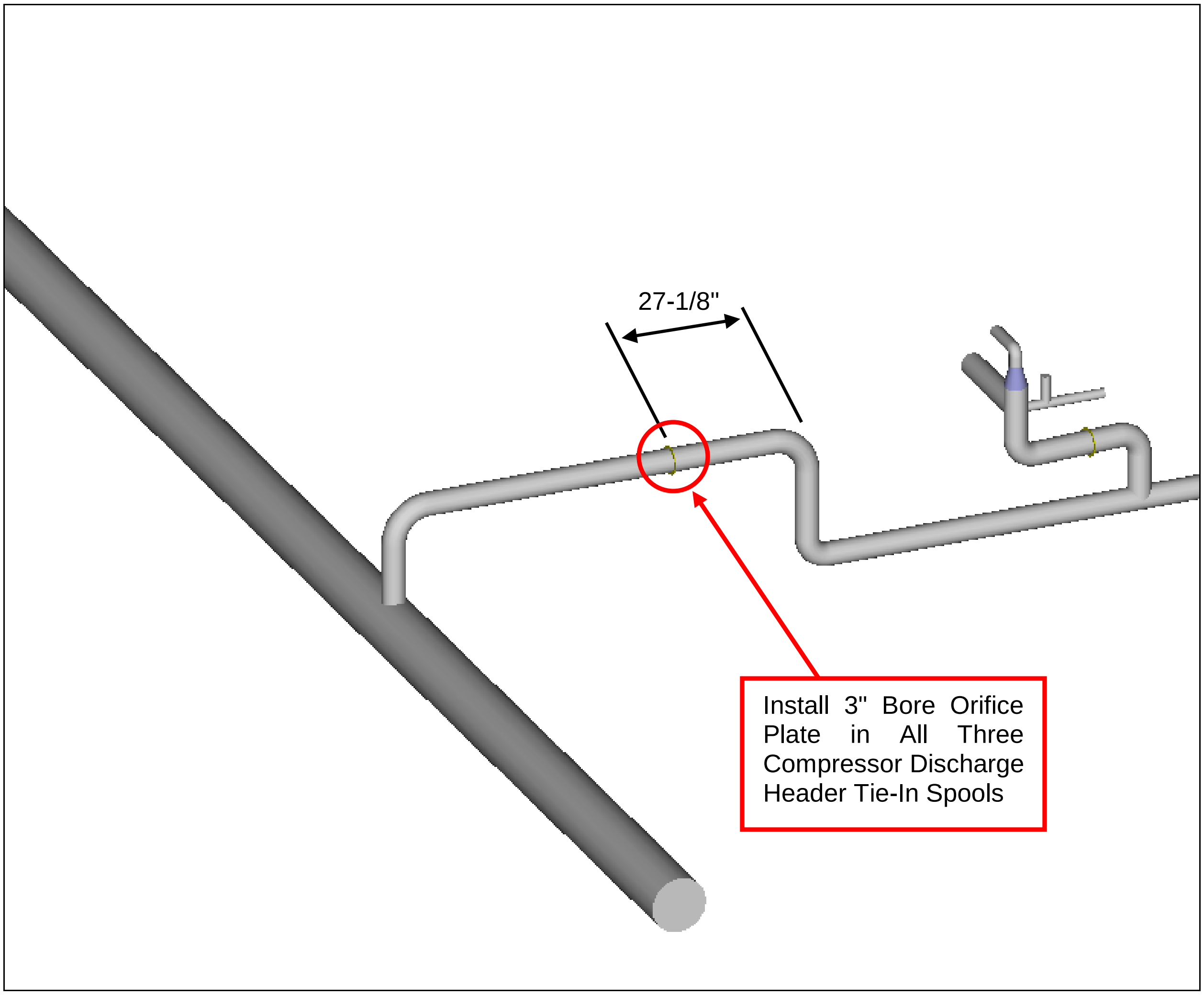


Figure 1.7 Location of Compressor Discharge Header Tie-In Orifice Plate(s)

1.3 MECHANICAL RECOMMENDATIONS

In order to meet the API 618 4th edition M4-M5 natural frequency guidelines the following modifications are required. Piping should be clamped per Table 1.3 through Table 1.4.

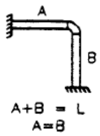
1. Long weld-neck flanges should be used for stage 1 and 2 suction bottle outlet nozzles.
2. Bottle wedge supports are required for both stage 1 and stage 2 discharge bottles as shown in Figure 1.8 and Figure 1.9. All wedges should be loose at start up and then tightened after the unit reaches operating temperature so that the thermal expansion of the cylinder and discharge bottle does not put a large vertical force on the cylinder during operation.
3. Add flange grabber as shown to stage 2 suction inlet pipe spool as shown in Figure 1.10.
4. Stage 1 scrubber skirt wall thickness should be increased to 25.4mm and skirt base should be welded to supporting wide flange beams.
5. Stage 2 scrubber skirt wall thickness should be increased to 25.4mm and skirt base should be welded to supporting wide flange beams.
6. The skid should have 4 piles under each corner of the scrubber bases.
7. Install 1/2" to 3/4" full depth gussets on both sides of the wide flange scrubber base beams.
8. Pile caps should be welded on all sides to the main skid members.
9. Ensure flanged connections meet ASME B31.3 2004 edition, paragraph 335.1, which prohibits distorting piping to bring it into alignment for joint assembly and specifies, before bolting up, flange faces shall be aligned to the design plane within 1/16"/ft ; flange bolt holes shall be aligned within 1/8" maximum offset.

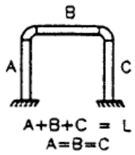
Table 1.3 Pipe Support Spans (in), Straight Pipe

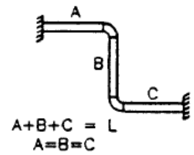
NPS	Cantilevered	Simply Supported	Fixed - Simply Supported	Fixed-Fixed
3/4	23.67	39.64	49.51	59.71
1	26.49	44.36	55.41	66.82
1-1/4	29.76	49.84	62.25	75.08
1-1/2	31.84	53.32	66.60	80.32
2	35.60	59.61	74.46	89.81
2.5	39.17	65.59	81.93	98.81
3	43.22	72.37	90.39	109.02
3.5	46.20	77.36	96.64	116.55
4	49.00	82.06	102.50	123.62
5	54.48	91.24	113.96	137.44
6	59.46	99.56	124.37	149.99
8	67.84	113.60	141.90	171.14
10	75.74	126.83	158.42	191.06
12	82.49	138.12	172.53	208.08
14	86.43	144.73	180.79	218.04
16	92.40	154.73	193.27	233.10
18	98.01	164.11	205.00	247.23
20	103.31	172.99	216.09	260.61
24	113.17	189.50	236.71	285.48

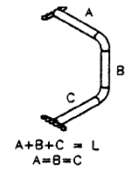
Note: Clamping main piping spools to each skid stringer beam should satisfy maximum pipe span clamping requirements.

Table 1.4 Pipe Support Spans (in), Spools With Elbows









NPS	L-Bend, Out of plane	L-Bend, In plane	U-Bend, out of Plane	U-bend, in plane	Z-Bend, Out of Plane	Z-Bend, In Plane	3D Bend
3/4	51.25	97.24	54.56	61.42	61.03	59.71	57.26
1	57.35	108.82	61.06	68.74	68.30	66.82	64.08
1-1/4	64.44	122.26	68.60	77.23	76.74	75.08	72.00
1-1/2	68.94	130.80	73.39	82.62	82.10	80.32	77.03
2	77.08	146.24	82.05	92.38	91.79	89.81	86.12
2.5	84.80	160.90	90.28	101.63	100.99	98.81	94.75
3	93.57	177.53	99.61	112.14	111.43	109.02	104.55
3.5	100.03	189.79	106.49	119.88	119.12	116.55	111.77
4	106.10	201.30	112.95	127.15	126.35	123.62	118.55
5	117.96	223.82	125.58	141.38	140.48	137.44	131.81
6	128.73	244.25	137.05	154.28	153.30	149.99	143.84
8	146.88	278.69	156.37	176.04	174.92	171.14	164.12
10	163.98	311.13	174.57	196.53	195.28	191.06	183.23
12	178.59	338.84	190.12	214.03	212.67	208.08	199.54
14	187.14	355.06	199.22	224.28	222.85	218.04	209.10
16	200.06	379.58	212.98	239.76	238.24	233.10	223.53
18	212.19	402.60	225.90	254.31	252.69	247.23	237.09
20	223.67	424.38	238.11	268.06	266.36	260.61	249.92
24	245.02	464.89	260.84	293.65	291.79	285.48	273.77

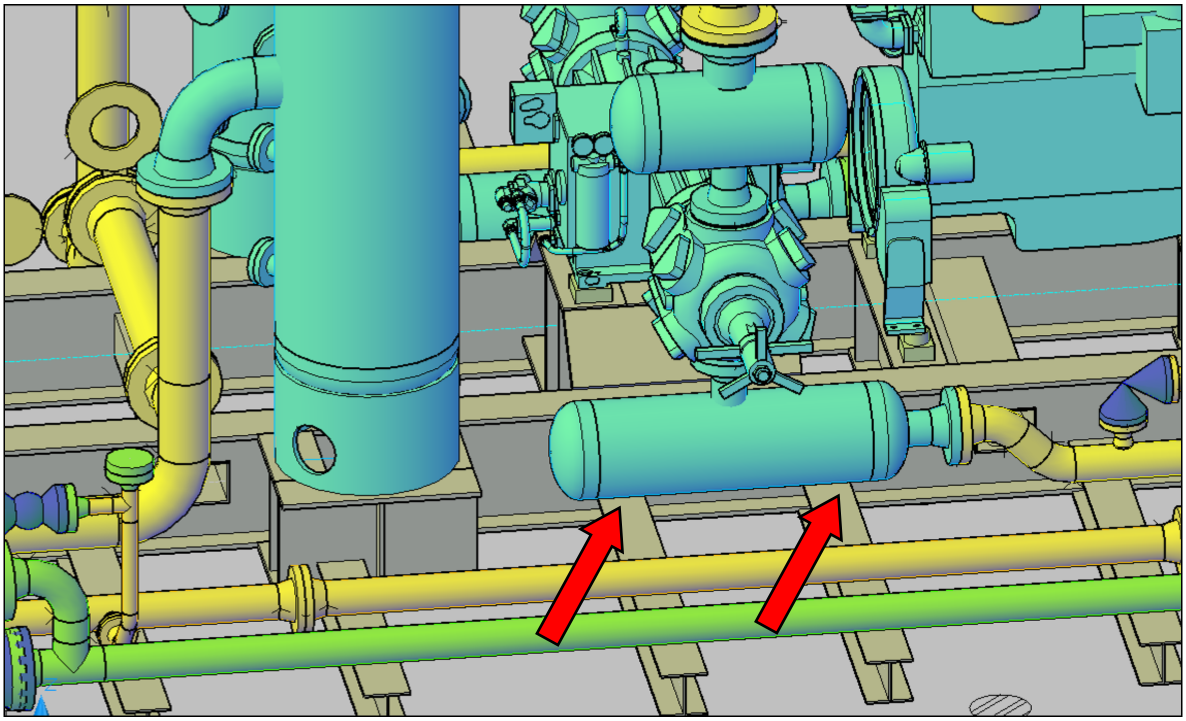


Figure 1.8 Stage 1 Discharge Bottle Wedge Locations

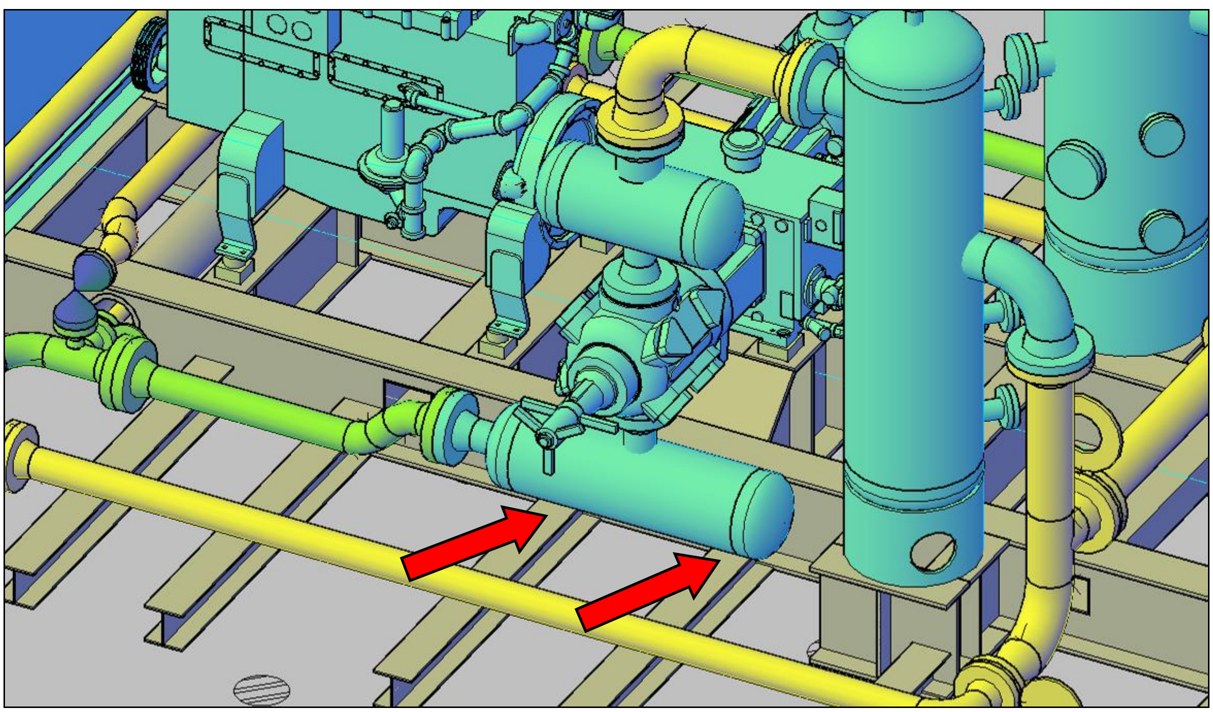


Figure 1.9 Stage 2 Discharge Bottle Wedge Locations

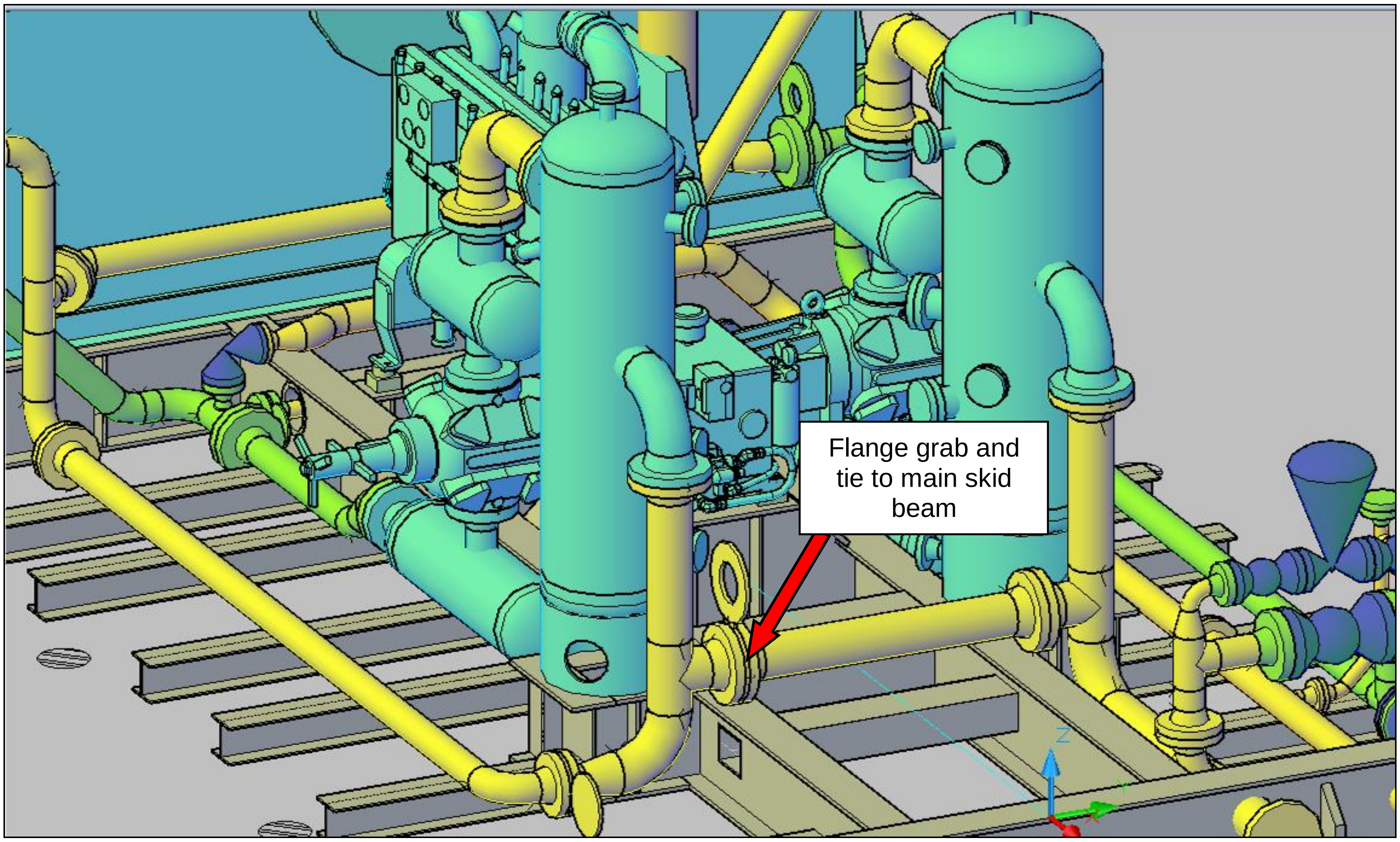


Figure 1.10 Stage 2 Scrubber Suction Spool Flange Grabber Location

2. ACOUSTICAL STUDY DETAILED RESULTS

2.1 LOAD CASES ANALYZED

The client provided 14 load cases to be analyzed, which were each split into 2 to cover the entire 1400 rpm to 1800 rpm range of the unit. The load cases are summarized in Table 2.1.

Table 2.1 Load Cases Summary

# Stages	Case	Speed, RPM	Flow Rate, MMSCFD	Suction Pressure, kPa	Suction Temp, °F	Discharge Pressure, kPa	Discharge Temp, °F	Throw 1 HE Clr, %	Throw 2 HE Clr, %
1	1	1800	5.08	965.53	125	1600	120	71.03	83.77
	2	1800	3.493	765.53	126	1600	120	71.03	83.77
	3	1800	5.092	1065.53	126	2000	120	71.03	83.77
	4	1800	3.915	915.53	127	2000	120	71.03	83.77
	1b	1600	4.516	965.53	125	1600	120	71.03	83.77
	2b	1600	3.105	765.53	126	1600	120	71.03	83.77
	3b	1600	4.526	1065.53	126	2000	120	71.03	83.77
	4b	1600	3.48	915.53	127	2000	120	71.03	83.77
2	5	1800	3.976	1065.53	124	2000	120	19.38	19.29
	6	1800	3.265	865.53	124	2000	120	19.38	19.29
	7	1800	4.665	1265.53	124	2400	120	19.38	19.29
	8	1800	3.243	865.53	124	2400	120	19.38	19.29
	9	1800	4.641	1265.53	124	2800	120	19.38	19.29
	10	1800	3.222	865.53	125	2800	120	19.38	19.29
	11	1800	4.618	1265.53	124	3200	120	19.38	19.29
	12	1800	3.201	865.53	125	3200	120	19.38	19.29
	13	1800	4.5	1265.53	124	3500	120	31.77	19.29
	14	1800	3.539	965.53	125	3500	120	19.38	19.29
	5b	1600	3.534	1065.53	124	2000	120	19.38	19.29
	6b	1600	2.902	865.53	124	2000	120	19.38	19.29
	7b	1600	4.147	1265.53	124	2400	120	19.38	19.29
	8b	1600	2.883	865.53	124	2400	120	19.38	19.29
	9b	1600	4.125	1265.53	124	2800	120	19.38	19.29
	10b	1600	2.864	865.53	125	2800	120	19.38	19.29
	11b	1600	4.105	1265.53	124	3200	120	19.38	19.29
	12b	1600	2.845	865.53	125	3200	120	19.38	19.29
	13b	1600	4	1265.53	124	3500	120	31.77	19.29
	14b	1600	3.146	965.53	125	3500	120	19.38	19.29

2.2 Acoustical System Definition

Every reciprocating compressor can be divided in (n + 1) independent acoustical systems, where n = the number of stages. The piston in the compressor's cylinder is the source of acoustical excitation and in order for pulsations to be transmitted into the piping, the relevant valves must be open (i.e. for the suction system, the cylinder's suction valves must be open). In order to achieve efficient compression, both suction and discharge valves should not be open at the same time thus there is no path for pulsations to travel across the cylinder from the suction into the discharge system and vice versa. Each system can be analyzed independently.

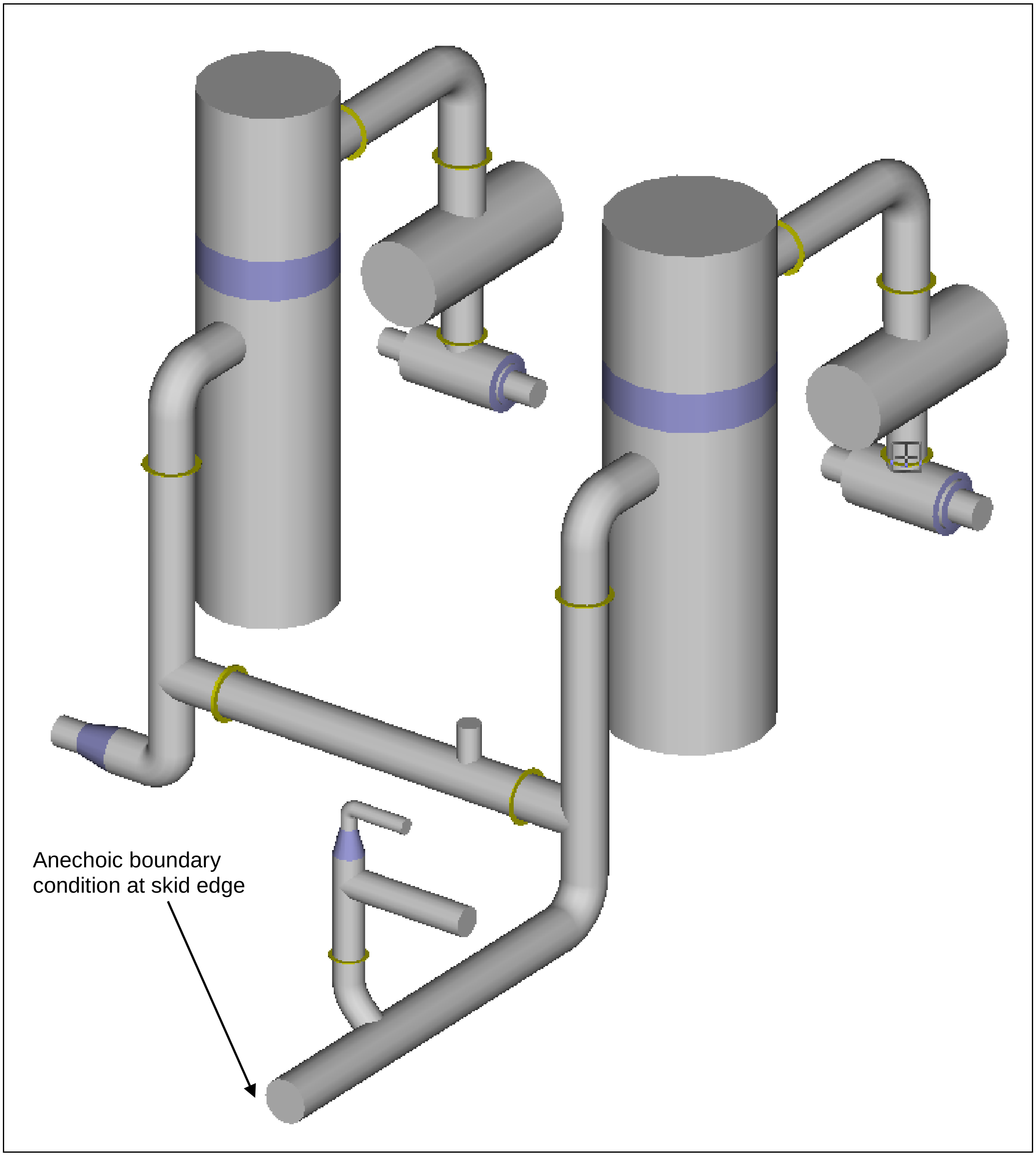


Figure 2.1 Single Stage Suction System

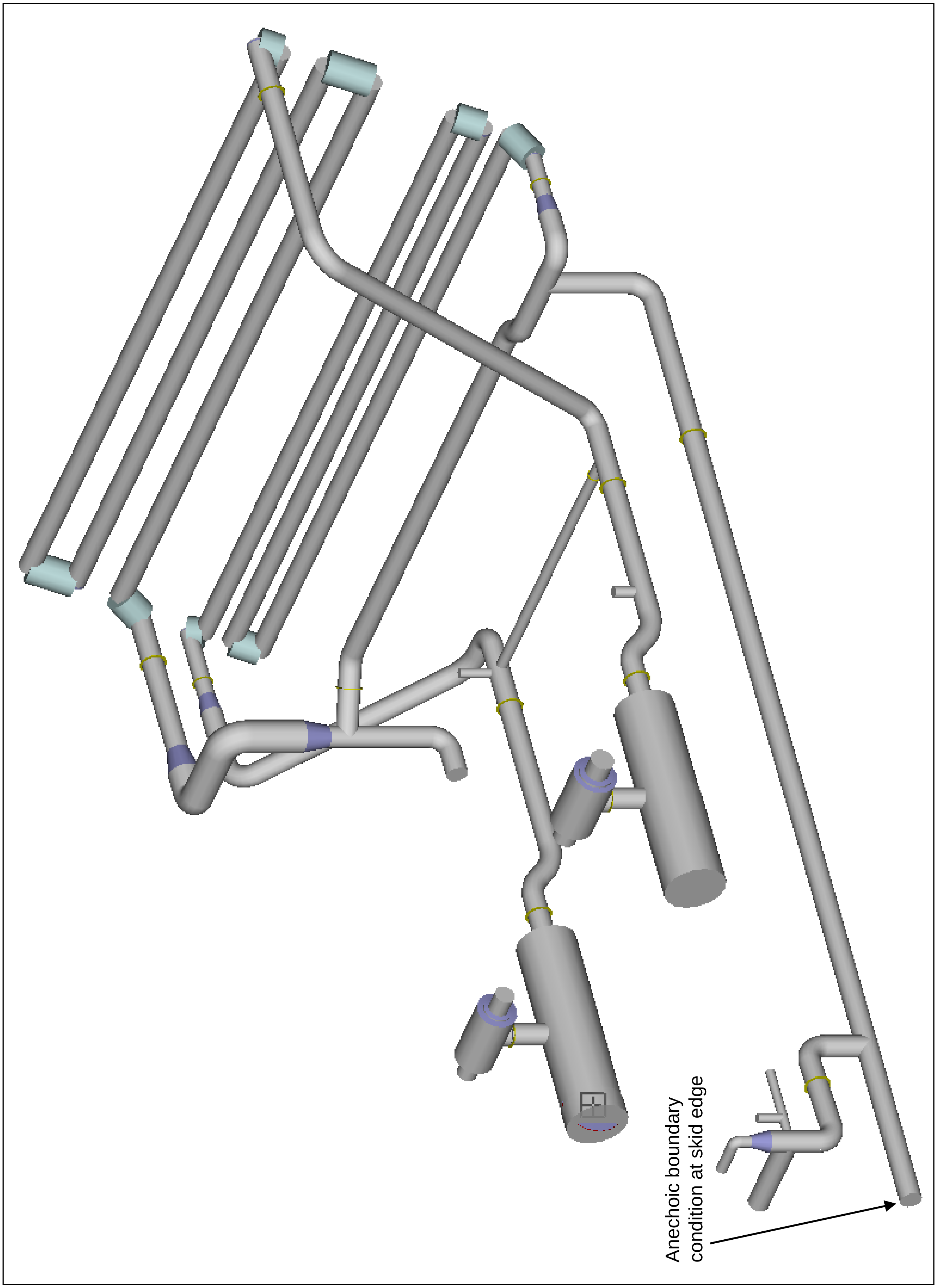


Figure 2.2 Single Stage Discharge System

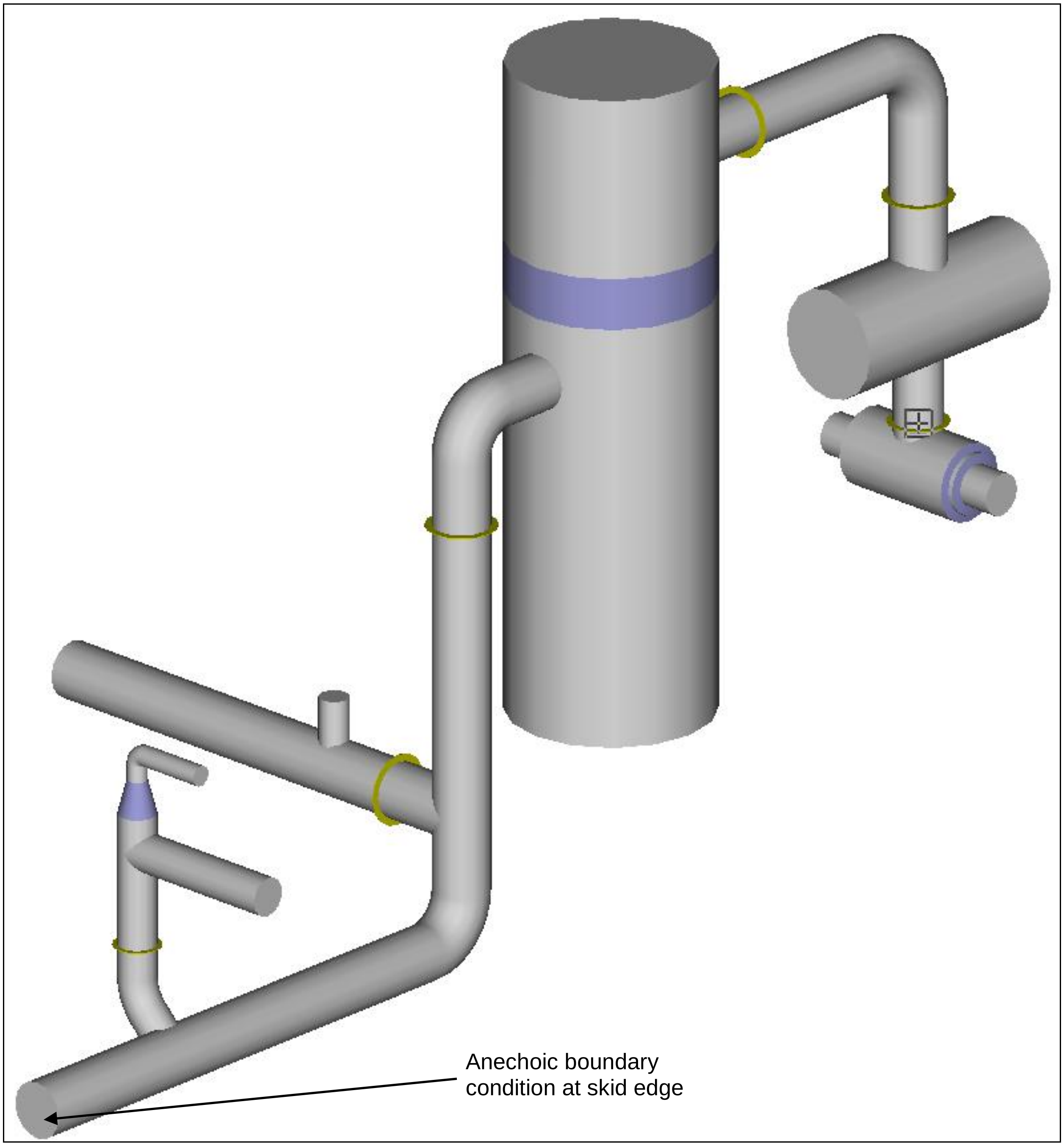


Figure 2.3 Two Stage Suction System

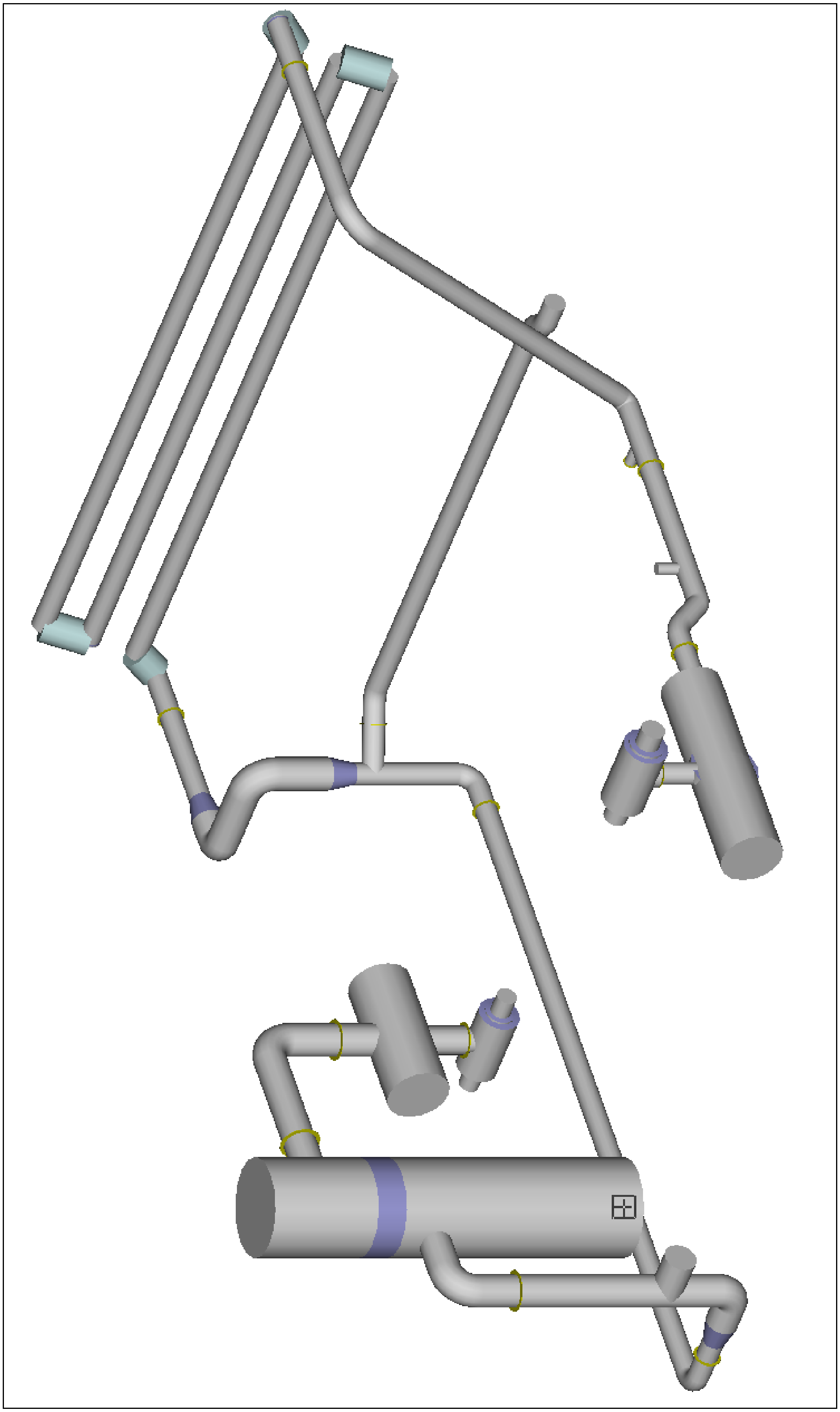


Figure 2.4 Two Stage Interstage System

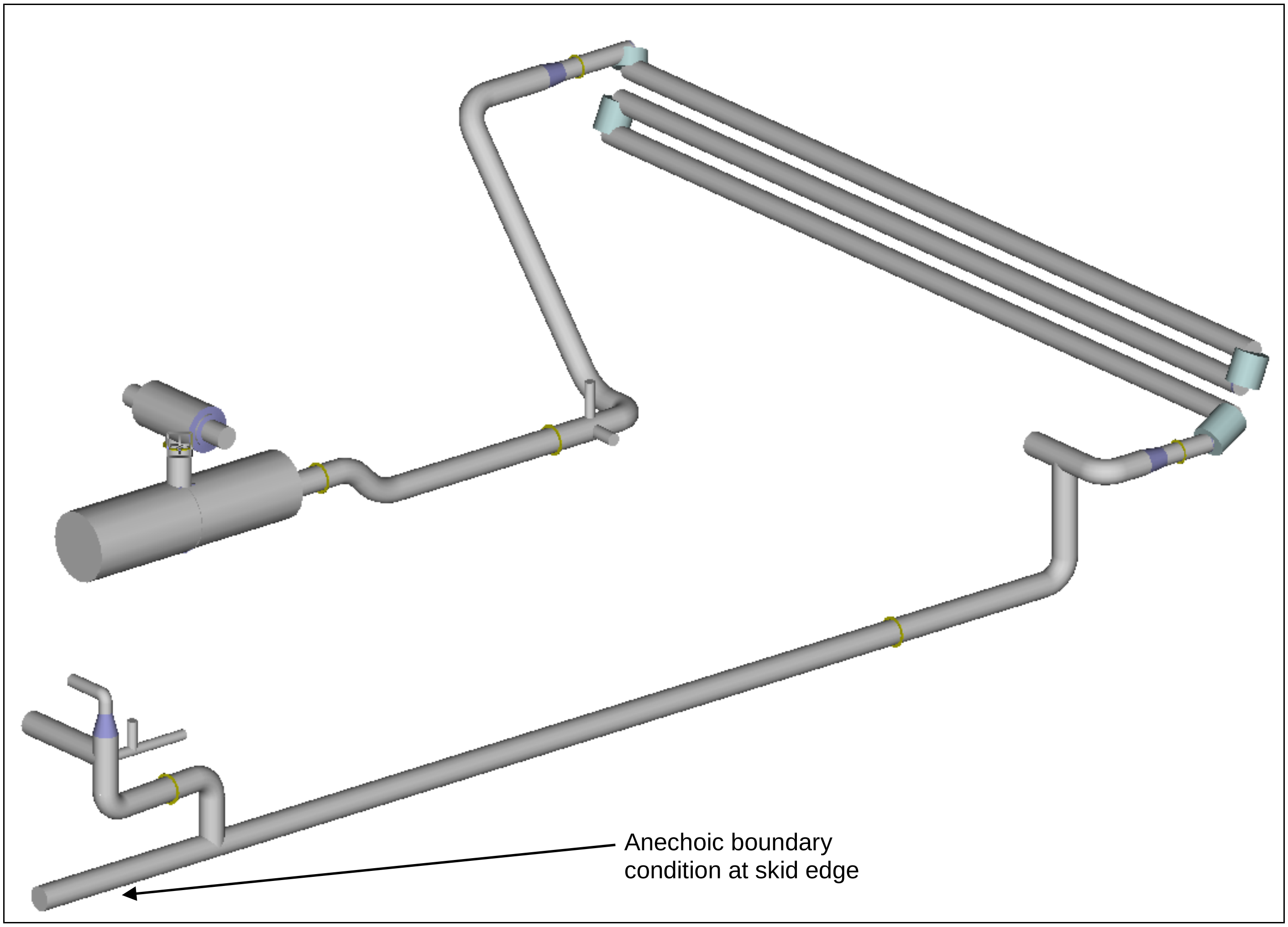


Figure 2.5 Two Stage Discharge System

2.3 SINGLE STAGE SUCTION RESULTS

Pulsation levels in the single stage suction system were 2.32x above API 618 4th edition guidelines for the worst as found case shown in Figure 2.6. After the installation of the recommended orifice plates pulsation levels are reduced to 1.01x guidelines as shown in Figure 2.7. Selected shaking forces before and after the recommendations are shown in Figure 2.8 through Figure 2.9. Shaking forces were as high as 550 N for the as found case. Shaking forces are well below guidelines before and after modifications.

