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1	1	Indep. Review R.L. Jorissen	<i>R.L. Jorissen</i>	2/24/95	H5-53				

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RELEASE AUTHORIZATION

Document Number: WHC-SD-WM-DA-165, Rev.0

Document Title: Structural Analysis of the Equipment Removal System
for Tank 241SY101

Release Date: February 28, 1995

**This document was reviewed following the
procedures described in WHC-CM-3-4 and is:**

APPROVED FOR PUBLIC RELEASE

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SUPPORTING DOCUMENT

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Structural Analysis of the Equipment Removal System for Tank 241SY101

3. Number

WHC-SD-WM-DA-165

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7. Abstract

The calculations documented in this report show that the ERS major components are structurally qualified to complete the objective, i.e., to install the removed equipment into a shipping container and transport and store the container at the Central Waste Complex (CWC). The analysis for the structural members of the ERS components considers live load with an impact factor of 125% added to dead load. An allowable stress of one-third yield is used for all structural components carrying the load based on DOE-RL-92-36. Adherence to DOE-RL-92-36 is not a code requirement. However, the loads considered make this factor of safety appropriate. The calculations meet the strength requirements of the American Institute for Steel Construction (AISC 1989) for all non-critical structural elements.

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STRUCTURAL ANALYSIS OF THE EQUIPMENT REMOVAL
SYSTEM FOR TANK 241SY101

October 1994

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Westinghouse Hanford Company
Hanford Operations and Engineering Contractor
for the
U. S. Department of Energy

DESIGN VERIFICATION METHOD

The need for design verification has been reviewed with the method selected as indicated below: (ESR/Work Plan # WP-23480-309)

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

R. B. Pan
Cognizant/~~Project~~/Design Manager

SD # WHC-SD-WM-DA-165

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TYPICAL CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed WHC-SD-WM-DA-165

Author T. C. Mackey

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 _____

(SEE COMPUTE CHECK-LIST IN APPENDIX C)

R. L. Jorissen
Reviewer

Randy Jorissen

PAGE C-18, C-30, and C-39

Date

11/3/94
12/22/94

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STRUCTURAL ANALYSIS OF THE EQUIPMENT REMOVAL SYSTEM FOR TANK 241SY101

1.0 INTRODUCTION

On July 3, 1993, an experimental circulation pump was installed in tank 241SY101. The pump circulates liquid waste from the upper layers of waste to the bottom of the tank to prevent hydrogen gas concentrations from building up in the tank. Before installation of the pump, hydrogen gas concentrations periodically exceeded the lower flammability limit of 4% in air, creating a threat of explosion. Successful operation of the experimental circulation pump has led to the construction of a replacement pump. Removal of the experimental pump required the design and development of an equipment removal system (ERS) to remove contaminated equipment from the tank and allow installation of the new equipment. The ERS equipment included in this analysis consists of a container, a strong-back, and an hydraulic trailer.

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). The analyses of miscellaneous equipment may be found in other referenced supporting documents (WHC 1994a, b, c, and d).

2.0 SUMMARY

The calculations shown in Appendix A and the computer analyses shown in Appendix C verify that the components of the ERS are structurally qualified to complete the objective, i.e., to install the removed equipment into a shipping container and transport and store the container at the Central Waste Complex (CWC).

The analysis for the structural members of the ERS components considers live load with an impact factor of 125% added to dead load. An allowable stress of one-third yield is used for all critical structural components on the basis of requirements in DOE-RL-92-36 (DOE-RL 1993b). Adherence to DOE-RL-92-36 is not a code requirement. However, the loads considered make this factor of safety appropriate. The calculations meet the strength requirements of the American Institute for Steel Construction (AISC 1989) for all non-critical structural elements. The load chart for the ERS for tank SY-101 appears in Appendix B and in the *Specification For Hydraulic Trailer* (WHC 1994e).

The load chart in Appendix B includes the design wind, live, and dead loads for the trailer and strong-back. There is the potential that future modifications to the ERS may be necessary. In the event that modifications are required (such as attaching a different container to the strongback), the load chart in Appendix B must be verified for the new loads.

3.0 DISCUSSION

Before installation of the replacement pump can begin, the existing experimental circulation pump in tank 241SY101 must be removed. The ERS is designed to accomplish this task. The contaminated experimental circulation pump will be removed from the waste tank and placed in a shipping container for transport. The container for the ERS is bolted to a strong-back. The base of the strong-back is attached to the hydraulic trailer at the pivot point. The front of the strong-back is attached to a large telescoping cylinder. The force provided by the hydraulic cylinder will move the strong-back and container from the horizontal position to the vertical position.

As the crane lifts the contaminated equipment from the tank, the equipment is sealed in a flexible receiver (WHC 1994f). The equipment then is lifted above the open container and inserted into the container. After the pump has come to rest on the supports inside the container, the hydraulic cylinder lowers the container assembly into the horizontal position. A crane positions the inner container flange at the front end of the container. The flange bolted into place provides the first boundary for containment. The crane then positions the top hat flange into position at the front end of the container. The top hat flange, when bolted into position, provides the second containment boundary.

After the flanges are secured, the hydraulic trailer is positioned beneath a framework holding a shot hopper. Steel or lead shot is poured into the 1.5-in. shield annulus in the container to reduce the radiation level outside the container. The shipping container then may be left attached to the strong-back and hydraulic trailer for transport to the CWC. Once the trailer and container are driven to the CWC, the spreader beams (WHC 1994a) will be attached to the container so that cranes can be used to lift the container. Once the container is removed, it is placed onto container support stands, which are designed to accept two air pallets for each support. After the air pallets are activated, the container supports will be towed into the storage building by two fork lifts.

3.1 LOAD TEST

The strong-back design is similar to a lifting device as defined by the *Hanford Site Hoisting and Rigging Manual* (DOE-RL 1993b). The strong-back was tested with a test weight assembly attached to the 54-ft container to check its capacity of 25% over rated load in accordance with DOE-RL-92-36. During

testing, the load was hoisted a sufficient angle to ensure that it was supported by only the hydraulic cylinder and pivot point on the trailer. After completion of the load test, all critical welds were magnetic-particle tested to verify weld integrity. After the hoisting load test, the trailer was load tested for the rated 100-ton transport load.

3.2 ROTATION BETWEEN 0 and 90°

The wind pressures acting on the strong-back and container when it is in the vertical position have been analyzed (Appendix A.1). Wind load is based on 10 lbf/ft², which is the minimum wind load allowed by code. This wind load is greater than the wind load due to the operating wind velocity limit of 15 mi/h at the tank farms. Due to wind frequency issues, as shown in the trailer manufacturers calculations, 15 mi/h is the maximum safe operating wind speed.

As Appendix B shows, the strong-back is connected to the end of the trailer by base pins and to the trailer by the hydraulic cylinder. The container is attached to the strong-back by four A449 bolts 2½-in. diameter. Each bolt is inserted through a hole on the 11½- by 8- by 2-in. plate welded to the double-plate ring. The bolts are at the end of the container and at 24 ft from the container end plate. Both strong-back and container are lifted into the vertical position by the hydraulic system, as shown in Appendix B. While the hydraulic cylinder telescopes, the strong-back rotates around the pivot pins on the strong-back base assembly. As the center of gravity of the container and strong-back passes over the pivot pins, the load is controlled by the telescoping cylinder's counter-balance valve.

3.3 EQUIPMENT TRANSPORT

Once the removed equipment and container are lowered to the horizontal position, they will be transported to a storage facility by the trailer. There are tiedown points on each side of the container to secure the container during transportation. The design of the tiedowns is in accordance with U.S. Department of Transportation (DOT) standards (DOT 1989) and can be found in the Safety Evaluation for Packaging (WHC 1994h).

3.4 HORIZONTAL HOIST

The shielded container with the pump may be lifted from the bed of the transport trailer by two cranes. Each crane must use a spreader beam designed per DOE-RL-1993b (WHC 1994a). The two pairs of lifting lugs are located approximately 5 ft-4 in. from the end plate and 5 ft-7½ in. from the top of the container (WHC 1994g). Each lug is welded to the double-plate stiffener and has a through-hole for attachment to the lifting beam via a pin.

The empty container may be lifted using the two holes, 1 11/16 in. in diameter, at the container stiffener ring. These holes are primarily for container tiedown points. Two each 17-ton shackles are adequate for the half-weight of the empty container. The empty container should be lifted with a 20 to 25 foot spreader beam considering the center of gravity of the container at the container midspan.

4.0 REQUIREMENTS

4.1 DESIGN CRITERIA

The purpose of the design criteria is to define a position on the allowable stresses for use in the 241SY101 pump removal project. The pump container, strong-back, spreader beam, and other ancillary hardware are designed using requirements of both DOE-RL 1993b and ANSI 1986. However, both references are vague on the practical application of the allowable stresses for use in analysis and design. The ANSI (1986) standard specifies basic allowables of one-third of tensile yield strength and one-fifth of tensile ultimate strength and recognizes that slight local yielding is necessary to relieve high local stresses (such as in a lug/pin assembly). DOE-RL 1993b is even more nebulous in that the allowable stress is one-third of yield strength only.

So that all design/analysis personnel use a consistent set of limits, the following interpretation of DOE-RL 1993b and ANSI 1986 are used for the structural calculations of steel members and connections in the critical components of SY-101.

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):

$$F_b = F_t = F_a = 12 \text{ kip/in}^2$$

Shear: $F_v = 7.2 \text{ kip/in}^2$

Bearing: $F_p = 12 \text{ kip/in}^2$.

Connections

The bolting of the container to the strong-back shall be performed in accordance with procedure WHC-SD-WM-DA-170 (WHC 1994d).

Bolts: Use AISC 1989 allowables divided by 2

Welds: 7.2 kip/in^2 on effective shear area
(effective shear area = effective throat times the weld length)

Special case for fillet welds - check stress on the weld leg, not the weld throat (do not use the 0.707 factor to determine throat area).

Notes:

- These allowables are based on A-36 steel, but are applicable to other mild steels.
- For combined stresses, the AISC 1989 approach should be used (see Chapter H).

Discussion

Three considerations influenced the development of these allowables.

- DOE-RL 1993b refers to allowables based on yield strength only, not ultimate strength. Therefore, the allowables used herein are based on yield strength (i.e., $1/3$ of yield). Some parameters, such as bearing, typically are expressed in terms of an ultimate failure condition. However, basing allowables on yield satisfies both DOE-RL 1993b and ANSI 1986.
- A popular interpretation of DOE-RL 1993b and ANSI 1986 permits uses of various ratios of the allowables specified in AISC 1989. Although AISC 1989 is a nationally recognized code for buildings constructed of structural steel, using it in conjunction with DOE-RL 1993b and ANSI 1986 requirements as the basis for material allowables results in inconsistencies in safety factors. Therefore, AISC 1989 is not directly used as the basis for structural steel allowables; instead, the allowables were developed from DOE-RL 1993b, ANSI 1986, and the first principles of failure theory. These allowables are more conservative than AISC 1989 allowables.
- A definitive interpretation of DOE-RL 1993b and ANSI 1986 allowables requires 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 DOE-RL 1993b and ANSI 1986 allowables for use at the Hanford Site. This interpretation of allowables should be considered as conservative.

4.2 COMPONENT DESIGN

In accordance with DOE-RL 1993b and ANSI 1986, the following stress limits are used in the structural calculations of steel members and connections in those critical components in SY-101 that are of A-36 steel or other mild steels: 12,000 lbf/in² for bending, tension, axial compression, and bearing stresses; 7,200 lbf/in² for shear stress; 7,200 lbf/in² on effective area for welds except for fillet welds which are checked with stress on the weld leg not on the weld throat; and one-half the stress limits given in AISC for bolts. Fundamentally, the allowable stresses are based on one-third of the yield strength.

4.3 TRANSPORTATION

The lugs located on the sides of the container are used to prevent lateral and some longitudinal movement; the double-plate stiffeners of the container are attached to the strong-back to prevent longitudinal movement. The design of the tiedowns is in accordance with U.S. Department of Transportation (DOT) standards (DOT 1989) and can be found in the Safety Evaluation for Packaging (WHC 1994h).

4.4 HOISTING

The critical lift procedure shall be based on the information in this document and shall be followed for correct hoisting of the container and pump. The manufacturers O&M manual shall be used to set up and operate the hydraulic trailer.

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- AISC, 1989, *Manual of Steel Construction, Allowable Strength Design*, Ninth Edition, American Institute of Steel Construction, Chicago, Illinois.
- ANSI, 1986, *Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500 kg) or More*, American National Standards Institute, New York, New York.
- DOE-RL, 1993a, *Standard Arch-Civil Design Criteria, Design Loads for Facilities*, SDC-4.1, Revision 12, Hanford Plant Standards, U.S. Department of Energy, Richland Field Office, Washington, 1993.
- DOE-RL, 1993b, *Hanford Site Hoisting and Rigging Manual*, DOE-RL-92-36, U. S. Department of Energy Richland Field Office, Richland, Washington.
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- WHC, 1994e, *Specification for Hydraulic Trailer*, WHC-S-0280, Westinghouse Hanford Company, Richland, Washington.
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WHC, 1994, *Hydrogen Mixer Pump Storage Transport Assembly Arrangement*, drawing H-2-83750, Westinghouse Hanford Company, Richland, Washington.

WHC, 1994, *HMT Flexible Receiver and Lifting Yoke Support Stand*, drawing H-2-83754, Westinghouse Hanford Company, Richland, Washington.

WHC, 1994, *64" Diameter Transport Assembly Removal Support*, drawing H-2-83755, Westinghouse Hanford Company, Richland, Washington.

Appendix A

A.1 Wind Loads

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____ PAGE A-2
(4) Building _____ (5) Rev. _____ (6) JOB NO. _____
(7) Subject 10154 HYD TRAILER; WIND GUST FACTOR FOR VERT. POSITION
(8) Originator J. J. SISK (AFTER T. PETERSON CALCS) Date 3-15-94
(9) Checker C. J. HARRIS Date 3-31-94

(10) ASCE 7-88 COMMENTARY P. 61

$$\bar{G} = 0.65 + \left(\frac{P}{\beta} + \frac{(3.32 T_1)^2 S}{1 + 0.002 C} \right)^{1/2}$$

EQ. C7 P. 61

TYPE OF EXPOSURE C

SDC 4.1

STRUCTURE HEIGHT ~ 61 ft.

