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18. B. M. Koons Signature of EDT Originator Date 2/24/95	19. M. J. Ostrom 2-24-95 Authorized Representative for Receiving Organization Date	20. C. E. Hanson 2/24/95 Cognizant/Project Engineer's Manager Date	21. DOE APPROVAL (if required) Ltr. No. ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments
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RELEASE AUTHORIZATION

Document Number: WHC-SD-WM-DA-167, REV.0

Document Title: Cradle Modification for Hydraulic Ram

Release Date: February 28, 1995

**This document was reviewed following the
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Signature

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57030/N2B2K

7. Abstract

The analysis of the cradle hydraulic system considers stress, weld strength, and hydraulic forces required to lift and support the cradle/pump assembly. The stress and weld strength of the cradle modifications is evaluated to ensure that they meet the requirements of the American Institute for Steel Construction (AISC 1989). The hydraulic forces are evaluated to ensure that the hydraulic system is capable of rotating the cradle and pump assembly to the vertical position (between 70° and 40°).

Koons 5/25/95

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Cradle Modification for Hydraulic Ram

September 1994

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B.M. Koons

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Equipment Stress Analysis

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DESIGN VERIFICATION METHOD

The need for design verification has been reviewed with the method selected as indicated below:

<u> x </u>	Independent Review
<u> </u>	Alternate Calculations
<u> </u>	Qualification Testing
<u> </u>	Formal Design Review

~~M.J. Ostrom~~
Cognizant/Project/Design Manager

SD # WHC-SD-WM-DA-167

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TYPICAL CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed WHC-SD-WM-DA-167

Author B.M. Koons *B.M. Koons* 11/18/94

Yes No N/A

☒	☐	☐	Problem completely defined.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☐	☐	☒	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	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.

MANDATORY Software QA Log Number N/A

R. L. Jorissen
Reviewer

Randy Jorissen

1/9/95
Date

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Cradle Modification for Hydraulic Ram

1.0 INTRODUCTION

Hydrogen buildup causes periodic roll over of radioactive waste in tank SY101, located in the 200W area of the Hanford Reservation. A 60 foot long, 20,000 pound mixer pump has been designed to mitigate the hydrogen buildup problem. A pump cradle was designed to transport and erect the mixer pump between a horizontal and vertical position. The pump was erected by rotating about a hinged axis using a crane, two air winches, and a snubber jack with a hand pump (WHC 1993). In an effort to reduce the system complexity, a hydraulic cylinder and power unit was procured to replace the air winches. With the addition of the hydraulic system, the cradle can be erected to vertical without the two air winches and snubber hand pump (WHC 1995a). This supporting document details the structural and hydraulic design work that went into the specification and procurement of the hydraulic system.

This supporting document reports on the structural analysis of the equipment based on requirements for safety class 3 (DOE-RL 1993a), the *Manual of Steel Construction* (AISC 1989), and the *Hanford Hoisting and Rigging Manual* (DOE-RL 1993b).

2.0 SUMMARY

The calculations in Appendix A show that the cradle modifications made for the hydraulic ram (WHC 1994a), are designed to raise the 241SY101 pump and cradle from a horizontal position to a vertical position and lower it back down to a horizontal position.

The calculations in Appendix B and Appendix C were used to develop criteria used in the *Specification for 241-SY Pump Cradle Hydraulic System* (WHC 1994b). Equipment detailed in (WHC 1994c) and (WHC 1994d) and procured per (WHC 1994b) meet the criteria developed by these calculations and will perform the following tasks:

1. Maintain the hydraulic ram full of fluid while minimizing force and allowing a crane to raise and lower the cradle between horizontal and 70 degrees.
2. Raise and lower the cradle between a 70 degree inclination and a vertical position.
3. Modify the snubber system to catch the cradle and gently lower it into position as the center of gravity passes over the pivoting pins.
4. The modified snubber system will also boost the cradle over during lowering until the weight of the cradle is capable of collapsing the telescopic cylinder.

The operability of the system was tested per *Acceptance Test Procedure for 241-SY Pump Cradle Hydraulic System* (WHC 1994e and WHC 1995b). Test results are described in the *Acceptance Test Report for 241-SY Pump Cradle Hydraulic System* (WHC 1995c).

3.0 DISCUSSION

The structural calculations are based on the following allowable stresses: 12,000 lbf/in² for bending, tension, and bearing; 7,200 lbf/in² for shear; 7,200 lbf/in² on effective area for welds. The *Hanford Site Hoisting and Rigging Manual* (DOE-RL 1993b) allowable stress of one-third of yield strength was determined to provide adequate factor of safety.

The cylinder calculations were performed to determine an appropriate cylinder size. These calculations were performed using trigonometric relations to solve the moment balance equation. This equation was then imported into a spreadsheet and the required cylinder force was obtained for one degree increments of inclination for the cradle between 70 degrees and vertical.

3.1 Structural Modifications to Cradle

The structural modifications to the cradle consist of an adaptation of structural steel to the underside of the cradle between support lines 3 and 4. This structure is designed to support the upper cylinder mounting clevis and transmit the cylinder forces into the cradle.

The structure is formed by three W8X67 sections coped and fit into an "H" segment starting at support line 3. From the center of the "H" segment two WT8X33.5 sections extend diagonally to the outside edges of the cradle at support line 4. The clevis is then located directly below cradle support line 3. All reactions from the cylinder are transmitted to the cradle through the structurally substantial elements at support lines 3 and 4.

3.2 Structural Modifications to Cradle Laydown Pad

The structural modifications to the cradle laydown pad consist of an addition of structural steel to the concrete pad. The addition is attached to the pad using existing anchor bolts at support lines 2 and 3. This structure is designed to support the lower cylinder mounting clevis and transmit the cylinder forces into the reinforced concrete pad.

The structure is formed by three W12X87 sections coped and fit into an "H" segment. Four base plates are welded to the corners of the "H" segment. These base plates are drilled for bolting to the eight existing anchor bolts in the concrete pad. The lower clevis is located on the top of this structure towards support line 2. All reactions from the cylinder are transmitted to the cradle laydown pad through the reinforced concrete pad at support lines 2 and 3.

3.3 Hydraulic Ram, Snubber, and Power Unit

The hydraulic cylinder was procured to lift 125% of the calculated weight of the cradle and pump assembly. It is a Standex model 8 1/4 5-26-280, five stage, 280 inch stroke with 8 1/4 inch bore on the first stage and 4 inch bore on the final stage. The cylinder has a design pressure of 2,000 psi and is proof tested to 2,500 psi.

As the cradle is rotated to the vertical position its center of gravity will cross over the axis of rotation causing the cradle to lash over to the vertical position. To prevent this a snubber cylinder is used to hold the cradle and lower it into the vertical position in a controlled manner. The snubber will also be used to push the cradle back over the lash point when it is being lowered. The snubber is a HyPower unit with a 5 inch diameter, 16 1/4 inch collapsed height and a 12 inch stroke. The snubber has a design pressure of 3,000 psi and is proof pressure tested. The new snubber is activated by the hydraulic power unit, replacing the ENERPAC® snubber and hand pump.

Due to limited space for mounting the cylinder, the system is only capable of lifting the cradle from an angle of 70 degrees, below that a crane will lift the cradle assembly. Because of this the hydraulic power unit is designed for two modes of operation, a crane handling mode and a hydraulic operator mode. During the crane lift, the hydraulic system will operate in a passive mode allowing the 50 gpm at low pressure to flow into or out of the cylinder as required. This will sustain fluid volume in the cylinder at a benign pressure while the cradle is rotated between horizontal and 70 degrees. At 70 degrees the system will be switched to a high pressure mode (2,000 psi) and the hydraulic operator will take over and raise or lower the cradle between 70 degrees and the vertical position. The power unit also controls the operation of the snubber cylinder. When raising, the cradle contacts the snubber and tries to collapse it. The power unit will only retract the snubber when the cradle is in contact with the snubber and the ram is pushing on the cradle. When the cradle is to be lowered, the snubber will push on the cradle and collapse the five stage ram.

4.0 CONCLUSION

The calculations in Appendices A, B and C show that the cradle modifications are qualified to carry the loads imparted by the hydraulic ram. These calculations also show that the cylinder is adequately sized to raise the cradle from 70 degrees to vertical when operated at 2,000 psi.

Review of the Acceptance Test Report (WHC-SD-WM-ATR-094) and the Certified Vendor Information File (CVI #22604) shows that the hydraulic system meets the requirements of Procurement Specification (WHC-S-0284).

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5.0 REFERENCES

- AISC 1989, *Manual of Steel Construction*, Ninth edition, American Institute for Steel Construction, Chicago, Illinois.
- DOE-RL 1993a, *Standard Arch-Civil Design Criteria*, Design Loads for Facilities, Hanford Plant Standard SDC-4.1, Rev. 12, U.S. Department of Energy Richland Field Office, Richland, Washington.
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- WHC 1994d, *Calkins Supplied SY-101 Cradle Hydraulic System*, certified vendor information file 22604, Westinghouse Hanford Company, Richland, Washington.
- WHC 1994e, *Acceptance Test Procedure for 241-SY Pump Cradle Hydraulic System*, document WHC-SD-WM-ATP-094, Westinghouse Hanford Company, Richland, Washington.
- WHC 1995a, *Operation and Maintenance Manual for 241SY101 Cradle Hydraulic System*, document WHC-SD-WM-OMM-014, Westinghouse Hanford Company, Richland, Washington.
- WHC 1995b, *ECN to Acceptance Test Procedure for 241-SY Pump Cradle Hydraulic System*, ECN 612248, Westinghouse Hanford Company, Richland, Washington.
- WHC 1995c, *Acceptance Test Report for 241-SY Pump Cradle Hydraulic System*, document WHC-SD-WM-ATR-094, Westinghouse Hanford Company, Richland, Washington.

Appendix A
Calculations for Cradle and Pad Modifications

THETA	BETA	GAMA	Fcyl	CRADLE FORCES		BASE FORCES	
degrees	degrees	degrees	lbs	axial	normal	axial	normal
55	40.65	84.35	45552.13	34559.06	29676.05	4487.022	45330.6
60	39.68	80.32	38533.00	29653.81	24805.75	6482.366	37983.82
65	38.53	76.47	31100.93	24330.17	19372.93	7275.514	30237.97
70	37.22	72.78	23192.08	18468.28	14028.37	6865.867	22152.48
71	36.94	72.06	21547.55	17221.63	12950.38	6638.049	20499.59
72	36.66	71.34	19880.91	15948.25	11870.29	6361.064	18835.8
73	36.37	70.63	18191.64	14647.33	10788.47	6034.631	17161.55
74	36.08	69.92	16479.20	13318.05	9705.335	5658.439	15477.28
75	35.79	69.21	14743.07	11959.59	8621.266	5232.155	13783.41
76	35.49	68.51	12982.69	10571.14	7536.684	4755.421	12080.41
77	35.18	67.82	11197.52	9151.891	6451.928	4227.854	10368.69
78	34.88	67.12	9386.99	7701.04	5367.462	3649.047	8648.706
79	34.56	66.44	7550.53	6217.773	4283.667	3018.567	6920.893
80	34.25	65.75	5687.54	4701.278	3200.95	2335.96	5185.691
81	33.93	65.07	19510.00	16187.56	10890.5	8224.159	17691.9
82	33.61	64.39	17700.00	14741.01	9797.59	7650.712	15961.1
83	33.29	63.71	15880.00	13274.87	8715.053	7032.312	14238.01
84	32.96	63.04	14630.00	12275.68	7958.932	6632.192	13040.36
85	32.63	62.37	13600.00	11453.96	7332.579	6306.414	12049.45
86	32.29	61.71	12560.00	10617.34	6710.12	5953.162	11059.54
87	31.96	61.04	11500.00	9757.211	6086.612	5567.631	10062.38
88	31.62	60.38	10420.00	8873.382	5462.554	5149.562	9058.61
89	31.28	59.72	9320.00	7965.665	4838.447	4698.701	8048.888
90	30.93	59.07	31400.00	26934.62	16139.59	16139.62	26934.6

t.

To Gary Harris 376-0279

from: B. Koons

New load on cradle

DESIGN CALCULATION

(1) Drawing H-2-83737 ^{SHTS.} 1-4 (2) Doc. No. _____ (3) Page _____ of _____
(4) Building _____ (5) Rev. _____ (6) Job No. _____
(7) Subject CRADLE-HYDRAULICS
(8) Originator G.J. HARRIS Date 7/29/94
(9) Checker Tw. L. L. Date 8/4/94

TWO CRITICAL CASES: (FROM ACCOMPANYING TABLE (B. KOONS))

$\phi = 55^\circ$ - CASE ①

MAXIMUM VERTICAL FORCE = 45330.6 lb.

AXIAL FORCE = 4487.0 lb.

$\phi = 90^\circ$ - CASE ②

VERTICAL FORCE = 26934.6 lb.

MAXIMUM AXIAL FORCE = 16139.62 lb.

USING 1.25 IMPACT FACTOR

CASE ① : $P_{Y-1} = (1.25)(45330) = 56.663k$

$P_{X-1} = (1.25)(4.482) = 5.609k$

CASE ② : $P_{Y-2} = (1.25)(26935) = 33.67k$

$P_{X-2} = (1.25)(16.139) = 20.18k$

DISTRIBUTION OF X-AXIS FORCES

STATICS: $P_x = P_a + P_b$

CONTINUITY:

$\Delta_a = \Delta_b + \Delta_o/6$

$\Delta_{ab} = \sum \frac{P_i L_i}{AE} = \frac{P_a(4.77)(12) + P_b(3.57)(12)}{(29000)(25.6)}$

$\Delta_a = \frac{P_a L^3}{48EI}$; $\Delta_b = \frac{P_b L^3}{48EI}$

$\Delta_a = \frac{P_a(6^3)(1728)}{(48)(241)(29000)}$; $\Delta_b = \frac{P_b(6^3)(1728)}{(48)(241)(29000)}$; $\therefore 0.0111 P_a = 0.0111 P_b + 0.00003 P_b + 0.0000 P_b$

$\therefore P_b = 0.887 P_a$

$\therefore P_a + 0.887 P_a = P_x$; $P_a = 0.530 P_x$; $P_b = 0.470 P_x$

* H-2-83737

DESIGN CALCULATION

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 (9) Checker P. W. Fickel Date 8/4/94

3

CRADLE-CYLINDER

(10)

DISTRIBUTION OF X-DIRECTION FORCES:

ANCHOR BOLT SHEARS

CASE ①: $V_e = V_d = V_c = V_f = (0.530)(\frac{1}{4})(5.609)$
 $= 0.743^k$

$V_g = V_h = V_i = V_j = (0.470)(\frac{1}{4})(5.609)$
 $= 0.659^k$

CASE ②: $V_c = V_d = V_e = V_f = (0.530)(\frac{1}{4})(20.18)$
 $= 2.674^k$

$V_g = V_h = V_i = V_k = (0.470)(\frac{1}{4})(20.18)$
 $= 2.371^k$

CASE ① TORSIONS ON BEAMS

BEAM ⑧

$\frac{1}{2}(w_{12 \times 8}) = (12.53)(\frac{1}{2}) = 6.265 \text{ in.}$
 $\text{MOMENT ARM}^* = 7.015 \text{ in.}$
 $T_{ob-1} = (4)(0.743)(\frac{7.015}{12})$
 $= 1.737^k \text{ FT.}$

BEAM ③

$T_{oc-1} = (2)(2)(0.659)(\frac{7.015}{12}) = 1.541^k \text{ ft.}$

CASE ②

BEAM ⑧

$T_{ob-2} = (2)(2)(2.674)(\frac{7.015}{12}) = 6.253^k \text{ ft.}$

BEAM ③

$T_{oc-2} = (2)(2)(2.371)(\frac{7.015}{12}) = 5.544^k \text{ ft.}$

* MOMENT ARM = $\frac{6.265}{2} + 0.75$ thickness of base plate = 7.015 in.