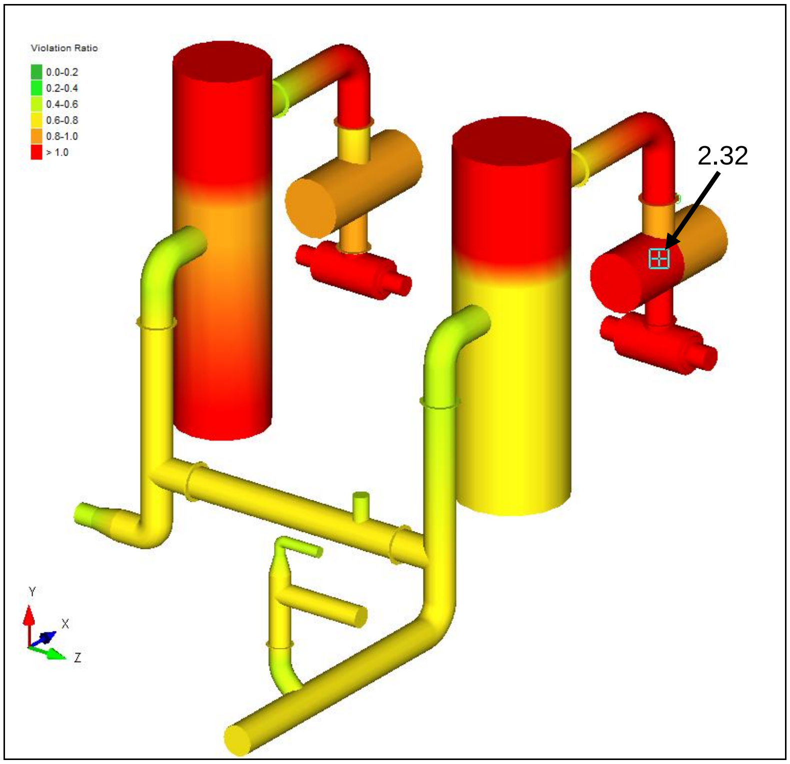


Figure 2.6 Pulsation Violation Ratio in Single Stage Suction System – As Found

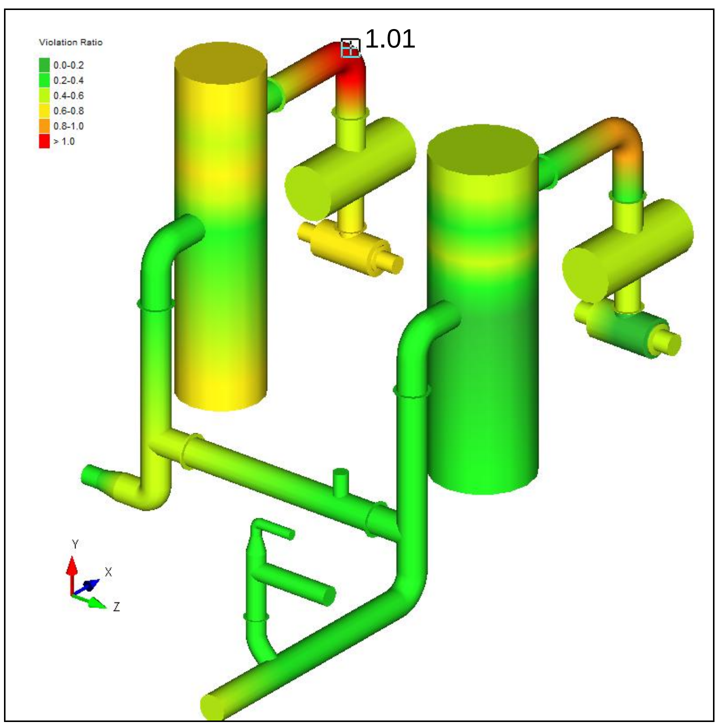


Figure 2.7 Pulsation Violation Ratio in Single Stage Suction System – After Modifications

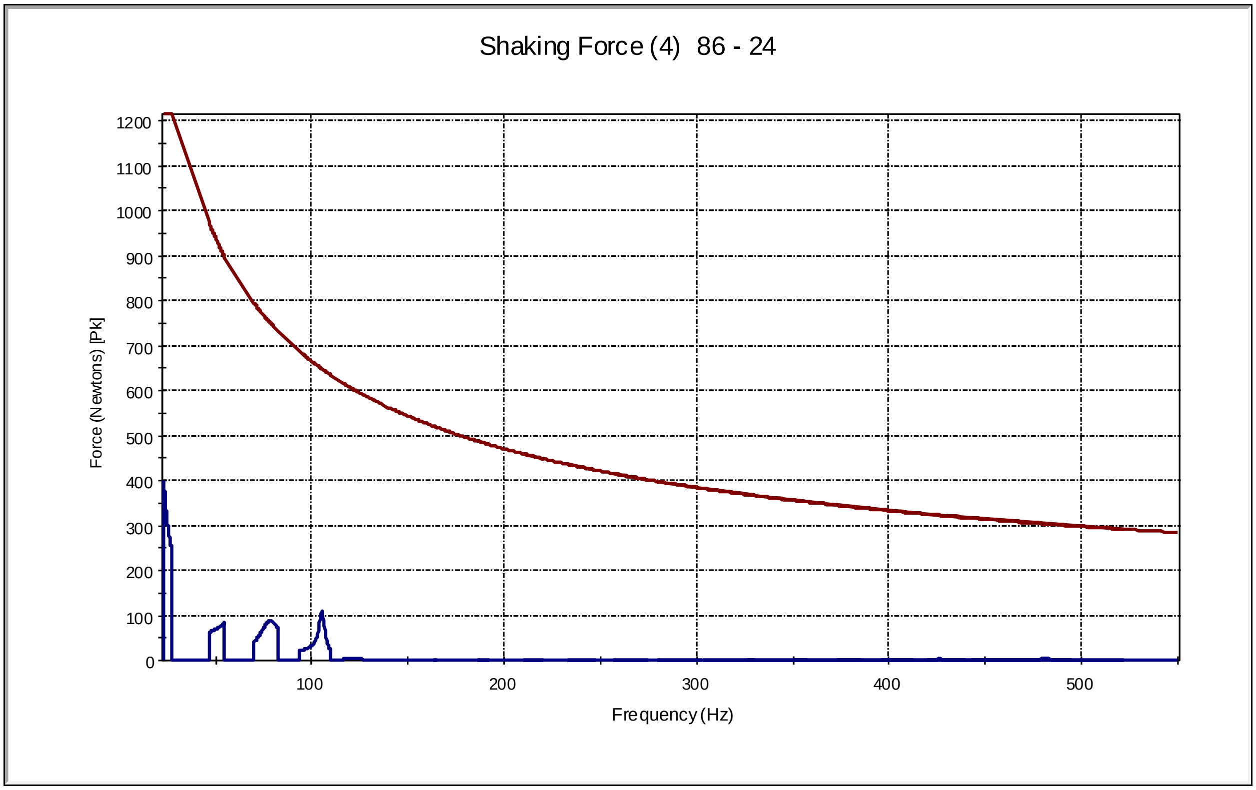


Figure 2.8 Shaking Force in Cylinder 1 Scrubber Outlet Spool – As Found

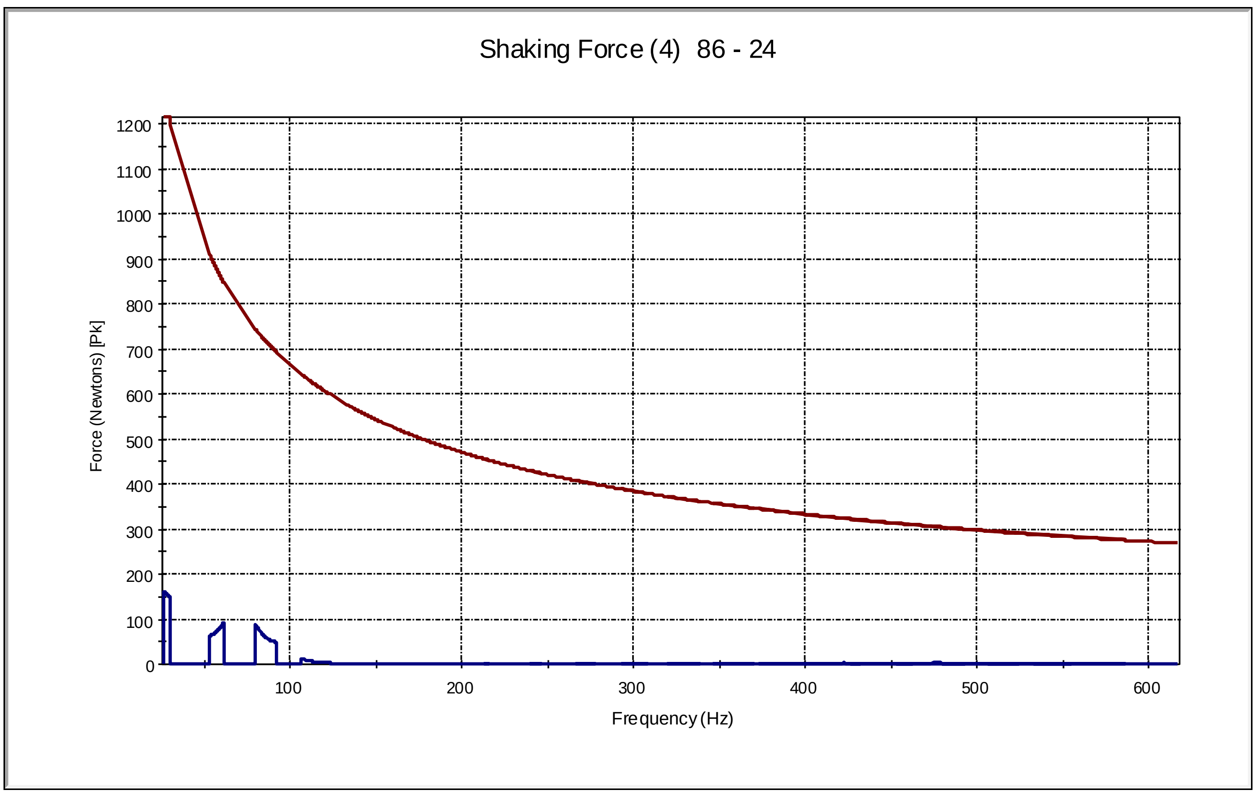


Figure 2.9 Shaking Force in Cylinder 1 Scrubber Outlet Spool – After Modifications

2.4 SINGLE STAGE DISCHARGE RESULTS

Pulsation levels in the single stage discharge system were 4.39x above API 618 4th edition guidelines for the worst as found case shown in Figure 2.10. After the implementation of the recommended changes pulsation levels are reduced to 1.73x guidelines shown in Figure 2.11. Selected shaking forces before and after the recommendations are shown in Figure 2.12 through Figure 2.16. Shaking forces were as high as 670 N for the as found case. After modifications, all shaking forces within the system are well below guideline.

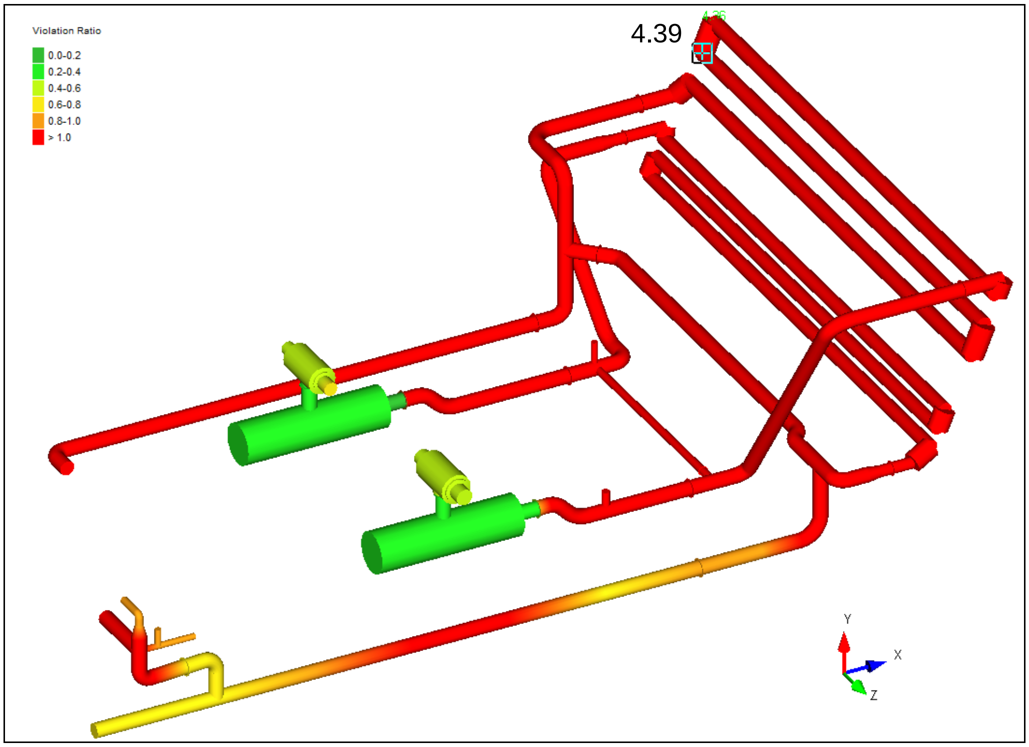


Figure 2.10 Pulsation Violation Ratio in Single Stage Discharge System – As Found

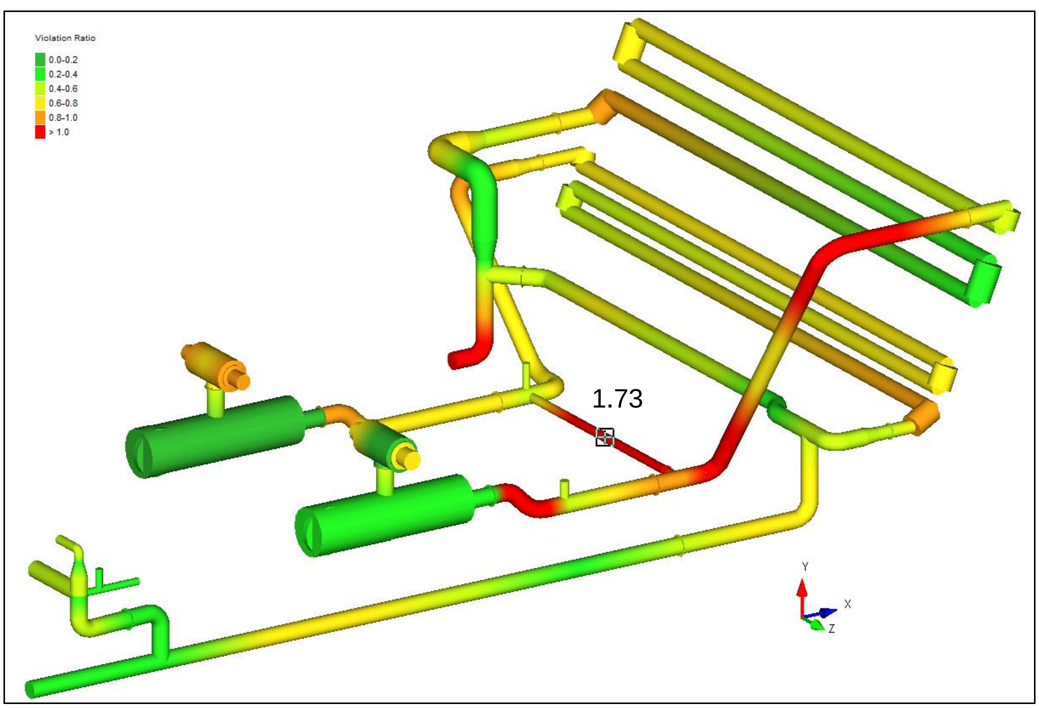


Figure 2.11 Pulsation Violation Ratio in Single Stage Discharge System – After Modifications

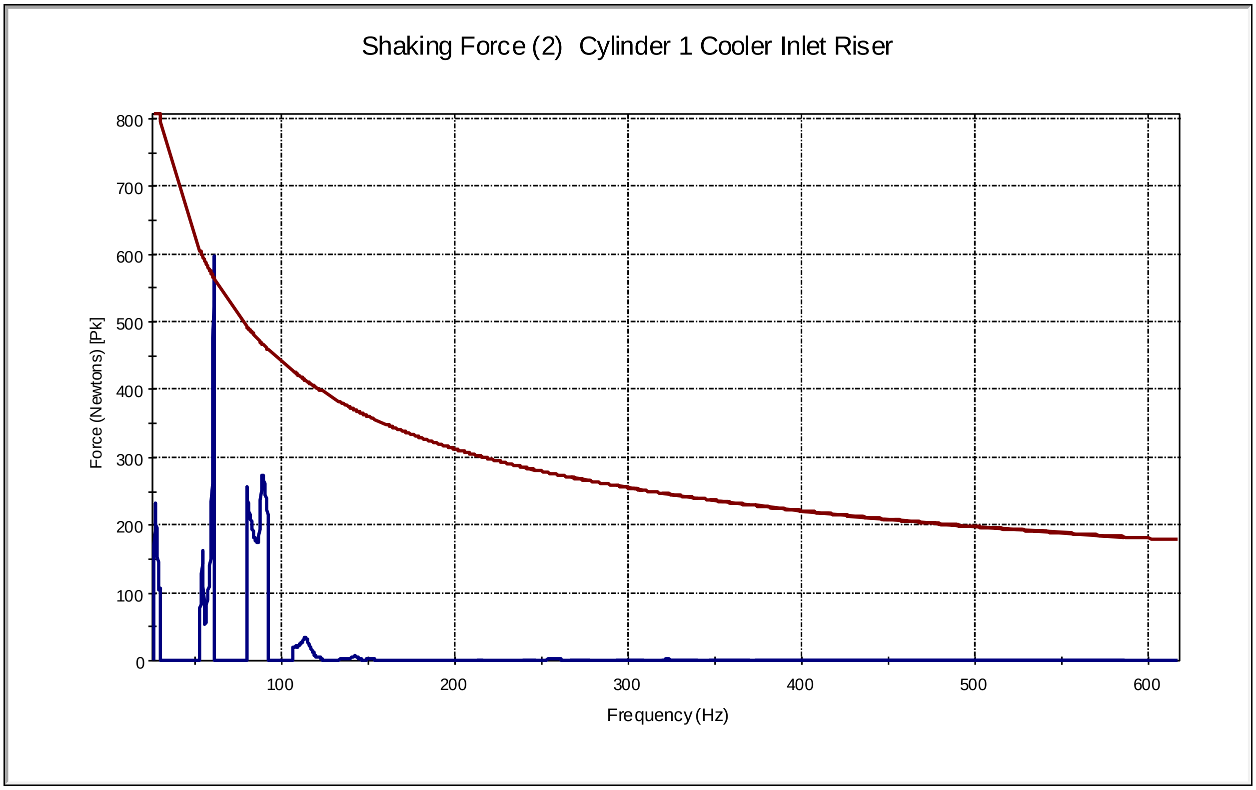


Figure 2.12 Shaking Force in Cylinder 1 Cooler Inlet Riser – As Found

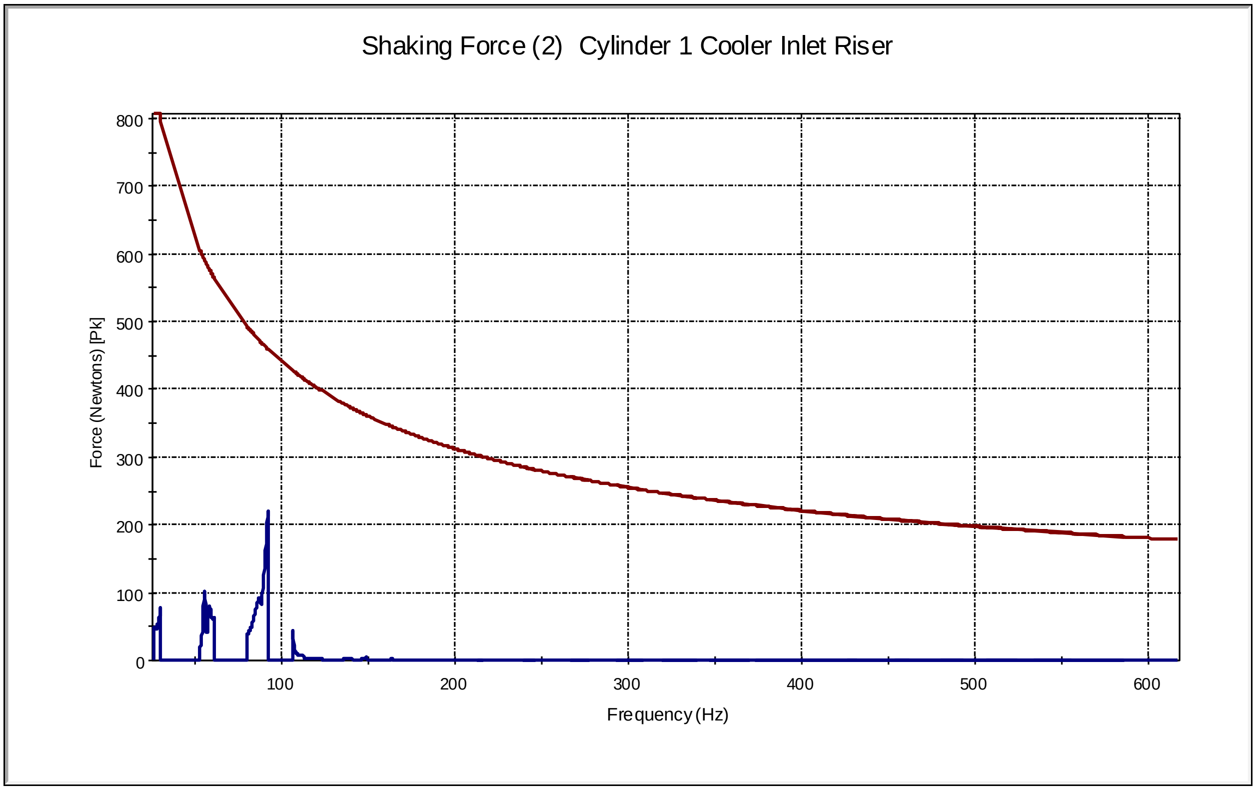


Figure 2.13 Shaking Force in Cylinder 1 Cooler Inlet Riser – After Modifications

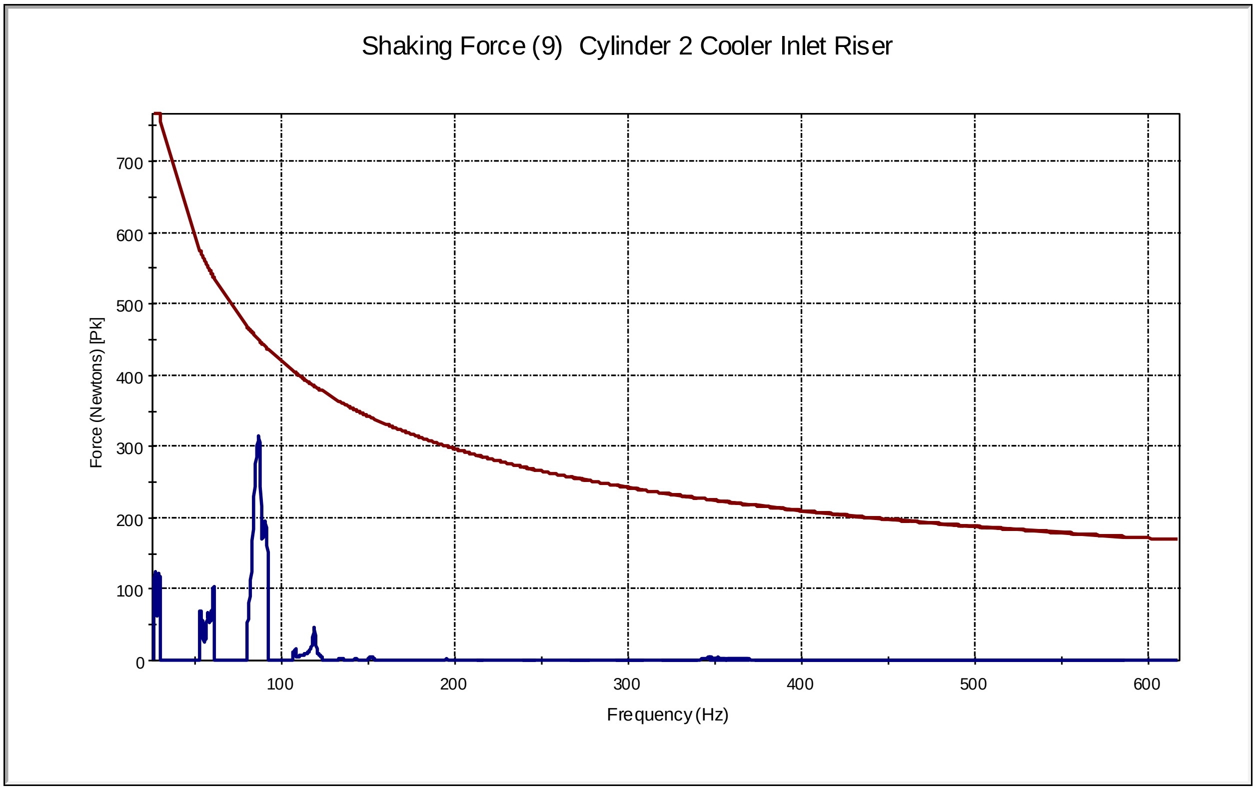


Figure 2.14 Shaking Force in Cylinder 2 Cooler Inlet Riser – As Found

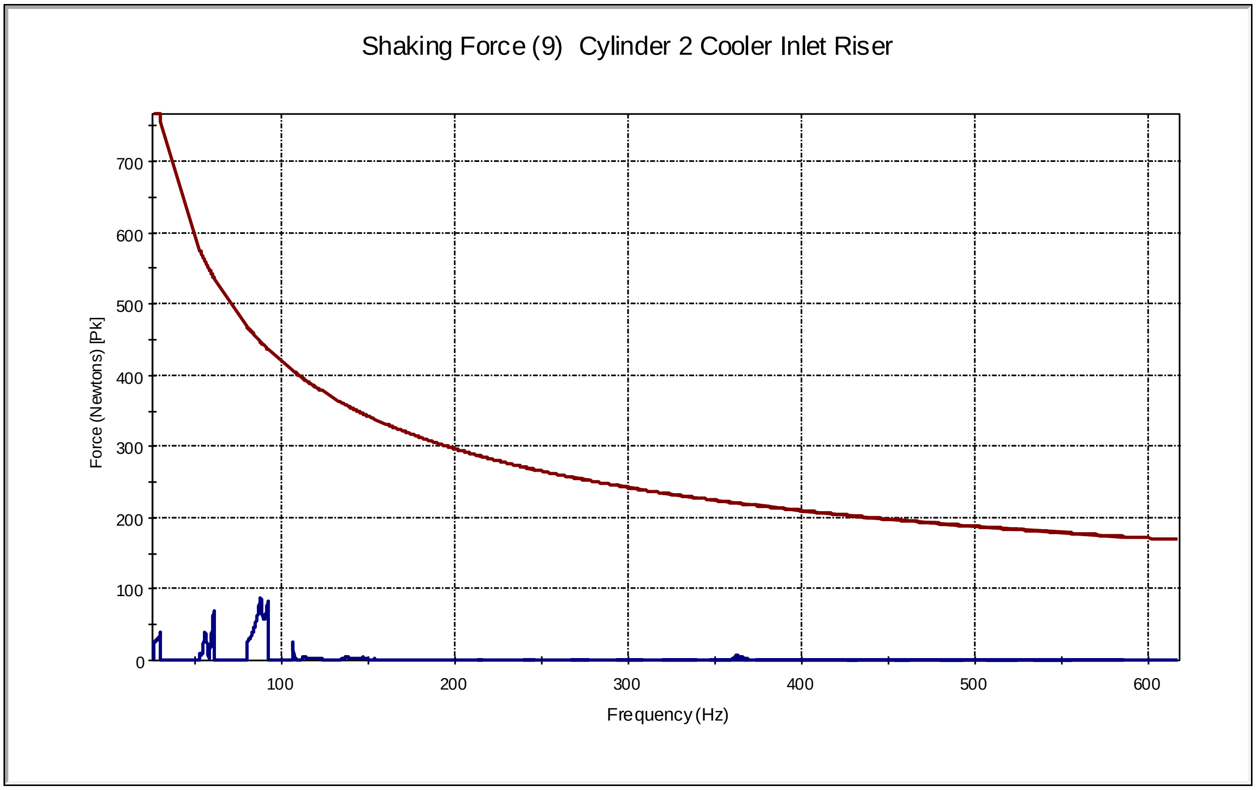


Figure 2.15 Shaking Force in Cylinder 2 Cooler Inlet Riser – After Modifications

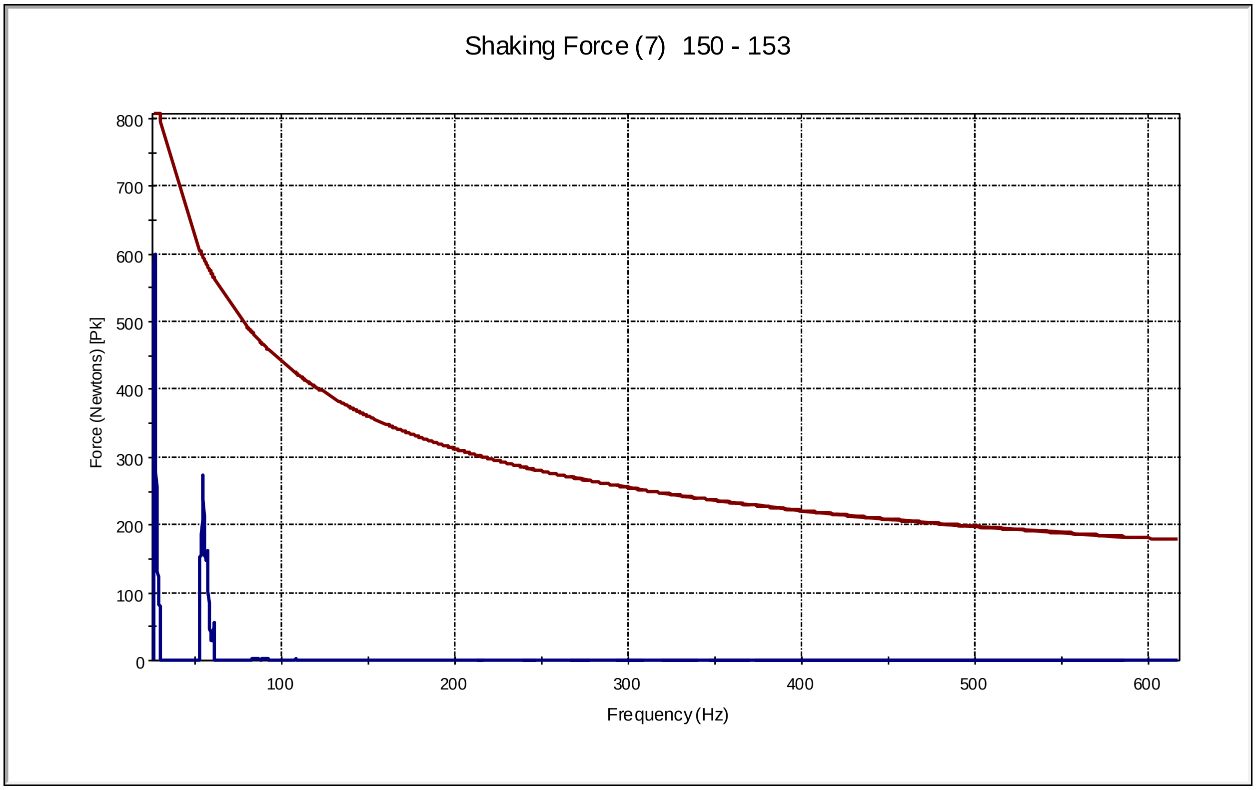


Figure 2.16 Shaking Force in Skid Level, Cylinder 2 Scrubber Feed Spool – As Found

Note: After modifications, the skid level cylinder 2 scrubber feed spool is completely isolated with blinds and has no shaking forces within the spool during 2 stage operation.

2.5 TWO STAGE SUCTION RESULTS

Pulsation levels in the two-stage suction system were 2.07x above API 618 4th edition guidelines for the worst as found case shown in Figure 2.17. After the installation of the recommended orifice plates pulsation levels are reduced to 1.48x guidelines shown in Figure 2.18. Selected shaking forces before and after the recommendations are shown in Figure 2.19 and Figure 2.20. Shaking forces are below guidelines before and after modifications.

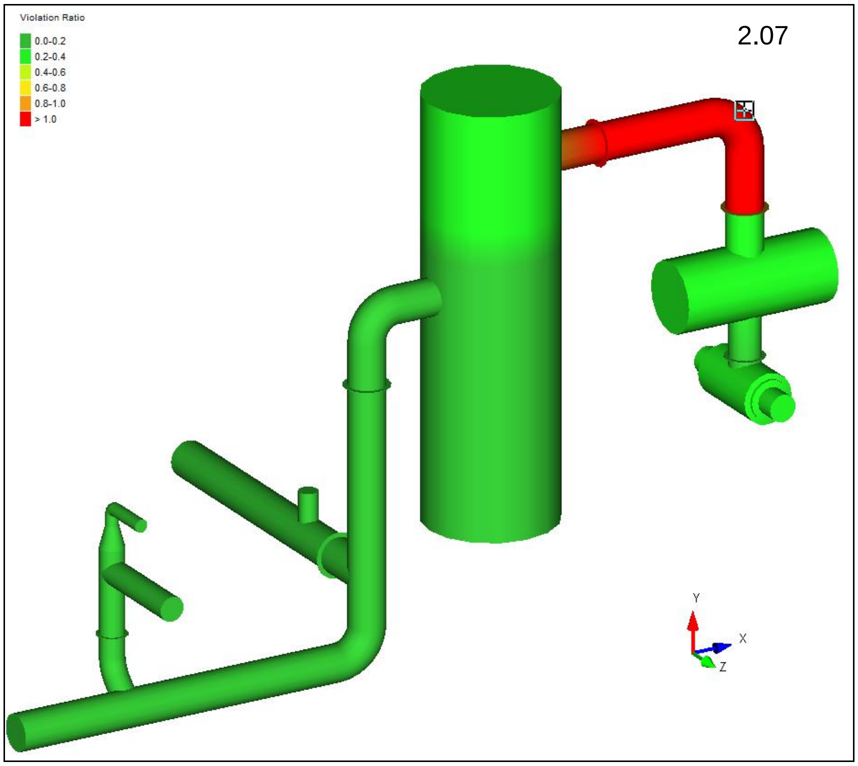


Figure 2.17 Pulsation Violation Ratio in Two Stage Suction System – As Found

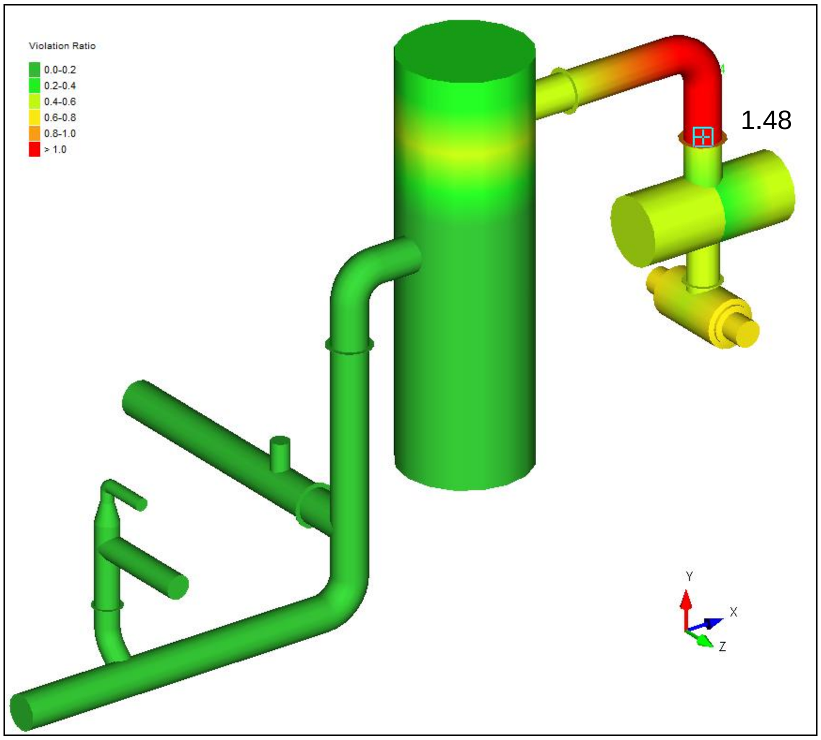


Figure 2.18 Pulsation Violation Ratio in Two Stage Suction System – After Modifications

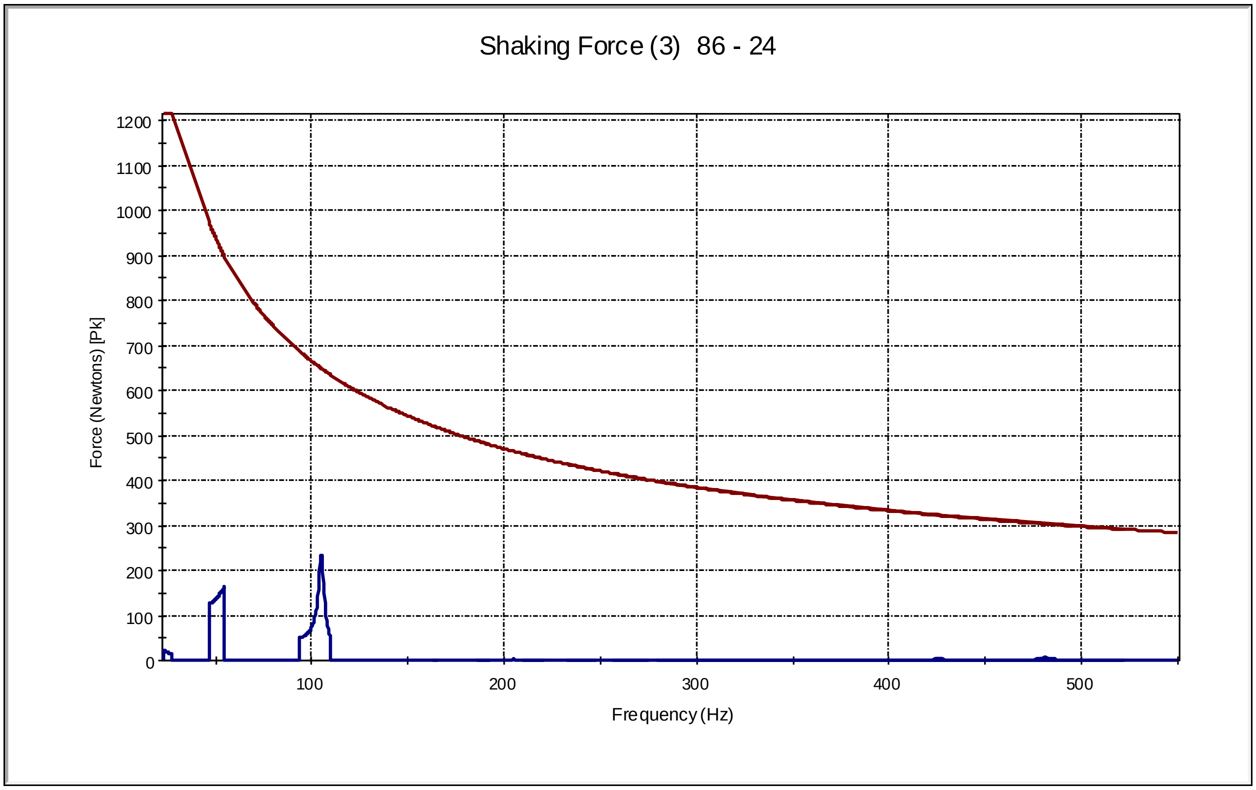


Figure 2.19 Shaking Force in Scrubber Outlet Spool – As Found

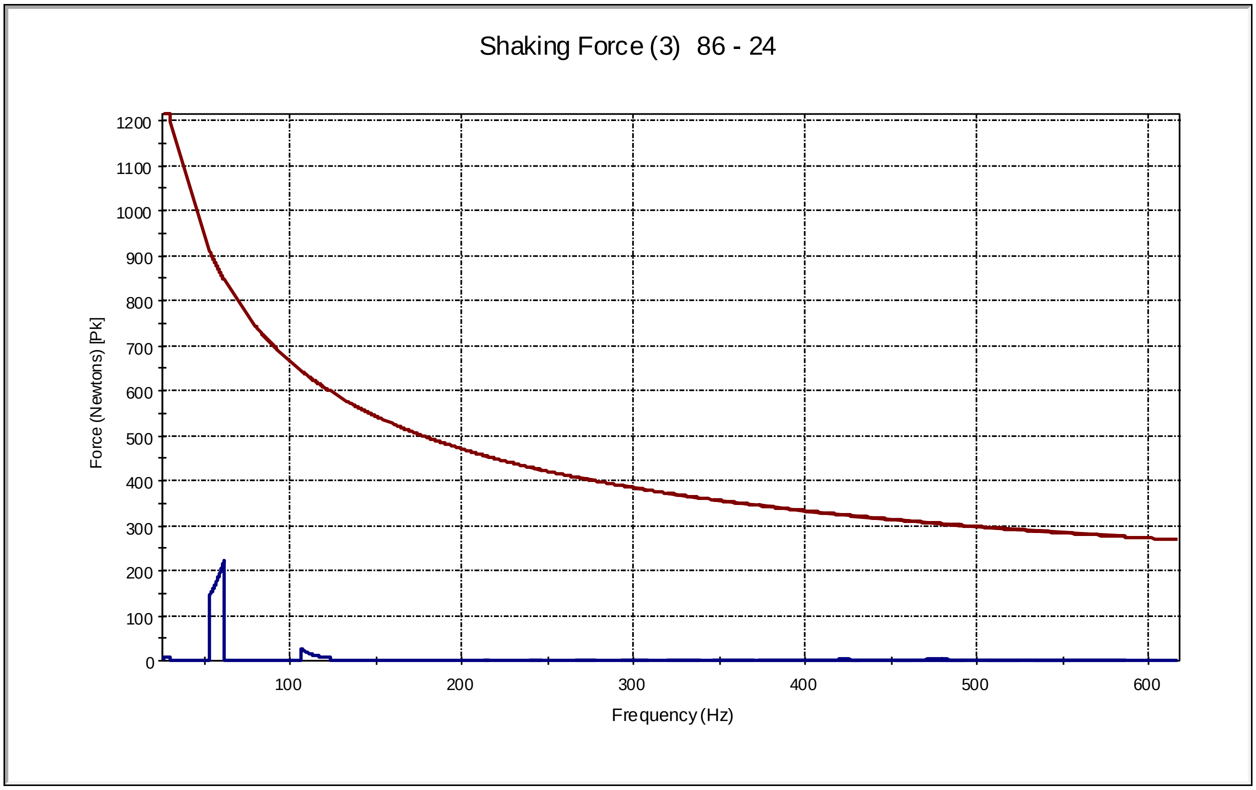


Figure 2.20 Shaking Force in Scrubber Outlet Spool – After Modifications

2.6 TWO STAGE INTERSTAGE RESULTS

Pulsation levels in the two-stage interstage system were 6.56x above API 618 4th edition guidelines for the worst as found case shown in Figure 2.21. After the implementation of the recommended changes pulsation levels are reduced to 0.98x guidelines shown in Figure 2.22. Selected shaking forces before and after the recommendations are shown in Figure 2.23 through Figure 2.26. Shaking forces were as high as 684N in the as found case; they are well below guidelines after modifications.

