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ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT

609705

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WHC-SD-WM-DA-148, REV. 0

**STRUCTURAL EVALUATION OF MIXER PUMP INSTALLED IN TANK 241-AN-107
FOR CAUSTIC ADDITION PROJECT**

G. A. LESHIKAR

MECHANICAL EQUIPMENT

MAY 16, 1995

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1.0 OBJECTIVE

This document provides justification for the suitability of the mixer pump design for installation in Tank 241-AN-107. This work is in accordance with the "Tank 107-AN Caustic Addition Project Mechanical Systems Engineering Work Plan - ETN-94-0010", WHC-SD-WM-WP-208, Rev. 2, (Reference 1).

1.1 SCOPE OF ANALYSIS

Analyzed within, to the criteria set forth in SDC 4.1, are the pump and pump stand for a design basis earthquake, the effects on the pump of unbalanced loads caused by a plugged discharge nozzle, the lifting capacity of the Hazleton-manufactured pump yoke, uncertainty of the discharge nozzle location for control purposes, and the caustic injection skid for natural phenomena hazards. The mixer pump's effects on internal tank components are documented in WHC-SD-WM-ANAL-018, "Structural Evaluation of Tank 241-AN-107 Internal Components for Caustic Addition Operations", (Reference 2).

1.2 SYSTEM DESCRIPTION

A mixer pump is to be installed in the central pump pit of Double-Shell Tank (DST) 241-AN-107 (hereafter referred to as Tank 107-AN) for the purpose of entraining caustic with the tank contents. The result will be to bring the -OH ion concentration into compliance with Tank Farm operating specifications. The caustic addition system consists of:

- A 75 horsepower Hazleton rotating submersible mixer pump (S/N N-20801). The mixer pump will be used as a platform to inject, mix, and entrain caustic material with the existing waste.
- A caustic injection skid containing a metering pump and monitoring system. The caustic metering pump will discharge caustic soda solution at a known flow rate. The monitoring system will track the quantity of caustic solution added over a given time period.
- Piping and hose connecting the caustic injection skid to the mixer pump. About 250 feet of line are necessary.
- A portable mixer pump control building containing electrical and instrumentation equipment for controlling system operation.

See Figure 1 for a depiction of the system layout.

1.3 BACKGROUND

Hazleton pump, S/N N-20801, was purchased in 1987 from Barrett, Haentjens & Co. of Hazleton, Pa as a mixer pump for the AY/AZ tank farm and stored at the 2101-M laydown yard since its arrival onsite in January 1988. The pump is physically the same design as the 150 horsepower Hazleton mixer pump that has

FIGURE 1

been modified for use as the Hydrogen Mitigation Pump for DST 241-SY-101. The pump is powered by a 75 horsepower, submersible, electric motor and it can deliver 950 gpm and 115 feet of total dynamic head at design conditions. The mixer pump has been modified to accommodate its mission of caustic addition and mixing, and a pump support frame built so that the pump does not rest on the 42" riser.

During operation, the mixer pump will not rotate continuously, but will operate at a specified angle for a specified period and then rotate through successive 10 degree angles. Due to the recommendations of References 2 and 3, an exclusion zone (zone of non-mixing) will exist around a thermocouple tree located approximately 60° NNW of tank center, at a radius of 20 feet.

1.4 PUMP CONFIGURATION

The mixer pump will be modified by removing 29 inches from the main column and adding 69 inches to the discharge points. This is done due to the configuration of the waste in Tank 107-AN. The waste in this tank has some sludge in the bottom which may interfere with pump suction. It is desired to mix the sludge with the added caustic. For this reason the pump column has been shortened to raise the pump suction above the level of the sludge, and extensions have been added to the discharge nozzles to allow the discharge nozzles to "blast" the sludge and increase the mixing within the sludge.

The pump support frame is designed to take the whole weight of the pump with no stress being transmitted into the waste tank riser. The only effect the pump will have is to increase the load on the 241 AN pump pit which will increase the overall load on the dome of the tank by the weight of the pump. WHC-SD-WM-DA-111 (Reference 4) shows the SY tank farm pump pit and dome (structurally equivalent to those in AN farm) to be structurally adequate for a 20,000 lb mixer pump. USQ 15-93-MXRPM-102-AP shows the installation of a similar, 13,000 lb mixer pump mounted in the 102-AP central pump pit to be acceptable. These analyses confirm that the 7,800 lb mixer pump analyzed herein will be well within tank dome structural limits.

1.5 SAFETY CLASSIFICATION

The pump assembly and caustic injection apparatus are classified safety class 3 per WHC-SD-WM-HIE-003 (Reference 5).

1.6 METHODS OF ANALYSIS / ACCEPTANCE CRITERIA

The mixer pump is modeled as a vertical cantilever beam with a fixed end condition at adaptor flange. The mass of the mixer pump was divided into four discrete masses, each with its own center-of-gravity. Seismic analysis was performed according to the provisions of SDC 4.1 for safety class 3 items, i.e. Uniform Building Code (Reference 6) methods were used. The resulting stresses were evaluated against allowable stresses for an extreme case loading condition as defined by ANSI/AISC N690 (Reference 7).

The pump stand analysis is based on the American Institute of Steel Construction (AISC), "Allowable Stress Design", (Reference 8). A section of particular use was "Specification for Allowable Stress Design of Single Angle Members". By symmetry, one side of the pump stand was modeled as a rigid frame with a concentrated load acting downward at its center. Two load conditions were defined, normal and extreme. The normal operating load condition (dead weight + 20% margin) was evaluated against AISC stress allowables. The extreme load condition (dead weight + seismic loading defined by SDC 4.1) was evaluated against ANSI/AISC N690 stress allowables. Pump stand anchor bolt sizes were based on SDC 4.2. Pump stand welds were modeled using methods and formulas given in Reference 9.

For the pump yoke and for the case of a plugged discharge nozzle, component stresses were calculated and evaluated against the criteria specified by the AISC (Reference 8).

Prediction of uncertainty of discharge nozzle angle was determined from the square root of the sum of the squares (SRSS) formula. This formula, derived from the general law of propagation of random errors, gives the error in the sum of quantities that each contain random errors.

The caustic injection skid structure was analyzed using wind loads from ANSI/ASCE 7-88 (Reference 10).

The concrete pad for the caustic injection skid was analyzed using ACI 360R-92 (Reference 11) which details several acceptable procedures for determining thicknesses of slab on grade.

2.0 RESULTS AND DISCUSSION

2.1 MIXER PUMP AND PUMP STAND STRUCTURAL

Structural calculations for the mixer pump and pump stand are located in Appendix B. The mixer pump was evaluated only for the extreme load condition while the pump stand was evaluated for both normal and extreme load conditions. Tables 1 thru 6 summarize the results of the stress analyses performed on the mixer pump and pump stand structures. The mixer pump, pump stand, and the given weld sizes were determined to be structurally adequate. Anchor bolts were qualified based on minimum spacing requirements for either a 2-bolt or 3-bolt configuration, for use with the multi-hole stand base plate shown in Figure B-9.

The mixer pump is NOT REQUIRED TO OPERATE DURING A EARTHQUAKE. The purpose of the calculations is to verify that the pump and pump support frame will not catastrophically fail causing damage to the facility. Because material failure would be necessary for catastrophic failure, the ultimate stress of the material is of prime importance. The difference between the extreme loading case allowable material stress and the ultimate stress is at least 30%.

2.2 DISCHARGE NOZZLE BLOCKAGE

Results were that the bending moment applied to the top of the pump support column due to a blocked discharge nozzle is less than that applied to the mixer pump during a seismic event. Therefore, seismic is the controlling loading for the mixer pump. Table 9 shows the effects of blocking-induced bending moment on the nozzle extension assembly to pump casing connection bolts. Calculations are located in Appendix C.

2.3 PUMP YOKE ANALYSIS

The calculations in Appendix E show that the pump yoke (or lifting bail) is adequate to lift the AN-107 mixer pump. The yoke is to be load tested to a 9,000 lb rating. Magnetic particle testing shall be used to examine the area of stress concentration on the pump yoke (where width constricts from 4 inches to 2 inches) both before and after the load test, to verify that no cracks or other stress-induced material flaws have developed.

2.4 UNCERTAINTY ANALYSIS OF DISCHARGE NOZZLE ORIENTATION

The uncertainty analysis is located in Appendix F. The calculated uncertainty was determined to be $X = 2^\circ$. This means that the discharge nozzle rotational location is known to $\pm 2^\circ$, which will be added to the recommended zone of reduced jet velocity. This zone is given by $10^\circ + 2X$, centered on the tank thermocouple tree.

2.5 CAUSTIC INJECTION SKID STRUCTURAL ANALYSIS

The caustic injection skid structure was determined to be structurally adequate through analysis performed by the vendor, Bran + Luebbe. This analysis is included in Appendix G.

2.6 CAUSTIC INJECTION SKID CONCRETE SLAB ANALYSIS

The concrete slab and anchoring design for the caustic injection skid was determined to be adequate in Appendix H.

3.0 CONCLUSIONS

The mixer pump, pump stand, and caustic injection skid are structurally adequate for the load cases analyzed in this report.

4.0 TANK AND CONFIGURATION DATA

Properties of Tank 241-AN-107:

Waste Density (from Reference 12):	87.36 lb/ft ³
Waste Viscosity:	10 - 30 centipoise
Waste Depth:	30 ft
Sludge Depth:	≈ 6.2 ft
Tank Diameter:	75 ft
42" Riser Elevation Above Pump Pit Floor:	≈ 11 inches

Dimensional data with mixer pump installed:

Nozzle Elevation Above Bottom of Tank:	9 inches
Nozzle Diameter:	1.5 inches
Pump stand height:	10 inches
Pump length from top of adaptor flange (which rests on pump stand) to bottom of discharge nozzles:	49 ft 11 inches

5.0 REFERENCES

5.1 DOCUMENTS

1. WHC-SD-WM-WP-208, Rev. 2, "Tank 107-AN Caustic Addition Project Mechanical Systems Work Plan - ETN-94-0010, G. A. Leshikar, Nov. 1993.
2. WHC-SD-WM-ANAL-018, "Structural Evaluation of Tank 241-AN-107 Internal Components for Caustic Addition Operations", J. Julyk, Oct. 1994.
3. WHC-SD-WM-ER-219, "Mixing Test Report for Tank 107-AN Caustic Addition Project", S. C. Chang.
4. WHC-SD-WM-DA-111, "Structural Analysis of Tank 241-SY-101 Mixing Pump", Rev. 1-A, Nov. 1993.
5. WHC-SD-WM-HIE-003, Rev. 0, "Safety Basis for the 241-AN-107 Mixer Pump Installation and Caustic Addition".
6. Uniform Building Code, 1991.
7. ANSI/AISC N690, "Nuclear Facilities - Steel Safety-Related Structures for Design Fabrication and Erection".
8. American Institute of Steel Construction, "Manual of Steel Construction, Allowable Stress Design", 1989.
9. Blodgett, Omer W., "Design of Welded Structures", 1966.
10. ANSI/ASCE 7-88, "Minimum Design Loads for Buildings and Other Structures".
11. ACI 360-R-92, "Design of Slabs on Grade".
12. 12110-PCL93-042, Internal Memo D.L. Herting to K.G. Carothers, "Tank 241-AN-107 Caustic Demand," May 13, 1993.

5.2 CERTIFIED VENDOR INFORMATION (CVI 22528)

Hazleton Bulletin 48,049, "Operation & Maintenance Manual for 5N-Hazleton Type SSB/Mixing Pump", Barrett, Haentjens & Co., Hazleton, Pa 18201, 1/21/88.

E-20801, Rev. 2, "Elevation", Hazleton 5N SSB Pump/Mixer, Model #360-75-1800 (R), Order #T7N-XBB-423827, 4-2-87.

17490B, "Grease Arrangement", Hazleton 5N Type SSB Pump/Mixer, 12-21-87.

Table 1 - Maximum Bending Stress on 10" diameter Pump Support Column

Load category	Bending Stress (ksi)	Allowable Bending Stress (ksi)
Extreme	24.6	36.9

Table 2 - Stresses on Mixer Pump Flange to Adaptor Flange Bolts

Load Category	Tensile Stress (ksi)	Allowable Tensile Stress (ksi)	Shear Stress (ksi)	Allowable Shear Stress (ksi)
Extreme	19.7	70.4	0.570	27.2

Table 3 - Bending Stresses on Pump Stand Side Rail

Load Category	Bending Stress (ksi)		Allowable Bending Stress (ksi)		Stress Ratio ⁽¹⁾
	Major Axis	Minor Axis	Major Axis	Minor Axis	
Normal	2.3	2.6	23.76	23.76	0.21
Extreme	15.3	18.0	38.0	38.0	0.87

(1) Stress Ratio ≤ 1.0 is acceptable

Table 4 - Shear Stresses on Pump Stand Side Rail

Load Category	Shear Stress (ksi)	Allowable Shear Stress (ksi)
Normal	1.7	14.4
Extreme	12.0	23.0

Table 5 - Compression and Bending Stresses on Pump Stand Corner Column

Load Category	Compressive Stress (ksi)	Allowable Compressive Stress (ksi)	Bending Stress (ksi)		Allowable Bending Stress (ksi)		Stress Ratio
			Major Axis	Minor Axis	Major Axis	Minor Axis	
Normal	0.39	21.3	0.59	0.82	23.76	23.76	0.07
Extreme	2.70	34.1	5.9	4.1	38.0	38.0	0.34

(1) Stress Ratio ≤ 1.0 is acceptable

Table 6 - Stresses on Mixer Pump Flange to Pump Stand Bolts

Load Category	Tensile Stress (ksi)	Allowable Tensile Stress (ksi)	Shear Stress (ksi)	Allowable Shear Stress (ksi)
Extreme	45.8	70.4	1.65	27.2

**Table 7 - Anchor Bolt Loads - 2 Bolts per Corner Configuration
(12" spacing required)**

Load Category	Calculated Loads (kips)		Allowable Loads from SDC 4.2 for a 1" SST Bolt (kips)		Accept. Ratio ⁽¹⁾
	Tensile	Shear	Tensile	Shear	
Extreme	5.26	0.277	6.00	6.16	0.92

(1) Ratio ≤ 1.0 is acceptable

**Table 8 - Anchor Bolt Loads - 3 Bolts per Corner Configuration
(6" spacing required)**

Load Category	Calculated Loads (kips)		Allowable Loads from SDC 4.2 for a 1" SST Bolt (kips)		Accept. Ratio ⁽¹⁾
	Tensile	Shear	Tensile	Shear	
Extreme	3.50	0.184	4.20	4.31	0.87

(1) Ratio ≤ 1.0 is acceptable

Table 9 - Stresses on Nozzle Extension Bolts due to a Blocked Discharge Nozzle

Load Category	Tensile Stress (ksi)	Allowable Tensile Stress (ksi)	Shear Stress (ksi)	Allowable Shear Stress (ksi)
Unbalanced Load due to a Plugged Nozzle	1.7	22.5	.259	16.5

APPENDIX A - DRAWINGS

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FIGURE A-15 - CAUSTIC INJECTION SKID BASE FRAME (H-2-85446, SHEET 2) .	A-16

NAME	JOHN W. SCHAFF	U.S. DEPARTMENT OF ENERGY
ADDRESS	10000 W. 10TH AVE.	WASHINGTON, D.C. 20545
CITY	WASH DC	OFFICE
STATE	DC	TELEPHONE
ZIP	20545	TELETYPE
DATE	10/20/73	TELEFAX
FROM	MR. SCHAFF	TO
SUBJECT	CAUSTIC ADDITION TANK 107 AN	REMARKS
	ASSEMBLY	
	MIXER PUMP	
	CAUSTIC ADDITION TANK 107 AN	
	F 101-101 7502	H-2-85264
	100-101-101 7502	101-101-101 7502

CONTAINER	DATE	WARRANT/DASH NUMBER	PARTS/MATERIAL LIST	INTERNAL/REFERENCE	NO PARTIAL
		-010	SUBSASSY NOZZLE EXTENSION		1
		-020	SUBSASSY NOZZLE EXTENSION		2
					3
					4
					5
1	1	-001	FLANGE BAR 1 THICK	ASTM A36 CS	6
1	1	-002	FLANGE BAR 1 THICK	ASTM A36 CS	7
3	3	-003	TAB BAR 1/4	ASTM A36 CS	8
1	1	-004	TAB BAR 1/4	ASTM A36 CS	9
1	1	-005	TAB BAR 1/4	ASTM A36 CS	10
1	1	-006	PIPE #4 IPS BLACK	ASTM A36 CS	11
1	1		PIPE #4 IPS BLACK SCHED 40	ASTM A36 CS	12

GENERAL NOTES (UNLESS OTHERWISE SPECIFIED)

1. DIMENSIONING AND "CLEANING" PER AXIS Y14.5U-87 DIMENSIONS ARE IN INCHES
2. TOLERANCES
DECIMALS: $X \pm .1$ $XX \pm .03$ $XXX \pm .010$
FRACTIONS: $1/8$
ANGULAR: $\pm 2^\circ$
3. ALL MACHINE SURFACES SHALL BE 125 OR BETTER IN ACCORDANCE WITH AMS B46.1
4. BREAK ALL SHARP EDGES & REMOVE ALL BURRS
5. WELD AND INSPECT PER AMS D 11-92 VIT FVAL PASS
WELDING QUALIFICATIONS PER ASME SECTION IX ARE ACCEPTABLE
6. WELDING FACILITIES AND INSPECTION FOR DRUGS SHALL BE PER ANSI
Z39.10-1993, CRACK, PORE AND PETROLEUM WELDING DRUGS
CODE FOR THE EVALUATION OF FVAL PASS WELDS WITH ACCEPTANCE CR
PER AMS B31.3
7. RECOMMEND MACHINE WORK ON FLANGES 7 & 8 BE DONE AFTER THE
FLANGES BE WELDED TO PART 6
TO PART 6

[illegible]

GENERAL NOTES (UNLESS OTHERWISE SPECIFIED)

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-82. DIMENSIONS ARE IN INCHES.

2. TOLERANCES: DECIMALS: $X = \pm .1$ $XX = \pm .03$ $XXX = \pm .010$
FRACTIONS: $\pm 1/8$
ANGULAR, $\pm 1^\circ$

3. ALL MACHINE SURFACES SHALL BE 250 OR BETTER IN ACCORDANCE WITH ANSI B46.1.

4. BREAK ALL SHARP EDGES & REMOVE ALL BURRS.

5. WELD AND INSPECT PER AWS D 1.1-92. V. FINAL PASS ALL WELDS. WELDING QUALIFICATIONS PER ASME SECTION IX ARE ACCEPTABLE.

6. PREPARE AND PAINT ALL EXPOSED CARBON STEEL SURFACES WITH AN EPOXY OR VINYL PAINT. IF EPOXY PAINT IS USED, ONE COAT OF VALSPAR VAL-CHENI SYSTEM PAINT SHALL BE APPLIED. IF A VINYL PAINT IS USED, ONE COAT OF AMERCOAT 187 PRIMER FLOWED BY TWO TOP COATS OF AMERCOAT 33 SHALL BE APPLIED. PAINT SHALL BE APPLIED IN ACCORDANCE WITH THE MANUFACTURER'S SPECIFICATIONS. FINAL COAT GRAY.