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page _____ of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject CRADLE-HYDRAULICS
 (8) Originator G.J. HARRIS Date 4/27/94
 (9) Checker TW Fisher Date 8/4/94

4

(10) CRADLE-CYLINDERBEAM "A" DESIGN - CASE ①

$$R_A = (56.663) \left(\frac{4.77}{8.33} \right) - \frac{(5.609)(1.105)}{(8.333)} + \left(\frac{1.737 + 1.105}{8.333} \right) = 32.031 \text{ K}$$

$$R_B = (56.663) \left(\frac{3.57}{8.33} \right) + \frac{(5.609)(1.105)}{(8.333)} - \left(\frac{1.737 + 1.541}{8.333} \right) = 24.632 \text{ K}$$

$$M_{max} = 117.537 \text{ K-ft}$$

$$f_b = \frac{(117.537)(12)}{(118.0)} = 11.958 \text{ ksi} \left(\begin{array}{l} \text{SEE PG. 30} \\ \text{FOR ALLOWABLE} \end{array} \right)$$

$$M_s = \frac{12}{11.958} - 1 = 0.004 \text{ OK}$$

$$f_a = \frac{4.296}{25.6} = 0.168 \text{ ksi (NEGLIGIBLE)}$$

FIND MAX DEFLECTIONMAX DEFLECTION @ $\phi = 0$

ROARK'S FORMULAS FOR STRESS & STRAIN - 6TH EDITION - PGS 100 & 105

$$\phi(x) = \phi_a + \frac{R_a x^2}{2EI} - \frac{W}{2EI} (x-a)^2 + \frac{M_a x}{EI} + \frac{M_o (x-3.57)}{EI} + \frac{M_b (x-8.33)}{EI}$$

$$M_a = -1.737 \text{ K-ft}, M_b = -1.541 \text{ K-ft}, W = 56.663 \text{ K}, M_o = (1.105)(5.609) = 6.198 \text{ K-ft}$$

$$R_a = 32.037 \text{ K}$$

$$\text{FIND } \phi_a: \phi_a = \frac{(144)}{(6)(29000)(740)(8.333)} \left((1.737)(2)(8.33)^2 - (1.541)(8.33)^2 + (6.198)(2)(8.33)^2 - (6)(3.57)(8.33) + (3)(3.57)^2 \right)$$

$$+ \frac{(56.663)(3.57)(144)}{(6)(29000)(740)(8.333)} (12)(8.33 - 3.57)(8.33 - 3.57) = -0.0017 \text{ rad}$$

$$\therefore \phi(x) = -0.0017 + \frac{144}{(29000)(740)} \left(\frac{32.037 x^2}{2} - \frac{56.663(x-3.57)^2}{2} - (1.737)x + 6.198(x-3.57) - 1.541(x-8.33) \right)$$

$$\text{FOR } \phi(x) = 0 \text{ ASSUME } x > 3.57' \therefore 0 = x^2 - 16.697x + 50.76 \quad x = 3.9975'$$

$$\therefore \Delta_x = (-0.0017)(3.997)(12) + \frac{(1728)}{(29000)(740)} \left(\frac{(32.037)(3.997)^2}{6} - \frac{(56.663)(3.997-3.57)^3}{6} + \frac{(6.198)(3.997-3.57)^2}{2} - (1.541)(3.997)^2 \right) = -0.056 \text{ in. } (< 0.1" \text{ OK})$$

$$* \frac{d}{2} (W 12 \times 87) = \left(\frac{1}{2} \right) (12.53)''$$

$$7'' \text{ DEPTH FROM BASE OF CLEVIS TO CENTER OF CLEVIS} \therefore e = \left(7 + \frac{12.53}{2} \right) \left(\frac{1}{4} \right) = 1.105'$$

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(10) CRADLE CYLINDERBEAM "A" DESIGN - CASE (2)

$$R_a = (33.67) \left(\frac{4.77}{8.33} \right) - (20.18) \left(\frac{1.105}{8.33} \right) + \left(\frac{6.253 + 5.544}{8.33} \right) = 18.026 \text{ k}$$

$$R_b = (33.67) \left(\frac{3.57}{8.33} \right) + (20.18) \left(\frac{1.105}{8.33} \right) - \left(\frac{5.544 + 9.951}{8.333} \right) = 15.65 \text{ k}$$

CHECK AXIAL FORCES

$$f_a = \frac{10.696}{19.1} = 0.560 \text{ ksi}$$

$$\left(\frac{KL}{r} \right)_y = \frac{(8.333)(12)}{(3.07)} = 32.573$$

$$F_a(33) = 19.73 \text{ ksi}$$

$$\frac{f_a}{F_a} = \frac{0.560}{19.73} = 0.028 < 0.15 \text{ USE AISC H-2}$$

$$f_{bx} = \frac{(79.810)(12)}{(118.0)} = 8.116 \text{ ksi}$$

$$\therefore 0.028 + \frac{8.116}{12.0} = 0.704 < 1.0$$

USE W 12x87

CHECK FOR BEARING STRESS - CASE (1)

$$N = 10.25 \text{ IN. WIDTH OF CLEVIS, } t = 1.5 \text{ IN}$$

$$f_{\text{bearing}} = \frac{54.663}{(12)(1.5) + 10.25(0.515)} = 8.304 \text{ ksi} < 12.0 \text{ ksi}$$

(SEE PG. 30
FOR REF
NO STIFFENERS
REQ'D.)

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(10) CRADLE-CYLINDER
FLOOR BEAMS (B)

TORSION STRESS

REF. ROARKE FORMULAS FOR STRESS AND STRAIN
 6TH EDITION - TABLE 20, PG. 348. # 4
 EQUIVALENT TORSIONAL INERTIA

$$K_i = a b_i^3 \left(\frac{16}{3} - 3.36 \frac{b_i}{a_i} \left(1 - \frac{b_i^4}{12 a_i^4} \right) \right)$$

ELEMENTS ① ③ : $a = \frac{12.125}{2} = 6.063 \text{ in.}$, $b = \frac{0.810}{2} = 0.405 \text{ in.}$
 $\therefore K_{1,3} = (6.063)(0.405)^3 \left[\frac{16}{3} - 3.36 \left(\frac{0.405}{6.063} \right) \left(1 - \frac{1}{12} \left(\frac{0.405}{6.063} \right)^4 \right) \right] = 2.058 \text{ in.}^4$

ELEMENT ② : $a = (12.53 - (2)(0.810)) \left(\frac{1}{2} \right) = 5.455 \text{ in.}$

$b = \left(\frac{1}{2} \right) (0.515) = 0.258 \text{ in.}$

$K_2 = (5.455)(0.258)^3 \left[\frac{16}{3} - 3.36 \left(\frac{0.258}{5.455} \right) \left(1 - \frac{1}{12} \left(\frac{0.258}{5.455} \right)^4 \right) \right] = 0.482 \text{ in.}^4$

STATICS: $T = T_1 + T_2 + T_3$

ANGLE OF TWIST: $\phi_1 = \phi_2 = \phi_3$

$\phi_1 = \frac{T_1 L}{J_1 G}$, $\phi_2 = \frac{T_2 L}{J_2 G}$, $\phi_3 = \frac{T_3 L}{J_3 G}$

$\therefore T_3 = T_1$, $T_2 = \frac{0.482}{2.058} T_1 = 0.234 T_1$

$\therefore (1 + 1 + 0.234) T_1 = T$, $T_1 = 0.448 T$

$T_2 = 0.105 T$

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(10) CRADLE CYLINDER FLOOR BEAMS (CONT.)

TORSION STRESSES (CONT.)

MAX. STRESS PER ELEMENT - ROARK'S FORMULAS FOR STRESS AND STRAIN.
 6TH EDITION - TABLE 20 PG. 348 # 4

$$\tau_{max} = \frac{3T}{8ab^2} \left[1 + 0.6095 \frac{b}{a} + 0.8865 \left(\frac{b}{a} \right)^2 - 1.8023 \left(\frac{b}{a} \right)^3 + 0.91 \left(\frac{b}{a} \right)^4 \right]$$

CASE ② CRITICAL

$$\text{ELEMENTS: } \tau_{max} = \frac{(3)(3.127)(12)(0.448)}{(8)(6.063)(0.405)^2} \left[1 + 0.6095 \left(\frac{0.405}{6.063} \right) + 0.8865 \left(\frac{0.405}{6.063} \right)^2 - 1.8023 \left(\frac{0.405}{6.063} \right)^3 + 0.91 \left(\frac{0.405}{6.063} \right)^4 \right]$$

① ③

$$= 6.618 \text{ ksi} < 7.2 \text{ ksi OK}$$

$$\text{ELEMENT: } \tau_{max} = \frac{(3)(3.127)(12)(0.105)}{(8)(5.455)(0.258)^2} \left[1 + 0.6095 \left(\frac{0.258}{5.455} \right) + 0.8865 \left(\frac{0.258}{5.455} \right)^2 - 1.8023 \left(\frac{0.258}{5.455} \right)^3 + 0.91 \left(\frac{0.258}{5.455} \right)^4 \right]$$

②

$$= 4.209 \text{ ksi} < 7.2 \text{ ksi OK}$$

BENDING / WARPAGE

$$\text{CASE ①: } M_x = (32.07) \left(\frac{6}{4} \right) = 48.056 \text{ kft} \quad M_y = (2.972) \left(\frac{6}{4} \right) = 4.458 \text{ kft}$$

$$f_{bx} = \frac{(48.056)(12)}{(48)} = 4.887 \text{ ksi} \quad f_{by} = \frac{(6.444)(12)}{(39.7)} = 1.948 \text{ ksi}$$

ROARK'S FORMULAS FOR STRESS AND STRAIN: PG 367 TABLE 21 - CROSS SECTION 6

$$f_{\text{WARPAGE}} = \frac{h^3 E \theta''}{4} \quad h = 12.53 - 0.810 = 11.720 \text{ in.}$$

$$\theta'' = - \frac{T_0}{2C_w B E} \tanh \frac{B l}{2}$$

ROARK'S FORMULAS FOR
 STRESS & STRAIN 6TH EDITION
 PG. 373 - TABLE 22
 RESTRAINTS 1

$$C_w = 8270.0 \text{ in.}^6, B = \frac{1}{64.8} = 0.015$$

$$\therefore \theta'' = - \frac{T_0}{(8270)(0.015)(29000.)(2)} \left(\frac{e^{(0.015)(6)(12)} - e^{-(0.015)(6)(12)}}{e^{(0.015)(6)(12)} + e^{-(0.015)(6)(12)}} \right)$$

$$= -1.087 \times 10^{-7} T_0$$

$$\therefore f_{\text{WARPAGE}} = \frac{(-0.759)(12)(11.725)(29000)(11.720)}{4} (-1.087 \times 10^{-7})$$

$$= 1.168 \text{ ksi}$$

(SEE PG. 39 FOR
 STRESS ALLOW REFERENCE)

$$\therefore \text{TOTAL BENDING STRESS} = 4.887 + 1.948 + 1.168 = 8.003 \text{ ksi} < 12.0 \text{ ksi OK}$$

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(10) CRADLE - CYLINDER
FLOOR BEAMS (B)

BENDING/WARPAGE:

$$\text{CASE ②: } M_x = \frac{(17.861)(6)}{4} = 26.792 \text{ k-ft. } f_{bx} = \frac{(26.792)(12)}{(118)} = 2.725 \text{ ksi}$$

$$M_y = \frac{(12.696)(6)}{4} = 16.044 \text{ k-ft. } f_{by} = \frac{(16.044)(12)}{(39.7)} = 4.850 \text{ ksi}$$

$$f_{\text{WARPAGE}} = \frac{(3.127)(12)(12.125)(29000)(11.720)(1.087 \times 10^{-7})}{4} = 4.201 \text{ ksi}$$

$$\text{TOTAL BENDING STRESS} = 4.201 + 4.850 + 2.725 = 11.776 \text{ ksi} < 12.0 \text{ ksi OK}$$

(SEE PG. 30 FOR STRESS ALLOWABLES)

USE W12X87

CONNECTION

WELD ①: CRITICAL FOR AXIAL FORCE & BENDING:

LOAD CASE ② CRITICAL: GROOVE WELD AS GOOD AS PARENT MATERIAL

$$f = \frac{10.696}{(2)(0.810)(12.15)} + \frac{(5.584)(12)}{(0.810)(12.15)(12.53 - 0.810)}$$

$$= 1.124 \text{ ksi OK}$$

WELD ②: CRITICAL FOR VERTICAL LOAD - LOAD CASE ①

$$A_{\text{WELD}} = (2)(5.805) + 10.910 = 22.520 \text{ in.}$$

$$\bar{X}_{\text{WELD}} = \frac{(5.805^2)(1/2)}{(22.520)} = 0.748 \text{ in.}$$

$$I_{\text{WELD}} = \frac{(2)(5.805 + 10.910)^3}{(12)} - \frac{(5.805)^2(5.805 + 10.910)^2}{((2)(5.805 + 10.910))}$$

$$= 533.682 \text{ in.}^3$$

$$T_{\text{WELD}} = (0.748)(32.037) = 23.964 \text{ k-in}$$

$$f_{x\text{-WELD}} = \frac{(23.964)(5.455)}{533.682} = 0.245 \text{ ksi}$$

$$f_{y\text{-WELD}} = \frac{32.037}{22.520} + \frac{(23.964)(6.057)}{533.682} = 1.650 \text{ ksi}$$

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CRADLE - CYLINDER
 (10) CONNECTION BEAM "A" TO BEAM "B"

$$f_r = (0.245^2 + 1.650^2)^{1/2} = 1.668 \text{ k/in.}$$

$$f_{\text{WELD}} = \frac{1.668}{1/2} = 3.336 \text{ ksi} < 7.2 \text{ ksi} \quad \text{WELDS SUFFICE}$$

(SEE PG. 30 FOR WELD STRESS ALLOWABLE)

BASE PLATE / ANCHOR BOLTS

CASE ① : GREATEST VERTICAL FORCE: $P = 16.019 \text{ k}$
 $V_{\text{BOLT}} = 0.743 \text{ k}$
 $M = 0.869 \text{ k-ft}$

CHECK FOR UPLIFT: $A_{\text{RATE}} = (36)(12) = 432.0 \text{ in.}^2$
 $S_{\text{RATE}} = \frac{(36)^2(12)}{6} = 2592.0 \text{ in.}^3$

$$f = \frac{16.019}{432.0} \pm \frac{(0.869)(12)}{2592.0} = \frac{0.033 \text{ ksf}}{0.041 \text{ ksf}} \quad \text{NO TENSION}$$

$$f_{a-a} = 0.033 + \left(\frac{18 + 6.063}{36} \right) (0.041 - 0.033) = 0.038 \text{ ksf}$$

$$M_{a-a} = \frac{(0.038)(12)(11.938)^2}{2} + \frac{(0.041 - 0.038)(12)(11.938)^2}{3} = 34.320 \text{ k-in.}$$

THIS MUST BE COMPARED WITH
 WITH CASE ②

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(10) BASE PLATE / ANCHOR BOLTSCASE (2) : GREATEST BENDING MOMENT :

$$M = 3.127 \text{ K-ft}$$

$$P = 8.931 \text{ K}$$

$$V_{\text{BOLT}} = \frac{5.348}{2} = 2.674 \text{ K}$$

CHECK FOR TENSION

$$f = \frac{8.931}{432.0} + \frac{(3.127)(12)}{2592} = 0.006 \text{ KSI} + 0.035 \text{ KSI}$$

$$f_{a-a} = (0.006) + \left(\frac{24.063}{36} \right) (0.035 - 0.006) = 0.025 \text{ KSI}$$

$$M_{a-a} = (0.025)(12) \left(\frac{11.938^2}{2} \right) + (0.035 - 0.025)(12) \left(\frac{11.938}{3} \right)^2 = 26.508 \text{ K-ft}$$

CASE (1) GOVERNS.

$$L_{\text{RATE}} = \sqrt{\frac{(6)(34.320)}{(27)(12)}} = 0.79 \text{ " N 0.75" OK}$$

(SEE H-2-B7737)

BOLTS : $V_{\text{BOLT}} = 2.674 \text{ K}$, $V_{\text{ALLOW}} = 3.56 \text{ K}$ OK

WELDS : $M_{\text{WELD}} = 3.127 \text{ K-ft}$, $V_x = (2.674)(2) = 5.348 \text{ K}$, $V_y = 8.931 \text{ K}$

CASE (2)
CRITICAL

$$S_{\text{WELD}} = (2)(2)(6.063) = 145.5 \text{ IN.}^2$$

$$A_{\text{WELD}} = 24 \text{ IN.}$$

$$f_{\text{WELD-Y}} = \frac{8.931}{24.0} + \frac{(3.127)(12)}{145.5} = 0.630 \text{ K/IN.}$$

$$f_{\text{WELD-X}} = \frac{5.348}{24.0} = 0.223 \text{ K/IN.}$$

$$f_r = (0.630^2 + 0.223^2)^{1/2} = 0.668 \text{ K/IN.}$$

(SEE PG. 30 FOR REF. ALLOW)

$$f_{\text{WELD}} = 0.668 / 0.25 = 2.673 \text{ KSI} < 7.2 \text{ KSI OK}$$

WELDS SUFFICE

* BASE PLATE IS CONSIDERED NON-HANDLING EQUIPMENT, USE AISC
 ALLOWABLE $F_b = 3/4 F_y$ AISC 6TH EDITION PG. 5-48
 EQ. F-2-1

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CRADLE - CYLINDER

(10)