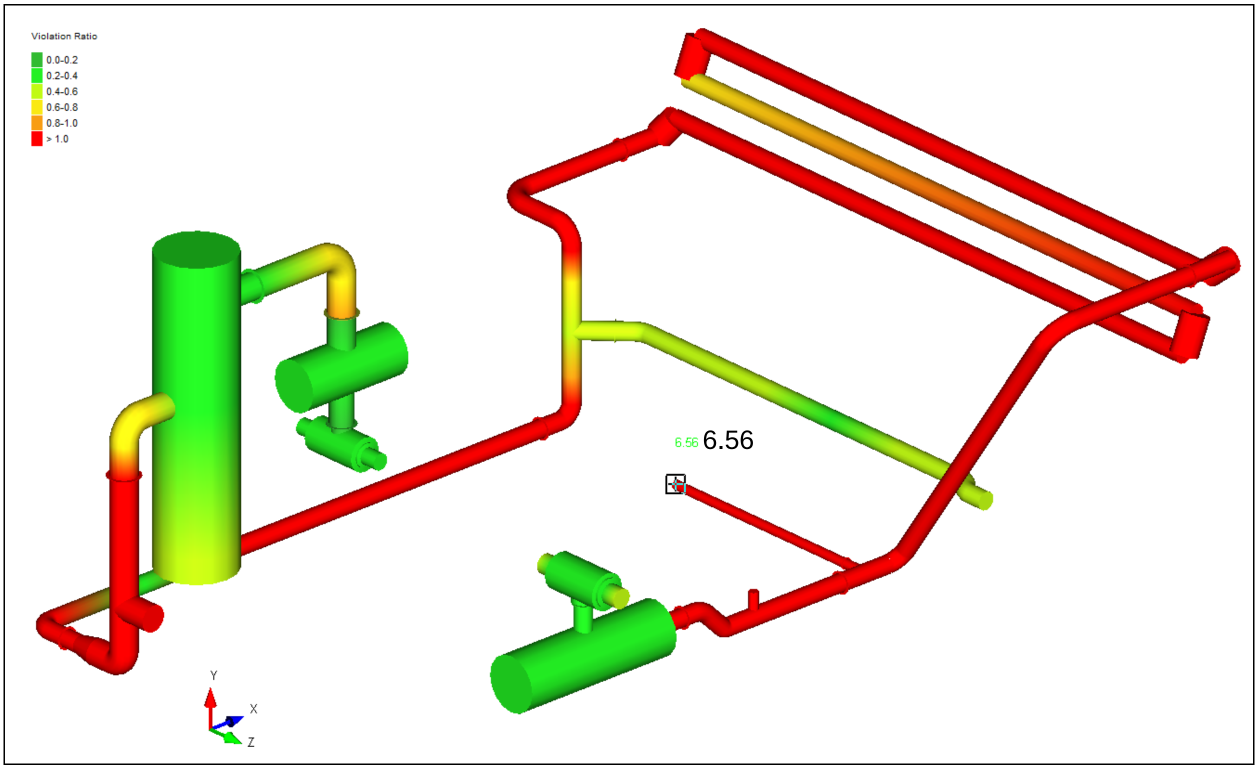


Figure 2.21 Pulsation Violation Ratio in Two Stage Interstage System – As Found

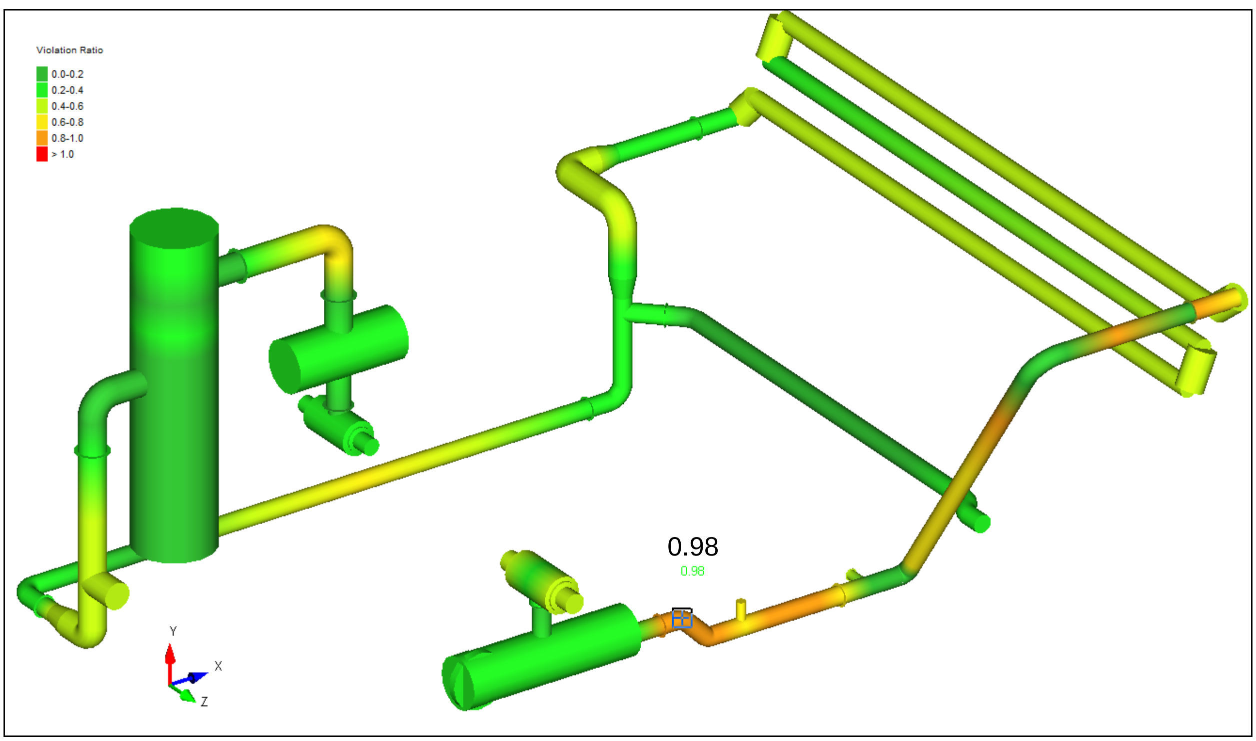


Figure 2.22 Pulsation Violation Ratio in Two Stage Interstage System – After Modifications

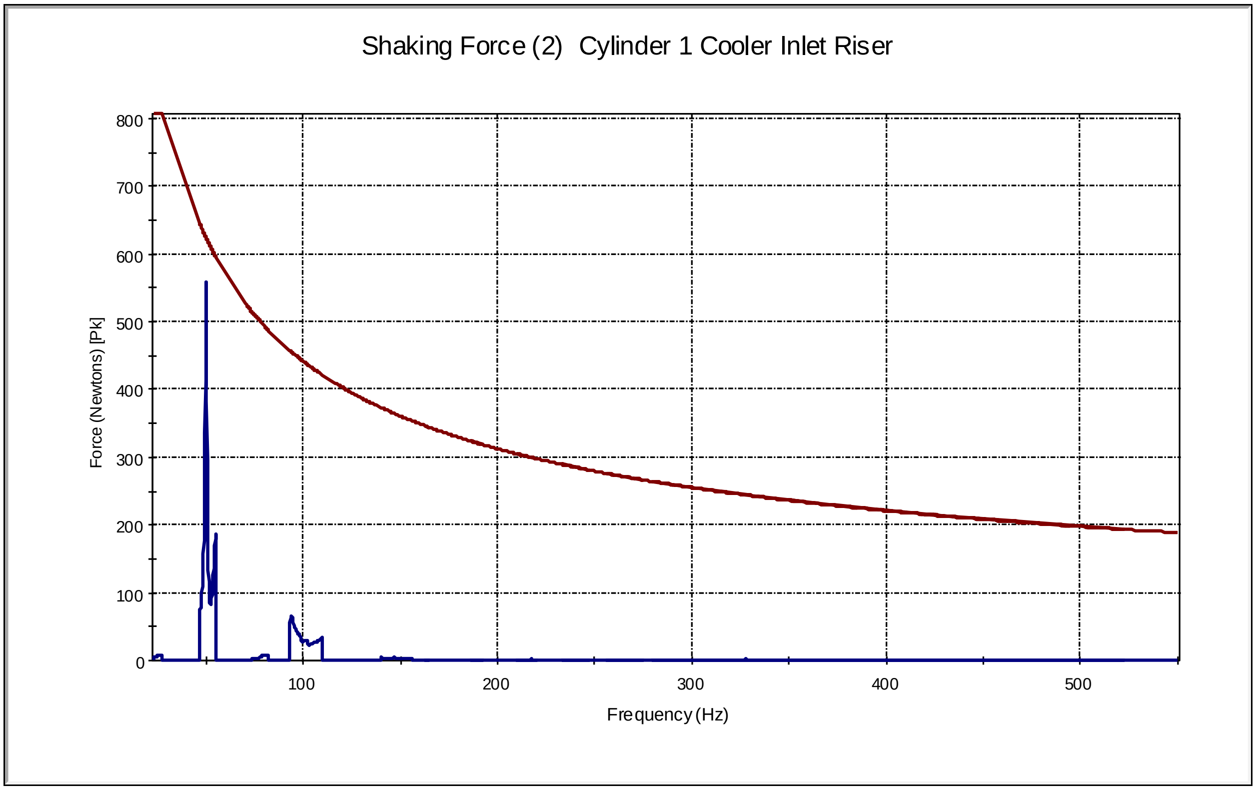


Figure 2.23 Shaking Force in Cylinder 1 Cooler Inlet Riser – As Found

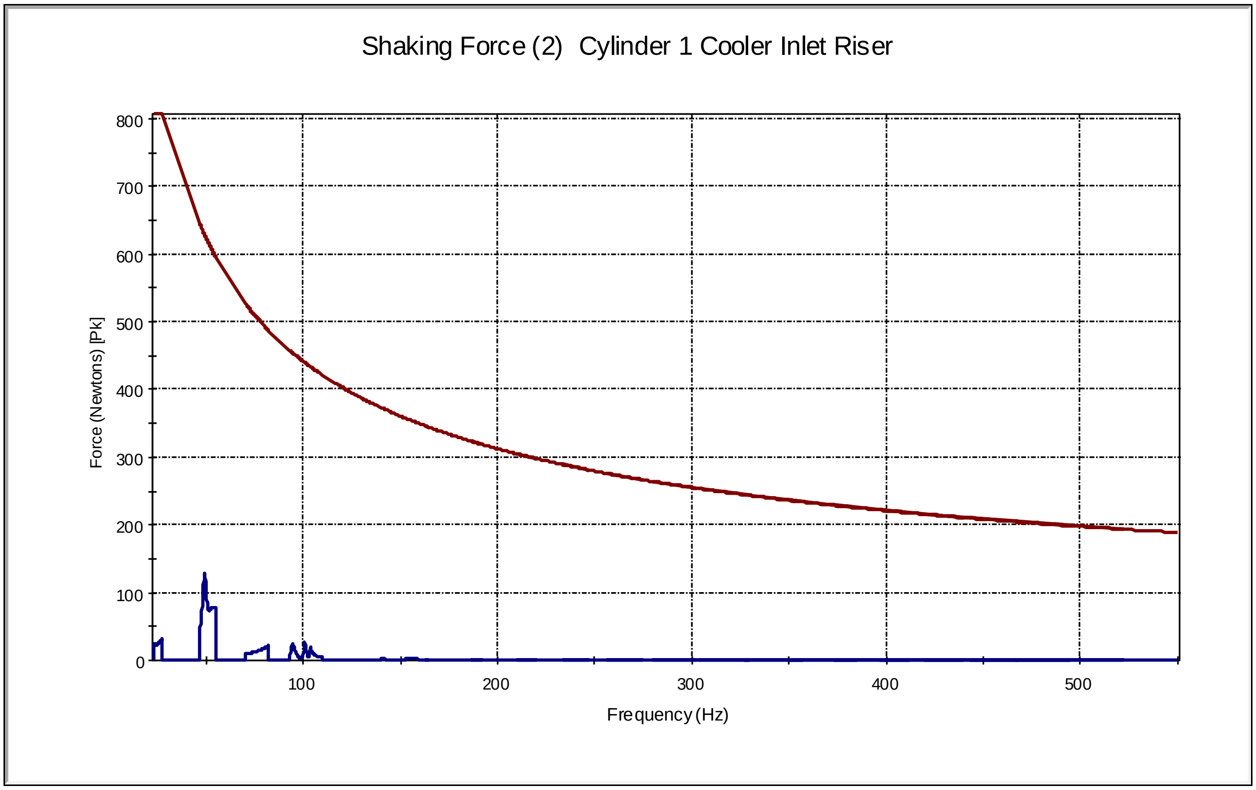


Figure 2.24 Shaking Force in Cylinder 1 Cooler Inlet Riser – After Modifications

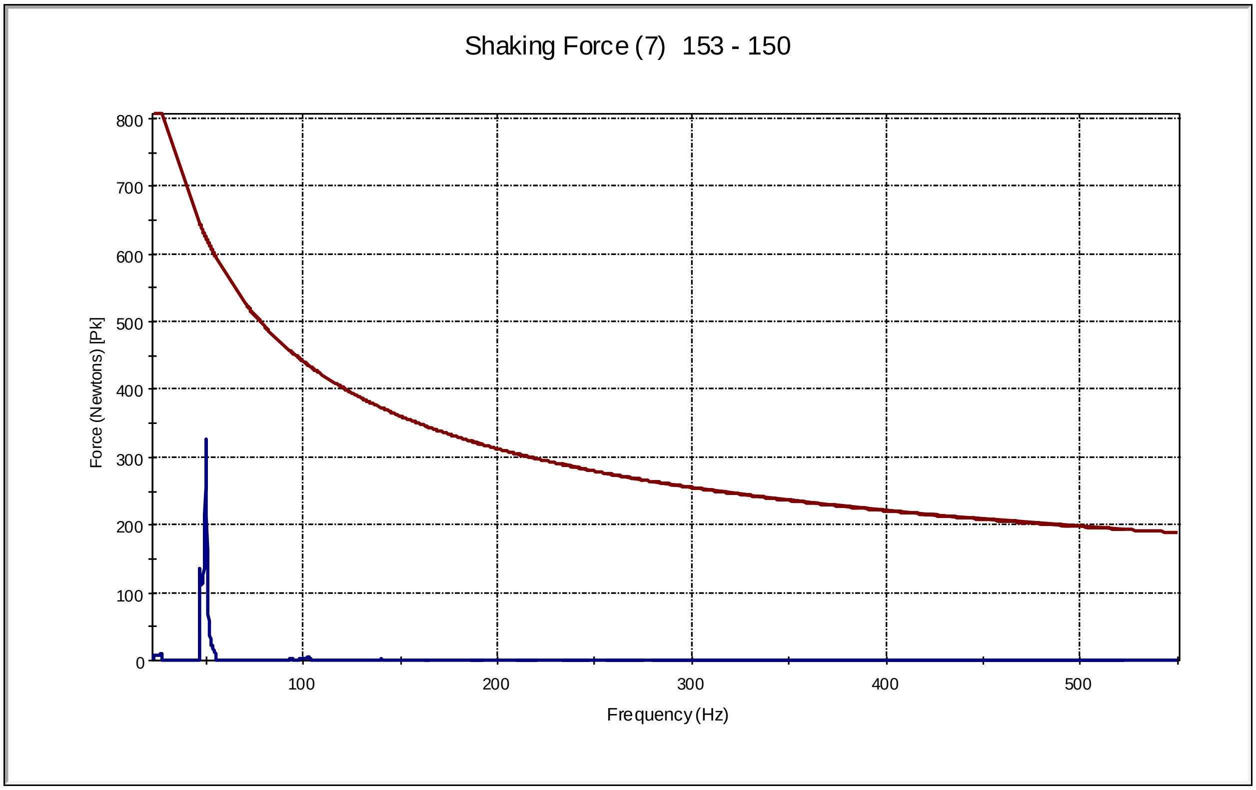


Figure 2.25 Shaking Force in Skid Level, Cylinder 2 Scrubber Feed Spool – As Found

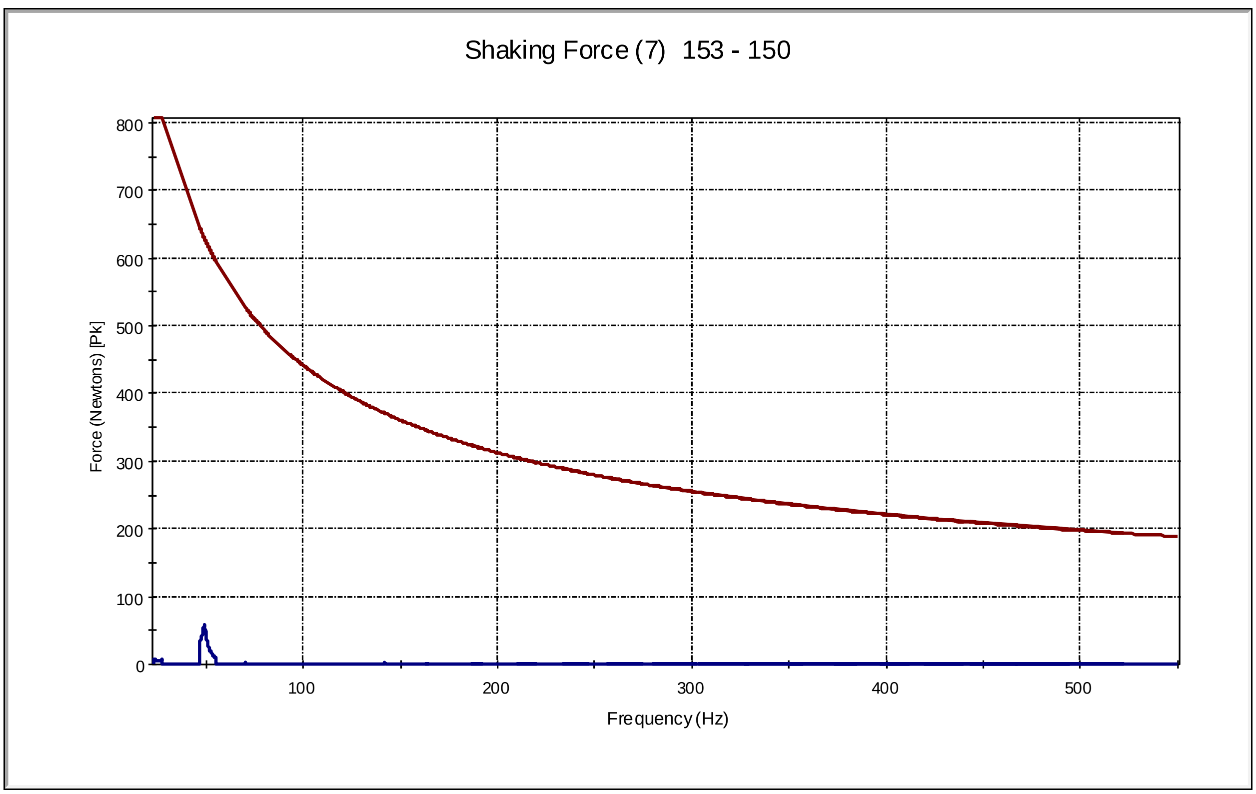


Figure 2.26 Shaking Force in Skid Level, Cylinder 2 Scrubber Feed Spool – After Modifications

2.7 Two Stage Final Discharge Results

Pulsation levels in the two stage final discharge system were 2.66x above API 618 4th edition guidelines for the worst as found case shown in Figure 2.27. After the implementation of the recommended changes pulsation levels are reduced to 1.54x guidelines shown in Figure 2.28. Selected shaking forces before and after the recommendations are shown in Figure 2.29 and Figure 2.30. Shaking forces are below guidelines before and after modifications.

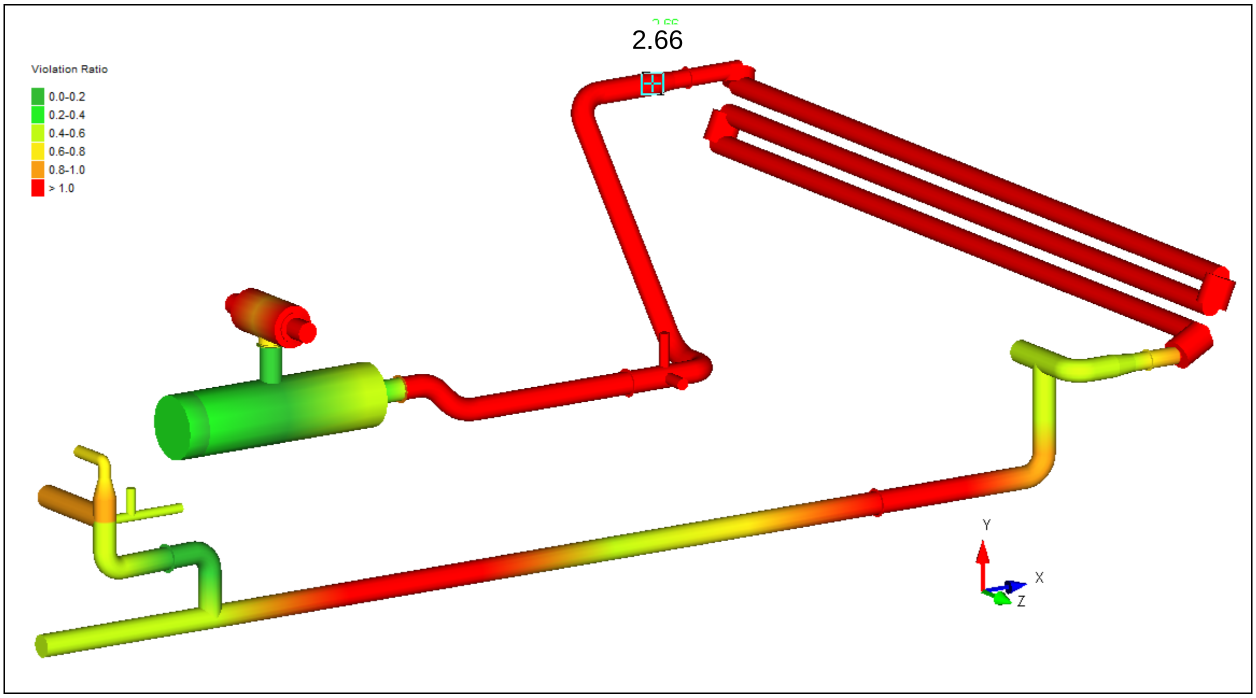


Figure 2.27 Pulsation Violation Ratio in Two Stage Discharge System – As Found

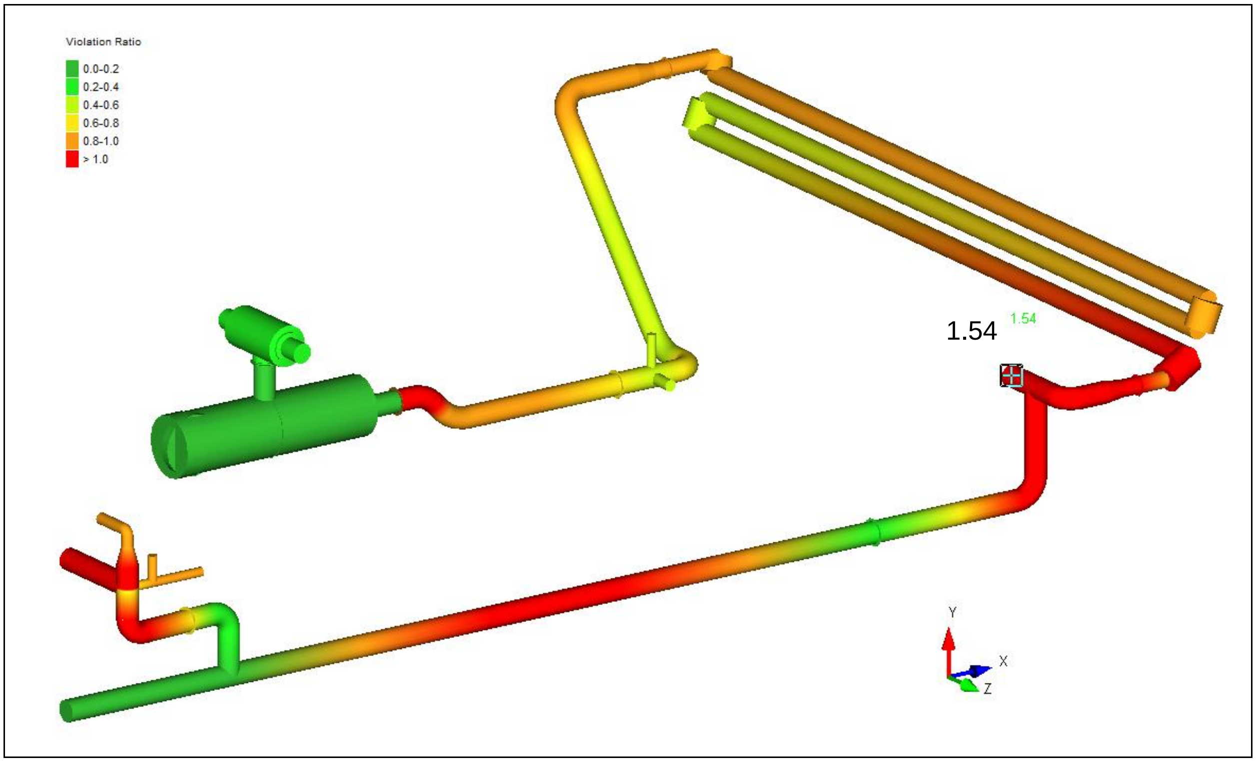


Figure 2.28 Pulsation Violation Ratio in Two Stage Discharge System – After Modifications

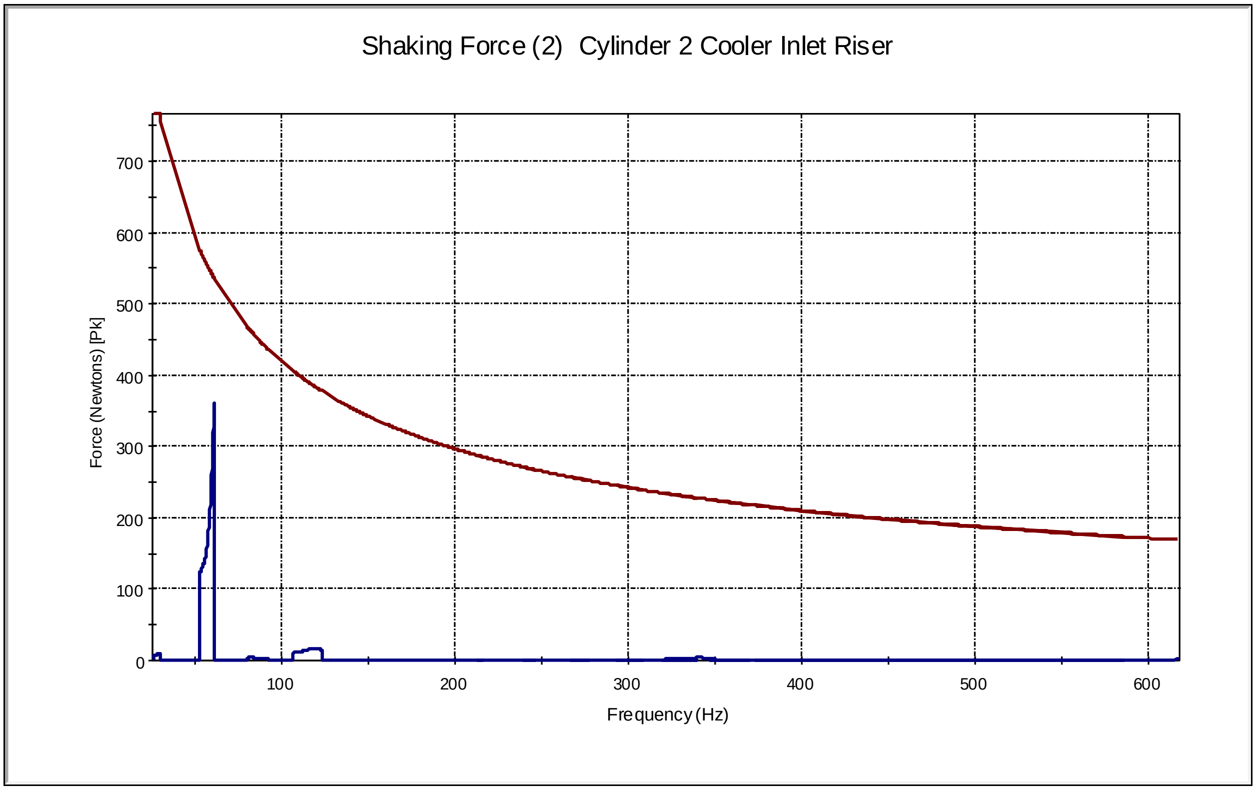


Figure 2.29 Shaking Force in Cylinder 2 Cooler Inlet Riser – As Found

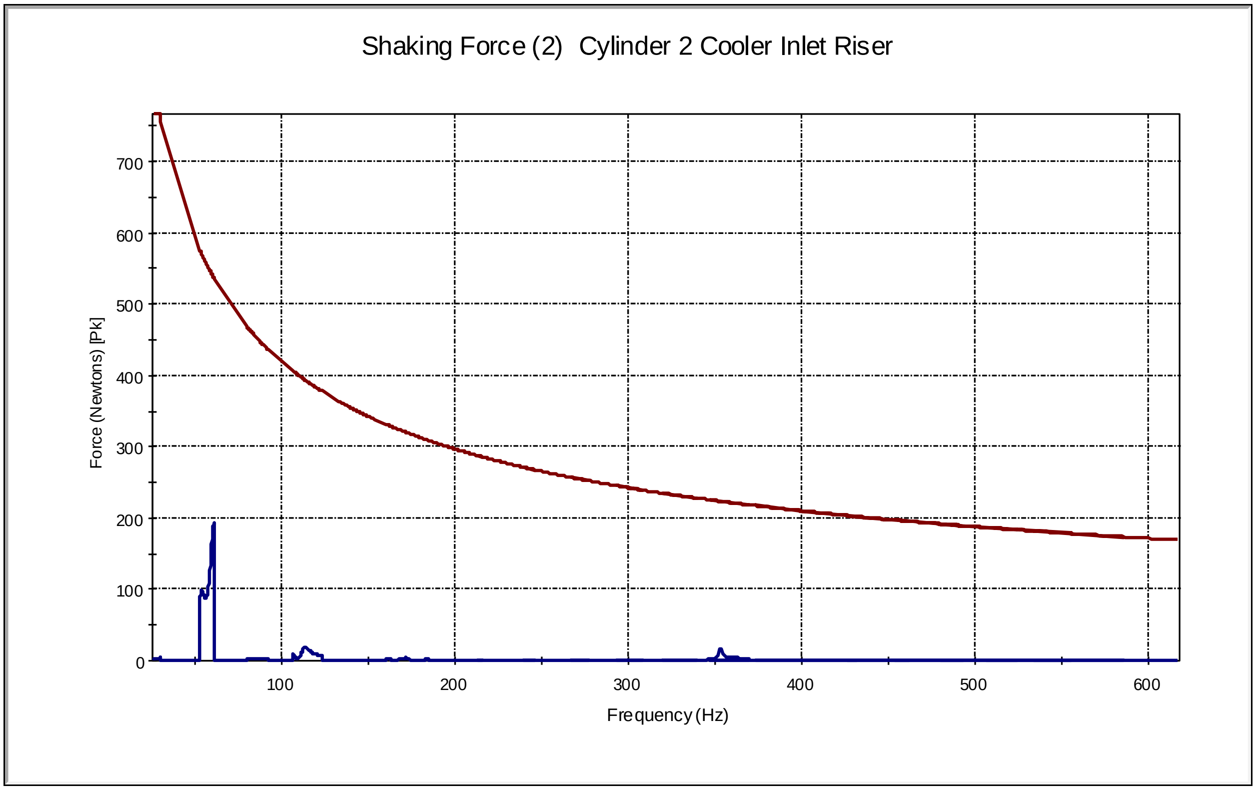


Figure 2.30 Shaking Force in Cylinder 2 Cooler Inlet Riser – After Modifications

2.8 PRESSURE DROPS AND HORSEPOWER LOSSES

The predicted pressure drops and horsepower losses, including the effects of cylinder orifice plates and bottle internals, are shown in the table below, together with the API 618 4th edition recommended maximum for the cases studied. In this respect, the design was dictated by the operating cases with the largest pressure drops. Where the pressure drops are different for cylinders sharing the same bottle (due, for example, to different clearance volumes or different paths through the bottle), the average is reported.

Table 2.2 Single Stage Pressure Drops and Power Losses

Case	System	Pressure Loss, kPa		Power Loss, kW	
		Calculated	Allowable	Calculated	Allowable
1	Single Stage Suction	6.41	13.7	0.67	1.34
1	Single Stage Discharge	8.97	22.23	0.72	1.62
1	**Total**	**15.38**	**35.93**	**1.39**	**2.96**
2	Single Stage Suction	3.74	14.44	0.35	1.24
2	Single Stage Discharge	4.55	28.88	0.28	1.58
2	**Total**	**8.29**	**43.32**	**0.63**	**2.82**
3	Single Stage Suction	5.9	17.71	0.58	1.61
3	Single Stage Discharge	7.6	32.45	0.52	2.01
3	**Total**	**13.5**	**50.16**	**1.1**	**3.62**
4	Single Stage Suction	4.01	17.79	0.36	1.46
4	Single Stage Discharge	4.71	37.44	0.27	1.89
4	**Total**	**8.72**	**55.23**	**0.63**	**3.35**
1b	Single Stage Suction	5.06	13.7	0.47	1.19
1b	Single Stage Discharge	7.1	22.23	0.51	1.44
1b	**Total**	**12.16**	**35.93**	**0.98**	**2.63**
2b	Single Stage Suction	2.95	14.44	0.24	1.1
2b	Single Stage Discharge	3.6	28.88	0.2	1.4
2b	**Total**	**6.55**	**43.32**	**0.44**	**2.5**
3b	Single Stage Suction	4.65	17.71	0.4	1.43
3b	Single Stage Discharge	6.01	32.45	0.37	1.79
3b	**Total**	**10.66**	**50.16**	**0.77**	**3.22**
4b	Single Stage Suction	3.17	17.79	0.25	1.3
4b	Single Stage Discharge	3.73	37.44	0.19	1.68
4b	**Total**	**6.9**	**55.23**	**0.44**	**2.98**

Table 2.3 Two Stage Pressure Drops and Power Losses, Cases 5-14

Case	System	Pressure Loss, kPa		Power Loss, kW	
		Calculated	Allowable	Calculated	Allowable
5	Stage 1 Suction	6.24	6.4	0.85	0.87
5	Stage 1 Discharge	11.26	9.56	1.21	1.03
5	Stage 2 Suction	6.64	5.47	0.61	0.5
5	Stage 2 Discharge	7.18	7.29	0.59	0.6
5	**Total**	**31.32**	**28.72**	**3.26**	**3**
6	Stage 1 Suction	5.08	5.62	0.68	0.75
6	Stage 1 Discharge	8.97	8.65	0.94	0.9
6	Stage 2 Suction	5.29	7.61	0.47	0.68
6	Stage 2 Discharge	5.08	11.53	0.36	0.81
6	**Total**	**24.42**	**33.41**	**2.45**	**3.14**
7	Stage 1 Suction	7.33	7.52	0.99	1.02
7	Stage 1 Discharge	13.2	11.25	1.42	1.21
7	Stage 2 Suction	7.8	6.82	0.71	0.62
7	Stage 2 Discharge	8.32	9.12	0.67	0.74
7	**Total**	**36.65**	**34.71**	**3.79**	**3.59**
8	Stage 1 Suction	5.01	5.9	0.67	0.79
8	Stage 1 Discharge	8.68	9.34	0.89	0.95
8	Stage 2 Suction	5.11	10.22	0.44	0.88
8	Stage 2 Discharge	4.4	17.62	0.27	1.09
8	**Total**	**23.2**	**43.08**	**2.27**	**3.71**
9	Stage 1 Suction	7.25	7.86	0.98	1.06
9	Stage 1 Discharge	12.87	12.01	1.36	1.27
9	Stage 2 Suction	7.61	10.27	0.68	0.92
9	Stage 2 Discharge	7.38	15.2	0.53	1.1
9	**Total**	**35.11**	**45.34**	**3.55**	**4.35**
10	Stage 1 Suction	4.96	6.16	0.66	0.82
10	Stage 1 Discharge	8.41	10.02	0.83	0.99
10	Stage 2 Suction	4.95	12.29	0.42	1.03
10	Stage 2 Discharge	3.88	23.74	0.21	1.3
10	**Total**	**22.2**	**52.21**	**2.12**	**4.14**
11	Stage 1 Suction	7.18	8.17	0.96	1.1
11	Stage 1 Discharge	12.55	12.75	1.3	1.32
11	Stage 2 Suction	7.42	13.05	0.65	1.14
11	Stage 2 Discharge	6.64	21.3	0.43	1.39
11	**Total**	**33.79**	**55.27**	**3.34**	**4.95**
12	Stage 1 Suction	4.89	6.42	0.65	0.85
12	Stage 1 Discharge	8.16	10.7	0.79	1.03
12	Stage 2 Suction	4.8	14	0.39	1.15
12	Stage 2 Discharge	3.47	29.88	0.17	1.49
12	**Total**	**21.32**	**61**	**2**	**4.52**
13	Stage 1 Suction	6.82	8.14	0.89	1.07
13	Stage 1 Discharge	11.93	12.68	1.21	1.29
13	Stage 2 Suction	7.05	14.92	0.6	1.28
13	Stage 2 Discharge	5.95	26.45	0.36	1.59
13	**Total**	**31.75**	**62.19**	**3.06**	**5.23**
14	Stage 1 Suction	5.42	7.06	0.72	0.93
14	Stage 1 Discharge	9.04	11.73	0.88	1.15
14	Stage 2 Suction	5.33	15.27	0.44	1.25
14	Stage 2 Discharge	3.89	32.29	0.19	1.61
14	**Total**	**23.68**	**66.35**	**2.23**	**4.94**

Table 2.4 Two Stage Pressure Drops and Power Losses, Cases 5b-14b

Case	System	Pressure Loss, kPa		Power Loss, kW	
		Calculated	Allowable	Calculated	Allowable
5b	Stage 1 Suction	4.92	6.4	0.59	0.77
5b	Stage 1 Discharge	8.9	9.56	0.85	0.91
5b	Stage 2 Suction	5.25	5.47	0.43	0.44
5b	Stage 2 Discharge	5.67	7.29	0.41	0.53
5b	**Total**	**24.74**	**28.72**	**2.28**	**2.65**
6b	Stage 1 Suction	4.01	5.62	0.48	0.67
6b	Stage 1 Discharge	7.09	8.65	0.66	0.8
6b	Stage 2 Suction	4.17	7.61	0.33	0.6
6b	Stage 2 Discharge	4.01	11.53	0.25	0.72
6b	**Total**	**19.28**	**33.41**	**1.72**	**2.79**
7b	Stage 1 Suction	5.78	7.52	0.7	0.91
7b	Stage 1 Discharge	10.44	11.25	1	1.07
7b	Stage 2 Suction	6.16	6.82	0.5	0.55
7b	Stage 2 Discharge	6.58	9.12	0.47	0.65
7b	**Total**	**28.96**	**34.71**	**2.67**	**3.18**
8b	Stage 1 Suction	3.96	5.9	0.47	0.7
8b	Stage 1 Discharge	6.86	9.34	0.62	0.85
8b	Stage 2 Suction	4.04	10.22	0.31	0.79
8b	Stage 2 Discharge	3.48	17.62	0.19	0.97
8b	**Total**	**18.34**	**43.08**	**1.59**	**3.31**
9b	Stage 1 Suction	5.72	7.86	0.69	0.94
9b	Stage 1 Discharge	10.17	12.01	0.95	1.12
9b	Stage 2 Suction	6	10.27	0.48	0.82
9b	Stage 2 Discharge	5.83	15.2	0.38	0.98
9b	**Total**	**27.72**	**45.34**	**2.5**	**3.86**
10b	Stage 1 Suction	3.91	6.16	0.46	0.73
10b	Stage 1 Discharge	6.65	10.02	0.58	0.88
10b	Stage 2 Suction	3.91	12.29	0.29	0.92
10b	Stage 2 Discharge	3.07	23.74	0.15	1.15
10b	**Total**	**17.54**	**52.21**	**1.48**	**3.68**
11b	Stage 1 Suction	5.67	8.17	0.68	0.97
11b	Stage 1 Discharge	9.92	12.75	0.91	1.17
11b	Stage 2 Suction	5.86	13.05	0.46	1.01
11b	Stage 2 Discharge	5.25	21.3	0.31	1.24
11b	**Total**	**26.7**	**55.27**	**2.36**	**4.39**
12b	Stage 1 Suction	3.86	6.42	0.45	0.75
12b	Stage 1 Discharge	6.45	10.7	0.55	0.92
12b	Stage 2 Suction	3.79	14	0.28	1.02
12b	Stage 2 Discharge	2.75	29.88	0.12	1.32
12b	**Total**	**16.85**	**61**	**1.4**	**4.01**
13b	Stage 1 Suction	5.38	8.14	0.63	0.95
13b	Stage 1 Discharge	9.43	12.68	0.85	1.14
13b	Stage 2 Suction	5.56	14.92	0.42	1.14
13b	Stage 2 Discharge	4.7	26.45	0.25	1.41
13b	**Total**	**25.07**	**62.19**	**2.15**	**4.64**
14b	Stage 1 Suction	4.28	7.06	0.5	0.83
14b	Stage 1 Discharge	7.15	11.73	0.62	1.02
14b	Stage 2 Suction	4.21	15.27	0.31	1.11
14b	Stage 2 Discharge	3.07	32.29	0.14	1.43
14b	**Total**	**18.71**	**66.35**	**1.57**	**4.39**

3. MECHANICAL STUDY DETAILED RESULTS

3.1 MECHANICAL MODEL SETUP

As required by API 618 4th edition M4 and M5, the natural frequencies of the pipe runs, cylinders, and manifolds were calculated and compared to the characteristic frequency of excitation corresponding to the running frequency of the compressor and engine. As specified by the client, a maximum running speed of 1800 RPM (corresponding to 30 Hz) was used in the study. The mechanical model of the pipeline and the supporting structure included in this analysis is shown in Figure 3.1.

3.2 MECHANICAL STUDY RESULTS

A mechanical system model that comprises piping, scrubber vessels, suction and discharge bottles and compressor cylinders, was created according to drawings and pictures provided by the client. The analysis was completed using AutoPIPE V8i, a piping stress analysis package that is widely accepted in the industry.

In determining locations and types of support used on pipes attention was paid to avoid multiples of operating speed.