SEE SKETCH P. 3 OF CALCS

STRUCTURE WIDTH (C) $\left(\frac{9.5 \text{ ft} + 5.67 \text{ ft}}{2} \right) = 7.6 \text{ ft}$

STRUCTURE DAMPING COEFFICIENT, $\beta = 0.05$ DOE-STD-1020-92

$$P(P_a = 0.04, 1 \text{ yr}) = 0.04$$

DUE TO ADMIN CONTROLS AND
TABLE CB P. 60

STRUCTURE SIZE FACTOR, $S = 1.1$

FIG. CB P. 64

$$T_1 = \frac{2.35 (D_0)^{1/2}}{(z/30)^{1/2}}$$

EQ. C6 P. 61

$$z = (2/3)(61 \text{ ft.}) = 41 \text{ ft.}$$

$$D_0 = 0.005$$

TABLE CB P. 56

$$\alpha = 7.0$$

TABLE CB P. 56

$$T_1 = \frac{2.35 (0.005)^{1/2}}{(41 \text{ ft}/30)^{1/2}} = 0.159$$

$$\bar{G} = 0.65 + \left(\frac{0.04}{0.05} + \frac{((3.32)(0.159))^2 (1.1)}{1 + (0.002)(7.6 \text{ ft})} \right)^{1/2}$$

$$\bar{G} = 1.7$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____ PAGE A-3
(4) Building _____ (5) Rev. _____ (6) Sub. No. _____
(7) Subject 10154 HYD. TRAILER; BASIC WIND SPEED CALC FOR VERT POSITION
(8) Originator J. J. SISK (APPROX T. PETERSON CALCS FOR C106) Date 3-15-94
(9) Checker G. J. HARRIS Date 3-31-94

$$(10) F = q_z \bar{G} C_f A_f$$

$$C_f = 1.6$$

$$\bar{G} = 1.7$$

$$F/A_f = 10 \text{ lbs/ft}^2$$

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

$$K_z = 2.58 \left(\frac{z}{z_g} \right)^{2/\alpha}$$

WHERE z IS HT. ABOVE GROUND LEVEL IN FT.

$$z_g = 900$$

$$\alpha = 7.0$$

$$K_z = 2.58 \left(\frac{61}{900} \right)^{2/7}$$

$$K_z = 1.2$$

$$I = 1.00$$

$$F/A_f = 10 \text{ lbs/ft}^2 = 0.00256 (1.2) (1.00 V)^2 (1.7) (1.6)$$

$$V = 35 \text{ MPH}$$

$\therefore$ 30 MPH ADMINISTRATIVE MAX. FOR OPERATION
OF HYD. TRAILER IS ADEQUATE

TABLE 4, p. 10

TABLE 12, p. 21

$$h/D = 64/5.67 = 11.3$$

FOR SQUARE SHAPE

FROM SH. 1

MIN. WIND LOADING PER
ASCE 7-88 p. 9

7-88 EQ. 3 p. 11

EQ. C3 p. 56

TABLE C6 p. 56

" " "

TABLE 5, p. 11

(1) Drawing _____ (2) Doc. No. _____ PAGE A-4
 (4) Building _____ (5) Rev. _____ (6) _____
 (7) Subject 10154 HYD. TRAILER; ANALYSIS OF WIND LOADING
 (8) Originator J. J. SISK Date 3-15-94
 (9) Checker G. J. HARRIS Date 3-3-94

(10)

$P_a = 10 \text{ lbs/ft}^2$ MINIMUM WIND
LOADING PER ASCE 7-88 p. 9

$$\alpha = 33^\circ \quad (\text{SH. 4})$$

AREA OF S.B. & CONT. PROJECTED
INTO WIND

$$A_1 = (L_1) (9.67 \text{ ft.})$$

$$A_1 = 242 \text{ ft}^2$$

TOTAL WIND LOAD ON S.B. & CONTAINER

$$F_1 = P_a A_1 = (10 \text{ lbs/ft}^2) (242 \text{ ft}^2)$$

$$F_1 = 2420 \text{ lbs}$$

SIDE WIND LOAD ON S.B. & CONT.

$$F_{1S} = F_1 \cos(90^\circ - \alpha) = 2420 \text{ lbs} \cos 33^\circ$$

$$F_{1S} = 2030 \text{ lbs}$$

FRONT WIND LOAD ON S.B. & CONT.

$$F_{1F} = F_1 \sin(90^\circ - \alpha) = 2420 \text{ lbs} \sin 33^\circ$$

$$F_{1F} = 1318 \text{ lbs}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____ PAGE A-5
(4) Building _____ (5) Rev. _____ (6) JOB NO. _____
(7) Subject 10154 HYD. TRAILER ; ANALYSIS OF WIND LOADING
(8) Originator J. J. SISK Date 3-17-94
(9) Checker G. J. HARRIS Date 3-31-94

(10)

MAX. PROJECTED AREA FOR WIND LOAD
DETERMINED GRAPHICALLY
DIMENSIONS FROM 10154 TRANSPORT CONCEPT Dwg.

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____ PAGE A-6
(4) Building _____ (5) Rev. _____ (6) SUB NO. _____
(7) Subject 10154 HYD. TRAILER; ANALYSIS OF WIND LOADING
(8) Originator J.J. SISK Date 3-17-94
(9) Checker G.J. HARRIS Date 3-31-94

(10) EQUIVALENT PRESSURE ON SIDE OF S.B. & CONT.

$$P_{1s} = \frac{F_{1s}}{L, H} = \frac{2,030 \text{ lbs}}{(25 \text{ ft})(7 \text{ ft})}$$

$$\rightarrow P_{1s} = 11.6 \text{ lbs/ft}^2$$

EQUIVALENT PRESSURE ON FRONT OF S.B. & CONT.

$$P_{1F} = \frac{F_{1F}}{L, W} = \frac{1,318 \text{ lbs}}{(25 \text{ ft})(9.5 \text{ ft})}$$

$$= 5.5 \text{ lbs/ft}^2$$

AREA OF CONT. ONLY (UPPER LENGTH L_2) PROJECTED INTO WIND

$$A_2 = L_2 D = (28 \text{ ft})(5.67 \text{ ft})$$

$$A_2 = 159 \text{ ft}^2$$

TOTAL WIND LOAD ON A_2

$$F_2 = A_2 P_a = (159 \text{ ft}^2)(10 \text{ lbs/ft}^2)$$

$$F_2 = 1590 \text{ lbs}$$

SIDE WIND LOAD ON A_2

$$F_{2s} = F_2 \cos(90^\circ - \alpha) = 1590 \text{ lbs} \cos 33^\circ$$

$$F_{2s} = 1,333 \text{ lbs}$$

FRONT WIND LOAD ON A_2

$$F_{2F} = F_2 \sin(90^\circ - \alpha) = 1590 \text{ lbs} \sin 33^\circ$$

$$F_{2F} = 866 \text{ lbs}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____ PAGE A-7
(4) Building _____ (5) Rev. _____ (6) JOU INV. _____
(7) Subject 10154 HYD. TRAILER; ANALYSIS OF WIND LOADING
(8) Originator J. J. SISK Date 3-16-94
(9) Checker G. J. HARRIS Date 3-31-94

(10) EQUIVALENT PRESSURE ON SIDE OF CONT., A_2

$$P_{2S} = \frac{F_{2S}}{L_2 D} = \frac{1,333 \text{ lbs}}{(28 \text{ ft})(5.67 \text{ ft})}$$

$$P_{2S} = 8.4 \text{ lbs/ft}^2$$

EQUIVALENT PRESSURE ON FRONT OF CONT., A_2

$$P_{2F} = \frac{F_{2F}}{L_2 D} = \frac{866 \text{ lbs}}{(28 \text{ ft})(5.67 \text{ ft})}$$

$$P_{2F} = 5.5 \text{ lbs/ft}^2$$

EQUIVALENT AVG. PRESSURE ON COMBINED S.B. $\frac{1}{2}$ CONT., SIDE

$$P_{\text{AVG. SIDE}} = \frac{(P_{1S} L_1 H) + (P_{2S} L_2 D)}{(L_1 + L_2) \cdot \frac{(H + D)}{2}}$$

$$= \frac{(11.6 \text{ lbs/ft}^2)(25 \text{ ft})(7 \text{ ft}) + (8.4 \text{ lbs/ft}^2)(28 \text{ ft})(5.67 \text{ ft})}{(25 \text{ ft} + 28 \text{ ft}) \cdot \frac{(7 \text{ ft} + 5.67 \text{ ft})}{2}}$$

$$P_{\text{AVG. SIDE}} = 10.0 \text{ lbs/ft}^2$$

EQUIVALENT AVG. PRESS. ON COMBINED S.B. $\frac{1}{2}$ CONT., FRONT

$$P_{\text{AVG. FRONT}} = \frac{(P_{1F} L_1 W) + (P_{2F} L_2 D)}{(L_1 + L_2) \cdot \frac{(W + D)}{2}}$$

$$= \frac{(5.5 \text{ lbs/ft}^2)(25 \text{ ft})(9.5 \text{ ft}) + (5.5 \text{ lbs/ft}^2)(28 \text{ ft})(5.67 \text{ ft})}{(25 \text{ ft} + 28 \text{ ft}) \cdot \frac{(9.5 \text{ ft} + 5.67 \text{ ft})}{2}}$$

$$P_{\text{AVG. FRONT}} = 5.42 \text{ lbs/ft}^2$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____ PAGE A-8
(4) Building _____ (5) Rev. _____ (6) _____
(7) Subject 10154 HYD. TRAILER; ANALYSIS OF WIND LOADING
(8) Originator J. J. SISK Date 3-17-94
(9) Checker G. J. HARRIS Date 3-3-94

(10) → EQUIVALENT WIND PRESSURE ON SIDE OF STRONG BACK AND
CONTAINER IS 11.6 lbs/ft^2 (SHEET 5)

∴ USE 12 lbs/ft^2 WIND LOAD, EITHER DIRECTION
FOR THIS LOCATION.

→ EQUIVALENT WIND PRESSURES ON OTHER SURFACES
ARE $\leq 10 \text{ lbs/ft}^2$ ∴ USE 10 lbs/ft^2 ,
EITHER DIRECTION ON THOSE SURFACES.

Appendix A

A.2 Pump, Lifting Lugs and Yoke

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____
(4) Building _____ (5) Rev. _____ (6) _____
(7) Subject _____

PAGE A-10

(8) Originator J. J. SISK Date 3-7-94
(9) Checker J. V. Eggen Date 10/12/94

101-SY

(10) PUMP WEIGHT AND C.G. - BEFORE REMOVAL OF ELEC. PIPE, PANEL & EQUIP
PUMP WEIGHT DIAGRAM FROM WHC-SD-WM-DA-121, REV. 0 PAGE A4.

TOTAL Wt. = 21,000# (FROM WHC-SD-TP-PDC-019, REV. 0)

→ INCLUDES FILM & PUMP HOLDUP Wt. TABLE 4

$$C.G. = \frac{\sum \text{MOMENTS}}{\text{Wt.}} = \frac{7,831,156 \text{ in-lb.}}{21,000 \text{ lb.}}$$

$$C.G. = 373''$$

→ 5376# + 1573# (FILM & PUMP HOLDUP Wt.
Applied at pump location,
ADJUSTED FOR 21,000 #
PUMP Wt.)

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____
(4) Building _____ (5) Rev. _____ (6) PAGE A-11
(7) Subject _____
(8) Originator J. J. SISK Date 3-8-74
(9) Checker A. V. Engle Date 10/12/94

(10) PUMP WEIGHT AND C.G. - AFTER REMOVAL OF ELEZ. PIPE, PANEL & EQUIP
PUMP WEIGHT DIAGRAM FROM WHC-SD-WM-DA-121, REV. 0, PAGE A4.
Pump w.t. = 21,000# (FROM WHC-SD-TP-PDC-019, REV. 0
TABLE 4)

Pump Wt. AFTER REMOVAL OF ELECTRICAL PIPE, PANEL
AND EQUIPMENT:

$$21,000\# - 1000\# - 350\# - 300\# = \underline{19,350\#}$$

$$C.G. = \frac{\sum M}{Wt.}$$

$$= \frac{(538 \times 12) + (3226 \times 150) + (538 \times 230) + (6949 \times 310) + (2151 \times 350) + (592 \times 360) + (1076 \times 450) + (4280 \times 590)}{19,350}$$

$$C.G. = \underline{349"}'$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing H-2-815003 (2) Doc. No. _____ PAGE A-12
(4) Building _____ (5) Rev. _____ (6) J _____
(7) Subject STRAIGHTENING OF 1015Y PUMP LIFTING LUGS
(8) Originator J. V. EGGER Date 7/12/94
(9) Checker L. H. Huang Date 10/24/94

(10)

LIFTING LUGS ON 1015Y PUMP (H-2-815003) WERE INSTALLED AS SHOWN ON THE MOUNTING PLATE ASSEMBLY, WHICH ONLY REQUIRED THE LUGS TO BE WELDED FLUSH WITH THE EXISTING PLATE. THE LUGS WERE FOUND TO BE NON PARALLEL

TO ALLOW THE LIFTING YOKE TO FIT ON THE LUGS AND ROTATE DURING LIFTING THE LUGS REQUIRED STRAIGHTENING. A 1" ϕ WAS PULLED THROUGH THE LIFTING HOLE AND TENSIONED WITH A HYDRAULIC JACK WHILE ONE LUG WAS HEATED TO A DULL RED COLOR (BETWEEN 1100°F AND 1300°F). THE PRESSURE WAS GRADUALLY INCREASED WHILE THE OUTSIDE OF THE LUG WAS HEATED UNTIL THE LUG WAS PULLED $3/16$ ". THE PROCESS WAS REPEATED FOR THE OPPOSITE LUG. NO YIELDING OF THE 1" ϕ BAR WAS OBSERVED.

REF AISC pg 6-5 USE OF HEAT TO STRAIGHTEN, CAMBER, OR CURVE MEMBERS

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

(1) Drawing H-2-815003 (2) Doc. No. _____
 (4) Building _____ (5) Rev. _____ (6) J. _____
 (7) Subject STRAIGHTENING OF LIFTING LUGS
 (8) Originator J.V. EGGER Date 7/12/94
 (9) Checker Z. J. Huang Date 10/24/94

PAGE A-13

(10)

LOAD TO YIELD 1" ϕ BAR.

$$P = A F_y \quad A = \frac{\pi d^2}{4} = \frac{\pi (1)^2}{4} = 0.7854$$

$$F_y = 36 \text{ K/in}^2$$

$$P = 0.7854 (36) = 28 \text{ K}$$

LOAD TO YIELD LIFTING LUG.

$$M = P d$$

$$d = 3"$$

$$M = F_y Z$$

$$F_y = 36$$

$$Z = \frac{b d^2}{4}$$

$$b = 6" \quad d = 1.5"$$

$$P(3") = 36 \left(\frac{6(1.5)^2}{4} \right)$$

$$P = 40.5 \text{ K}$$

$$M = F_y S$$

$$S = \frac{b d^2}{6}$$

$$P(3) = 36 \left(\frac{6(1.5)^2}{6} \right)$$

$$P = 27 \text{ K}$$

THE 1" ϕ BAR WOULD YIELD BEFORE YIELDING OF THE LIFTING LUG OCCURED.

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing H-2-83687 (2) Doc. No. _____ PAGE A-14
(4) Building _____ (5) Rev. _____ (6) _____
(7) Subject LIFTING YOKE
(8) Originator J. V. EGGEN Date 7/12/94
(9) Checker S. M. Huang Date 10/24/94

(10)

THE LIFTING LUG DETAIL 2, H-2-815003,
SHEET 2, REQUIRES A $2\frac{1}{8}"$ ϕ HOLE. ($\pm \frac{1}{16}$)
THE HOLE WAS FLAME CUT AND SMOOTHED.

THE LIFTING YOKE REQUIRES A $2\frac{1}{16}" + 0"$
 $- \frac{1}{32}"$
DIAMETER HOLE. AND A PIN DIAMETER
OF $2" + \frac{1}{32}"$
 $- 0"$

AISC REQUIRES HOLES IN BEARING CONNECTIONS
TO BE BOLT DIAMETER $+ \frac{1}{16}"$ (TABLE J3.1)

TO MEET AISC FOR THE PUMP LIFTING
LUG, THE HOLES ON PUMP LIFTING LUG AND
THE LIFTING YOKE WILL BE DRILLED TO THE
NEXT LARGER DRILL DIAMETER OF $2\frac{3}{16}"$. AND
THE PIN DIAMETER WILL BE INCREASED TO
 $2\frac{1}{8}" \phi$.

CHECK MINIMUM EDGE DISTANCE AISC J3.9

$$L_e \geq \frac{2P}{F_u t}$$

$$P = \frac{40}{2} = 20^k \quad F_u = 58^k/in^2$$

$$t = 1" - \frac{1}{8} = 0.875 in.$$

$$L_e \geq \frac{2(20)}{58(0.875)} = 0.788 in.$$

$$L_e \geq 1\frac{1}{4} \times DIA. = 1.25(2.125) = 2.656$$

$$L_e = 3" \text{ OK.}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

(1) Drawing H-2-83687 (2) Doc. No. _____
 (4) Building _____ (5) Rev. _____
 (7) Subject LIFTING YOKES
 (8) Originator J. V. EGGEN Date 7/11/94
 (9) Checker Z. H. Hwang Date 10/24/94

PAGE A-15

(10)

CHECK LIFTING YOKES FOR REDUCED THICKNESS TO ALLOW CLEARANCE FOR LIFTING LUGS ON PUMP. REDUCE 1" THICK PLATES BY $\frac{1}{8}$ ". AND INCREASE HOLE TO $2\frac{3}{16} + \frac{1}{32}$

$$A = \left[.3 - \frac{(2\frac{3}{16} + \frac{1}{32})}{2} \right] \times (1 - \frac{1}{8}) \times 2 \text{ SIDES} = 3.309 \text{ IN}^2$$

$$PALLOWABLE = 3.309 (11.6) = 38.38 \text{ K}$$

38.38 K $\neq$ 40 K REQUIRED N.G.
 INCREASE LUGS TO $1\frac{1}{4}$ ".

GRIND INSIDE SURFACES OF YOKES TO PROVIDE CLEARANCE FOR LIFTING LUGS

Appendix A

A.3 Container

ENGINEERING ANALYSIS

PAGE A-17

Drawing H-2-83734 Doc. No. 101-SY-WTCG-01 Page 1 of 25
Building Tank 241-SY-101 Rev. 0 Job No.
Subject Weight and Center of Gravity Determination
Originator S. S. Shiraga Date 07/29/94
Checker S. R. Crow Date 08/25/94

I. Objectives:

The objective of this is to determine the weight and center of gravity of the Hydrogen Mitigation Mixer Pump Package.