CONCRETE PAD / SOIL STRESSES

$$A_{ftng.} = 30.0 \text{ ft.}^2, W_{FTNG.} = (0.15)(30)(10) = 4.5^k$$

$$\text{CASE ①: } M_{FTNG.} = (6.265 + 12.0)(1.486)(\frac{1}{2}) = 2.362^{\text{kft}}$$

$$\text{CASE ②: } M_{FTNG.} = (6.265 + 12.0)(10.696)(\frac{1}{2}) = 16.280^{\text{kft}}$$

$$\text{CASE ①: } P = 4.5 + 16.018 + (0.087)(6 + \frac{8.33}{2}) = 21.403^k$$

← WT. OF FLOOR BEAMS

$$\text{CASE ②: } P = 4.5 + 17.861 + (0.087)(6 + \frac{8.33}{2}) = 23.246^k$$

$$S_{ftng} = \frac{3^2(10)}{6} = 15.0 \text{ ft.}^2$$

SOIL STRESSES:

$$\text{CASE ①: } \frac{21.403}{30} \pm \frac{2.362}{15.0} = \begin{matrix} 0.888 \text{ ksf} \\ 0.573 \text{ ksf} \end{matrix} \begin{matrix} \text{ } \\ \text{ } \end{matrix} \begin{matrix} 1.5 \text{ ksf} \\ \text{ } \end{matrix} \begin{matrix} \text{OK} \\ \text{NO UPLIFT} \end{matrix}$$

$$\text{CASE ②: } \frac{23.246}{30} \pm \frac{16.280}{15} = \begin{matrix} -0.340 \text{ ksf} \\ 1.86 \text{ ksf} \end{matrix} \begin{matrix} \text{ } \\ \text{ } \end{matrix} \begin{matrix} \text{REDISTRIBUTE} \end{matrix}$$

$$e = \frac{16.280}{23.246} = 0.7 \text{ ft.}$$

$$\therefore \frac{d}{2} - \frac{X_o}{3} = e$$

$$\therefore \frac{X_o}{3} = \frac{d}{2} - e = 1.5 - 0.7$$

$$X_o = 2.399'$$

$$\therefore f_c = \frac{23.246}{(\frac{1}{2})(10)(2.399)} = 1.938 \text{ ksf}$$

SOIL IS OVERSTRESSED

CONSIDER AN ADDITION 3' ON EACH SIDE OF THICKENER SLAB

$$f_c = \frac{1.938(10)}{(16)} = 1.211 \text{ ksf} < 1.5 \text{ ksf OK}$$

PUNCHING SHEAR: CASE ① - CRITICAL: $P_u = (1.7)(32.000) + (1.4)(4.5)(0.087)(6 + \frac{8.33}{2})$
 $= 76.752^k$

PUNCHING SHEAR PERIMETER

$$\therefore b_o = (12.125 + \frac{9}{2})(2) + (12 + \frac{9}{2})(2) = 186.25 \text{ in.}$$

ACI 318-89
EQ. 11-38

$$f_{pu} = \frac{(76.752)(1000)}{(186.25)(0.85)(9)} = 53.868 \text{ psi}, \frac{1}{2} = 4\sqrt{f'_c} = 4\sqrt{4500.00} = 266.33 \text{ psi OK}$$

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(10) CRADLE - CYLINDER

SLAB - REBAR

CASE ① : $P_u = (1.7)(16.016) = 27.231^k$
 $M_u = (1.7)(0.753) \left(\frac{6}{12} + \frac{12.53}{(2)(12)} \right) = 1.312^k\text{-ft}$
 $w_u = \frac{27.231}{3.0} \pm \frac{1.312}{3^2/6} = \frac{8.198^k}{ft} \pm \frac{9.956^k}{ft}$

LOCAL AREA AROUND
ANCHOR BOLTS

$$M_u = \left(\frac{9.373 - 8.198}{3} (0.995)^2 \right) + \left(\frac{8.198 (0.995)^2}{2} \right) = 4.446^k\text{-ft}$$

CONSIDER A 1- FOOT WIDTH

$$\frac{bd^2}{12000} = \frac{(12)(9)^2}{12000} = 0.081$$

$$R_u = \frac{4.446}{0.081} = 54.889$$

$$m = \frac{60}{(0.85)(45)} = 15.686$$

$$\rho = \frac{1}{15.686} \left(1 - \sqrt{1 - \frac{(2)(15.686)(54.889)}{60000}} \right) = 0.001$$

$$A_{s,REQ} = (0.001)(12)(9) = 0.108 \text{ in}^2/\text{ft.} \quad A_{s,prov} (\#5 @ 12") = 0.31 \frac{\text{in}^2}{\text{ft}} \quad \text{OK}$$

CASE ② : $P_u = (1.7)(8.931) = 15.183^k$
 $M_u = (1.7)(5.348) \left(\frac{6}{12} + \frac{12.53}{(2)(12)} \right) = 9.292^k\text{-ft}$

$$w_u = \frac{15.183}{3} \pm \frac{(9.292)(6)}{3^2} = \frac{-1.134^k}{ft} \pm \frac{11.256^k}{ft} \quad \text{TENSION NOT ALLOWED}$$

$$e = \frac{9.292}{15.183} = 0.612'$$

$$x_b = \left(\frac{3}{2} - 0.612 \right) = 2.664'$$

$$f_c = \frac{15.183}{\left(\frac{1}{2} \right) (2.664)} = 11.399^k/\text{ft}$$

$$M = (7.142) \left(\frac{0.995^2}{2} \right) + (11.399) \left(\frac{0.995^2}{3} \right) = 7.297^k\text{-ft}$$

$$R_u = \frac{7.297}{0.081} = 90.091$$

$$\rho = \frac{1}{15.686} \left(1 - \sqrt{1 - \frac{(2)(90.091)(15.686)}{60000}} \right) = 0.002$$

$$A_{s,prov} = (0.002)(12)(9) = 0.164 \frac{\text{in}^2}{\text{ft}} \quad \text{OK}$$

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(10) CRADLE - CYLINDER

BEAMS ① ONLY ONE CRITICAL CASE $\theta = 55^\circ$

$$P_{AXIAL} = 34.559^k, P_{NORMAL} = 29.676^k$$

$$\text{WITH IMPACT FACTOR, } P_{AXIAL} = (1.25)(34.559) = 43.199^k$$

$$P_{NORMAL} = (1.25)(29.676) = 37.095^k$$

CHECK EXISTING W6x15

$$m = \frac{(37.095)(4.5)}{4} = 41.732^k\text{-ft}$$

$$f_b = \frac{(41.732)(12)}{9.72} = 51.521^k\text{ksi} > 12.0^k\text{ksi}$$

MUST REINFORCE

TRY A SLIGHTLY CUT W8x67

BEAM ②

$$m = (43.199)(11.5) = 41.399^k\text{-ft}$$

$$V = \frac{41.399}{4.17} + \frac{72.177}{12} = 11.37^k$$

∴ TOTAL VERTICAL FORCE

$$= 37.095 + 11.37 = 48.465^k$$

$$∴ M = \frac{(48.465)(4.5)}{4} = 54.523^k\text{-ft}$$

COMPOSITE SECTION

ELEMENT	AREA (IN. ²)	y_c (IN.)	$A_i y_i$ (IN. ³)	$A_i y_i^2$ (IN. ⁴)	I_{ox} (IN. ⁴)
① W6x15	14.43	9+3 = 12	58.160	637.920	29.1
② W8x67 (Full)	19.7	4.5	88.650	398.925	272.0
③	-3.469	8.533	-29.601	-252.585	-0.253
	20.661		112.209	784.260	301.353

$$\bar{y} = \frac{112.209}{20.661} = 5.431 \text{ IN.}$$

$$I_{xx} = 301.353 + 784.260 - (20.661)(5.431)^2 = 476.210 \text{ IN.}^4$$

$$f_{bx} = \frac{(54.523)(12)(15 - 5.431)}{476.210} = 13.149^k\text{ksi} > 12.0^k\text{ksi}$$

CONSIDER CLEVIS PLATE

A-15

DESIGN CALCULATION

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(10) CRADLE - CYLINDER BEAM ①

$$A = 20.661 + (6.125)(1.0) = 26.786 \text{ in.}^2$$

$$\bar{Y} = \frac{(6.125)(0.5) + (20.661)(1+5.43)}{26.786} = 5.075 \text{ in.}$$

$$\bar{X} = \frac{(6.125)(-2.25 + \frac{6.125}{2})}{26.786} = 0.186 \text{ in.}$$

$$I_{xx} = 476.210 + (20.661)(5.43 - 5.075)^2 + \frac{6.125}{12}(1)^3 + (6.125)(5.075 - 0.5)^2 = 607.527 \text{ in.}^4$$

$$I_{yy} = 2.09 + \frac{(0.935)(8.28)^3}{12} + \frac{(4.57)^3(0.935)}{12} + (6.125)(0.935)(0.186)^2 + (4.57)(0.186)^2(0.935) + \frac{(0.57)^3(9 - 2 \times 0.935)}{12} + 10.570(9 - 2 \times 0.935)(0.186)^2 + (6.125)^3(\frac{1}{12}) + (6.125)(1)(-2.25 + \frac{6.125}{2} + 0.186)^2 = 60.320 \text{ in.}^4$$

$$I_{xy} = (20.661)(-0.186)(5.43 - 5.075) + (6.125)(1)(-2.25 + \frac{6.125}{2} + 0.186)(5.075 - 0.5) = 26.612 \text{ in.}^4$$

$$f_{(x,y)} = \frac{(54.523)(26.612)(12)Y}{((607.527)(60.320) - 26.612^2)} + \frac{(54.523)(60.320)(12)X}{((607.527)(60.320) - 26.612^2)} = 0.484Y + 1.098X$$

$$@ Y = 15 - 5.075 = 10.925 \text{ in.}, X = (3 - 0.186) = 2.814 \text{ in.}$$

$$\therefore f_{\max} = (0.484)(10.925) + (1.098)(2.814) = 8.383 \text{ ksi} < 12.0 \text{ ksi} \quad (\text{SEE PG. 30 FOR ALLOWABLES})$$

WELDS: $V = \frac{47.031}{2} = 23.516 \text{ k}$

$$Q_{a-a} = (16 - 3 - 5.075)(4.43) + (0.935)(4.56)(16 - 6 - 0.935 - 5.075) = 52.120 \text{ in.}^3$$

$$f_v = \frac{(23.516)(52.120)}{(607.527)(2)(\frac{3}{16})} = 5.381 \text{ ksi} < 7.2 \text{ ksi} \quad (\text{SEE PG. 30 FOR WELDS ALLOWABLE})$$

2 - WELDS

DEFLECTION: $\Delta = \frac{(47.031)(4.5)^3(1728)}{(48)(607.527)(29000)} = 0.009 \text{ in.} < 0.1 \text{ in.}$

USE W8X67 (REF. T. MACKAY INSTRUCTIONS)

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CRADLE-CYLINDER
 (10) BEAM ⑤ TORSION STRESSES

$$\therefore T_2 = \frac{0.418}{2.102} T_1, T_3 = T_1$$

$$\therefore 2.399 T_1 = 0.042 \text{ k-ft}, T_1 = 0.019 \text{ k-ft}$$

$$T_2 = 0.004 \text{ k-ft}$$

$$\text{ELEMENT ①: } \tau_{\max} = \frac{3T}{8ab^2} \left[1 + 0.6095 \left(\frac{b}{a} \right) + 0.8865 \left(\frac{b}{a} \right)^2 - 1.8023 \left(\frac{b}{a} \right)^3 + 0.91 \left(\frac{b}{a} \right)^4 \right]$$

$$\therefore \tau_{\max} = \frac{(3)(0.019)(12)}{(8)(4.140)(0.468)^2} \left[1 + 0.6095 \left(\frac{0.468}{4.140} \right) + 0.8865 \left(\frac{0.468}{4.140} \right)^2 - 1.8023 \left(\frac{0.468}{4.140} \right)^3 + 0.91 \left(\frac{0.468}{4.140} \right)^4 \right]$$

$$= 0.102 \text{ ksi (NEGLIGIBLE)}$$

CONNECTION A

WELD A - FULL PENETRATION TAKES
MOMENT

$$T = \frac{(41.399)(12)}{(9 - 0.935)} = 61.598 \text{ k}$$

$$f = \frac{61.598}{(8.280)(0.935)} = 7.957 \text{ ksi} < 12 \text{ ksi OK}$$

WELD B - AXIAL FORCE / SHEAR

$$A_{\text{WELD}} = 2 + 7.13 + 3.855$$

$$= 12.985 \text{ in.}$$

$$\bar{x} = \frac{(2)(1) + (3.855)^2(\frac{1}{2})}{12.985} = 0.726 \text{ in.}$$

$$\bar{y} = \frac{(2)(7.13)(\frac{1}{2}) - (7.13)(\frac{1}{2})(3.855)}{12.985} = -0.509 \text{ in.}$$

$$43.199 \text{ k} \rightarrow 7.13''$$

$$T_{\text{WELD}} = (43.199)(0.509) - (9.94)(0.726) = 14.784 \text{ k-in.}$$

$$J_{\text{WELD}} = \frac{(7.13)^3}{12} + \frac{(2)^3}{12} + \frac{3.855^3}{12} + (7.13)(0.509)^2 + (2)\left(\frac{7.13}{2} + 0.509\right)^2$$

$$+ (2)\left(\frac{7.13}{2} - 0.509\right)^2 + (2)(1 - 0.726)^2 + (4)(2 - 0.726)^2 = 96.005 \text{ in.}^3$$

$$f_{x-\text{WELD}} = \frac{43.199}{(2)(12.985)} \pm \frac{(14.784)(\frac{7.03}{2 + 0.509})}{(2)(96.005)} = 1.973 \text{ k/in.}$$

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(10) CRADLE-CYLINDER - CONNECTION "A" - WELD B

$$f_{y-weld} = \frac{9.94}{(2)(12.985)} + \frac{(14.784)(1-0.726)}{(2)(96.005)} = 0.384 \frac{k}{in.}$$

$$f_{r-weld} = (1.973^2 + 0.384^2)^{1/2} = 2.010 \frac{k}{in.}$$

$$\sigma_{weld} = \frac{306}{\frac{5}{16}} = 6.433 ksi < 7.2 ksi \quad (\text{SEE PG. 30 FOR REF.})$$

MEMBER (2) :

$$P = 43.199^k, M_x = 41.399 \text{ k-ft.}$$

$$f_a = \frac{43.199}{19.7} = 2.193 \text{ ksi}$$

$$\left(\frac{KL}{r_y}\right) = \frac{(4.167)(12)}{(2.12)} = 23.585, f_a = 20.35 \text{ ksi}$$

$$\frac{f_a}{F_a} = 0.108 < 0.15 \quad \text{USE AISC EQ. H-2}$$

$$f_{bx} = \frac{(41.399)(12)}{(60.4)} = 8.225 \text{ ksi} \quad \text{AISC EQ. H-2}$$

$$\therefore 0.108 + \frac{8.225}{12} = 0.793 < 1.0$$

USE W8X67

REACTION FROM (2) $9.94 - (1.934)(2) = 6.072^k$ MEMBER (5) :

REACTIONS FROM (3) (4)

$$M = (6.072)\left(\frac{4.5}{4}\right) = 6.831 \text{ k-ft}$$

$$f_b = \frac{(6.831)(12)}{(60.4)} = 1.357 \text{ ksi OK.}$$

$$\Delta = \frac{(6.072)(4.5)(12)^3}{(48)(29000)(272)} = 0.003 \text{ in.} < 0.1 \text{ in.}$$

0.1-TOM MACKAY INSTRUCTIONS

MEMBERS (3) (4) :

$$e_L = \frac{9}{2} - 1.56 = 2.94 \text{ in.}$$

$$e_R = 1.17"$$

END ECCENTRICITIES
WT 8X53.5

$$P_{BRACE} = \frac{43.199}{2} \frac{(4.17^2 + 2.25^2)^{1/2}}{(4.17)} = 24.55^k$$

$$\therefore M_L = (2.94)(24.55) = 72.177 \text{ k-in.}, M_R = (24.255)(1.56) = 37.838 \text{ k-in.}$$

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(10) CRADLE-CYLINDER BEAM ② ⑤

REDUNDANT TO 1ST DEGREE:
FLEXIBILITY EQ.

$$\phi_{b0} + T_b \phi_{b1} + T_b \phi_{b2} + T_b \phi_{b3} = 0$$

$$\phi_{b1} \text{ (FLEXIBILITY FOR SPAN ②) } = \frac{L_2}{3EI} = \frac{(4.167)(12)}{(3)(29000)(272)} = 2.113 \times 10^{-6}$$

ϕ_{b2} (WARPAGE FROM SPAN ⑤) — PG. 372 "FORMULAS FOR STRESS & STRAIN" PG. 373—BOTH ENDS FREE TO WARP BUT NOT TWIST

$$= \frac{\frac{El}{2} - \tanh \frac{\beta l}{2}}{2CwE\beta^3 E}, \quad \beta = \sqrt{\frac{GJ}{ECw}} = \frac{1}{27.2} = 0.037/\text{in.}$$

$$\frac{\beta l}{2} = (0.037)(4.167)(12)(1/2) = 0.919$$

$$\therefore \phi_{b2} = \frac{0.919 - \frac{e^{0.919} - e^{-0.919}}{e^{0.919} + e^{-0.919}}}{(2)(1440)(0.037)^3 (29000)} = 4.577 \times 10^{-5}$$

$$\phi_{b3} \text{ (PURE TORSION ROTATION) } = \frac{L_6}{J_{EQ} G} = \frac{(4.5)(12)}{(5.06)(11200)} = 0.001$$

$$\phi_{b0} = \frac{T_a}{3EI} = \frac{(41.399)(12)(4.167)(12)}{(3)(29000)(272)} = 4.199 \times 10^{-5}$$

$$\therefore T_b = \frac{-4.199 \times 10^{-5}}{0.001} = -0.042 \text{ k-ft} \quad \text{NEGLECTIBLE EFFECT ON SHEARS}$$