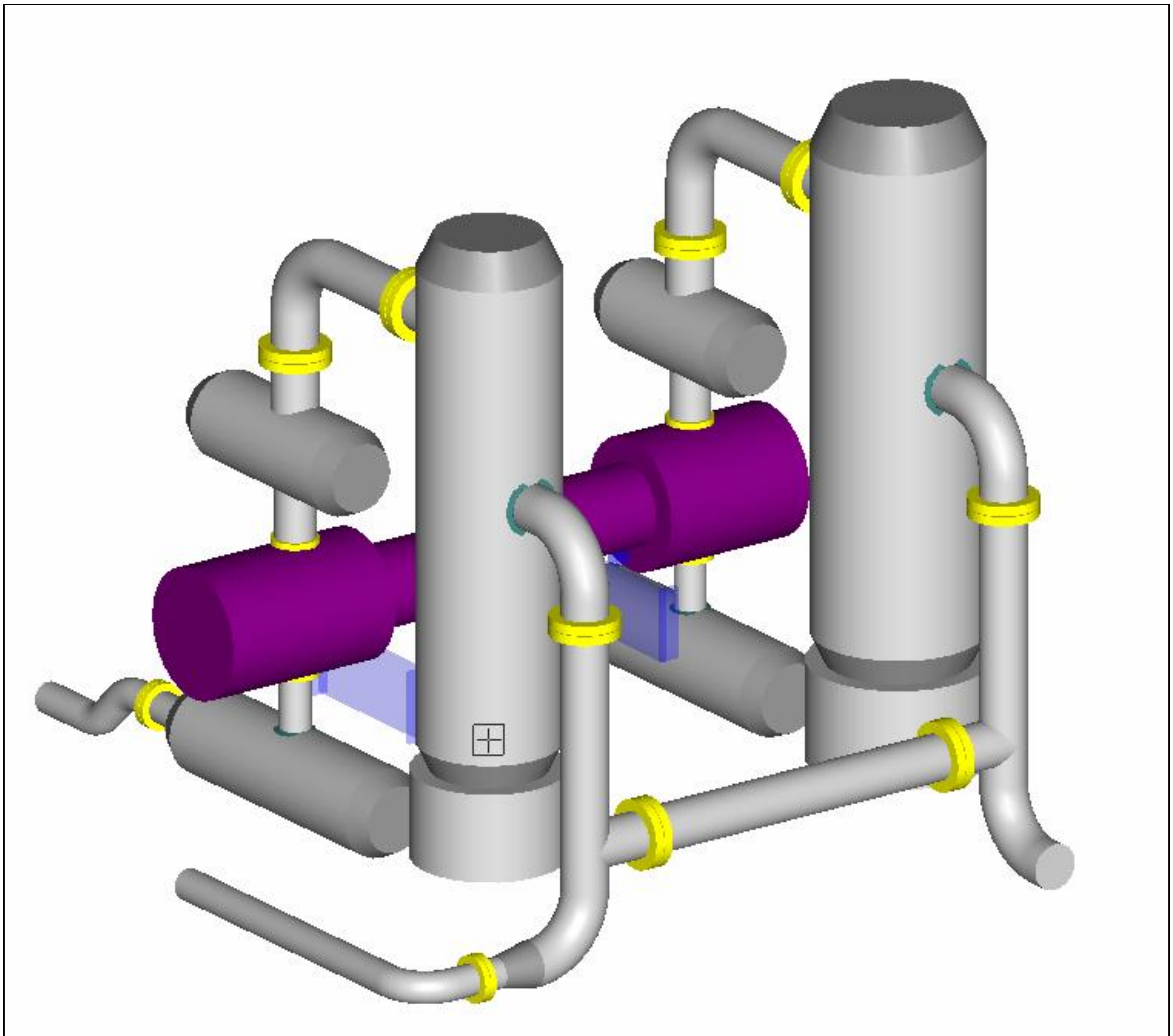


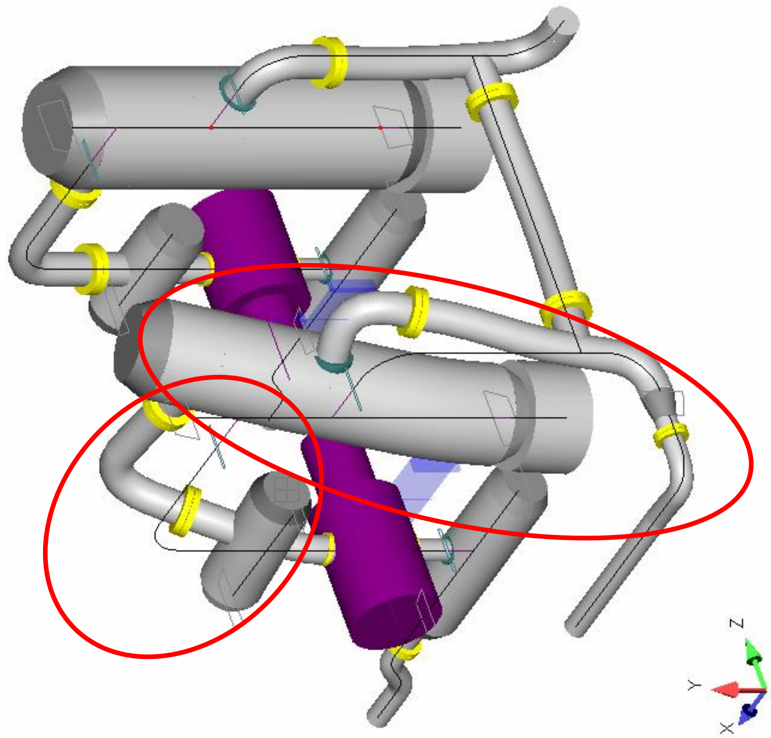
Figure 3.1 Mechanical Model General View

3.3 MECHANICAL MODEL MODAL ANALYSIS RESULTS

The natural frequencies and mode shape descriptions are given in Table 3.1 and the mode shapes of the modified piping are shown in Figure 3.2 through Figure 3.11.

Table 3.1 Natural Frequencies After Recommendations

Mode Number	Frequency	Running Speed Multiple	Location
1	77.3 Hz	2.58	Cylinder 2 Suction Bottle, Scrubber & Scrubber Inlet Piping
2	81.4 Hz	2.71	Cylinder 2 Suction Bottle, Scrubber & Scrubber Inlet Piping
3	84.2 Hz	2.8	Cylinder 1 Suction Bottle, Scrubber & Scrubber Inlet Piping
4	86.5 Hz	2.88	Cylinder 1 Suction Bottle, Scrubber & Scrubber Inlet Piping
5	93.6 Hz	3.12	Cylinders 1 & 2 Scrubber Inlet Piping
6	100.1 Hz	3.34	Cylinder 2 Suction Bottle
7	103 Hz	3.43	Cylinder 1 Suction Bottle
8	118.5 Hz	3.95	Cylinders 1 & 2 Scrubber Inlet Piping
9	126.3 Hz	4.21	Cylinders 1 & 2 Scrubber Inlet Piping
10	149 Hz	4.97	Cylinder 2 Scrubber Inlet Piping



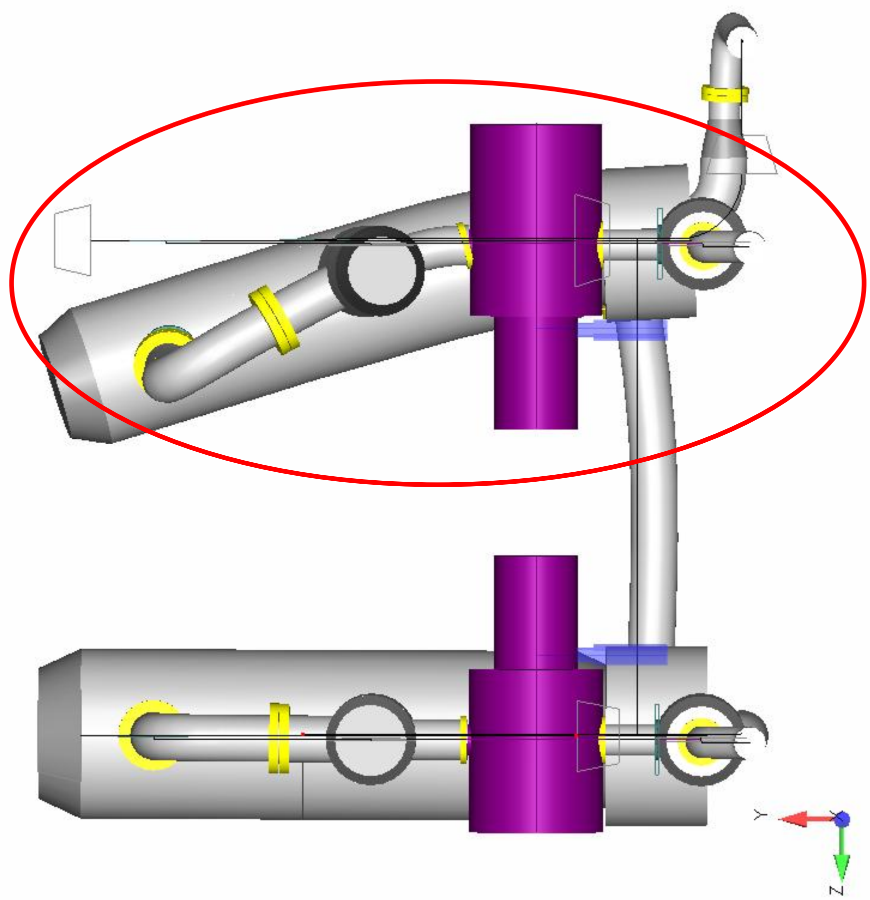


Figure 3.2 Mode Shape 1 – 77.3 Hz – Modified System

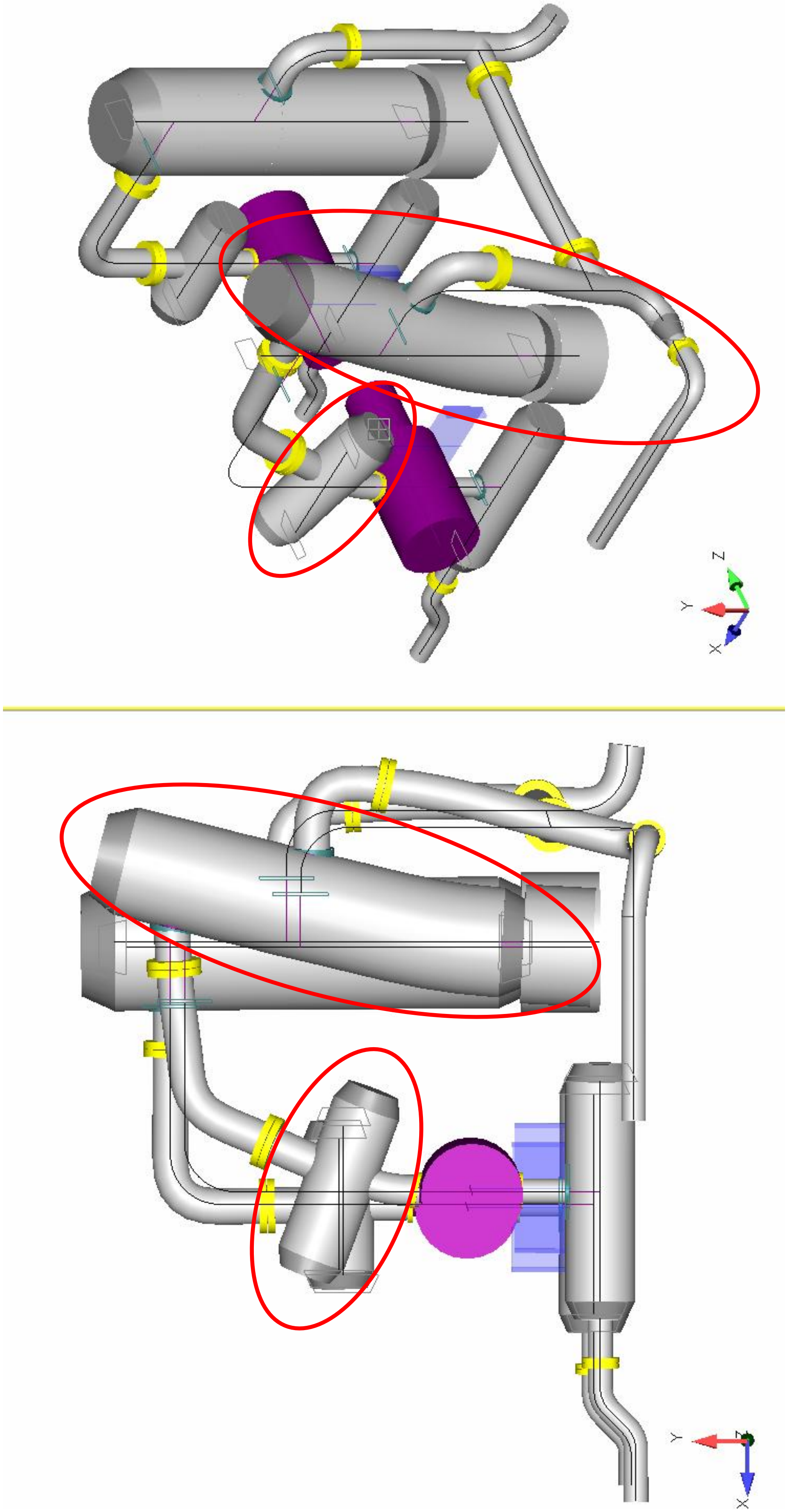


Figure 3.3 Mode Shape 2 – 81.4 Hz – Modified System

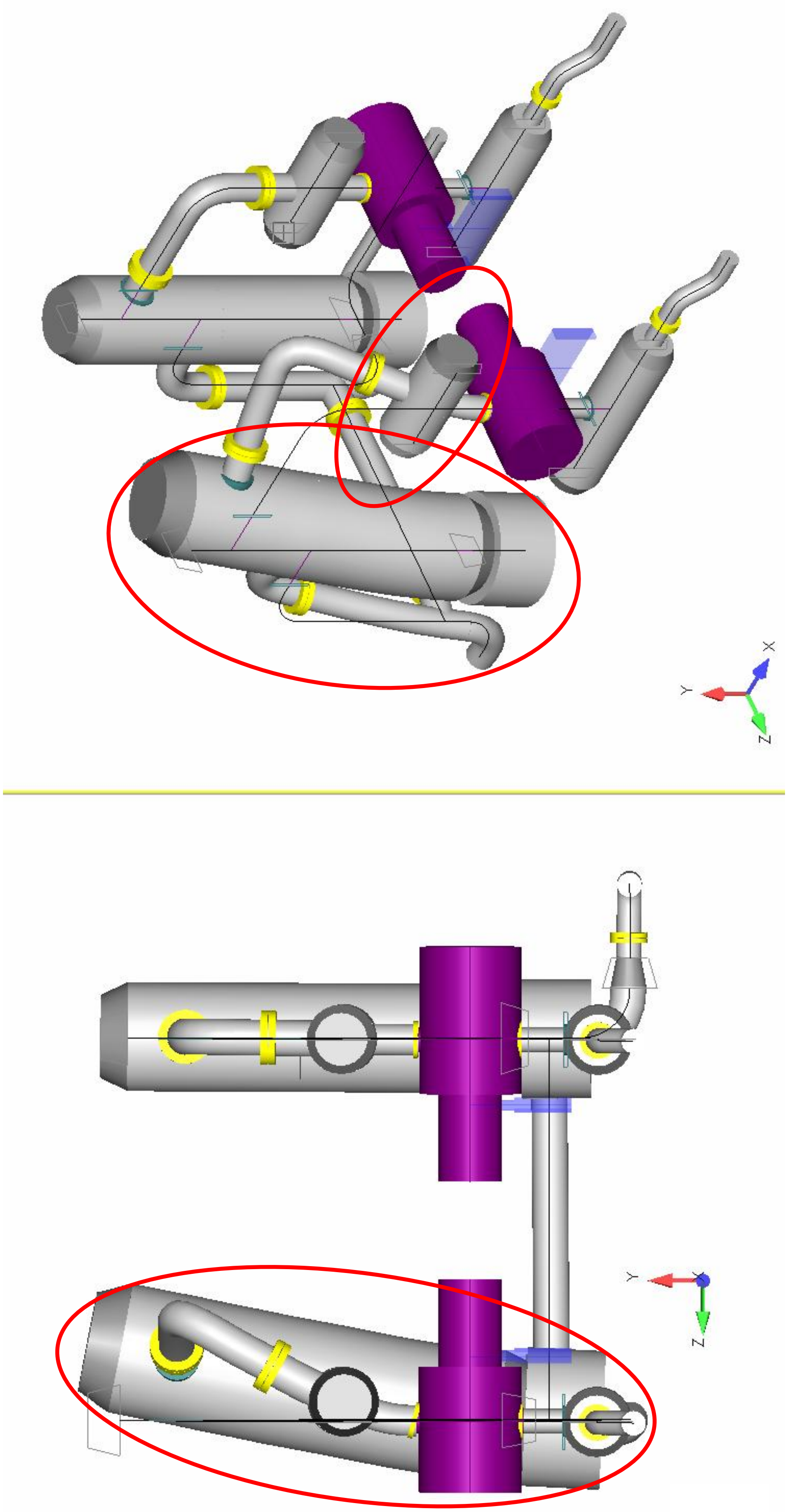


Figure 3.4 Mode Shape 3 – 84.2 Hz – Modified System

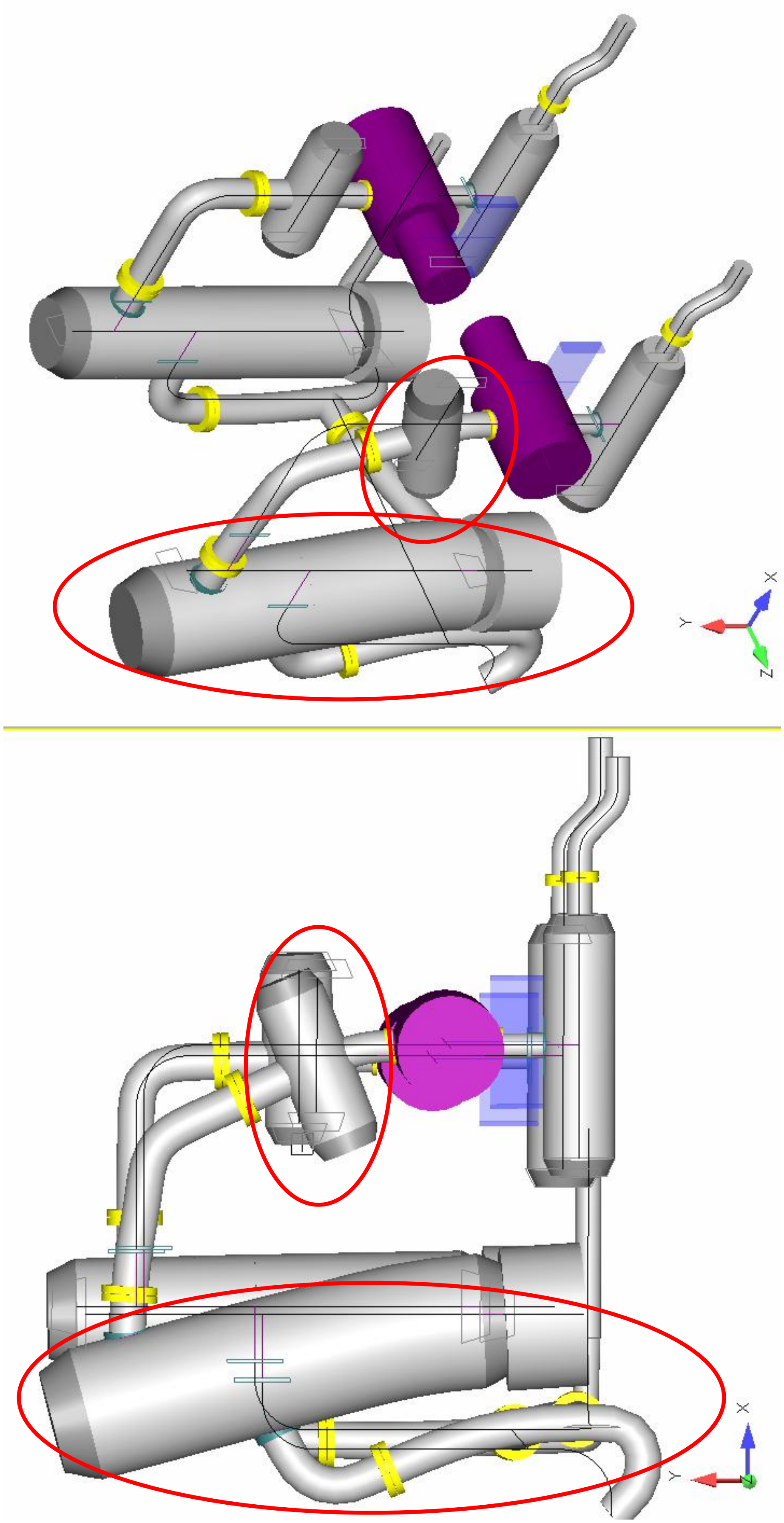


Figure 3.5 Mode Shape 4 – 86.5 Hz – Modified System

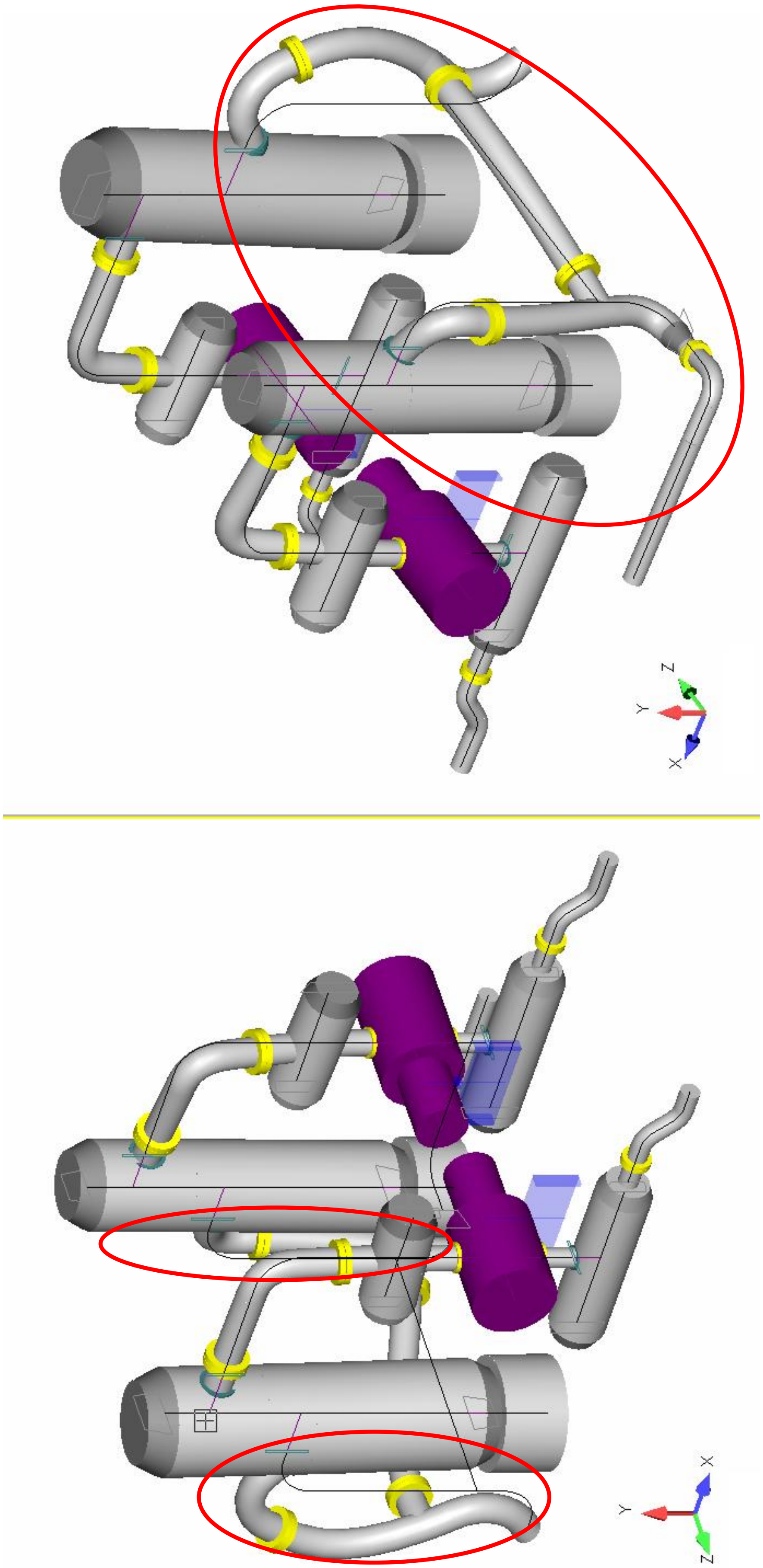


Figure 3.6 Mode Shape 5 – 93.6 Hz – Modified System

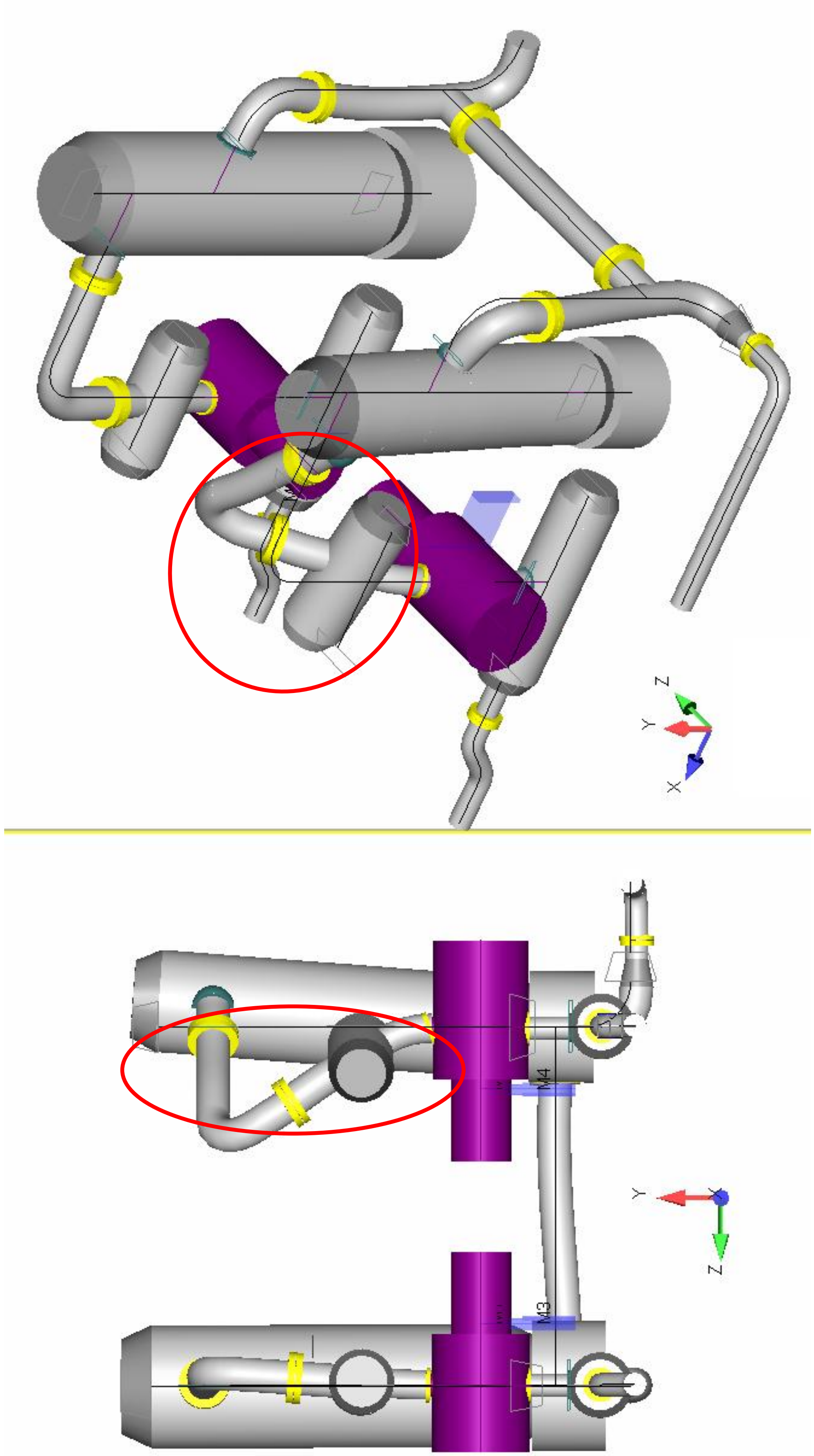


Figure 3.7 Mode Shape 6 – 100.1 Hz – Modified System

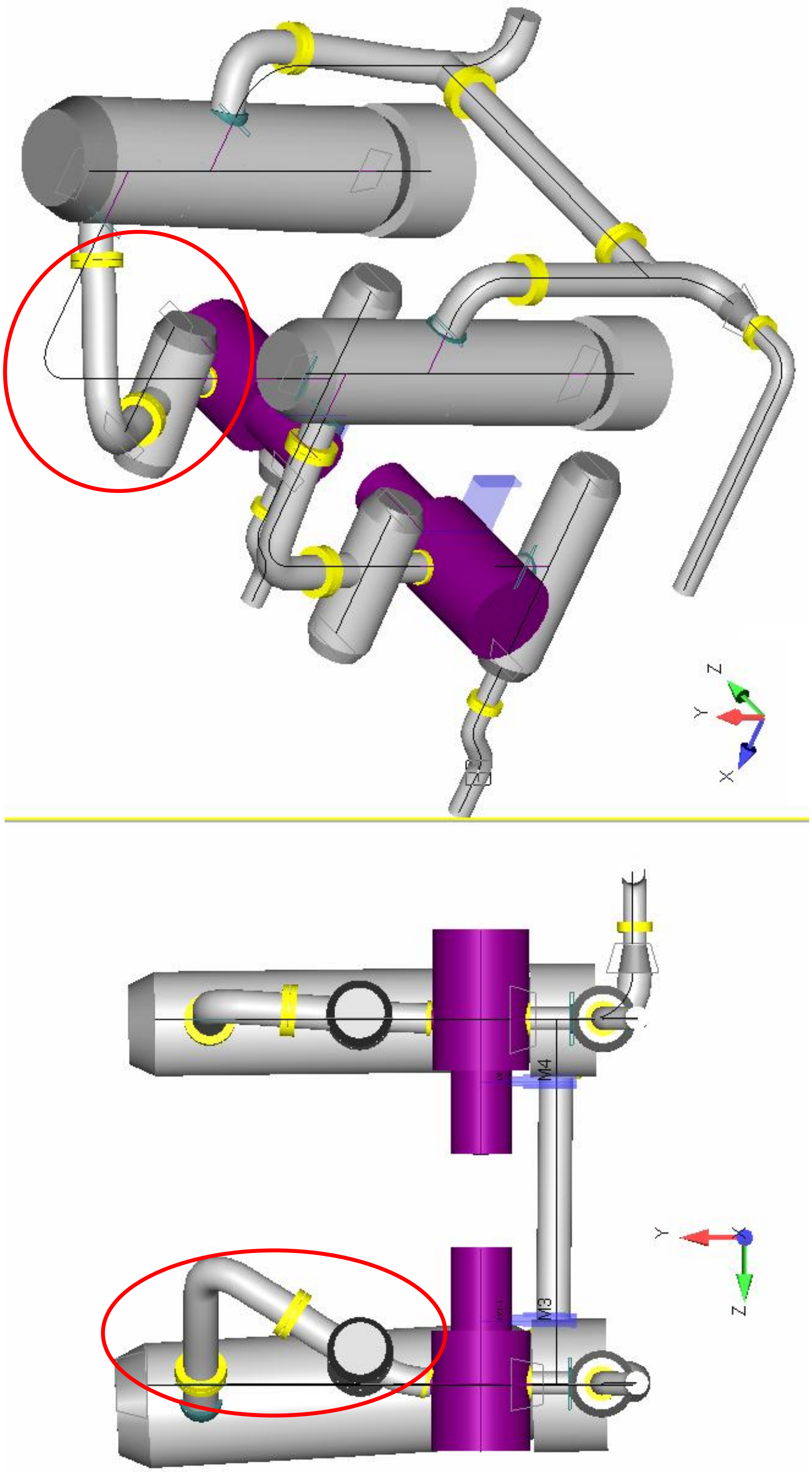


Figure 3.8 Mode Shape 7 – 103 Hz – Modified System

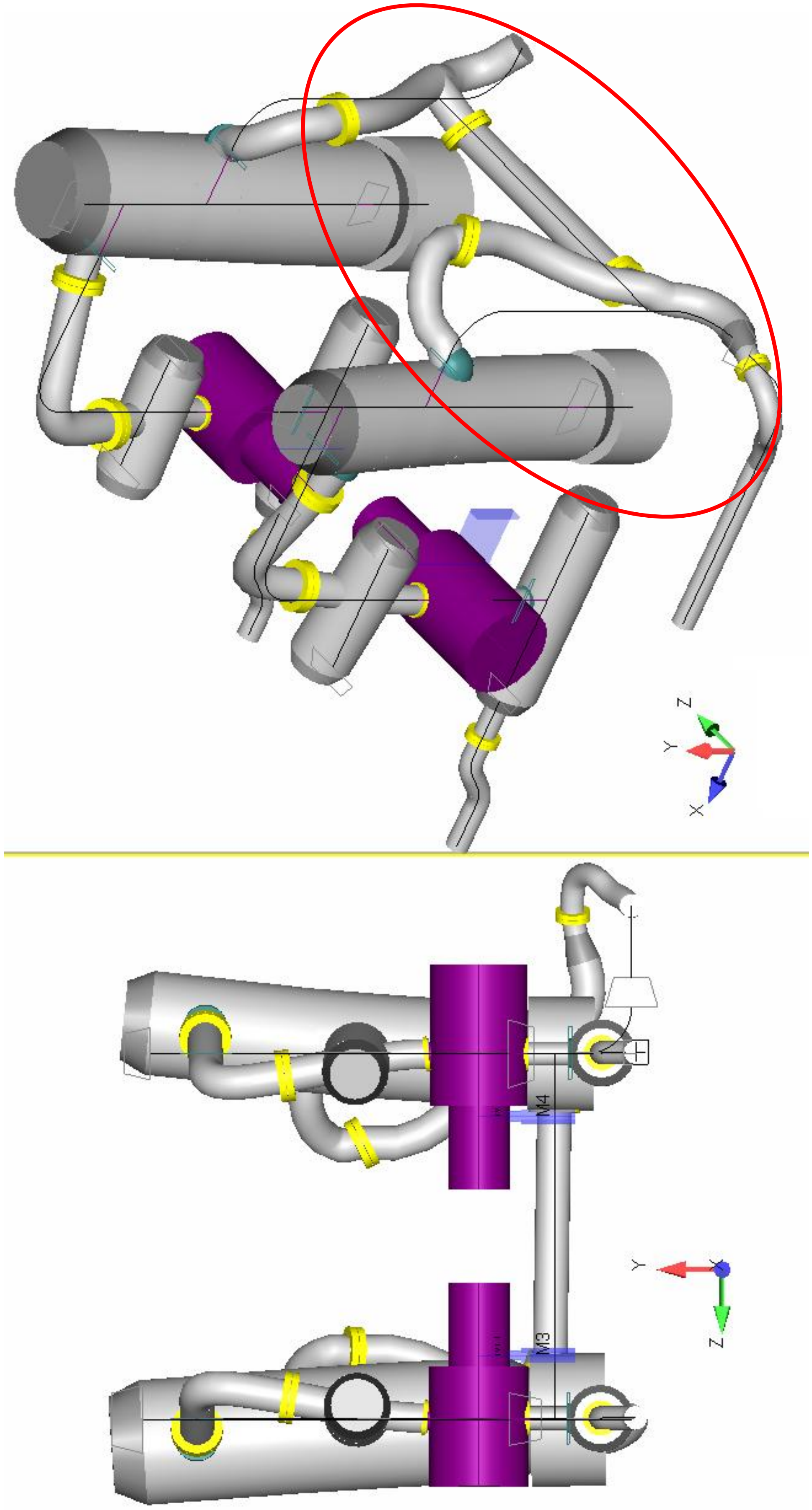


Figure 3.9 Mode Shape 8 – 118.5 Hz – Modified System

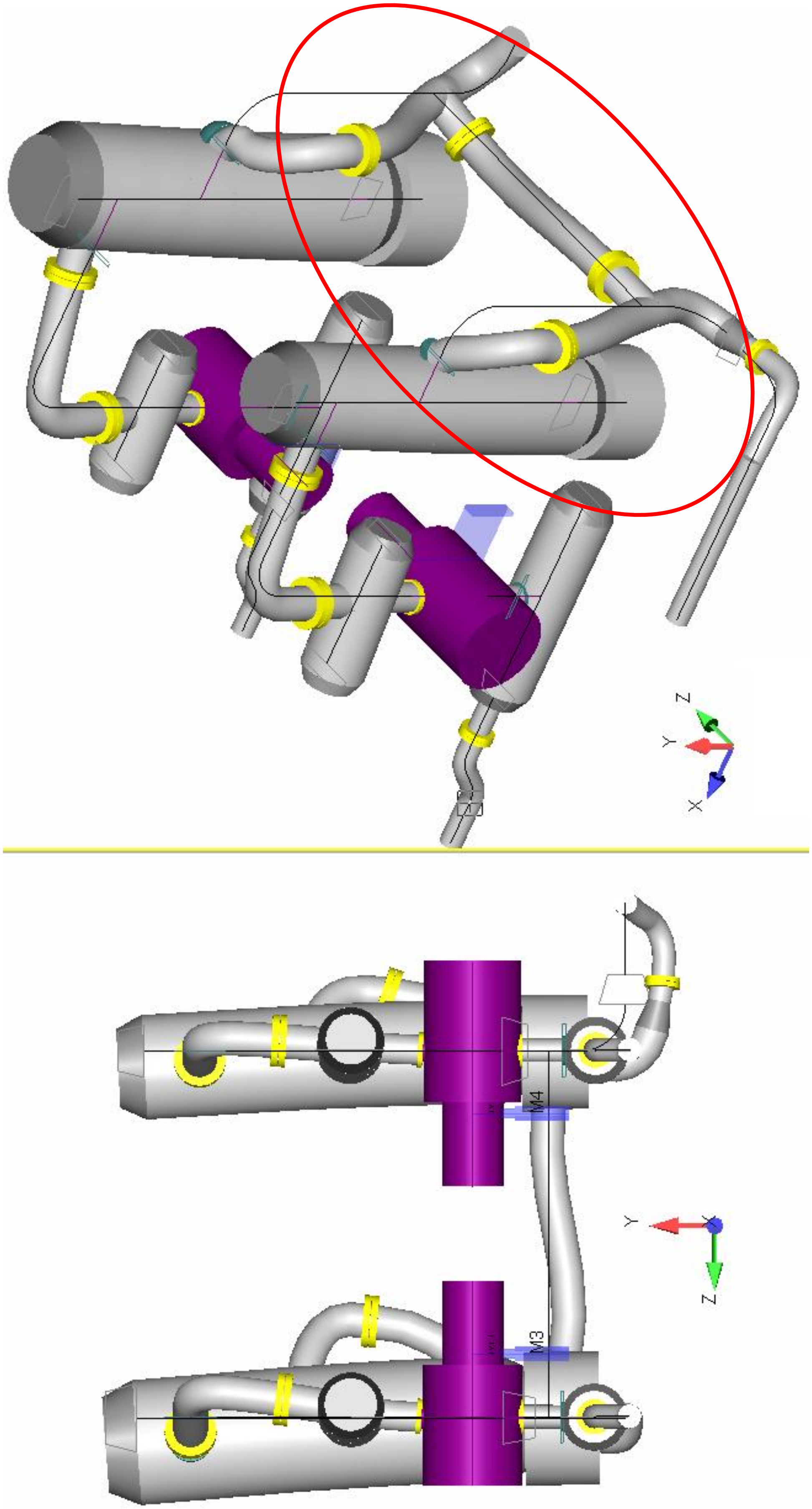


Figure 3.10 Mode Shape 9 – 126.3 Hz – Modified System

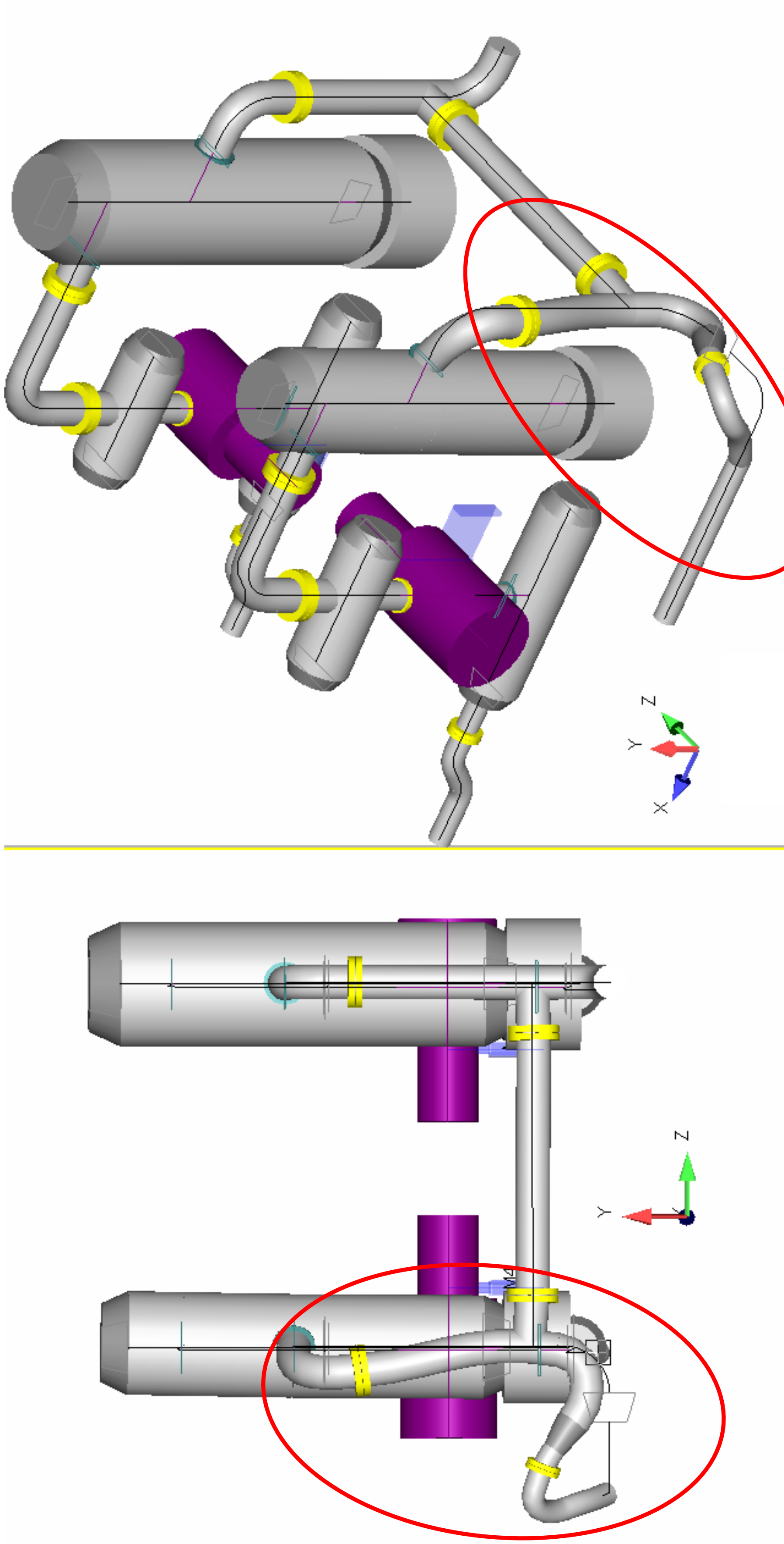


Figure 3.11 Mode Shape 10 – 149 Hz – Modified System

4. METHODOLOGY

4.1 ACOUSTICAL ANALYSIS

The analysis was performed using acoustic simulation software. The intent of the analysis is to adjust the pipeline and bottles designs of the compressor system to make it compliant with API 618 4th edition guidelines.

The software is based on the transfer matrix approach, which relates acoustic pressures and acoustic volume velocities across the all elements of the model. The elements of the model are lengths of pipe, expansions and contractions, acoustic volumes, orifice plates, Tee's, pulsation sources such as the compressor pistons and terminations, either open end, closed end, or anechoic. In essence, any configuration of piping system can be accurately modeled by combining these acoustical elements.

The program calculates the pulsation at the nodes entered as part of the model and displays the resulting pulsation spectrum on a frequency scale. These pulsations are translated into acoustically excited shaking forces. The software also provides the pressure drop across each element in the model, and if desired compares the pressure loss to the API 618 4TH EDITION allowable losses.

For reciprocating compressors, specialized boundary conditions are used to account for the losses across the valves and the intermittent sinusoidal excitation. The compressor boundary conditions can be unloaded to simulate the excitation introduced by removing the valves from a cylinder and changing it to single acting. If required, the modeling software can produce sinusoidal excitation at any node, sweeping in frequency to cover the band of interest to demonstrate the response of the system. These excitation sources can be set to be pressure sources or velocity sources.

4.2 API 618 4TH EDITION GUIDELINES

1. Pulsations in the piping system

As per §3.9.2.7 of API 618 4TH EDITION, the limit for pulsations allowed in the piping system is given by:

$$P_P = \frac{3 \times P_L}{\sqrt{P_L \times D \times f}}$$

where: P_L = line pressure (kPa)
D = inside diameter (m)
f = frequency (Hz)

2. Pulsations in the compressor cylinder and bottles

As per §3.9.2.2.3 of API 618 4TH EDITION, the limit for pulsations allowed at the cylinder flange is given by:

$$P_P = 0.03 \times P_L \times R \ \leq \ 0.07 \times P_L$$

where: P_L = line pressure (kPa)
f = frequency (Hz)
R= compression ratio for the stage

In the absence of any specific guideline for compressor nozzles and pulsation bottles, this guideline is typically used for these components of the system as well.