II. References:

1. Industrial Press, Machinery's Handbook, 20th Edition.
2. AISC, American Institute Of Steel Construction, Manual Steel Construction, Ninth Edition.
3. WHC, Drawing, No. H-2-83734, "Hydrogen Mixer Pump Storage Container".
4. Ingersoll-Rand, Compressed Air and Gas Data, 2nd Edition.

III. Results and Conclusions:

The weight and center of gravity calculated herein, form the basis for other engineering evaluations applicable to this package. The calculated values are conservative estimates of the actual weight and are the primary input parameters for the drop, lifting, and vibration evaluations. For reasons of conservatism all calculated weights have been rounded upwards. Center of gravity values are all relative to the center of the Bottom End Blind Flange, except for the Top Caps which are relative to the front face of the Top End Flange. The weight and center of gravity of the package for various loading combinations are as follows:

1. Weight of empty package no shielding: $W_{empty} = 57,000 \text{ lbs}$

CG of empty package no shielding: $cg_{epack} = 27.3 \text{ ft}$

2. Weight of empty package with shielding to Column 14:

$$W_{sh1pack} = 88,000 \text{ lbs}$$

CG of empty package with shielding to Column 14:

$$cg_{sh1pack} = 22.36 \text{ ft}$$

3. Weight of empty package with full shielding (Column 25):

$$W_{sh2pack} = 130,000 \text{ lbs}$$

CG of empty package with full shielding (Column 25):

$$cg_{sh2pack} = 26.62 \text{ ft}$$

4. Weight of Loaded package with no shielding:

ENGINEERING ANALYSIS

Drawing H-2-83734 Doc. No. 101-SY-WTCG-01 Page 2 of 25
Building Tank 241-SY-101 Rev. 0 Job No.
Subject Weight and Center of Gravity Determination
Originator S. S. Shiraga Date 07/29/94
Checker S. R. Crow Date 08/25/94

$$W_{\text{pack}} = 76,000 \text{ lbs}$$

CG of loaded package with no shielding:

$$cg_{\text{pack}} = 28.45 \text{ ft.}$$

5. Weight of loaded package shielded to Column 14:

$$W_{\text{packsh1}} = 110,000 \text{ lbs}$$

CG of loaded package shielded to Column 14:

$$cg_{\text{packsh1}} = 29.59 \text{ ft}$$

6. Weight of loaded package fully shielded to Column 25:

$$W_{\text{packsh2}} = 145,000 \text{ lbs}$$

CG of loaded package fully shielded to Column 25:

$$cg_{\text{packsh2}} = 31.83 \text{ ft}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____ PAGE A-19
(4) Building _____ (5) Rev. _____
(7) Subject Top Cap Lifting Lug 59-101
(8) Originator Shirley Peterson Date 8/9/94
(9) Checker JDW Date 10/26/94

(10) Use $\frac{3}{4}$ " Thick Plate

use $8\frac{1}{2}$ Ton shackle

hole = $1\frac{3}{16}$ " $\varnothing$

pin = $1\frac{1}{8}$ " $\varnothing$

$$R = (1.5 \times 1\frac{3}{16}) = 1.78 \text{ in}$$

use 2" edge distance

$$A = (2" - 1\frac{3}{16}) \times \frac{3}{4}" = 0.61 \text{ in}^2$$

$$F_a = (0.61 \text{ in}^2 \times \frac{36 \text{ Ksi}}{3}) = 7312.5 \text{ lbs}$$

the heaviest top cap weighs 1709 lbs and

the lightest top cap weighs 1703 lbs

this is less than the allowable load for tensile tearing.

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____ PAGE A-20
(4) Building _____ (5) Rev. _____ (6) Job No. _____
(7) Subject C.G. BASED ON LOAD CHART
(8) Originator J. S. Sisk Date 6/1/74
(9) Checker J. J. Sisk Date 6-1-74

(10)

LOAD CART, 10154

FIND COMBINED C.G. OF CONTAINER, PUMP & STRONG-BACK

$$\text{PUMP LIVE LOAD } 210 \text{ #/FT} \times 53' - 3" = 11,183 \text{ #}$$

$$\text{" " " } 150 \text{ #/FT} \times (66 - 53' - 3") = 1913 \text{ #}$$

$$\text{POINT LOADS } 5000 + 1000 = 12,000 \text{ #}$$

$$\text{TOTAL PUMP} = 25,096 \text{ #}$$

$$\text{CONTAINER WT} = 1000 \text{ #/FT} \times 53' - 3" = 53,250 \text{ #}$$

$$\text{TOTAL PUMP \& CONT} = 78,346 \text{ #}$$

$$\text{C.G.} = 28' - 11" \text{ FROM PIVOT PT.}$$

$$\text{TOTAL STRONG-BACK} = 30,000 \text{ #}$$

$$\text{C.G.} = 15' - 0" \text{ FROM PIVOT PT.}$$

$$\Sigma M @ \text{PIVOT PT.} = 0$$

$$(78,346 \times 28' - 11") + (30,000 \times 15' - 0") = 108,346 \times \bar{X}$$

$$\bar{X} = 25' - 0" \text{ HORE POSITION.}$$

FOR VERT POSITION

DISTANCE FROM PIVOT PIN TO BOTTOM OF STRONG-BACK,
FROM LOAD CHART STRONG-BACK C.G. IS 8 1/16" ABOVE PIN.

∴ STRONG BACK C.G. 8 1/16" AFT OF PIN.

CONTAINER & IS AT & BOLTS OR 8 1/8"

∴ CONTAINER C.G. 36" + 8 1/8" - 8 1/8" = 36"

Σ M @ PIVOT PT.

DIST. TO PIN FROM BOTTOM &

$$(30,000 \times 8 \frac{1}{16}) + (78,346 \times 36) = (78,346 + 30,000) \bar{X}$$

$$\bar{X} = 28.4" \therefore \text{USE } 28 \frac{1}{2}" \text{ AFT. C.G. FOR CONT. \& S/B.}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____ PAGE A-21
(4) Building _____ (5) Rev. _____ (6) _____
(7) Subject C.G. BASED ON LOAD CHART
(8) Originator C. S. Mack Date 6/1/94
(9) Checker J. J. SISK Date 6-1-94

(10) LOAD CHART, 10154

COMBINE CONTAINER & PUMP C.G.

$$(1210 \times 53'-3") \times (53'-3"/2) + (150 \times 12.75) \times 59.625' \\ + 7000 \times 28'-11" + 5000 \times 52'-5" = 78,346 \times \bar{x} \\ 29.28' \approx 29'-3"$$

THE C.G. OF PUMP & CONTAINER SHOWN ON
LOAD CHART IS 28'-11". THIS C.G. IS BASED
ON MORE ACCURATE PUMP DATA. THE 29'-3"
IS MORE CONSERVATIVE. USE OF 28'-11" FOR
C.G. CALCULATIONS IS OK.

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____ PAGE A-22
(4) Building _____ (5) Rev. _____ (1)
(7) Subject Loads on 24154101 Load Chart for Hydraulic Trailer
(8) Originator Theresa Peterson Date 5/24/94
(9) Checker Z. H. Zhang Date 10/26/94

- (10) Comparing calculation by J.J. Sisk [Pump Weight and C.G. Before Removal of Elect. Pipe, Panel + Equip.] with Figure 1 WHC-S-0280 Rev 0A page 14 [Load Chart].

Considering Film and Pump holdup wt not part of pump weight while in container.

From J.J. Sisk calculation (see page A-11)

$$\text{pump wt} = 21,000 \text{ lb} - 1573 \text{ lb} = 19427 \text{ lb}$$

$$\text{Pump wt at 125\%} = (19427 \text{ lb}) \times 1.25 = 24283.75 \text{ lbs}$$

$$\begin{aligned} \text{Using live loads from Load chart as pump wt} &= (210 \text{ lb/ft} \times 53.25 \text{ ft}) \\ &+ (150 \text{ lb/ft} \times 12.75 \text{ ft}) + 5000 \text{ lb} + 7000 \text{ lb} = 25095 \text{ lbs} \\ 25095 \text{ lbs} &> 24283.75 \text{ lbs} \end{aligned}$$

∴ The live loads shown on the load chart are more conservative than the 125% of the calculated pump wt. The difference would allow for approximately 800 lbs of film and extra waste on the pump. This also considers the pump hold up wt to be the extra force required to break the pump free from the tank waste.

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____ PAGE A- 23
(4) Building _____ (5) Rev. _____ (6) _____
(7) Subject Center of Gravity of Pump from 2415Y101 Hydraulic Trailer Load Chart
(8) Originator Sheresa Peterson Date 5/24/94
(9) Checker JH Huang Date 10/26/94

- (10) Calculating the center of gravity of the pump from the load chart on Figure 1 page 11 in WHC-S-0280 Rev. 011

$$C.G._p = \frac{\sum M}{\sum Wt}$$

$$C.G._p = \frac{(210 \text{ lb} \times 53.25 \text{ ft}) + (7000 \text{ lb} \times 29 \frac{1}{2} \text{ ft}) + (5000 \text{ lb} \times 52 \frac{1}{2} \text{ ft}) + (150 \text{ lb} \times 12.75 \text{ ft})}{(210 \text{ lb}) + (7000 \text{ lb}) + (5000 \text{ lb}) + (150 \text{ lb})}$$

$$C.G._p = \frac{877433.5 \text{ ft-lb}}{25090 \text{ lb}} = 34.97 \text{ ft from pivot pin + Support A}$$

From J.J. Sisk's calculation: Pump Weighted and C.G. - Before Removal of Elec. Pipe, Panel, and Equip.

$C.G._s = 373 \text{ in} \Rightarrow 31.1 \text{ ft}$ from bottom end of pump (see page A-10)
Since the bottom end of the pump will be approximately 1 ft from the bottom of the container and pivot pin + Support A due to the pump assembly head resting on the container funnel about 6" inside. The new c.g. would then be 32.1 ft from the pivot pin + Support A.

∴ The pump and container c.g. shown on the load chart is more conservative than the calculations done by J.J. Sisk

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____
(4) Building _____ (5) Rev. _____
(7) Subject 101-SY PUMP & CONT. C.G.
(8) Originator J. J. SISK
(9) Checker L. H. Huming

PAGE A-24

Date 3-23-94
Date 10-26-94

- (10) DETERMINE C.G. OF 101-SY TEST PUMP AND CONTAINER COMBINED.
CONTAINER AND PUMP WTS FROM LOAD CHART,
FIGURE 1, WHC-S-0280.

$$\bar{X} = \frac{(53,000 \text{ lbs})(320") + (25,000 \text{ lbs})(404")}{(53,000 \text{ lbs}) + (25,000 \text{ lbs})}$$

$$\text{C.G. } \bar{X} = \underline{347"}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

(1) Drawing _____ (2) Doc. No. _____

(4) Building _____ (5) Rev. _____

PAGE A-25

(7) Subject WEIGHT AND C.G. OF 101 SY CONTAINER

(8) Originator PH HUANG

Date 3-22-94

(9) Checker J. J. SISK

Date 3-30-94

(10)

101 SY CONTAINER

WEIGHT OF STIFFENER

$$A = \frac{\pi}{4} (73^2 - 64^2) + \pi (2.5)^2$$

$$= 988 \text{ in}^2$$

$$W = 988 \times 1.5 \times 0.284$$

$$= 421 \text{ #}$$

WEIGHT OF END PLATE

$$A = \frac{\pi}{4} (73)^2 + \pi (2.5)^2$$

$$= 4205 \text{ in}^2$$

$$W = 4205 \times 2 \times 0.284$$

$$= 2388.5 \text{ #}$$

WEIGHT OF TOP CAP

$$W_1 = \left[\frac{\pi}{4} (58^2 - 57^2) \times 33 + \frac{\pi}{4} (57)^2 \times 9.5 \right] \times 0.284$$

$$= 1209 \text{ #}$$

$$W_2 = \left[\frac{\pi}{4} (68^2 - 67.375^2) \times 36 + \frac{\pi}{4} (67.375)^2 \times 5.16 \right] \times 0.284$$

$$= 995.8 \text{ #}$$

$$W_T = 1209 + 995.8$$

$$= 2205 \text{ #}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____
 (4) Building _____ (5) Rev. _____
 (7) Subject WEIGHT AND C.G. OF 101 SY CONTAINER
 (8) Originator PH Huang
 (9) Checker J. J. SISK

PAGE A-26

Date 3-22-94Date 3-30-94

(10)

WEIGHT OF SHELL

$$W_s = \frac{\pi}{4} (68^2 - 67.375^2) \times 30 \times 0.284$$

$$= 566.2 \#$$

WEIGHT OF PIPE

$$W_p = \frac{\pi}{4} (64^2 - 63^2) \times 53 \times 12 \times 0.284 + \frac{\pi}{4} (63)^2 \times \frac{1}{2} \times 0.284$$

$$= 18459 \#$$

WEIGHT OF INTERNAL STOP

$$W_{IS} = \pi (64 - 17) \times 17 \times \frac{3}{8} \times 2 \times 0.284$$

$$= 534.7 \#$$

WEIGHT OF INTERNAL THROUGH SUPPORT

$$W_{TS} = (24 \times 2 + 6) \times (53 \times 12) \times \frac{3}{16} \times 0.284$$

$$= 1828.8 \#$$

WEIGHT OF PVC ($\frac{1}{4}$ " thick, as $\frac{1}{8}$ " steel WT.)

$$W_v = \frac{\pi}{4} [(46 \frac{1}{4})^2 - 46^2] \times 53 \times 12 \times 0.284$$

$$= 3272 \#$$

TOTAL WEIGHT OF 101 SY CONTAINER

$$W_T = 421 \times 24 + 2388.5 + 3272$$

$$566.2 \times 20 + 18459 + 534.7$$

$$+ 1828.8$$

$$= 47,911 \text{ lb (TOP CAP NOT INCLUDED)}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____ PAGE A-27
(4) Building _____ (5) Rev. _____ (6) Job No. _____
(7) Subject WEIGHT AND C.G. OF 101 SY CONTAINER
(8) Originator FH Huang Date 3-22-94
(9) Checker J.J. Sisk Date 3-30-94

(10)

101 SY CONTAINER
UNIFORM LOAD = $(18459 + 566.2 \times 20) / 53$
= $562.06 / ft$

$$47911 \bar{X} = 2388.5 \times 1 + (29783 + 1828.8 + 3272 + 1684) 320$$

$$+ 8420 \times 335 + 534.7 \times 627$$

$$C.G. \quad \bar{X} = \frac{14,860,040}{47911} = 310"$$

Appendix A

A.4 Strong-back

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing H-2-83736 (2) Doc. No. _____
(4) Building _____ (5) Rev. _____ (6) Jc _____
(7) Subject PRELIMINARY EVALUATION STRONGBACK
(8) Originator J.V. EGGER Date 5/24/94
(9) Checker A.W. CLINE Date 5/24/94

PAGE A-29

(10)

SCOPE

PERFORM A PRELIMINARY STRUCTURAL EVALUATION
OF THE EVOLVING STRONGBACK DESIGN.
STRUCTURAL EVALUATION INCLUDES CHECKING
STRESSES IN THE W36X160 BEAMS, THE
STRONGBACK CONTAINER CONNECTION, HYDRAULIC
BEAM ASSEMBLY AND THE BASE CLEVIS ASSEMBLY

REFERENCES

1. DRAWINGS H-2-83736 SH 1-15
2. AISC STEEL CONSTRUCTION MANUAL
ALLOWABLE STRESS DESIGN 7th EDITION
3. ROARK'S FORMULAS FOR STRESSES & STRAINS
6th EDITION
4. ASTM A400-69 STANDARD PRACTICE
FOR STEEL BARS, SELECTION GUIDE, COMPOSITION
AND MECHANICAL PROPERTIES.
5. BLODGETT, DESIGN OF WELDED STRUCTURES

DESIGN CALCULATION

WHC-SD-WM-UA-165
REV. 0

(1) Drawing H-2-83736 (2) Doc. No. _____ PAGE A-30
(4) Building _____ (5) Rev. _____ (6) Job No. ER4695
(7) Subject PRELIMINARY EVALUATION STRONGBACK
(8) Originator J. V. EGGER Date 5/3/94
(9) Checker A. H. ZILVER Date 5/5/94

- (10) REACTIONS FROM CONTAINER (SEE ATTACHED COMPUTER OUTPUT RELIEVED FROM BRAD COVERDELL 5/1/94)

CONTAINER IN HORIZONTAL POSITION

$$\Sigma X = 0.1 \quad \Sigma Y = +82922 \quad \Sigma Z = +5084.7$$

CONTAINER IN VERTICAL POSITION

$$\Sigma X = 80700 \quad \Sigma Y = -0.00007 \quad \Sigma Z = 5084.0$$

[6] From: Bradford L Coverdell at ~WHC240 5/1/94 10:2

1)

PAGE A-3/

To: James V Egger at ~KEH10

Subject: REQUESTED REACTION FORCES FOR SY101 SHIPPING CONTAINER

----- Message Contents -----

Text item 1:

See attached WordPerfect file. If you have any problems, give me a call. This may take a while to print.