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ADD VIEWS ON THIS PAGE TO H-2-71998, REV 4

IS

ADD VIEWS ON THIS PAGE
TO H-2-72010, REV 4
AND REVISE PLAN AS SHOWN

ALSO CHANGE THE FOLLOWING AT ZONE D9
WCS: PUMP-PIT 07A THRU 07A
IS: PUMP-PIT 07A THRU 07A

PLAN- PUMP PIT 07A

SCALE: 1"=1'-0"

(VERTICAL TO PITS 01A TO 06A
EXCEPT FOR CLOUTED AREA
EXISTING FEATURES SHOWN ON
PLAN-PIT 01A TO 06A)

ROTATIONAL MOTOR ASSEMBLY
H-2-85264

SECTION B-B

SCALE: 1"=1'-0"

SHW AS REQD TO
LEVEL 1/4" PLATE

DETAIL 1

SCALE: 1"=1'-0"

FLANGE SEAL EXTRUSION, 30 ± 10 DUROMETER
RUBBER SEAL, RUBBER SEAL CORPORATION
RUBBER SEAL, RUBBER SEAL CORPORATION
DRAWING NUMBER 00150485

SECTION C-C

SCALE: 1/1

SECTION D-D

SCALE: 1/4

[illegible]

PARTS/MATERIAL LIST			UNIT/NOTES
LINE NO.	PART NAME / NUMBER	QUANTITY	DESCRIPTION
1	ASSEMBLY	1	ASSEMBLY
2	ASSEMBLY	1	ASSEMBLY
3	ASSEMBLY	1	ASSEMBLY
4	ASSEMBLY	1	ASSEMBLY
5	ASSEMBLY	1	ASSEMBLY
6	ASSEMBLY	1	ASSEMBLY
7	ASSEMBLY	1	ASSEMBLY
8	ASSEMBLY	1	ASSEMBLY
9	ASSEMBLY	1	ASSEMBLY
10	ASSEMBLY	1	ASSEMBLY
11	ASSEMBLY	1	ASSEMBLY
12	ASSEMBLY	1	ASSEMBLY
13	ASSEMBLY	1	ASSEMBLY
14	ASSEMBLY	1	ASSEMBLY
15	ASSEMBLY	1	ASSEMBLY
16	ASSEMBLY	1	ASSEMBLY
17	ASSEMBLY	1	ASSEMBLY
18	ASSEMBLY	1	ASSEMBLY
19	ASSEMBLY	1	ASSEMBLY
20	ASSEMBLY	1	ASSEMBLY
21	ASSEMBLY	1	ASSEMBLY
22	ASSEMBLY	1	ASSEMBLY
23	ASSEMBLY	1	ASSEMBLY
24	ASSEMBLY	1	ASSEMBLY
25	ASSEMBLY	1	ASSEMBLY
 
78	ASSEMBLY	1	ASSEMBLY
79	ASSEMBLY	1	ASSEMBLY
80	ASSEMBLY	1	ASSEMBLY
81	ASSEMBLY	1	ASSEMBLY
82	ASSEMBLY	1	ASSEMBLY
83	ASSEMBLY	1	ASSEMBLY
84	ASSEMBLY	1	ASSEMBLY
85	ASSEMBLY	1	ASSEMBLY
86	ASSEMBLY	1	ASSEMBLY
87	ASSEMBLY	1	ASSEMBLY
88	ASSEMBLY	1	ASSEMBLY
89	ASSEMBLY	1	ASSEMBLY
90	ASSEMBLY	1	ASSEMBLY
91	ASSEMBLY	1	ASSEMBLY
92	ASSEMBLY	1	ASSEMBLY
93	ASSEMBLY	1	ASSEMBLY
94	ASSEMBLY	1	ASSEMBLY
95	ASSEMBLY	1	ASSEMBLY
96	ASSEMBLY	1	ASSEMBLY
97	ASSEMBLY	1	ASSEMBLY
98	ASSEMBLY	1	ASSEMBLY
99	ASSEMBLY	1	ASSEMBLY
100	ASSEMBLY	1	ASSEMBLY

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[illegible][illegible]

241-AN	0003	H-2-85348	Ö
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CAUSTIC ADDITION SKID
TANK 107-AN

F 241-AH	8803	1947	H-2-85348	0
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ISOMETRIC ALL VALVES HAVE PRESSURE GA-

[illegible]

ROOF NOT SHOWN FOR CLARITY
NOTE: CROSSMEMBERS TO BE FLUSH WITH TOP OF CHANNEL

GENERAL NOTES (UNLESS OTHERWISE SPECIFIED)

- 1) WELD AND INSPECT PER AWS D11.1. VT WELDS AT FINAL PASS.
- 2) DIRECTION, FABRICATION AND TOLERANCES SHALL BE IN ACCORDANCE WITH AMERICAN INSTITUTE OF STEEL CONSTRUCTION (AISC), MANUAL OF STEEL CONSTRUCTION, 8TH EDITION.
- 3) TOLERANCES:
LINEAR TOLERANCES $\pm 1/8"$, ANGULAR $\pm 1/2^\circ$,
BOLT CENTERS $\pm 1/32"$.
- 4) ALL WELDS TO BE 3/16" CONTINUOUS FILLET WELDS, OTHERWISE WELD AS REQD.
- 5) ALL HOLES AND SLOTS SHALL BE MACHINED OR PUNCHED ONLY.
- 6) PREPARE AND PAINT ALL EXPOSED CARBON STEEL SURFACES WITH 3 MIL DRY THICKNESS ZINCODYK (ZS OR VALSPAR 78 SERIES) COLOR GRAY, PROMOTE TO BE MANUFACTURE STANDARD, PER MANUFACTURER'S INSTRUCTION. DO NOT PAINT FLOUT, CUTTER, DOWNPOUT OR DRIP PAN.
- 7) APPROXIMATE BASEPANEL WIDTH: 1000 LBS
- 8) CAP ALL OPEN TUBING.
- 9) MARK PER HS-85-00115, TYPE B WITH DRAWING NUMBER AND PART NUMBER IN LOCATION INDICATED USING 1 INCH WHITE CHARACTERS. COLOR ENCODING TO BE LOCATED AS SHOWN. USE INDUSTRIAL GRADE ENAMEL, PER MANUFACTURER'S INSTRUCTION.

A14343-402 PIPE SUPPORT DETAILS CH22078 BRAN LUBRIC A14343-401		CAUSTIC ADDITION SKID BASE FRAME ASSEMBLY	
H-2-85348 PWS ID	CAUSTIC ADDITION SKID IN 107-IN TITLE	H-2-85348 NEXT STEP ON	H-2-85446 CAUSTIC ADDITION SKID BASE FRAME ASSEMBLY
CHANGING TRACKABILITY LIT		CHANGING TRACKABILITY LIT	

FOR PARTS LIST AND GENE
SEE SHEET 1

2 DETAIL 10 GALLON SADDLE FRAME SCALE 1" = 1'-0"		3 DETAIL 10 MONO PUMP MOUNT DETAIL SCALE 1/2" = 1'-0"		4 WELD UPOCKET TO DROP PAN		5 WELD UPOCKET TO DROP PAN		6		7		8		9	
10		11		12		13		14		15		16		17	
18		19		20		21		22		23		24		25	
26		27		28		29		30		31		32		33	
34		35		36		37		38		39		40		41	
42		43		44		45		46		47		48		49	
50		51		52		53		54		55		56		57	
58		59		60		61		62		63		64		65	
66		67		68		69		70		71		72		73	
74		75		76		77		78		79		80		81	
82		83		84		85		86		87		88		89	
 	
186		187		188		189		190		191		192		193	
194		195		196		197		198		199		200		201	
202		203		204		205		206		207		208		209	
210		211		212		213		214		215		216		217	
218		219		220		221		222		223		224		225	
226		227		228		229		230							

DATE: 05/01/01

BY: []

U.S. DEPARTMENT OF ENERGY
Nuclear Energy Research Center

CAUSTIC ADDITION
PUMP SKID
TANK 107-AN

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230

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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230

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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230

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APPENDIX B - STRUCTURAL CALCULATIONS

Analyst: G. A. Leshikar

Reviewer: J. A. Tuck

Independent Review Checklist for Verification of Analysis/Calculations (from EP 1.11)

Document Checked - Number: Appendix B Revision: 0

Title: Structural Analysis of Mixer Pump Assembly

Yes	No	N/A	
☒	☐	☐	Problem completely defined.
☒	☐	☐	Appropriate analytical method used.
☒	☐	☐	Necessary assumptions are appropriate, explicitly stated, and supported.
☐	☐	☒	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Sources of non-standard formulae/data are referenced and the correctness of the reference verified.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☐	☐	☒	Mathematical derivations checked including dimensional consistency of results.
☐	☐	☒	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors.
☐	☐	☒	Code run streams correct and consistent with analysis documentation.
☐	☐	☒	Code output consistent with input and with results reported in analysis documentation.
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

I have checked the analysis/calculation and it is complete and accurate to the best of my knowledge.

James A. Tuck 22 Nov. '94
Engineer/Checker Date

Note: Any hand calculations, notes, or summaries generated as part of this check should be signed, dated, and attached to this checklist. Material should be labeled and recorded so that it is intelligible to a technically qualified third party.

Structural Analysis of Mixer Pump Assembly**1.0 INTRODUCTION**

The objective of this analysis is to determine the loads applied to the mixer pump due to an earthquake of magnitude determined by SDC 4.1 (Reference B-1), and to the pump stand due to normal operating loads and/or an earthquake.

2.0 ANALYSIS DESCRIPTION

The mixer pump is a purchased assembly. For that reason, calculations regarding the pump structure will be limited to analysis of a few critical points:

1. Bending load on the mixer pump support column.
2. Adequacy of bolts connecting mixer pump flange to the adaptor flange.

The pump stand will be analyzed for:

1. Bending load on the side rails.
2. Shear load on the side rails.
3. Maximum deflection of the side rails.
4. Combined compression and bending load on the corner columns.
5. Adequacy of side rail to column welds.
6. Adequacy of bolts connecting adaptor flange to pump stand.
7. Baseplate design and sizing
8. Sizing of anchor bolts connecting pump stand to pump pit.

The mixer pump is NOT REQUIRED TO OPERATE DURING A EARTHQUAKE. The purpose of these calculations is to verify that the pump and pump support frame will not catastrophically fail causing damage to the facility. Because material failure would be necessary for catastrophic failure, the ultimate stress of the material is of prime importance. The difference between the extreme loading case allowable material stress and the ultimate stress is at least 30%. This 30% margin is not considered in these calculations.

3.0 NOMENCLATURE

Variables not defined below are defined near their point of use in the analysis. As used in the analysis, the subscript _E represents the extreme load condition.

A	= Area, in ²
A ₁	= Minimum required pump stand base plate area, in ²
A ₂	= Pump stand base plate area, in ²
A _{bolt}	= Tensile stress area of bolt, in ²
c	= Distance from outer surface of member to its neutral axis, in
C _p	= Rigidity coefficient (given by Table 23-P of 1991 UBC)
E	= Modulus of Elasticity, ksi
f _a	= Axial stress, ksi

Structural Analysis of Mixer Pump Assembly

f_b	= Bending stress, ksi
f_{bw}	= Bending stress about major principal axis, ksi
f_{bz}	= Bending stress about minor principal axis, ksi
f_p	= Bearing stress on concrete, ksi
f_r	= Resultant force per inch of weld, kips/in
f_t	= Tensile stress, ksi
f_v	= Shear stress, ksi
F_a	= Allowable axial stress, ksi
F_b	= Allowable bending stress, ksi
F_{bw}	= Allowable bending stress about major principal axis, ksi
F_{bz}	= Allowable bending stress about minor principal axis, ksi
F_p	= Allowable bearing stress on concrete, ksi
F_v	= Allowable shear stress, ksi
F_t	= Allowable tensile stress, ksi
F_u	= Ultimate stress of material, ksi
F_y	= Yield stress of material, ksi
g	= Gravitational constant, ft/s ²
I	= Importance Factor
I_b	= Moment of inertia about pump stand column, in ⁴
I_d	= Moment of inertia about pump stand side rail, in ⁴
I_w	= Moment of Inertia about major principal axis, in ⁴
I_x	= Moment of Inertia about geometric axis, in ⁴
I_y	= Moment of Inertia about geometric axis, in ⁴
I_z	= Moment of Inertia about minor principal axis, in ⁴
J_w	= Polar moment of Inertia of weld, in ³
k	= Slenderness ratio of any unbraced column length
L_i	= Pump stand inside width, in
L_o	= Pump stand outside width, in
L_{cg}	= Distance from mixer pump overall center-of-gravity to bottom of adaptor flange, in
L_w	= Length of weld, in
M_A	= Moment at pump adaptor flange due to a seismic event, in-kips
M_{bw}	= Moment about major principal axis of side rail, in-kips
M_{bz}	= Moment about minor principal axis of side rail, in-kips
M_{cw}	= Moment about major principal axis of column, in-kips
M_{cz}	= Moment about minor principal axis of column, in-kips
ρ	= Waste density, lb/ft ³
P_D	= Normal load, kips
P_E	= Extreme load, kips
P_h	= Horizontal seismic force, kips
P_{rail}	= Vertical force on pump stand member due to translation of moment from a seismic event into a couple, kips

Structural Analysis of Mixer Pump Assembly

P_v	=	Shear force, kips
P_t	=	Tensile force, kips
r_w	=	Radius of gyration with respect to major principal axis, in
r_z	=	Radius of gyration with respect to minor principal axis, in
α	=	Angle of inclination of principal axes with respect to y-y axis, °
S_w	=	Section modulus with respect to major principal axis, in ³
S_z	=	Section modulus with respect to minor principal axis, in ³
T	=	Period of vibration, sec
ω_n	=	Fundamental frequency, hz
W_p	=	Weight of component, lb
$W_{am1..n}$	=	Added mass contribution to pump weight, kips
$W_{t1..n}$	=	Mixer pump assembly weight, kips
Z	=	Seismic zone coefficient (free field horizontal acceleration), g

4.0 ASSUMPTIONS

The general assumptions used in evaluating the mixer pump assembly are presented below:

1. The maximum bending stress in the cantilevered pump support column occurs at the adaptor flange. This facilitates ease of calculation and is conservative. In actuality, the maximum bending stress will likely occur at the carbon bumper blocks, which are located 17" below the adaptor flange. The 1/16-in or less gap between the bumper blocks could be ignored for calculation purposes. LA-UR-92-3196, "A Safety Assessment for Proposed Pump Mixing Operations to Mitigate Episodic Gas Release in Tank 241-101-SY", (Reference B-2) used this assumption in the analysis of a similar mixer pump installed in Tank 101-SY.
2. Tank 107-AN pump pit is a covered structure that will shield the pump from both wind and missiles. For this reason, wind and missile analysis was not considered justified.
3. Experience data given in WHC-SD-GN-DGS-30006, Rev. 1, (Reference B-3), shows piping to be robust and resistive to damage from seismic events. Therefore, the caustic addition and water flush line piping and attachments are assumed to be adequate for a seismic event.
4. For dynamic response of the mixer pump assembly, only added mass and seismic-induced waste sloshing are considered. This is the same assumption made in References B-2 and B-4 for the mixer pump installed in Tank 101-SY, where these effects were a small contributor to the overall load. In Appendix K of Reference B-2, reaction forces between the 101-SY mitigation pump assembly and tank dome caused by seismic-induced sloshing were calculated to comprise less than 5% of the total earthquake reaction force. Herein, fluid sloshing is being accounted for by adding a factor

Structural Analysis of Mixer Pump Assembly

of 5% to the results of the seismic analysis. Added mass is determined in Section 7.2 of this analysis.

Note that this assumption is a conservative since consideration of seismic dynamic response is not a requirement of SDC 4.1 for SC-3 equipment.

5. Buoyancy due to the gas-filled pump support column is ignored in this analysis. This is a conservative assumption with respect to the pump stand analysis because the upward buoyant force counteracts the pump weight on the pump stand. For a tank waste height of 30 feet and an average mixer pump column diameter of 10 inches, the resulting buoyant force is on the order of 1000 lbs ($= \rho g V$).

5.0 LOAD COMBINATIONS

For this analysis, the following two load conditions are defined:

Load Condition	Definition	Stress Limit Coefficient
Normal	dead weight + 20% (margin)	1.0
Extreme	dead weight + seismic loading defined by SDC 4.1	1.6 (bending or tension) 1.4 (shear)

ANSI/AISC N690 (Reference B-6) allows stress limit coefficients to be applied to stress allowables based on yield stress, under certain "extreme" load combinations. Because our extreme load condition qualifies as an "extreme" loading, ANSI/AISC N690 allows usage of a load factor of 1.6 for members subject to bending, tension, and/or compression and a load factor of 1.4 for members subject to shear. These coefficients, and corresponding stress allowables, are the same as those used in Reference B-2 and more conservative than those used in Reference B-4.

For the mixer pump, bolts, and anchorage to concrete, the normal load condition has been judged satisfactory by engineering judgement. Only the extreme load condition is to be evaluated herein.

Both normal and extreme load conditions are evaluated for the pump stand structure.

Structural Analysis of Mixer Pump Assembly**6.0 ALLOWABLE STRESSES**Allowable stresses on the 10" dia. pump support column

Allowable stresses on the 10" dia. pump support column are determined in the same manner as done in Sections 4.2 and 4.3 of Reference B-4, for a similar mixer pump installed in SY-101:

Per Table B5.1 of AISC, "Manual of Steel Construction / Allowable Stress Design" (Reference B-5), the requirement for a compact section (circular) is:

$$\frac{D}{t} < \frac{3300}{F_y}$$

where: D = outside diameter of pipe, in
 t = thickness of the pipe, in
 F_y = yield stress of the pipe, ksi

For the 10" ASTM A53 Schedule 40 pipe (D= 10.75 in, t= 0.365 in, and F_y = 35 ksi from Reference 5), the D/t ratio is:

$$D/t = 10.75/0.365 = 29.4 < 3300/35.0 = 94.3$$

Therefore, the pump support column is a compact section.

Normal Load Case: Allowable bending and shear stresses for a compact section are given in Reference B-5 by:

$$\begin{aligned} F_b &= 0.66 F_y = 0.66 \times 35.0 \text{ ksi} = 23.1 \text{ ksi} \\ F_v &= 0.40 F_y = 0.40 \times 35.0 \text{ ksi} = 14.0 \text{ ksi} \end{aligned}$$

Extreme Load Case:

$$\begin{aligned} F_{bE} &= 1.6 \times 23.1 \text{ ksi} = 36.9 \text{ ksi} \\ F_{vE} &= 1.4 \times 14.0 \text{ ksi} = 19.6 \text{ ksi} \end{aligned}$$

Allowable stresses on structural members comprising the pump stand

The pump stand is constructed of ASTM A36 carbon steel. Pump stand allowable stresses are determined from AISC, "Specification for Allowable Stress Design of Single Angle Members", (Reference B-7). Stress limit coefficients are applied per ANSI/AISC N690, Section Q1. Due to the length and involvement of calculations to determine pump stand allowable stresses, they are contained as a part of the analysis.