These guideline pulsation levels are automatically calculated by the software and compared to the pulsation present in the system. The pulsations are shown as a violation ratio, or as a ratio between the pulsation and the API 618 4TH EDITION allowable levels.

4.3 ACOUSTICAL ANALYSIS PROCEDURE

1. **Data Gathering**
    - Piping Isometric Drawings.
    - Vessel Design Drawings.
    - Compressor information.
    - Gas composition.
    - Cooler information.
    - System general arrangement.
2. **Generate parameter model**
    - Define independent systems for analysis.
    - Define model for bottles, scrubber and cooler.
    - Build compressor model.
3. **Troubleshooting and verification of the model**
    - The input data is verified.
    - Model is run to assess initial 'as found' conditions for loading case.
4. **Trial runs for several possible solutions are conducted.**
5. **Developing Solutions**
    - Several presented options are tried in the model, ranging from the simplest and most economical to the more elaborate.
    - Optimization (de-tuning of resonant frequencies) is attempted for various solutions.
6. **Generation of results files**
    - Result files are created and analyzed for all cases under study.
    - Results are plotted for defining case only.
    - Plots are created for various parts of the model, in particular for the components that need to be modified.

4.4 MECHANICAL ANALYSIS

The objective of the mechanical analysis is to assess the response of the system to the type of dynamic loading under which the systems should operate. These dynamic loads, in the form of harmonic forces are the product of the engine and compressor rotating masses. In addition, shaking forces are produced by pulsating pressures at pipeline locations where there are changes of section or direction, such as elbows, reductions, scrubbers and bottles.

For the mechanical analysis, the elements of the system are divided in two groups:

a) large elements, including the cylinder heads, vessels and larger diameter pipeline; and

b) smaller elements, including all small diameter pipes, valves, gauges and other ancillary elements attached to vessels and pipeline.

The analysis is conducted in two steps:

1.) The dynamic characteristics of the large elements are assessed using a computational model and recommendations for the attenuation of excessive vibrations are given based on the results of the computer analysis. This analysis is conducted using a combination of piping stress analysis software (AutoPIPE V8i) and finite element analysis software (FEMAP 9.3).Recommendations are the number type and location of pipe clamps. Also, notifications to the pulsation bottles result from the analysis.

2.) The small elements attached to the main system are surveyed and assessed for potential vibration problems and recommendations are given based on experience and the results of the simulation.

Harmonic forces can also excite vibration modes of the system if the frequencies of excitation coincide with the natural frequencies of the structure. The distribution of masses, the stiffness of the pipeline components, the stiffness of the compressor cross-head guides, and the stiffness of the pipeline and compressor supports determine the natural frequencies of the structure.

Particular attention should be given to the dynamic characteristics of the compressor manifold system. Supports should be designed to provide adequate stiffness in such a way that vibration modes of the manifold-cylinder assembly are above the range of frequencies corresponding to 2.4 times crankshaft rotation speed.

The most widely accepted method to determine the natural frequencies of the system consist of:

a) building an approximate model with elastic beams, springs and masses; and

b) assembling the stiffness and mass matrices and then calculating the eigenvalues and eigenvectors of the approximate system using numerical analysis techniques. The eigenvalues of the system represent the resonant frequencies, whilst the eigenvectors provide the deformed shape corresponding to each natural frequency.

The elastic and geometric properties for the beams in the model are derived from the properties of the piping. Suction and discharge bottles are modeled as pipe elements, as well as the cross-head guide and nozzles.

Precise calculation of frequencies and modal shapes depend on the accuracy with which the stiffness of the supports can be estimated. Pipeline supports are usually attached to crossbeams between the main skid beams. In this manner, the equivalent spring constant for displacements in every direction can be accurately calculated by using beam theory results.

The stiffness of the cross-guide assembly is determined from data available from the compressor manufacturer. The stiffness of the cross-guide support and crankcase are the most uncertain of the parameters. However, a combination of finite element analysis and sensitivity analysis can be used to assess the minimum stiffness necessary for adequate support.

The harmonic loading corresponding to the pressure pulsations can be accurately calculated using simulation software. If the system complies with API 618 4^{th} edition guidelines for pulsation, the level of pressure pulsation shaking forces is normally too low to produce significant deformation, unless the frequency of the shaking force coincides with one of the natural frequencies of the system causing resonance.

Piping system natural frequencies are calculated and compared with pulsation excitation frequencies (corresponding to API 618 4^{th} edition M.4). Recommendations on the position of supports are then made.

Finite element model of manifolds will be used to predict natural frequencies and modal shapes. The vibration characteristics will then be compared to the characteristic frequencies of excitation sources (mechanical and acoustical) in conformance to API M.5.

4.5 MECHANICAL ANALYSIS PROCEDURES

1. **Data Gathering**
   - Piping Isometric Drawings.
   - Vessel Design Drawings.
   - Compressor information (mass and stiffness for different parts).
   - System general arrangement.

2. **Model Generation**
   - Select relevant operating cases.
   - Select nodes on piping system to be represented in the model.
   - Define model for cylinder heads, cross-head guides, bottles, scrubbers and main pipeline.
   - Define forces in terms of the harmonic content of inertia loads, gas loads and pressure pulsations.

3. **Troubleshooting and verification of the model**
   - The input data is verified.
   - Model is run to assess initial 'as found' conditions for each loading case.

4. **Developing Solutions**
   - Additional supports are implemented and tested in the model.
   - Optimization (de-tuning of resonant frequencies) is attempted for various solutions.

5. **Generation of Results Files**
   - Results are plotted for defining cases only.

5. REFERENCES

1. Alves, P. *Practical Vibrations Handbook,* Calgary: APD, 2001.
2. *API Standard 618* -- 4^{th} ed., (June). Washington: American Petroleum Institute, 1995.
3. *ASME B31.3 Process Piping: Code for Pressure Piping*. New York: ASME, 1996.
4. *ASME Boiler & Pressure Vessel Code VIII*, Div. 2. Alternate Rules. New York: ASME, 2001.
5. DenHartog, J. *Mechanical Vibrations* -- 4^{th} ed. New York: McGraw-Hill, 1956.
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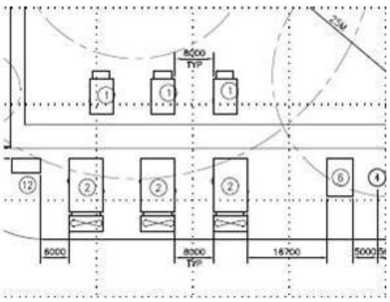
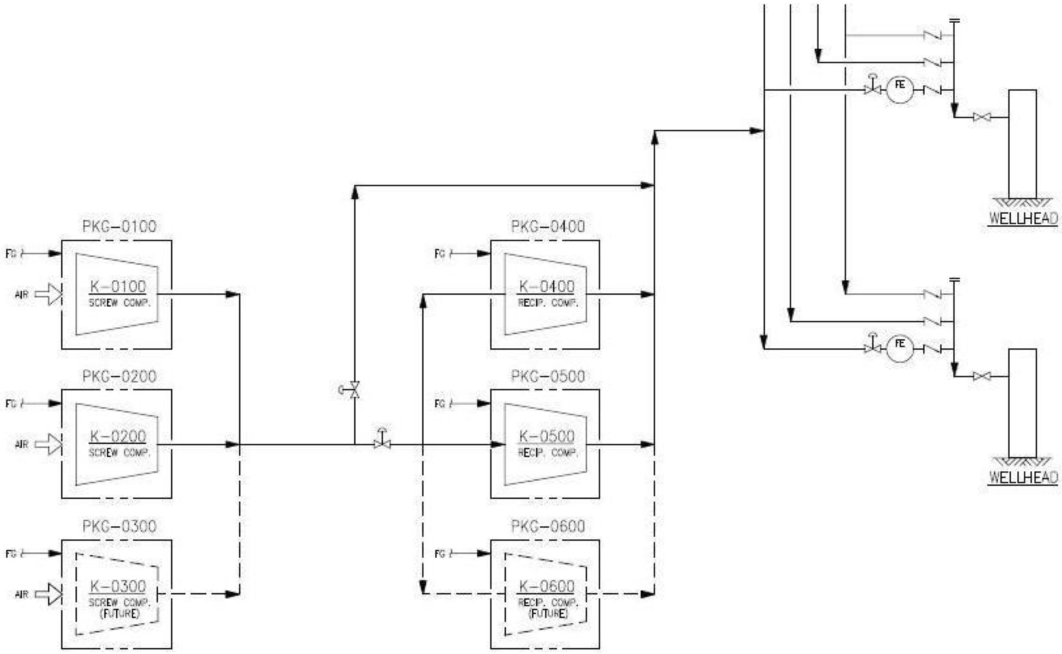
7. Megyesy, E. *Pressure Vessel Handbook* -- 13^{th} ed. Tulsa: Pressure Vessel Pub., 2004.
8. Rebis, *AutoPIPE User's Manual*, v. 6.3
9. Thomson, W.T. *Mechanical Vibrations* -- 2^{nd} ed., New Jersey: Prentice-Hall, 1953.

6. APPENDIX

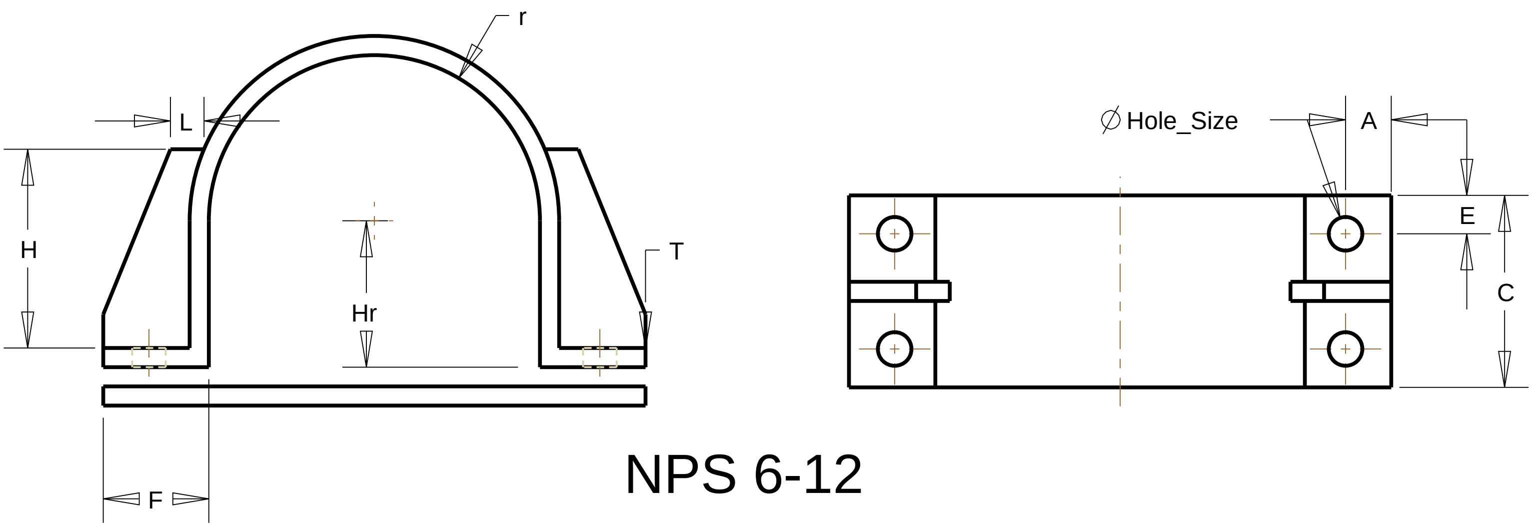
Part of the plot plan relevant to the air compressors is shown here. No. 1's are the Recip Compressor packages and No. 2's are the Screw compressor packages (s and between them is the pipe rack and No. 12 is the barrel dock. All dimensions shown are preliminary.



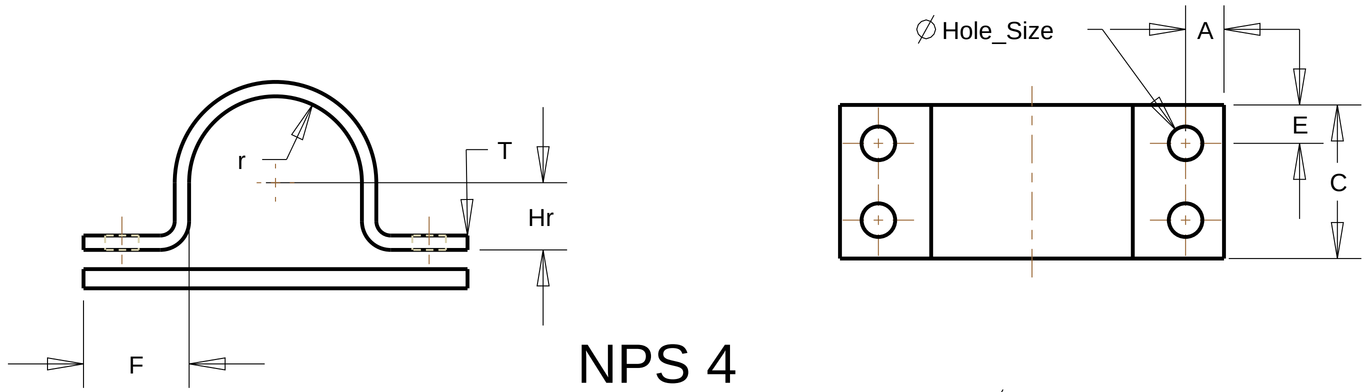
Part of the PFD relevant to the air compressors is shown here.



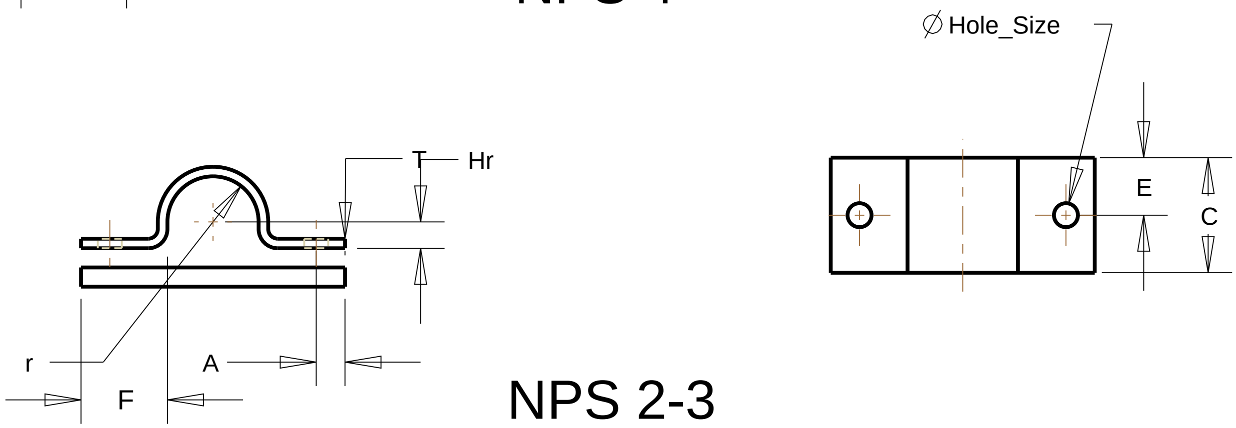
Name	r	A	C	E	F	T	Hole Size	Bolt_Size	Hr	H	L
NPS_2	1-3/16	3/4	3	1-1/2	2-1/4	1/4	5/8	0.500	11/16	-	-
NPS_3	1-3/4	1	4	2	2-3/4	1/4	7/8	0.750	1-1/4	-	-
NPS_4	2-1/4	1	4	1	2-3/4	3/8	7/8	0.750	1-3/4	-	-
NPS_6	3-5/16	1-1/8	5	1	2-3/4	3/8	7/8	0.750	2-13/16	4	11/16
NPS_8	4-5/16	1-3/16	5	1	2-3/4	1/2	7/8	0.750	3-13/16	5-3/16	7/8
NPS_10	5-3/8	1-1/2	6	1-3/16	3-1/2	1/2	1-1/8	1.000	4-7/8	6-1/2	1-1/8
NPS_12	6-3/8	1-11/16	6	1-3/16	3-3/4	1/2	1-1/8	1.000	5-7/8	7-11/16	1-5/16



NPS 6-12



NPS 4



NPS 2-3

All Dimensions in inches unless otherwise noted

Note: Use double-nuts or lock nuts to prevent loosening of the clamp over time

AP Dynamics

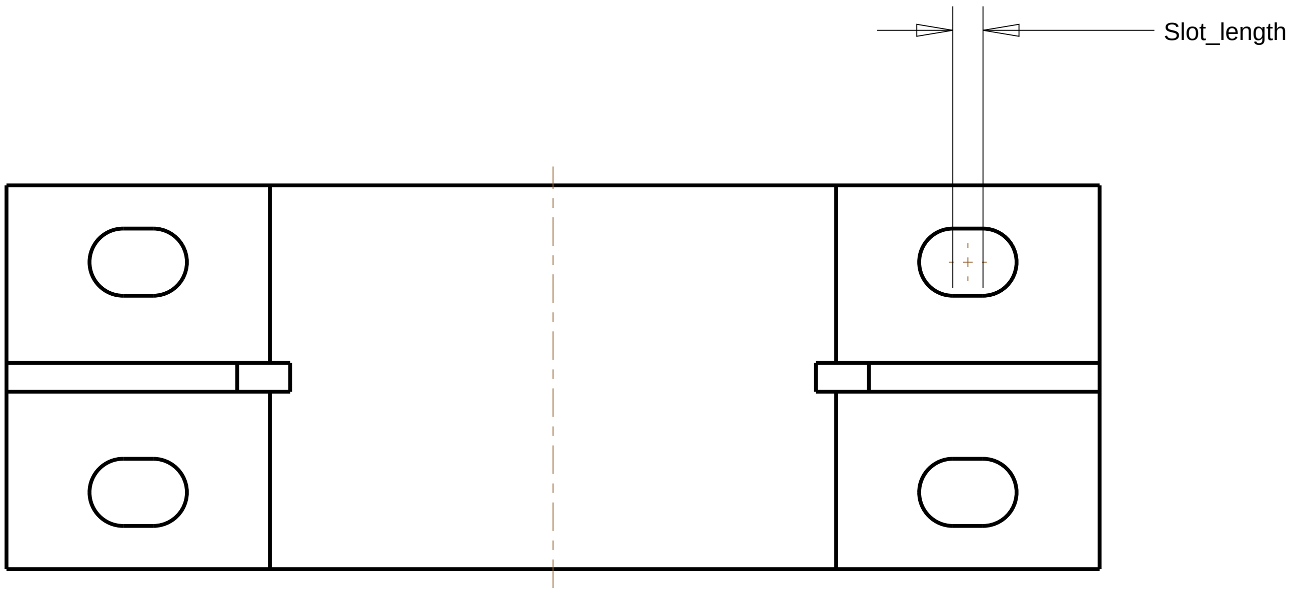
Calgary Alberta - Houston Texas

Pipe clamps for vibrating service

D268-001

1 OF 2

Slotted Clamp Variation



For lateral slots, increase clamp tab length "F" by slot length
For axial slots, increase clamp length "C" to accomodate

AP Dynamics
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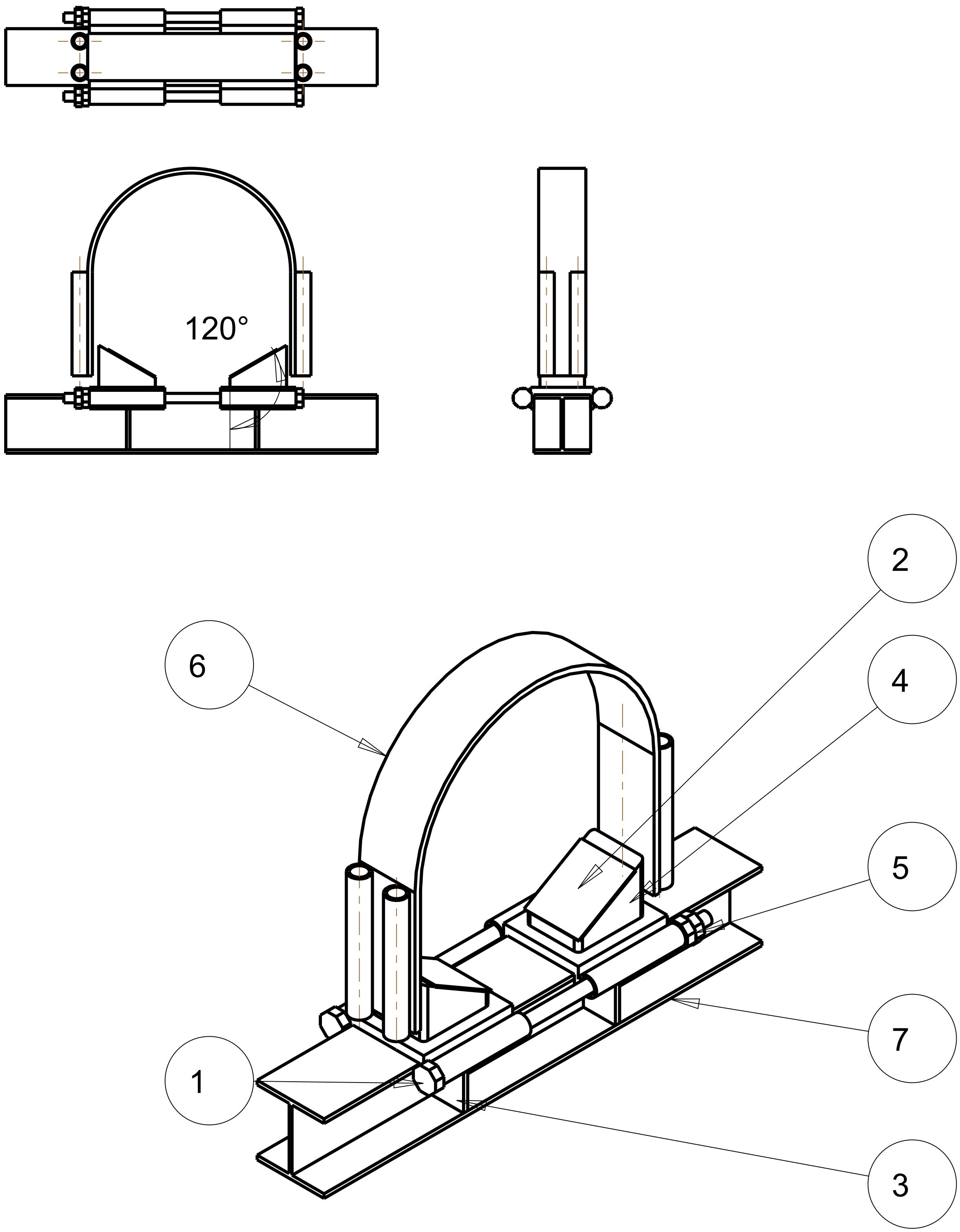
Pipe clamps for vibrating service

D268-001

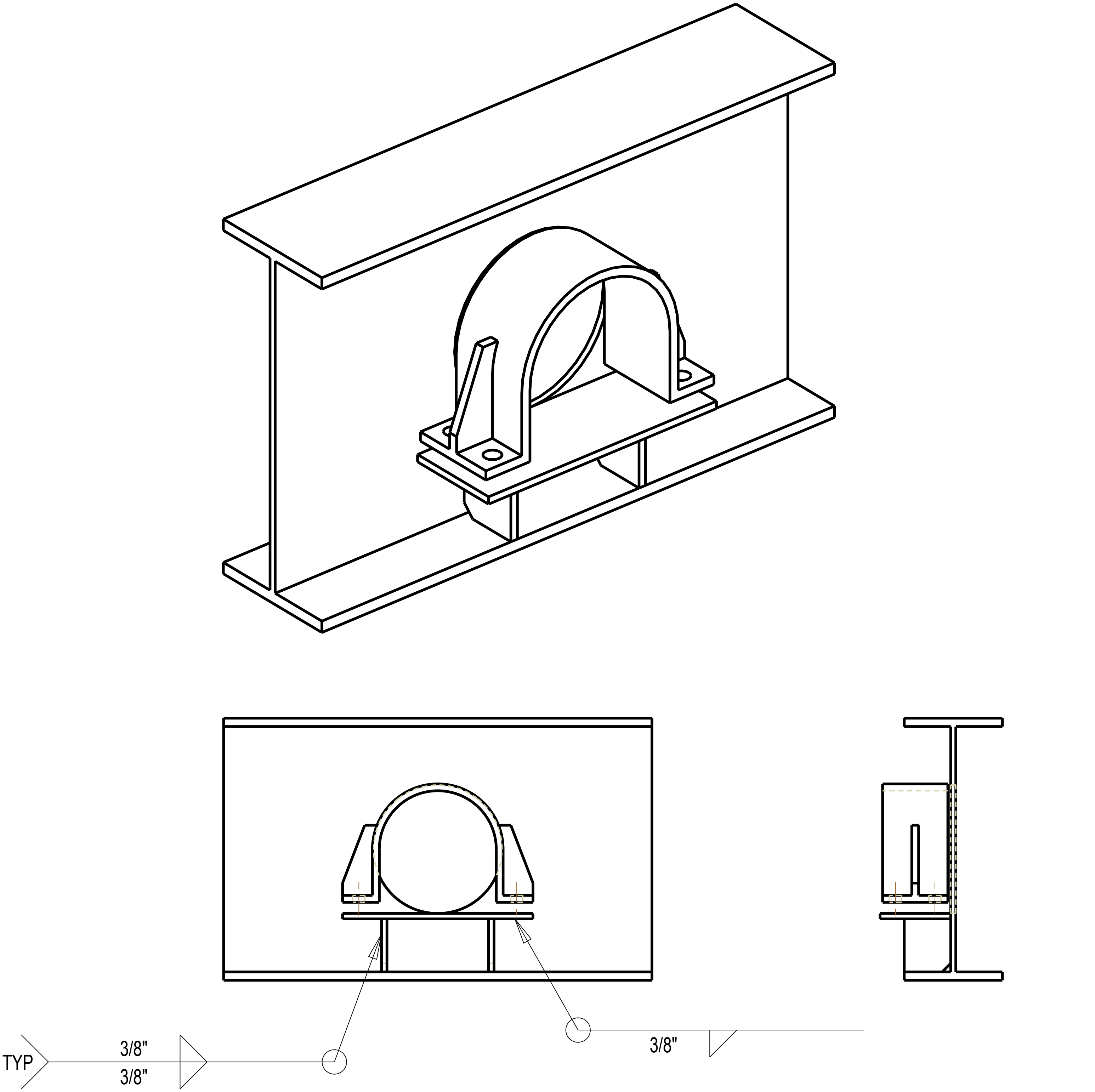


Item	Description	QTY
1	1" Bolt in 1-1/4 SCH 80 Pipe Collar	2
2	1/8" Fabreeka Pad	2
3	3/8" Full Depth Gusset	4
4	HSS cut to fit	2
5	Nut	4
6	Optional Strap, 1/2" Thick	1
7	Wide Flange or HSS Member	1

AP DYNAMICS
CALGARY ALBERTA - HOUSTON TEXAS

Bottle Wedge with optional strap

D268-002

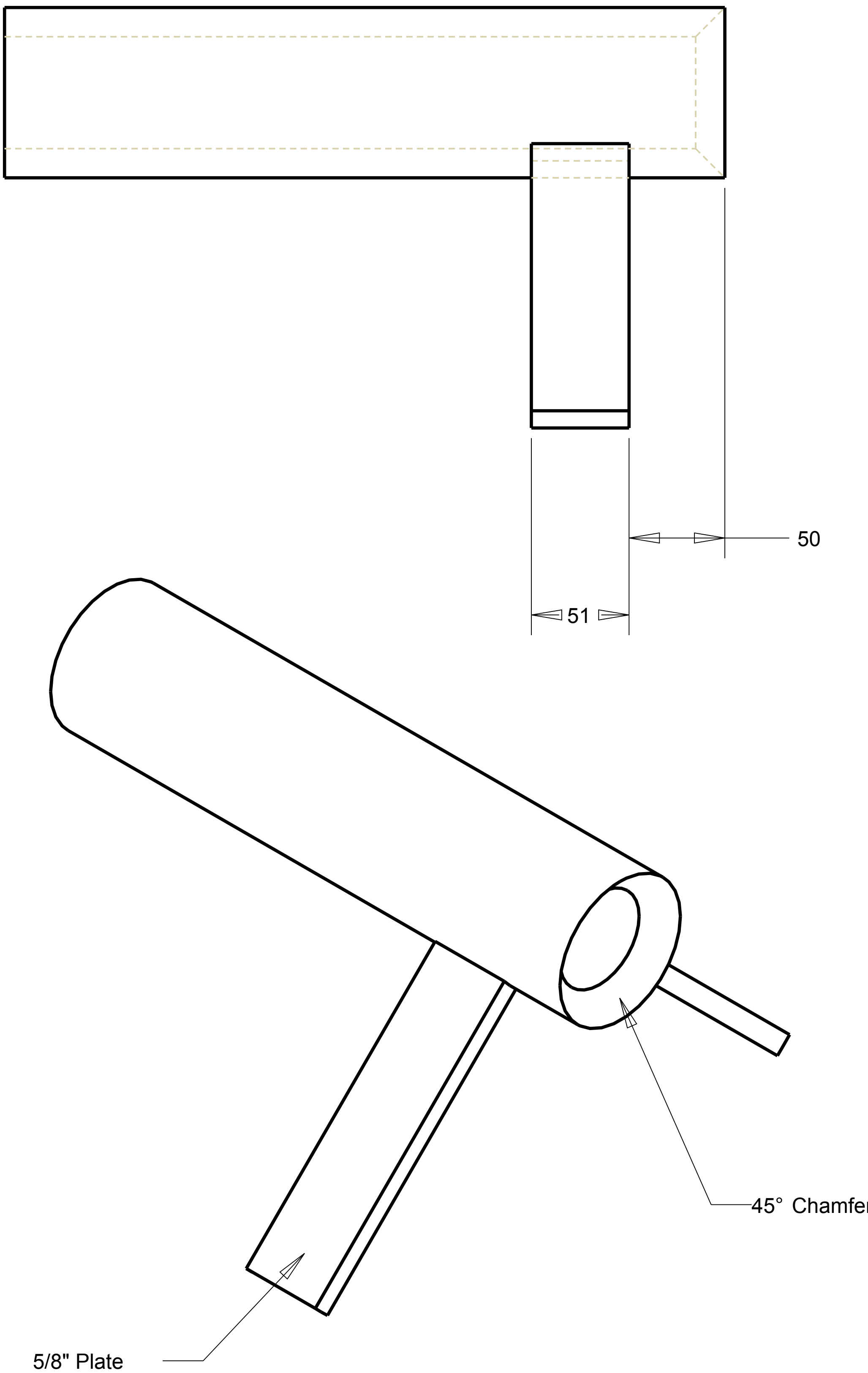


AP DYNAMICS

CALGARY ALBERTA - HOUSTON TEXAS

Typical Skid Edge Support

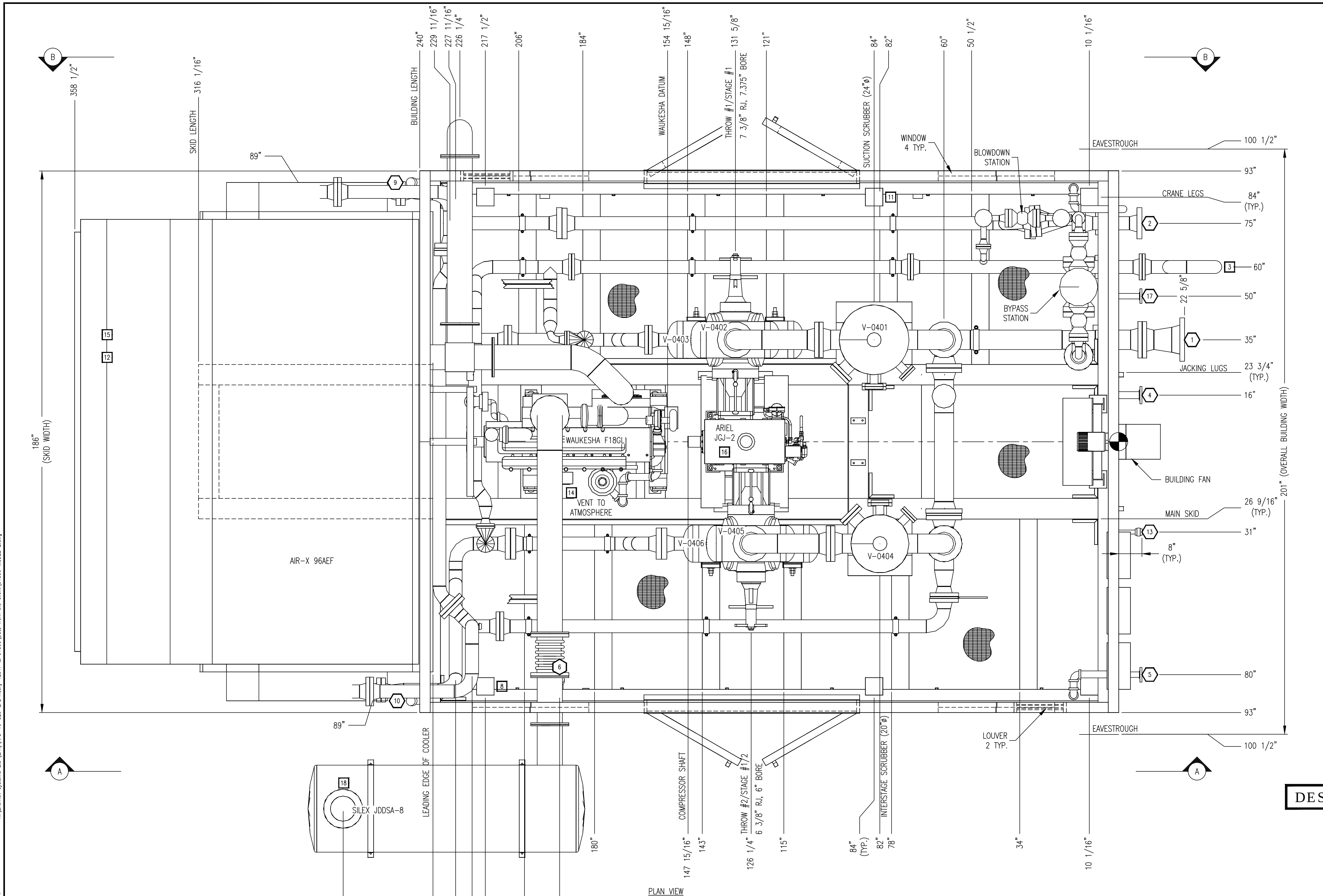
D268-011	1 OF 1



AP DYNAMICS
CALGARY ALBERTA - HOUSTON TEXAS

Typical choke tube end support

D268-010	1 OF 1



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PLOT DATE October 20, 2010

NOZZLE SCHEDULE

MARK	SERVICE	SIZE	RATING	TYPE
1	AIR INLET	8"	300#	RF
2	FINAL DISCHARGE	4"	600#	RF
3	HIGH PRESSURE VENT HEADER (AIR)	4"	150#	RF
4	SCRUBBER DRAIN HEADER	2"	150#	RF
5	FUEL GAS INLET	1 1/2"	150#	RF
6	GLYCOL STAND PIPE	2"	3000#	MNPT
7	RECIP BYPASS OUTLET	4"	600#	RF
8	GLYCOL FILL	1"	3000#	FNPT
9	WASTE OIL DRAIN	2"	3000#	MNPT
10	WASTE GLYCOL DRAIN	2"	3000#	MNPT
11	ENGINE/COMP LUBE OIL FILL	3/4"	–	HOSE
12	STARTER VENT	2"	–	PIPE
13	INSTRUMENT AIR SUPPLY	1"	3000#	FNPT
14	HIGH PRESSURE VENT HEADER (GAS)	2"	–	–
15	LP INSTRUMENT VENT HEADER	1"	–	PIPE
16	COMPRESSOR OIL FILL	2"	–	MNPT
17	START GAS INLET	1 1/2"	150#	RF
18	EXHAUST	8"	12GA	TUBE

GENERAL SPECIFICATIONS

OVERALL PACKAGE LENGTH			31'-9 1/8"
OVERALL PACKAGE WIDTH			16'-9"
OVERALL PACKAGE HEIGHT (w/STACK)			24'-9"
OVERALL OPERATING PACKAGE WEIGHT (LBS)			T.B.C.
MAIN SKID SHIPPING WEIGHT (LBS)			T.B.C.
BRIDGE CRANE RATING			3 TON
SEAL PAN	■ FLAT	☐ NONE	☐ SLOPED
LOADING METHOD	☐ LIVE ROLL	☐ CRANE	■ JACK & ROLL

NOTES:

1. ALL (Z) DIMENSIONS TAKEN FROM TOP OF SKID.
2. ALL OTHER NOTES FOUND ON DWG. #LEGEND.
3. ALL SKID EDGE CONNECTIONS ±1/4" TOLERANCE.
4. ALL TAIL DIMENSIONS FROM REFERENCE POINT.
6. SKID DEPTH:
5. CENTER OF GRAVITY:
   'X' FROM REF. POINT:
   'Y' FROM REF. POINT:
   'Z' FROM REF. POINT:

'Z' DIMENSION FROM TOP OF SKID

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REV	DESCRIPTION	DATE	BY	APR
2	REMOVE HOT BYPASS SPOOLING - IFC	09/15/10	BM	K.G.
1	ISSUED FOR CONSTRUCTION	08/04/10	TT	K.G.