Brad

Reaction forces for the SY101 shipping container in the horizontal position.

Node	Csid	RFX	RFY	RFZ	RMX	RMY	RMZ
11417	0	-2.917e+02	-6.749e+03	8.484e+02	-	-	-
11426	0	5.088e+02	-6.749e+03	-1.677e+02	-	-	-
11432	0	-2.821e+03	4.821e+04	5.624e+03	-	-	-
11441	0	2.604e+03	4.821e+04	-1.220e+03	-	-	-
		+ 0.1	+82922	+5084.7			

Reaction forces for the shipping container in the vertical position.

Node	Csid	RFX	RFY	RFZ	RMX	RMY	RMZ
11417	0	1.349e+04	2.961e-05	-1.075e+03	-	-	-
11426	0	1.429e+04	-4.605e-04	1.755e+03	-	-	-
11432	0	2.375e+04	1.175e-04	2.370e+03	-	-	-
11441	0	2.917e+04	3.134e-04	2.034e+03	-	-	-
		+80,700	+1.0 E-8	+5084.0			

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WHC-SD-WM-DA-165
REV. 0

PAGE A-33

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Appendix A

A.4 Strong-back
A.4.1 Frame I-Beam

DESIGN CALCULATION

WHC-SU-WM-DA-165
REV. 0
PAGE A- 6

(1) Drawing H-2-83736 (2) Doc. No. _____
(4) Building _____ (5) Rev. _____ (6) _____
(7) Subject CHECK W 36X160
(8) Originator J.V. EGER Date 7/29/94
(9) Checker J.H. ZIAVI Date 8/5/94

(10)

CHECK W 36X160 USING CONTAINER REACTIONS FROM
BRAD COVERDELL'S COMPUTER ANALYSIS

$$\sum M_3 = 6749(14.0625) + R_2(235) - 48210(302.0625) = 0$$

$$R_2 = \frac{48210(302.0625) - 6749(14.0625)}{235}$$

$$R_2 = 61564\#$$

$$\sum V = -R_3 + 6749 + 61564 - 48210 = 0$$

$$R_3 = 6749 + 61564 - 48210$$

$$R_3 = 20,103\#$$

DESIGN CALCULATION

WHC-SU-WM-DA-165

REV. 0

PAGE A-7

(1) Drawing H-2-83736 (2) Doc. No. _____
 (4) Building _____ (5) Rev. _____ (6) Job No. 1012
 (7) Subject CHECK W36X160
 (8) Originator J.V. EGGEN Date 7/29/84
 (9) Checker A.H. ZIAU-1 Date 8/5/84

(10)

SHEAR DIAGRAM

MOMENT DIAGRAM

W36 X 160

$A = 47.0 \text{ in}^2$	$d = 36.01 \text{ in}$	$t_w = 0.65$
$b_f = 12.0 \text{ in}$	$t_f = 1.02 \text{ in}$	$d/A_f = 2.94$
$S_x = 542 \text{ in}^3$	$S_y = 49.1 \text{ in}^3$	$r_t = 3.02$

CHECK BENDING STRESS

$$f_{bx} = \frac{3,233,000}{542} = 5965 \text{ #/in}^2$$

AISC TABLE B5.1

$$\frac{b_f}{2t_f} = \frac{12}{2(1.02)} = 5.88$$

$$\frac{d}{t_w} = \frac{36.01}{0.65} = 55.4$$

$$\frac{65}{\sqrt{F_y}} = \frac{65}{\sqrt{36}} = 10.83$$

$$\frac{640}{\sqrt{F_y}} = \frac{640}{\sqrt{36}} = 106.7$$

$$\frac{b}{t} < \frac{65}{\sqrt{F_y}} \text{ OK}$$

$$\frac{d}{t} < \frac{640}{\sqrt{36}} \text{ OK}$$

DESIGN CALCULATION

WHC-SU-WM-DA-165
REV. 0

(1) Drawing H-2-83736 (2) Doc. No. _____ PAGE A- 8
(4) Building _____ (5) Rev. _____ (6) Job No. CA 707
(7) Subject CHECK W 36x160
(8) Originator J.V. EGGER Date 7/29/94
(9) Checker A.H. ELIWA Date 8/5/94

(10)

AISC F1.1

$$L_b = 3(6')(12) + 19" = 235"$$

$$\frac{76 b_f}{\sqrt{F_y}} = \frac{76(12)}{\sqrt{36}} = 152"$$

$$\frac{20000}{(d/A_f) F_y} = \frac{20,000}{(2.94)(36)} = 189"$$

$$L_c = 152"$$

$L_b \nless L_c$ BEAM EXCEED UNBRACED LENGTH FOR $0.66 F_y$.

AISC F1.3

$$\frac{L}{r_t} = \frac{235}{3.02} = 77.8 \quad C_b = 1$$

$$\sqrt{\frac{102 \times 10^3 C_b}{F_y}} = \sqrt{\frac{102 \times 10^3 (1)}{36}} = 53.2$$

$$\sqrt{\frac{510 \times 10^3 C_b}{F_y}} = \sqrt{\frac{510 \times 10^3 (1)}{36}} = 119.0$$

$$\sqrt{\frac{102 \times 10^3 C_b}{F_y}} \leq \frac{L}{r_t} \leq \sqrt{\frac{510 \times 10^3 C_b}{36}}$$

$$F_b = \left[\frac{2}{3} - \frac{F_y \left(\frac{L}{r_t} \right)^2}{1530 \times 10^3 C_b} \right] F_y$$

$$= \left[\frac{2}{3} - \frac{36 (77.8)^2}{1530 \times 10^3 (1)} \right] 36 = 18.87 \text{ ksi}$$

$$f_{bx} < F_b \text{ OK.}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing H-2-83736 (2) Doc. No. _____
 (4) Building _____ (5) Rev. _____ (6) J
 (7) Subject CHECK W36X160
 (8) Originator J.V. EUGEN Date 7/29/94
 (9) Checker A.H. ZIADA Date 8/5/94

PAGE A-4

(10)

CHECK SHEAR STRESS OF WEB

$$f_v = \frac{48210}{36.01(0.65)} = 2060 \text{ #/in}^2$$

AISC F4

$$\frac{h}{t_w} = \frac{36.01}{0.65} = 55.4$$

$$\frac{380}{\sqrt{F_y}} = \frac{380}{\sqrt{36}} = 63.3$$

$$\frac{h}{t_w} \leq \frac{380}{\sqrt{F_y}}$$

$$F_y = 0.4 F_y = 0.4(36) = 14.4 \text{ #/in}^2$$

$$f_v < F_y \text{ OK}$$

CHECK LOCAL WEB YIELDING

$$R = 61564 \text{ #} \quad K = 1 \frac{15}{16} \text{ #} \quad N = K \text{ CONSERVATIVE}$$

AISC K1.3

$$\frac{R}{t_w(N + 2.5K)} = \frac{61564}{(0.65)(3.5(1.9375))} = 13.97 \text{ #/in}^2$$

$$0.66 F_y = 0.66(36) = 24 \text{ #/in}^2$$

$$\frac{R}{t_w(N + 2.5K)} \leq 0.66 F_y \text{ OK}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

(1) Drawing H-2-93736 (2) Doc. No. _____
 (4) Building _____ (5) Rev. _____ (6) J. _____
 (7) Subject CHECK W 36 X 160
 (8) Originator J.V. EGGER Date 7/29/94
 (9) Checker A.H. ZI-MU Date 8/5/94

PAGE A-40

(10)

CHECK WEB CRIPPLING

AISC K1.4

$$R = 34 t_w^2 \left[1 + 3 \left(\frac{N}{d} \right) \left(\frac{t_w}{t_f} \right)^{1.5} \right] \sqrt{F_{yw} \left(\frac{t_f}{t_w} \right)}$$

$$R = 34 (0.65)^2 \left[1 + 3 \left(\frac{1.9375}{36.01} \right) \left(\frac{0.65}{1.02} \right)^{1.5} \right] \sqrt{36 \left(\frac{1.02}{0.65} \right)}$$

$$= 116.8^k$$

$$R > 61.564^k \quad \text{OK.}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing H-2-83736 (2) Doc. No. _____ PAGE A-4
(4) Building 200G (5) Rev. _____ (6) JOB NO. CK4643
(7) Subject ALLOWABLE BOLTING STRESS
(8) Originator J.V. EGGER Date 4/11/94
(9) Checker A.H. ZIAHAT Date 8/5/94

(10)

ALLOWABLE BOLTING STRESS

ASTM A325 BOLTS ULTIMATE TENSILE STRESS.

$\frac{1}{2}" - 1"$ $F_y = 92 \text{ K/in}^2$ $F_u = 120 \text{ K/in}^2$
 $1\frac{1}{8}" - 1\frac{1}{2}"$ $F_y = 81 \text{ K/in}^2$ $F_u = 105 \text{ K/in}^2$

ALLOWABLE BOLT TENSION STRESS CRITERIA
BOLT DIA. $\frac{1}{2}" - 1"$ $1\frac{1}{8}" - 1\frac{1}{2}"$

① AISC TABLE J3.2 44 K/in^2 44 K/in^2
② $\frac{1}{3} F_y$ 30.7 K/in^2 40 K/in^2
③ $\frac{1}{5} F_u$ 22 K/in^2 21 K/in^2

USE $\frac{1}{2}$ AISC FOR ALLOWABLE TENSION $\frac{1}{2} 44 = 22 \text{ K/in}^2$

ASTM A325 BOLTS ULTIMATE SHEAR STRESS

$\frac{1}{2}" - 1"$ $V_y = 53 \text{ K/in}^2$ $V_u = 72 \text{ K/in}^2$
 $1\frac{1}{8}" - 1\frac{1}{2}"$ $V_y = 46.7 \text{ K/in}^2$ $V_u = 63 \text{ K/in}^2$

(MAX. SHEAR STRESS THEORY $V_y = 0.577 F_y$, SEE
ATTACHED BOEING COMPANY TABLE)

ALLOWABLE BOLT SHEAR STRESS CRITERIA.

$\frac{1}{2}" - 1"$ $1\frac{1}{8}" - 1\frac{1}{2}"$
① AISC TABLE J3.2
THREADS INCLUDED 21 K/in^2 21 K/in^2
THREADS EXCLUDED 30 K/in^2 30 K/in^2
② $\frac{1}{3} V_u$ 17.6 K/in^2 15.6 K/in^2
③ $\frac{1}{5} V_u$ 14.4 K/in^2 12.6 K/in^2

USE $\frac{1}{2}$ AISC FOR ALLOWABLE SHEAR $\frac{1}{2} (21) = 10.5 \text{ K/in}^2$

WHC-SD-WM-DA-165
REV. 0

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Appendix A

A.4 Strong-back

A.4.2 Strongback Container Connection

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing H-2-83736 SHS (2) Doc. No. _____
(4) Building 200 G (5) Rev. _____ (6) PAGE A-44
(7) Subject DETAIL 1
(8) Originator J. V. EGGER Date 5/5/94
(9) Checker A. H. ZIADA Date 8/5/94

(10)

STRONG BACK CONTAINER CONNECTION

MAXIMUM SHEAR LOAD BETWEEN CONTAINER
AND STRONG BACK

$$V' = \sqrt{48.21^2 + 2.821^2} = 48.29^k$$

MAXIMUM SINGLE SHEAR ON 2" ϕ
A449 BOLT

$$F_u = 90^k/in^2$$

$$F_v = 0.17(90) = 15.3^k/in^2 \text{ ALLOWABLE } 7.65^k/in^2$$

$$f_v = \frac{48.29}{\frac{\pi}{4}(2)^2} = 15.37^k/in^2 > 7.65^k/in^2 \quad \text{AISC}$$

REQ'D AREA

$$A = \frac{48.29}{(15.3/2)} = 6.31 in^2 \quad 3" \phi \text{ BOLT REQ'D}$$

EXCLUDE THREADS FROM SHEAR PLANE

$$F_v = 0.22(90) = 19.8^k/in^2$$

REQ'D AREA

$$\frac{48.29}{(19.8/2)} = 4.88 in^2 \quad 2\frac{1}{2}" \phi \text{ BOLT REQ'D}$$

* USE $\frac{1}{2}$ AISC ALLOWABLE VALUES.

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing H-2-83736 SH5 (2) Doc. No. _____ PAGE A-5
(4) Building 200-G (5) Rev. 0 (6) Job No. _____
(7) Subject DETAIL 1
(8) Originator J.V. EGGER Date 4/2/94
(9) Checker A.H. ZIARA Date 8/5/94

(10)

MAXIMUM VERTICAL LOAD $V = 27.17 + 14.29$

$$\Sigma V = V + 44 = 0$$

$$= 43.5^k$$

SAY 44^k

$$V = 44^k$$

$$\Sigma H = T - C = 0$$

$$T = C$$

$$\Sigma M_A = T(19\frac{1}{4}) - 44(7\frac{3}{8}) = 0$$

$$T = \frac{44(7\frac{3}{8})}{19\frac{1}{4}}$$

$$T = 16.86^k$$

ASSUME CG OF C AT
C OF BOLTS.

ALLOWABLE TENSION ON
1" ϕ A325 BOLTS (AISC pg 4-3)

$$T_{allowable} = \frac{34.6}{2} = 17.3^k$$

TENSION ON BOLTS

$$T = \frac{16.86}{2} = 8.43^k < 17.3^k \text{ OK.}$$

CHECK SHEAR STRESS IN 2" PLATE
AT CENTERLINE OF 2 1/2" ϕ BOLT

$$f_v = \frac{44}{2(20.8)} = 1.1^k/in^2$$

NOTE:
20.8" SCALED
FROM DRAWING.