Allowable stresses on ASTM A325 Bolts

All hole dimensions are standard size as defined by Table J3.1 of AISC. Table J3.2 of AISC and Section Q1 of ANSI/AISC N690 gives:

Structural Analysis of Mixer Pump Assembly

Normal Load Case: $F_t = 44 \text{ ksi}$
 $F_v = 17 \text{ ksi}$

Extreme Load Case: $F_{tE} = 1.6 \times 44 \text{ ksi} = 70.4 \text{ ksi}$
 $F_{vE} = 1.4 \times 17 \text{ ksi} = 23.8 \text{ ksi}$

Allowable Weld Stresses

Allowable stresses on welds are taken from Table J2.5 of Reference B-5.

Fillet Welds

Type of Weld Stress	Permissible Stress
Shear on effective area	0.3 x nominal tensile strength of weld metal (ksi)
Tension or compression parallel to axis of weld	same as base metal

The allowable stress on a fillet weld using E70XX electrodes is:

Normal Load Case: $F_v = 0.3 \times 70 \text{ ksi} = 21.0 \text{ ksi}$

Extreme Load Case: $F_{vE} = 1.4 \times 0.3 \times 70 \text{ ksi} = 29.4 \text{ ksi}$

Compressive Strength of Pump Pit Concrete

From drawing H-2-71916, the minimum compressive strength of the 107-AN central pump pit concrete is $f'_c = 3000 \text{ psi}$.

7.0 ANALYSIS OF MIXER PUMP7.1 Seismic Loading on Mixer Pump

Per SDC 4.1, the seismic loading on the Safety Class 3 mixer pump is calculated using the following equation from the UBC (Reference B-8):

$$P_h = ZIC_p W_p$$

where: Z = seismic zone coefficient (free field horizontal acceleration, g)
 $= 0.12$ from SDC 4.1

I = Importance Factor = 1.25 from SDC 4.1

C_p = Rigidity Coefficient (given by Table 23-P of 1991 UBC)

W_p = Weight of component, lb

P_h = Horizontal seismic force, lb

Structural Analysis of Mixer Pump Assembly

The rigidity coefficient for rigid rotating equipment is 0.75 per the UBC. This number is multiplied by 2 if the rotating equipment is considered flexible. Rigid or rigidly supported equipment is defined as having a fundamental period less than or equal to 0.06 second. The mixer pump can be modeled as a vertical cantilever beam with concentrated mass at its end, whose fundamental frequency of vibration can be approximated by the following equation:

$$\omega_n = \frac{1.732}{2\pi} \sqrt{\frac{EI_x g}{WL^3}}$$

where: E = modulus of elasticity
 I_x = moment of inertia
 g = gravitational constant
 W = weight of concentrated mass
 L = length of cantilever beam

For the mixer pump:

E = 29×10^6 psi, for steel
 I_x = 161 in⁴ for 10" schedule 40 pipe
 g = 386.4 in/s²
 W = W_{2+3+4} = mixer pump weight below adaptor flange = 6115.5 lb from pg. D-9 of Appendix D, (neglecting added mass)
 L = L_{cg} = distance from adaptor flange to center of gravity of the cantilevered portion of the pump assembly = 417 in, from pg. D-9 of Appendix D

$$\omega_n = \frac{1.732}{2\pi} \sqrt{\frac{29 \times 10^6 \times 161 \times 386.4}{6115.5 \times 417^3}}$$

$$\omega_n = 0.56 \text{ Hz}$$

$$T_n = \text{period} = 1/\omega_n = 1/0.56 \text{ Hz} = 1.80 \text{ sec}$$

====> since 1.80 sec > 0.06 sec, equipment is flexible - use $C_p = 1.5$

$$ZIC_p = (0.12)(1.25)(1.5) = 0.225$$

Multiply ZIC_p by a factor of 1.05 to account for dynamic effects of fluid sloshing as discussed in Section 4.0.

$$====> (1.05)ZIC_p = (1.1)0.225 = 0.236$$

Structural Analysis of Mixer Pump Assembly7.2 Added Mass

Added mass is calculated based on the assumption that the submerged portion of the pump is a 10.75 inch diameter circular cylinder. Using Reference B-9, R.D. Blevins, "Flow-Induced Vibration", the resulting added mass per submerged foot of pump is:

$$\rho \pi r^2 = (87.4 \text{ lb/ft}^3) \pi (5.375/12 \text{ ft})^2 = 55 \text{ lb/ft}$$

Based on a waste depth of 30 feet (360 inches) and dimensions from Appendix D:

Pump Section	Added Mass, W_{am} , lb
1. Flange Assembly	0
2. Shaft Assembly	$[360 \text{ in} - 9 \text{ in} - (599 \text{ in} - 462 \text{ in})](\text{ft}/12 \text{ in})(55 \text{ lb/ft}) = 980 \text{ lb}$
3. Pump Motor Assembly	$[523 \text{ in} - 462 \text{ in}](\text{ft}/12 \text{ in})(55 \text{ lb/ft}) = 279 \text{ lb}$
4. Nozzle Extension Assembly	$[599 \text{ in} - 523 \text{ in}](\text{ft}/12 \text{ in})(55 \text{ lb/ft}) = 348 \text{ lb}$

7.3 Bending Stress on Pump Support Column at Location A - Adaptor Flange

Assumptions:

1. Mass located above the adaptor flange does not contribute to the pump column bending stress.

The mixer pump has been divided into four sections for application of horizontal seismic forces. See Figure D-1 of Appendix D for mass and center-of-gravity information, Figure B-1 for depiction and dimensional information, and the previous section for added mass information. Acceleration will be applied in one critical horizontal direction at each center of gravity. The contribution to the total seismic load is proportional to each section's weight and distance from the point in question.

$$M_A = ZIC_p \sum M_{AI} = ZIC_p [M_{A2} + M_{A3} + M_{A4}]$$

$$M_A = 0.236 [(1995 \text{ lb} + 980 \text{ lb})(-233 \text{ in}) + (3873 \text{ lb} + 279 \text{ lb})(-503 \text{ in}) + (247 \text{ lb} + 348 \text{ lb})(-564 \text{ in})]$$

$$= 0.236 [-693,175 \text{ in-lb} - 2,088,456 \text{ in-lb} - 335,580 \text{ in-lb}]$$

$$M_A = - 736 \text{ in-kips} \quad (\text{take absolute value})$$

Structural Analysis of Mixer Pump Assembly

$$f_{bE} = M_A c / I_x$$

$$f_{bE} = (736 \text{ in-kips})(5.375 \text{ in}) / (161 \text{ in}^4)$$

$$= 24.6 \text{ ksi}$$

$$\implies f_{bE} = 24.6 \text{ ksi} < F_{bE} = 36.9 \text{ ksi} \quad ; \text{ok}$$

7.4 Mixer Pump Flange to Adaptor Flange Bolting

There are (4) 1-1/4" dia. bolts attaching the the two flanges together. These bolts were supplied with the mixer pump. The Hazleton 75 HP submersible mixer pump was designed by the manufacturer to rest on a 34" riser; therefore the need for a adaptor flange to adapt the pump to a 42" riser. The flanges have 4 equally spaced holes drilled on a 38.5" diameter (see H-2-85264 and Figure B-2).

The seismic induced horizontal force on the pump assembly is:

$$P_h = ZIC_p \sum [Wt_n + Wam_n]$$

$$P_h = 0.236 [(1662 \text{ lb} + 0 \text{ lb}) + (1995 \text{ lb} + 980 \text{ lb}) + (3873 \text{ lb} + 279 \text{ lb}) + (247 \text{ lb} + 348 \text{ lb})]$$

$$P_h = 2.21 \text{ kips}$$

Assuming the entire moment acts upon one bolt, maximum tension on any one bolt is given by:

$$P_t = M_A / \text{bolt-to-bolt distance}$$

$$= 736 \text{ in-kip} / 38.5 \text{ in}$$

$$P_t = 19.1 \text{ kips}$$

Tensile stress area, $A_{\text{bolt}} = 0.969 \text{ in}^2$, for 1-1/4" dia. bolt

$$f_{tE} = P_t / A_{\text{bolt}} = 19.1 \text{ kips} / 0.969 \text{ in}^2 = 19.7 \text{ ksi}$$

$$\implies f_{tE} = 19.7 \text{ ksi} < F_{tE} = 70.4 \text{ ksi} \quad ; \text{ok}$$

Shear force on each bolt is given by:

$$P_v = P_h / \text{number of bolts}$$

$$= 2.21 \text{ kips} / 4$$

$$P_v = 0.552 \text{ kips}$$

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$$f_{VE} = P_v / A_{bolt} = 0.552 \text{ kip} / 0.969 \text{ in}^2 = 0.570 \text{ ksi}$$

$$\Rightarrow f_{VE} = 0.570 \text{ ksi} < F_{VE} = 23.8 \text{ ksi} \quad ; \text{ok}$$

8.0 ANALYSIS OF MIXER PUMP STAND

Drawing H-2-85261 shows the pump stand. The mixer pump adaptor flange rests on angle iron members which are defined as "side rails" and "corner rails" as seen in Figure B-3. The adaptor flange bolts to the stand near each corner, and the stand itself is to be Hilti-bolted to the pump pit floor.

Throughout the following pump stand structural analysis, the seismic load placed on the Safety Class 3 pump stand is the same as that used in the mixer pump analysis. Due to symmetry, only one side of the pump stand will be analyzed in detail (see Figure B-4). The moment due to the seismic load will be translated into a couple, and that vertical force applied to the center of one side of the structure to simulate worst-case conditions. Also, some general assumptions are made in order to simplify the analysis in a conservative manner.

General Assumptions Used in Analysis of Pump Stand Structure

1. The components of the pump stand frame will be analyzed separately based on the loading and moment diagram shown in Figure B-5 (taken from Reference B-10, Blodgett, "Design of Weldments, Section 7.4).
2. For both load categories, the entire load acts as a point load downward at the center of the side rail.
3. The portion of each L 6" x 4" x 1/2" side rail that rests over the 42" riser will have the tip of its compression leg shaved by 1/2" to allow for removal of the shield plug through the stand, if necessary. Side rail inside-to-inside distance is slightly greater than 44". Therefore, this analysis will use the properties of an L 6" x 3-1/2" x 1/2" to conservatively compensate for this modification.
4. The strengthening effects of the corner rails and other side rails are neglected. This is a conservative assumption.

The normal load acting on the side rail is:

$$P_D = 1/4 Wt_{1+2+3+4}(1.2)$$

$$P_D = 1/4 (7.78 \text{ kips})(1.2) = 2.3 \text{ kips}$$

The moment due to a seismic event which acts on the 6" x 4" x 1/2" side rail can be translated into a couple using:

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$$P_{\text{rail}} = M_A / L_o$$

$$P_{\text{rail}} = 736 \text{ in-kips} / 52 \text{ in}$$

$$P_{\text{rail}} = 14.1 \text{ kips}$$

For extreme load category, the total load acting on the side rail is:

$$P_E = 1/4 Wt_{1+2+3+4} + P_{\text{rail}}$$

$$P_E = 1/4 (7.78 \text{ kips}) + 14.1 \text{ kips}$$

$$P_E = 16.0 \text{ kips}$$

8.1 Bending Load on Side Rails

Determine Allowable Stresses

Allowable stress on the side rail is determined using Reference B-7, AISC "Specification for Allowable Stress Design of Single-Angle Members". The L 6" x 4" x 1/2" side rail falls under Section 5.3.2 of Reference B-7, "Bending about Principal Axes", which states that unequal angles without lateral-torsional restraint shall be designed considering principal axis bending. (Assumption #4 above removes the corner rail lateral-torsional restraints for simplicity and conservatism). It also states that bending about both of the principal axes shall be evaluated using the interaction equations in AISC Section H1 (Reference B-5).

Accordingly, for major axis bending, the principal bending compression stress f_{bw} shall be limited by F_b in Section 5.1.3 of Reference B-7 where:

$$F_{ob} = \frac{143,100 I_z}{S_w l^2} C_b (\sqrt{\beta_w^2 + 0.052 (lt/r_z)^2} + \beta_w)$$

and by b/t provisions in Section 5.1.1 of Reference B-7 for the compression leg.

where: F_{ob} = elastic lateral-torsional buckling stress, ksi
 l = unbraced length, in
 b = full width of angle leg in compression, in
 t = thickness of angle, in
 S_w = section modulus to tip of leg in compression, in³
 r_z = radius of gyration for minor principal axis, in
 β_w = special section property for unequal leg angles, positive for short leg in compression and negative for long leg in compression, in. $\beta_w = 3.69$ from Table C5.1 of Reference B-7.
 C_b = bending coefficient dependent on the moment gradient. In this case, $C_b = 1$

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The principle axis properties of L 6" x 3-1/2" x 1/2" are:

$$\begin{aligned}
 A &= \text{area} = 4.50 \text{ in}^2 \\
 I_x &= 16.6 \text{ in}^4 \\
 I_y &= 4.25 \text{ in}^4 \\
 I_z &= A r_z^2 = (4.50 \text{ in}^2)(0.759 \text{ in})^2 = 2.59 \text{ in}^4 \\
 I_w + I_z &= I_x + I_y \\
 &= 16.6 \text{ in}^4 + 4.25 \text{ in}^4 = 20.85 \text{ in}^4 \\
 I_w &= 20.85 \text{ in}^4 - I_z = 18.26 \text{ in}^4 \\
 r_w &= (I_w / A)^{1/2} = (18.26 / 4.50)^{1/2} = 2.01 \text{ in} \\
 r_z &= 0.759 \text{ in} \\
 \tan \alpha &= 0.344 \\
 \alpha &= 19.0^\circ \\
 c_w &= 2.8 \text{ in (from Figure B-6)} \\
 c_z &= 1.4 \text{ in (from Figure B-6)} \\
 S_w &= I_w / c_w = 18.26 / 2.8 = 6.5 \text{ in}^3 \\
 S_z &= I_z / c_z = 2.59 / 1.4 = 1.9 \text{ in}^3
 \end{aligned}$$

See Figure B-6 for cross-sectional sketch of side rail with dimensions.

$$F_{ob} = \frac{(143,100)(2.59)}{(6.5)(52)^2} (1) \left(\sqrt{3.69^2 + 0.052 \left(\frac{(52)(0.5)}{(0.759)} \right)^2} + 3.69 \right)$$

$$F_{ob} = 260 \text{ ksi} \quad ; \quad F_{ob} > F_y$$

To prevent lateral-torsional buckling, the maximum compression stress shall not exceed:

when $F_{ob} > F_y$:

$$F_b = \left[0.95 - 0.50 \sqrt{\frac{F_y}{F_{ob}}} \right] F_y \leq 0.66 F_y$$

$$F_b = \left[0.95 - 0.50 \sqrt{\frac{36}{248}} \right] 36 \leq 0.66 (36)$$

$$F_b = 27.3 \leq 23.76 \quad ; \quad F_b = 23.76 \text{ ksi}$$

==> The bending stress is not dictated by lateral-torsional buckling.

The b/t provisions for the compression leg are to prevent local buckling when the tip of the angle leg is in compression.

$$\text{when } b/t \leq 65/(F_y)^{1/2}: \quad 4/0.5 = 8 \leq 65/6 = 10.8$$

$$\text{then:} \quad F_b = 0.66 F_y = 23.76 \text{ ksi}$$

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==> Major axis bending is governed by the lower of the above allowable stresses.

==> $F_{bw} = 23.76 \text{ ksi}$

For minor axis bending, from Section 5.3.2.b of Reference B-7, $F_{bz} = 0.66F_y$.

Determine Calculated Stresses

For the loading shown in Figure B-5 (concentrated load at mid-span), the maximum moment on the side rail can be determined using Reference B-12:

$$M_b = M_{\max} = M_c + \frac{Pb}{4}$$

and:

$$M_c = -\frac{Pb}{8} \left[\frac{\frac{3b}{I_b}}{\frac{3b}{I_b} + \frac{2d}{I_d}} \right]$$

where: M_b = maximum moment on side rail, in-kips
 M_c = maximum moment on column, in-kips
 $b = L_o$ = length of side rail, in = 52 in
 d = height of column, in = 10 in
 I_b = moment of inertia of side rail, in⁴
 I_d = moment of inertia of column, in⁴

To compare the calculated stresses on the same basis as the allowable stresses, calculations will be made about the principal axes. For the side rail, the principal moments of inertia I_y and I_z calculated above will replace I_b . For the column, the principal moments of inertia calculated in Section 8.4 will replace I_d . The downward load, P , in the following equations is split into components about the principal axes (see Figure B-6).

The major principal axis bending moment on the column is:

Normal Load Category:

$$M_{cw} = -\frac{(2.3) \cos 19^\circ (52)}{8} \left[\frac{\frac{(3)(52)}{18.3}}{\frac{(3)(52)}{18.3} + \frac{(2)(10)}{139.6}} \right] = -13.5 \text{ inch-kips}$$

Extreme Load Category:

$$M_{cWE} = -\frac{(16.0) \cos 19^\circ (52)}{8} \left[\frac{\frac{(3)(52)}{18.3}}{\frac{(3)(52)}{18.3} + \frac{(2)(10)}{139.6}} \right] = -96.7 \text{ inch-kips}$$

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The minor principal axis bending moment on the column is:

Normal Load Category:

$$M_{cz} = -\frac{(2.3) \sin 19^\circ (52)}{8} \left[\frac{\frac{(3)(52)}{2.59}}{\frac{(3)(52)}{2.59} + \frac{(2)(10)}{34.9}} \right] = -4.82 \text{ inch-kips}$$

Extreme Load Category:

$$M_{czE} = -\frac{(16.0) \sin 19^\circ (52)}{8} \left[\frac{\frac{(3)(52)}{2.59}}{\frac{(3)(52)}{2.59} + \frac{(2)(10)}{34.9}} \right] = -33.5 \text{ inch-kips}$$

M_b is equal to the side rail maximum moment plus the column moment (which has negative sign). The side rail major principal axis bending moment is:

Normal Load Category:

$$M_{bw} = -13.5 + \frac{(2.3)(\cos 19^\circ)(52)}{4} = 14.8 \text{ inch-kips}$$

Extreme Load Category:

$$M_{bwE} = -96.7 + \frac{(16.0)(\cos 19^\circ)(52)}{4} = 99.9 \text{ inch-kips}$$

The side rail minor principal axis bending moment is:

Normal Load Category:

$$M_{bz} = -4.82 + \frac{(2.3)(\sin 19^\circ)(52)}{4} = 4.91 \text{ inch-kips}$$

Extreme Load Category:

$$M_{bzE} = -33.5 + \frac{(16.0)(\sin 19^\circ)(52)}{4} = 34.2 \text{ inch-kips}$$

As a check for whether the above moments are reasonable, calculate the side rail bending moment assuming the side rail is a fixed ended beam (not part of a frame).

Normal: $M_b = P_b b/8 = (2.3 \text{ kips})(52 \text{ in})/8 = 15.0 \text{ in-kips}$

Extreme: $M_{bE} = P_E b/8 = (16.0 \text{ kips})(52 \text{ in})/8 = 104.0 \text{ in-kips}$

Comparing the fixed ended beam moments to the resultant of M_{bw} and M_{bz} , the calculated bending moments appear reasonable.