CHECK W8X40 FOR TORSION STRESSES

$$\text{STATICS: } T = T_1 + T_2 + T_3$$

$$\text{CONTINUITY: } \phi_1 = \phi_2 = \phi_3$$

$$\frac{T_1 L}{K_1 G} = \frac{T_2 L}{K_2 G} = \frac{T_3 L}{K_3 G}$$

$$K_i = a_i b_i^3 \left(\frac{16}{3} - 3.36 \frac{b_i}{a_i} \left(1 - \frac{b_i^4}{12 a_i^4} \right) \right)$$

$$\text{ELEMENTS ①③: } a = \frac{8.28}{2} = 4.140 \text{ in.}, \quad b = \frac{0.935}{2} = 0.468 \text{ in.}$$

$$K_1 = (4.140)(0.468)^3 \left(\frac{16}{3} - 3.36 \frac{0.468}{4.140} \left(1 - \frac{0.468^4}{12(4.140)^4} \right) \right) = 2.102 \text{ in}^4$$

$$\text{ELEMENT ②: } a = (3-2)(0.935)(1/2) = 3.665 \text{ in.}, \quad b = (0.570)(1/2) = 0.285 \text{ in.}$$

$$K_2 = (0.285)^3 (3.665) \left(\frac{16}{3} - 3.36 \left(\frac{0.285}{3.665} \right) \left(1 - \frac{(0.285)^4}{12(3.665)^4} \right) \right) = 0.418 \text{ in}^4$$

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(10) CRADLE - CYLINDER
MEMBERS ③ ④ WT 6 X 25

$$f_a = \frac{24.55}{9.84} = 2.495 \text{ ksi}, \quad \left(\frac{KL}{r_x}\right) = \frac{(1.0)(4.74)(12)}{2.22} = 25.622$$

$$F_a = 20.22 \text{ ksi}$$

$$\frac{f_a}{F_a} = \frac{2.495}{20.22} = 0.123 < 0.15 \quad \text{USE AISC EQ. H-2}$$

$$f_{bx} = \frac{72.177}{7.36} = 9.807 \text{ ksi}$$

$$\text{AISC EQ. H-1: } 0.123 + \frac{9.807}{12} = 0.941 < 1.0$$

USE WT 8 X 33.5

MEMBERS ⑥ ⑦ W6 X 15 (EXISTING)

$$M_b = (3.036)\left(\frac{8.33}{4}\right) - \frac{(33.308)}{(12)(8.33)}\left(\frac{8.33}{2}\right) = 4.937 \text{ k-ft}$$

$$P = (24.55)\left(\frac{4.17}{\sqrt{4.17^2 + 2.25^2}}\right) = 21.606 \text{ k}$$

$$f_a = \frac{21.606}{4.43} = 4.877 \text{ ksi}, \quad \left(\frac{KL}{r_y}\right) = \frac{(8.33)(12)}{(1.46)} = 68.493 \text{ ksi}$$

$$F_a = 16.53 \text{ ksi}$$

$$\frac{f_a}{F_a} = \frac{4.877}{16.53} = 0.295 > 0.15 \quad \text{USE AISC EQ. H-1a, H-1b}$$

$$\text{EQ. H-1a: } \frac{f_a}{F_a} + \frac{C_{mx} f_{bx}}{\left(1 - \frac{f_a}{F_{ex}}\right) F_{bx}} \leq 1.0$$

$$C_{mx} = 1.0, \quad \left(\frac{KL}{r_x}\right) = \frac{(8.33)(12)}{(2.56)} = 39.063$$

$$F_{ex} = 98.18 \text{ ksi}$$

$$f_{bx} = \frac{(4.932)(12)}{(9.72)} = 6.095 \text{ ksi}$$

$$F_{bx} = 12.0 \text{ ksi}$$

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CRADLE-CYLINDER

(10) MEMBERS ⑥ ⑦ (CONT.)

$$EQ. H-1a : 0.295 + \frac{(1.0)(6.095)}{(1 - \frac{4.877}{98.10})(12)} = 0.829 < 1.0 \text{ OK}$$

$$EQ. H-1b : \frac{4.877 + 6.095}{12} = 0.914 < 1.0 \text{ OK}$$

W6x15 WILL SUFFICE
CONNECTION ①

$$WELD : (2)(6.080) = 12.16 \text{ in.}$$

$$F_v = \frac{3.036}{(12.16)(3/16)} = 1.382 \text{ ksi}$$

$$F_{allow} = 7.2 \text{ ksi OK}$$

SEE PG. 30 FOR ALLOWABLES

CONNECTION ②

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(10) CONNECTION B

$$A_{WELD} = (3.855 + 7.23 + 3.855) = 14.94 \text{ in.}$$

$$\bar{X} = \frac{(3.855)^2}{(2)(14.94)} = 0.497 \text{ in.}$$

$$T_{WELD} = -24.55(7.23 \times \frac{1}{2}) - 0.625 + (72.177) + (1.934)(0.497)$$

$$= -0.266 \text{ k-in.}$$

$$I_{WELD} = \frac{(12)(3.855) + 7.23}{12} - \frac{(3.855)^2(3.855 + 7.23)^2}{(2)(3.855 + 7.23)} = 155.661 \text{ in.}^2$$

$$\therefore f_{x-\max} = \frac{24.55}{14.94} + \frac{(0.266)(\frac{1}{2})(7.23)}{155.661} = 1.649 \text{ k/in.}$$

$$f_{y-\max} = \frac{1.934}{14.94} + \frac{(0.266)(0.497)}{155.661} = 0.130 \text{ k/in.}$$

$$f_r = (1.649^2 + 0.130^2)^{1/2} = 1.655 \text{ k/in.}$$

$$f_{WELD} = \frac{1.655}{5/16} = 5.295 \text{ ksi} < 7.2 \text{ ksi OK}$$

SEE PG. 30 FOR REFERENCE

$$M_{X-WELD} = 33.294 \text{ k-in.}$$

$$M_{WELD} = 37.838 \text{ k-in.}$$

EXISTING WELD

$$A_{WELD} = 17.0 \text{ in.}$$

$$\bar{X} = \frac{5^2}{(2)(17.0)} = 0.735 \text{ in.}$$

$$\bar{Y} = \frac{12^2}{(2)(17.0)} = 4.235 \text{ in.}$$

$$S_{W-TOP} = \frac{(4)(5)(12) + 12^2}{6} = 64.0 \text{ in.}^2$$

$$S_{W-BOTTOM} = \frac{(12)^2(4)(5) + 12^2}{(6)(17.0 + 5)} = 34.909 \text{ in.}^2$$

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(10) CONNECTION (C)

$$P_x = 21.602^k \quad P_y = 11.665^k$$

$$f_x = \frac{21.602}{17} = 1.271 \frac{k}{in.} \quad f_y = \frac{11.665}{17} = 0.686 \frac{k}{in.}$$

$$S_{y-TOP-Y} = \frac{(4)(5)(17) + 5^2}{6} = 60.833 in.^2$$

$$S_{y-BOTTOM-Y} = \frac{(5)^2(4)(17) + 5}{(6)((2)(17) + 5)} = 17.799 in.^2$$

$$f_{z_{TOP}} = \frac{1.934}{17} + \frac{33.294}{64} + \frac{17.979}{7.799} = 2.939 \frac{k}{in.}$$

$$f_{r-weld} = \sqrt{2.939^2 + 1.271^2 + 0.686^2} = 3.275 \frac{k}{in.}$$

INCREASE WELD

$$\theta = \tan^{-1} \frac{2.25}{4.17} = 28.35^\circ$$

$$I_3 = \frac{7^3}{12} = 28.583 in.^3$$

$$I_x = 28.583 \cos^2 28.35 = 22.138 in.^3$$

$$I_y = 28.583 - 22.138 in.^3 = 6.445 in.^3$$

$$I_4 = \frac{8^3}{12} = 42.667 in.^3$$

$$I_x = 42.667 \cos^2 28.35 = 33.046 in.^3$$

$$I_y = 42.667 - 33.046 = 9.621 in.^3$$

ELEMENT	AREA	y_i	$A_i y_i$	$A_i y_i^2$	I_{ox_i}
①	12.0	6.0	72.0	432.0	144.0
②	5.0	12.0	60.0	720.0	—
③	7.0	8.927	62.489	557.839	22.138
④	8.0	-8.52	-28.160	99.123	9.621
	32.0		166.329	1808.963	112.241

$$\bar{y} = \frac{166.329}{32.0} = 5.198 in.$$

ELEMENT	x_i	I_{xx}	$A_i x_i$	$A_i x_i^2$	I_{yy}
①	0.0	0.0	0.0	0.0	0.0
②	2.5	12.5	12.5	31.25	10.417
③	6.62	46.340	306.771	306.771	6.445
④	8.0	15.192	28.850	28.850	9.621
	32.0	74.032	360.870	266.870	26.483

$$I_{xx} = 112.241 + 1808.963 - (32)(5.198)^2 = 1056.662 in.^3$$

$$\bar{x} = \frac{360.870}{32} = 2.314 in.$$

$$I_{yy} = 26.483 + 366.870 - (32)(2.314)^2 = 227.88 in.^3$$

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(10) CONNECTION © (CONT.)

WELD ANALYSIS

$$f_x = \frac{21.602}{32.0} = 0.675 \frac{\text{K}}{\text{IN}}, f_y = \frac{11.665}{32.0} = 0.375 \frac{\text{K}}{\text{IN}}$$

$$f_z = \frac{1.934}{32} \pm \frac{33.294 Y}{1056.662} \pm \frac{17.979 X}{222.080}$$

CHECK @ "a" $X = 5 + 7 \sin(28.35) - 2.34 = 6.010 \text{ IN.}$

$Y = 12 - 5.198 - 7 \cos(28.35) = 0.642 \text{ IN.}$

$$\therefore f_z = \frac{1.934}{32} + \frac{(33.294)(0.642)}{1056.662} + \frac{(17.979)(6.010)}{222.080} = 0.567 \frac{\text{K}}{\text{IN.}}$$

$$f_r = (0.675^2 + 0.375^2 + 0.567^2)^{1/2} = 0.958 \frac{\text{K}}{\text{IN}}$$

$$\sigma_{\text{weld}} = \frac{0.958}{3/16} = 5.110 \text{ ksi} < 7.2 \text{ ksi (PG. 30)}$$

CHECK @ "b" $X = 5 - 2.34 = 2.686 \text{ IN.}$

$Y = 12 - 5.198 = 6.802 \text{ IN.}$

$$\therefore f_z = \frac{1.934}{32} + \frac{(33.294)(6.802)}{1056.662} + \frac{(17.979)(2.686)}{222.080} = 0.462 \frac{\text{K}}{\text{IN.}}$$

BY INSPECTION LESS THAN PT "a"

CHECK @ "c" $X = 8 \sin(28.35) - 2.34 = 1.485 \text{ IN.}$

$Y = -5.198 + 8 \cos(28.35) = -12.239 \text{ IN.}$

$$\therefore f_z = \frac{1.934}{32} - \frac{(33.294)(12.239)}{1056.662} + \frac{(17.979)(1.485)}{222.080} = -0.205 \frac{\text{K}}{\text{IN.}}$$

LESS THAN A

$\therefore 3/16$ WELD SUFFICES

DESIGN CALCULATION

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(7) Subject CRADLE-HYDRAULICS
(8) Originator G. J. HARRIS Date 4/27/94
(9) Checker [Signature] Date 8/9/94

CLEVIS PIN

(10) @ 55° $V_{CLEVIS} = (1.25)(45.552) = 56.940^k$

FOR BENDING CONSIDER AS A UNIFORM LOAD, $w = \frac{56.940}{2} = 28.47^k/in.$
LENGTH OF SHAFT

$$m = (28.47) \left(\frac{2^2}{8} \right) = 14.235^k-in$$

$$V = \frac{56.940}{2} = 28.47^k$$

FOR A 2" Ø SHAFT: $f_b = \frac{(14.235)}{\pi (2)^3} = 13.125^k/in$

$$f_y = \frac{(4)(28.47)}{(3)(3.14)(2)^2} = 12.083^k/in$$

UPPER CLEVIS

REF. MCGUIRE STEEL
STRUCTURES PG. 219

LUG: (1) THICKNESS UNIFORM OK

(2) $wt = (1.625)(2)(2.25) = 7.313 > \frac{28.47}{(0.6)(36)} = 1.313$ OK

(3) $2bt = (2)(0.625)(2.25) = 2.813 > \frac{28.47}{(0.45)(36)} = 1.757$ OK

(4) $t \geq \frac{1}{2}$ " OK

(5) $(1.625)(2) = 3.25$ "(8)(2.25) = 18" OK

(6) NOT APPLICABLE

(7) NOT APPLICABLE

(8) $a = b$, $0.625 = 0.625$ " OK

(9) NOT APPLICABLE

(10) $(2\frac{1}{16} - 2)\frac{1}{2} = \frac{1}{32}$ OK

DESIGN CALCULATION

WHC-SD-WM-DA-167

Rev. 0

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 (8) Originator G. J. HARRIS Date 4/27/94
 (9) Checker W. F. L. O. Date 8/4/94

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(10) CLEVIS PIN
 UPPER CLEVIS (CONT.)

$$f_{b-b} = \frac{28.47}{(0.625)(2)(2.25)} = 10.123 \text{ ksi} < 20.0 \text{ ksi (SEE PG. 30 FOR REF.)}$$

MAXIMUM LUG CONCENTRATION STRESS (SEE ACCOMPANYING TABLE)

$$D/E = \frac{2.063}{2.25} = 0.917 \text{ USE } \leq 2 \text{ CURVE}$$

$$K_{br} = 1.6$$

$$f_{conc} = (1.6)(10.123) = 16.197 \text{ ksi} < 20.0 \text{ ksi (A-572 60 ksi)}$$

LUG BENDING: $M_{a-a} = (34.559)(1.25)(6)(1/2) = 129.596 \text{ k-in}$

$$f_{b-b} = \frac{(129.596)(6)}{(5.125^2)(2.25)} = 13.158 \text{ ksi}$$

$$f_{a-a} = \frac{29.676}{(2)(5.125)(2.25)} = 1.287 \text{ ksi}$$

14.445 ksi < 20.0 ksi OK

DESIGN CALCULATION

WHC-SD-WM-DA-167

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 (8) Originator G.W. HARRIS Date 4/27/94
 (9) Checker J.W. Fisher Date 8/4/94

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(10) SNAPPER JACK & BASE

$$M = (50) \left(\frac{4}{4} \right) = 50.0 \text{ k-ft.}$$

$$f_b = \frac{(50.0)(12)}{\frac{(24^2)(1)}{6}} = 6.25 \text{ ksi OK}$$

ALLOWABLE f_b

$$r_T = \frac{12}{\sqrt{12}} = 3.46 \text{ IN.}$$

$$\frac{l}{r_T} = \frac{48}{3.46} = 13.86$$

$$C_b = 1.75$$

CHECK UPPER LIMIT $\sqrt{\frac{(510)(1.75)(10)^3}{36}} = 497.91$

AISC PGS. B-46, 47
EQ. F1-8

CHECK LOWER LIMIT $\sqrt{\frac{(102)(1.75)(10)^3}{36}} = 222.67$

$\frac{f_b}{r_T} < 222.67$ $\therefore$ USE f_b OK

DESIGN CALCULATION

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 (7) Subject CRADLE HYDRAULICS
 (8) Originator G. J. HARRIS Date 5-2-94
 (9) Checker P. W. Fisher Date 8/4/94

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(10) LOWER CLEVIS

CASE (1)
GREATEST VERTICAL
FORCE

$$M_{a-a} = (2.804)(6) = 16.824 \text{ K-in}$$

$$S_{a-a} = (1.625)(10.25)^2/6 = 28.454 \text{ in}^3$$

$$A_{a-a} = (1.625)(10.25) = 16.556 \text{ in}^2$$

$$f_{a-a} = \frac{28.470}{16.556} \pm \frac{16.824}{28.454} = -0.006 \text{ ksi} / 1.177 \text{ ksi} < 12.0 \text{ ksi} \text{ OK (SEE PG. 30 FOR REFERENCES)}$$

CASE (2)
GREATEST LATERAL
FORCE

$$f_{a-a} = \frac{16.834}{16.556} \pm \frac{(10.088)(6)}{28.454} = -1.16 \text{ ksi} / 3.144 \text{ ksi}$$

SEE PG 30 FOR REFERENCES

CLEVIS OK

DESIGN CALCULATION

Rev. 0

(1) Drawing _____ (2) Doc. No. _____ (3) Page _____ of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject CRADLE HYDRAULICS
 (8) Originator G. J. HARRIS Date 8/3/94
 (9) Checker W. Fisher Date 8/9/94