DATE 06/07/10 SCALE 3/4"=1'-0"

DRAWN BY B. McLean CHECKED BY K. Green APPROVED BY D. Campbell

CUST PO N/A

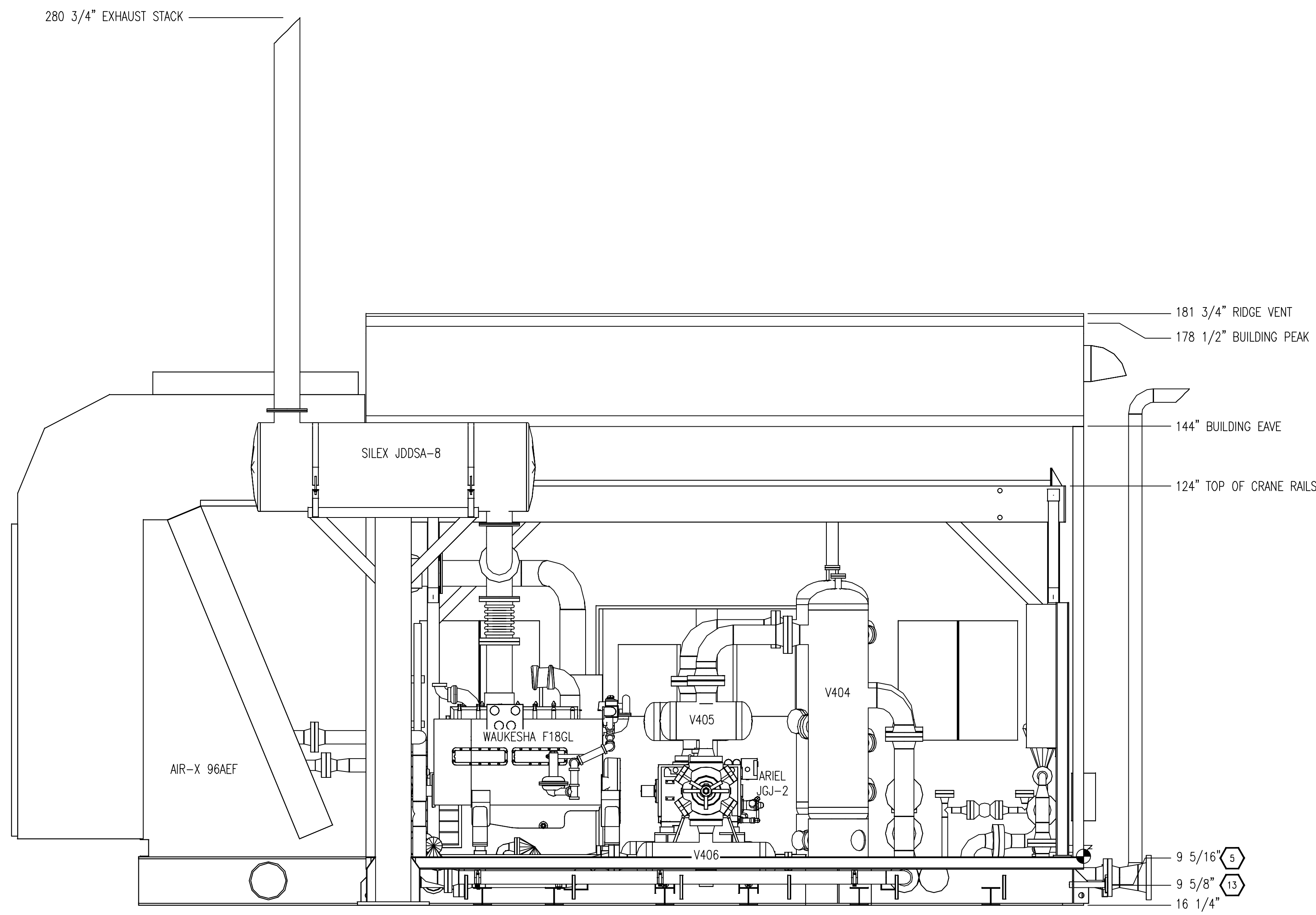
STEP CODE 198 298 490 511 591

FOR HUSKY OIL OPERATIONS LTD.
WAUKESHA F18GL
ARIEL JGJ/2-1/2 STD

ENERFLEX
10121 – BARLOW TRAIL N.E.
CALGARY ALBERTA CANADA

TITLE PLAN VIEW

DWG NO 31833-201 SHT 1 REV 2



ELEVATION VIEW A-A

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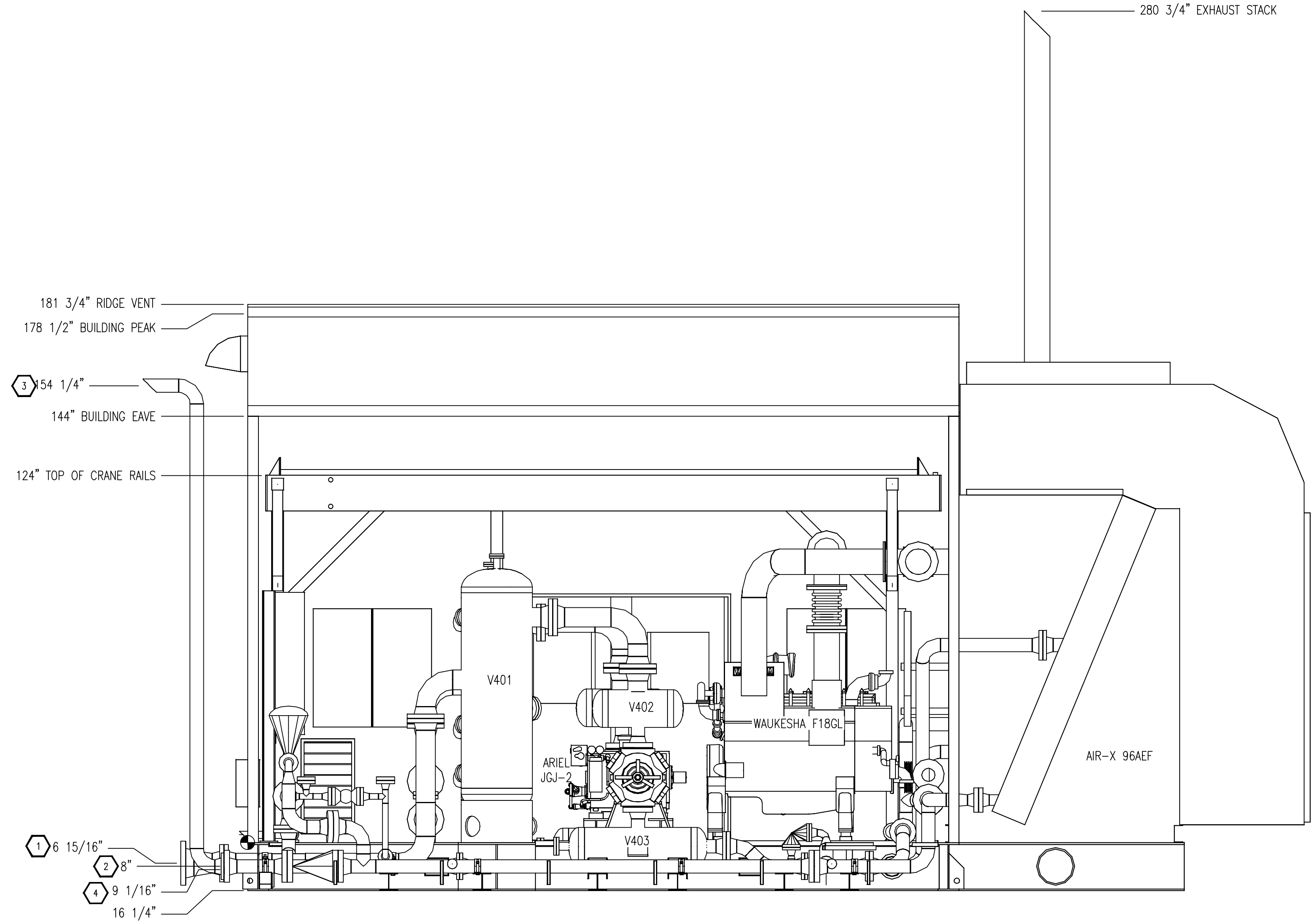

ELEVATION VIEW B-B

NOTE:
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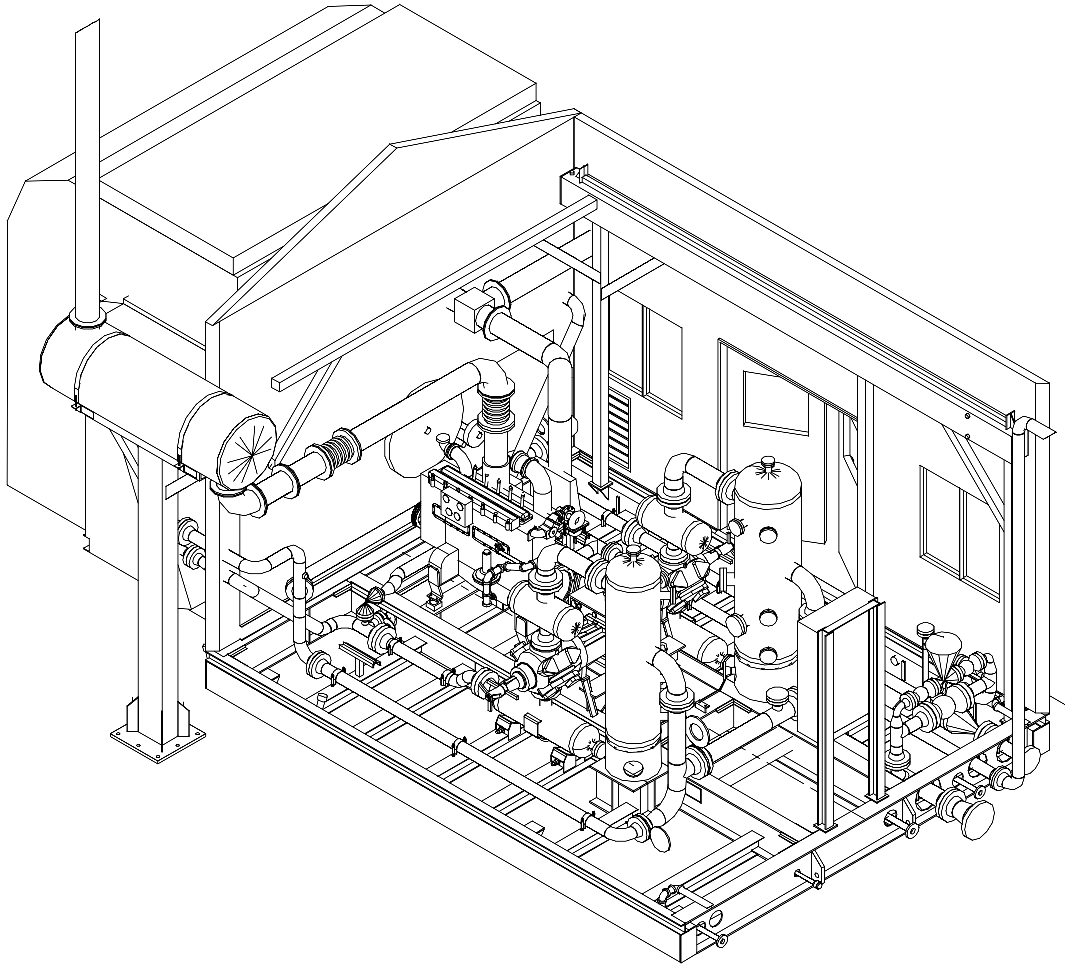

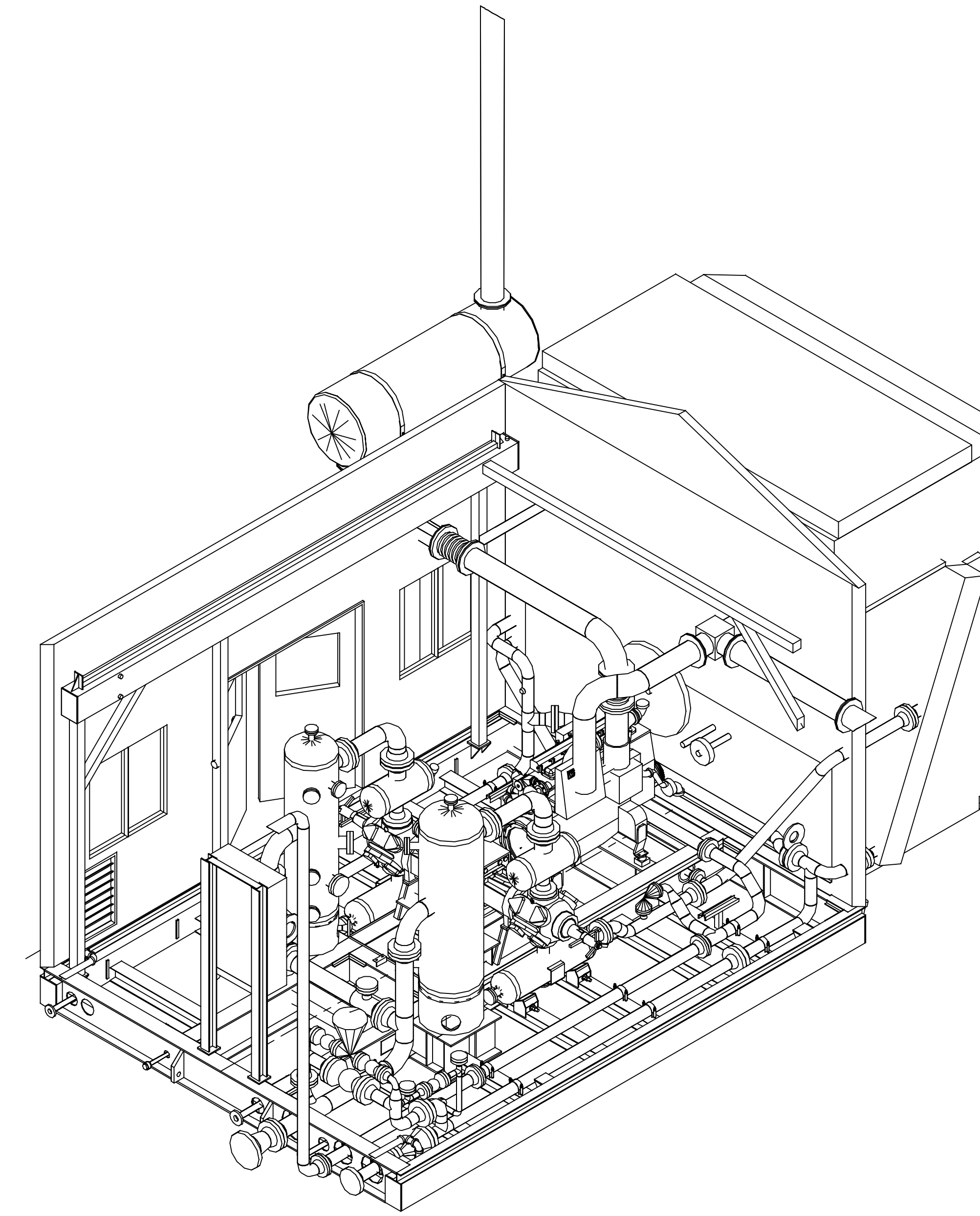

3D VIEW

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1	ISSUED FOR CONSTRUCTION	08/04/10	TT	KG

DATE 06/07/10	SCALE 3/8"=1'-0"		FOR HUSKY OIL OPERATIONS LTD. WAUKESHA F18GL ARIEL JGJ/2-1/2 STD
DRAWN BY B. McLean	CHECKED BY K. Green	APPROVED BY D. Campbell	
CUST PO N/A			
STEP CODE 198 298 490 511 591			

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TITLE 3D VIEW

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PLOT DATE October 20, 2010

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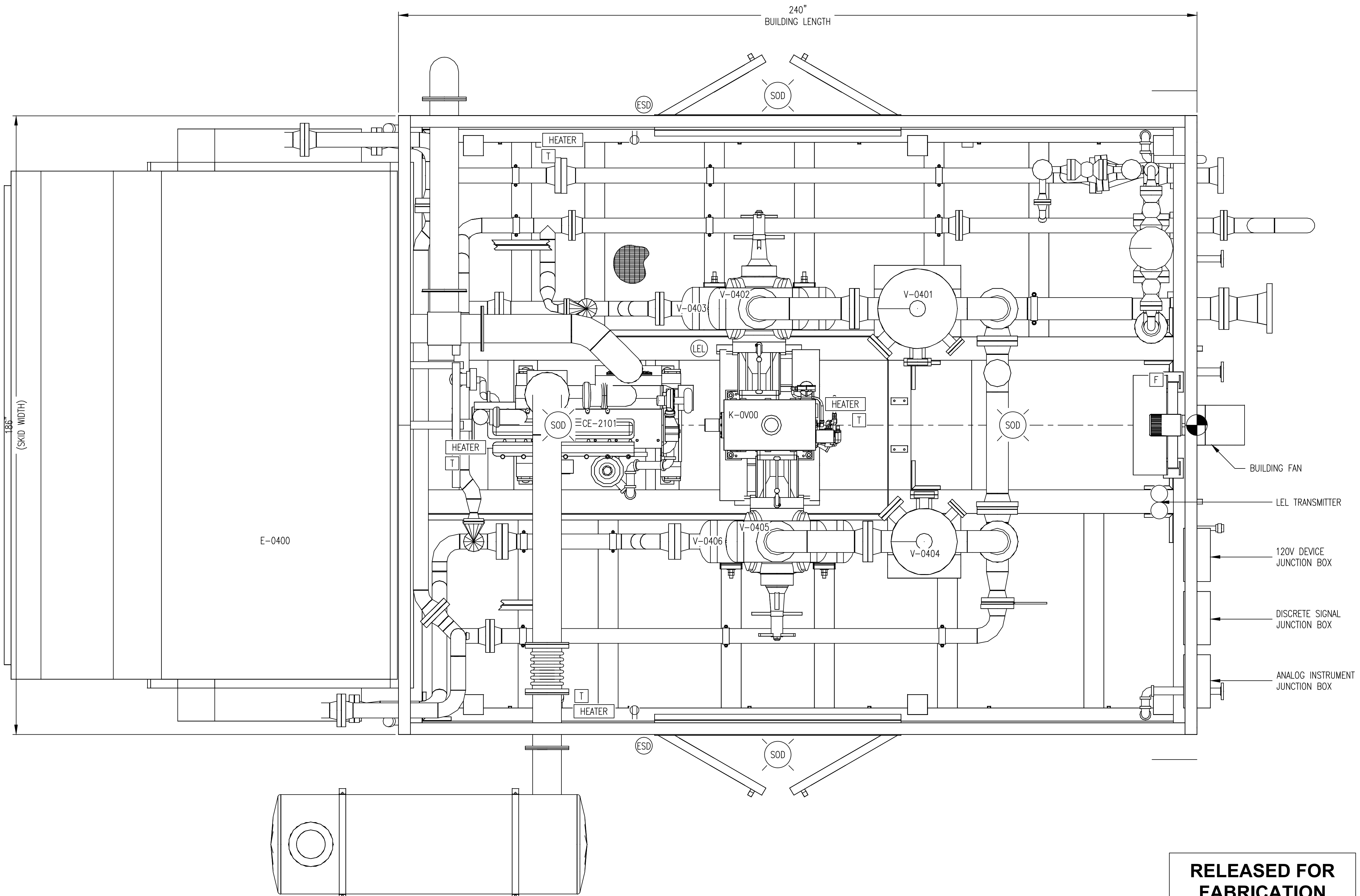

PLAN VIEW

ELECTRICAL LEGEND	
SYMBOL	DESCRIPTION
	LIGHT
INC	INCANDESCENT LIGHT
SOD	H.P. SODIUM LIGHT
E	BATTERY POWERED EMERGENCY LIGHT
	RECEPTACLE
T	THERMOSTAT
F	FIRE EYE
H F	FIRE PULL STATION
R	COMBUSTIBLE LEL GAS ALARM BEACON
B	TOXIC GAS H2S ALARM BEACON
C F	FIRE ALARM STROBE
F	ALARM HORN
CO	CO SENSOR
LEL	COMBUSTIBLE DETECTION
H2S	H2S SENSOR
HEATER	HEATER
TIME	TIMER SWITCH
ESD	EMERGENCY SHUT DOWN BUTTON
	–
	–
	–
	–
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ENERFLEX
10121 – BARLOW TRAIL N.E.
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PERMIT TO PRACTISE APEGGA PERMIT: No. P8651

TITLE ELECTRICAL LAYOUT

DWG NO 31833-201 SHT 5 REV 1

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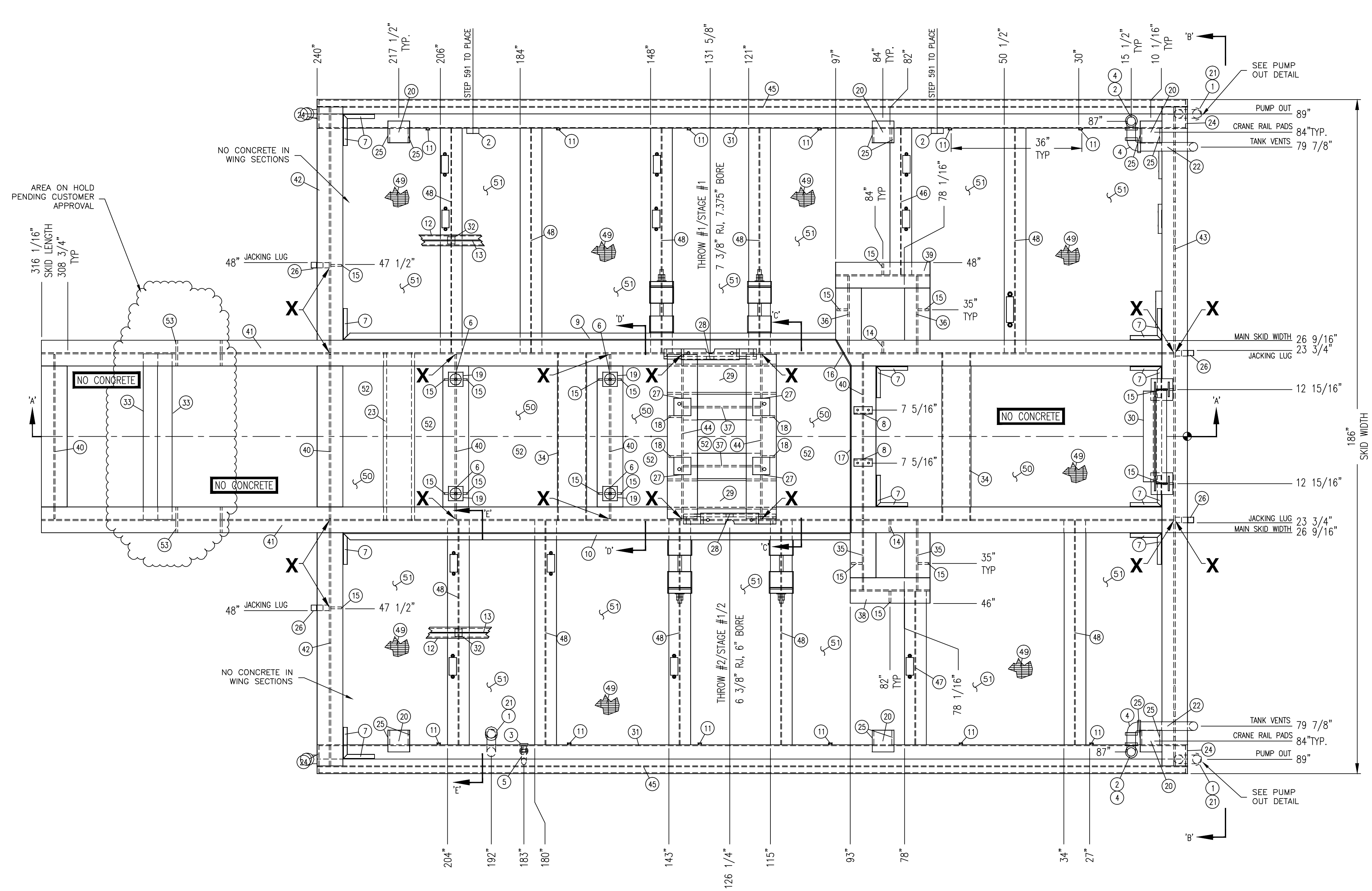

PLAN VIEW

BILL OF MATERIAL

MK	QTY	DESCRIPTION	MAT.	LENGTH	PART_NUMBER
1	3	CAP,2",3000#,NPT	SA-105	–	115-HRB-0200
2	4	COUPLING,2",3000#,NPT,HALF	SA-105	–	123-HRB-0200
3	1	ELBOW,1",3000#,45D,NPT	SA-105	–	142-HRB-0100
4	4	ELBOW,2",3000#,90D,NPT	SA-105	–	146-HRB-0200
5	1	PIPE,1",XS,SMLS,TOExPOE (CUT TO SUIT)	SA-106-B	4	600-HPA-0100
6	4	VIBRACON SM16 ADJUSTABLE CHOCK		–	NPN
7	1	ANGLE,1-1/4" X 1-1/4",3/16" THK	G40.2144W	900	005-HA-0125-0125-0018
8	2	ANGLE,2" X 2",1/4" THK	G40.2144W	5	005-HA-0200-0200-0025
9	1	ANGLE,2" X 2",1/4" THK	G40.2144W	135 15/16	005-HA-0200-0200-0025
10	1	ANGLE,2" X 2",1/4" THK	G40.2144W	139 15/16	005-HA-0200-0200-0025
11	12	CHANNEL,1" X 0.83#	G40.2144W	8	018-HA-0100-0008
12	2	CHANNEL,3" X 4.1#	G40.2144W	225 7/8	018-HA-0300-0041
13	2	FLAT BAR,1" X 1/4" THK	G40.2144W	225 7/8	010-HA-0100-0025
14	2	FLAT BAR,3" X 1/2" THK	G40.2144W	4 1/2	010-HA-0300-0050
15	18	FLAT BAR,3" X 1/2" THK	G40.2144W	15	010-HA-0300-0050
16	1	FLAT BAR,3/4" X 1/4" THK	G40.2144W	8 1/8	010-HA-0075-0025
17	1	FLAT BAR,3/4" X 1/4" THK	G40.2144W	46	010-HA-0075-0025
18	4	FLAT BAR,3-1/2" X 1/2" THK	G40.2144W	19 3/4	010-HA-0350-0050
19	4	MOUNTING BLOCK 4"SQUARE.x 2"t, C1018 COLD ROLLED, FLAT BAR(SEE DWG. EMB-H24-F18 REV.0)	C1018	4	NPN
20	6	FLAT BAR,6" X 1/2" THK	G40.2144W	6	010-HA-0600-0050
21	3	PIPE,2",S/80(XS),ERW	SA-106-B	15	602-HPB-0200
22	1	PIPE,2",S/80(XS),ERW	SA-106-B	48	602-HPB-0200
23	1	PIPE,8",XXS,SMLS	SA-106-B	46 3/8	600-PPA-0800
24	4	PLATE,1/2",SMOOTH X 1' X 8"	G40.2144W	12	040-HA-0050
25	12	PLATE,1/2",SMOOTH X 7 3/16" X 3 5/16"(ONE CUTS TWO)	G40.2144W	7 3/16	040-HA-0050
26	4	PLATE,1-1/2",SMOOTH X 1' X 5" (SEE DWG.# LIFT LUG REV.0)	G40.2144W	12	040-HA-0150
27	4	MOUNTING BLOCK 4 3/4"SQUARE.x 2"t, C1018 COLD ROLLED, FLAT BAR(SEE DWG. ARIEL-MB-JGRJ2 REV.0)	C1018	4 3/4	NPN
28	2	CYLINDER SUPPORT, SEE DWG. #JGJ-ALL CYLINDER SUPPORT	G40.2144W	–	NPN
29	2	PLATE,3/4",SMOOTH X 2'-6" X 10 3/4"	G40.2144W	30	040-HA-0075
30	1	PANEL STAND, 30" WIDE, SEE DWG. PANEL STAND REV.1	G40.2144W	–	NPN
31	2	TUBING,12"X8",1/4" THK	G40.21350W	239	020-HA-1200-0800-0025
32	12	TUBING,2"X2",3/16" THK	G40.21350W	9 1/8	020-HA-0200-0200-0018
33	2	TUBING,4"X4",1/4" THK	G40.21350W	47 1/4	020-HA-0400-0400-0025
34	2	TUBING,8"X6",1/4" THK	G40.21350W	46 3/8	020-HA-0800-0600-0025
35	2	WIDE FLANGE,16" X 50#	G40.2150W	19 1/16	034-HA-1600-0500
36	2	WIDE FLANGE,16" X 50#	G40.2150W	21 1/16	034-HA-1600-0500
37	2	WIDE FLANGE,16" X 50#	G40.2150W	21 5/16	034-HA-1600-0500
38	1	WIDE FLANGE,16" X 50#	G40.2150W	22	034-HA-1600-0500
39	1	WIDE FLANGE,16" X 50#	G40.2150W	26	034-HA-1600-0500
40	5	WIDE FLANGE,16" X 50#	G40.2150W	45 3/8	034-HA-1600-0500
41	2	WIDE FLANGE,16" X 50#	G40.2150W	312 5/16	034-HA-1600-0500
42	2	WIDE FLANGE,16" X 50#	G40.2150W	67 5/8	034-HA-1600-0500
43	1	WIDE FLANGE,16" X 50#	G40.2150W	181 11/16	034-HA-1600-0500
44	2	WIDE FLANGE,21" X 68#	G40.2150W	45 3/8	034-HA-2100-0680
45	2	WIDE FLANGE,4" X 13#	G40.2150W	240	034-HA-0400-0130
46	1	WIDE FLANGE,6" X 15#	G40.2150W	40 3/8	034-HA-0600-0150
47	1	WIDE FLANGE,6" X 15#	G40.2150W	42 3/8	034-HA-0600-0150
48	10	WIDE FLANGE,6" X 15#	G40.2150W	61 13/16	034-HA-0600-0150
49	–	BAR GRATING, 1" DEEP X 3/16"T (SQ. FT.)	–	220	049-19W4-HAP-0018-0100
50	1	PLATE,12 GA,SMOOTH SHEAR TO 3'-6" (CTS) (SHOP TO ORDER)	G40.2144W	228	044-HA-0012
51	–	PLATE,12 GA,SMOOTH (CTS) (SQ. FT.) (SHOP TO ORDER)	G40.2144W	200	044-HA-0012
52	–	CONCRETE, MIX 20B5GN1, 20 MPA, STRENGTH C/W AIR, 2292 KG/M CU. (142LBS/FT3) (M. CU.)(SEE SECTION A-A FOR LOCATIONS)	–	2.1	CONCRETE-20B57GN1-350
53	2	PIPE,12",XS,SMLS	SA-106-B	7 1/16	602-JPB-1200

IMPORTANT NOTICE TO OWNER/OPERATOR

THE DESIGN OF THE FOUNDATION FOR THIS COMPRESSOR PACKAGE IS NOT IN THE SCOPE OF SUPPLY BY TOROMONT ENERGY SYSTEMS INC. ("TESI"). AS SUCH, THE DESIGN AND ADEQUACY OF THE FOUNDATION IS ENTIRELY THE RESPONSIBILITY OF THE OWNER/OPERATOR AND/OR ITS ENGINEERING FIRM AND THEIR REPRESENTATIVES. REFER TO TESI DWG. NO. 31833-351, SHEET 1 FOR FURTHER INFORMATION, AND OWNER/OPERATOR'S OBLIGATIONS AND LEGAL LIMITATIONS.

NOTES

1. GRIND ALL ROUGH EDGES & WELD SPLATTER.
2. SANDBLAST INTERNALS OF GLYCOL STORAGE TANK PRIOR TO FINAL ASSEMBLY.
3. AIR PRESSURE TEST GLYCOL & OIL TANKS TO 10 PSI.
4. CONSTRUCT STRUCTURE FLUSH TO TOP UNLESS OTHERWISE NOTED.
5. ALL TAIL DIMENSIONS FROM REFERENCE POINT.
6. WEIGHT OF SKID (w/o CONCRETE) 10,500 lbs.
7. 1/4" IN LENGTH HAS BEEN REMOVED FROM ITEMS #40 & 44 FOR FIT UP.
8. SEAL PAN IS FLAT.
9. PRIMER- TPS-SP-001, FIN-1, RED OXIDE
   PAINT- TPS-SP-001, FIN-1, 20-F "WARM GREY"
10. ALL WELDS TO BE 1/4" MIN. FILLETS ALL AROUND, UNLESS OTHERWISE NOTED.
11. ● FULL PENETRATION WELD REQUIRED AT THESE LOCATIONS.
12. x FULL STRENGTH WELD REQUIRED AT THESE LOCATIONS.

RELEASED FOR FABRICATION
NAME B. McLean DATE 07/08/10

DESTROY PREVIOUS COPIES

REV	DESCRIPTION	DATE	BY	APR
2	REV. FOR CWB WELDING PROCEDURES.	07/08/10	BM	CK
1	ISSUED FOR CONSTRUCTION	06/30/10	BM	CK
A	ISSUED FOR APPROVAL	06/18/10	BM	CK

DATE 06/18/10 SCALE 3/4"=1'-0"
DRAWN BY B. McLean CHECKED BY C. Kam APPROVED BY D. Campbell
CUST PO N/A
STEP CODE 400

FOR HUSKY OIL OPERATIONS LTD.
WAUKESHA F18GL
ARIEL JGJ/2-1/2 STD

ENERFLEX
10121 – BARLOW TRAIL N.E.
CALGARY ALBERTA CANADA

PERMIT TO PRACTISE APEGGA PERMIT: No. P8651

TITLE STRUCTURAL STEEL

DWG NO 31833-301 SHT 1 REV 2

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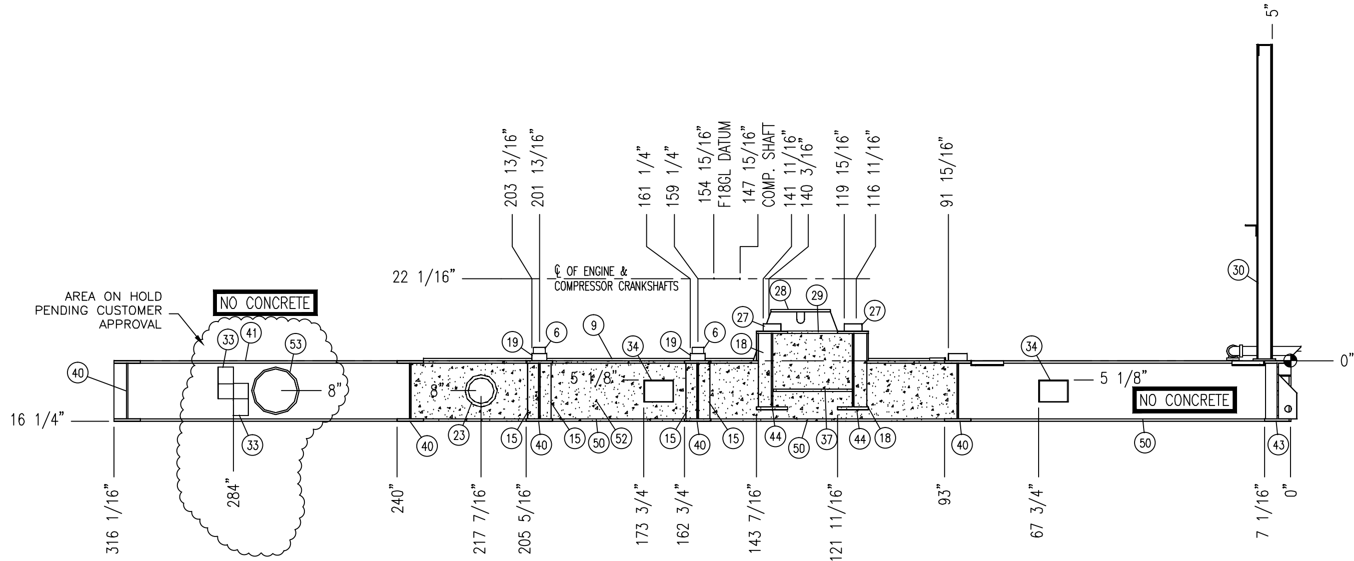
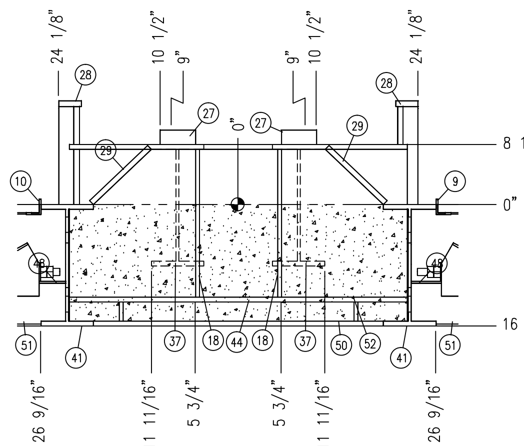
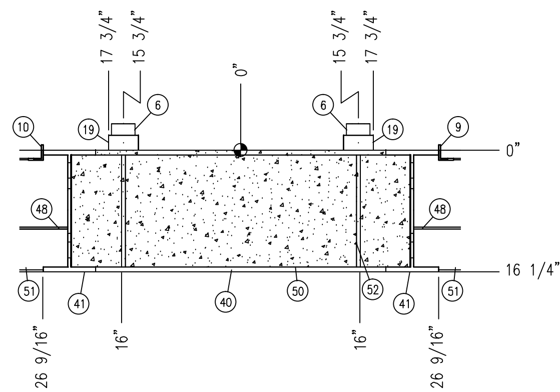
K:\Enerflex Systems Ltd (EFX)\APD-10-825-EFL Husky 12517 & 31833\Data from the Client\31833-MODEL-2.dwg
PLOT DATE October 20, 2010



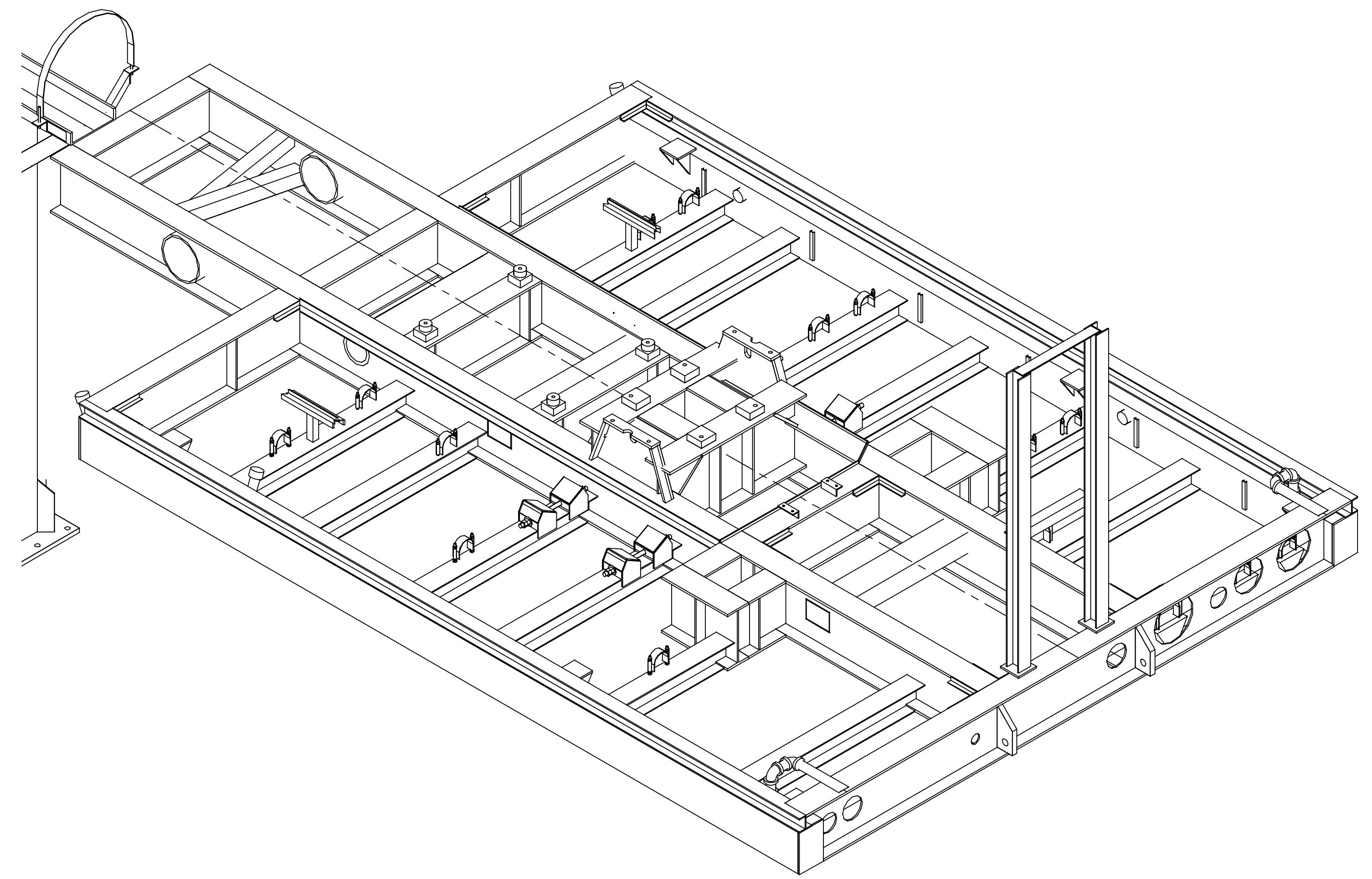
ELEVATION VIEW A-A
SCALE: 1/2"=1'-0"



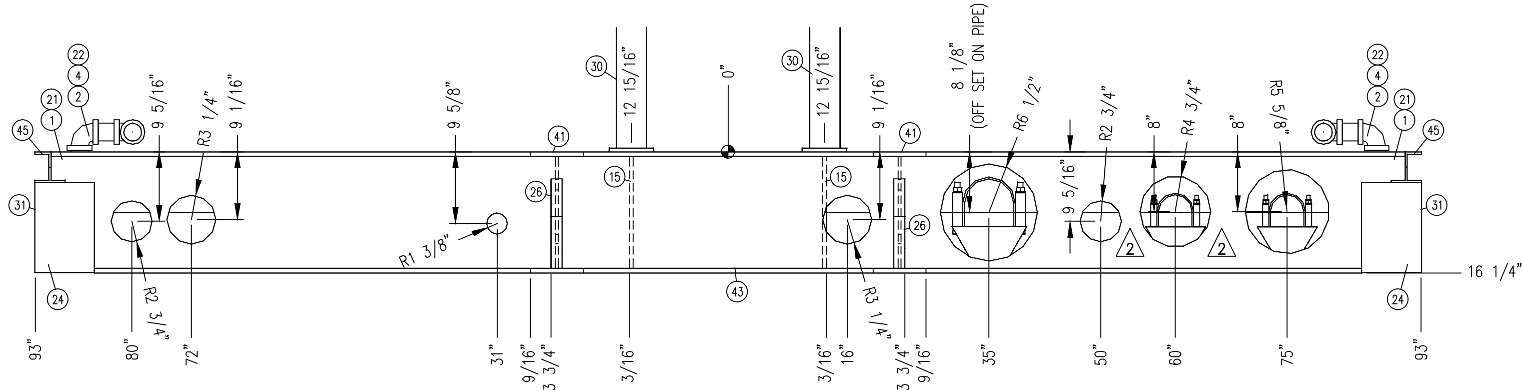
SECTION VIEW C-C
SCALE: 1"=1'-0"



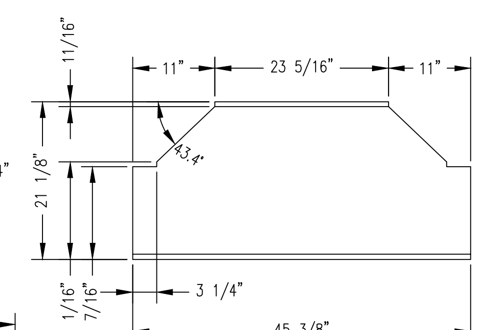
SECTION VIEW D-D
SCALE: 1"=1'-0"



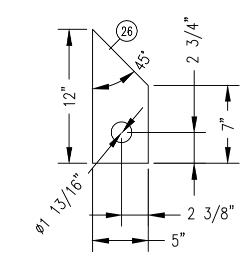
3D SKID ELEVATION
SCALE: NTS



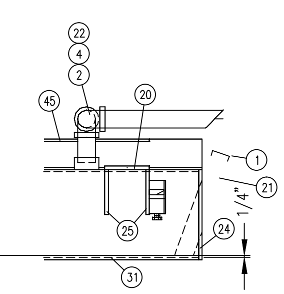
SECTION VIEW B-B
SCALE: 1"=1'-0"



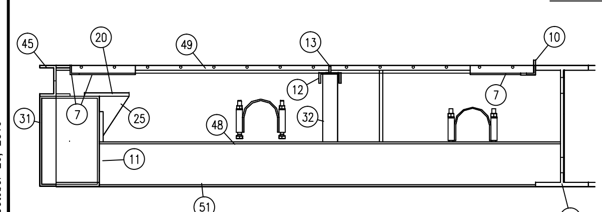
ITEM #44 DETAIL
SCALE: 1"=1'-0"



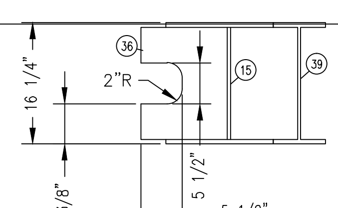
ITEM #26 DETAIL
SCALE: 1 1/2"=1'-0"



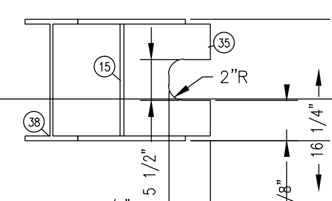
PUMP OUT DETAIL
SCALE: 1"=1'-0"



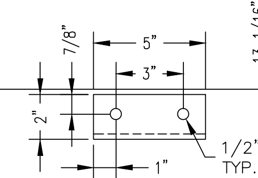
SECTION VIEW E-E
SCALE: 1"=1'-0"



PASS THROUGH DETAIL
SCALE: NTS



PASS THROUGH DETAIL
SCALE: NTS



ITEM #8 DETAIL
SCALE: 3"=1'-0"

RELEASED FOR FABRICATION
NAME B. McLean DATE 07/07/10

DESTROY PREVIOUS COPIES

REV	DESCRIPTION	DATE	BY	APR
2	REV. VIEW B-B	07/07/10	BM	CK
1	ISSUED FOR CONSTRUCTION	06/30/10	BM	CK
A	ISSUED FOR APPROVAL	06/18/10	BM	CK