Normal: $M_b = (M_{bw}^2 + M_{bz}^2)^{1/2} = (13.5^2 + 4.82^2)^{1/2} = 14.3 \text{ in-kips}$

Extreme: $M_{bE} = (M_{bwE}^2 + M_{bzE}^2)^{1/2} = (96.7^2 + 33.5^2)^{1/2} = 102.3 \text{ in-kips}$

Structural Analysis of Mixer Pump Assembly

The major principal axis bending stress on the side rail is:

Normal:

$$f_{bw} = M_{bw}/S_w$$

$$f_{bw} = (14.8 \text{ in-kips})/(6.5 \text{ in}^3) = 2.3 \text{ ksi}$$

Extreme: $f_{bWE} = M_{bWE}/S_w$

$$f_{bWE} = (99.9 \text{ in-kips})/(6.5 \text{ in}^3) = 15.3 \text{ ksi}$$

The minor principal axis bending stress on the side rail is:

Normal: $f_{bz} = M_{bz}/S_z$

$$f_{bz} = (4.91 \text{ in-kips})/(1.9 \text{ in}^3) = 2.6 \text{ ksi}$$

Extreme: $f_{bzE} = M_{bzE}/S_z$

$$f_{bzE} = (34.2 \text{ in-kips})/(1.9 \text{ in}^3) = 18.0 \text{ ksi}$$

Combined Stresses

Bending stresses are combined based on AISC Section H1:

Normal:

$$\frac{f_{bw}}{F_{bw}} + \frac{f_{bz}}{F_{bz}} \leq 1.0$$

$$\frac{2.3}{23.76} + \frac{2.6}{23.76} \leq 1.0$$

$$\Rightarrow 0.10 + 0.11 = 0.21 \leq 1.0 \quad ; \text{ok}$$

Extreme:

$$\frac{f_{bWE}}{1.6 F_{bw}} + \frac{f_{bzE}}{1.6 F_{bz}} \leq 1.0$$

$$\frac{15.3}{38.0} + \frac{18.0}{38.0} \leq 1.0$$

$$\Rightarrow 0.40 + 0.47 = 0.87 \leq 1.0 \quad ; \text{ok}$$

8.2 Shear on Side Rails

Determine Allowable Stresses

Allowable shear stress on the side rail is determined using Section 3 of Reference B-7, "Specification for Allowable Stress Design of Single-Angle Members":

$$F_v = 0.4F_y$$

Normal: $F_v = 0.4(36 \text{ ksi}) = 14.4 \text{ ksi}$

Extreme: $F_{vE} = 0.4(1.6)(36 \text{ ksi}) = 23.0 \text{ ksi}$

Calculate Stresses

Shear stresses in a single angle member are the result of the gradient in the bending moment along the length and the torsional moment. The shear stress may be computed from Section 3 of Reference B-7 as:

$$f_v = 1.5V_b/bt$$

where V_b = component of the shear force parallel to the angle leg with length b , and thickness, t , kips

Normal: $f_v = 1.5(2.3 \text{ kips})/(4 \text{ in})(0.5 \text{ in})$
 $= 1.7 \text{ ksi}$

Extreme: $f_{vE} = 1.5(16.0 \text{ kips})/(4 \text{ in})(0.5 \text{ in})$
 $= 12.0 \text{ ksi}$

Compare Stresses

Normal: $f_v = 1.7 \text{ ksi} < F_v = 14.4 \text{ ksi} \quad ; \text{ok}$

Extreme: $f_{vE} = 12.0 \text{ ksi} < F_{vE} = 23.0 \text{ ksi} \quad ; \text{ok}$

Structural Analysis of Mixer Pump Assembly8.3 Maximum Deflection of Side Rails

Maximum deflection of the side rail occurs under Extreme Case Loading. This value is important due to the 3/8" clearance between the bottom of the side rail angle member and the top of the riser spray ring. Treating the side rail as a fixed ended beam with a concentrated load at its midpoint results in the following equation for deflection:

$$\Delta_{\max} = \frac{PL^3}{192EI}$$

Plugging values in for downward force P (kips), side rail length L (in), and steel modulus of elasticity E (ksi) results in:

$$\Delta_{\max} = \frac{(16)(52)^3}{192(30 \times 10^3)I}$$

$$\Delta_{\max} = \frac{0.390}{I_x}$$

Assuming deflection is about the geometric (x-axis) shown in Figure B-6, the moment of inertia is $I_x = 16.6 \text{ in}^4$ from Section 8.1. The maximum deflection is:

$$\Delta_{\max} = \frac{0.390}{16.6} = 0.023 \text{ inch}$$

==> Since maximum deflection is less than side rail-to-spray ring clearance, design is ok.

$$\Delta = 0.023" < 0.375" \quad ; \text{ok}$$

Structural Analysis of Mixer Pump Assembly8.4 Combined Compression and Bending Load on the Corner ColumnsDetermine Allowable StressesSimplifying Assumptions (in addition to previous assumptions)

1. The built-up column, which consists of an L 4" x 4" x 3/8" gusseted by (2) 12" W x 1/4" thick steel plates, shall be treated as an L 4" x 4" x 5/8" having the moment of inertia of a 12" x 12" x 1/4" angle member.

See Figure B-7 for a sketch of the built-up corner column. The principle axis properties of a 12" x 12" x 1/4" angle can be determined using Table 1 from Reference B-10, "Roark's Formulas for Stress and Strain":
(see Figure B-7)

$$\begin{aligned}
 A &= t(2a - t) = 5.93 \text{ in}^2 \\
 I_z &= (a^4 - b^4)/12 - (0.5ta^2b^2)/(a + b) = 34.9 \text{ in}^4 \\
 I_w &= (a^4 - b^4)/12 = 139.6 \text{ in}^4 \\
 r_z &= (I_z / A)^{1/2} = 2.42 \text{ in} \\
 r_w &= (I_w / A)^{1/2} = 4.85 \text{ in} \\
 y_{1a} &= 4.37 \text{ in} \\
 y_{1b} &= 4.28 \text{ in} \\
 y_2 &= 8.48 \text{ in} \\
 S_w &= I_w / y_2 = 139.6 / 8.48 = 16.5 \text{ in}^3 \\
 S_z &= I_z / y_{1b} = 34.9 / 4.28 = 8.15 \text{ in}^3 \\
 \alpha &= 45^\circ
 \end{aligned}$$

The column is an equal leg angle without lateral-torsional restraint. Accordingly, for major axis bending, the principal bending compression stress f_{bw} shall be limited by F_b in Section 5.1.3 of Reference B-7 where:

$$F_{ob} = C_b \frac{28,250}{l/t}$$

and by b/t provisions in Section 5.1.1.

where: F_{ob} = elastic lateral-torsional buckling stress, ksi
 l = unbraced length, in = 10 in
 t = leg thickness, in $\approx$ 0.625 in
 C_b = bending coefficient dependent on the moment gradient. In this case, $C_b = 1$

$$F_{ob} = (1) \frac{28,250}{10/0.625} = 1766 \text{ ksi}$$

To prevent lateral-torsional buckling, the principal bending compression stress shall not exceed:

when $F_{ob} > F_y$

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$$F_b = [0.95 - 0.50 \sqrt{\frac{F_y}{F_{ob}}}] F_y \leq 0.66 F_y$$

$$F_b = [0.95 - 0.50 \sqrt{\frac{36}{1766}}] 36 \leq 0.66 (36)$$

$$F_b = 31.6 \leq 23.76$$

==> The bending stress is not dictated by lateral-torsional buckling.

The b/t provisions for the compression leg are to prevent local buckling when the tip of the angle leg is in compression.

$$\text{when } b/t \leq 65/(F_y)^{1/2}: \quad 4/0.625 = 6.4 \leq 65/6 = 10.8 \quad ; \text{ok}$$

$$\text{then:} \quad F_b = 0.66 F_y = 23.76 \text{ ksi}$$

==> Major axis bending is governed by the lower of the above allowable stresses.

$$\text{==>} \quad F_{bw} = 23.76 \text{ ksi}$$

For minor axis bending, Section 5.3.1.b of Reference B-7 gives $F_{bz} = 0.66 F_y = 23.76 \text{ ksi}$.

Using Reference B-7 to determine allowable compressive stress, first determine the largest effective slenderness ratio of any unbraced length. The effective length factor, k, is chosen to be 2 per Figure 6.9.5 of Reference B-11 (Salmon & Johnson).

$$kl/r_z = (2)(10 \text{ in})/(2.42 \text{ in}) = 8.3$$

The applicable stress equation is determined by comparing the slenderness ratio to the result of the following equation:

$$C_c = \sqrt{\frac{2\pi^2 E}{Q F_y}}$$

where the reduction factor Q from Section 4 of Reference B-7 equals 1 when $b/t \leq 76/(F_y)^{1/2}$.

Structural Analysis of Mixer Pump Assembly

$$C_c = \sqrt{\frac{2\pi^2 29,000}{(1)(36)}}$$

$$C_c = 126$$

$kl/r_z = 8.3 < C_c = 126$, therefore:

$$F_a = \frac{(1 - \frac{(kl/r)^2}{2C_c^2}) F_y}{5/3 + \frac{3(kl/r)}{8C_c} - \frac{(kl/r)^3}{8C_c^3}}$$

$$F_a = \frac{(1 - \frac{(8.3)^2}{2 \times 126^2}) 36}{5/3 + \frac{3(8.3)}{8 \times 126} - \frac{(8.3)^3}{8 \times 126^3}} = 21.3 \text{ ksi}$$

Determine Calculated Stresses

The bending moment about the principal axes of the column was determined in Section 8.1 for the loading shown in Figure B-5. The values were:

Normal Load Category:	$M_{cw} = 13.5 \text{ in-kips}$	$M_{cz} = 4.82 \text{ in-kips}$
Extreme Load Category:	$M_{cwe} = 96.7 \text{ in-kips}$	$M_{cze} = 33.5 \text{ in-kips}$

The bending stress on the column is:

$$f_b = M_c / S_w$$

Major principle axis bending stress on the column is:

Normal: $f_{bw} = 13.5 \text{ in-kips} / 16.5 \text{ in}_3 = 0.82 \text{ ksi}$

Extreme: $f_{bwe} = 96.7 \text{ in-kips} / 16.5 \text{ in}_3 = 5.9 \text{ ksi}$

Minor principle axis bending stress on the column is:

Normal: $f_{bz} = 4.82 \text{ in-kips} / 8.15 \text{ in}_3 = 0.59 \text{ ksi}$

Extreme: $f_{bze} = 33.5 \text{ in-kips} / 8.15 \text{ in}_3 = 4.1 \text{ ksi}$

Structural Analysis of Mixer Pump Assembly

The compressive stress applied to the column corner is given by:

$$f_a = P/A$$

Where A = cross-sectional area of 12" x 12" x 1/4" angle

$$\begin{aligned}\text{Normal: } f_a &= (2.3 \text{ kips})/(5.93 \text{ in}^2) \\ &= 0.39 \text{ ksi}\end{aligned}$$

$$\begin{aligned}\text{Extreme: } f_{aE} &= (16.0 \text{ kips})/(5.93 \text{ in}^2) \\ &= 2.70 \text{ ksi}\end{aligned}$$

Combined Stresses

The column axial stress ratio is:

$$f_a/F_a = 0.39 \text{ ksi} / 21.3 \text{ ksi} = 0.018$$

When $f_a/F_a \leq 0.15$, AISC Section H1 permits the following:

$$\frac{f_a}{F_a} + \frac{f_{bw}}{F_{bw}} + \frac{f_{bz}}{F_{bz}} \leq 1.0$$

Normal Load Category:

$$\frac{0.39}{21.3} + \frac{0.82}{23.76} + \frac{0.59}{23.76} \leq 1.0$$

$$\Rightarrow 0.02 + 0.03 + 0.02 = 0.07 \leq 1.0 \quad ; \text{ok}$$

Extreme Load Category:

$$\frac{f_{aE}}{1.6 F_a} + \frac{f_{bwE}}{1.6 F_{bw}} + \frac{f_{bzE}}{1.6 F_{bz}} \leq 1.0$$

$$\frac{2.70}{34.1} + \frac{5.9}{38.0} + \frac{4.1}{38.0} \leq 1.0$$

$$\Rightarrow 0.08 + 0.15 + 0.11 = 0.34 \leq 1.0 \quad ; \text{ok}$$

8.5 Pump Support Frame Side Rail to Column Welds

The welds that attach the side rails to the angle iron columns are modeled based on Section 7.4 of Reference B-12, "Design of Welded Structures", by O. W. Blodgett and pg. 4-72 of AISC (Reference B-5). They will be analyzed using the elastic vector method of weld analysis, which generally yields conservative results. By assuming each weld element as a line coincident with the edge of a fillet weld, each unit element is assumed to support an equal share of the vertical and horizontal components of the load, and a proportional share of the eccentric moment portion of the load. The maximum load is determined from the vectorial resolution of these stresses at the element most remote from the group's centroid.

The weld under consideration is a 1/4" fillet as seen in drawing H-2-85261 and Figure B-8.

Assumptions (in addition to previous assumptions):

1. The weld can be represented as a 4" x 4" square (see Figure B-8).
2. Strengthening effects of the corner rail and gusset plate are ignored for simplicity and conservatism.
3. The resulting loading on the welds is a combination of twist and shear.

Determine the center-of-gravity of the weld:

$$\begin{aligned}x &= 2 \text{ in} \\y &= 2 \text{ in}\end{aligned}$$

The weld length is: $L_w = (4)(4 \text{ in}) = 16 \text{ in}$

From Blodgett (Reference B-12) the polar moment of inertia of the weld is:

$$J_w = (b + d)^3/6 = (4 + 4)^3/6 = 85.3 \text{ in}^3$$

1. Twisting (horizontal component)

$$f_{th} = Tc_h/J_w$$

where: c_h = vertical distance from weld center of gravity to outermost point of section, in = 2.0 in
 T = twisting moment, in-kips = $PL_o/8$ for fixed beam
 f_{th} = horizontal component of twisting force per inch of weld, kips/in

Normal Load Category:

$$f_{th} = (2.3 \text{ kips})(52 \text{ in})(2 \text{ in})/(8)(85.3 \text{ in}^3) = 0.35 \text{ kips/in}$$

Structural Analysis of Mixer Pump Assembly

Extreme Load Category:

$$f_{thE} = (16.0 \text{ kips})(52 \text{ in})(2 \text{ in}) / (8)(85.3 \text{ in}^3) = 2.4 \text{ kips/in}$$

2. Twisting (vertical component)

$$f_{tv} = Tc_v / J_w$$

where: c_v = horizontal distance from weld center of gravity to outermost point of section, in = 2.0 in
 T = twisting moment, in-kips = $PL_o/8$ for fixed beam

By symmetry, $f_{tv} = f_{th}$.

3. Vertical shear

$$f_v = P / L_w$$

Vertical load acting on each weld equals $P/2$. Therefore:

Normal Load Category: $P_D/2 = 2.3/2 = 1.15 \text{ kips}$

Extreme Load Category: $P_E/2 = 16.0/2 = 8.0 \text{ kips}$

Normal Load Category:

$$f_v = 1.15 \text{ kips} / 16 \text{ in} = 0.07 \text{ kips/in}$$

Extreme Load Category:

$$f_{vE} = 8.0 \text{ kips} / 16 \text{ in} = 0.50 \text{ kips/in}$$

Resultant force on welds

$$f_r = \sqrt{f_{th}^2 + (f_{tv} + f_v)^2}$$

Normal Load Category:

$$f_r = \sqrt{0.35^2 + (0.35 + 0.07)^2} = 0.54 \text{ kips/inch}$$

Extreme Load Category:

$$f_{rE} = \sqrt{2.4^2 + (2.4 + 0.50)^2} = 3.76 \text{ kips/inch}$$

Structural Analysis of Mixer Pump Assembly

Weld size $0.707w = f_r / F_v$

where: w = required weld size, in
 0.707 = converts weld leg thickness to weld effective throat thickness
 f_r = resultant force per inch of weld, in
 F_v = allowable shear stress on weld, ksi (see Section 6)

Normal Load Category:

$\Rightarrow$ $w = 1.41(0.54 \text{ kips/in}) / 21.9 \text{ ksi} = 0.035 \text{ in}$
 $0.035 < 0.25$; 1/4" fillet weld is ok

Extreme Load Category:

$\Rightarrow$ $w = 1.41(3.76 \text{ kips/in}) / 29.4 \text{ ksi} = 0.18 \text{ in}$
 $0.18 < 0.25$; 1/4" fillet weld is ok

8.6 Pump to Pump Stand Bolting

The pump adaptor flange is bolted to the pump stand with (4) equally spaced 3/4" diameter ASTM A325 bolts. See H-2-85261, H-2-85264, and Figure B-2 of this document. Shortest distance from the center of the 13/16" diameter hole in the pump stand corner rail to the rail's edge is 2", which meets the minimum edge distance requirement of 1" given by Table J3.5 of AISC. The horizontal shear force and moment on the pump stand due to a seismic event were determined in Sections 7.3 and 7.4 to be:

$$M_A = 736 \text{ in-kips}$$

$$P_h = 2.21 \text{ kips}$$

Maximum tension on any one bolt is given by (conservatively for y-y direction):

$$P_t = M_A / \text{bolt-to-bolt distance (see Figure B-2)}$$

$$= 736 \text{ in-kips} / 48 \text{ in}$$

$$P_t = 15.3 \text{ kips}$$

$$\text{Tensile stress area, } A_{\text{bolt}} = 0.334 \text{ in}^2 \text{ for } 3/4" \text{ dia. bolts}$$

$$f_t = P_t / A_{\text{bolt}} = 15.3 \text{ kips} / 0.334 \text{ in}^2 = 45.8 \text{ ksi}$$

$\Rightarrow$ $f_t = 45.8 \text{ ksi} < F_t = 70.4 \text{ ksi}$; ok

Structural Analysis of Mixer Pump Assembly

Shear force on each bolt is given by:

$$P_v = P_h / \text{number of bolts}$$

$$= 2.21 \text{ kips} / 4$$

$$P_v = 0.553 \text{ kips}$$

$$f_v = P_v / A_{\text{bolt}} = 0.553 \text{ kips} / 0.334 \text{ in}^2 = 1.65 \text{ ksi}$$

$$f_v = 1.65 \text{ ksi} < F_v = 23.8 \text{ ksi} \quad ; \text{ok}$$

8.7 Pump Stand Base Plate Calculations

Pump stand base plates are made of ASTM A36 carbon steel and welded to the built-up column. Grout is to be placed underneath the base plates for the purpose of leveling the pump stand and transmitting loads to the pit floor. A typical base plate is shown in Figure B-9. From AISC, Sect. J-9 (Reference B-5), the minimum required base plate area, A_1 , is:

$$A_1 \geq P_E / 0.7 f_c = 16.0 \text{ kips} / 0.7(3 \text{ ksi}) = 7.6 \text{ in}^2$$

The actual base plate area is:

$$\begin{aligned} & (17.5")(5.5") = 96.25 \text{ in}^2 \\ + & (12.0")(5.5") = 66.00 \text{ in}^2 \\ \text{====>} & A_2 = 162.25 \text{ in}^2 > 7.6 \text{ in}^2 \quad ; \text{ok} \end{aligned}$$

Drawing H-2-72010 calls out a non-shrink grout with a minimum compressive strength of 7 ksi at 28 days. The pit concrete minimum compressive strength, f_c , is 3 ksi; this value will be used for calculations. From AISC, Sect. J-9, the allowable bearing stress on concrete is:

$$F_p = 0.35 f_c = 0.35(3 \text{ ksi}) = 1.05 \text{ ksi}$$

The calculated bearing stress which would occur during an earthquake is:

$$f_p = P_E / A_2 = 16.0 \text{ kips} / 162.25 \text{ in}^2 = 0.099 \text{ ksi}$$

$$\text{====>} \quad f_p < F_p \quad ; \text{ok}$$

Base plate thickness can be estimated using a design procedure presented in AISC, p. 3-106, and Reference B-12 (Blodgett). The primary function of the plate thickness is to provide sufficient resistance to the bending moment on the overhanging portion of the plate. The overhanging portion of the plate is modeled as a cantilever beam with its fixed end at the column's edge. The formula from AISC for estimating plate thickness, t_p , is:

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$$t_p = 2m \sqrt{\frac{f_p}{F_y}}$$

See Figure B-9 (baseplate drawing) for dimension m.

$$t_p = 2(4.25) \sqrt{\frac{0.099}{36}} = 0.44$$

8.8 Concrete Anchor Bolting of Pump Stand

The pump stand base plate is designed with installation in mind, in particular the possibility of hitting rebar when drilling holes for the expansion anchor bolts. The pit concrete has #5 rebar on 12 inch centers in each direction according to drawing H-2-71912. On Figure B-9, there are (5) 1-1/8" diameter holes in each base plate available to house 1" diameter Hilti Kwik-Bolt II anchor bolts, spaced so that one of the following conditions can always be met:

1. Two (2) anchors at standard embedment with anchor spacing and edge distance required to develop maximum allowable load.
2. Three (3) anchors at standard embedment, minimum allowable anchor spacing, and edge distance required to develop maximum allowable load. Table C-6 of SDC 4.2 mandates a 30% reduction in the working load when using minimum allowable anchor spacing.