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(10) UPPER CLEVIS THICKNESS = $1\frac{1}{2}$ " / LUG

$$P = \frac{(1.25)(45.512)}{2} = 28.45^k$$

$$P_x = 12.43^k, P_y = 21.58^k$$

$$M_{a-a} = (18.43)(6) + (21.58)\left(\frac{w}{2} - 2.125\right)$$

$$A_{a-a} = 1.5(w-1)$$

$$S_{a-a} = \frac{1.5(w-1)^2}{6} = 0.25(w-1)^2$$

$$\therefore f_{a-a} = \frac{21.58}{(1.5)(w-1)} + \frac{111.58 + 21.58\left(\frac{w}{2} - 2.125\right)}{(0.25)(w-1)^2}$$

SET TO 12 ksi (SEE PG. 30)

$$\therefore \text{COMPRESSION: } w^2 - 6.7956w - 20.7086 = 0$$

$$w = 9.0770 \text{ IN. USE } 9\frac{1}{8}"$$

CHECK STRESS DISTRIBUTION

EQUATION OF RADIUS

$$x^2 + y^2 = 1.625^2$$

EQUATION OF ab:

$$y = \tan(42.71 + 10.59)x + b$$

$$y = 1.34x + b \quad b = 6 - (1.34)(6.5) = -2.72$$

$$\therefore y = 1.34x - 2.72$$

$$x = \frac{1}{1.34}(y + 2.72) \text{ AND } w(x) = 1.625 + \frac{1}{1.34}(y + 2.72)$$

FIND POINT OF TANGENCY

$$\text{DIST } ab = \sqrt{6^2 + 6.5^2 - 1.625^2} = 8.7"$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page _____ of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject PARALLEL HYDRAULICS
 (8) Originator G. J. HARRIS Date 5-3-94
 (9) Checker W. L. Lidel Date 8/4/94

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UPPER CLEVIS

(10) CHECK STRESS DISTRIBUTION FROM c-c TO a-a

$$A(y) = (1.5)(1.625 + (\frac{1}{1.34})(y + 2.72)) = 1.119y + 5.482$$

$$S(y) = (\frac{1.5}{6})(1.625 + (\frac{1}{1.34})(y + 2.72))^2 = 0.139y^2 + 1.364y + 3.340$$

$$\begin{aligned} M(y) &= 18.43y + 21.43(x(y) - \frac{1}{2}w(y)) \\ &= 18.43y + 21.43(\frac{1}{1.34}(y + 2.72) - \frac{1}{2}(1.625 + \frac{1}{1.34}(y + 2.72))) \\ &= 26.426 + 18.092y \end{aligned}$$

$$f(y) = \frac{21.43}{1.119y + 5.482} \pm \frac{26.426 + 18.092y}{0.139y^2 + 1.364y + 3.340}$$

CHECK FOR MAX. COMPRESSION

$$f(y) = \frac{21.43}{(1.119y + 5.482)} + \frac{26.426 + 18.092y}{0.139y^2 + 1.364y + 3.340}$$

FIND MAX

$$\frac{df(y)}{dx} = \frac{-(23.980)(0.139y^2 + 1.364y + 3.340)^2 + (1.119y^2 + 2)(1.119y + 5.482^2)(-2.515y^2 - 7.347y + 24.381)}{(1.119y + 5.482)^2(0.139y^2 + 1.364y + 3.340)^2}$$

$$\therefore \text{SET TO } 0 : y^4 + 14.697y^3 + 62.643y^2 + 42.763y - 141.931 = 0$$

$$y = 1.0919 \text{ in}$$

$$f(y) = \frac{21.43}{(1.119)(1.0919) + 5.482} + \frac{26.426 + 18.092(1.0919)}{(0.139)(1.0919)^2 + (1.364)(1.0919) + 3.340} = 12.44 \text{ ksi}$$

$$\text{INCREASE THICKNESS } t = \frac{12.44}{12.0}(1.5) = 1.55''$$

USE 1.625"

$$\therefore f_{\max} = (\frac{1.5}{1.625})(12.44) = 11.90 \text{ ksi OK}$$

USE 1 7/8" THK. PLATE

Design Criteria

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Subject: Allowable Stresses for Use in C-106 Project

References:

1. DOE-RL, 1993, *Hanford Site Hoisting and Rigging Manual*, DOE-RL-92-36, U.S. Department of Energy Richland Field Office, Richland, Washington.
2. ANSI, 1986, *Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500 kg) or More*, American National Standards Institute, New York, New York.
3. AISC, 1989, *Manual of Steel Construction, Allowable Stress Design*, 9th Edition, American Institute of Steel Construction, Chicago, Illinois.

The purpose of this correspondence is to define a position on the allowable stresses for use in the C-106 pump removal project (and other similar projects). The pump container, strongback, spreader beam, and other ancillary hardware are designed to meet the requirements of both References 1 and 2. However, both references are vague on the practical application of the allowable stresses for use in analysis and design. Reference 2 specifies basic allowables of 1/3 of tensile yield strength and 1/5 of tensile ultimate strength and recognizes that slight local yielding is necessary to relieve high local stresses (such as in a lug/pin assembly). Reference 1 is even more nebulous in that it's allowable stress parameter is 1/3 of yield strength only.

In order to have all design/analysis personnel using a consistent set of allowables, the following interpretation of References 1 and 2 should be used for the structural calculations of steel members and connections in C-106 critical components.

Structural Steel

Bending (F_b), tension (F_t), and axial compression (F_a - where buckling is not a concern and there are no bending moments):

$$F_b = F_t = F_a = 12 \text{ ksi}$$

Shear: $F_v = 7.2 \text{ ksi}$

Bearing: $F_p = 12 \text{ ksi}$

Connections

Bolts: Use Reference 3 allowables divided by 2

Welds: 7.2 ksi on effective area
(effective area = effective throat x weld length)

Special case for fillet welds - check stress on the weld leg, not the weld throat (do not use the .707 factor to determine throat area).

Notes:

- These allowables are based on A-36 steel, but are applicable to other mild steels.
- For combined stresses, use Reference 3 approach (Chapter H).

Discussion

Three considerations were used in developing these allowables.

1. Reference 1 refers to allowables based on yield strength only, not ultimate strength. Therefore, the allowables are based on yield strength (i.e., 1/3 of yield). Some parameters, such as bearing, are typically expressed in terms of an ultimate failure condition. However, basing allowables on yield satisfies both References 1 and 2. Also, selecting allowables that are conservative is acceptable for the C-106 project because it is new design; changes can easily be incorporated at the design stage.
2. A popular interpretation of References 1 and 2 is to use various ratios of the allowables specified in Reference 3. Although Reference 3 is a nationally-recognized code for buildings constructed of structural steel, using it as the basis for material allowables in conjunction with References 1 and 2 requirements results in inconsistencies in safety factors. Therefore, Reference 3 is not used as the basis for structural steel allowables; instead, the allowables were developed exclusively from References 1 and 2 and first principles of failure theory. The above-mentioned allowables are more conservative than Reference 3 allowables.
3. It must be recognized that a definitive interpretation of Reference 1 and 2 allowables will require research into a variety of topics. Engineering Excellence proposals have been submitted to address portions of this issue. To date, there are no firm commitments within Westinghouse to pursue a definitive interpretation of References 1 and 2 allowables for use at the Hanford Site. This interpretation of the above-mentioned allowables should be considered as conservative.

KAISER ENGINEERS HANFORD	CALCULATION IDENTIFICATION AND INDEX	Page 1 of ii
		Date 8/18/94

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline Mechanical WO/Job No. ER4645

Calculation No. ER4645-006

Project No. & Name SY-101 Mitigation Pump

Calculation Item Raising Cradle Hydraulics, Upper Clevis Weld Stress

These calculations apply to:

Dwg. No. H-2-83737 Sheet 3

Rev. No. 0

Dwg. No.

Rev. No.

Other (Study, CDR)

Rev. No.

The status of these calculations is:

- ☐ Preliminary Calculations
☒ Final Calculations
☐ Check Calculations (On Calculation Dated)
☐ Void Calculation (Reason Voided)

Incorporated in Final Drawings?

☐ Yes ☐ No

This calculation verified by independent "check" calculations?

☐ Yes ☐ No

Original and Revised Calculation Approvals:

	Rev. 0 Signature/Date	Rev. 1 Signature/Date	Rev. 2 Signature/Date
Originator	B. M. [Signature] 8/18/94		
Checked by	A. R. [Signature] 8/22/94		
Approved by	[Signature] 11/4/94		
Checked Against Approved Vendor Data			

INDEX

Design Analysis
Page No.

Description

1	Objective & Design Inputs
2	Analysis - Free Body Diagram, Moment Formula
3	Analysis - Force Formula, Weld Group Characteristics
4	Analysis - Max Stress
5	Analysis - Geometry of system
6	Analysis - Spread sheet
7	Analysis - Spread sheet
8	Conclusion

CALCULATION CROSS INDEX (Typical)

Subject Calculation No. ER4645-006

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WHC:SD-BM-DA-160 Rev. C

Client <u>WHC</u>	WO/Job No. <u>ER4645</u>
Subject <u>Upper Clevis Welds</u>	Date <u>8/10/94</u> By <u>B.M. Koons</u>
	Checked <u>8/22/94</u> By <u>Angel R. Kameo</u>
Location	Revised By

1.0 Objective: Determine the stresses in a weld group used to mount the cradle hydraulic system upper clevis.

2.0 Design Inputs:

2.1 Criteria and Source

2.1.1 Structural Welding Code, AWS D1.1

2.2 Given / Known Data

2.2.1 Clevis material is ASTM A.36, $S_y = 36 \text{ K}$

2.3 Assumptions

2.3.1 Strength of weld equals the strength of steel.

2.4 References

2.4.1 'Mechanical Engineering Design', Shigley & Mitchell published by McGraw Hill, 4th Edition

2.4.2 H-2-83737, sheets 1-4, Rev 0

2.4.3 Calc. No. CR1209-001

2.4.4 Calc. No. CR1209-002

2.4.5 Calc. No. CR1209-003

2.4.6 Calc. No. CR1209-004

2.4.7 Calc. No. ER1209-005

2.4.5 WHC-S-0284, Cradle Hydraulic Specification, Table 2, pg 15, Rev 0
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DESIGN ANALYSIS

Client WHC
Subject Upper Clevis WeldWO/Job No. ER4645
Date 8/10/94 By B.M. Koons
Checked 8/22/94 By Angel R. Kimes
Revised _____ By _____

Location _____

Analysis

Note: The clevis is shown upside down from its actual position on the cradle.

$P_c \equiv$ External force of the hydraulic cylinder.

$F_g \equiv$ Force of the weld group acting on the clevis base.

$M \equiv$ Moment of the weld group acting on the clevis base.
 M acts to produce compression at the left & tension at the right of the weld group.

Determine Formula For M :

$$M = P_c \cdot l_{dc} \quad (l_{dc} \equiv \text{length between points d and c})$$

$$l_{dc} = l_{ad} \sin B$$

$$l_{ad} = l_{ab} - 2 \frac{7}{16}''$$

$$l_{ab} = 7'' \cot B$$

$$\therefore M = P_c [(7'' \cot B - 2 \frac{7}{16}'') \sin B] \quad \text{for any angle } B.$$

KAISER ENGINEERS
HANFORDCalc. No. ER4645-006Revision 0Page No. 3 of 8

DESIGN ANALYSIS

Client WHCWO/Job No. ER4645Subject Upper Clevis WeldsDate 8/10/94 By B.M. KoonsChecked 8/22/94 By Angel V. Komes

Location

Revised

By

Force F_G :

$$F_G = P$$

$$F_{Gx} = P \cos \beta$$

 F_{Gx} acts to produce shear in the weld group.

$$F_{Gy} = P \sin \beta$$

 F_{Gy} acts to produce compression in the weld group.Weld Group:

$$A = 1.414h(9.125" + 7") = \underline{22.801 h} \text{ (in}^2\text{)}$$

$$I_u = \frac{7 \cdot 9.125^2}{2} + \frac{9.125^3}{6} = 418.063 \text{ (in}^3\text{)}$$

$$I = \underline{0.707 h I_u} \text{ (in}^4\text{)}$$

$$A = \underline{11.4 \text{ (in}^2\text{)}}$$

$$I = \underline{147.8 \text{ (in}^4\text{)}}$$

DESIGN ANALYSIS

Client WHC
Subject Upper Clevis WeldsWO/Job No. ER4645
Date 8/10/04 By B.M. Koons
Checked 8/22/04 By Angel R. Koons
Revised By

Location

Max Compression Stress: (at left of weld group)

$$\sigma_{yc} = \frac{F_{cy}}{A} + \frac{M_c}{I} = \frac{P \sin \beta}{11.4 \text{ (in}^2\text{)}} + \frac{M 4.5625 \text{ (in)}}{147.8 \text{ (in}^3\text{)}}$$

$$\tau_x = \frac{F_{cx}}{A} = \frac{P \cos \beta}{11.4 \text{ (in}^2\text{)}}$$

$$\sigma_{\max} = (\sigma_y^2 + 3\tau_x^2)^{1/2}$$

(Distortion Energy Theory)

Max Tension Stress:

$$\sigma_{yt} = \frac{M_c}{I} - \frac{F_{cy}}{A}$$

$$\tau_x = \frac{F_{cx}}{A}$$

Min Yield Stress

$$S_y = 36,000 \text{ psi (A36 steel)}$$

DESIGN ANALYSIS

Client WHC
Subject Upper Clevis Welds
Location

WO/Job No. ER4645
Date 8/10/94 By B.M. Hoons
Checked 9/22/94 By Angel R. Reyes
Revised By

The above geometry was used to determine the force vectors in the following spreadsheet.

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Client *WHC*
Subject *Upper Clevis Welds*

Calc. No *ER4645-006*
Revision *0*
Page No. *6* of *8*
WO/Job No. *ER4645*
Date *8/10/94* By *B.M. Koons*
Check *8/24/94* By *Angela R. Rame*
Rev By

Assumes cradle weight of 57,000 lbs and CG at 333.6"

THETA	ALPHA	a	BETA	GAMA	Angle CG	Lcyl	Fcyl
degrees	degrees	Law of Cos	Law of Sin	degrees	degrees	inches	lbs
0 to 60 degrees, max cylinder force = 4050 lbs (see specification WHC-S-0284)							
0	4.06	78.87	10.29	165.64	7.07	49.35	4050.00
5	9.06	85.53	21.50	149.44	12.07	101.19	4050.00
10	14.06	96.11	30.21	135.73	17.07	138.92	4050.00
15	19.06	109.41	36.45	124.49	22.07	164.04	4050.00
20	24.06	124.48	40.68	115.25	27.07	180.01	4050.00
25	29.06	140.65	43.42	107.52	32.07	189.80	4050.00
30	34.06	157.48	45.06	100.88	37.07	195.45	4050.00
35	39.06	174.68	45.89	95.05	42.07	198.26	4050.00
40	44.06	192.03	46.12	89.82	47.07	199.03	4050.00
45	49.06	209.37	45.90	85.04	52.07	198.29	4050.00
50	54.06	226.60	45.33	80.61	57.07	196.36	4050.00
55	59.06	243.62	44.49	76.45	62.07	193.49	4050.00
60	64.06	260.35	43.43	72.51	67.07	189.83	4050.00
65 to 80 degrees, cylinder force required to raise cradle							
65	69.06	276.73	42.20	68.74	72.07	185.48	31565.57
70	74.06	292.70	40.83	65.11	77.07	180.54	23572.70
71	75.06	295.85	40.54	64.40	78.07	179.49	21905.50
72	76.06	298.97	40.25	63.69	79.07	178.41	20214.26
73	77.06	302.07	39.95	62.99	80.07	177.32	18498.45
74	78.06	305.16	39.65	62.29	81.07	176.20	16757.54
75	79.06	308.22	39.35	61.59	82.07	175.07	14990.99
76	80.06	311.27	39.04	60.90	83.07	173.91	13198.24
77	81.06	314.30	38.72	60.22	84.07	172.74	11378.74
78	82.06	317.30	38.41	59.53	85.07	171.55	9531.89
79	83.06	320.28	38.09	58.85	86.07	170.34	7657.09
80	84.06	323.25	37.76	58.17	87.07	169.11	5753.72
81 to 90 degrees, snubber in contact with cradle.							
81	85.06	326.19	37.44	57.50	88.07	167.86	20034.51
82	86.06	329.10	37.11	56.83	89.07	166.60	18194.97
83	87.06	332.00	36.78	56.16	90.07	165.32	16328.45
84	88.06	334.88	36.44	55.50	91.07	164.02	14434.30
85	89.06	337.73	36.10	54.84	92.07	162.71	12511.89
86	90.06	340.55	35.76	54.18	93.07	161.38	10560.55
87	91.06	343.36	35.42	53.52	94.07	160.03	8579.58
88	92.06	346.14	35.07	52.87	95.07	158.67	6568.25
89	93.06	348.90	34.73	52.21	96.07	157.29	4525.81
90	94.06	351.63	34.37	51.56	97.07	155.90	25120.00