ALLOWABLE SHEAR STRESS

$$F_v = 7.2^k/in^2 > 1.1^k/in^2 \text{ OK.}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

(1) Drawing H-2-93736 SH3 (2) Doc. No. _____
 (4) Building 200 G (5) Rev. _____ (6) _____
 (7) Subject VIEW C
 (8) Originator J.V. EGGER Date 7/29/94
 (9) Checker A.H. ZIACA Date 8/5/94

PAGE A- 6

(10)

STRESS ON 1" BEARING PLATE

$$M = 44(6) = 264 \text{ K-IN}$$

$$S = \frac{bd^2}{6} = \frac{1(12)^2}{6} = 24 \text{ IN}^3$$

$$f_b = \frac{264}{24} = 11 \text{ K/IN}^2$$

$$f_a = \frac{44}{(12)(1)} = 3.67 \text{ K/IN}^2$$

BEARING STRESS ON 1" PLATE

$$\text{TENSION} = 11 \text{ K/IN}^2 - 3.67 \text{ K/IN}^2 = 7.33 \text{ K/IN}^2$$

$$\text{COMPRESSION} = -11 \text{ K/IN}^2 - 3.67 \text{ K/IN}^2 = -14.7 \text{ K/IN}^2$$

TENSION STRESS RESISTED BY SHEAR IN BOLTS.

$$\left(\frac{1}{2}\right) 7.33(4) = 14.66 \text{ K}$$

$$V = \frac{14.66}{3} = 4.89 \text{ K/BOLT}$$

ALLOWABLE TENSILE STRESS IN BOLTS (AISC TABLE J3.3)

$$F_T = \sqrt{44^2 - 4.39 \left(\frac{4.89}{0.7854}\right)^2} = 42.0 \text{ K/IN}^2$$

$$T = 42.0(0.7854)\left(\frac{1}{2}\right) = 16.5 \text{ K} > 3.42 \text{ K OK}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

(1) Drawing H-2-83736 S#3 (2) Doc. No. _____
 (4) Building _____ (5) Rev. _____ (6) _____
 (7) Subject SECTION E
 (8) Originator J. V. EGGER Date 7/29/94
 (9) Checker A. H. ELADA Date 8/5/94

PAGE A-7

- (10) WELD ON $1" \times 4\frac{3}{4}" \times 1'-0"$ PLATE
 $P = \frac{1}{2} 14.7(8) = 58.8^k$ @ $2.61"$ from edge

$$J_w = \frac{(b+d)^3}{6}$$

$$= \frac{(4\frac{3}{4} + 12)^3}{6} = 783 \text{ in}^5$$

$$A = 2(12) + 2(4\frac{3}{4}) = 33.5 \text{ in}^2$$

$$\frac{58.8^k}{33.5 \text{ in}^2} = 1.755^k/\text{in}$$

$$M = 3.33(58.8) = 196^k - \text{in}$$

$$\frac{M c_b}{J} = \frac{196(\frac{4\frac{3}{4}}{2})}{783} = 0.595^k/\text{in}$$

$$\frac{M c_t}{J} = \frac{196(6)}{783} = 1.502^k/\text{in}$$

$$f_w = \sqrt{(1.755 + 1.502)^2 + (0.595)^2} = 3.31^k/\text{in}$$

$$\frac{3.31^k/\text{in}}{7.2^k/\text{in}} = 0.46 \text{ in EFFECTIVE THICKNESS REQ'D.}$$

WHC-SD-WM-DA-165

REV. 0

(1) Drawing H-2-83736 SH3 (2) Doc. No. _____

(4) Building _____ (5) Rev. _____ (6) _____

PAGE A-48

(7) Subject SECTION D

(8) Originator J. V. EGGER

Date 7/29/20

(9) Checker A.H. ZIADA

Date 8/5/94

(10)

CHECK WELD STRESS BETWEEN 2" END PLATE AND 3" LUG.

SECTION PROPERTIES

$$A = 12(1) + 3(7) = 33 \text{ W}^2$$

$$\bar{x} = \frac{(12)(1)(\frac{1}{2}) + (3)(7)(4.5)}{33}$$

$$= 3.045''$$

$$I_x = \frac{12(1)^3}{12} + (12)(1)(2.545)^2 + \frac{3(7)^3}{12} + (3)(7)(1.455)^2$$

$$= 209 \text{ m}^4$$

$$I_y = \frac{1(12)^3}{12} + \frac{7(3)^3}{12} = 160 \text{ in}^4$$

$$M_x = 58.8 \left(\frac{1}{2} + 3.045 \right) = 208 \text{ K-IN}$$

$$M_y = 58.8 (3.33) = 196 \text{ K-in}$$

$$P = 58.8^\circ$$

STRESS AT A

$$\frac{58.8}{33} + \frac{208(4.955)}{209} + \frac{196(\frac{3}{2})}{160} = 8.55 \text{ k/ft}^2$$

STRESS AT B

$$\frac{58.8}{33} + \frac{208(3.045)}{209} + \frac{196(6)}{110} = 12.16 \text{ k/ft}^2$$

ALLOWABLE WELD STRESS FOR FULL PENETRATION WELDS IS SAME AS THE BASE METAL

$$F_T = 10.0 \text{ kN/m}^2 > 9.55 \text{ kN/m}^2 \text{ OK}$$

12.16 K/m^2 IS 1.3% OVER ALLOWABLE OK.

TOTAL VERTICAL CONTAINER LOAD ON 1 SIDE WAS USED TO CALCULATE STRESS.

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing H-2-83736 (2) Doc. No. _____
(4) Building _____ (5) Rev. _____
(7) Subject STRONG BACK REACTION FORCES.
(8) Originator J. V. ELLER Date 6/7/94
(9) Checker A.H. ZIADA Date 8/5/94

PAGE A- 9

(10)

VERTICAL REACTION ON STRONG BACK IN HORIZONTAL POSITION
(SEE LOAD CHART.)

$$\frac{R_{2x}}{R_{2y}} = \tan 48^\circ$$

$$\sum H = R_{2x} + R_{3x} = 0$$

$$R_{3x} = -R_{2x}$$

$$\sum V = -(150/2)(153) - 5000 - (1210/2)(639) - 7000 - 301,000 + R_{2y} + R_{3y} = 0$$

$$R_{3y} = 108,345 - R_{2y}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

(1) Drawing H-2-93736 (2) Doc. No. _____
 (4) Building _____ (5) Rev. _____
 (7) Subject STRONGBACK REACTION FORCES
 (8) Originator J. V. EGGER Date 6/7/94
 (9) Checker A. H. ZIADA Date 8/5/94

(10)

$$\sum M_{\textcircled{3}} = (150/12)(153)(153/2 + 639) + (5000)(629) + (1210/12)(639)(639/2) \\ + (7000)(349) + (30,000)(180) - R_{2y}(232) \\ - R_{2x}(19.439) = 0$$

$$= 32942577.5 - R_{2y}(232) - R_{2y}(\tan 45^\circ)(19.439) = 0$$

$$253.59 R_{2y} = 32943000$$

$$R_{2y} = 129,905 \#$$

$$R_{2x} = 129,905(\tan 45^\circ) = 144,274 \#$$

$$R_{3y} = 108345 - 129,905 = -21560 \#$$

$$R_{3x} = -144,274$$

$$R_2 = 194,140 \#$$

$$R_3 = -145,876 \#$$

Load Chart of the Equipment Removal System for Tank 241SY101.

WHC-SD-WM-DA-165
REV. 0

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KAMP SYS INC

PRELIMINARY

33412 334.402"

347.125"

102.352"
87864 87.107"
82913 82.913"

TOP OF TRAILER

15000 16" & PIN
12000 MIN 12"
0000 0.0
GROUND LEVEL

19439"
0.0 8.000

157.736"
157.736"

232.050"
100.0"

5/8"

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WHC-SD-WM-DA-165
REV. 0

PAGE A-52

22 OF 36 0004

FAB PROCUREMENT

3008 312 3183

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing H-2-83736 (2) Doc. No. _____
(4) Building _____ (5) Rev. _____ (6) _____
(7) Subject STRONGBACK/CONTAINER INTERFACE
(8) Originator J. V. EGGER Date 7/13/94
(9) Checker Z. J. Huang Date 10/11/94

PAGE A-53

(10) H-2-783736 SH 5 DETAIL 1 BASE PLATE PLAN
H-2-783736 SH 14 VIEWS OR SH 15 SECTION F

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

PAGE A-54

(1) Drawing H-2-83736 (2) Doc. No. _____
 (4) Building _____ (5) Rev. _____ (6) JOU NO. _____
 (7) Subject STRONGBACK / CONTAINER INTERFACE
 (8) Originator J.V. EGGER Date 7/18/94
 (9) Checker F.H. Haug Date 10/11/94

(10)

¢ STRONGBACK TO ¢ BEAM $3' - 10\frac{1}{2}"$
 ¢ CONTAINER TO FACE OF SUPPORT $3' - 4"$
 ¢ BEAM TO FACE OF CONTAINER
 SUPPORT $6\frac{1}{2}"$

MAXIMUM SPACING OF BEAMS

$$\begin{array}{r} 3'-4 \\ 2 \\ 2\frac{5}{16} \\ 2\frac{3}{4} \\ \hline 3'-11\frac{1}{6} \rightarrow 7'-10\frac{1}{8} \end{array}$$

MINIMUM SPACING OF BEAMS

$$\begin{array}{r} 3'-4 \\ 1 \\ 2\frac{3}{4} \\ 2 \\ \hline 3'-9\frac{3}{4} - 7'-7\frac{1}{2}" \end{array}$$

SPACING ON FABRICATED STRONG BACK

$$\left. \begin{array}{l} 7'-8\frac{3}{8} \text{ MIN.} \\ 7'-8\frac{3}{4} \text{ MAX.} \end{array} \right\} \text{OK}$$

Appendix A

A.4 Strong-back

A.4.3 Hydraulic Beam Assembly

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing H-2-93736 (2) Doc. No. PAGE A-56
(4) Building (5) Rev. (6) Jt.
(7) Subject STRESS IN HYDRAULIC BEAM PLATES
(8) Originator J. V. EGGER Date 7/29/94
(9) Checker A.H. ZIADA Date 8/15/94

$$\tan \theta = \frac{A}{B}$$

$$A = 36.01 + 5\frac{1}{16} - 2 - 1.02 = 38.6775"$$

$$B = 29\frac{1}{4} - 6 - \frac{7}{8} + \frac{1\frac{1}{2}}{\sin \theta} = 22.375 + \frac{1.5}{\sin \theta}$$

θ	B	A/B	$\tan \theta$
57	24.1635	1.6007	1.5399
58	24.1438	1.6020	1.6003
58.03	24.1432	1.6020	1.6022
58.027	24.1432	1.6020	1.6020

$$\theta = 58.027^\circ$$

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

(1) Drawing H-2-83736 (2) Doc. No. _____

(4) Building _____ (5) Rev. _____ (6) _____

PAGE A-7

(7) Subject STRESS IN HYDRAULIC BEAM PLATES

(8) Originator J.V. EGGER Date 7/29/04

(9) Checker A.H. ZIABA Date 8/5/14

(10)

$$\sum V = P - 61564 = 0$$

$$P = 61564\#$$

$$\sum M_A = M - 61564(x) = 0$$

$$M = 61564(x)$$

ASSUME 61564# LOAD IS TRANSFER
AS COMPRESSION IN 1 1/2" PLATE AND
MOMENT IS TRANSFERRED AS SHEAR IN
2" PLATE.

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing H-2-83-736 (2) Doc. No. _____ PAGE A- 8
(4) Building _____ (5) Rev. _____ (6) J. _____
(7) Subject STRESS IN HYDRAULIC BEAM PLATES
(8) Originator J. V. EAGER Date 7/29/94
(9) Checker A. H. ZIADA Date 8/5/94

(10)

$$P = \frac{61564^{\#}}{\sin 58.0270} = 72754^{\#} \quad \left(72754^{\#} \text{ USE IN CALC IS CONSERVATIVE } \right)$$

CONSERVATIVELY ASSUME ONLY $12\frac{5}{8}''$
OF PLATE TRANSFER LOAD.

$$f_a = \frac{P}{A} = \frac{72754}{(12.625)(1.5)} = 3870^{\#}/\text{IN}^2$$

CRITICAL NORMAL BUCKLING STRESS FOR
 $1\frac{1}{2}''$ THICK PLATE

$$\sigma_a' = K \frac{E}{1 - \nu^2} \left(\frac{t}{b} \right)^2 \quad \left(\text{ROARK 6TH EDITION PG 684 TABLE 35 FORM 1A} \right)$$

$$a/b = \frac{38.6775 / \sin(58.027)}{(12.625)} = 3.6$$

$$K = 3.29$$

$$\sigma_a' = 3.29 \frac{29,000,000}{1 - (0.3)^2} \left(\frac{1.5}{12.625} \right)^2$$

$$= 1,480,000^{\#}/\text{IN}^2$$

$$1\frac{1}{2}'' \text{ A IS OK } f_a < \sigma_a'$$

$$\text{CHECK } \frac{Kl}{r} \quad K = 1.0 \quad l = \frac{38.6775}{\sin(58.027)}$$

$$r = \frac{t}{\sqrt{12}} \quad l = 45.6 \text{ IN}$$

$$r = \frac{1.5}{\sqrt{12}} = 0.433$$

$$\frac{Kl}{r} = \frac{1(45.6)}{0.433} = 105.3 \leq 120 \text{ OK.}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

(1) Drawing H-Z-83736 (2) Doc. No. _____
 (4) Building _____ (5) Rev. _____ (6) PAGE A-59
 (7) Subject STRESS IN HYDRAULIC BEAM PLATES
 (8) Originator J.V. EGGER Date 7/29/94
 (9) Checker A.H. ZIADA Date 8/5/94

(10)

ALLOWABLE AXIAL STRESS (AISC E2.)

$$C_c = 126.1 \quad (\text{AISC TABLE 4})$$

$$\frac{K L}{r} = \frac{105.3}{126.1} = 0.84$$

$$C_a = 0.339 \quad (\text{AISC TABLE 3})$$

$$F_a = C_a F_y$$

$$F_a = 0.339 (36,000) = 12,204 \text{ #/in}^2 > 3870 \text{ #/in}^2$$

OK.

CHECK 2" PLATE FOR SHEAR STRESS.

$$V = 61564 \text{ #}$$

CONSERVATIVELY ASSUME ONLY 9 9/16" HEIGHT OF 2" PLATE

SHEAR STRESS IN 2" PLATE

$$f_v = \frac{61564}{(9.56)(2)} = 3219 \text{ #/in}^2$$

CRITICAL SHEAR BUCKLING STRESS FOR 2" PLATE

$$F_v' = K \frac{E}{1 - \nu^2} \left(\frac{t}{b} \right)^2 \quad \text{ROARK 6th EDITION}$$

Pg. 686 TABLE 35
FORM 4a)

$$a = \frac{36.01 + 5.69}{\cos 45^\circ} = 58.97 \text{ in.} \quad b = 9.56$$

$$a/b = \frac{58.97}{9.56} = 6.17 \quad K = 4.4$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing H 2-93736 (2) Doc. No. _____
(4) Building _____ (5) Rev. _____ (6) _____
(7) Subject STRESS IN HYDRAULIC BEAM PLATES
(8) Originator J.Y. EGGCK Date 7/29/74
(9) Checker A.H. ZIADA Date 8/5/74

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(10)

$$\tau' = 4.4 \frac{(29,000,000)}{(1 - 0.3^2)} \left(\frac{2}{9.56} \right)^2$$

$$= 6,134,000 \text{ #/in}^2$$

2" PLATE IS OK $f_v < \tau'$

ALLOWABLE SHEAR STRESS (AISC F4)

$$\frac{h}{t_w} = \frac{58.97}{2} = 29.5$$

$$\frac{380}{\sqrt{F_y}} = \frac{380}{\sqrt{36}} = 63.33$$

$$h/t_w \leq \frac{380}{\sqrt{F_y}} \quad F_y = 0.4(36)$$

$$F_y = 0.4 F_y$$

$$= 0.4(36) = 14.4 \text{ #/in}^2 > 3.219 \text{ #/in}^2 \text{ OK.}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing H-2-83736 (2) Doc. No. _____
(4) Building _____ (5) Rev. _____ (6) _____
(7) Subject STRESS IN HYDRAULIC BEAM PLATES
(8) Originator J.V. EGGER Date 7/29/74
(9) Checker A.H. ZIADA Date 8/5/74

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(10)

CHECK BENDING STRESS AT ϕ OF HYDRAULIC
BEAM ASSEMBLY (H-2-83736 SH 10 SECTION WV)

FOR SECTIONAL PROPERTIES SEE pg. 29-31
(A-56 to A-58)

MOMENT @ ϕ

$$M = 61564 (46.5) = 2,863,000 \text{ #-IN}$$

$$f_b = \frac{Mc}{I}$$

$$c = 7.077 \text{ IN} \quad I = 2133 \text{ IN}^4$$

$$f_b = \frac{2,863,000 (7.077)}{2133} = 9500 \text{ #/IN}^2$$

$< 12 \text{ K/IN}^2 \text{ OK.}$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing H-2-93736 (2) Doc. No. _____
(4) Building _____ (5) Rev. _____ (6) _____
(7) Subject STRESS IN HYDRAULIC BEAM
(8) Originator J. V. EGGER Date 8/5/94
(9) Checker A. H. ZIABA Date 8/5/94

(10)