From Section 8.5, the shear force at each corner of the pump stand is:

$$P_v = 0.553 \text{ kips}$$

which divided among 2 bolts gives:

$$P_v = 0.553 \text{ kips} / 2 = 0.277 \text{ kips per bolt}$$

and divided among 3 bolts gives:

$$P_v = 0.553 \text{ kips} / 3 = 0.184 \text{ kips per bolt}$$

From Figure B-10 (pump stand), the seismic induced tensile force in the x'-x' direction is the most critical. For 2 bolts:

$$\begin{aligned} P_t &= M_A / (\text{average bolt-to-bolt distance})(\# \text{ of bolts in tension}) \\ &= 736 \text{ in-kips} / (70 \text{ in})(2) \end{aligned}$$

$$P_t = 5.26 \text{ kips}$$

Structural Analysis of Mixer Pump Assembly

For 3 bolts:

$$P_t = 736 \text{ in-kips} / (70 \text{ in})(3)$$

$$P_t = 3.50 \text{ kips}$$

Case #1

Per SDC 4.2, Table 16 for $f'_c = 3000 \text{ psi}$, (Note: This table is valid for safety class 1, 2, 3, or 4 applications):

- Choose 1" diameter stainless steel Hilti Kwik-Bolt II anchors
- Minimum concrete compressive strength: 3,000 psi (from H-2-71912 & H-2-71916)
- Standard embedment depth: 6"
- Edge distance to obtain maximum working load: 10"
- Spacing between anchors to obtain maximum working load: 12"
- Allowable tensile and shear loads:

$$P_{t \text{ allow}} = 6.00 \text{ kips}$$

$$P_{v \text{ allow}} = 6.16 \text{ kips}$$

- The criterion to be satisfied is: $P_v/P_{v \text{ allow}} + P_t/P_{t \text{ allow}} \leq 1$

$$0.277/6.16 + 5.26/6.00 = 0.04 + 0.88 = 0.92 \leq 1 \quad ; \text{ok}$$

Case #2

Per SDC 4.2, Table 16 for $f'_c = 3000 \text{ psi}$, (Note: This table is valid for safety class 1, 2, 3, or 4 applications):

- Choose 1" diameter stainless steel Hilti Kwik-Bolt II anchors
- Minimum concrete compressive strength: 3,000 psi (from H-2-71912 & H-2-71916)
- Standard embedment depth: 6"
- Edge distance to obtain maximum working load: 10"
- Minimum allowable spacing between anchors: 6" (30% reduction in working load)
- Allowable tensile and shear loads:

$$P_{t \text{ allow}} = (0.70)6.00 \text{ kips} = 4.20 \text{ kips}$$

$$P_{v \text{ allow}} = (0.70)6.16 \text{ kips} = 4.31 \text{ kips}$$

- The criterion to be satisfied is: $P_v/P_{v \text{ allow}} + P_t/P_{t \text{ allow}} \leq 1$

$$0.184/4.31 + 3.50/4.20 = 0.04 + 0.83 = 0.87 \leq 1 \quad ; \text{ok}$$

Structural Analysis of Mixer Pump Assembly8.9 Drilling Through Pump Pit Floor Rebar

When drilling holes for the Hilti bolts that fasten the pump stand to the floor of the pump pit, it is likely that the top layer of rebar in the pit floor will be hit. The pit concrete has two layers of #5 rebar on 12 inch centers in each direction according to drawing H-2-71912. Question: Is it permissible to cut through rebar in the top layer? Answer: Yes, with the following justification.

Without Mixer Pump Installed

The dead load on the pump pit floor totals the weight of the pit walls and cover blocks. This load is transmitted downward at the perimeter of the pit. The need for an upper layer of rebar is based on the amount of center lift (negative moment) that can occur. Center lift, in turn, is partly based on the sub-base deflection that occurs. A relatively pliable sub-base, such as clay, can be compressed at the load points (the perimeter) causing deflection which results in a negative bending moment, putting the upper layer of rebar in tension. A relatively rigid and unyielding sub-base, such as the 107-AN concrete tank dome, permits very little deflection for all but the largest loads. Therefore very little tension is applied to rebar in the upper portion of the slab. An example would be laying a plank down on a sidewalk and placing a large vertical load at each end. Because the sidewalk is rigid, the plank can not bend at its center.

With Mixer Pump Installed

The loading on the upper portion of the pump pit floor with the addition of the mixer pump / pump stand is compressive. Rebar in the compression zone is not required as it does not significantly add to slab strength. The pit concrete compressive strength, 3 ksi, is adequate per Section 8.7 of this Appendix. Punching shear is not a realistic failure mode due to the thick slab and relatively light column loads. In the case of a seismic event, the anchor bolt analysis shown in the previous section is applicable.

Structural Analysis of Mixer Pump Assembly**9.0 REFERENCES****9.1 DOCUMENTS**

- B-1 SDC 4.1, Standard Arch-Civil Design Criteria, "Design Loads for Facilities", Rev. 12, September 1993.
- B-2 LA-UR-92-3196, "A Safety Assessment for Proposed Pump Mixing Operations to Mitigate Episodic Gas Release in Tank 241-101-SY", Rev. 3, May 1993.
- B-3 WHC-SD-GN-DGS-30006, "Guidelines for Assessing the Seismic Adequacy of Safety Class 3 and 4 Equipment at the Hanford Site", Rev. 1, 1993.
- B-4 WHC-SD-WM-DA-111, "Structural Analysis of Tank 241-SY-101 Mixing Pump", Rev. 1-A, November 1993.
- B-5 American Institute of Steel Construction, "Manual of Steel Construction, Allowable Stress Design", 1989.
- B-6 ANSI/AISC N690, "Nuclear Facilities - Steel Safety-Related Structures for Design Fabrication and Erection".
- B-7 American Institute of Steel Construction, "Allowable Stress Design of Single-Angle Members", 1989.
- B-8 Uniform Building Code, 1991.
- B-9 Blevins, Robert D., "Flow-Induced Vibration", 2nd Edition, 1990.
- B-10 Young, Warren C., "Roark's Formulas for Stress & Strain", 6th Edition, 1989.
- B-11 Salmon, Charles G., and Johnson, John E., "Steel Structures - Design and Behavior", 3rd Edition, 1990.
- B-12 Blodgett, Omer W., "Design of Welded Structures", 1966.
- B-13 SDC 4.2, Standard Arch-Civil Design Criteria, "Design and Installation of Expansion Anchors", Rev. 0, October 1992.

9.2 CERTIFIED VENDOR INFORMATION (CVI 22528)

Hazleton Bulletin 48,049, "Operation & Maintenance Manual for 5N-Hazleton Type SSB/Mixing Pump", Barrett, Haentjens & Co., Hazleton, Pa 18201, 1/21/88.

E-20801, Rev. 2, "Elevation", Hazleton 5N SSB Pump/Mixer, Model #360-75-1800 (R), Order #T7N-XBB-423827, 4-2-87.

17490B, "Grease Arrangement", Hazleton 5N Type SSB Pump/Mixer, 12-21-87.

NOTE: CG and all measurements relative to Line A.
Line A is defined as the top of the 52" adaptor plate.
Figure B-1 Mixer Pump Assembly with Applied Forces
(No Scale)

FIGURE B-2
MIXER PUMP TURNTABLE ASSEMBLY
PLAN VIEW

FIGURE B-3 PUMP STAND ISOMETRIC

Figure B-4 Applied Load on Rigid Frame

(Use proper signs for moments.)

At corners,

$$M_c = -\frac{Pb}{8} \left[\frac{\frac{3b}{I_b}}{\frac{3b}{I_b} + \frac{2d}{I_d}} \right]$$

At center,

$$M_b = M_c + \frac{Pb}{4}$$

$$F = \frac{M_c}{d}$$

Figure B-5 Rigid Frame Force & Moment Diagrams
(From Blodgett, Reference B-12)

Note: At point of greatest moment (center of side rail, see Figure B-5), the compression leg has been shaved $\frac{1}{2} \text{ in}$ to allow removal of shield plug. For conservatism, properties of an $L 6 \times 3 \frac{1}{2} \times \frac{1}{2}$ are used (shown above) instead of $L 6 \times 4 \times \frac{1}{2}$ properties.

Figure B-6 Side Rail Cross-Section
Scale: $\frac{1}{2} \text{ in} = 1 \text{ in}$

$$y_{1a} = \frac{0.7071(a^2 + at - t^2)}{2a - t}$$

$$y_{1b} = \frac{0.7071a^2}{2a - t}$$

$$y_2 = 0.7071a$$

$$I_z = \frac{a^4 - b^4}{12} - \frac{0.5a^2b^2}{a+b}$$

$$I_w = \frac{a^4 - b^4}{12} \quad \text{where } b = a - t$$

From Roark's Formulas for Stress and Strain

Figure B-7 Built-Up Column Cross-Section

Figure B-8 Side Rail to Column Welds

PLATFORM BASE

SCALE: 1/4

FIGURE B-9

FIGURE B-10 ANCHOR BOLT FORCE DIAGRAM

APPENDIX C - BLOCKED NOZZLE CALCULATIONS

Analyst: G. A. Leshikar

Reviewer: J. A. Tuck

Independent Review Checklist for Verification of Analysis/Calculations (from EP 1.11)

Document Checked - Number: Appendix C Revision: 0
 Title: Blocked Nozzle Calculations

Yes	No	N/A	
☒	☐	☐	Problem completely defined.
☒	☐	☐	Appropriate analytical method used.
☒	☐	☐	Necessary assumptions are appropriate, explicitly stated, and supported.
☐	☐	☒	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Sources of non-standard formulae/data are referenced and the correctness of the reference verified.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☐	☐	☒	Mathematical derivations checked including dimensional consistency of results.
☐	☐	☒	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors.
☐	☐	☒	Code run streams correct and consistent with analysis documentation.
☐	☐	☒	Code output consistent with input and with results reported in analysis documentation.
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

I have checked the analysis/calculation and it is complete and accurate to the best of my knowledge.

James A. Tice 22 Nov 94
 Engineer/Checker Date

Note: Any hand calculations, notes, or summaries generated as part of this check should be signed, dated, and attached to this checklist. Material should be labeled and recorded so that it is intelligible to a technically qualified third party.

Blocked Nozzle Calculations**1.0 OBJECTIVE**

The objective of this analysis is to determine the adequacy of the mixer pump for unbalanced forces caused by a blocked or plugged discharge nozzle.

2.0 BACKGROUND

The Hazleton 75 HP submersible mixer pump, S/N N-20801, has two opposing discharge nozzles located at its bottom, about 1 foot above the tank floor. Normally the jet forces will cancel each other out. With one nozzle blocked or plugged, the pump will experience assymetrical thrust corresponding to the hydraulic force through one nozzle.

Due to the characteristics of the waste within Tank 107-AN, plugging of the discharge nozzles is not expected. For more information see internal memo 7C240-93-062, "Revised Estimate for Caustic Addition to Tank 107-AN Waste", D. H. Fouad to K. G. Carothers, 9-15-93, and WHC-SD-WM-HIE-003, Rev. 0, "Safety Basis for the 241-AN-107 Mixer Pump Installation and Caustic Addition. 10-4-94.

The mixer pump has a load cell attached to the pump support column that will warn when the pump experiences assymetrical thrust.

3.0 NOMENCLATURE

A_{bolt}	= Cross-sectional area of bolt, in ²
f_b	= Bending stress, ksi
F_b	= Allowable bending stress, ksi
f_v	= Shear stress, ksi
F_v	= Allowable shear stress, ksi
F_u	= Ultimate stress of material, ksi
F_y	= Yield stress of material, ksi
L_d	= Distance from bumper blocks to discharge nozzle centerline, in
L_e	= Distance from top of nozzle extension to discharge nozzle centerline, in
L_f	= Center to center distance between discharge legs, in
m	= Mass flow thru discharge nozzle, lb/s
M_A	= Moment at adaptor flange, in-kips
M_C	= Moment at top of nozzle extensions, in-kips
ρ	= Waste density, lb/ft ³
P_n	= Force due to a blocked discharge nozzle, lb
P_v	= Shear force, lb
P_t	= Tensile force, lb
Q	= Volumetric flow rate, ft ³ /s
V	= Velocity of jet discharging from nozzle, ft/s

Blocked Nozzle Calculations**4.0 ALLOWABLE STRESSES**

Pump support column allowable stresses are based on AISC criteria and are the same as those presented in Appendix B for a normal loading:

$$\begin{aligned} F_b &= 23.1 \text{ ksi} \\ F_v &= 14.0 \text{ ksi} \end{aligned}$$

Type 316 stainless steel bolts are used to attach the nozzle extension assembly to the pump casing. Minimum mechanical properties of 316 stainless steel are (from ASTM F593):

$$\begin{aligned} F_u &= 75 \text{ ksi} \\ F_y &= 30 \text{ ksi} \end{aligned}$$

Bolt allowable stresses are based on AISC criteria:

$$\begin{aligned} F_t &= 0.3 F_u \\ F_v &= 0.22 F_u \end{aligned}$$

$$\begin{aligned} F_t &= 0.3(75 \text{ ksi}) = 22.5 \text{ ksi} \\ F_v &= 0.22(75 \text{ ksi}) = 16.5 \text{ ksi} \end{aligned}$$

5.0 ANALYSIS

The mixer pump will provide 960 gpm and 115 ft of total dynamic head at 1770 rpm. See Figure C-1 for Barrett, Haentjens & Co. centrifugal pump test record. The system curve for one-nozzle operation is shown in Figures C-2 and C-3. The two-nozzle system curve is shown in Figure C-3. When one of the discharge nozzles is blocked, the one-nozzle system curve gives the pump operating point. That point is approximately 520 gpm @ 135 ft of head.

Discharge nozzle diameter is 1.5 inches.

Mass Flow thru one nozzle:

$$m = Q \rho \quad \Rightarrow \text{Specific gravity of waste} = 1.4$$

$$m = 520 \text{ gpm} (ft^3/7.48 \text{ gallon})(\text{min}/60 \text{ sec})(62.4 \text{ lb}/ft^3)(1.4)$$

$$m = 1.16 \text{ ft}^3/\text{sec} (62.4 \text{ lb}/ft^3)(1.4)$$

$$m = 100.4 \text{ lb}/\text{sec}$$

Force due to a blocked nozzle:

$$P_n = mV/g$$

$$V = Q / \text{Area of discharge nozzle}$$

Blocked Nozzle Calculations

$$V = 1.16 \text{ ft}^3/\text{sec} / [(\pi 1.5''^2 / 4)(\text{ft}^2/144 \text{ in}^2)]$$

$$V = 94.4 \text{ ft/sec}$$

$$P_n = (100.4 \text{ lb/sec})(94.4 \text{ ft/sec}) / 32.2 \text{ ft/sec}^2$$

$$P_n = 294 \text{ lb or } 0.294 \text{ kips}$$

Resultant Moment at the Adaptor Flange:

$$M_A = P_n L_d = (294 \text{ lb})(598 \text{ in}) = 176 \text{ in-kips}$$

This is less than the moment due to an earthquake per Appendix B ;ok

Resultant Moment at Top of Nozzle Extension:

$$M_C = P_n L_e = (294 \text{ lb})(74 \text{ in}) = 21.8 \text{ in-kips}$$

Stresses on Nozzle Extension due to Blocked Nozzle

Determine the load on (4) - 1/2" dia. Type 316 stainless steel flange bolts at top of each leg of nozzle extension assembly. The discharge leg that is experiencing flow will be in compression and the plugged discharge leg will be in tension. See Figure C-4.

Tensile Load at Flange due to moment generated by unbalanced forces:

$$P_t = M_C / L_f$$

$$P_t = 21.8 \text{ in-kips} / 22.19 \text{ in} = 0.98 \text{ kips}$$

Tensile stress on each flange bolt:

$$A_{\text{bolt}} = 0.1419 \text{ in}^2$$

$$f_t = P_t / (A_{\text{bolt}})(\# \text{ of Bolts})$$

$$= 0.98 \text{ kips} / (0.1419 \text{ in}^2)(4)$$

$$f_t = 1.7 \text{ kips}$$

$$\Rightarrow f_t = 1.7 \text{ kips} < F_t = 22.5 \text{ ksi} \quad \text{:ok}$$

Shear Load at Flange due to moment generated by unbalanced forces:

$$P_n = 0.294 \text{ kips, from above}$$

Blocked Nozzle Calculations

Shear stress on each flange bolt:

$$P_v = P_n / (\text{total \# of bolts at both flanges})$$

$$P_v = 0.294 \text{ kips} / 8 = 0.036 \text{ kips}$$

$$f_v = P_v / A_{\text{bolt}}$$

$$= 0.036 \text{ kips} / 0.1419 \text{ in}^2 = 0.259 \text{ ksi}$$

$$f_v = 0.259 \text{ ksi} < F_v = 16.5 \text{ ksi}$$

Nov. 12/97

BARRETT, HAENTJENS & CO. HAZLETON, PA. 18201
 5" N HAZLETON TYPE "SSB" PUMP/MIXER N-20801
 NOZZLE "A" CALIBRATION CURVE

T.D.H. IN FEET

Figure C-2
 12/9/87
 Craig Shaw

DATE: 12-7-87
 BY: [Signature]
 CERTIFIED
 BARRETT, HAENTJENS & CO.
 HAZLETON, PA. 18201

SENT BY:HAZLETON PUMPS

:11-22-94 :11:47AM : HAZLETON APPL. ENG. -

HAZLETON PUMPS, INC.