WHC-SD-WM-DA-167

Rev 0

Client WHC
Subject Upper Clevis Welds

Calc. No ER4645-006

Revision 0

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WO/Job No. ER4645

Date 8/10/94 By B.M. Koon

Check 9/22/94 By A.R. Romero

Rev By

THETA	BETA-c	GAMA-c	Fcyl	UPPER CLEVIS				
degrees	degrees	degrees	lbs	moment	Fx	Fy	max Comp	max Tens
0	8.53	171.47	4050.00	26571.94	4005.192	600.7818	1064.12577	979.5164
5	19.73	155.27	4050.00	23351.99	3812.163	1367.447	1020.99878	834.6043
10	28.44	141.56	4050.00	20226.57	3561.171	1928.875	960.480382	707.0656
15	34.68	130.32	4050.00	17695.45	3330.398	2304.549	903.406202	611.9142
20	38.92	121.08	4050.00	15854.96	3150.98	2544.371	858.502456	547.7948
25	41.66	113.34	4050.00	14619.72	3025.897	2691.923	826.998469	507.5984
30	43.29	106.71	4050.00	13864.71	2947.757	2777.27	807.248954	484.3322
35	44.12	100.88	4050.00	13477.51	2907.212	2819.684	796.982498	472.8254
40	44.35	95.65	4050.00	13369.46	2895.842	2831.359	794.101365	469.6689
45	44.13	90.87	4050.00	13473.58	2906.799	2820.11	796.877815	472.7102
50	43.56	86.44	4050.00	13739.71	2934.702	2791.061	803.944661	480.5846
55	42.72	82.28	4050.00	14130.09	2975.364	2747.674	814.232014	492.389
60	41.67	78.33	4050.00	14615.96	3025.511	2692.356	826.901101	507.48
65	40.44	74.56	31565.57	118273.7	24025.42	20473.51	6556.98019	4094.636
70	39.07	70.93	23572.70	91903.17	18302.13	14856.11	4987.32152	3175.696
71	38.78	70.22	21905.50	86097.46	17077	13719.59	4652.00103	2974.366
72	38.49	69.51	20214.26	80098.57	15823.06	12579.63	4309.03954	2766.59
73	38.19	68.81	18498.45	73899.73	14539.49	11436.6	3958.22085	2552.108
74	37.89	68.11	16757.54	67494.19	13225.46	10290.88	3599.32937	2330.659
75	37.58	67.42	14990.99	60875.19	11880.13	9142.87	3232.14965	2101.982
76	37.27	66.73	13198.24	54035.95	10502.68	7992.953	2856.46588	1865.811
77	36.96	66.04	11378.74	46969.68	9092.269	6841.518	2472.06142	1621.879
78	36.64	65.36	9531.89	39669.56	7648.055	5688.955	2078.71832	1369.914
79	36.32	64.68	7657.09	32128.68	6169.191	4535.654	1676.21685	1109.642
80	36.00	64.00	5753.72	24340.12	4654.824	3382.006	1264.33497	840.7859
81	35.67	63.33	20034.51	85445.49	16274.92	11683.68	4419.10763	2952.179
82	35.35	62.65	18194.97	78232.84	14841.34	10525.76	4028.5179	2703.655
83	35.01	61.99	16328.45	70778.02	13373.41	9368.562	3628.86496	2446.733
84	34.68	61.32	14434.30	63074.31	11870.32	8212.469	3219.93474	2181.14
85	34.34	60.66	12511.89	55114.88	10331.21	7057.875	2801.50974	1906.598
86	34.00	60.00	10560.55	46892.8	8755.237	5905.174	2373.36846	1622.825
87	33.66	59.34	8579.58	38401	7141.532	4754.758	1935.28491	1329.532
88	33.31	58.69	6568.25	29632.31	5489.203	3607.019	1487.02795	1026.425
89	32.96	58.04	4525.81	20579.38	3797.338	2462.352	1028.36076	713.2042
90	32.61	57.39	25120.00	115121.4	21159.96	13537.75	5728.45649	3991.826

A-42

DESIGN ANALYSIS

Client WHC

WO/Job No. ER4645

Subject Upper Clevis Welds

Date 8/10/94

By B.M. Lyons

Checked 8/22/94

By Angel K. Kump

Location

Revised

By

Conclusion

The max compressive stress occurs at an angle of 65°. This is the minimum angle presumed for raising the cradle with the hydraulic ram. The max tensile stress in the weld also occurs at this angle (65°). The factors of safety are:

$$FS_c = \frac{36K}{6.6K} = \underline{5.5}$$

$$FS_t = \frac{36K}{4.1K} = \underline{8.8}$$

By the above factors of safety, a $\frac{1}{2}$ " fillet weld will provide adequate strength for attaching the upper clevis.

Appendix B
Calculations for Hydraulic Ram

**KAISER ENGINEERS
HANFORD****CALCULATION IDENTIFICATION AND INDEX**Page i of iiDate 4/11/94

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline Mechanical WO/Job No. CR1209 Calculation No. CR1209-001Project No. & Name SY-101 Mitigation PumpCalculation Item Raising Cradle Hydraulic Cylinder Forces

These calculations apply to:

Dwg. No. _____ Rev. No. _____

Dwg. No. _____ Rev. No. _____

Other (Study, CDR) "Specification for 241-SY Pump Cradle Hydraulic System"
WHC Specification = WHC-S-284 Rev. No. —

The status of these calculations is:

☐ Preliminary Calculations☒ Final Calculations☐ Check Calculations (On Calculation Dated _____)☐ Void Calculation (Reason Voided _____)

Incorporated in Final Drawings?

☐ Yes☒ No

This calculation verified by independent "check" calculations?

☐ Yes☒ No

Original and Revised Calculation Approvals:

	Rev. 0 Signature/Date	Rev. 1 Signature/Date	Rev. 2 Signature/Date
Originator	<u>B.M. Jones</u> 4/11/94		
Checked by	<u>AR Romero</u> 4/13/94		
Approved by	<u>E. Mackay</u> 11/7/94		
Checked Against Approved Vendor Data			

INDEXDesign Analysis
Page No.

Description

<u>1</u>	<u>Objective & Design Inputs</u>
<u>2</u>	<u>Analysis - Geometry</u>
<u>3</u>	<u>Analysis - Description of Spreadsheet</u>
<u>4</u>	<u>Analysis - Friction Considerations</u>
<u>5</u>	<u>Analysis - Spreadsheet - W/O Friction</u>
<u>6</u>	<u>Analysis - Spreadsheet - W/ Friction</u>
<u>7</u>	<u>Conclusion</u>

Subject Calculation No. CR1209-001

Page 11 of 11[illegible]

WHC-SD-WM-DA-167 Rev.C

DESIGN ANALYSIS

Client WHC
Subject Cylinder Forces

WO/Job No. CR1209 11000027100
Date 4/8/94 By Brian M Koons
Checked 4/13/94 By ANGEL R. ROMERA
Revised _____ By _____

Location _____

1.0 Objective

Determine the forces required to raise a cradle and mixer pump. The cradle will be raised using a telescoping hydraulic cylinder.

2.0 Design Inputs

2.1 Criteria and Source

2.1.1 "Two Crane Lift Drawing", Attached.

* Note: This drawing has no drawing number and thus no signatures. A cemail was sent out requesting clarification on this.

2.1.2 4/8/94 cemail from Brian Koons to Theresa Peters. "Weight and CG of Cradle and Pump Assembly".

2.1.3 Drawing H-2-83737 "Lifting Cradle Structural Modification"

2.1.4 Telecon with Dale Miller 4/4/94, "Pin Locations of Hydraulic Cylinder", Day Planner Notes attached.

2.1.5 Drawing H-2-83693, "Raising Cradle Base"

2.2 Given or Known Data

2.2.1 Cylinder Specification: 5 stage, 8" primary, 280" stroke.

2.3 Assumptions

2.3.1 Coefficient of Friction between Steel to Steel contact is $\mu_f = 0.39$; Marks Handbook, pg 3.25

2.3.2 Cylinder will lift the cradle from 70° to 90° - Operational Criteria.

2.3.3 Cylinder hinge pins are greased, $\mu_f = 0.11$; Marks Handbook, pg 3.26

2.4 Methods to be used:

Use trigonometric relations to determine Force equations and enter data in an Excel spreadsheet to obtain output for various angles.

2.5 References: 1. Marks standard Handbook for Mechanical Engineers, 9th Edition
2. Math text which shows trigonometric Relations. (B-4)

DESIGN ANALYSIS

Client WHC
Subject Cylinder Forces

WO/Job No. CR1209 11000027100

Date 4/8/94 By R.M. KOWALIS

Checked 4/13/94 By A.R. Romero

Location

Revised

By

$3 \frac{9}{16}" \theta$ pivot lug (use this to determine friction force) Ref 2.1.2

use $4" \theta$ for conservatism

$\mu_s = 0.11$ (Steel on steel)

Info for above from H-2-83737 Ref 2.1.3

Line c is from the pivot to the upper cylinder pivot.
Line b is from the pivot to the lower cylinder pivot.
Line a is along the axis of the cylinder
 θ is the angle of the cradle.

DESIGN ANALYSIS

Client WHC

WO/Job No. CR1209 11000027100

Subject Cylinder Forces

Date 4/8/94 By B. M. KOONS

Checked 4/13/94 By A. R. ROMERO

Location

Revised

By

The method for determining cylinder force is:

- 1) Use the 'law of cosines' to determine a, length of cylinder extension. For this, c & b are constants and a is related to θ and the geometry.
- 2) Use the 'law of sines' to determine B , angle of cylinder and line segment c.
- 3) Determine the moment arm of the cylinder,
 $l_{cyl} = c \sin B$
- 4) Sum moments about origin (pivot lug).

The above method was employed in the attached spreadsheet, P31. The spreadsheet analyzed angles $\theta = 55^\circ$ to $\theta = 90^\circ$.

Friction ForcesAssumption 2.3.1Pivot Lug

Need to determine $R_0 \rightarrow$ use vector addition.

Use Law of cosines:

$$R_0 = (W^2 + F_{cyl}^2 - 2W \cdot F_{cyl} \cos(90 - \theta + 3.934))^{1/2}$$

DESIGN ANALYSIS

Client WHC
Subject Cylinder Forces

WO/Job No. CR1209 11000027100

Date 4/8/94 By B.M. KOONS

Checked 4/13/94 By A.R. ROMERS

Location

Revised By

Friction Forces (cont.)Pivot Lug (cont.)

Moment induced by friction:

$$M_{f_0} = R_0 \mu_f r = R_0 \cdot 0.39 \cdot 2 \text{ in} \cdot \frac{1 \text{ ft}}{12 \text{ in}}$$

Cylinder

Moment from friction:

$$M_{f_0} = 2 F_{cy} \cdot \mu \cdot r$$

$$M_{f_0} = 2 F_{cy} \cdot 0.11 \cdot 1 \frac{1}{12}$$

Force to resist M_{f_0} :

$$F_m = 2 \cdot 0.11 \cdot 1 \frac{1}{12} \frac{F_{cy}}{a}$$

$$F_{mr} = F_m / \cos \beta$$

Moment induced by cylinder friction about origin:

$$M_{f_c} = F_{mr} \cdot c$$

$$M_{f_c} = \frac{2 \cdot 0.11 \cdot F_{cy} \cdot c}{12 \cdot a \cos \beta}$$

After the initial cylinder forces were calculated, these forces were used to determine the friction forces & the cylinder forces were re-calculated with the friction moments included. This was done on page two of the attached spreadsheet.

Cylinder Forces

WHC-30-WM-BA-100
Rev. 0CR1207-001, Rev. 0
Pg 5 of 7

Assumes cradle weight of 54,000 lbs and CG at 26'-5"

4/8/94

B.M. KOONS

A.P. EDMERD

4/12/94

THETA	A	a	BETA	GAMA	Angle CG	Lcyl	Fcyl
	degrees	Law of Cos	Law os Sin	degrees	degrees		
55	57.31	19.78	44.59	78.11	62.39	16.15	41225.23
60	62.31	21.18	43.62	74.07	67.39	15.87	34798.79
65	67.31	22.55	42.46	70.23	72.39	15.53	27980.61
70	72.31	23.89	41.15	66.54	77.39	15.14	20711.55
71	73.31	24.15	40.88	65.82	78.39	15.05	19198.69
72	74.31	24.41	40.59	65.10	79.39	14.97	17665.10
73	75.31	24.67	40.31	64.39	80.39	14.88	16110.33
74	76.31	24.93	40.02	63.68	81.39	14.79	14533.90
75	77.31	25.19	39.72	62.97	82.39	14.70	12935.35
76	78.31	25.44	39.42	62.27	83.39	14.61	11314.20
77	79.31	25.70	39.12	61.58	84.39	14.51	9669.94
78	80.31	25.95	38.81	60.88	85.39	14.41	8002.09
79	81.31	26.20	38.50	60.19	86.39	14.32	6310.12
80	82.31	26.45	38.18	59.51	87.39	14.22	4593.50
81	83.31	26.70	37.87	58.83	88.39	14.12	2851.67
82	84.31	26.94	37.54	58.15	89.39	14.02	1084.08
83	85.31	27.19	37.22	57.47	90.39	13.91	-709.86
84	86.31	27.43	36.89	56.80	91.39	13.81	-2530.77
85	87.31	27.67	36.56	56.13	92.39	13.70	-4379.27
86	88.31	27.91	36.23	55.47	93.39	13.59	-6256.02
87	89.31	28.14	35.89	54.80	94.39	13.48	-8161.70
88	90.31	28.38	35.55	54.14	95.39	13.37	-10097.02
89	91.31	28.61	35.21	53.48	96.39	13.26	-12062.71
90	92.31	28.84	34.86	52.83	97.39	13.15	-14059.55

4/8/94 B.M. Koons
4/13/94 A.R. Romero

Ro lbs.	Mfo lb*ft	Mfc lb*ft	Fcyl* lb	THETA degrees
33943.87	2206.35	1233.93	41438.31	55
31761.45	2064.49	957.06	34989.22	60
32468.60	2110.46	709.28	28162.21	65
36061.89	2344.02	485.58	20898.49	70
37081.38	2410.29	443.33	19388.27	71
38188.00	2482.22	401.83	17857.81	72
39376.06	2559.44	361.05	16306.62	73
40640.10	2641.61	320.96	14734.22	74
41974.92	2728.37	281.53	13140.13	75
43375.68	2819.42	242.72	11523.85	76
44837.89	2914.46	204.50	9884.88	77
46357.44	3013.23	166.86	8222.70	78
47930.61	3115.49	129.75	6536.79	79
49554.02	3221.01	93.16	4826.59	80
51224.65	3329.60	57.05	3091.56	81
52939.82	3441.09	21.40	1331.13	82
54697.14	3555.31	-13.83	-455.30	83
56494.52	3672.14	-48.65	-2268.33	84
58330.11	3791.46	-83.09	-4108.60	85
60202.33	3913.15	-117.18	-5976.75	86
62109.82	4037.14	-150.94	-7873.48	87
64051.42	4163.34	-184.40	-9799.48	88
66026.16	4291.70	-217.59	-11755.48	89
68033.26	4422.16	-250.52	-13742.26	90

CYL DIAM. in	AREA square in	FORCE @ 100 psi	FORCE @ 1500 psi	FORCE @ 2000 psi	FORCE @ 2500 psi	STAGE	EXTEN 280 in tot.
8 1/4	53.5	5350	80250	107000	133750	1	11.13542
7	38.48	3348	57720	76960	96200	2	15.80208
6	28.27	2827	42405	56540	70675	3	20.46875
5	19.63	1963	29445	39260	49075	4	25.13542
4	12.56	1256	18840	25120	31400	5	29.80208

DESIGN ANALYSIS

Client WHC

WO/Job No CR1209 11000027100

Subject Cylinder Forces

Date 4/8/94 By B.M. Koons

Checked 4/13/94 By A.R. Romero

Location

Revised

By

The maximum force required in the cylinder between the angles of 60° to 90° is approx 35,000 lbs. The extension of the cylinder at this point is approx. 21". This is at the 4th stage, or 5" diameter cylinder. The maximum force on the 5th stage (4" diameter) is at 25" extension, or 75". The force required at this point is approx. 13,000 lbs. The moments induced by friction only increase the cylinder forces by approx. 200 lbs.

The hydraulic pressure required to power the cylinder is under 1500 psi. The power unit should adjustable between 1,000 psi and 2500 psi.

The system pressure should be selected to provide a 20% factor of safety on the lifting force between 70° to 90° .

CRANE "B"
 518 LINK BELT
 150 TON
 54' RADIUS

ALLOWABLE LOAD =
 $51,180 \times .75 = 38,385\#$

31,968# CRADLE

+4,800# RIGGING

36,768# ACTUAL LOAD

ALLOWABLE LOAD 38,385#
~~ACTUAL LOAD 35,800#~~ $36,768\#$
 SAFETY FACTOR $\frac{38,385\#}{2,585\#} = 1.61 =$

TWO CRANE L
 COL. 1 & COL.

Ref 2.1.3

~~B~~ This ref. is incomplete at this time. This shows the configuration of the cylinder.
See Ref. 2.1.4.