Section properties of the hydraulic beam assembly for bending

13. Trapezoid (Roark 6th edition, Table 1, page 66)

$$a := \left(5 + \frac{11}{16}\right) + \left(5 + \frac{5}{8}\right) + \left(\frac{1}{4}\right) - 2 \quad b := \left(1 \cdot 12 + \frac{5}{8}\right) - 2 \cdot \left(\frac{5}{16}\right) + 2 \cdot \left(\frac{2}{\cos(45 \cdot \text{deg})}\right) + 2 \cdot a$$

$$c := \left(1 \cdot 12 + \frac{5}{8}\right) - 2 \cdot \left(\frac{5}{16}\right) + 2 \cdot \left(\frac{2}{\cos(45 \cdot \text{deg})}\right) \quad d := \left[\left(5 + \frac{11}{16}\right) + \left(5 + \frac{5}{8}\right) + \left(\frac{1}{4}\right)\right] - 2$$

$$a = 9.563 \quad b = 36.782 \quad c = 17.657 \quad d = 9.563$$

$$A := \frac{d}{2} \cdot (b + c)$$

$$A = 260.285$$

$$y_l := \frac{d \cdot 2 \cdot b + c}{3 \cdot b + c}$$

$$y_l = 5.341$$

$$I_l := \frac{d^3 \cdot b^2 + 4 \cdot b \cdot c + c^2}{36 \cdot b + c}$$

$$I_l = 1.902 \cdot 10^3$$

$$y_m := \frac{2 \cdot b^2 + 2 \cdot b \cdot c - a \cdot b - 2 \cdot a \cdot c - c^2}{3 \cdot (b + c)}$$

$$y_m = 18.391$$

$$I_m := \frac{d}{36 \cdot (b + c)} \cdot \left[\begin{aligned} &b^4 + c^4 + 2 \cdot b \cdot c \cdot (b^2 + c^2) \dots \\ &+ a \cdot (b^3 + 3 \cdot b^2 \cdot c - 3 \cdot b \cdot c^2 - c^3) \dots \\ &+ a^2 \cdot (b^2 + 4 \cdot b \cdot c + c^2) \end{aligned} \right]$$

$$I_m = 1.805 \cdot 10^4$$

13. Trapezoid (Roark 6th edition, Table 1, page 66)

$$a := \left(5 + \frac{11}{16}\right) + \left(5 + \frac{5}{8}\right) + \left(\frac{1}{4}\right) - 2 \quad b := \left[\left(1 \cdot 12 + \frac{5}{8}\right) - 2 \cdot \left(\frac{5}{16}\right)\right] + 2 \cdot a$$

$$c := \left(1 \cdot 12 + \frac{5}{8}\right) - 2 \cdot \left(\frac{5}{16}\right) \quad d := \left(5 + \frac{11}{16}\right) + \left(5 + \frac{5}{8}\right) + \left(\frac{1}{4}\right) - 2$$

$$a = 9.563 \quad b = 31.125 \quad c = 12 \quad d = 9.563$$

$$A := \frac{d}{2} \cdot (b + c)$$

$$A = 206.191$$

$$y_l := \frac{d \cdot 2 \cdot b + c}{3 \cdot b + c}$$

$$y_l = 5.488$$

$$I_l := \frac{d^3 \cdot b^2 + 4 \cdot b \cdot c + c^2}{36 \cdot b + c}$$

$$I_l = 1.468 \cdot 10^3$$

$$y_m := \frac{2 \cdot b^2 + 2 \cdot b \cdot c - a \cdot b - 2 \cdot a \cdot c - c^2}{3 \cdot (b + c)}$$

$$y_m = 15.563$$

$$I_m := \frac{d}{36 \cdot (b + c)} \cdot \left[\begin{aligned} &b^4 + c^4 + 2 \cdot b \cdot c \cdot (b^2 + c^2) \dots \\ &+ a \cdot (b^3 + 3 \cdot b^2 \cdot c - 3 \cdot b \cdot c^2 - c^3) \dots \\ &+ a^2 \cdot (b^2 + 4 \cdot b \cdot c + c^2) \end{aligned} \right]$$

$$I_m = 9.56 \cdot 10^3$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing H-2-83736 (2) Doc. No. _____
(4) Building _____ (5) Rev. _____ (6) PAGE A-63
(7) Subject STRESSES IN HYDRAULIC BEAM PLATES
(8) Originator J. U. EGGER Date 8/5/94
(9) Checker A.H. ZIAVA Date 8/5/94

(10)

2. Rectangle (Roark 6th edition, Table 1, page 62)

$$b := \left(1.12 + \frac{5}{8}\right) d := 2$$

$$b = 12.625 \quad d = 2$$

$$A := b \cdot d$$

$$A = 25.25$$

$$y_1 := \frac{d}{2} \quad I_1 := \frac{1}{12} \cdot b \cdot d^3$$

$$y_1 = 1 \quad I_1 = 8.417$$

$$y_2 := \frac{b}{2} \quad I_2 := \frac{1}{12} \cdot d \cdot b^3$$

$$y_2 = 6.313 \quad I_2 = 335.384$$

2. Rectangle (Roark 6th edition, Table 1, page 62)

$$b := \left(1.12 + \frac{5}{8}\right) - 2 \cdot \left(\frac{5}{16}\right) + 2 \cdot \left[\left(5 + \frac{11}{16}\right) + \left(5 + \frac{5}{8}\right) + \left(\frac{1}{4}\right) - 2 - 2\right] d := 2$$

$$b = 27.125 \quad d = 2$$

$$A := b \cdot d$$

$$A = 54.25$$

$$y_1 := \frac{d}{2} \quad I_1 := \frac{1}{12} \cdot b \cdot d^3$$

$$y_1 = 1 \quad I_1 = 18.083$$

$$y_2 := \frac{b}{2} \quad I_2 := \frac{1}{12} \cdot d \cdot b^3$$

$$y_2 = 13.563 \quad I_2 = 3.326 \cdot 10^3$$

2. Rectangle (Roark 6th edition, Table 1, page 62)

$$b := 2 \quad d := \left(5 + \frac{11}{16}\right) + \left(5 + \frac{5}{8}\right) + \left(\frac{1}{4}\right) - 2 - 2$$

$$b = 2 \quad d = 7.563$$

$$A := b \cdot d$$

$$A = 15.125$$

$$y_1 := \frac{d}{2} \quad I_1 := \frac{1}{12} \cdot b \cdot d^3$$

$$y_1 = 3.781 \quad I_1 = 72.085$$

$$y_2 := \frac{b}{2} \quad I_2 := \frac{1}{12} \cdot d \cdot b^3$$

$$y_2 = 1 \quad I_2 = 5.042$$

DESIGN CALCULATION

WMC-SD-WM-DA-165
REV. 0

PAGE A-64

(1) Drawing H-2-83736 (2) Doc. No. _____
(4) Building _____ (5) Rev. _____ (6) _____
(7) Subject STRESS (a) HYDRAULIC Beam PLATES
(8) Originator L.Y. EAGER Date 8/5/74
(9) Checker A.H. ZIABA Date 8/5/74

(10)

	Extreme Fiber		Moment of Inertia		Distance to Centroid							
Description	Area	x	y	lx	ly	dx	dy	A*dx	A*dy	A*(dy^2)	A*(dx^2)	
Section properties of Hydraulic Beam Assembly for bending												
Trapezoid	260.285	18.391	5.341	1902	18050	18.391	7.341	4786.901	1910.752	14026.83	88035.9	
Trapezoid	-206.191	15.563	5.488	-1468	-9560	18.39143	7.488	-3792.15	-1543.96	-11561.2	-69743	
Rectangle	25.25	6.313	1	8.417	335.384	18.39143	1	464.3835	25.25	25.25	8540.676	
Rectangle	54.25	13.563	1	18.083	3326	18.39143	10.5625	997.7349	573.0156	6052.478	18349.77	
Rectangle	15.125	1	3.781	72.085	5.042	18.39093	5.781	278.1628	87.43763	505.4769	5115.671	
Total	148.719			532.585	12156.43			2735.036	1052.497	9048.877	50299.03	
Section Properties at Centroid								18.39063	7.077086	2132.848	12156.43	
								X	Y	lx	ly	

Appendix A

A.4 Strong-back

A.4.4 Base Clevis Assembly

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

(1) Drawing 14-2-3711, S&S (2) Doc. No. 5
 (4) Building _____ (5) Rev. _____ (6) Jo _____
 (7) Subject PLATE 2
 (8) Originator J.V. EGGER Date 8/1/74
 (9) Checker A.H. ZIADA Date 8/5/74

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(10) CHECK SHEAR ON 3" ϕ PIN.

$$P_y = 145.8^K$$

$$A = \frac{\pi (3)^2}{4} = 7.069 \text{ in}^2$$

$$f_y = \frac{145.8^K}{7.069} = 20.63^K/\text{in}^2$$

CHECK BEARING STRESS ON 3" ϕ PIN.

$$f_b = \frac{145.8^K}{(3)(3)} = 16.2^K/\text{in}^2$$

ASTM A400 TABLE 4 GRADE E4340 HAS 51
 ULTIMATE TENSILE STRENGTH $F_u = 170,000^{\text{psi}}/\text{in}^2$
 YIELD STRENGTH $F_y = 170,000^{\text{psi}}/\text{in}^2$

ALLOWABLE PIN SHEAR STRESS CRITERIA

AISC TABLE J3.2

$$0.17 F_u$$

$$32.3^K/\text{in}^2$$

$$\frac{1}{3} V_y = \frac{1}{3} (0.577) F_y$$

$$32.7^K/\text{in}^2$$

$$\frac{1}{5} V_u = \frac{1}{5} (0.577) F_u$$

$$21.9^K/\text{in}^2 > 20.63^K/\text{in}^2 \text{ OK.}$$

ALLOWABLE BEARING STRESS $\frac{1}{2}$ AISC ALLOWABLE

$$F_p = 1.2 F_u$$

AISC J3.7

$$\frac{1}{2} F_p = \frac{1}{2} (1.2) (170) = 102^K/\text{in}^2 > 16.2^K/\text{in}^2 \text{ OK.}$$

$$F_p = \frac{1}{3} F_y$$

$$= \frac{1}{3} (170) = 56.7^K/\text{in}^2 > 16.2^K/\text{in}^2 \text{ OK.}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

(1) Drawing H-2-93736 SH5 (2) Doc. No. _____

(4) Building _____ (5) Rev. _____ (6) _____

PAGE A-67

(7) Subject DETAIL 2

(8) Originator J-V EGGERS

Date 8/1/74

(9) Checker A.H. JANA

Date 8/5/74

(10) CHECK STRESS IN 2" JOINT PLATE

$$P = 21.56^k \quad M = 144.2 (13.1875) = 1902^k\text{-in}$$

$$V = 144.2^k$$

$$A = 2(7.625)(2)(2) = 61 \text{ in}^2$$

$$S = \frac{bd^2}{6} = \frac{2(2)[(2)(7.625)]^2}{6} = 155 \text{ in}^3$$

$$f_a = \frac{21.56}{61} = 0.353 \text{ k/in}^2$$

$$f_b = \frac{1902}{155} = 12.27 \text{ k/in}^2$$

$$f_a + f_b = 12.62 \text{ k/in}^2 \quad 5.2\% \text{ OVER STRESS}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing H-2-83736 SH5 (2) Doc. No. _____
(4) Building _____ (5) Rev. _____ (6)
(7) Subject DETAIL 2
(8) Originator J.V. EGGER Date 8/1/74
(9) Checker A.H. ZIADA Date 8/5/74

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- (10) CALCULATION DOES NOT TAKE CREDIT FOR 2" STIFFENER PLATES. STRESS CALCULATED IS CONSERVATIVE. CHECK SHEAR STRESS.

$$f_y = 144.2 = 2.36 \text{ K/IN}^2 < 7.2 \text{ K/IN}^2 \text{ OK}$$

DETERMINE WELD FOR 2" BASE PLATE

$$2'-9\frac{1}{8} \times 1'-3\frac{1}{4}$$

(BLODGETT pg 7.4-7
TABLE 5)

$$A = 2(15.25) + 2(33.125) = 96.75 \text{ IN}$$

$$S = bd + \frac{d^2}{3} = (33.125)(15.25) + \frac{(15.25)^2}{3} = 582.7 \text{ IN}^2$$

SHEAR f_x

$$f_x = \frac{144.2}{96.75} = 1.49 \text{ K/IN}$$

TENSION f_{y1}

$$f_{y1} = \frac{21.56}{96.75} = 0.223 \text{ K/IN}$$

BENDING f_{y2}

$$f_{y2} = \frac{144.2(15.1875)}{582.7} = 3.76 \text{ K/IN}$$

$$\text{COMBINED } f = \sqrt{1.49^2 + (3.76 + 0.223)^2} = 4.25 \text{ K/IN}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

(1) Drawing H-2-93736 (2) Doc. No. _____
 (4) Building _____ (5) Rev. _____ (6) _____
 (7) Subject DETAIL 2
 (8) Originator J. V. EGGER Date 8/1/74
 (9) Checker A. H. ZIADA Date 8/5/74

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(10)

REQUIRED WELD SIZE

$$W = \frac{4.25 \text{ K/IN}}{7.2 \text{ K/IN}} = 0.591 \text{ IN.}$$

REQUIRE $\frac{5}{8}$ GROOVE WELD

$$\text{OR } (1.414)(0.591) = 0.835 \text{ IN}$$

$\frac{7}{8}$ " FILLET WELD.

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

(1) Drawing H-2-83736 SH3 (2) Doc. No. _____ PAGE A-70
 (4) Building _____ (5) Rev. _____ (6) Job No. 2-1-12-1
 (7) Subject SECTION D
 (8) Originator J.V. EGGER Date 8/5/99
 (9) Checker A.H. IAWA Date 8/5/99

(10)

CHECK BEARING ON 3" LUG

$$P = 145.8 \text{ K}$$

$$f_p = \frac{145.8}{3(3.5)} = 13.84 \text{ K/in}^2 > 12.0 \text{ K/in}^2 \text{ NG.}$$

ALLOWABLE BEARING $\frac{1}{2}$ AISC ALLOWABLE

$$F_p = 1.2 F_u \quad \text{AISC J3.7}$$

$$\frac{1}{2} F_p = \frac{1}{2} (1.2)(59) = 34.8 \text{ K/in}^2 \quad \text{OK (LESS CONSERVATIVE CRITERIA)}$$

CHECK MINIMUM EDGE DISTANCE

$$L_e > 1\frac{1}{2} d \quad \text{AISC J3.9}$$

$$1.5(3.5) = 5.25 < 6\frac{5}{8} \text{ OK}$$

$$L_e \geq \frac{2P}{F_u t} \quad \text{AISC J3.9}$$

$$\frac{2P}{F_u t} = \frac{2(145.8)}{59(3)} = 1.68 \text{ IN} \leq 6\frac{5}{8} \text{ OK}$$

Appendix A

A.4 Strong-back
A.4.5 Reaction Forces

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing H-2-83736 (2) Doc. No. _____
(4) Building _____ (5) Rev. _____ (6) _____
(7) Subject STRONGBACK REACTION FORCES
(8) Originator J. V. EGGER Date 6/22/94
(9) Checker Z. H. Huang Date 10/11/94

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- (10) DETERMINE REACTIONS AT STRONGBACK/HYDRAULIC RAM (R_2) AND AT BASE CLEVIS ASSEMBLY PIN (R_3) DURING LIFTING OF THE STRONGBACK.