A MEMBER OF THE WARMAN INTERNATIONAL GROUP

WHC-SD-WM-DA-148

Revision 0

Page C-9.0:# 1/ 1

HAZLETON, PA 18201-0488 Telephone: 717-455-7711 Fax: 717-459-2586

CHARACTERISTIC CURVE 5BN TYPE SSB PUMP @ 1770 RPM

Figure C-3

FIGURE C-4. NOZZLE EXTENSIONS

APPENDIX D - CENTER OF GRAVITY AND WEIGHTS

Analyst: G. A. Leshikar

Reviewer: J. A. Tuck

Independent Review Checklist for Verification of Analysis/Calculations (from EP 1.11)

Document Checked - Number: Appendix D Revision: 0

Title: Center of Gravity and Weights of Mixer Pump

Yes	No	N/A	
☒	☐	☐	Problem completely defined.
☒	☐	☐	Appropriate analytical method used.
☒	☐	☐	Necessary assumptions are appropriate, explicitly stated, and supported.
☐	☐	☒	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Sources of non-standard formulae/data are referenced and the correctness of the reference verified.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☐	☐	☒	Mathematical derivations checked including dimensional consistency of results.
☐	☐	☒	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors.
☐	☐	☒	Code run streams correct and consistent with analysis documentation.
☐	☐	☒	Code output consistent with input and with results reported in analysis documentation.
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

I have checked the analysis/calculation and it is complete and accurate to the best of my knowledge.

William A. Turk 22 Nov 94
Engineer/Checker Date

Note: Any hand calculations, notes, or summaries generated as part of this check should be signed, dated, and attached to this checklist. Material should be labeled and recorded so that it is intelligible to a technically qualified third party.

NOTE: CG and all measurements relative to Line A.
 Line A is defined as the top of the 52' adaptor plate.
 Figure B-1 Mixer Pump Assembly with Applied Forces
 (No Scale)

1. FLANGE ASSEMBLY

Item	Weight (lb)	Center of Gravity (Ref to Line A) (in)	Wt x CG (lb x in)
1 HP Reliance Motor	50	21	1050
Gear Motor Speed Reducer	120	12	1440
Mounting Plate, 45" Dia. OD, 20" ID (45x45 - 20x20)pi/4 x (1 3/8")(.283 lbs/in3)	497	0.6875	342
*Adaptor Plate, 52" Dia. OD, 34" ID (52x52 - 34x34)pi/4 x (1 3/8")(.283 lbs/in3)	473	-0.6875	-325
Lifting Lugs	35	7.5	263
26" Dia. Pipe, 16 1/2" long, 1/4" thck 26" x pi (16 1/2")(1/4")(.283 lbs/in3)	95	-8.25	-784
Rim on 26" Dia. Pipe, 1/4" thck 26"pi (4")(1/4")(.283 lbs/in3)	23	-16.5	-380
Carbon Bumper Blocks (3) 6 lbs(ea)	18	-17.25	-311
Mounting Plate, 28" Dia. (28"x28")pi/4 (1 3/8")(.283 lbs/in3)	240	4.125	990
Bearing Track Assbly	35	3	105
Misc. Bolts	30	1.5	45
Flange on Top of the 10 3/4" Pipe 14"pi x (5/8")(4")(.283 lbs/in3)	31	3.5	109
*2" Pipes & Attachments 4 ft x 3 lbs/ft x 1.25#	15	-8	-120
TOTAL	1662		2424

* - Items added during assembly at WHC

- 25% factor to account for extra weight of fittings

Weight not including * items: 1174 lbs

CG = SUM WTxCg/SUM WT = 2424 in lbs/1662 lbs = 1.46" above Line A

2. SHAFT ASSEMBLY

Item	Weight (lb)	Center of Gravity (Ref to Line A) (in)	Wt x CG (lb x in)
10" Schd 40 Pipe 40.5 lbs/ft x 38 1/2 ft	1559	-229	-357011
(2) Flanges (2) 12 1/2"(pi)(5/8)(.283 lbs/in ³)	14	-131	-1834
Flange	14	-282	-3948
Flange	14	-462	-6468
*Flexhose (2)(72")(2.5lb/ft)(ft/12in)	30	-52	-1560
*(2) 1 1/2" Schd 40 Piped Fittings (2)(32.5ft)(3lb/ft)(1.25)#	243	-267	-64881
Misc. Electrical Fastners	100	-231	-23100
*Bump Guards (2) 7 1/2"x14"(1/2)(1/4")(.283lbs/in ³)	7	-126	-882
*Bump Guards	7	-277	-1939
*Bump Guards	7	-457	-3199
TOTAL	1995		-464822

* - Items added during assembly at WHC

- 25% factor to account for extra weight of fittings

Weight not including * items: 1701 lbs

CG = SUM WTxCG/SUM WT = -464822in lbs/1995 lbs = 232.99" Below Line A

3. PUMP MOTOR ASSEMBLY

Weight of the pump motor assembly = Total wt - (sections 1 & 2)

Total wt. from manufacturer = 6710 lbs (see CVI 22528)

Wt. of section 1 not incl "*" items = 1174 lbs

Wt. of section 2 not incl "*" items = 1701 lbs

Wt. of section 3 = 6710 lbs - (1174 + 1701)lbs = 3835 lbs

Assume the CG at approx. 2/3 down the length.

Length = 5' - 1" = 61"

CG = -462 + [(-)2/3(61)] = -503" Below Line A

Item	Weight (lb)	Center of Gravity (Ref to Line A) (in)	Wt x CG (lb x in)
Pump Motor Assbly (for Wt. & CG, see above)	3835	-503	-1929005
*(2) 1/2" Schd 40 Pipe & Fittings (2)(61")(3lb/ft)(ft/12in)(1.25)	38.1	-492.5	-18764
TOTAL	3873.1		-1947769

* - Parts added at WHC

CG = SUM WTxCG/SUM WT = -1947769in lbs/3873.1 lbs = 502.9" Below Line A

4. NOZZLE EXTENSION ASSEMBLY

Item	Weight (lb)	Center of Gravity (Ref to Line A) (in)	Wt x CG (lb x in)
(2) 4" Schd. 40 Flanges (2)(6x6-4.375x4.375)pi/4(.5")(.283 lbs/in3)	3.7	-524	-1939
(2) 4" Schd. 40 Flanges	3.7	-591	-2187
(2) Schd. 4" 40 Pipe, 67 3/4" long (2)(67 3/4")(ft/12in)(10.79 lbs/ft) (discharge pipes)	121.8	-557	-67843
2 x 2 Horizontal Bracing (2+2)"(1/4")(.283 lbs/in3)(17.7")	5	-546.5	-2733
2 x 2 Horizontal Bracing	5	-560.3	-2802
2 x 2 Horizontal Bracing	5	-574	-2870
2 x 2 Horizontal Bracing	5	-587.8	-2939
2 x 2 Angle Bracing (2+2)"(1/4")(.283 lbs/in3)(22.4")	6.3	-556.3	-3505
2 x 2 Angle Bracing	6.3	-570	-3591
2 x 2 Angle Bracing	6.3	-583.8	-3678
(2) Nozzles	25	-593.8	-14845
1 1/2" Schd. 40 Pipe & Fittings (87")(3lb/ft)(ft/12in)(1.25)#	26.6	-557	-14816
3/4" Schd. 40 Pipe (76")(1lb/ft)(ft/12in)(1.25)#	7.7	-557	-4289
1/2" Schd. 40 Pipe (18")(.851 lbs/ft)(ft/12in)(1.25)#	1.6	-593.8	-950
Misc. Bracing Tabs	20	-573	-11460
TOTAL	247.4		-139495

25% factor to account for extra weight of fittings

$$CG = \text{SUM } WT \times CG / \text{SUM } WT = -139495 \text{ in lbs} / 247.4 \text{ lbs} = 563.84" \text{ Below Line A}$$

PUMP STAND

Item	Weight (lb)	Center of Gravity (Ref to Line A) (in)	Wt x CG (lb-in)
L 6 x 4 x 1/2 (4)(16.2 lb/ft)(52")(ft/12")	281.00	1.96	550.76
L 4 x 4 x 3/8 (4)(9.8 lb/ft)(13")(ft/12")	43.00	-0.14	-6.02
L 4 x 4 x 3/8 (4)(9.8 lb/ft)(13")(ft/12")	43.00	5	215.00
Plate (8)(1/4" steel @ 11.26 lb/ft ²) x (12")(6")(ft ² /144in ²)	45.00	7	315.00
Plate (4)(1/2" steel @ 21.47 lb/ft ²) x (29")(5.5")(ft ² /144in ²)	95.00	10	950.00
TOTAL	507.00		2,024.74

$$CG = \frac{\sum Weight}{\sum Weight \times CG} = \frac{2024.74}{507} = 4.0$$

Center of gravity is 4.0 inches below line A.

TOTALS

Total Weight of Pump = 7778. 1b

Total Weight of Pump and Pump stand = 8285. 1b

Total Weight of Pump Assembly located below the mounting flange = 6115.5 1b

Overall CG of Pump Assembly located below the mounting flange (Sections 2,3, & 4) =

$$\frac{\sum (WT_2 CG_2) + (WT_3 CG_3) + (WT_4 CG_4)}{WT_2 + WT_3 + WT_4}$$

$$(464822 + 1947769 + 139495) / (1995 + 3873 + 247) = -417" \text{ below line A}$$

APPENDIX E - PUMP YOKE ANALYSIS

Analyst: J. A. Tuck

Reviewer: J. R. Kriskovich

Independent Review Checklist for Verification of Analysis/Calculations (from EP 1.11)

Document Checked - Number: Appendix E Revision: 0

Title: AN-107 MIXER PUMP YOKE

Yes	No	N/A	
☒	☐	☐	Problem completely defined.
☒	☐	☐	Appropriate analytical method used.
☒	☐	☐	Necessary assumptions are appropriate, explicitly stated, and supported.
☐	☐	☒	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☐	☐	☒	Sources of non-standard formulae/data are referenced and the correctness of the reference verified.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☒	☐	☐	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors.
☐	☐	☒	Code run streams correct and consistent with analysis documentation.
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☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

I have checked the analysis/calculation and it is complete and accurate to the best of my knowledge.

Jim Bustard
Engineer/Checker

9-19-94
Date

Note: Any hand calculations, notes, or summaries generated as part of this check should be signed, dated, and attached to this checklist. Material should be labeled and recorded so that it is intelligible to a technically qualified third party.

PUMP YOKE ANALYSIS FOR THE AN-107 CAUSTIC ADDITION MIXER PUMP

1.0 INTRODUCTION

This contains calculations reflecting safe static load test weights and maximum safe rated working capacity for a self locking pump yoke. The yoke will be used for lifting and installing the AN-107 caustic addition mixer pump (WHC, 1992). All work is completed to standards in the *Hanford Site Hoisting and Rigging Manual* (DOE-RL 1993).

2.0 DISCUSSION

The basic pump yoke design is per H-2-35765, *Self Locking Pump Yokes*, (US-AEC/ARHC, 1970). The yoke in question is modified in the following ways:

Part No. 10, spreader beam, is lengthened to 48 inches and made from a W 8x15 section, instead of an S 8x18.4 section per the drawing. In addition, the beam is reinforced with 4 stiffening ribs instead of the original single rib.

Part No. 11, lifting bail, is 2.5 inches wide x 2 inches thick, instead of 3 in. x 1 in. thick per the drawing.

In addition, the static test load (General Note #4) is reduced from 9 tons to 5.625 tons (11.25 kips), and the maximum rated load from 12,000 lb to 9,000 lb (9 kips). This is more than adequate for the intended purpose of lifting the 7,800-lb, AN-107 mixer pump.

Other than these modifications, the yoke was built to the same configuration and with the same materials as shown in the drawing.

It is assumed for the purpose of analysis that a point load will be exerted on the lifting bail by the crane hook or lifting device during testing and normal use. It is also assumed that the entire load will initially be taken up by one yoke hook, before both yoke hooks engage and share the load.

Five load cases are identified and analysed in this document: 1) the lifting bail in flexure or shear; 2) stress on the welds connecting the bail (PN #11) to the spreader beam (PN #10); 3) the spreader beam in flexure; 4) stress on the welds connecting the spreader beam to the yoke hook assemblies (PN #2&3); 5) and the concentrated stress at the neck area of either yoke hook assembly. In the last case, the effective notch radius at the neck area is not specified on the drawing, but appears by inspection to be greater than 1/32 inch.

3.0 MATERIAL PROPERTIES

The calculations are based on the following material properties:

Carbon steel, ASTM A36, for bail and spreader beam: yield stress, $F_y = 36$ ksi per AISC (1989); allowable stress (S_{allow}) used for analysis is one third of this value, or 12 ksi, per DOE-RL (1993).

Carbon steel, ASTM A514, for hook assemblies: yield stress, $F_y = 100$ ksi per AISC (1989); allowable stress used for analysis is one third of this value, or 33 ksi, per DOE-RL (1993).

Weld metal allowable stress equal to that of materials joined (if two parts are of different materials, the lower stress allowable is used).

4.0 CONCLUSIONS

The calculations show that the pump yoke shown in H-2-35765 is adequate to lift the AN-107 mixer pump. Due to the uncertain nature of the analysis done for the last case it is recommended that both yoke hooks be examined before and after the static load test, in the area of stress concentration (where width constricts from 4 in. to 2 in.) using magnetic particle testing, to verify that no cracks or other stress-induced material flaws have developed.

5.0 REQUIREMENTS

The assembly must be used in accordance with DOE-RL (1993). This includes both the static load test and normal lifting operations. The assembly should be clearly marked as having a maximum operating load rating of 9,000 lb. The static test load shall be $1.25 \times 9,000 \text{ lb} = 11,250 \text{ lb}$.

6.0 REFERENCES

AISC, 1989, *Manual of Steel Construction - Allowable Stress Design*, Ninth Edition, American Institute of Steel Construction, Chicago.

DOE-RL, 1993, *Hanford Site Hoisting and Rigging Manual*, DOE-RL-92-36, U. S. Department of Energy, Richland Field Office, Richland, WA.

Roark, R. J., and W. C. Young, 1989, *Roark's Formulas for Stress and Strain*, Sixth Edition, McGraw-Hill, New York.

US-AEC/ARHC, 1970, *Self Locking Pump Yokes*, Drawing H-2-35765, Sheet 1, Atlantic Richfield Hanford Company, Richland, Washington.

WHC, 1992, Engineering Services Request #TF-92-107, "AN-107 Mixer Pump Caustic Addition Project", TWRS Facilities and Equipment Engineering, Westinghouse Hanford Company, Richland, WA.

Westinghouse
Hanford Company

WHC-SD-WM-DA-148

Revision 0

Page E-5

ANALYSIS

PAGE 1 OF 9

JOB NO. _____

DATE 5 AUGUST 1993

BY JAMES A. TUCK

CHECKED BY Jim Kunkel E-7-93

FOR _____
LOCATION H-2-35765, AS MODIFIED
SUBJECT AN-107 MIXER PUMP YOKE

Five load cases are to be analyzed:

1. Lifting Bail
2. Fillet weld joining bail to beam
3. Spreader beam
4. Fillet welds joining beam to yoke hooks
5. Neck of yoke hook (stress concentration)

Pump yoke is to be analyzed to the provisions of DOE-RL-92-36, *Hanford Site Hoisting and Rigging Manual*, Chapter 11, "Below-the-Hook Lifting Devices". This manual states that lifting devices shall be "designed to withstand the forces imposed by its rated load, with a minimum design factor of 3, based on yield strength, for load-bearing structural components".

Rated load, $P = 9000 \text{ lb.}$

ANALYSIS

PAGE 2 OF 9

JOB NO. _____

DATE 5 AUGUST 1993

BY JAMES A. TUCK

CHECKED BY Jim Kuntz 8-9-93

FOR _____

LOCATION H-2-35765, AS MODIFIED

SUBJECT AN-107 MIXER PUMP YOKE

LOAD CASE #1 - LIFTING BAIL, $S_{allow} = 12 \text{ ksi}$

r_i = inside radius of bail
= 2 in.

r_o = outside radius = $4 \frac{1}{2}$ in.

$$R = \frac{r_i + r_o}{2} = 3.25 \text{ in.}$$

$$c = r_o - R = R - r_i = 1.25 \text{ in.}$$

$$R/c = \frac{3.25}{1.25} = 2.6$$

FOR A STRAIGHT BEAM (CANTILEVER), MAX MOMENT =

$$M = \frac{1}{2} PR = \frac{1}{2} (9) (3.25) = 14.63 \text{ kip}\cdot\text{in}$$

$$\therefore \sigma = \frac{Mc}{I} = \frac{(14.63)(1.25)(12)}{(2)(2.5)^3} = 7.2 \text{ ksi.}$$

• FROM ROARK + YOUNG (1989), MAXIMUM BENDING STRESS =

$$\sigma_i = k_i \sigma \quad \text{FOR A CURVED BEAM,}$$

CONT'D →

ANALYSIS

PAGE 3 OF 9

JOB NO. _____

DATE 5 AUGUST 1993

BY James A. Tuck

CHECKED BY Jim Henderson 8-9-93

FOR _____
LOCATION H-2-35765, AS MODIFIED
SUBJECT AN-107 MIXER PUMP YOKE

LOAD CASE #1, CONT'D.

$$\text{WHERE: } k_i = \frac{(1 - \frac{h}{c})}{3(\frac{h}{c})(\frac{R}{c} - 1)}$$

WHERE:

$$h = R - r_N$$

$$\text{AND: } \frac{h}{c} = \frac{R}{c} - \frac{2}{\ln \frac{R/c + 1}{R/c - 1}} = 2.6 - \frac{2}{\ln(\frac{3.6}{1.6})}$$

$$= 0.134$$

$$\therefore k_i = \frac{1 - 0.134}{3(0.134)(1.6)} = 1.347$$

$$\therefore \delta_i = k_i \delta = (1.347)(7.2) = \underline{9.7 \text{ ksi'}}$$

$$\text{TENSILE STRESS, } \delta_{\text{tensile}} = \frac{\frac{1}{2}P}{A} = \frac{\frac{1}{2}(9)}{(2)(2.5)} = \underline{0.9 \text{ ksi'}}$$

$\therefore$ TOTAL STRESS

$$= \delta_{\text{total}} = \delta_i + \delta_{\text{tensile}} = \underline{10.6 \text{ ksi'}}$$

$$\therefore \underline{\delta_{\text{total}} < S_{\text{allow}}}$$

ANALYSIS

FOR _____
LOCATION H-2-35765, AS MODIFIED
SUBJECT AN-107 MIXER PUMP YOKE

PAGE 4 OF 9
JOB NO. ESR # TF-92-107
DATE 5 AUGUST 1993
BY W. J. A. Tuck
CHECKED BY [Signature] F-9-93

LOAD CASE # 2, FILLET WELD ON BAIL, $S_{allow} = 12 \text{ ksi}$

$$A, \text{ area of weld, } = h \cos 45^\circ (2)(b+d) = \frac{3}{8} (1.414) (2+2.5) \\ = 2.39 \text{ in}^2$$

$$I = h \cos 45^\circ \frac{d^2}{6} (3b+d) = \frac{3}{8} (0.707) \left(\frac{1}{6}\right) (2.5)^2 (6+2.5) \\ = 2.35 \text{ in}^4$$

$$\text{Bending stress, } \sigma_M = \frac{Mc}{I} = \frac{(14.63)(1.25)}{2.35} = \underline{7.78 \text{ ksi}}$$

$$\text{Axial stress, } \sigma_{ax} = \frac{P}{A} = \frac{4.5}{2.39} = \underline{1.88 \text{ ksi}}$$