Ref: 2.1.4

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KEH 0378.00 (06/92) KEF072

Subject Calculation No. CR1209-003

Page 11 of 11[illegible]

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WAC-2D-WM-DA-kg
Rev. 0

DESIGN ANALYSIS

Client WHC

WO/Job No. ER4645 11000027100

Subject Cylinder Forces

Date 4/26/94 By B.M. KOONS

Checked 5/4/94 By A.P. Rando

Location

Revised

By

1.0 Objective

Determine the forces required to raise a cradles mixer pump with a 2000# lifting yoke and a 1000# flexible receiver bag attached at the top flange of the pump.

2.0 Design Inputs

2.1 Criteria and Source

2.1.1 Calculation CR1209-001

2.1.2 Telecon with Tom Mackey (structural head) on weight & location of lifting yoke and bag.

2.2 Given or Known Data

2.2.1 Cylinder Specification: 5 stage, 8 $\frac{1}{2}$ primary
280" stroke

2.3 Assumptions

Same as in calculation CR1209-001

2.4 Methods Used

Same as in calculation CR1209-001

2.5 References

Same as in calculation CR1209-001

DESIGN ANALYSIS

Client WHC
Subject Cylinder Forces

WO/Job No. GR4645 11000027100

Date 4/26/94 By B.M. KOONS

Checked 5/4/94 By A.P. ROMEOS

Location

Revised

By

All geometry is the same except for the weight and location of the CG.

$$WT = 54,000^{\#} + 2,000^{\#} + 1,000^{\#} = 57,000^{\#}$$

$$CG = \frac{54,000^{\#}(26.417') + (2,000^{\#} + 1,000^{\#})(49.833')}{57,000^{\#}}$$

$$CG = 27.65'$$

Ref 2.1.1 on
calc CR1209-001.
Items located at
panel ⑥.

Assume negligible change in Normal component of CG.

From the pivot pin the CG is at (27.65, 3.428)

This gives:

$$l_{cg} = 27.8' \quad (\text{old was } 26.6')$$

$$\angle_{cg} = 7.667^{\circ} \quad (\text{old was } 7.394^{\circ})$$

To get corrected force values, change spreadsheet
to reflect new weight, CG, and angle.

Note: CG of additions

$$2' + 2(5') + 2(9'4") + 2(9'7") = 49.833'$$

hinge &
to panel A

Assumes cradle weight of 57,000 lbs and CG at 27.8'

4/26/94 B.M. KOONS

A. F. Romeo 5/4/94

THETA	A	a	BETA	GAMA	Angle CG	Lcyl	Fcyl
	degrees	Law of Cos	Law of Sin	degrees	degrees		
55	57.31	19.78	44.59	78.11	62.07	16.15	45974.24
60	62.31	21.18	43.62	74.07	67.07	15.87	38914.70
65	67.31	22.55	42.46	70.23	72.07	15.53	31422.14
70	72.31	23.89	41.15	66.54	77.07	15.14	23431.17
71	73.31	24.15	40.88	65.82	78.07	15.05	21767.70
72	74.31	24.41	40.59	65.10	79.07	14.97	20081.32
73	75.31	24.67	40.31	64.39	80.07	14.88	18371.52
74	76.31	24.93	40.02	63.68	81.07	14.79	16637.79
75	77.31	25.19	39.72	62.97	82.07	14.70	14879.60
76	78.31	25.44	39.42	62.27	83.07	14.61	13096.42
77	79.31	25.70	39.12	61.58	84.07	14.51	11287.71
78	80.31	25.95	38.81	60.88	85.07	14.41	9452.91
79	81.31	26.20	38.50	60.19	86.07	14.32	7591.45
80	82.31	26.45	38.18	59.51	87.07	14.22	5702.75
81	83.31	26.70	37.87	58.83	88.07	14.12	3786.18
82	84.31	26.94	37.54	58.15	89.07	14.02	1841.14
83	85.31	27.19	37.22	57.47	90.07	13.91	-133.04
84	86.31	27.43	36.89	56.80	91.07	13.81	-2137.02
85	87.31	27.67	36.56	56.13	92.07	13.70	-4171.50
86	88.31	27.91	36.23	55.47	93.07	13.59	-6237.21
87	89.31	28.14	35.89	54.80	94.07	13.48	-8334.88
88	90.31	28.38	35.55	54.14	95.07	13.37	-10465.32
89	91.31	28.61	35.21	53.48	96.07	13.26	-12629.33
90	92.31	28.84	34.86	52.83	97.07	13.15	-14827.76

Cylinder Forces

WHC-SD-WM-DA-168

Rev. 0

CR1209-003

Pg 4 of 5

4/26/94 B.M. Koons

5/4/94 A.R. Romero

Ro	Mfo	Mfc	Fcyl*	THETA
lbs.	lb*ft	lb*ft	lb	degrees
35857.51	2330.74	1376.08	46203.83	55
32903.77	2138.75	1070.26	39116.94	60
33186.68	2157.13	796.52	31612.36	65
36831.37	2394.04	549.34	23625.63	70
37913.95	2464.41	502.66	21964.83	71
39098.56	2541.41	456.80	20281.66	72
40378.23	2624.59	411.73	18575.60	73
41746.23	2713.50	367.42	16846.11	74
43196.16	2807.75	323.84	15092.66	75
44722.10	2906.94	280.95	13314.69	76
46318.55	3010.71	238.72	11511.64	77
47980.51	3118.73	197.11	9682.94	78
49703.48	3230.73	156.10	7828.01	79
51483.38	3346.42	115.66	5946.24	80
53316.61	3465.58	75.75	4037.03	81
55199.97	3588.00	36.34	2099.73	82
57130.63	3713.49	-2.59	133.70	83
59106.13	3841.90	-41.08	-1861.74	84
61124.33	3973.08	-79.15	-3887.28	85
63183.37	4106.92	-116.82	-5943.66	86
65281.68	4243.31	-154.14	-8031.61	87
67417.92	4382.16	-191.13	-10151.92	88
69591.00	4523.42	-227.81	-12305.40	89
71800.03	4667.00	-264.21	-14492.89	90

DESIGN ANALYSIS

Client WHC
Subject Cylinder ForcesWO/Job No. ER4645 11000027100
Date 4/26/94 By B.M. KOONS
Checked 5/4/94 By A.R. ROMERO
Revised By

Location

Conclusion

With the revised weight of the cradle and pump assembly, the force requirements in the cylinder have increased significantly. The ~~new~~ Hydraulic Specification should reflect these number rather than those in calculation CR1209-001.

The maximum force required between 60° - 90° is approximately 40,000 lb.

The results of calc. CR1209-003 supersede those of calc. CR1209-001. Calc CR1209-001 is used for ~~the~~ reference on formula generation.

KEH 0378.00 (06/92) KEF072

Subject Calculation No. CR1209-004

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WAC-SD-WM-DA-160
Req. 0

DESIGN ANALYSIS

Client WHC

WO/Job No. ER4645 11000027100

Subject Cylinder Forces

Date 4/26/94 By RM KOONS

Checked 5/4/94 By A.R. Romero

Location

Revised By

1.0 Objective

Determine the forces required to support a cradle assembly (without mixer pump). Weight is 34,000#.

2.0 Design Inputs

2.1 Criteria and Source

2.1.1 Calculation CR1209-001

2.1.2 Telecon with Tom Mackey (Structural Lead) on weight of mixer pump.

2.2 Given or Known Data

2.2.1 Weight of mixer pump is 20,000#.

2.2.2 Cylinder Specification: 5 stage, 8 1/4" primary
280" stroke

2.3 Assumptions

2.3.1 CG of cradle is the same as in calculation CR1209-001.

2.4 Methods

Same as Calculation CR1209-001

2.5 References

Same as Calculation CR1209-001

Cylinder Forces

WHC-SD-WM-DA-160
Rev. 0

CR1209-004

Pg 2 of 4

Assumes cradle weight of 34,000 lbs and CG at 26'-6"

4/26/94 R.M. KOONS

5/4/94 A.R. RIVERS

THETA	A	a	BETA	GAMA	Angle CG	Lcyl	Fcyl
	degrees	Law of Cos	Law of Sin	degrees	degrees		
55	57.31	19.78	44.59	78.11	62.39	16.15	25956.63
60	62.31	21.18	43.62	74.07	67.39	15.87	21910.35
65	67.31	22.55	42.46	70.23	72.39	15.53	17617.42
70	72.31	23.89	41.15	66.54	77.39	15.14	13040.60
71	73.31	24.15	40.88	65.82	78.39	15.05	12088.06
72	74.31	24.41	40.59	65.10	79.39	14.97	11122.47
73	75.31	24.67	40.31	64.39	80.39	14.88	10143.54
74	76.31	24.93	40.02	63.68	81.39	14.79	9150.97
75	77.31	25.19	39.72	62.97	82.39	14.70	8144.48
76	78.31	25.44	39.42	62.27	83.39	14.61	7123.75
77	79.31	25.70	39.12	61.58	84.39	14.51	6088.48
78	80.31	25.95	38.81	60.88	85.39	14.41	5038.35
79	81.31	26.20	38.50	60.19	86.39	14.32	3973.04
80	82.31	26.45	38.18	59.51	87.39	14.22	2892.20
81	83.31	26.70	37.87	58.83	88.39	14.12	1795.50
82	84.31	26.94	37.54	58.15	89.39	14.02	682.57
83	85.31	27.19	37.22	57.47	90.39	13.91	-446.95
84	86.31	27.43	36.89	56.80	91.39	13.81	-1593.45
85	87.31	27.67	36.56	56.13	92.39	13.70	-2757.32
86	88.31	27.91	36.23	55.47	93.39	13.59	-3938.98
87	89.31	28.14	35.89	54.80	94.39	13.48	-5138.85
88	90.31	28.38	35.55	54.14	95.39	13.37	-6357.38
89	91.31	28.61	35.21	53.48	96.39	13.26	-7595.04
90	92.31	28.84	34.86	52.83	97.39	13.15	-8852.31

Cylinder Forces

WHC-SD-WM-DA-160

Rev. 0

CR1209-004

PS 3 of 4

4/26/94 B.M. Koons

5/4/94 A.P. Rimes

Ro	Mfo	Mfc	Fcyl*	THETA
lbs.	lb*ft	lb*ft	lb	degrees
21372.07	1389.18	776.92	26090.79	55
19997.95	1299.87	602.59	22030.25	60
20443.19	1328.81	446.59	17731.76	65
22705.63	1475.87	305.74	13158.31	70
23347.54	1517.59	279.13	12207.43	71
24044.30	1562.88	253.01	11243.80	72
24792.34	1611.50	227.33	10267.13	73
25588.21	1663.23	202.09	9277.10	74
26428.65	1717.86	177.26	8273.42	75
27310.61	1775.19	152.82	7255.76	76
28231.26	1835.03	128.76	6223.82	77
29188.02	1897.22	105.06	5177.26	78
30178.53	1961.60	81.70	4115.75	79
31200.68	2028.04	58.66	3038.96	80
32252.56	2096.42	35.92	1946.54	81
33332.48	2166.61	13.47	838.12	82
34438.94	2238.53	-8.71	-286.67	83
35570.62	2312.09	-30.63	-1428.21	84
36726.36	2387.21	-52.31	-2586.89	85
37905.17	2463.84	-73.78	-3763.14	86
39106.18	2541.90	-95.04	-4957.38	87
40328.67	2621.36	-116.11	-6170.04	88
41572.03	2702.18	-137.00	-7401.60	89
42835.76	2784.32	-157.74	-8652.54	90

The weight of the cradle system alone is 34,000 #.

The center of gravity is at the same location as in calc. CR1209-001: (26.417, 3.928)

The spread sheet in calculation CR1209-001 was modified for this weight and CG.

Conclusion

The forces in this spreadsheet are the minimum forces on the cylinder. These must be enough to collapse the cylinder when the cradle is lowered. These should be listed in the specification.

The maximum force required between 60° to 90° is approximately 22,000 lb. The minimum force between 60° to 81° (81° is where the snubber contacts the crad is approximately 2,000 lb.

B-27

Subject Calculation No. CR1207-005

Page ii of ii[illegible]

B-28

WHC-SD-WM-DA-168
Rev 0

Client WHC

WO/Job No. ER4645 11000027100

Subject Cylinder Forces

Date 4/26/94 By B.M. MOORE

Checked 5/4/94 By A.P. BOWERS

Location

Revised By

1.0 Objective

Determine cylinder forces when the cradle is in contact with the snubber. Determine these forces for the cradle with and without the mixer pump.

2.0 Design Inputs

2.1 Criteria and Source

2.1.1 Calc. CR1209-002, Snubber force & angle of contact

2.1.2 Calc. CR1209-003, Cylinder forces with pump

2.1.3 Calc. CR1209-004, Cylinder forces without pump.

2.2 Given Data

2.2.1 Results from above mentioned calculations

2.3 Assumptions

2.3.1 Moment arm of snubber is constant

2.4 Methods used

Force and Moment Balance

DESIGN ANALYSIS

Client **WHC**

WO/Job No. **ER4645 11000027100**

Subject **Cylinder Forces**

Date **4/26/94** By **B.M. KOONS**

Checked **5/4/94** By **A.R. RIVERS**

Location

Revised

By

* Initial angle of contact with snubber is 81° (Ref 2.1.1)

The force required in the cylinder can be determined by ~~the~~ $\sum M_{Pivot} = 0$.

$$\sum M_{PP} = F_{cyl} \bar{x}_{cyl} - Wt \bar{x}_{wt} - F_{sn} \bar{x}_{sn}$$

$$F_{sn} = 36,000^\# ; \bar{x}_{sn} = 6.29' \quad (\text{Ref 2.1.1})$$

$$F_{cyl} = F_{cyl_{wt}} + F_{cyl_{sn}} \quad (\text{Force of cylinder required to overcome weight + force to overcome snubber})$$

$F_{cyl_{wt}}$ is determined by the spreadsheets in Ref 2.1.2 and 2.1.3.

$$F_{cyl_{sn}} = \frac{F_{sn} \bar{x}_{sn}}{\bar{x}_{cyl}} ; \bar{x}_{cyl} \text{ is determined in spreadsheets in Ref 2.1.2 \& 2.1.3}$$

$$F_{cyl} = F_{cyl_{wt}} + \frac{36,000^\#(6.29')}{\bar{x}_{cyl}}$$

↑ ↑
Spreadsheets ↑

Cylinder Forces

WHC-SD-WM-DA-167
Rev.0

CR1209-005

Pg 3 of 4.

4/26/94 B.M. KOONS

5/4/94 A.R. ROMERO

Cradle weight = 57,000 pounds

THETA degrees	Lcyl feet	Fcyl,wt pounds	Fcl,sn pounds	Fcyl pounds
81	14.12	4037	16036.83	20073.83
82	14.02	2100	16151.21	18251.21
83	13.91	134	16278.94	16412.94
84	13.81	-1862	16396.81	14534.81
85	13.7	-3887	16528.47	12641.47
86	13.59	-5944	16662.25	10718.25
87	13.48	-8032	16798.22	8766.22
88	13.37	-10152	16936.42	6784.425
89	13.26	-12305	17076.92	4771.923
90	13.15	-14493	17219.77	2726.772

Cradle weight = 34,000 pounds

THETA degrees	Lcyl feet	Fcyl,wt pounds	Fcl,sn pounds	Fcyl pounds
81	14.12	1947	16036.83	17983.83
82	14.02	839	16151.21	16990.21
83	13.91	-286	16278.94	15992.94
84	13.81	-1428	16396.81	14968.81
85	13.7	-2586	16528.47	13942.47
86	13.59	-3763	16662.25	12899.25
87	13.48	-4957	16798.22	11841.22
88	13.37	-6170	16936.42	10766.42
89	13.26	-7401	17076.92	9675.923
90	13.15	-8652	17219.77	8567.772

DESIGN ANALYSIS

Client WHC
Subject Cylinder ForcesWO/Job No. ER4645 11000027100
Date 4/26/94 By B.M. KOONS
Checked 5/4/94 By A.R. ROSEN
Revised By

Location

Conclusion

These forces are what are required by the cylinder to move the ~~cradle~~ cradle against the snubber. The first case is the cradle and pump assembly. The second table shows the cradle without the pump installed.

These forces should be listed in the specification for the cradle hydraulic system.