DATE 06/18/10	SCALE AS SHOWN	
DRAWN BY B. McLean	CHECKED BY C. Kam	APPROVED BY D. Campbell
CUST PO N/A		
STEP CODE 400		

FOR HUSKY OIL OPERATIONS LTD.
WAUKESHA F18GL
ARIEL JGJ/2-1/2 STD

ENERFLEX
10121 – BARLOW TRAIL N.E.
CALGARY ALBERTA CANADA

PERMIT TO PRACTISE APEGGA PERMIT: No. P8651

TITLE STRUCTURAL STEEL DETAILS & SECTIONS

DWG NO 31833-301 SHT 2 REV 2

PLOT DATE October 20, 2010

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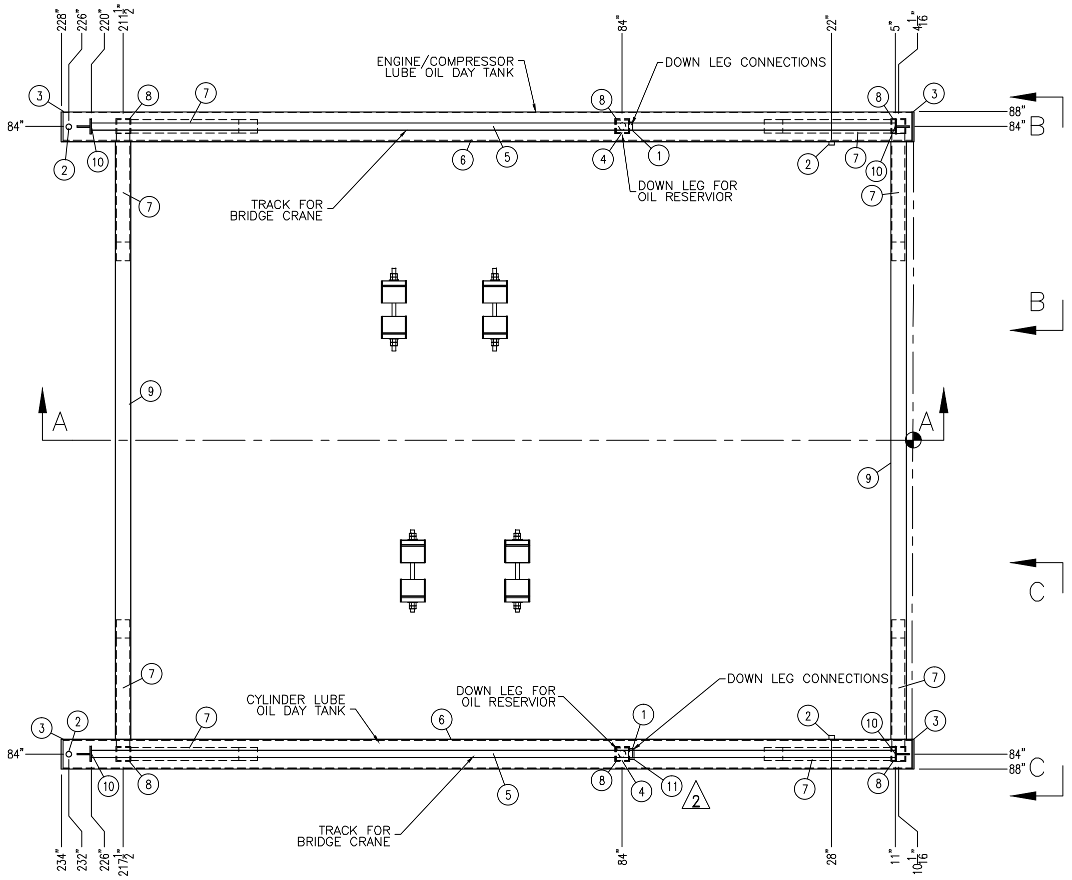
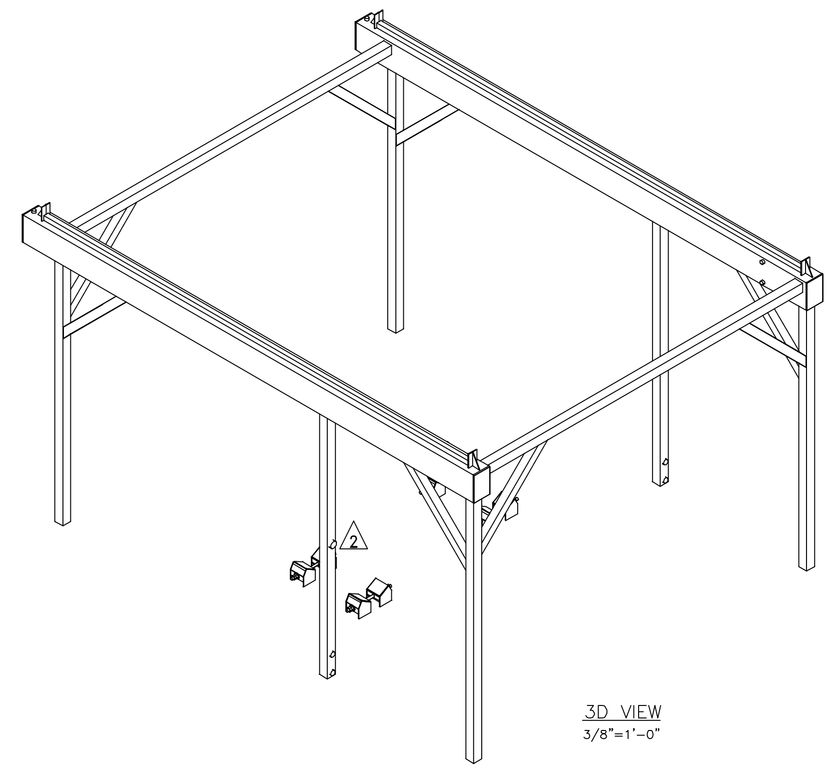


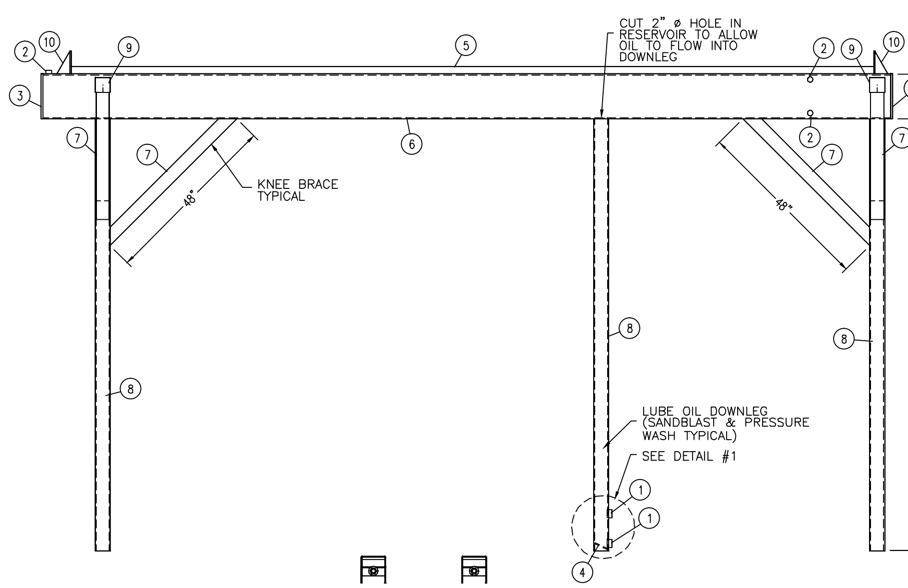
PLAN VIEW
1/2"=1'-0"



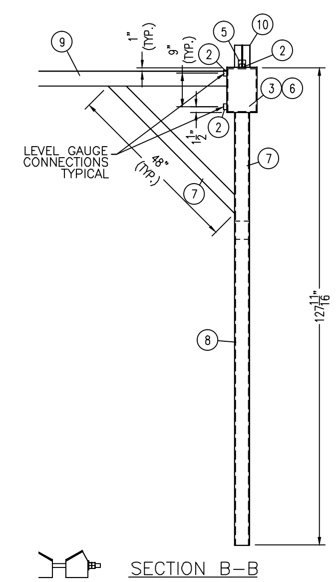
3D VIEW
3/8"=1'-0"

MK	QTY	DESCRIPTION	MAT.	LENGTH	PART_NUMBER
1	4	COUPLING,1",3000#,NPT,HALF	SA-105	–	123-HRA-0100
2	6	COUPLING,1/2",3000#,NPT,HALF	SA-105	–	123-HRA-0050
3	4	PLATE,1/2",SMOOTH X 1' X 8"	G40.2144W	12	040-HA-0050
4	2	PLATE,1/4",SMOOTH X 3 3/4" X 3 3/8"	G40.2144W	3 3/4	040-HA-0025
5	2	SQUARE BAR: 2	G40.2144W	215	014-HA-0200
6	2	TUBING,12"X8",1/4" THK	G40.21350W	227	020-HA-1200-0800-0025
7	8	TUBING,3-1/2"X3-1/2",1/4" THK	G40.21350W	48	020-HA-0350-0350-0025
8	6	TUBING,4"X4",1/4" THK	G40.21350W	115 11/16	020-HA-0400-0400-0025
9	2	TUBING,4"X4",1/4" THK	G40.21350W	160	020-HA-0400-0400-0025
10	4	WIDE FLANGE,4" X 13# (ONE CUTS TWO)	G40.2150W	6	034-HA-0400-0130
11	1	COUPLING,1 1/2",3000#,NPT,HALF	SA-105	7/8	123-HRA-0150

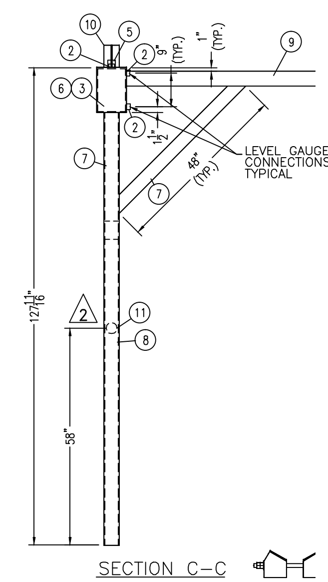
BILL OF MATERIAL



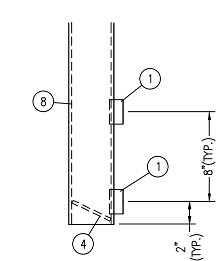
SECTION A–A
1/2"=1'-0"



SECTION B–B
1/2"=1'-0"



SECTION C–C
1/2"=1'-0"



DETAIL #1
1 1/2"=1'-0"

DESTROY PREVIOUS COPIES

ENG. STAMP

RELEASED FOR FABRICATION
NAME B. McLean DATE 09/01/10

NOTE:
1. ALL TAIL DIMENSIONS ARE TAKEN FROM REFERENCE POINT
2. ALL FABRICATION TO BE IN ACCORDANCE TO CSA W59-M.
3. ALL MATERIAL TO BE GRADE G40.21-M.
   - 300W FOR SECTIONS & PLATE
   - 350W FOR HSS SECTION
4. ALL BOLTS/CONNECTIONS – GRADE A325 UNC.

REV	DESCRIPTION	DATE	BY	APR
2	ADD LS CONNECTION	09/01/10	BM	BM
1	ISSUED FOR CONSTRUCTION	09/01/10	BM	BM

PERMIT TO PRACTISE: APEGGA PERMIT: No. P8651

DATE 09/01/10	SCALE AS SHOWN	
DRAWN BY B. McLean	CHECKED BY KG	APPROVED BY –
CUST PO N/A		
STEP CODE 415		

FOR HUSKY OIL OPERATIONS LTD.
WAUKESHA F18GL
ARIEL JGJ/2-1/2 STD

ENERFLEX
10121 – BARLOW TRAIL N.E.
CALGARY ALBERTA CANADA

TITLE: CRANE RAILS

DWG NO 31833-301 | SHT 3 | REV 2

K:\Enerflex Systems Ltd (EFX)\APD-10-825-EFL Husky 12517 & 31833\Data from the Client\31833-MODEL-2.dwg

PLOT DATE October 20, 2010

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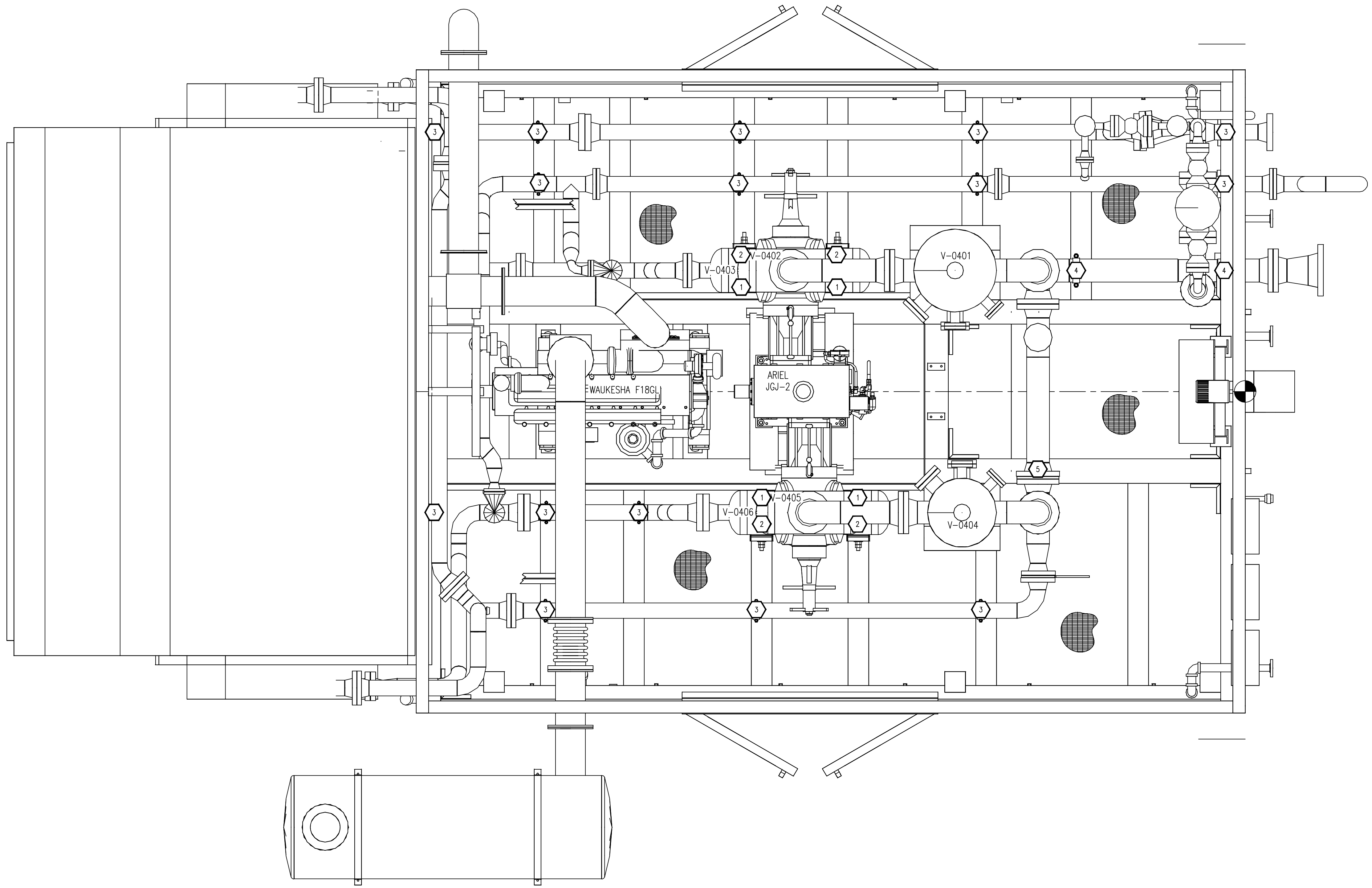
SCBW DETAIL LEGAND			
MARK	SERVICE	SIZE	QTY
1	BOTTLE CLAMPS	12 3/4"	4
2	LOW PRO BOTTLE WEDGES	STD	4
3	4"-PIPE CLAMPS	4"	15
4	6"-PIPE CLAMPS	6"	2
5	6"-FLANGE GRABBER	-	1



PLAN VIEW

FOR APPROVAL

PLEASE SUBMIT ONE SET OF APPROVED DRAWINGS BY ________

NAME *T. Tocher* DATE 08/04/10

PERMIT TO PRACTISE APEGGA PERMIT: No. P8651

REV	DESCRIPTION	DATE	BY	APR
1	ISSUED FOR CONSTRUCTION	08/04/10	TT	K.G.

DATE 06/07/10 SCALE 3/4"=1'-0"

DRAWN BY *B. McLean* CHECKED BY *K. Green* APPROVED BY *D. Campbell*

CUST PO N/A

STEP CODE 198 298 490 511 591

FOR HUSKY OIL OPERATIONS LTD.
WAUKESHA F18GL
ARIEL JGJ/2-1/2 STD

ENERFLEX
10121 - BARLOW TRAIL N.E.
CALGARY ALBERTA CANADA

TITLE PLAN VIEW

DWG NO 31833-301 SHT 4 REV 1

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PLOT DATE October 20, 2010

K:\Enerflex Systems Ltd (EFX)\APD-10-825-EFL Husky 12517 & 31833\Data from the Client\31833-MODEL-2.dwg

air-x-limited

2230 East 49th Street Tulsa, Oklahoma 74105
PHONE: (918) 743-6111 FAX: (918) 742-7039
E-mail: jmcurley@airxlimited.com

Purchaser:	*ENERFLEX (CGY)*	*From:*	*John Curley*
To:	*Abi Fatokun*	*Date:*	*May 11, 2010*
Inquiry #:	*Q190393*	*End User:*	*HUSKY*
Proposal #:	*105370*	*Destination:*	
No. Pages:	*2*	*Reference:*	*F18GL - JGJ/2 (formerly 95466)*

PROPOSAL

In response to subject inquiry, we propose the following design in accordance with specification sheet **105370**

Dated: **5/11/2010**

Comments:

(1) Model 96AEF
Mounted enclosed slide idler
Extended lube lines
(2) Sets manual discharge shutters over water - tied together
(2) Sets automatic discharge shutters over gas with Garzo (or equal) / Kimray controls
Water Services – 15% excess over std duties
SA214 Tubing
1" NPT vent
Gas Services - 5% excess
350°F / -49°F MDMT
SA214 Tubing
1/16" Corrosion Allowance
1" Coupling opposite each discharge nozzle
Spot X-Ray
PWHT
AXH standard paint system tinted to grey
Discharge guard
Soft removable bugscreens
CRN Registration: AB, BC, SASK
Customer specifications with clarifications and exceptions attached

Fan(s): *(1) MOORE-10K S30VT* *Tip speed (fpm): 10,505*
Dia, In / # Blades: 96 / 6 *Est. Noise Data: 85 dBA @1m, 64 dBA @ 15m*

Net price* (USD) *Shipment: FOB Calgary AB* ***$47,435***

**The quoted price is firm for 30 days based on shipment in accordance with our current production schedule.*

Shipment is: 8 weeks ARO and released for fabrication. Please confirm availability at time of order.

AXH air-coolers
air-x-limited

401 E. Lowry Road, Claremore, OK 74017
Phone (918) 283-9200 Fax (918) 283-9229
info@axh.com www.axh.com

Proposal / Job No.	105370
Date	5/11/2010
Page	1 OF 1

#						
1	*Purchaser*	ENERFLEX (CGY)			*Ultimate User*	HUSKY
2	*Inquiry / PO#*	Q190393			*Destination*	
3	*# Units*	1	*Model*	96AEF	*Reference*	F18GL - JGJ/2 (formerly 95466)
4	*Assembly*	PACKAGED	*Draft*	FORCED	*Overall Size (WxL), Ft*	*Est Wt* 11500 LBS

THERMAL & MECHANICAL DESIGN

#					
5	**Service**	EJW	AUX-W	IC	AC
6	*Flow*	124GPM	35GPM	5.03MMSCFD	5.03MMSCFD
7	*Fluid*	50%GLY	50%GLY	AIR	AIR
8	*Temp. In / Out, °F*	180.0 / 165.0	156.8 / 130.0	235.0 / 115.7	249.0 / 122.0
9	*Pressure, PSI*			322PSIG	518PSIG
10	*Pressure Drop, PSI*	2.1	5.0	4.0	4.0
11	*Heat Load, BTU/HR*	864800	425735	475155	512019
12	*True LMTD*	48.5	28.8	39.5	47.6
13	*Overall Rate, U*	161.7	152.1	57.6	65.0
14	*Fouling Factor*	.0005	.0005	.0020	.0020
15	*Surface, Tube / Total, Sq Ft*	112 / 1789	99 / 1574	209 / 4468	166 / 3544
16	**Sections, #**	(1) - COMBINED	(1) - COMBINED	(1)	(1)
17	*Design Temp, °F Max / Min*	300 / -20	300 / -20	350 / -49	350 / -49
18	*MWP / Test Press, PSIG*	* 14 / 75	* 14 / 75	645 / 839	1287 / 1674
19	*Pass Arrangement*	CROSSFLOW	CROSSFLOW	CROSSFLOW	CROSSFLOW
20	*# Tube Rows*	3	3	4	4
21	*# Tube Passes*	1	3	3	3
22	**Tubes, OD x BWG**	5/8X16	5/8X16	1X16	1X16
23	*Material*	SA214 STEEL	SA214 STEEL	SA214 STEEL	SA214 STEEL
24	*# Per Section / Length, Ft*	50 / 14	44 / 14	58 / 14	46 / 14
25	*Turbulators*				
26	*Accelerators*				
27	**Fins, Type**	HI-EFF	HI-EFF	HI-EFF	HI-EFF
28	*Material*	AL	AL	AL	AL
29	**Nozzles, Rating / Type**	150RF	150RF	300RF	600RF
30	*Material*	SA105	SA105	SA350LF2	SA350LF2
31	*#-Inlets / Size In*	(1) 3	(1) 2	(1) 4	(1) 3
32	*#-Oulets / Size In*	(1) 3	(1) 2	(1) 4	(1) 3
33	**Headers, Type**	REC TUBE	REC TUBE	BOX	BOX
34	*Material*	A500	A500	SA516-70N	SA516-70N
35	*Corrosion Allow, In*			.0625	.0625
36	*Grooved Tubesheet*	SGL	SGL	DBL	DBL
37	*Plugs, Type*	TAPER	TAPER	SHOULDER	SHOULDER
38	*Plugs Material*	STEEL	STEEL	SA350LF2	SA350LF2
39	*PWHT*			YES	YES
40	*ASME Code & Nat'l Board*			YES	YES
41	*CRN*			AB, BC, SK	AB, BC, SK
42	**Add'l Specs & Options**				
43	*API*				
44	*Louvers / Hail Screen*	MAN /	MAN /	MAN /	MAN /
45	**Inspection / NDT**			SX	SX

FX= *100% X-Ray of all header seam, attachment & nozzle butt welds.* ***SX=*** *Spot X-Ray of 1 long seam & 1 end closure, per header*
BX= *100% X-Ray of all nozzle butt welds.* ***UT =*** *100% UT of all header seam, attachment & nozzle butt welds.* ***H*** *= Hardness testing.*

#	AIR-SIDE PERFORMANCE		FAN DATA		DRIVER DATA	STRUCTURAL	
46	*Ambient Air Temp, In °F*	104	*Fan(s)*	(1) MOORE-10K S30VT	*Type*	*Guards*	FAN
47	*Elevation, Ft*	1900	*Blade Material*	ALUMINUM	V-BELT BY OTHERS		DISCHARGE GUARD
48	*Air Flow, SCFM*	82,740	*HP / Fan*	21.3			SOFT BUG SCREENS
49	*Outlet Air Temp, °F*	128.9	*Dia, In / # Blades*	96 / 6			
50	*Min Air Temp, °F*	-20	*RPM*	418			
51			*Tipspeed, FPM*	10505			
52	**Est. Noise Data:**	85 dBA @1m, 64 dBA @ 15m	*Pitch, Deg*	19			

#		
53	**Additional Info.**	*-BUILT TO STANDARD 150# DESIGN BUT DESIGNATED 14# TO AVOID THE NEED FOR PROVINCIAL REGISTRATION
54		
55		
56		
57		
58		

PLOT DATE July 07, 2010 P:\30000 Projects\31833 Husky R400 F18GL JGJ2\Drafting\P&ID\31833-111-0.dwg

V-0401 1ST STAGE SUCTION SCRUBBER

MFG: EFX
SIZE: 24" OD X 66" S/S
MAWP: 4516.1 kPag @ 149°C
MDMT: -29°C @ 4516.1 kPag
CA: 1/16"
MAT'L: SA-106-B
ELEMENTS: MESH PAD

V-0402 1ST STAGE SUCTION BOTTLE

MFG: EFX
SIZE: 12 3/4" OD X 20" S/S
MAWP: 4516.1 kPag @ 149°C
MDMT: -29°C @ 4516.1 kPag
CA: 1/16"
MAT'L: SA-106-B

V-0403 1ST STAGE DISCHARGE BOTTLE

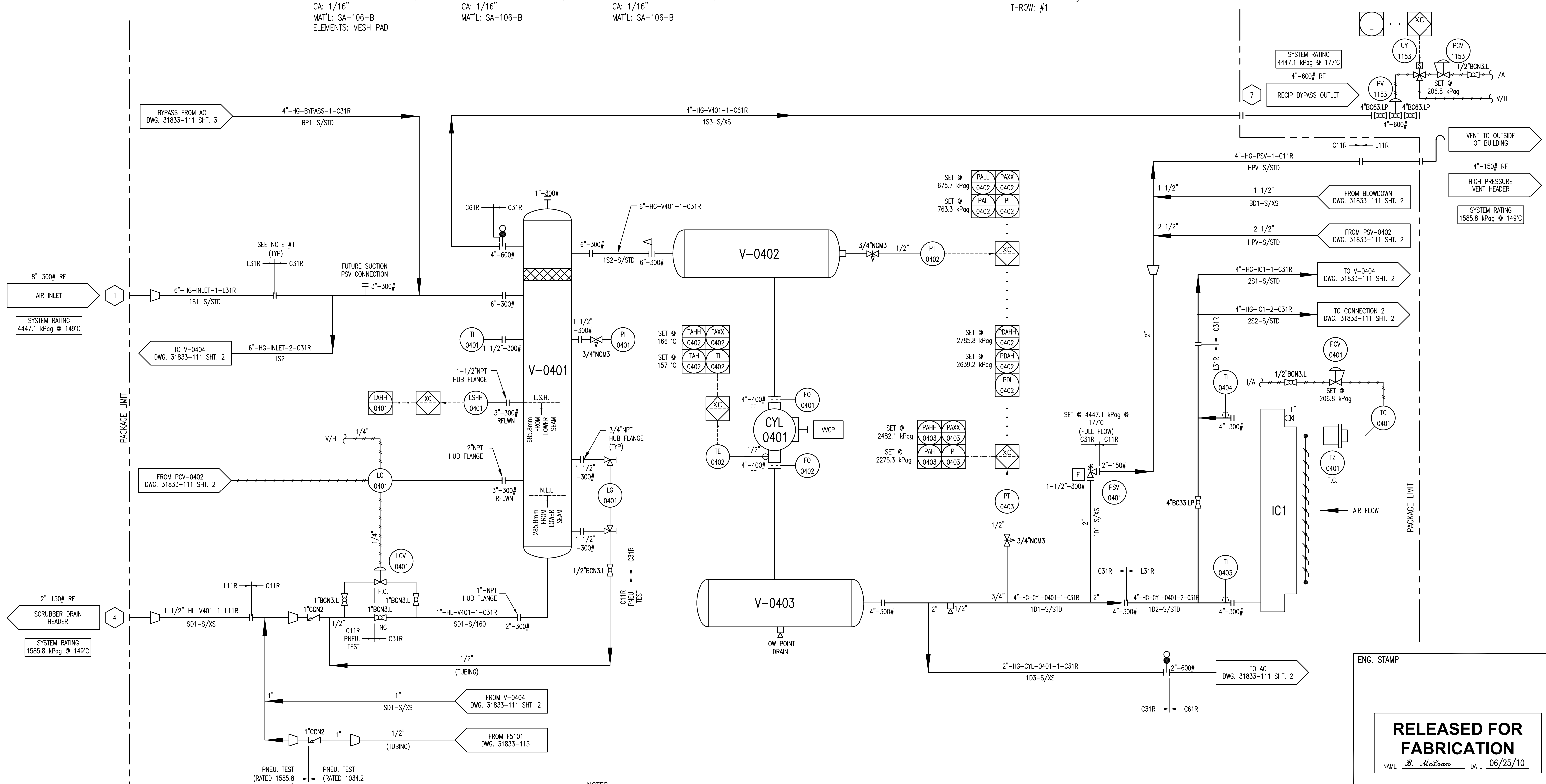
MFG: EFX
SIZE: 12 3/4" OD X 36" S/S
MAWP: 4447.1 kPag @ 177°C
MDMT: -29°C @ 4447.1 kPag
CA: 1/16"
MAT'L: SA-106-B

CYL-0401 1ST STAGE COMPRESSION CYLINDER

MFG: ARIEL
MODEL: 7 3/8 RJ
SIZE: 7.375" BORE
MAWP: 5826.1 kPag
THROW: #1

IC1 1ST STAGE COOLER SECTION

MAWP: 4447.1 kPag @ 177°C
MDMT: -45°C @ 4447.1 kPag
CA: 1/16"



NOTES:
1. ALL SKID EDGE AND OFF SKID PIPING TO BE LOW TEMP. PIPE AND FITTINGS UP TO FIRST FLANGE BREAK INSIDE BUILDING.

REV	DESCRIPTION	DATE	BY	APR
1	ISSUED FOR FABRICATION	06/25/10	BM	DC
A	ISSUED FOR APPROVAL	06/04/10	CE	DC

DATE	06/04/10
SCALE	NTS
DRAWN BY	C. EASTHOPE
CHECKED BY	K. GREEN
APPROVED BY	B. CAMPBELL
CUST PO	N/A
STEP CODE	198 490 511 591
PERMIT TO PRACTISE	APEGGA PERMIT: No. P8651
FOR	HUSKY OIL OPERATIONS LTD. WAUKESHA F18GL ARIEL JGJ/2-1/2 STD
ENERFLEX	10121 - BARLOW TRAIL N.E. CALGARY ALBERTA CANADA
TITLE	P & I DIAGRAM PROCESS GAS STAGE #1
DWG NO	31833-111
SHT	1
REV	1

ENG. STAMP

RELEASED FOR FABRICATION
NAME B. McLean DATE 06/25/10

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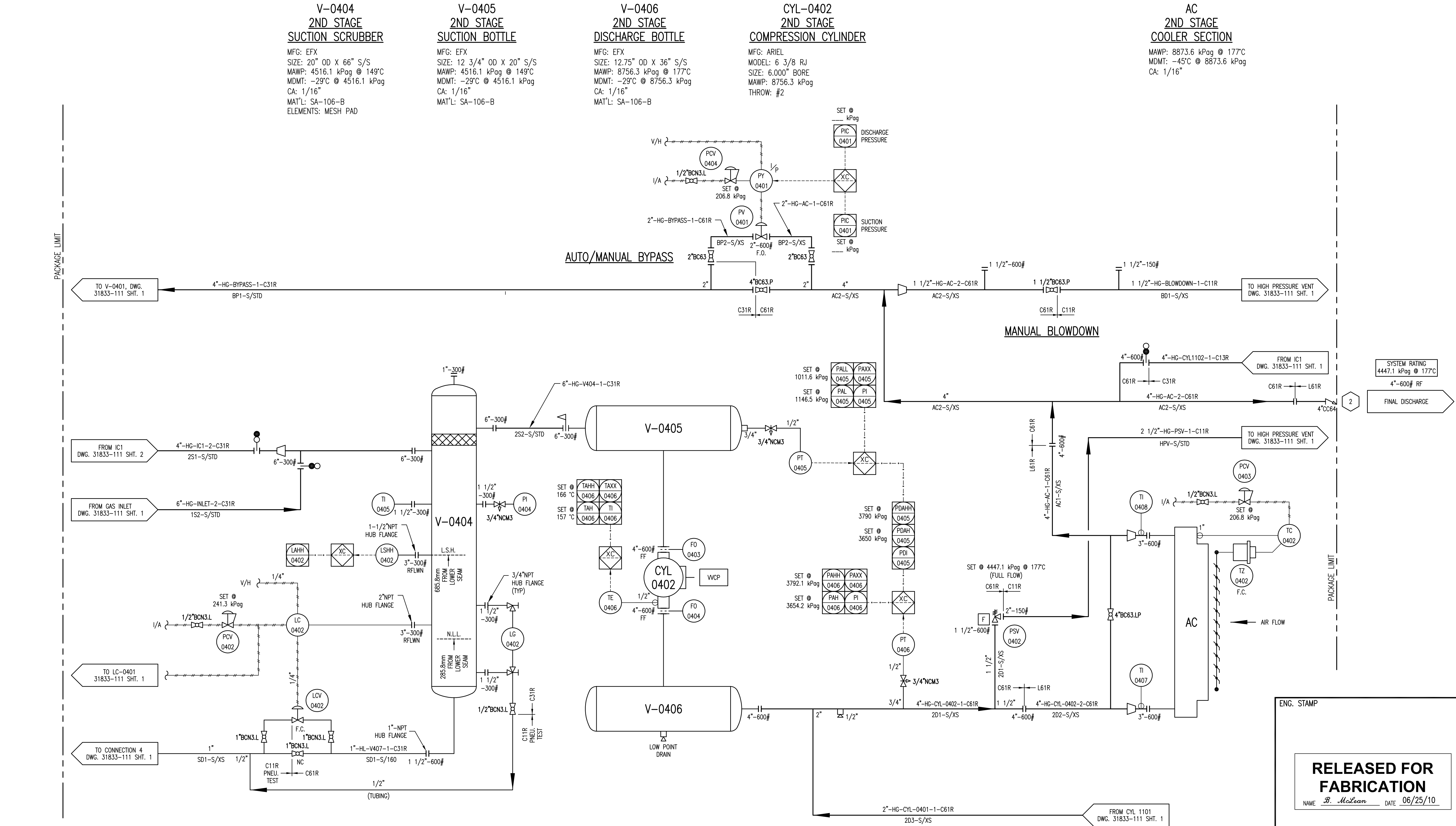

ENG. STAMP

RELEASED FOR FABRICATION
NAME B. McLean DATE 06/25/10

PERMIT TO PRACTISE APEGGA PERMIT: No. P8651

REV	DESCRIPTION	DATE	BY	APR
1	ISSUED FOR FABRICATION	06/25/10	BM	DC
A	ISSUED FOR APPROVAL	06/04/10	CE	DC

DATE 06/04/10		SCALE NTS
DRAWN BY C. EASTHOPE	CHECKED BY K. GREEN	APPROVED BY D. CAMPBELL
CUST PO N/A		
STEP CODE 198 490 511 591		

FOR HUSKY OIL OPERATIONS LTD. WAUKESHA F18GL ARIEL JGJ/2-1/2 STD

ENERFLEX
10121 - BARLOW TRAIL N.E.
CALGARY ALBERTA CANADA

TITLE P & I DIAGRAM PROCESS GAS STAGE #2

DWG NO 31833-111 SHT 2 REV 1

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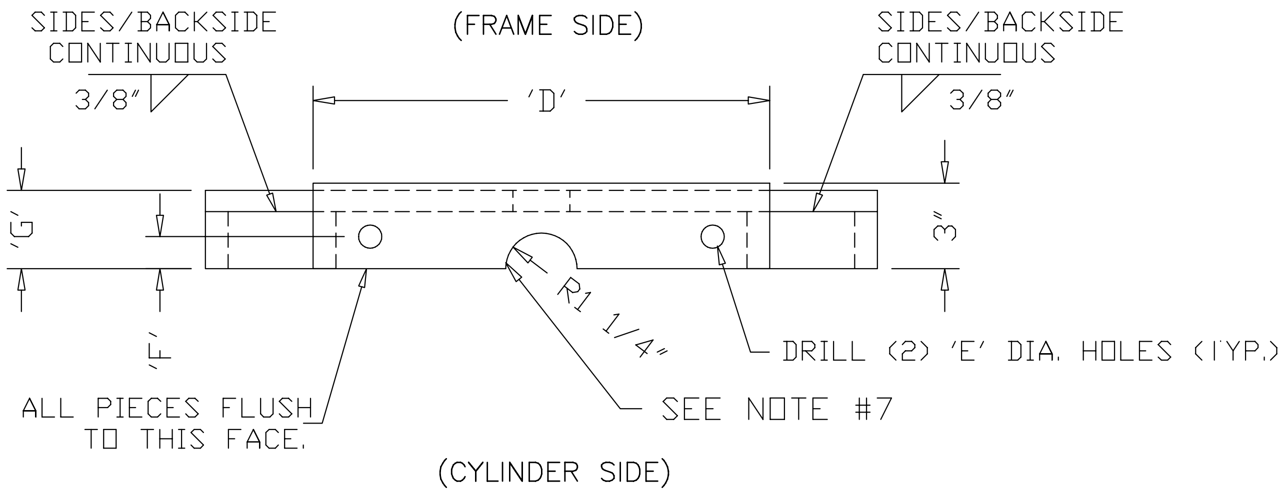
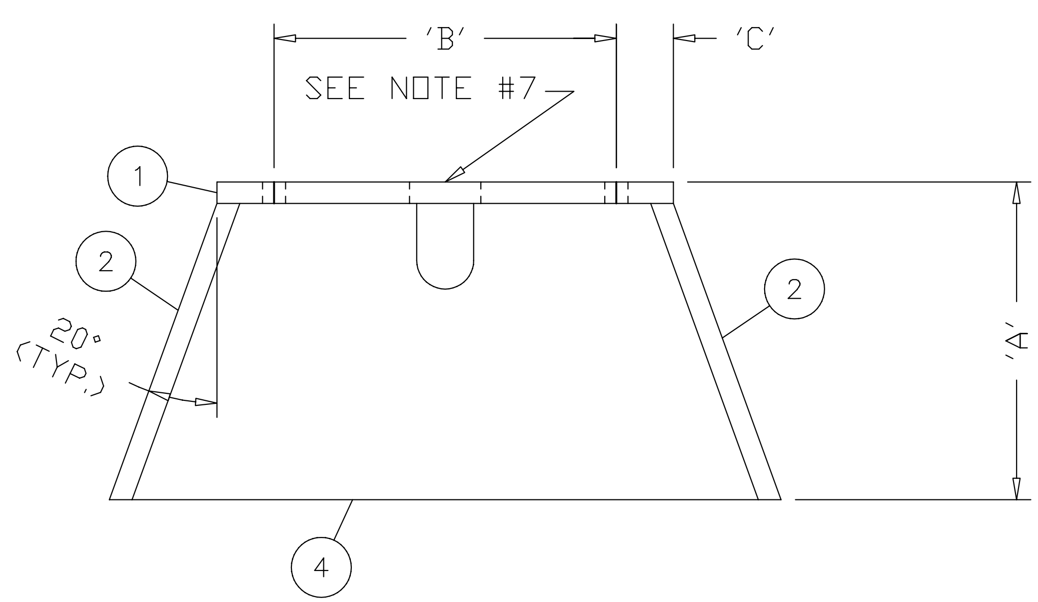
BILL OF MATERIALS

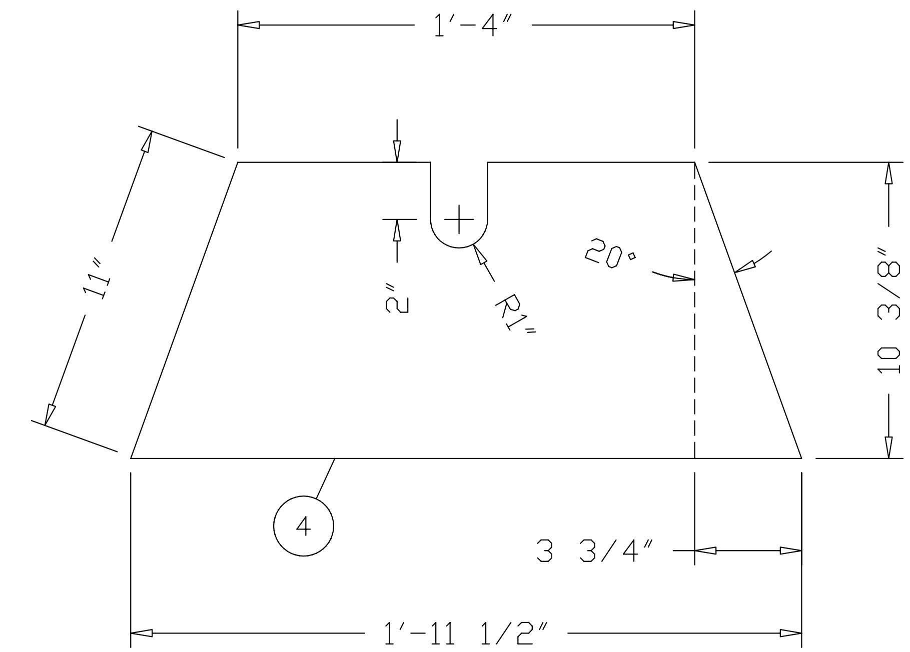
MODEL	ITEM	PART#	DESCRIPTION	MATERIAL	QT'Y
JGJ	1	010-HA-0300-0075	BAR, FLAT, 3/4" x 3.0" x 16"LG.	SA-36	1
	2	010-HA-0200-0075	BAR, FLAT, 3/4" x 2.0" x 11"LG.	SA-36	2
	3	-	-	-	-
	4	040-HA-0075	PLATE, 3/4" (SEE DETAIL - A)	SA-36	1



PLAN



ELEVATION



DETAIL - A

	DIMENSION CHART (ALL DIMENSIONS SHOWN ARE IN INCHES)						
MODEL	A	B	C	D	E	F	G
JGJ	11.125"	12.0"	2.0"	16.0"	0.8125"	1.125"	2.75"

PROPRIETARY MATERIAL: NOT TO BE REPRODUCED OR DISTRIBUTED WITHOUT THE PRIOR WRITTEN CONSENT OF TOROMONT ENERGY SYSTEMS INC.

TOROMONT
TOROMONT ENERGY SYSTEMS
10121 - BARLOW TRAIL N.E. CALGARY ALBERTA CANADA

NOTES:

1. DIMENSION TOLERANCE ± 0.125"
2. ALL ASSEMBLIES TO BE TRIMMED TO FIT EACH INSTALL.
3. USE GOOD WELDING PRACTICES - "JETROD" NOT ACCEPTABLE.
4. LABEL EACH SUPPORT ACCORDINGLY.
5. DIMENSIONS ALLOW FOR 1/4" SHIM.
6. CUT TO FIT VARIOUS DRIVER CONFIGURATIONS.
7. RADIUS CORNERS TO 1/8" TO REDUCE STRESS CONCENTRATIONS.