Stresses are additive,

A-7400-276 (9-87)

$$\therefore \sigma_{max} = \sigma_M + \sigma_{ax} = \underline{9.7 \text{ ksi}} < S_{allow}$$

ANALYSIS

PAGE 5 OF 9

JOB NO. _____

DATE 5 AUGUST 1993

BY JAMES A. THORP

CHECKED BY Jim Burkholder 8-9-93

FOR _____
LOCATION H-2-35765, AS MODIFIED
SUBJECT AN-107 MIXER PUMP YOKE

LOAD CASE #3, SPREADER BEAM FLEXURE, $S_{allow} = 12 \text{ ksi}$

TWO SYMMETRICAL POINT LOADS NEAR CENTER
OF SPAN, ENDS SUPPORTED

$$a = 20.75''$$

$$b = 27.25''$$

$$F = 4.5 \text{ kips}$$

- FROM AISC (1989), FOR A W8 X 15 BEAM,

$$I = 48.0 \text{ in}^4; \text{ SEC. MOD, } S = 11.8 \text{ in}^3; A = 4.44 \text{ in}^2$$

$$\text{MAX. RESISTING MOMENT, } M_R = 23 \text{ kip}\cdot\text{ft} = 276 \text{ kip}\cdot\text{in}$$

$$\text{MAX. UNSUPPORTED LENGTH, } L_C = 4.2 \text{ FT} < 48'' (\text{GIVEN})$$

- FROM ROARK + YOUNG (1989),

MAX. MOMENT IS NEAR CENTER OF SPAN FOR A SIMPLY
SUPPORTED BEAM, OR:

$$M_{MAX} = F_a = (4.5)(20.75) = 93.4 \text{ kip}\cdot\text{in.}$$

$$\therefore M_{MAX} < M_R$$

ANALYSIS

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JOB NO. _____

DATE 5 AUGUST 1993

BY VARAD TRICK

CHECKED BY J. J. Kunkel 8-9-93

FOR _____

LOCATION H-2-35765, AS MODIFIED

SUBJECT AN-107 MIXER PUMP YOKE

LOAD CASE #3, CONT'D.

$$\therefore \text{MAX. BENDING STRESS, } \sigma = \frac{M}{S} = \frac{93.4}{11.8} = \underline{7.9 \text{ ksi}}$$

$$\therefore \underline{\sigma < S_{allow}}$$

- FROM ROARK + YOUNG (1989), MAX. SHEAR STRESS OCCURS IN WEB OF BEAM AND IS APPROXIMATED BY

$$\tau_{max} = \frac{V_{max}}{A_{web}}$$

- FROM AISC (1989), WEB OF W8x15 BEAM IS
0.245 in. THICK x $6\frac{5}{8}$ in. DEEP

- $V_{max} = F = 4.5 \text{ kips.}$

$$\therefore \tau_{max} = \frac{4.5 \text{ kips}}{(0.245") (6\frac{5}{8}"))} = \underline{2.8 \text{ ksi} < S_{allow}}$$

ALSO, STIFFENERS PROVIDE ADDITIONAL SUPPORT.

ANALYSIS

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JOB NO. _____

DATE 5 AUGUST 1993

BY VANESSA TUCKER

CHECKED BY Jim Gullerud 8-9-93

FOR _____
LOCATION H-2-35765, AS MODIFIED
SUBJECT AN-107 MIXER PUMP YOKE

LOAD CASE #4, FILLET WELDS, ENDS OF BEAM, $S_{allow} = 12 \text{ ksi}$.

- FROM ROARK + YOUNG (1989),

MAX. MOMENT ON SPAN IS AT ENDS (WELDS) FOR A BEAM
FIXED AT BOTH ENDS; OR:

$$M = F \left(\frac{ab^2 + a^2b}{l^2} \right)$$

$$= 4.5 \left[\frac{(20.75)(27.25)^2 + (20.75)^2(27.25)}{(48)^2} \right]$$

$$= 53.0 \text{ kip}\cdot\text{in}$$

- DIMENSIONS OF W8x15 BEAM
FROM AISC (1989):

COMBINED
CALCULATED MOMENT OF INERTIA OF
INNER AND OUTER FILLET WELDS:

$$I = 0.707 h \left[\frac{d_i^2}{6} (3b_i + d_i) + \frac{b_o d_o^2}{2} \right]$$

$$= 0.707 \left(\frac{1}{4} \right) \left[\frac{(7.5)^2}{6} (19.5) + \frac{4(8.11)^2}{2} \right]$$

$$= 55.0 \text{ in}^4$$

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JOB NO. _____

DATE 5 AUGUST 1993

BY JAMES A. TUCK

CHECKED BY Jim [Signature] 8-9-93

FOR _____
LOCATION H-2-35765, AS MODIFIED
SUBJECT AN-107 MIXER PUMP YOKE

LOAD CASE #4, CONT'D

^{WELD}
FILLET_A IN BENDING; MAX. MOMENT ON BEAM IS AT WELDED
FIXED ENDS (SEE CASE #3):

$$\sigma = \frac{Mc}{I} = \frac{(53.0 \text{ kip}\cdot\text{in})(4 \text{ in.})}{(55.0 \text{ in}^4)} = \underline{3.9 \text{ ksi}}$$

FILLET WELD LOADED IN PURE SHEAR;

$$P = 9 \text{ kips}$$

$$\text{AREA, } A = 0.707\left(\frac{1}{4}\right)(2)(7.5 + 4 + 4) = 5.4 \text{ in}^2$$

$$\therefore \text{SHEAR STRESS, } \tau' = \frac{P}{A} = \frac{9}{5.4} = \underline{1.7 \text{ ksi}}$$

• STRESSES ARE ADDITIVE,

$$\therefore \tau_{\text{total}} = \sigma + \tau' = \underline{5.6 \text{ ksi}} < S_{\text{allow}}$$

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ANALYSIS

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JOB NO. _____

DATE 5 AUGUST 1993

BY James A. Tuck

CHECKED BY Jim Lawrence 8-9-93

FOR _____

LOCATION H-2-35765, AS MODIFIED

SUBJECT AN-107 MIXER PUMP YOKE

LOAD CASE #5, NECK OF YOKE HOOK (STRESS CONCENTRATION)

$S_{allow} = 33 \text{ ksi}$

ACTUAL GEOMETRY,
H-2-35765:

MODELLED AS A DOUBLE-NOTCHED MEMBER:

• FROM ROARK + YOUNG (1989),
STRESS CONCENTRATION FACTOR,

$$K_1 = 5.1$$

$$\therefore \sigma = K_1 \frac{P}{A} = 5.1 \frac{(9)}{(2)} = \underline{23.0 \text{ ksi} < S_{allow}}$$

APPENDIX F - UNCERTAINTY ANALYSIS OF DISCHARGE NOZZLE ORIENTATION

Analyst: G. A. Leshikar

Reviewer: J. A. Tuck

Independent Review Checklist for Verification of Analysis/Calculations (from EP 1.11)

Document Checked - Number: Appendix F Revision: 0

Title: Uncertainty Analysis of Discharge Nozzle Orientation

Yes	No	N/A	
☒	☐	☐	Problem completely defined.
☒	☐	☐	Appropriate analytical method used.
☒	☐	☐	Necessary assumptions are appropriate, explicitly stated, and supported.
☐	☐	☒	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Sources of non-standard formulae/data are referenced and the correctness of the reference verified.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☐	☐	☒	Mathematical derivations checked including dimensional consistency of results.
☐	☐	☒	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors.
☐	☐	☒	Code run streams correct and consistent with analysis documentation.
☐	☐	☒	Code output consistent with input and with results reported in analysis documentation.
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☒	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

I have checked the analysis/calculation and it is complete and accurate to the best of my knowledge.

Sammy A. Tuck 22 Nov. '94
Engineer/Checker Date

Note: Any hand calculations, notes, or summaries generated as part of this check should be signed, dated, and attached to this checklist. Material should be labeled and recorded so that it is intelligible to a technically qualified third party.

Uncertainty Analysis**1.0 OBJECTIVE**

The purpose of this analysis is to predict the uncertainty of the discharge nozzle angle for a mixer pump mounted on a stand over the 42" riser in the pump pit of Tank 107-AN.

2.0 BACKGROUND

The mixer pump is a Hazleton 75 Hp submersible type pump which takes pump suction about 7 feet off the bottom of the tank and discharges through two opposing horizontal discharge nozzles that will be located approximately 1 foot off the bottom of the tank. The pump is capable of rotating through 190° which provides 360° of coverage.

The reason why the discharge nozzle angle uncertainty is important is because analysis has shown the tank thermocouple tree located 60° NNW of tank center, at a 20 feet radius, to potentially experience resonance in the third mode of vibration at 0° and 5° impingement angles when the mixer pump is at full power. This could possibly reduce the tree's fatigue life to unacceptable levels. See Reference 1. Subscale test report, WHC-SD-WM-ER-219, "Mixing Test Report for Tank 107-AN Caustic Addition Project", (Reference 2), recommends that an uncertainty of the discharge nozzle location be determined and this value added to the dimension of the non-mixing zone near the thermocouple tree. The calculated uncertainty must strike a balance between risk of jet impingement on the thermocouple tree and the desire to mix the entire tank contents. Caustic will be entrained only in the portion of the waste that is mixed; non-mixed areas will still be out of compliance with Tank Farm operating specifications for hydroxide concentration and large non-mixed areas would still subject the tank walls in those areas to larger-than-desired corrosion rates. Therefore it is in our best interests to determine the "true" uncertainty; overconservatism in either direction is bad.

The pump will be oriented on the stand to give the optimum configuration for mixer pump control. This will be done before the Integrated Operational Test of the pumping system which will verify, among other things, control of the mixer pump's rotational travel to prevent operation in the non-mixing zone.

3.0 RECOMMENDED MIXING PROCEDURE

The following is the recommended procedure taken from WHC-SD-WM-ER-219, Rev 0, "Mixing Test Report for Tank 107-AN Caustic Addition Project", to accomplish the required mixing while ensuring the structural integrity of the thermocouple tree:

1. Determine the angle of direct impingement direction, which is the direction from the centerline of the pump location to the centerline of the thermocouple tree.
2. Determine the uncertainty of the impingement direction, say X degrees.

Uncertainty Analysis

3. Define "indexing" and "nonindexing" regions such that the "non-indexing region" covers a 10 + 2X degree angle centered at the direct impingement direction.
4. Divide the "indexing region" in approximate 10 degree sectors.
5. Operate the mixing jets intermittently one hour in each sector. All sectors in the indexing region should be covered by at least one of the mixing jets.

See Figure F-1 for a graphical representation of the mixer pump installed in the 107-AN pump pit and the exclusion zone around the thermocouple tree.

4.0 METHOD OF ANALYSIS

Originally, a Kline and McClintock type of uncertainty analysis was the analysis of choice (Reference 3). However, that type of analysis requires an equation relating variables that is not present in this circumstance. The uncertainties in this case are all dimensional type and are not all interrelated. One can assume that the uncertainties resemble errors. The following formula, derived from the general law of propagation of random errors, gives the error in the sum of quantities that each contain random errors (Reference 4):

$$E_{\text{sum}} = \sqrt{E_a^2 + E_b^2 + E_c^2 + \dots}$$

where E represents any specified error and a, b, and c are the separate measurements. Herein, uncertainties will be represented by the letter X.

5.0 IDENTIFIED UNCERTAINTIES

Identified uncertainties in the location of the mixer pump discharge nozzles with respect to the thermocouple tree are:

- X_a = Mixer pump rotational turntable overtravel as measured by position resolver
- X_b = Bolt hole clearance for mounting flange to pump stand interface
- X_c = Placement of arrow on mixer pump mounting flange
- X_d = Location of thermocouple tree riser (tank manufacturing tolerances)
- X_f = Parallelness of discharge nozzles to each other
- X_g = Placement of pump stand in pump pit
- X_h = Straightness of thermocouple tree in tank

Uncertainty Analysis**6.0 DETERMINING INDIVIDUAL UNCERTAINTIES**

X_a - Mixer pump rotational turntable overtravel as measured by position resolver

The manufacturer supplied position resolver measures the movement of the gears that rotate the turntable. The resolver sends a signal to the programmable position controller which has a readout in degrees. See Figure F-2. When the 1 Hp motor that drives the turntable shuts off at the end of mixer pump rotation, a slight overtravel is observed. This is believed due to gear clearances. Observations of the angular readout show that the overtravel is approximately 0.75° each time the turntable stops. Observation test data is shown in Table F-1.

X_b - Bolt clearance for mounting flange to pump stand interface

Four $3/4$ " bolts are to be used to attach the mounting flange to the pump stand. The bolt hole width is 0.812 inches. The bolt clearance is $(0.812" - 0.75") / 2 = 0.031"$. The bolts are on a 48" diameter.

The angular uncertainty is:

$$\text{circumference} = \pi d = 3.14 \times 48" = 150.8"$$

$$\text{circumference} / 360 = \text{arc length per degree}$$

$$150.8" / 360 = 0.42" \text{ per degree}$$

$$0.031" / 0.42" \text{ per degree} = 0.07^\circ$$

X_c - Placement of arrow on mixer pump turntable

According to the manufacturer, the placement of the arrow with respect to the centerline of the discharge nozzles was 100% accurate. However, casting a skeptical eye on this bit of information, the discharge nozzle centerline was surveyed at the 272-E shop and the reference arrow was found to be 10° off the centerline of the discharge nozzles. The method of survey was to use a transit to line up the discharge nozzles parallel to the ground, then etch a mark at the exact elevation of the nozzle centerline on the turntable. Assuming the cumulative surveying error is $1/8"$ (0.125 in) and for the turntable diameter of 28", the angular uncertainty is:

$$\text{circumference} = \pi d = 3.14 \times 28" = 87.9"$$

$$\text{circumference} / 360 = \text{arc length per degree}$$

$$87.9" / 360 = 0.24" \text{ per degree}$$

$$0.125" / 0.24" \text{ per degree} = 0.52^\circ$$

Uncertainty AnalysisX_d - Location of thermocouple tree riser (tank manufacturing tolerances)

According to Drawing H-2-71161, the angular tolerance (or uncertainty) for riser location on Tank 107-AN is 0°-15'.

Converting to decimal notation, 0°-15' = 0.25°

X_f - Parallelness of discharge nozzles to each other

The discharge nozzles have been painstakingly adjusted to get them as close to 180° to each other as possible. The measurement uncertainty (arc length offset) is approximately $\pm 1/16"$ (0.062"). The distance between nozzle faces is 32".

The angular uncertainty is:

$$\text{circumference} = \pi d = 3.14 \times 32" = 100.5"$$

$$\text{circumference} / 360 = \text{arc length per degree}$$

$$100.5" / 360 = 0.28" \text{ per degree}$$

$$0.062" / 0.28" \text{ per degree} = 0.22^\circ$$

X_g - Placement of pump stand in pump pit

The pump stand is to be placed in the pump pit as squarely as possible. Uncertainty due to stand placement has both angular and translational components. The translational component will be ignored as its contribution is judged to be negligible. The angular component can be seen in Figure 2. Assume the stand is placed in the pit with one corner a 1/2 inch farther from the wall than the other. The corresponding angular uncertainty is determined from Figure F-3 to be 0.55°.

X_h - Straightness of thermocouple tree in tank

The thermocouple tree is a 55 foot long, 2 inch Schedule 40 ASTM A-106, Gr. B, carbon steel pipe, extending from riser #4 into the waste. This pipe, being very long and thin, is unlikely to be hanging perfectly straight initially. Direction and amount of initial deflection is unknown. The pipe has the potential to deflect over 60 inches without exceeding its allowable bending stress at the riser attachment. Being that there is no motive force acting to constantly hold the pipe in deflection, it will be assumed that the pipe is straight within 3 inches. At a radius of 20 feet, every degree corresponds to approximately a 2 inch arc length which gives an angular uncertainty of 3 in / 2 inch per degree = 1.5°.

Uncertainty Analysis

7.0 CUMULATIVE UNCERTAINTY

The uncertainty in the location of the mixer pump discharge nozzles with respect to the thermocouple tree is calculated by:

$$X_{sum} = \sqrt{X_a^2 + X_b^2 + X_c^2 + X_d^2 + X_f^2 + X_g^2 + X_h^2}$$

Units are degrees.

$$X_{sum} = \sqrt{0.75^2 + 0.07^2 + 0.52^2 + 0.25^2 + 0.22^2 + 0.55^2 + 1.5^2}$$

$$X_{sum} = \sqrt{3.50}$$

$$X_{sum} = 1.87^\circ$$

Therefore the "nonindexing" region defined by the recommended mixing procedure becomes

$$10 + 2X = 10 + 2(1.87) = 13.74^\circ$$

centered at the thermocouple tree centerline. For ease of use and introducing a slight amount of conservatism

Define: $X = 2^\circ$

so that the non-indexing region becomes:

$$10 + 2X = 14^\circ$$

8.0 REFERENCES

1. WHC-SD-WM-ANAL-018, Rev. 0, "Structural Evaluation of Tank 241-AN-107 Internal Components for Caustic Addition Mixing Operations".
2. WHC-SD-WM-ER-219, Rev. 0, "Mixing Test Report for Tank 107-AN Caustic Addition Project."
3. Kline and McClintock, "Describing Uncertainties in Single-Sample Experiments", Mechanical Engineering, p. 3, January 1953.
4. Brinker and Wolf, "Elementary Surveying", 7th Edition.

0° NORTH

0°

240.0

5.00°
10.00°

THERMOCOUPLE TREE

FIGURE F-1

FIGURE F-2. TEST SET-UP AT 272-E
MIXER PUMP ROTATIONAL EQUIPMENT

FIGURE F-3. ANGULAR UNCERTAINTY
OF PUMP STAND PLACEMENT

Hazleton N-20301 Mixer Pump

Overtravel test 1/24/94

1/24/94

Observations of Programmable Position Transducer Readout	
<u>Set pt, °</u>	<u>Stops at, °</u>
191	191.59
	191.67
	191.72
	191.73
	191.73
	191.75
	191.75
	191.77
	191.77
	191.77

TABLE F-1

APPENDIX G - CAUSTIC INJECTION SKID STRUCTURAL ANALYSIS

Analyst: Bran + Luebbe Co.

Reviewer: G. A. Leshikar

Independent Review Checklist for Verification
of Analysis/Calculations (from EP 1.11)Document Checked - Number: Appendix G Revision: 0Title: Caustic Injection Skid Structural Analysis

Yes	No	N/A	
☒	☐	☐	Problem completely defined.
☒	☐	☐	Appropriate analytical method used.
☒	☐	☐	Necessary assumptions are appropriate, explicitly stated, and supported.
☐	☐	☒	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☐	☐	☒	Sources of non-standard formulae/data are referenced and the correctness of the reference verified.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☒	☐	☐	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors.
☐	☐	☒	Code run streams correct and consistent with analysis documentation.
☐	☐	☒	Code output consistent with input and with results reported in analysis documentation.
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

I have checked the analysis/calculation and it is complete and accurate to the best of my knowledge.