Appendix C
Calculations for Hydraulic Snubber

KAISER ENGINEERS
HANFORD

CALCULATION IDENTIFICATION AND INDEX

Page i of ii
Date 4/26/94

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline Mechanical WO/Job No. CR1209 Calculation No. CR1209-002
Project No. & Name S4-101 Mitigation Pump
Calculation Item Raising Cradle Snubber Forces

These calculations apply to:

Dwg. No. _____ Rev. No. _____
Dwg. No. _____ Rev. No. _____
Other (Study, CDR) "Specification for 241-S4 Pump Cradle Hydraulic System" WHC #- WHC-S-284 Rev. No. —

The status of these calculations is:

- ☐ Preliminary Calculations
- ☒ Final Calculations
- ☐ Check Calculations (On Calculation Dated _____)
- ☐ Void Calculation (Reason Voided _____)

POOR COPY RECEIVED
DOCUMENT PROCESSINGIncorporated in Final Drawings? ☐ Yes ☒ No
This calculation verified by independent "check" calculations? ☐ Yes ☒ No

Original and Revised Calculation Approvals:

	Rev. 0 Signature/Date	Rev. 1 Signature/Date	Rev. 2 Signature/Date
Originator	<u>B.M. K...</u> <u>4/12/94</u>	<u>B.M. K...</u> <u>4/26/94</u>	
Checked by	<u>Angel R. K...</u> <u>4/13/94</u>	<u>Angel R. K...</u> <u>5/4/94</u>	
Approved by	<u>E.C. Mackey</u> <u>11/3/94</u>	<u>E.C. Mackey</u> <u>11/3/94</u>	
Checked Against Approved Vendor Data			

INDEXDesign Analysis
Page No.Description

<u>1</u>	<u>Objective & Design Criteria</u>
<u>2</u>	<u>Analysis - Snubber Height</u>
<u>3</u>	<u>Analysis - Geometry</u>
<u>4</u>	<u>Analysis - Force & Snubber Force</u>
<u>5</u>	<u>Analysis - Cylindrical Snubber</u>

CALCULATION CROSS INDEX (Typical)

Subject Calculation No. CFR 100-1001

Page 11 of 11[illegible]

WJC-SD-WM-DA-168
Rev. 0

DESIGN ANALYSIS

Client <u>WHC</u>	WO/Job No. <u>CR1209 11000027100</u>
Subject <u>Snuber</u>	Date <u>5/11/94</u> By <u>B.M. KOONS</u>
	Checked <u>4/13/94</u> By <u>Angel E. Romero</u>
Location	Revised <u>4/26/94</u> By <u>R.M. KOONS</u>
	Checked: <u>5/4/94</u> <u>A.R. Porras</u>

1.0 Objective:

Determine the angle of the raising cradle at the point of ~~in~~ contact with the snuber. Then determine adequate force and pressure settings for the snuber and cylinder. The snuber must be able to hold the cradle in a static position when the cylinder is not pressurized. When the cylinder is pressurized the snuber will ~~collapse~~ collapse under the additional load ~~applied~~ applied by the cylinder. The cylinder pressure must be ~~designed~~ selected to overcome the cradle weight and the snuber force.

2.0 Design Inputs

2.1 Criteria and Source

- 2.1.1 Calculation # CR1201-001 and CR1209-003] R1
- 2.1.2 Drawing # H-2-83693
- 2.1.3 Enerpak Hydraulic Cylinder Catalog, pgs. 10 & 25
- 2.1.4 WHC-SD-WM-DA-121
- 2.1.5 Two Crane Lift Drawing - Attached

2.2 Given or Known Data

- 2.2.1 Snuber is a RC-2510 with CAT-50 saddle, and REB-25 Base Clevis.

2.3 Assumptions

- 2.3.1 Assume Negligible friction.

2.4 Methods to be Used

Trigonometric and static analysis methods

2.5 References:

- 2.5.1 Attached photos: MAR -16CN, -17CN, -18CN

KAISER ENGINEERS
HANFORD

DESIGN ANALYSIS

Calc. No. CR1209-002
Revision 1
Page No. 2 of 5

Client WHC
Subject Snubber

WO/Job No. CR1209 11000027100

Date 4/11/94 By T.M. KOONS

Checked 4/17/94 By A.R. Rasmussen

Location

Revised 4/26/94 By B.M. KOONS

Checked: 5/4/94 A.R. Rasmussen

RC-2510; Cylinder Height extended, $h_e = 25$ in
collapsed, $h_e = 14.75$ in

REB-25; Base Clevis, ϕ to Base, $h_b = D - E - B$
 $= 3\frac{3}{8} - 1\frac{1}{4} - \frac{1}{4}$
 $h_b = 1.875$ in

CAT-50; Diff. from standard, $h_s = 1 - \frac{1}{32}$
 $h_s = \frac{19}{32}$ in

Total height from hinge ϕ to saddle;

$$h_{\text{tot},e} = 25 + 1.875 + \frac{19}{32} = \underline{27.47 \text{ in}}$$

$$h_{\text{tot},c} = 14.75 + 1.875 + \frac{19}{32} = \underline{17.22 \text{ in}}$$

Base to ϕ of snubber clevis, $h_{sc} = \underline{1.5 \text{ in}}$

Base to ϕ of hinge clevis, $h_{hc} = \underline{11.125 \text{ in}}$

Distance between clevis ϕ , $d_c = 6' 3.5' = \underline{75.5 \text{ in}}$

DESIGN ANALYSIS

WHC-SB-WH-BA-167
Rev. 0

Calc. No. CR1209-002
Revision 1
Page No. 3 of 5

Client WHC
Subject SWRCC

WO/Job No. CR1209 11000027100

Date 4/11/94 By B.M. KOONS

Checked 4/13/94 By A.R. ROMERO

Revised 4/26/94 By B.M. KOONS

Location

Checked 5/4/94 A.R. Romero

KAISER ENGINEERS
HANFORD

DESIGN ANALYSIS

Calc. No. CR1209-002

Revision 1

Page No. 4 of 5

Client WHC

WO/Job No. CR1209 11000027100

Subject Snubber

Date 4/11/94 By B.M. KOONS

Checked 4/13/94 By A.R. ROMERO

Location

Revised 4/26/94 By B.M. KOONS

Checked 5/4/94 A.R. Romero

$$28.9 = 11.125 + 6 \sin \theta + (73.75 + 6 \cos \theta) \frac{\cos \theta}{\sin \theta}$$

$$17.775 \sin \theta = 6 \sin^2 \theta + 6 \cos^2 \theta + 73.75 \cos \theta$$

$$17.775 \sin \theta - 73.75 \cos \theta - 6 = 0 = f(\theta)$$

By Iteration:

θ	$f(\theta)$
75°	-8.20
80°	-1.30
82°	1.34
81°	0.02

* The cradle will first contact the snubber at approx 81°.

The maximum reaction for the snubber will be required just before $\theta = 90^\circ$. Sum Moments to determine this reaction:

$$\Sigma M_o = Wt \cdot \bar{x}_{cg} - F_s \cdot \bar{x}_s = \boxed{57,000}^{lb} - \cancel{54,000}^{lb} - 41.14'' - F_s \cdot 75.5'' = 0 \quad R$$

$$F_s = \frac{\boxed{31,060}^{lb}}{\boxed{27,425}} = \boxed{1,132}^{lb}$$

Revised per calc CR1209-003

Set pressure control such that the cylinder will collapse under a load of $\boxed{36,000}^{lb}$. This will allow for 15% factor of safety in the snubers.

$$P_{sn} = \frac{\boxed{36,000}^{lb}}{5.15 (in^2)} = \frac{\boxed{7,000}^{psi}}{\boxed{6,600}^{psi}}$$

DESIGN ANALYSIS

Client WHC
Subject Snubber

WO/Job No. CR1209 11000027100

Date 4/11/94 By B.M. KOONS

Checked 4/13/94 By A.R. ROMERO

Location

Revised 4/26/94 By R.M. KOONS

Checked 5/4/94 A.R. ROMERO

required by
The maximum force the cylinder will occur at the point of initial contact of the snubber. This is because the snubber contacts prior to the cradle going over-center. Thus the cylinder must counter the moment due to the weight of the cradle and the moment due to the snubber.

At $\theta = 81^\circ$, Moment arm of cylinder; $l_{cy} = 14.12 \text{ ft}$

Ref 2.1.1

Force due to cradle wt; $F_{wt} = 4,082 \text{ lb}$

Ref 2.1.1

Moment arm of snubber; $l_{sn} = 75.5 \text{ in} = 6.3 \text{ ft}$ Force of snubber; $R_{sn} = 36,000 \text{ lb}$

Cylinder force due to snubber:

$$F_{sn} \cdot 14.12 - 36,000 \cdot 6.3 = 0$$

$$F_{sn} = 16,063 \text{ lb}$$

Combined effect on cylinder $F_{cy} = F_{wt} + F_{sn} = 20,145 \text{ lb}$

Supply pressure to the cylinder such that the lifting force will be $25,200 \text{ lb}$. This will provide a minimum 25% factor of safety. (at the 5th stage)

$$P_{cy} = 25,200 \text{ lb} / 12.56 \text{ in}^2 = 2,000 \text{ psi}$$

The snubber will first contact the cradle at $\theta = 81^\circ$. The maximum force the snubber will have to react is $31,060 \text{ lb}$. Setting the pressure relief on the snubber line to $2,000 \text{ psi}$ will allow the snubber to react up to $36,000 \text{ lb}$ before collapsing. With the snubber set at $36,000 \text{ lb}$, the max cylinder force is $20,145 \text{ lb}$. Setting the cylinder pressure to $2,000 \text{ psi}$ will allow it to react up to $25,200 \text{ lb}$.

PLAN

SCALE: 3/4" = 1'-0"

(F) SNUBBER SUPPORT

SCALE: 1 1/2" = 1'-0"

DWG NO	TITLE
5	DRAWING TRACEABILITY LIST

H-2-83693

WHC-
Rev. 0
D-WM-DA-168

WHC-SD-WM-DA-167
REV. 0

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WHC-SD-WM-DA-160
REV. 0

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DESIGN CALCULATION

(1) Drawing _____ (2) Doc No. _____ (3) Page _____ of _____
 (4) Building _____ (5) Rev _____ (6) Job No. _____
 (7) Subject _____
 (8) Originator W. C. M. H. Date 12/11/92
 (9) Checker D. E. Ryan Date 12/30/92

(10)

SNUBBER JACK & RISE

DETERMINING JACK HT. AT EXTENDED AND COLLAPSED
 BASED ON EXHAUSTIVE KC-2510 JACK, CAT-50 TOP, CURVIS
 BASE & MOUNT.

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page _____ of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject _____
 (8) Originator PP C. H. H. Date 12/4/17
 (9) Checker D. E. R. J. J. Date 12/29/17

(1) E
(4) F
(7) S
(8) C
(9) C

(10) Check Snubber For Cattle Loads

(10)

Check $1\frac{1}{4}" \phi$ pin For cattle Loads

OR 25 Ton Rated Capacity For Pin

A490 Bolt, Double shear Allowable = 51,500 lbs (AISC, 9th ed)
 ← use

check A325 Material For Pin = Allowable = 41,700 lbs
 Less than Capacity of 25 Tons - Not Good

CRANE 'B'
 518 LINK BELT
 150 TON
 54' RADIUS
 ALLOWABLE LOAD=
 $51,180 \times .75 = 38,385\#$

$38,385\# = 31,968\#$ CRADLE
 $+4,800\#$ RIGGING
 $36,768\#$ ACTUAL LOAD

ALLOWABLE LOAD	38,385#
ACTUAL LOAD	<u>35,800#</u> 36,768#
SAFETY FACTOR	2,385# 1,617#

TWO CRANE
 COL. 1 & CO

22,032# CRADLE
+2,500# RIGGING
24,532# ACTUAL LOAD

CRANE 'A'
75 TON LIMA
40' RADIUS
ALLOWABLE LOAD=
 $38,960\# \times .75 = 29,175\#$
900

CALCULATION CROSS INDEX (Typical)

Subject Calculation No. ER4645-007

Page ii of ii[illegible]

C-15

WHC-SD-WM-DA-169 Rev. ~~0~~

Client	WHC	WO/Job No.	ER4645-11000027100
Subject	Snubber	Date	9/1/94 By B.M. Koons
		Checked	9/12/94 By Theresa P. [unclear]
Location	241-SY	Revised	By

1.0 Objective: Determine the offset of a new snubber ram for the SY-101 pump raising cradle.

2.0 Design Inputs:

2.1 Given Know Data

2.1.1 Max allowable collapsed length of snubber assembly is $17\frac{1}{2}"$ (WHC-SD-WM-DA-121, Rev 0 pg A102)

2.1.2 Max extended length of Enerpac RC2510 w/ REB-25 & CAT-50 is 27.438 in. (WHC-SD-WM-DA-121, Rev 0 pg A102)

2.1.3 Max extended length of Hypower cylinder w/ CAT-50 is 29.25 in (attached Hypower Dwg & Discussion with Konrad) (1800 851-1188)

2.2 Assumptions

2.2.1 The location of the top of the cylinder when retracted (cradle in the vertical position) is $1\frac{1}{4}"$ to the North. This will prevent the snubber from falling away from the support if it loses contact with the cradle.

2.3 References

2.3.1 H-2-83693 Sheet 1, Rev 0

2.3.2 WHC-SD-WM-DA-121, Rev 0, pg A102

2.3.3 Enerpac vendor catalog, E318, "High Force Hydraulic Tools"

2.3.4 Hypower Cylinder drawing, Attached

2.4 Methods

Use information known & assumption to develop the offset on the drawing for existing enerpac snubber. Use this method to determine the offset for the new, longer snubber.

DESIGN ANALYSIS

Client WHC
Subject Snubber

WO/Job No. ER4645
Date 9/1/94 By B.M. Koons

Checked 9/12/94 By Theresa Peterson

Location 241-SY

Revised By

Analysis

DESIGN ANALYSIS

Client WHC
Subject Snubber
Location 241-SYWO/Job No. ER4645
Date 9/1/94 By B.M. Koons
Checked 9/12/94 By J. J. Johnson
Revised ByLaw of cosine

$$a^2 = b^2 + c^2 - 2bc(\cos A)$$

$$\cos A = \frac{b^2 + c^2 - a^2}{2bc}$$

$$\cos A = \frac{76.315^2 + 27.438^2 - 75.520^2}{2 \cdot 76.315 \cdot 27.438}$$

$$\cos A = 0.209$$

$$A = 77.960^\circ$$

Offset

$$OS = 27.438'' \cos(77.960^\circ + 8.382^\circ)$$

$$OS = 1.75''$$

This offset matches the original drawing (H-2-83693, sht. 1, zone B-7). Therefore use this method to determine the offset of the new snubber with the longer stroke.

DESIGN ANALYSIS

Client WHC
Subject Snubber

WO/Job No. ER 4645
Date 9/1/94 By B.M. Koons

Location 241-SY

Checked 9/12/94 By Sheresa Peterson
Revised By

DESIGN ANALYSIS

Client WHC

WO/Job No. ER4645

Subject Snubber

Date 9/1/94 By T.M. Koons

Checked 9/12/94 By Theresa Peterson

Location 241-SY

Revised By

Law of cosine

$$a^2 = b^2 + c^2 - 2bc(\cos A)$$

$$2bc(\cos A) = b^2 + c^2 - a^2$$

$$\cos A = \frac{b^2 + c^2 - a^2}{2bc} = \frac{76.315^2 + 29.25^2 - 75.520^2}{2 \cdot 76.315 \cdot 29.25}$$

$$\cos A = 0.219$$

$$\angle A = 77.369^\circ$$

Off-set

$$OS = 29.25 \cos(77.369^\circ + 8.382^\circ)$$

$$OS = 2.167''$$

$$\text{Off-set} \approx 2 \frac{1}{8}''$$

Conclusion

Change drawing to show new dimension for locating cylinder. Dwg should state:

Field adjust so that fully extended the cylinder is $2 \frac{1}{8}''$ off vertical.

DESIGN CALCULATION

WHC-SD-WM-DA-107 Rev. 0

ER4645-007

Ref 2.3.2

(1) Drawing _____ (2) Doc. No. _____ (3) Page _____ of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject _____
 (8) Originator D. F. Ryman Date 12/11/92
 (9) Checker D. F. Ryman Date 12/30/92

(10)

SNUBBER JACK & BASE

DETERMINE JACK HT. AT EXTENDED AND COLLAPSED
 BASED ON ENVIRO KC-2510 JACK, CAT-50 TOP, CLAVIS
 BASE & MOUNT.

CAT 50 $1'' - \frac{13}{32}'' = \frac{9}{16}''$
 HEIGHT OF UNSEA. CLAVIS
 D-E-B
 $3 \frac{3}{8}'' - 1 \frac{1}{4}'' - \frac{1}{4}'' = 1 \frac{1}{8}''$
 CL HOLE TO END CLAVIS = $1 \frac{1}{4}''$
 USE $h = 1 \frac{1}{2}''$

COLLAPSED $h = 14 \frac{3}{4}''$
 $+ 1 \frac{1}{8}''$
 CAT 50 $+ \frac{9}{16}''$

$17 \frac{1}{16}''$
 BASE $1 \frac{1}{2}''$
 COLLAPSED HT. = $18 \frac{11}{16}''$
 $10 \frac{1}{4}''$
 EXTENDED HT. = $28 \frac{15}{16}''$

~~Page 1000~~

WHC-SD-WM-DA-160
REV. 0

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C-1023

WHC-SD-WM-DA-167
REV. 0

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C-1824

T = 14 1/4
S = 14 1/4
TANG = 1/2 x 2 1/2 x 3"
PLUG = 1/2 THICK

JNS

HYPOWER HYDRAULICS		DRAWN BY KH	
SCALE: NONE	APPROVED BY:	REVISED	
DATE: 9-1-94			
CALKINS DISTR.		DRAWING NUMBER	
IT 5x 12 - 3" ROD