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing H-2-83736 (2) Doc. No. _____ PAGE A- 73
(4) Building _____ (5) Rev. _____ (6) JOB NO. _____
(7) Subject Strong Back Reaction Forces
(8) Originator J. V. ELLER Date 10/11/94
(9) Checker F. A. Huang Date 10/11/94

(10)

Total vertical load on the strongback from Load Chart - 101SY

$$P_v := 150 \cdot \left(\frac{153}{12} \right) + 1210 \cdot \left(\frac{639}{12} \right) + 5000 + 7000 + 30000$$

$$P_v = 1.083 \cdot 10^5$$

Location of center of gravity of the vertical load on the trailer

Horizontal location from Load Chart - 101SY

$$x_c := \frac{150 \cdot \left(\frac{153}{12} \right) \cdot \left(639 + \frac{153}{2} \right) + 1210 \cdot \left(\frac{639}{12} \right) \cdot \left(\frac{639}{2} \right) + 5000 \cdot (629) + 7000 \cdot (349) + 30000 \cdot (180)}{P_v}$$

$$x_c = 304.053$$

Vertical location from Load Chart - 101SY and the Strongback drawings H-2-83736

$$y_c := \frac{\left[-\left(6 + \frac{5}{8} \right) - \left(1 + \frac{1}{2} \right) + 36.01 + \left(1 + \frac{1}{2} \right) + \left(6 + \frac{5}{8} \right) \right] \cdot (P_v - 30000) + \left[(7 \cdot 12 + 9) - \left(7 \cdot 12 + \frac{5}{16} \right) \right] \cdot 30000}{P_v}$$

$$y_c = 28.445$$

Determine the coordinates of the center of gravity and the hydraulic beam

Radius of the container center of gravity

$$r_1 := \sqrt{(x_c)^2 + (y_c)^2}$$

$$r_1 = 305.38$$

Initial angle of the container center of gravity

$$\alpha := \text{atan} \left(\frac{y_c}{x_c} \right)$$

$$\alpha = 5.345 \cdot \text{deg}$$

x coordinate of the container center of gravity

$$x_1(\theta) := r_1 \cdot \cos(\theta + \alpha)$$

y coordinate of the container center of gravity

$$y_1(\theta) := r_1 \cdot \sin(\theta + \alpha)$$

$$\theta := 0 \cdot \text{deg}, 1 \cdot \text{deg} \dots 90 \cdot \text{deg}$$

Radius of the hydraulic beam from the Kamp Sys Inc fax

$$r_2 := \sqrt{(232.05)^2 + (102.352 - 82.913)^2}$$

$$r_2 = 232.863$$

Initial angle of the hydraulic beam

$$\beta := \text{atan} \left[\frac{(102.352 - 82.913)}{232.05} \right]$$

$$\beta = 4.789 \cdot \text{deg}$$

x coordinate of the hydraulic beam

$$x_2(\theta) := r_2 \cdot \cos(\theta - \beta)$$

y coordinate of the hydraulic beam

$$y_2(\theta) := r_2 \cdot \sin(\theta - \beta)$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing H-2-93736 (2) Doc. No. _____
(4) Building _____ (5) Rev. _____ (6) _____
(7) Subject STRONGBACK REACTION FORCES
(8) Originator J. V. EGGER Date 10/11/94
(9) Checker F. H. Huang Date 10/11/94

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(10)

Determine when the container center of gravity is above hydraulic cylinder reaction on the strong back

$\theta := 0\text{-deg}$

$$\theta_1 := \text{root}[(x_1(\theta) - x_2(\theta)), \theta]$$

$$\theta_1 = 56.375 \text{ deg}$$

Determine when the container center of gravity is level with the hydraulic cylinder reaction on the strong back

$$\theta_2 := \text{root}[(y_1(\theta) - y_2(\theta)), \theta]$$

$$\theta_2 = -33.625 \text{ deg}$$

Determine the angle and length of the hydraulic cylinder

Angle between the vertical axis and the hydraulic cylinder

$$\gamma(\theta) := \text{atan}\left[\frac{x_2(\theta) - (157.736)}{y_2(\theta) + (102.352 - 16)}\right]$$

$\theta := 0\text{-deg}, 1\text{-deg}..90\text{-deg}$

$$\gamma(0\text{-deg}) = 48\text{-deg}$$

$$\gamma(90\text{-deg}) = -23.478\text{-deg}$$

$$\theta := 1$$

$$\theta_\gamma := \text{root}(\gamma(\theta), \theta)$$

$$\theta_\gamma = 52.086\text{-deg}$$

Length of the hydraulic cylinder

$$r(\theta) := \frac{y_2(\theta) + (102.352 - 16)}{\cos(\gamma(\theta))}$$

$$r(0\text{-deg}) = 100$$

$$r(90\text{-deg}) = 347.14$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing 14-2-83736 (2) Doc. No. _____ PAGE A-75
(4) Building _____ (5) Rev. _____ (6) Job No. _____
(7) Subject STRONG BACK REACTION FORCES
(8) Originator J. V. EGGER Date 10/11/94
(9) Checker F. H. Huang Date 10/11/94

(10)

Determine the reaction of the hydraulic beam on the strongback

Reaction at the hydraulic beam

$$R_2(\theta) := \frac{P_v \cdot (x_1(\theta))}{\cos(\gamma(\theta)) \cdot x_2(\theta) - \sin(\gamma(\theta)) \cdot y_2(\theta)}$$

Horizontal reaction at the hydraulic beam

$$R_{2x}(\theta) := R_2(\theta) \cdot \sin(\gamma(\theta))$$

Vertical reaction at the hydraulic beam

$$R_{2y}(\theta) := R_2(\theta) \cdot \cos(\gamma(\theta))$$

$\theta := 0\text{-deg}, 1\text{-deg}..90\text{-deg}$

$$R_{2x}(0\text{-deg}) = 1.442 \cdot 10^5$$

$$R_{2x}(90\text{-deg}) = 1.113 \cdot 10^4$$

$$R_{2y}(0\text{-deg}) = 1.299 \cdot 10^5$$

$$R_{2y}(90\text{-deg}) = -2.563 \cdot 10^4$$

$$R_2(0\text{-deg}) = 1.941 \cdot 10^5$$

$$R_2(90\text{-deg}) = -2.795 \cdot 10^4$$

Determine maximum value for R_{2y}

2

$\theta := 0\text{-deg}$

$$\theta_{\max} = \text{root} \left(\frac{d}{d\theta} R_{2y}(\theta), \theta \right)$$

$$\theta_{\max} = 20.35\text{-deg}$$

$$R_{2y}(\theta_{\max}) = 1.518 \cdot 10^5$$

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

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(1) Drawing H-2-83 736 (2) Doc. No. _____
 (4) Building _____ (5) Rev. _____ (6) _____
 (7) Subject STRONG BACK REACTION FORCES
 (8) Originator J. V. EGGER Date 10/11/94
 (9) Checker F. H. Huang Date 10/11/94

(10)

Determine the reactions on the strongback clevis pin

Vertical reaction at the end of the strongback

$$R_{3y}(\theta) := P_v - R_{2y}(\theta)$$

Horizontal reaction at the end of the strongback

$$R_{3x}(\theta) := -R_{2x}(\theta)$$

Resultant reaction at the end of the strongback

$$\theta_0 := \text{root}(R_{3x}(\theta), \theta) \quad \theta_0 = 52.149 \cdot \text{deg}$$

$$R_3(\theta) := \text{if}(\theta < \theta_0, -\sqrt{R_{3x}(\theta)^2 + R_{3y}(\theta)^2}, \sqrt{R_{3x}(\theta)^2 + R_{3y}(\theta)^2})$$

$$\theta := 0 \cdot \text{deg}, 1 \cdot \text{deg} \dots 90 \cdot \text{deg}$$

$$R_{3x}(0 \cdot \text{deg}) = -1.442 \cdot 10^5$$

$$R_{3x}(90 \cdot \text{deg}) = -1.113 \cdot 10^4$$

$$R_{3y}(0 \cdot \text{deg}) = -2.153 \cdot 10^4$$

$$R_{3y}(90 \cdot \text{deg}) = 1.34 \cdot 10^5$$

$$R_3(0 \cdot \text{deg}) = -1.458 \cdot 10^5$$

$$R_3(90 \cdot \text{deg}) = 1.344 \cdot 10^5$$

$$R_{3y}(\theta_{\text{max}}) = -4.348 \cdot 10^4$$

Determine the direction of the reactions on the strongback

Angle of the reaction at the end of the hydraulic beam with the vertical

$$\beta_2(\theta) := \text{atan}\left(\frac{R_{2x}(\theta)}{R_{2y}(\theta)}\right)$$

Angle of the reaction at the end of the strongback with the vertical

$$\beta_3(\theta) := \text{atan}\left(\frac{R_{3x}(\theta)}{R_{3y}(\theta)}\right)$$

$$\theta := 0 \cdot \text{deg}, 0.1 \cdot \text{deg} \dots 90 \cdot \text{deg}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

(1) Drawing H-2-93736 (2) Doc. No. _____ PAGE A-77
 (4) Building _____ (5) Rev. _____ (6) Sub No. _____
 (7) Subject STRONG ROCK REACTION FORCES
 (8) Originator J.V. EGGER Date 10/11/94
 (9) Checker F.H. Huang Date 10/11/94

(10)

$$\beta_2(0 \cdot \text{deg}) = 48 \cdot \text{deg} \quad \beta_2(90 \cdot \text{deg}) = -23.478 \cdot \text{deg}$$

$$\beta_3(0 \cdot \text{deg}) = 81.509 \cdot \text{deg} \quad \beta_3(90 \cdot \text{deg}) = -4.75 \cdot \text{deg}$$

Check the reactions calculated

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Appendix A

A.5 Trailer Support

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____ (3) Page _____ of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject 101-SY CONTAINER, STRONGBACK & PUMP REACTIONS AT TRAILER SUPPORTS
 (8) Originator J. J. SISK Date 3-28-94
 (9) Checker JVE/gm Date 10/26/94

(10) DIMENSIONS AND WEIGHTS TAKEN FROM LOAD CHART, FIGURE 1, WHC-S-0280, "SPEC. FOR 101-SY HYDRAULIC TRAILER"; EXCEPT:

- END OF PUMP REMOVED FOR TRANSPORT
- 66,000 lbs OF LEAD SHOT SHIELDING ADDED, DISTRIBUTED UNIFORMLY ALONG CONTAINER (PER S. CROW)
- STRONGBACK TAKEN AS UNIFORM LOAD ALONG 24.7 ft. LENGTH

ASSUME CONTAINER AND STRONGBACK ARE RIGID; NO BENDING.
FIND REACTIONS AT TRAILER SUPPORTS.

LOAD CASE 1 (ASSUME SIMPLE SUPPORTED BEAMS)

FIND REACTIONS AT A, B & C

$$\begin{aligned}\Sigma \text{ REACTIONS} &= 30,000 \text{ lbs} + (2,450 \text{ lbs/ft} \times 53.3 \text{ ft}) + 5,000 \text{ lbs} \\ &\quad + 7,000 \text{ lbs} \\ &= 173,000 \text{ lbs}\end{aligned}$$

$$\begin{aligned}\text{REACTION AT C} &= 5,000 \text{ lbs} + ((53.3 \text{ ft} - 48.6 \text{ ft}) \times 2,450 \text{ lbs/ft}) \\ &\quad + \left(\frac{48.6 \text{ ft} - 24.7 \text{ ft}}{2} \times \frac{2,450 \text{ lbs}}{\text{ft}} \right) + \left(\frac{29.1 \text{ ft} - 24.7 \text{ ft}}{48.6 \text{ ft} - 24.7 \text{ ft}} \times 7,000 \text{ lbs} \right) \\ C_1 &= \underline{47,100 \text{ lbs}}\end{aligned}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

- (1) Drawing _____ (2) Doc. No. _____ (3) Page 1 of 1
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject 101-54 CONTAINER STRONGBACK / PUMP REACTIONS AT TRAILER SUPPORTS
 (8) Originator J. J. SISK Date 3-28-94
 (9) Checker J. J. Sisk Date 10/26/94

$$(10) \text{ REACTION AT } B_1 = \left(\frac{48.6\text{ft} - 24.7\text{ft}}{2} \times \frac{2,450\text{lbs}}{\text{ft.}} \right) + \left(\frac{48.6\text{ft} - 29.1\text{ft}}{48.6\text{ft} - 24.7\text{ft}} \times 7,000\text{lbs} \right) \\ + \left(\frac{24.7\text{ft}}{2} \times \frac{1,215\text{lbs}}{\text{ft.}} \right) + \left(\frac{24.7\text{ft}}{2} \times \frac{2,450\text{lbs}}{\text{ft.}} \right)$$

$$B_1 = \underline{80,300\text{lbs}}$$

$$\text{REACTION AT } A_1 = \left(\frac{24.7\text{ft}}{2} \times \frac{2,450\text{lbs}}{\text{ft.}} \right) + \left(\frac{24.7\text{ft}}{2} \times \frac{1,215\text{lbs}}{\text{ft.}} \right)$$

$$A_1 = \underline{45,300\text{lbs}}$$

$$\Sigma \text{ REACTIONS} = A_1 + B_1 + C_1 = 47,100\text{lbs} + 80,300\text{lbs} + 45,300\text{lbs}$$

$$= \underline{173,000\text{lbs}} \quad \text{CKS W/ PAGE 1}$$

FOR LOAD CASE 1:

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____ (3) Page 1 of 1
(4) Building _____ (5) Rev. _____ (6) Job No. _____
(7) Subject 101-SY CONTAINER, STRONG-BACK PUMP REACTIONS AT TRAILER SUPPORTS
(8) Originator J. J. SISK Date 3-28-94
(9) Checker C. J. Sisk Date 10/26/94

(10) FOR LOAD CASE 2, DELETE SUPPORT AT B:

$$\text{REACTION AT C} = 5,000 \text{ lbs} + (153.3 \text{ ft} - 48.6 \text{ ft}) \times \frac{2,450 \text{ lbs}}{\text{ft}} \\ + \left(\frac{48.6 \text{ ft}}{2} \times \frac{2,450 \text{ lbs}}{\text{ft}} \right) + \left(\frac{29.1 \text{ ft}}{48.6 \text{ ft}} \times 7,000 \text{ lbs} \right) + \left(\frac{24.7 \text{ ft}}{2} \times 24.7 \text{ ft} \times \frac{1,215}{\text{ft}} \right)$$

$$C_2 = 87,900 \text{ lbs}$$

$$\text{REACTION AT A} = \left(\frac{48.6 \text{ ft}}{2} \times \frac{2,450 \text{ lbs}}{\text{ft}} \right) + \left(\frac{48.6 \text{ ft} - 29.1 \text{ ft}}{48.6 \text{ ft}} \times 7,000 \text{ lbs} \right) \\ + \left(\frac{48.6 \text{ ft} - \frac{24.7 \text{ ft}}{2}}{48.6 \text{ ft}} \times 24.7 \text{ ft} \times \frac{1,215 \text{ lbs}}{\text{ft}} \right)$$

$$A_2 = 84,700 \text{ lbs}$$

$$\Sigma \text{ REACTIONS} = A_2 + C_2 = 87,900 \text{ lbs} + 84,700 \text{ lbs} \\ = 173,000 \text{ lbs} \text{ CKS W/ PAGE 1}$$

FOR LOAD CASE 2:

ANALYTICAL CALCULATIONS

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Subject. 101-SY : CONTAIN./STRGBK - REACTIONS INTO TRANSPORT TRAILEROriginator CALCS. FOR INDEPENDENT REVIEW Date 3/23/94Checker Andy Jansen Date _____

REACTIONS - CONTAINER/STRONGBACK INTO TRANSPORT TRAILER

• FEM OF CONTAIN./STRONGBK WITH SUPPORTS - 2 CONFIGS.

1.) 3 SUPPORTS

2.) 2 " (DELETE MIDDLE SUPPORT)

CONTAINER

CONFIG./LOAD
ESTIMATES FROM
JOHN SISK 3/23/94

68 O.D. x $\frac{5}{16}$ " WALL 64 O.D. x $\frac{1}{2}$ " WALLANNULUS = $1 \frac{1}{16}$ "

→ IGNORE STRONGBACK STIFFNESS

ANSYS INPUT - STIFF BEAMS

$$E = 29 \text{ EG psi} \times 144 \text{ in}^2/\text{ft}^2 = 4176 \text{ EG lb/ft}^2$$

$$A = \text{OUTER + INNER TUBES} = \frac{\pi}{4} (68^2 - 67.375^2) + \frac{\pi}{4} (64^2 - 63^2) = 66.45 + 99.75 = 166.20 \text{ in}^2 = 1.154 \text{ ft}^2$$

$$I = \text{OUTER + INNER TUBES} = \frac{\pi}{64} (68^4 - 67.375^4) + \frac{\pi}{64} (64^4 - 63^4) = 38,058 + 50,278 = 88,336 \text{ in}^4 = 4.260 \text{ ft}^4$$

$$\text{TUBE HT.} = 68" = 5.667'$$

ANALYTICAL CALCULATIONS

PAGE A-83

Page 2 of 2Subject 101-SY: CONTAIN./STRONGBACK - REACTIONS INTO TRANSPORT TRAILEROriginator CALCS. FOR INDEPENDENT REVIEWDate 3/23/94Checker Randy Jensen

Date

53' CONTAINER

$$\left\{ \begin{array}{l} 1000 \text{ lb/ft D.L.} \\ 33 \text{ TONS LEAD SHOT} = \frac{66,000 \text{ lb}}{53'} = 1245.3 \text{ lb/ft.} \\ 210 \text{ lb/ft PUMP LOAD} \end{array} \right.$$

$$2455.3 \text{ lb/ft}$$

STRONGBACK

$$= \frac{30,000 \text{ lb}}{24.67'} = 1216.1 \text{ lb/ft.}$$

2000 lb. CLEVIS WT.

$$w_{S.B.} = 1216.1 \text{ lb/ft}$$

$$28.83' \rightarrow 7000 \text{ lb.}$$

$$52.17' \rightarrow 5000 \text{ lb.}$$

ERECTION
PIVOT PT. PUMP LOADS

$$= 210 \text{ lb/ft}$$

DIST. LL (INCLUDED IN

PT. LOADS - 5000 lb. @ 10" FROM TOP

- 7000 lb @ 24'-2" "

$$\Sigma \text{ REACTIONS} = 2000 + 7000 + 5000 + 1216.1(24.67') + 2455.3(53')$$

$$= 174,132 \text{ lb}$$

RESULTSCASE 1 - 3 SUPPORTS

FEM RESULTS

$$38.02 \text{ K}$$

RECOMMEND
SPEC

$$50 \text{ K} \rightarrow 45 \text{ K}$$

$$97.50 \text{ K}$$

$$120 \text{ K} \rightarrow 110 \text{ K}$$

$$38.6 \text{ K}$$

$$50 \text{ K} \rightarrow 45 \text{ K}$$

CASE 2 - 2 SUPPORTS

FEM RESULTS

$$86.0 \text{ K}$$

RECOMMEND
SPEC

$$110 \text{ K} \rightarrow 100 \text{ K}$$

$$88.13 \text{ K}$$

$$110 \text{ K} \rightarrow 100 \text{ K}$$

A-83

Appendix A

A.6 Yoke Support Stand

WHIC-SD-WM-DA-165

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(4) Building _____ (5) Rev. _____ (6) _____

(8) Originator Theresa Peterson

Date 8/15/94

(9) Checker T W FISHER

Date 8-18-94

- Assumptions: The lifting yoke assembly, containment bag assembly, and blast shield alignment guide assembly is not attached to the support stand. The equipment on the support stand is suspended above ground level. The support stand is not located near any other equipment while in use. Seismic loading is not considered as support stand is for temporary use only.