No.	REVISION	DATE	BY
2	MODIFIED DIMENSIONS "B" "C" "D"	11/14/07	GG
1	ISSUED FOR CONSTRUCTION	10/24/06	GP
0	ISSUED FOR CONSTRUCTION	05/11/04	CD

TITLE: CROSSHEAD SUPPORT STRUCTURE
FOR ARIEL JGJ, STD, S2C & L2C CROSSHEAD GUIDE
(FOR FRAMES WITH MAX 19 1/4" CENTERLINE TO TOS)

SCALE: NTS	DATE: 05/11/04	BY: CD	DATE RELEASED:	RELEASED BY:
STEP #: 412	UNIT #: -	DRAWING NO.: JGJ-ALL CYLINDER SUPPORT		REV.2

Ariel Performance

7.6.4.0	Company:	Toromont Energy Systems	Customer:	Husky Oil Operations Ltd
	Quote:	Q190393B	Inquiry:	
	Case 1:	Max	Project:	31833 & 31834

Compressor Data:						**Driver Data:**	
Elevation,m:	575.00	Barmtr,bara:	0.945	Ambient,°C:	40.00	Type:	Nat. Gas
Frame:	JGJ/2	Stroke, mm:	88.90	Rod Dia, mm:	38.100	Mfg:	Waukesha
Max RL Tot, kN:	187	Max RL Tens, kN:	94	Max RL Comp, kN:	103	Model:	F18GL
Rated RPM:	1800	Rated kW:	462.3	Rated PS m/s:	5.3	kW:	298 (294)
Calc RPM:	1800.0	kW:	156	Calc PS m/s:	5.3	Avail:	279 (15)

Services	**1**	
Stage Data:	**1**	---
Flow Req'd, Nm3/h	0.000	---
Flow Calc, Nm3/h	5672.961	---
Cyl kW per Stage	151.5	---
Specific Gravity	0.9953	---
Ratio of Sp Ht (N)	1.3988	---
Comp Suct (Zs)	0.9947	---
Comp Disch (Zd)	0.9971	---
Pres Suct Line, barg	10.00	---
Pres Suct Flg, barg	9.66	---
Pres Disch Flg, barg	16.35	---
Pres Disch Line, barg	16.00	---
Pres Ratio F/F	1.631	---
Temp Suct, °C	48.89	---
Temp Clr Disch, °C	48.89	---
Cylinder Data:	**Throw 1**	**Throw 2**
Cyl Model	7-3/8RJ	6-3/8RJ
Cyl Bore, mm	187.325	152.400
Cyl RDP (API), barg	53.0	79.6
Cyl MAWP, barg	58.3	87.6
Cyl Action	DBL	DBL
Cyl Disp, m3/h	518.3	339.3
Pres Suct Intl, barg	8.54	8.69
Temp Suct Intl, °C	51	51
Suct Zsph	0.9950	0.9949
Pres Disch Intl, barg	18.12	18.06
Temp Disch Intl, °C	123	120
HE Suct Gas Vel, m/s	46	43
HE Disch Gas Vel, m/s	42	41
HE Spcrs Used/Max	0/2	0/0
HE Vol Pkt Avail, %	1.11+51.64	1.29+64.48
Vol Pkt Used, %	100.00 (V)	100.00 (V)
HE Min Clr, %	18.28	18.00
HE Total Clr, %	71.03	83.77
CE Suct Gas Vel, m/s	44	40
CE Disch Gas Vel, m/s	40	39
CE Spcrs Used/Max	0/2	0/0
CE Min Clr, %	19.21	19.41
CE Total Clr, %	19.21	19.41
Suct Vol Eff HE/CE, %	65.5/86.6	60.3/86.5
Disch Event HE/CE, ms	7.5/9.9	7.1/9.9
Suct Pseudo-Q HE/CE	11.4/10.5	9.5/8.3
Gas Rod Ld Comp, %	26.8 C	17.8 C
Gas Rod Ld Tens, %	26.0 T	16.0 T
Gas Rod Ld Total, %	27.7	17.7
Xhd Pin Deg/%Rvrsl kN	166/89.4	165/77.3
Flow Calc, Nm3/h	3478.571	2194.390
Cyl kW	94.0	57.5

Compressor Data: | **Driver Data:**

Elevation,m:	575.00	Barmtr,bara:	0.945	Ambient,°C:	40.00	Type:	Nat. Gas
Frame:	JGJ/2	Stroke, mm:	88.90	Rod Dia, mm:	38.100	Mfg:	Waukesha
Max RL Tot, kN:	187	Max RL Tens, kN:	94	Max RL Comp, kN:	103	Model:	F18GL
Rated RPM:	1800	Rated kW:	462.3	Rated PS m/s:	5.3	kW:	298 (294)
Calc RPM:	1800.0	kW:	144	Calc PS m/s:	5.3	Avail:	279 (15)

Services	**1**	
Stage Data:	**1**	---
Flow Req'd, Nm3/h	0.000	---
Flow Calc, Nm3/h	3900.374	---
Cyl kW per Stage	139.2	---
Specific Gravity	0.9944	---
Ratio of Sp Ht (N)	1.3973	---
Comp Suct (Zs)	0.9956	---
Comp Disch (Zd)	0.9986	---
Pres Suct Line, barg	8.00	---
Pres Suct Flg, barg	7.66	---
Pres Disch Flg, barg	16.35	---
Pres Disch Line, barg	16.00	---
Pres Ratio F/F	2.010	---
Temp Suct, °C	48.89	---
Temp Clr Disch, °C	48.89	---
Cylinder Data:	**Throw 1**	**Throw 2**
Cyl Model	7-3/8RJ	6-3/8RJ
Cyl Bore, mm	187.325	152.400
Cyl RDP (API), barg	53.0	79.6
Cyl MAWP, barg	58.3	87.6
Cyl Action	DBL	DBL
Cyl Disp, m3/h	518.3	339.3
Pres Suct Intl, barg	6.75	6.87
Temp Suct Intl, °C	52	52
Suct Zsph	0.9958	0.9958
Pres Disch Intl, barg	18.01	17.96
Temp Disch Intl, °C	147	144
HE Suct Gas Vel, m/s	46	43
HE Disch Gas Vel, m/s	42	41
HE Spcrs Used/Max	0/2	0/0
HE Vol Pkt Avail, %	1.11+51.64	1.29+64.48
Vol Pkt Used, %	100.00 (V)	100.00 (V)
HE Min Clr, %	18.28	18.00
HE Total Clr, %	71.03	83.77
CE Suct Gas Vel, m/s	44	40
CE Disch Gas Vel, m/s	40	39
CE Spcrs Used/Max	0/2	0/0
CE Min Clr, %	19.21	19.41
CE Total Clr, %	19.21	19.41
Suct Vol Eff HE/CE, %	49.3/82.0	41.3/81.8
Disch Event HE/CE, ms	5.7/8.8	5.2/8.7
Suct Pseudo-Q HE/CE	11.3/10.4	9.1/8.3
Gas Rod Ld Comp, %	31.2 C	20.6 C
Gas Rod Ld Tens, %	30.9 T	19.4 T
Gas Rod Ld Total, %	32.5	21.0
Xhd Pin Deg/%Rvrsl kN	171/89.7	168/76.8
Flow Calc, Nm3/h	2420.508	1479.865
Cyl kW	87.2	52.0

Compressor Data:						**Driver Data:**	
Elevation,m:	575.00	Barmtr,bara:	0.945	Ambient,°C:	40.00	Type:	Nat. Gas
Frame:	JGJ/2	Stroke, mm:	88.90	Rod Dia, mm:	38.100	Mfg:	Waukesha
Max RL Tot, kN:	187	Max RL Tens, kN:	94	Max RL Comp, kN:	103	Model:	F18GL
Rated RPM:	1800	Rated kW:	462.3	Rated PS m/s:	5.3	kW:	298 (294)
Calc RPM:	1800.0	kW:	186	Calc PS m/s:	5.3	Avail:	279 (15)

Services	**1**	
Stage Data:	**1**	---
Flow Req'd, Nm3/h	0.000	---
Flow Calc, Nm3/h	5685.970	---
Cyl kW per Stage	181.2	---
Specific Gravity	0.9956	---
Ratio of Sp Ht (N)	1.3989	---
Comp Suct (Zs)	0.9943	---
Comp Disch (Zd)	0.9978	---
Pres Suct Line, barg	11.00	---
Pres Suct Flg, barg	10.66	---
Pres Disch Flg, barg	20.42	---
Pres Disch Line, barg	20.00	---
Pres Ratio F/F	1.842	---
Temp Suct, °C	48.89	---
Temp Clr Disch, °C	48.89	---
Cylinder Data:	**Throw 1**	**Throw 2**
Cyl Model	7-3/8RJ	6-3/8RJ
Cyl Bore, mm	187.325	152.400
Cyl RDP (API), barg	53.0	79.6
Cyl MAWP, barg	58.3	87.6
Cyl Action	DBL	DBL
Cyl Disp, m3/h	518.3	339.3
Pres Suct Intl, barg	9.43	9.59
Temp Suct Intl, °C	52	52
Suct Zsph	0.9946	0.9946
Pres Disch Intl, barg	22.54	22.47
Temp Disch Intl, °C	137	134
HE Suct Gas Vel, m/s	46	43
HE Disch Gas Vel, m/s	42	41
HE Spcrs Used/Max	0/2	0/0
HE Vol Pkt Avail, %	1.11+51.64	1.29+64.48
Vol Pkt Used, %	100.00 (V)	100.00 (V)
HE Min Clr, %	18.28	18.00
HE Total Clr, %	71.03	83.77
CE Suct Gas Vel, m/s	44	40
CE Disch Gas Vel, m/s	40	39
CE Spcrs Used/Max	0/2	0/0
CE Min Clr, %	19.21	19.41
CE Total Clr, %	19.21	19.41
Suct Vol Eff HE/CE, %	56.5/84.0	49.7/83.9
Disch Event HE/CE, ms	6.5/9.3	6.0/9.3
Suct Pseudo-Q HE/CE	11.4/10.5	9.4/8.3
Gas Rod Ld Comp, %	36.4 C	24.1 C
Gas Rod Ld Tens, %	35.8 T	22.3 T
Gas Rod Ld Total, %	37.9	24.4
Xhd Pin Deg/%Rvrsl kN	168/96.0	167/82.7
Flow Calc, Nm3/h	3508.167	2177.803
Cyl kW	113.0	68.2

Compressor Data:						**Driver Data:**	
Elevation,m:	575.00	Barmtr,bara:	0.945	Ambient,°C:	40.00	Type:	Nat. Gas
Frame:	JGJ/2	Stroke, mm:	88.90	Rod Dia, mm:	38.100	Mfg:	Waukesha
Max RL Tot, kN:	187	Max RL Tens, kN:	94	Max RL Comp, kN:	103	Model:	F18GL
Rated RPM:	1800	Rated kW:	462.3	Rated PS m/s:	5.3	kW:	298 (294)
Calc RPM:	1800.0	kW:	170	Calc PS m/s:	5.3	Avail:	279 (15)

Disch Temp

Services	**1**	
Stage Data:	**1**	---
Flow Req'd, Nm3/h	0.000	---
Flow Calc, Nm3/h	4371.736	---
Cyl kW per Stage	166.0	---
Specific Gravity	0.9951	---
Ratio of Sp Ht (N)	1.3978	---
Comp Suct (Zs)	0.9949	---
Comp Disch (Zd)	0.9990	---
Pres Suct Line, barg	9.50	---
Pres Suct Flg, barg	9.16	---
Pres Disch Flg, barg	20.42	---
Pres Disch Line, barg	20.00	---
Pres Ratio F/F	2.115	---
Temp Suct, °C	48.89	---
Temp Clr Disch, °C	48.89	---
Cylinder Data:	**Throw 1**	**Throw 2**
Cyl Model	7-3/8RJ	6-3/8RJ
Cyl Bore, mm	187.325	152.400
Cyl RDP (API), barg	53.0	79.6
Cyl MAWP, barg	58.3	87.6
Cyl Action	DBL	DBL
Cyl Disp, m3/h	518.3	339.3
Pres Suct Intl, barg	8.10	8.23
Temp Suct Intl, °C	53	52
Suct Zsph	0.9952	0.9952
Pres Disch Intl, barg	22.45	22.38
Temp Disch Intl, °C	*153*	*151*
HE Suct Gas Vel, m/s	46	43
HE Disch Gas Vel, m/s	42	41
HE Spcrs Used/Max	0/2	0/0
HE Vol Pkt Avail, %	1.11+51.64	1.29+64.48
Vol Pkt Used, %	100.00 (V)	100.00 (V)
HE Min Clr, %	18.28	18.00
HE Total Clr, %	71.03	83.77
CE Suct Gas Vel, m/s	44	40
CE Disch Gas Vel, m/s	40	39
CE Spcrs Used/Max	0/2	0/0
CE Min Clr, %	19.21	19.41
CE Total Clr, %	19.21	19.41
Suct Vol Eff HE/CE, %	45.1/80.8	36.3/80.6
Disch Event HE/CE, ms	5.4/8.5	4.7/8.5
Suct Pseudo-Q HE/CE	11.2/10.4	8.8/8.3
Gas Rod Ld Comp, %	39.7 C	26.3 C
Gas Rod Ld Tens, %	39.5 T	24.8 T
Gas Rod Ld Total, %	41.5	26.8
Xhd Pin Deg/%Rvrsl kN	172/95.3	170/82.2
Flow Calc, Nm3/h	2723.324	1648.413
Cyl kW	104.4	61.6

Compressor Data:						**Driver Data:**	
Elevation,m:	575.00	Barmtr,bara:	0.945	Ambient,°C:	40.00	Type:	Nat. Gas
Frame:	JGJ/2	Stroke, mm:	88.90	Rod Dia, mm:	38.100	Mfg:	Waukesha
Max RL Tot, kN:	187	Max RL Tens, kN:	94	Max RL Comp, kN:	103	Model:	F18GL
Rated RPM:	1800	Rated kW:	462.3	Rated PS m/s:	5.3	kW:	298 (294)
Calc RPM:	1800.0	kW:	179	Calc PS m/s:	5.3	Avail:	279 (15)

Services	**1**	
Stage Data:	**1**	**2**
Flow Req'd, Nm3/h	0.000	0.000
Flow Calc, Nm3/h	4440.256	4426.965
Cyl kW per Stage	104.1	70.3
Specific Gravity	0.9956	0.9967
Ratio of Sp Ht (N)	1.3995	1.4020
Comp Suct (Zs)	0.9943	0.9922
Comp Disch (Zd)	0.9963	0.9938
Pres Suct Line, barg	11.00	N/A
Pres Suct Flg, barg	10.66	16.04
Pres Disch Flg, barg	16.38	20.42
Pres Disch Line, barg	N/A	20.00
Pres Ratio F/F	1.494	1.258
Temp Suct, °C	48.89	48.89
Temp Clr Disch, °C	48.89	48.89
Cylinder Data:	**Throw 1**	**Throw 2**
Cyl Model	7-3/8RJ	6-3/8RJ
Cyl Bore, mm	187.325	152.400
Cyl RDP (API), barg	53.0	79.6
Cyl MAWP, barg	58.3	87.6
Cyl Action	DBL	DBL
Cyl Disp, m3/h	518.3	339.3
Pres Suct Intl, barg	9.43	14.47
Temp Suct Intl, °C	51	50
Suct Zsph	0.9945	0.9924
Pres Disch Intl, barg	18.21	22.71
Temp Disch Intl, °C	113	93
HE Suct Gas Vel, m/s	46	43
HE Disch Gas Vel, m/s	42	41
HE Spcrs Used/Max	0/2	0/0
HE Vol Pkt Avail, %	1.11+51.64	1.29+64.48
Vol Pkt Used, %	0.00 (V)	0.00 (V)
HE Min Clr, %	18.28	18.00
HE Total Clr, %	19.38	19.29
CE Suct Gas Vel, m/s	44	40
CE Disch Gas Vel, m/s	40	39
CE Spcrs Used/Max	0/2	0/0
CE Min Clr, %	19.21	19.41
CE Total Clr, %	19.21	19.41
Suct Vol Eff HE/CE, %	88.3/88.4	91.5/91.5
Disch Event HE/CE, ms	9.6/10.6	11.0/11.8
Suct Pseudo-Q HE/CE	11.4/10.5	9.5/8.4
Gas Rod Ld Comp, %	24.8 C	16.4 C
Gas Rod Ld Tens, %	23.6 T	13.3 T
Gas Rod Ld Total, %	25.4	15.6
Xhd Pin Deg/%Rvrsl kN	165/90.6	161/82.3
Flow Calc, Nm3/h	4440.256	4426.965
Cyl kW	104.1	70.3

Compressor Data:						**Driver Data:**	
Elevation,m:	575.00	Barmtr,bara:	0.945	Ambient,°C:	40.00	Type:	Nat. Gas
Frame:	JGJ/2	Stroke, mm:	88.90	Rod Dia, mm:	38.100	Mfg:	Waukesha
Max RL Tot, kN:	187	Max RL Tens, kN:	94	Max RL Comp, kN:	103	Model:	F18GL
Rated RPM:	1800	Rated kW:	462.3	Rated PS m/s:	5.3	kW:	298 (294)
Calc RPM:	1800.0	kW:	175	Calc PS m/s:	5.3	Avail:	279 (15)

Services	**1**	
Stage Data:	**1**	**2**
Flow Req'd, Nm3/h	0.000	0.000
Flow Calc, Nm3/h	3645.451	3631.626
Cyl kW per Stage	90.0	81.0
Specific Gravity	0.9949	0.9963
Ratio of Sp Ht (N)	1.3985	1.4006
Comp Suct (Zs)	0.9951	0.9932
Comp Disch (Zd)	0.9969	0.9957
Pres Suct Line, barg	9.00	N/A
Pres Suct Flg, barg	8.66	13.49
Pres Disch Flg, barg	13.83	20.42
Pres Disch Line, barg	N/A	20.00
Pres Ratio F/F	1.539	1.480
Temp Suct, °C	48.89	48.89
Temp Clr Disch, °C	48.89	48.89
Cylinder Data:	**Throw 1**	**Throw 2**
Cyl Model	7-3/8RJ	6-3/8RJ
Cyl Bore, mm	187.325	152.400
Cyl RDP (API), barg	53.0	79.6
Cyl MAWP, barg	58.3	87.6
Cyl Action	DBL	DBL
Cyl Disp, m3/h	518.3	339.3
Pres Suct Intl, barg	7.64	12.16
Temp Suct Intl, °C	51	51
Suct Zsph	0.9953	0.9934
Pres Disch Intl, barg	15.38	22.60
Temp Disch Intl, °C	116	110
HE Suct Gas Vel, m/s	46	43
HE Disch Gas Vel, m/s	42	41
HE Spcrs Used/Max	0/2	0/0
HE Vol Pkt Avail, %	1.11+51.64	1.29+64.48
Vol Pkt Used, %	0.00 (V)	0.00 (V)
HE Min Clr, %	18.28	18.00
HE Total Clr, %	19.38	19.29
CE Suct Gas Vel, m/s	44	40
CE Disch Gas Vel, m/s	40	39
CE Spcrs Used/Max	0/2	0/0
CE Min Clr, %	19.21	19.41
CE Total Clr, %	19.21	19.41
Suct Vol Eff HE/CE, %	87.7/87.8	88.5/88.5
Disch Event HE/CE, ms	9.4/10.3	9.7/10.6
Suct Pseudo-Q HE/CE	11.4/10.5	9.5/8.3
Gas Rod Ld Comp, %	21.7 C	20.1 C
Gas Rod Ld Tens, %	20.9 T	17.6 T
Gas Rod Ld Total, %	22.3	19.8
Xhd Pin Deg/%Rvrsl kN	164/85.4	162/85.1
Flow Calc, Nm3/h	3645.451	3631.626
Cyl kW	90.0	81.0

Ariel Performance

	Company:	Toromont Energy Systems	Customer:	Husky Oil Operations Ltd
	Quote:	Q190393B	Inquiry:	
7.6.4.0	Case 7:	Max	Project:	31833 & 31834

Compressor Data:

Elevation,m:	575.00	Barmtr,bara:	0.945	Ambient,°C:	40.00	Type:	Nat. Gas
Frame:	JGJ/2	Stroke, mm:	88.90	Rod Dia, mm:	38.100	Mfg:	Waukesha
Max RL Tot, kN:	187	Max RL Tens, kN:	94	Max RL Comp, kN:	103	Model:	F18GL
Rated RPM:	1800	Rated kW:	462.3	Rated PS m/s:	5.3	kW:	298 (294)
Calc RPM:	1800.0	kW:	212	Calc PS m/s:	5.3	Avail:	279 (15)

(Driver Data: columns 7–8)

Services	**1**	
Stage Data:	**1**	**2**
Flow Req'd, Nm3/h	0.000	0.000
Flow Calc, Nm3/h	5209.182	5195.702
Cyl kW per Stage	122.4	85.1
Specific Gravity	0.9961	0.9971
Ratio of Sp Ht (N)	1.4003	1.4030
Comp Suct (Zs)	0.9935	0.9911
Comp Disch (Zd)	0.9960	0.9932
Pres Suct Line, barg	13.00	N/A
Pres Suct Flg, barg	12.66	19.01
Pres Disch Flg, barg	19.39	24.50
Pres Disch Line, barg	N/A	24.00
Pres Ratio F/F	1.495	1.275
Temp Suct, °C	48.89	48.89
Temp Clr Disch, °C	48.89	48.89
Cylinder Data:	**Throw 1**	**Throw 2**
Cyl Model	7-3/8RJ	6-3/8RJ
Cyl Bore, mm	187.325	152.400
Cyl RDP (API), barg	53.0	79.6
Cyl MAWP, barg	58.3	87.6
Cyl Action	DBL	DBL
Cyl Disp, m3/h	518.3	339.3
Pres Suct Intl, barg	11.22	17.17
Temp Suct Intl, °C	51	50
Suct Zsph	0.9938	0.9914
Pres Disch Intl, barg	21.54	27.22
Temp Disch Intl, °C	113	94
HE Suct Gas Vel, m/s	46	43
HE Disch Gas Vel, m/s	42	41
HE Spcrs Used/Max	0/2	0/0
HE Vol Pkt Avail, %	1.11+51.64	1.29+64.48
Vol Pkt Used, %	0.00 (V)	0.00 (V)
HE Min Clr, %	18.28	18.00
HE Total Clr, %	19.38	19.29
CE Suct Gas Vel, m/s	44	40
CE Disch Gas Vel, m/s	40	39
CE Spcrs Used/Max	0/2	0/0
CE Min Clr, %	19.21	19.41
CE Total Clr, %	19.21	19.41
Suct Vol Eff HE/CE, %	88.3/88.4	91.3/91.2
Disch Event HE/CE, ms	9.6/10.5	10.9/11.7
Suct Pseudo-Q HE/CE	11.4/10.5	9.5/8.4
Gas Rod Ld Comp, %	29.1 C	19.9 C
Gas Rod Ld Tens, %	27.7 T	16.2 T
Gas Rod Ld Total, %	29.8	19.0
Xhd Pin Deg/%Rvrsl kN	165/95.6	162/87.4
Flow Calc, Nm3/h	5209.182	5195.702
Cyl kW	122.4	85.1

Ariel Performance

	Company:	Toromont Energy Systems	Customer:	Husky Oil Operations Ltd
	Quote:	Q190393B	Inquiry:	
7.6.4.0	Case 8:	Min	Project:	31833 & 31834

Compressor Data: | **Driver Data:**

Elevation,m:	575.00	Barmtr,bara:	0.945	Ambient,°C:	40.00	Type:	Nat. Gas
Frame:	JGJ/2	Stroke, mm:	88.90	Rod Dia, mm:	38.100	Mfg:	Waukesha
Max RL Tot, kN:	187	Max RL Tens, kN:	94	Max RL Comp, kN:	103	Model:	F18GL
Rated RPM:	1800	Rated kW:	462.3	Rated PS m/s:	5.3	kW:	298 (294)
Calc RPM:	1800.0	kW:	200	Calc PS m/s:	5.3	Avail:	279 (15)

Services	**1**	
Stage Data:	**1**	**2**
Flow Req'd, Nm3/h	0.000	0.000
Flow Calc, Nm3/h	3621.139	3606.615
Cyl kW per Stage	93.5	102.3
Specific Gravity	0.9949	0.9964
Ratio of Sp Ht (N)	1.3985	1.4004
Comp Suct (Zs)	0.9951	0.9930
Comp Disch (Zd)	0.9971	0.9970
Pres Suct Line, barg	9.00	N/A
Pres Suct Flg, barg	8.66	13.91
Pres Disch Flg, barg	14.25	24.50
Pres Disch Line, barg	N/A	24.00
Pres Ratio F/F	1.583	1.713
Temp Suct, °C	48.89	48.89
Temp Clr Disch, °C	48.89	48.89
Cylinder Data:	**Throw 1**	**Throw 2**
Cyl Model	7-3/8RJ	6-3/8RJ
Cyl Bore, mm	187.325	152.400
Cyl RDP (API), barg	53.0	79.6
Cyl MAWP, barg	58.3	87.6
Cyl Action	DBL	DBL
Cyl Disp, m3/h	518.3	339.3
Pres Suct Intl, barg	7.64	12.54
Temp Suct Intl, °C	51	51
Suct Zsph	0.9953	0.9933
Pres Disch Intl, barg	15.82	26.99
Temp Disch Intl, °C	120	127
HE Suct Gas Vel, m/s	46	43
HE Disch Gas Vel, m/s	42	41
HE Spcrs Used/Max	0/2	0/0
HE Vol Pkt Avail, %	1.11+51.64	1.29+64.48
Vol Pkt Used, %	0.00 (V)	0.00 (V)
HE Min Clr, %	18.28	18.00
HE Total Clr, %	19.38	19.29
CE Suct Gas Vel, m/s	44	40
CE Disch Gas Vel, m/s	40	39
CE Spcrs Used/Max	0/2	0/0
CE Min Clr, %	19.21	19.41
CE Total Clr, %	19.21	19.41
Suct Vol Eff HE/CE, %	87.2/87.2	85.6/85.6
Disch Event HE/CE, ms	9.3/10.1	8.8/9.6
Suct Pseudo-Q HE/CE	11.4/10.5	9.5/8.3
Gas Rod Ld Comp, %	22.9 C	27.3 C
Gas Rod Ld Tens, %	22.1 T	24.8 T
Gas Rod Ld Total, %	23.6	27.3
Xhd Pin Deg/%Rvrsl kN	165/86.6	164/92.5
Flow Calc, Nm3/h	3621.139	3606.615
Cyl kW	93.5	102.3

Compressor Data:						**Driver Data:**	
Elevation,m:	575.00	Barmtr,bara:	0.945	Ambient,°C:	40.00	Type:	Nat. Gas
Frame:	JGJ/2	Stroke, mm:	88.90	Rod Dia, mm:	38.100	Mfg:	Waukesha
Max RL Tot, kN:	187	Max RL Tens, kN:	94	Max RL Comp, kN:	103	Model:	F18GL
Rated RPM:	1800	Rated kW:	462.3	Rated PS m/s:	5.3	kW:	298 (294)
Calc RPM:	1800.0	kW:	242	Calc PS m/s:	5.3	Avail:	279 (15)

Services	**1**	
Stage Data:	**1**	**2**
Flow Req'd, Nm3/h	0.000	0.000
Flow Calc, Nm3/h	5182.314	5168.261
Cyl kW per Stage	126.4	110.6
Specific Gravity	0.9961	0.9971
Ratio of Sp Ht (N)	1.4003	1.4028
Comp Suct (Zs)	0.9935	0.9910
Comp Disch (Zd)	0.9961	0.9945
Pres Suct Line, barg	13.00	N/A
Pres Suct Flg, barg	12.66	19.44
Pres Disch Flg, barg	19.85	28.58
Pres Disch Line, barg	N/A	28.00
Pres Ratio F/F	1.529	1.448
Temp Suct, °C	48.89	48.89
Temp Clr Disch, °C	48.89	48.89
Cylinder Data:	**Throw 1**	**Throw 2**
Cyl Model	7-3/8RJ	6-3/8RJ
Cyl Bore, mm	187.325	152.400
Cyl RDP (API), barg	53.0	79.6
Cyl MAWP, barg	58.3	87.6
Cyl Action	DBL	DBL
Cyl Disp, m3/h	518.3	339.3
Pres Suct Intl, barg	11.22	17.56
Temp Suct Intl, °C	51	51
Suct Zsph	0.9938	0.9913
Pres Disch Intl, barg	22.03	31.62
Temp Disch Intl, °C	116	108
HE Suct Gas Vel, m/s	46	43
HE Disch Gas Vel, m/s	42	41
HE Spcrs Used/Max	0/2	0/0
HE Vol Pkt Avail, %	1.11+51.64	1.29+64.48
Vol Pkt Used, %	0.00 (V)	0.00 (V)
HE Min Clr, %	18.28	18.00
HE Total Clr, %	19.38	19.29
CE Suct Gas Vel, m/s	44	40
CE Disch Gas Vel, m/s	40	39
CE Spcrs Used/Max	0/2	0/0
CE Min Clr, %	19.21	19.41
CE Total Clr, %	19.21	19.41
Suct Vol Eff HE/CE, %	87.9/87.9	89.0/89.0
Disch Event HE/CE, ms	9.4/10.4	9.9/10.7
Suct Pseudo-Q HE/CE	11.4/10.5	9.5/8.4
Gas Rod Ld Comp, %	30.4 C	27.1 C
Gas Rod Ld Tens, %	29.1 T	23.5 T
Gas Rod Ld Total, %	31.2	26.6
Xhd Pin Deg/%Rvrsl kN	167/96.7	163/95.7
Flow Calc, Nm3/h	5182.314	5168.261
Cyl kW	126.4	110.6

Compressor Data:						**Driver Data:**	
Elevation,m:	575.00	Barmtr,bara:	0.945	Ambient,°C:	40.00	Type:	Nat. Gas
Frame:	JGJ/2	Stroke, mm:	88.90	Rod Dia, mm:	38.100	Mfg:	Waukesha
Max RL Tot, kN:	187	Max RL Tens, kN:	94	Max RL Comp, kN:	103	Model:	F18GL
Rated RPM:	1800	Rated kW:	462.3	Rated PS m/s:	5.3	kW:	298 (294)
Calc RPM:	1800.0	kW:	222	Calc PS m/s:	5.3	Avail:	279 (15)

Services	**1**	
Stage Data:	**1**	**2**
Flow Req'd, Nm3/h	0.000	0.000
Flow Calc, Nm3/h	3597.825	3582.690
Cyl kW per Stage	96.9	120.5
Specific Gravity	0.9949	0.9964
Ratio of Sp Ht (N)	1.3984	1.4001
Comp Suct (Zs)	0.9951	0.9929
Comp Disch (Zd)	0.9972	0.9983
Pres Suct Line, barg	9.00	N/A
Pres Suct Flg, barg	8.66	14.31
Pres Disch Flg, barg	14.65	28.58
Pres Disch Line, barg	N/A	28.00
Pres Ratio F/F	1.625	1.936
Temp Suct, °C	48.89	48.89
Temp Clr Disch, °C	48.89	48.89
Cylinder Data:	**Throw 1**	**Throw 2**
Cyl Model	7-3/8RJ	6-3/8RJ
Cyl Bore, mm	187.325	152.400
Cyl RDP (API), barg	53.0	79.6
Cyl MAWP, barg	58.3	87.6
Cyl Action	DBL	DBL
Cyl Disp, m3/h	518.3	339.3
Pres Suct Intl, barg	7.65	12.91
Temp Suct Intl, °C	51	52
Suct Zsph	0.9953	0.9933
Pres Disch Intl, barg	16.26	31.37
Temp Disch Intl, °C	122	141
HE Suct Gas Vel, m/s	46	43
HE Disch Gas Vel, m/s	42	41
HE Spcrs Used/Max	0/2	0/0
HE Vol Pkt Avail, %	1.11+51.64	1.29+64.48
Vol Pkt Used, %	0.00 (V)	0.00 (V)
HE Min Clr, %	18.28	18.00
HE Total Clr, %	19.38	19.29
CE Suct Gas Vel, m/s	44	40
CE Disch Gas Vel, m/s	40	39
CE Spcrs Used/Max	0/2	0/0
CE Min Clr, %	19.21	19.41
CE Total Clr, %	19.21	19.41
Suct Vol Eff HE/CE, %	86.6/86.7	82.9/82.8
Disch Event HE/CE, ms	9.1/10.0	8.1/9.0
Suct Pseudo-Q HE/CE	11.4/10.5	9.5/8.3
Gas Rod Ld Comp, %	24.1 C	34.5 C
Gas Rod Ld Tens, %	23.4 T	32.1 T
Gas Rod Ld Total, %	24.9	34.9
Xhd Pin Deg/%Rvrsl kN	165/87.7	166/98.5
Flow Calc, Nm3/h	3597.825	3582.690
Cyl kW	96.9	120.5

Compressor Data:						**Driver Data:**	
Elevation,m:	575.00	Barmtr,bara:	0.945	Ambient,°C:	40.00	Type:	Nat. Gas
Frame:	JGJ/2	Stroke, mm:	88.90	Rod Dia, mm:	38.100	Mfg:	Waukesha
Max RL Tot, kN:	187	Max RL Tens, kN:	94	Max RL Comp, kN:	103	Model:	F18GL
Rated RPM:	1800	Rated kW:	462.3	Rated PS m/s:	5.3	kW:	298 (294)
Calc RPM:	1800.0	kW:	268	Calc PS m/s:	5.3	Avail:	279 (15)

Services	**1**	
Stage Data:	**1**	**2**
Flow Req'd, Nm3/h	0.000	0.000
Flow Calc, Nm3/h	5156.543	5141.968
Cyl kW per Stage	130.3	133.0
Specific Gravity	0.9961	0.9972
Ratio of Sp Ht (N)	1.4002	1.4026
Comp Suct (Zs)	0.9935	0.9908
Comp Disch (Zd)	0.9963	0.9959
Pres Suct Line, barg	13.00	N/A
Pres Suct Flg, barg	12.66	19.86
Pres Disch Flg, barg	20.29	32.66
Pres Disch Line, barg	N/A	32.00
Pres Ratio F/F	1.561	1.615
Temp Suct, °C	48.89	48.89
Temp Clr Disch, °C	48.89	48.89
Cylinder Data:	**Throw 1**	**Throw 2**
Cyl Model	7-3/8RJ	6-3/8RJ
Cyl Bore, mm	187.325	152.400
Cyl RDP (API), barg	53.0	79.6
Cyl MAWP, barg	58.3	87.6
Cyl Action	DBL	DBL
Cyl Disp, m3/h	518.3	339.3
Pres Suct Intl, barg	11.22	17.94
Temp Suct Intl, °C	51	51
Suct Zsph	0.9938	0.9912
Pres Disch Intl, barg	22.50	36.01
Temp Disch Intl, °C	118	120
HE Suct Gas Vel, m/s	46	43
HE Disch Gas Vel, m/s	42	41
HE Spcrs Used/Max	0/2	0/0
HE Vol Pkt Avail, %	1.11+51.64	1.29+64.48
Vol Pkt Used, %	0.00 (V)	0.00 (V)
HE Min Clr, %	18.28	18.00
HE Total Clr, %	19.38	19.29
CE Suct Gas Vel, m/s	44	40
CE Disch Gas Vel, m/s	40	39
CE Spcrs Used/Max	0/2	0/0
CE Min Clr, %	19.21	19.41
CE Total Clr, %	19.21	19.41
Suct Vol Eff HE/CE, %	87.5/87.5	86.9/86.8
Disch Event HE/CE, ms	9.4/10.2	9.2/10.0
Suct Pseudo-Q HE/CE	11.4/10.5	9.5/8.4
Gas Rod Ld Comp, %	31.7 C	34.4 C
Gas Rod Ld Tens, %	30.5 T	30.8 T
Gas Rod Ld Total, %	32.6	34.2
Xhd Pin Deg/%Rvrsl kN	167/97.7	165/98.7
Flow Calc, Nm3/h	5156.543	5141.968
Cyl kW	130.3	133.0

Compressor Data:

Elevation,m:	575.00	Barmtr,bara:	0.945	Ambient,°C:	40.00	**Driver Data:**	
Frame:	JGJ/2	Stroke, mm:	88.90	Rod Dia, mm:	38.100	Type:	Nat. Gas
Max RL Tot, kN:	187	Max RL Tens, kN:	94	Max RL Comp, kN:	103	Mfg:	Waukesha
Rated RPM:	1800	Rated kW:	462.3	Rated PS m/s:	5.3	Model:	F18GL
Calc RPM:	1800.0	kW:	241	Calc PS m/s:	5.3	kW:	298 (294)
						Avail:	279 (15)

Disch Temp

Services	**1**	
Stage Data:	**1**	**2**
Flow Req'd, Nm3/h	0.000	0.000
Flow Calc, Nm3/h	3574.283	3558.573
Cyl kW per Stage	100.1	136.3
Specific Gravity	0.9949	0.9965
Ratio of Sp Ht (N)	1.3983	1.3999
Comp Suct (Zs)	0.9951	0.9927
Comp Disch (Zd)	0.9974	0.9996
Pres Suct Line, barg	9.00	N/A
Pres Suct Flg, barg	8.66	14.70
Pres Disch Flg, barg	15.06	32.66
Pres Disch Line, barg	N/A	32.00
Pres Ratio F/F	1.667	2.149
Temp Suct, °C	48.89	48.89
Temp Clr Disch, °C	48.89	48.89
Cylinder Data:	**Throw 1**	**Throw 2**
Cyl Model	7-3/8RJ	6-3/8RJ
Cyl Bore, mm	187.325	152.400
Cyl RDP (API), barg	53.0	79.6
Cyl MAWP, barg	58.3	87.6
Cyl Action	DBL	DBL
Cyl Disp, m3/h	518.3	339.3
Pres Suct Intl, barg	7.65	13.26
Temp Suct Intl, °C	52	52
Suct Zsph	0.9954	0.9932
Pres Disch Intl, barg	16.70	35.73
Temp Disch Intl, °C	125	*154*
HE Suct Gas Vel, m/s	46	43
HE Disch Gas Vel, m/s	42	41
HE Spcrs Used/Max	0/2	0/0
HE Vol Pkt Avail, %	1.11+51.64	1.29+64.48
Vol Pkt Used, %	0.00 (V)	0.00 (V)
HE Min Clr, %	18.28	18.00
HE Total Clr, %	19.38	19.29
CE Suct Gas Vel, m/s	44	40
CE Disch Gas Vel, m/s	40	39
CE Spcrs Used/Max	0/2	0/0
CE Min Clr, %	19.21	19.41
CE Total Clr, %	19.21	19.41
Suct Vol Eff HE/CE, %	86.1/86.2	80.4/80.3
Disch Event HE/CE, ms	8.9/9.8	7.5/8.4
Suct Pseudo-Q HE/CE	11.4/10.5	9.5/8.3
Gas Rod Ld Comp, %	25.3 C	41.7 C
Gas Rod Ld Tens, %	24.6 T	39.4 T
Gas Rod Ld Total, %	26.2	42.5
Xhd Pin Deg/%Rvrsl kN	165/88.8	168/95.9
Flow Calc, Nm3/h	3574.283	3558.573
Cyl kW	100.1	136.3

Compressor Data: | **Driver Data:**

Elevation,m:	575.00	Barmtr,bara:	0.945	Ambient,°C:	40.00	Type:	Nat. Gas
Frame:	JGJ/2	Stroke, mm:	88.90	Rod Dia, mm:	38.100	Mfg:	Waukesha
Max RL Tot, kN:	187	Max RL Tens, kN:	94	Max RL Comp, kN:	103	Model:	F18GL
Rated RPM:	1800	Rated kW:	462.3	Rated PS m/s:	5.3	kW:	298 (294)
Calc RPM:	1800.0	kW:	279	Calc PS m/s:	5.3	Avail:	279 (15)

Services	**1**	
Stage Data:	**1**	**2**
Flow Req'd, Nm3/h	0.000	0.000
Flow Calc, Nm3/h	5024.525	5010.378
Cyl kW per Stage	126.5	148.6
Specific Gravity	0.9961	0.9972
Ratio of Sp Ht (N)	1.4002	1.4023
Comp Suct (Zs)	0.9935	0.9909
Comp Disch (Zd)	0.9963	0.9972
Pres Suct Line, barg	13.00	N/A
Pres Suct Flg, barg	12.66	19.79
Pres Disch Flg, barg	20.25	35.69
Pres Disch Line, barg	N/A	35.00
Pres Ratio F/F	1.558	1.767
Temp Suct, °C	48.89	48.89
Temp Clr Disch, °C	48.89	48.89
Cylinder Data:	**Throw 1**	**Throw 2**
Cyl Model	7-3/8RJ	6-3/8RJ
Cyl Bore, mm	187.325	152.400
Cyl RDP (API), barg	53.0	79.6
Cyl MAWP, barg	58.3	87.6
Cyl Action	DBL	DBL
Cyl Disp, m3/h	518.3	339.3
Pres Suct Intl, barg	11.22	17.88
Temp Suct Intl, °C	51	51
Suct Zsph	0.9938	0.9913
Pres Disch Intl, barg	22.45	39.25
Temp Disch Intl, °C	118	130
HE Suct Gas Vel, m/s	46	43
HE Disch Gas Vel, m/s	42	41
HE Spcrs Used/Max	0/2	0/0
HE Vol Pkt Avail, %	1.11+51.64	1.29+64.48
Vol Pkt Used, %	23.98 (V)	0.00 (V)
HE Min Clr, %	18.28	18.00
HE Total Clr, %	31.77	19.29
CE Suct Gas Vel, m/s	44	40
CE Disch Gas Vel, m/s	40	39
CE Spcrs Used/Max	0/2	0/0
CE Min Clr, %	19.21	19.41
CE Total Clr, %	19.21	19.41
Suct Vol Eff HE/CE, %	83.0/87.6	85.0/85.0
Disch Event HE/CE, ms	9.0/10.3	8.6/9.4
Suct Pseudo-Q HE/CE	11.4/10.5	9.5/8.4
Gas Rod Ld Comp, %	31.6 C	40.3 C
Gas Rod Ld Tens, %	30.3 T	36.8 T
Gas Rod Ld Total, %	32.5	40.4
Xhd Pin Deg/%Rvrsl kN	167/98.5	167/94.9
Flow Calc, Nm3/h	5024.525	5010.378
Cyl kW	126.5	148.6

Compressor Data: **Driver Data:**

Elevation,m:	575.00	Barmtr,bara:	0.945	Ambient,°C:	40.00	Type:	Nat. Gas
Frame:	JGJ/2	Stroke, mm:	88.90	Rod Dia, mm:	38.100	Mfg:	Waukesha
Max RL Tot, kN:	187	Max RL Tens, kN:	94	Max RL Comp, kN:	103	Model:	F18GL
Rated RPM:	1800	Rated kW:	462.3	Rated PS m/s:	5.3	kW:	298 (294)
Calc RPM:	1800.0	kW:	264	Calc PS m/s:	5.3	Avail:	279 (15)

Disch Temp

Services	**1**	
Stage Data:	**1**	**2**
Flow Req'd, Nm3/h	0.000	0.000
Flow Calc, Nm3/h	3951.352	3935.580
Cyl kW per Stage	110.2	148.9
Specific Gravity	0.9953	0.9968
Ratio of Sp Ht (N)	1.3987	1.4005
Comp Suct (Zs)	0.9947	0.9921
Comp Disch (Zd)	0.9972	0.9997
Pres Suct Line, barg	10.00	N/A
Pres Suct Flg, barg	9.66	16.28
Pres Disch Flg, barg	16.68	35.69
Pres Disch Line, barg	N/A	35.00
Pres Ratio F/F	1.663	2.127
Temp Suct, °C	48.89	48.89
Temp Clr Disch, °C	48.89	48.89
Cylinder Data:	**Throw 1**	**Throw 2**
Cyl Model	7-3/8RJ	6-3/8RJ
Cyl Bore, mm	187.325	152.400
Cyl RDP (API), barg	53.0	79.6
Cyl MAWP, barg	58.3	87.6
Cyl Action	DBL	DBL
Cyl Disp, m3/h	518.3	339.3
Pres Suct Intl, barg	8.54	14.70
Temp Suct Intl, °C	52	52
Suct Zsph	0.9950	0.9926
Pres Disch Intl, barg	18.48	39.05
Temp Disch Intl, °C	125	*152*
HE Suct Gas Vel, m/s	46	43
HE Disch Gas Vel, m/s	42	41
HE Spcrs Used/Max	0/2	0/0
HE Vol Pkt Avail, %	1.11+51.64	1.29+64.48
Vol Pkt Used, %	0.00 (V)	0.00 (V)
HE Min Clr, %	18.28	18.00
HE Total Clr, %	19.38	19.29
CE Suct Gas Vel, m/s	44	40
CE Disch Gas Vel, m/s	40	39
CE Spcrs Used/Max	0/2	0/0
CE Min Clr, %	19.21	19.41
CE Total Clr, %	19.21	19.41
Suct Vol Eff HE/CE, %	86.1/86.2	80.7/80.6
Disch Event HE/CE, ms	8.9/9.8	7.6/8.5
Suct Pseudo-Q HE/CE	11.4/10.5	9.5/8.3
Gas Rod Ld Comp, %	27.8 C	45.2 C
Gas Rod Ld Tens, %	27.0 T	42.6 T
Gas Rod Ld Total, %	28.7	46.1
Xhd Pin Deg/%Rvrsl kN	165/92.3	170/92.4
Flow Calc, Nm3/h	3951.351	3935.580
Cyl kW	110.2	148.9