G. A. Deshpande 9-15-94
Engineer/Checker Date

Note: Any hand calculations, notes, or summaries generated as part of this check should be signed, dated, and attached to this checklist. Material should be labeled and recorded so that it is intelligible to a technically qualified third party.

WESTING HOUSE HARTFORD CAUSTIC / ADDITION SKID

A-14343

A. ROOF DESIGN

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Page G-3

1. WIND LOADING

ASCE 7-88 MINIMUM DESIGN LOADS & G WIND LOADS

$$F = q_z \cdot G_z \cdot C_f \cdot A_f$$

$$q_z = 0.00256 K_z (IV)^2$$

$$K_z = \text{EXPOSURE "C" @ 0-5 ft} = 0.80$$

$$I = 1.0$$

$$q_z = 0.00256 \times 0.8 \times (1.0 \times 70 \text{ MPH})^2$$

$$= 10.04 \text{ #/ft}^2$$

$$G_z = 1.32 \text{ Exposure "C" Table 8}$$

$$C_f = \frac{L}{B} = \frac{101}{48} = 2.1$$

$$\frac{48}{101} = 0.47$$

$$F = \pm 10.04 \text{ #/ft}^2 \times 1.32 \times 0.55 \times 4' \times 8.42$$

$$= \pm 246 \text{ # WIND NORMAL TO ROOF}$$

$$= \frac{3}{55} \times 246 = 134 \text{ # WIND PARALLEL TO ROOF}$$

Center of pressure from Windward edge of roof

TABLE 11

$$\frac{L}{B} = 2.1 \quad C_f = 0.3$$

$$\frac{L}{B} = 0.47 \quad C_f = 0.55$$

$$246 \text{ #} \div 8.42' = 29.23 \text{ #/ft}$$

$$14.615 \text{ #/ft}$$

WIND LOAD DIAGRAM

Use 15 #/ft for design of corrugated roofing

2.) CORRUGATED SHEET - GALVANIZED use 18 GA - 27 1/2" WIDTH 2.67' x 12"

$$S = .0665 \text{ m}^2$$

$$M = \frac{15 \text{ #/ft} \times 4.26'^2}{8} = 34 \text{ #/ft}$$

$$f_b = \frac{34 \text{ #/ft} \times 12}{.0665} = 6,140 \text{ #/ft}^2 < 20,000 \text{ #/ft}^2 \text{ OK}$$

FASTENERS No. 14 .242" Diameter

$$F_t = 19,100 \text{ #/ft}^2$$

$$A = \pi \times .242^2 = 0.046 \text{ ft}^2$$

$$\text{Tension on fastener} = 19,100 \text{ #/ft}^2 \times 0.046 = 879 \text{ #} > 72 \text{ #}$$

Use No. 14 SELF-TAPPING SCREWS

GALVANIZED WITH COPPED GALVANIZAWASHERS WITH BONDED NEOSPRE WASHERS -

Space on sides @ 12" OC and Ends approx every third corrugation

WESTINGHOUSE

CAUSTIC ADDITION SKID

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3. ROOF FRAMING

a) Beam BI

$$M = .1283 \times W \times L$$

$$= .1283 \times 144 \# \times 4$$

$$= 73.9 \#$$

$$S_{req} = \frac{73.9 \times 12}{21,600 \times \frac{4}{3}} = .031 \text{ in}^3$$

$$\text{try } 2 \times 2 \times 1/4 \text{ L } S = .247 \text{ in}^3$$

$$f_b = \frac{73.9 \times 12}{.247} = 3570 \#/\text{in}^2 < 28,800 \#/\text{in}^2$$

$$W_c = 6 \text{ kft} \times \frac{1}{2} \times 4' = 1500 \# > 144 \# \text{ use } 2 \times 2 \times 1/4 \text{ L}$$

b) Perimeter members - Rigid Frame - Structural Tubular Section $F_y = 36 \text{ ksi}$

$$1/25 \times 97 \frac{1}{2} = 3.9 \text{ inches}$$

use min of 4" depth - 4x3x1/4 Structural Tubing for 97 1/2" Span
 3x3x1/4 " " " for 48" Span

WESTINGHOUSE HANFORD

CAUSTIC ADDITION SKID

A-14343

4. SKID ELEVATION

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FRONT ELEVATION

d) WIND LOAD ON TANK

$$F = q G_z C_F A_f$$

$$G_z = 1.32$$

$$C_F = 0.71$$

$$A_f = \frac{51.4 \times 32}{144} = 11.39 \text{ ft}^2$$

$$\frac{h}{D} = \frac{51.4}{32} = 1.6$$

$$F = 10.04 \times 1.32 \times 0.71 \times 11.39 = 107 \text{ #}$$

$$\text{OVT } M = 107 \times \frac{51.25}{2} = 2742 \text{ #}$$

$$\text{Righting } M = 80 \times 16 = 1280 \text{ #}$$

OVT M > Righting M anchor tank to skid.

e) Weight of Frame

$$4 \times 3 \times \frac{1}{4} \times 129.5/12 \times 8.81 = 380 \text{ #}$$

$$2 \times 4 \times \frac{3}{4} \times 97.5/12 \times 10.51 = 171 \text{ #}$$

$$1 \times 2 \times \frac{1}{2} \times \frac{1}{4} \times 48/12 \times 4.1 = 16 \text{ #}$$

$$\text{Rising 18 GA } 2.18 \times \frac{97.5 \times 48}{144} = 71 \text{ #}$$

$$\text{Channel } 2 \times 15.3 \times \frac{97.5}{12} = 250 \text{ #}$$

$$2 \times 15.3 \times \frac{48}{12} = 122 \text{ #}$$

$$\text{Drip Pan } 4 \times \frac{97.5 \times 48}{144} \times 10.2 = 331 \text{ #}$$

$$1341$$

$$10\% = 134$$

$$1475 \text{ #}$$

b) WEIGHT of 150 gal tank

$$\text{TANK} = 150 \text{ #}$$

$$\text{CONTENTS} = 150 \times 8.33 \times 1.5 = 1874 \text{ #}$$

$$\text{Total W} = 2024 \text{ lbs.}$$

PIPING

$$200 \text{ #}$$

PUMP

$$200 \text{ #}$$

TANKS

$$150 \text{ #}$$

c) TANK Support by ST 2x2x1/4

$$P = 2024 \div 4 = 506 \text{ #}$$

$$l = \frac{51.75}{1.694} = 75 < 120$$

$$f_R = \frac{506}{1.59} = 318 \text{ #/ft}^2$$

$$F_A = 5900 \text{ #/ft}^2$$

$$\frac{F_R}{F_A} = \frac{318}{5900} = 0.02$$

use ST 2x2x1/4

TOTAL WT TANK Empty

$$2025 \text{ #}$$

SNG

$$2200 \text{ #}$$

WT Contents

$$2000 \text{ #}$$

$$\text{TOTAL (D.L. + L.L.)} = 4200 \text{ #}$$

5. LIFTING LUG

Total Dead Load = 2200 lbs

Load per lug = $2200 \div 4 \times 1.25 = \text{say } 700^*$

F.S. = 3.1

$L_D = 700 \times 3 = 2100^*$

use 1/2" SHACKLE W.L.L. = 2 TON

* 5/8" hole changed to 9/16" hole upon WHC review on 12/9/93. Validity of this analysis is unchanged.

Tension Net Section = $A_n = \frac{1}{4} (2.58) = 0.344^*$

$f_t = \frac{2100}{0.344} = 6109^* / \text{in}^2 < 21,600^* / \text{in}^2$

MIN. EDGE DISTANCE = $\frac{2100}{2 \times \frac{1}{4} \times 14,400} + \frac{5/8}{2}$
 $= 0.292 + .312$
 $= 0.604 < .75$

DESIGN of WELD

$f_y = \frac{2100}{.6} = 350^* / \text{in}$

$f_x = \frac{1212 \times 2 \times 6 \times 1}{48 \times 6} = 227^* / \text{in}$

$f_r = \sqrt{350^2 + 227^2} = 416^* / \text{in}$

$f_{bending} = \frac{2100}{.25 \times .5} = 16800^* / \text{in}^2 < 0.90 \times 36,000$

$f_v = \frac{2100}{2 \times .25 \times \left(\frac{.75 - (.625)}{.4375} \right)} = 9600 < 14,400 \text{ OK}$

$f_{bending} = \frac{1212 \times 1 \times 6}{.25 \times \frac{2^2}{4}} = 7272^* / \text{in}^2$

$f_{bending} = \frac{.05 \times 2100 \times 6}{.2 \times .25 \times \frac{2^2}{1.25}} = 5040^* / \text{in}^2$

Combined Stress = $\sqrt{6109^2 + 9600^2 + 5040^2}^{\frac{1}{2}}$
 $= 12,445 < 21,600^* / \text{in}^2$

3/16" Weld

$F_v = .3 \times 60 \times 1707$
 $= 2386^* / \text{in} > 416$

use 3/16" Weld

APPENDIX H - CONCRETE SLAB AND TIEDOWN FOR CAUSTIC INJECTION SKID

Analyst: G. A. Leshikar

Reviewer: J. A. Tuck

Independent Review Checklist for Verification of Analysis/Calculations (from EP 1.11)

Document Checked - Number: Appendix H Revision: 0

Title: Concrete Slab and Tiedown for Caustic Addition Skid

Yes No N/A

☒	☐	☐	Problem completely defined.
☒	☐	☐	Appropriate analytical method used.
☒	☐	☐	Necessary assumptions are appropriate, explicitly stated, and supported.
☐	☐	☒	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Sources of non-standard formulae/data are referenced and the correctness of the reference verified.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☐	☐	☒	Mathematical derivations checked including dimensional consistency of results.
☐	☐	☒	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors.
☐	☐	☒	Code run streams correct and consistent with analysis documentation.
☐	☐	☒	Code output consistent with input and with results reported in analysis documentation.
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

I have checked the analysis/calculation and it is complete and accurate to the best of my knowledge.

James A. Truck 22 Nov '94
Engineer/Checker Date

Note: Any hand calculations, notes, or summaries generated as part of this check should be signed, dated, and attached to this checklist. Material should be labeled and recorded so that it is intelligible to a technically qualified third party.

DESIGN CALCULATION

(1) Drawing H-2-85347 (2) Doc. No. WHC-SD-WM-DA-148 (3) Page H-2 of H-7
(4) Building _____ (5) Rev. 0 (6) Job No. ETN-94-0010
(7) Subject Concrete Slab and Tiedown for Caustic Addition Skid
(8) Originator G.A. Leshikar Date 2-2-94
(9) Checker James A. Truck Date 22 Nov. 94

Background

The caustic injection skid is a procured piece of equipment which will rest on a concrete slab just outside the AN Tank Farm. Requirements are contained in WHC-SD-WM-RD-031, Rev. 0, "Tank 107-AN Caustic Addition Pump Skid Requirements", 3/93. The skid contains a positive displacement pump rated at 15 gpm @ 50 psi which will pump 19 molar sodium hydroxide solution at 150°F to a discharge alongside the mixer pump discharge nozzles. The skid contains piping, valves, pressure relief valves, flowmeter, totalizer, pressure detector/readout, temperature sensor/readout, chart recorder and alarms. A 125 gallon flush tank and a 10 gallon drain tank are also part of the skid. Drawing H-2-85348 shows the caustic injection skid and drawing H-2-85347 shows the concrete pad including its installation next to AN farm.

The concrete slab is classified Safety Class 4 while the skid itself is Safety Class 3.

Determine:

1. Thickness of the concrete slab
2. Size of Hilti-Bolts to anchor skid

Data:

Injection Skid Weight = 4200 lb with 150 gallon tank fully filled
= 2025 lb empty
Concrete Slab Area = 8'-11" x 5'-5" = 48.3 ft² (See H-2-85347)
Assumed Concrete Thickness = 6" (value to be verified later in analysis)
Concrete Compressive Strength = 4000 psi
Concrete Density = 150 lb / ft³

Per UBC 1991, Table 29B, Soil Class 4:

Allowable foundation pressure = 1500 psf

1. Thickness of the concrete slab

Design Method for Concrete Slab

American Concrete Institute (ACI) Committee 360, Report ACI 360R-92, "Design of Slabs on Grade", defines slab on grade as:

"a slab, continuously supported by ground, whose total loading when uniformly distributed would impart a pressure to the grade or soil that is less than 50 percent of the allowable bearing capacity thereof."

Verifying application of ACI 360 to this analysis:

DESIGN CALCULATION

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(9) Checker _____ Date _____

Foundation pressure $\approx$ Skid Weight / Slab Area + Concrete Density * Thickness

$$P_{\text{bear}} \approx 4200 \text{ lb} / 48.3 \text{ ft}^2 + (150 \text{ lb} / \text{ft}^3)(0.5 \text{ ft})$$
$$\approx 87.0 \text{ psf} + 75.0 \text{ psf}$$

$$P_{\text{bear}} \approx 162 \text{ psf} < 750 \text{ psf} \quad \text{o.k.}$$

==> ACI 360 applies

U. S. Army Corps of Engineers Procedure

Use the U. S. Army Corps of Engineers (COE) procedure of determining slab thickness as described in ACI 360R-92, Appendix A3 and in "Designing Floor Slabs on Grade", by Ringo and Anderson. The COE method is based on limiting edge stresses in the concrete slab. Nomographs have been designed so that slab thickness can be determined knowing the concrete's modulus of rupture, the subgrade modulus, and the load. The COE method uses an impact factor of 25 percent, a concrete modulus of elasticity of 4000 ksi, and a joint transfer coefficient of 0.75. The COE method was devised to evaluate vehicular loads but applies to this application as well (conservatively, because the skid is a more uniform loading than a vehicle). Note that the COE method does not require the use of concrete reinforcement.

Material: Concrete

Compressive Strength = 4000 psi

Modulus of Rupture = $9(f_c)^{1/2}$ psi per Reference 1, pg. 8.
= 570 psi

Subgrade modulus $k = 100 \text{ lb/in}^3$ per Reference 1, Table 1

Using Table H-1 for a Design Index = 2 for $\leq 6000 \text{ lb}$, and Figure H-1, shown on next page:

Required thickness = 5 inches

The selected slab thickness is 6", which is more conservative than the required 5" thickness. See drawing H-2-85347.

DESIGN CALCULATION

(1) Drawing H-2-B5347 (2) Doc. No. WHC-SD-WM-DA-148(3) Page H-4 of H-7
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 (9) Checker James A. Truck Date 22 Nov 94

Design index categories used with the COE slab thickness selection method

Category	I	II	III	IV	V	VI
Capacity, lb	4000	6000	10000	16000	20000	52000
Design axle load, lb	10000	15000	25000	36000	43000	120000
No. of tires	4	4	6	6	6	6
Type of tire	Solid	Solid	Pneumatic	Pneumatic	Pneumatic	Pneumatic
Tire contact area, sq in.	27.0	36.1	62.5	100	119	316
Effective contact pressure, psi	125	208	100	90	90	95
Tire width, in.	6	7	8	9	9	16
Wheel spacing, in.	31	33	11.52.11	13.58.13	13.58.13	20.79.20
Aisle width, in.	90	90	132	144	144	192
Spacing between dual wheel tires, in.	—	—	3	4	4	4

TABLE H-1

FIGURE H-1 COE Chart for Slab Thickness Selection for Light Vehicle Loading

DESIGN CALCULATION

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(9) Checker James A. Trull Date 22 Nov. 94

2. Size of Hilti-Bolts to anchor skid

Design Loads

Maximum wind loading on the injection skid was calculated to be 134 lb from Appendix G of this report.

Seismic loading is performed per SDC 4.1 for Safety Class 4 equipment. Earthquake forces are calculated in the most critical horizontal direction using the following equation:

$$F_p = Z I C_p W_p$$

where: Z = seismic zone coefficient (free field horizontal acceleration, g) = 0.12 from SDC 4.1, Safety Class 4

I = importance factor = 1.25 from SDC 4.1, Safety Class 4

C_p = rigidity coefficient = 0.75 from Table 23-P of 1991 UBC

W_p = Weight of component = 4200 lb (Skid with 150 gallon tank fully filled)

F_p = Total lateral seismic force

therefore: $F_p = (0.12)(1.25)(0.75)(4200 \text{ lb}) = 473 \text{ lb}$

Since $F_p = 473 \text{ lb} > F_{\text{wind}} = 134 \text{ lb}$, seismic is the controlling force.

Free Body Diagram

See Figure H-2 for a free body diagram of the system. Assumptions made are:

1. Seismic force acts at height equal the vertical center of the 150 gallon tank = 77 3/8".

2. Maximum tensile force on anchor bolt occurs when short side of skid is loaded as shown in Figure H-2.

3. There is a triangular distribution of bearing forces exerted by the concrete against the frame.

Maximum Shear Force per Anchor Bolt

$$\sum F_x = 0; F_p = F_{Ax} + F_{Bx} + F_{Cx} + F_{Dx}$$

$$F_p = 4F_x \quad (\text{equal reaction forces})$$

$$F_x = F_p/4 = 473 \text{ lb} / 4 = 118 \text{ lb}$$

DESIGN CALCULATION

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(9) Checker James A. Tuck Date 22-Nov-94

Maximum Tensile Force per Anchor Bolt

Sum moments about a line thru points C and D.

$$\Sigma M_x = 0; \quad F_p(h) - F_{Ay}(a) - F_{By}(a) - W(a/2) + (W/a)(a/2)(a/3) = 0$$

$$(F_{Ay} = F_{By} \text{ by symmetry})$$

$$F_p(h) - 2F_y(a) - Wa/2 + Wa/6 = 0$$

$$\begin{aligned} F_y &= F_p(h)/2a - W/4 + W/12 \\ &= (473 \text{ lb})(77.375 \text{ in})/2(45 \text{ in}) - 4200 \text{ lb}/4 \\ &\quad + (4200 \text{ lb})/12 \\ &= -293 \text{ lb} \end{aligned}$$

Since F_y is negative, there is no upload, or tension, on the anchors.

Anchor Bolt Size

Per SDC 4.2, Table 13, $f_c = 4000$ psi, (Note: This table is valid for safety class 1, 2, 3, or 4 applications):

- Choose 3/4" diameter carbon steel Hilti Kwik-Bolt II anchors because 7/8" diameter holes are provided in the skid's base channel.

- Per manufacturer's recommendations:

Minimum base material thickness = $1.3 \times \text{embedment depth}$
Embedment depth = 3-3/4"
Minimum base material thickness = $1.3 \times 3\text{-}3/4" = 4.875"$
==> 6" thick slab is ok

- Per manufacturer's recommendations:

Edge spacing = 9-3/4" (shear), 4-7/8" (tension)
==> ok per H-2-85347

- Allowable tensile and shear loads using values for minimum embedment (conservative because embedment depth is greater than minimum):

$$\begin{aligned} T &= 2500 \text{ lb} \\ V &= 3410 \text{ lb} \end{aligned}$$

- Verify $V/V_{\text{allow}} + T/T_{\text{allow}} \leq 1$

$$118/3410 + 0/2500 = 0.03 + 0 = 0.03 < 1 \quad ; \text{ok}$$

DESIGN CALCULATION

(1) Drawing H-2-B5347 (2) Doc. No. WHC-SD-WM-DA-148 (3) Page H-7 of H-7
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FIGURE H-2. CAUSTIC INJECTION SKID, FREE BODY DIAGRAM