Safety Class 3

using a $\frac{3}{16}$ partial penetration weld on TS $5 \times 5 \times \frac{1}{4}$
and TS $3 \times 3 \times \frac{1}{4}$

web calculations used a force of 5583.9 lbs over three legs. The Force was then split into its X and Y components. A moment was calculated based on the force acting as a couple on the tube steel. The force of 5583.9 lbs is based on the weight of stand top plate, lifting yoke assembly, bag assembly, and blast shield assembly.

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

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(1) Drawing _____ (2) Doc. No. _____
 (4) Building _____ (5) Rev. _____ (6) _____
 (7) Subject Yoke Support Stand
 (8) Originator J. H. Patterson Date 8/17/94
 (9) Checker T. W. Fisher Date 8-18-94

(10) WELDS

TS 5X5X 1/4 and TS 3X3X 1/4

use force of 5583.9 lbs (top plate + Equipment)
 distribute over 3 legs

$$F = \frac{5583.9 \text{ lbs}}{3} = 1861.3 \text{ lbs}$$

$$F_y = 1980.8 \text{ lbs}$$

$$F_x = 677.5 \text{ lbs}$$

moments on TS 5X5X 1/4

$$M_x = (677.5 \text{ lbs})(2.5 \text{ in}) = 1693.6 \text{ in-lb}$$

$$M_y = (1980.8 \text{ lbs})(2.5 \text{ in}) = 4951.9 \text{ in-lb}$$

moments on TS 3X3X 1/4

$$M_x = (677.5 \text{ lbs})(2.5 \text{ in}) = 1693.6 \text{ in-lb}$$

$$M_y = (1980.8 \text{ lbs})(1.5 \text{ in}) = 2971.1 \text{ in-lb}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____
(4) Building _____ (5) Rev. _____ (6) _____
(7) Subject Yoke Support Stand
(8) Originator Theresa Peterson Date 8/15/94
(9) Checker TW FISHER Date 8-18-94

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WELD CALCULATIONS FOR JOINT:

(10)

TS 5X5 X 1/4

WELD PROPERTIES:

$b = 5$	$d = 5$
$C_y = \frac{b}{2}$	$C_y = 2.5$
$C_z = \frac{d}{2}$	$C_z = 2.5$
$A_w = 2 \cdot (b + d)$	$A_w = 20$
$S_{wy} = b \cdot d + \frac{b^2}{3}$	$S_{wy} = 33.333$
$S_{wz} = b \cdot d + \frac{d^2}{3}$	$S_{wz} = 33.333$
$J_w = \frac{(b + d)^3}{6}$	$J_w = 166.667$

JOINT LOADS:

$F_x = 677.5$	$F_y = 1980.8$	$F_z = 0$
$M_x = 1693.6$	$M_y = 4951.9$	$M_z = 0$

WELD STRESS:

$$f_w = \left[\left(\frac{F_x}{A_w} + \frac{M_y}{S_{wy}} + \frac{M_z}{S_{wz}} \right)^2 + \left(\frac{F_y}{A_w} + \frac{M_x \cdot C_y}{J_w} \right)^2 + \left(\frac{F_z}{A_w} + \frac{M_x \cdot C_z}{J_w} \right)^2 \right]^{0.5}$$

$$f_w = 222.291$$

FILLET WELD SIZE REQUIRED:

$S = 14500$ psi ALLOWABLE WELD STRESS PER CODE B31.1

$$w = \frac{f_w}{0.707 \cdot S}$$

$$w = 0.022$$

INCHES < 3/16 DESIGNED PARTIAL PENETRATION WELD SIZE.

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

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(1) Drawing _____ (2) Doc. No. _____
 (4) Building _____ (5) Rev. _____ (6) _____
 (7) Subject Yoke Support Stand
 (8) Originator Theresa Peterson Date 8/15/94
 (9) Checker TW FISHER Date 8-15-94

WELD CALCULATIONS FOR JOINT:

(10)

TS 3X3 x 1/4

WELD PROPERTIES:

$b=3$	$d=3$
$C_y = \frac{b}{2}$	$C_y = 1.5$
$C_z = \frac{d}{2}$	$C_z = 1.5$
$A_w = 2 \cdot (b + d)$	$A_w = 12$
$S_{wy} = b \cdot d + \frac{b^2}{3}$	$S_{wy} = 12$
$S_{wz} = b \cdot d + \frac{d^2}{3}$	$S_{wz} = 12$
$J_w = \frac{(b + d)^3}{6}$	$J_w = 36$

JOINT LOADS:

$F_x = 677.5$	$F_y = 1980.8$	$F_z = 0$
$M_x = 1693.6$	$M_y = 2971.1$	$M_z = 0$

WELD STRESS:

$$f_w = \left[\left(\frac{F_x}{A_w} + \frac{M_y}{S_{wy}} + \frac{M_z}{S_{wz}} \right)^2 + \left(\frac{F_y}{A_w} + \frac{M_x \cdot C_y}{J_w} \right)^2 + \left(\frac{F_z}{A_w} + \frac{M_x \cdot C_z}{J_w} \right)^2 \right]^{0.5}$$

$$f_w = 391.087$$

FILLET WELD SIZE REQUIRED:

$S = 14500$ psi ALLOWABLE WELD STRESS PER CODE B31.1

$$w = \frac{f_w}{0.707 \cdot S}$$

$$w = 0.038$$

INCHES < 3/16 DESIGNED PARTIAL PENETRATION WELD SIZE.

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____
(4) Building _____ (5) Rev. _____ (6) PAGE A-89
(7) Subject Yoke Support Stand
(8) Originator Thomas J. Stewer Date 7/26/94
(9) Checker TW FISHER Date 8-18-94

(10) Buckling

assume legs have no bracing

$$\frac{KL}{r} = \frac{(1)(17.027\text{ ft})(12\text{ in/ft})}{1.92\text{ in}} = 106.4$$

$$F_a = 12\text{ ksi} \quad \text{AISC 9th ed p. 3-16}$$

load assuming resting on only 3 legs

$$\text{use load} = \frac{5,583.9\text{ lb}}{3} \quad (\text{equipment + top plate})$$

$$A = 4.59\text{ in}^2 \text{ for TS } 5 \times 5 \times \frac{3}{4}$$

$$P = \frac{5,583.9\text{ lb}}{3(4.59\text{ in}^2)} = 405.5\text{ psi} < 12\text{ ksi}$$

∴ bracing is not necessary for buckling

legs ok for buckling

Check for side load Buckling

4ft span TS 3x3x1/4

impact loading of bag + yoke into stand

$$\text{impact wt} = (1.5)(4875\text{ lbs}) = 7312.5\text{ lbs}$$

$$\frac{KL}{r} = \frac{(1)(4\text{ ft})(12\text{ in/ft})}{1.10\text{ in}} = 43.6$$

$$F_a = 18.9\text{ ksi} \quad \text{from AISC Table C-36 p. 3-16}$$

$$A = 2.59\text{ in}^2 \text{ for TS } 3 \times 3 \times \frac{1}{4}$$

$$P = \frac{7312.5\text{ lbs}}{2.59\text{ in}^2} = 2.82\text{ ksi} < 18.9\text{ ksi}$$

stiffeners ok for side load buckling

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____
(4) Building _____ (5) Rev. _____ (6) J. _____
(7) Subject Yoke Support Stand
(8) Originator Howard Peterson Date 7/26/94
(9) Checker TW FISHER Date 8-18-94

PAGE A-90

(10) Weight calculations

$$4-1" \text{ Thick } - 2' \text{ } \phi \text{ PLATES} = 4(1 \text{ in} \times \pi \times 12 \text{ in})^2 (0.284 \text{ lb/in}^3) = 513.9 \text{ lbs}$$

$$\text{Top plate} = (32 \text{ in} \times 78 \text{ in} \times 1 \text{ in} \times 0.284 \text{ lb/in}^3) = 708.9 \text{ lbs}$$

$$4 \text{ legs} = 4(16.85 \text{ ft}) (15.62 \text{ lb/ft}) = 1052.76 \text{ lbs}$$

$$4 \text{ lower bracing} = 4(8 \text{ ft} \times 12.21 \text{ lb/ft}) = 390.72 \text{ lbs}$$

(4x4x 1/4)

$$\text{top plus sign} = (4 \text{ ft} + 3 \text{ ft } 7 \text{ in}) (15.62 \text{ lb/ft}) = 118.45 \text{ lbs}$$

$$\text{Support Stand Wt} = \underline{2784.7 \text{ lbs}}$$

Equipment on Support Stand

Lifting Yoke Crown Assy

Containment Bag Assy

Blast Shield Alignment Guide Assy

Lifting Yoke Assy

$$\text{Equipment Wt} \approx \underline{4,875 \text{ lbs}}$$

Ref. H-2-815378
H-2-815379
H-2-815380
H-2-815381
H-2-815383

$$\text{Total weight of loaded support stand} \approx 7659.7 \text{ lbs}$$

$$\text{assume} = 7675 \text{ lbs}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____
(4) Building _____ (5) Rev. _____ (6) PAGE A-91
(7) Subject Yoke Support Stand
(8) Originator Shirley Peterson Date 7/26/94
(9) Checker TW FISHER Date 8-18-94

(10) Foot print Calc's

$$Wt = 7675 \text{ lbs}$$

$$\# \text{ base plates } A = 4(\pi)(12 \text{ in})^2 = 1809.6 \text{ in}^2$$

$$P = \frac{7675 \text{ lbs}}{1809.6 \text{ in}^2} = 4.24 \text{ psi} = 610.7 \text{ psf}$$

per UBC 1991 p. 590 Table 29B #4

$$F_a = 1500 \text{ psf} > 610.7 \text{ psf}$$

Soil bearing pressure ok

DESIGN CALCULATION

WHC-SD-WM-DA-165

REV. 0

(1) Drawing _____ (2) Doc. No. _____
 (4) Building _____ (5) Rev. _____ (6) _____
 (7) Subject Yoke Support Stand
 (8) Originator Theresa Peterson Date 7/26/94
 (9) Checker T. FISHER Date 8-18-94

PAGE A-92

(10) Wind Load using ASCE 7-88

$$F = q_z G_h C_f A_F \quad \text{Table 4 Other structures p. 10}$$

$$q_z = 0.00256 K_z (IV)^2 \quad \text{Eq. 3 p. 11}$$

$$q_z = 0.00256 (0.87) (1.07 (70 \text{ mph}))^2 = 12.49$$

$$K_z = 0.87 \quad \text{Table 6 Exposure C @ 20 ft p. 12}$$

$$I = 1.07 \quad \text{Table 5 p. 11}$$

$$V = 70 \text{ mph}$$

$$G_h = 1.29 \quad \text{Table 8 Exposure C @ 20 ft p. 15}$$

$$C_f = 0.75 \quad \text{Table 12 Round D } \sqrt{q_z} > 2.5 \quad h/D = 3.67$$

$$A_F = (6 \text{ ft}) (6 \text{ ft}) = 36 \text{ ft}^2$$

$$F = (12.49) (1.29) (0.75) (36 \text{ ft}^2) = 435.2 \text{ lb}$$

WIND VS WEIGHT

$$(435.2 \text{ lb}) (19 \text{ ft}) + X = (7675 \text{ lb}) (6.22 \text{ ft})$$

$$X = 39469.7 \text{ ft-lbs}$$

gravity is sufficient to keep
stand from over turning in 70 mph
wind

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____
(4) Building _____ (5) Rev. _____
(7) Subject YOKE SUPPORT STAND
(8) Originator J. V. EGGER Date 9/15/94
(9) Checker SLA. Huang Date 10/27/94

PAGE A-93

(10)

OBJECTIVE

DETERMINE ADEQUACY OF THE YOKE
SUPPORT STAND DUE TO ECCENTRIC LOAD
OF EQUIPMENT.

ASSUMPTIONS

1. TOTAL WEIGHT OF EQUIPMENT PLACED
AT EXTREME EDGE OF SUPPORT.
2. TOTAL WEIGHT OF EQUIPMENT USED
TO LOAD SINGLE TS 5X5 AND
1" ϕ PIPE.

CONCLUSIONS

1. SUPPORT WILL RESIST OVERTURNING
2. TS 5X5 AND 1" ϕ PIPE MEET
AISC ALLOWABLES

REFERENCES

1. AISC MANUAL OF STEEL CONSTRUCTION
ALLOWABLE STRESS DESIGN, 9th ED.
2. DRAWINGS
H-2-815379
H-2-815381
H-2-83687
H-2-815378

DESIGN CALCULATION

PAGE A-94

(1) Drawing
(2) Doc. No.
(3) Rev.
(4) Building
(5) Subject
(6) Date
(7) Originator
(8) Checker

Assume C.G. of equipment is located
anywhere within the 3' radius of the
physical center of the equipment.

OVERTURNING MOMENT
 $M_o = 435(18) = 7830 \text{ #-FT}$

RESISTING MOMENT
 $M_R = 2500(9/2) + 4900(9/2 - 5.5/2)$

$= 19825 \text{ #}$

$SF = 19825 / 7830 = 2.5 \text{ OK.}$

A-94

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____
(4) Building _____ (5) Rev. _____ (6) J PAGE A-95
(7) Subject YOKE SUPPORT STAND
(8) Originator J. V. EGGER Date 8/15/94
(9) Checker J. J. Hwang Date 10/27/94

(10)

REACTION AT B

$$\sum M_A = 7830 - 19825 + R_B (9)$$

$$R_B = 1333 \#$$

$$R_A = 4900 + 2500 - 1333 = 6067 \#$$

MAY. PRESSURE ON BASE PLATE

$$p_a = \frac{6067}{\frac{\pi (2)^2}{4}} = 1930 \#/\text{ft}^2$$

ALLOWABLE PRESSURE $1500 \left(\frac{4}{3}\right) = 2000 \#/\text{ft}^2$
 $\frac{1}{3}$ INCREASE IN ALLOWABLE FOR WIND

CHECK BENDING STRESS IN $5 \times 5 \times \frac{1}{4}$ " TUBE
WITH 4900# LOAD ON 2'-9" CANTILEVER

$$M = 4900 (33") = 161,700 \#/\text{in}$$

SECTION MODULUS FOR $5 \times 5 \times 0.25$

$$S = 6.78$$

BENDING STRESS

$$f_b = \frac{M}{S} = \frac{161,700}{6.78} = 23849 \#/\text{in}^2$$

(AISC TABLE B5.1)

$$\frac{b}{t} \leq \frac{190}{\sqrt{F_y}}$$

$$5/0.25 = 20 \leq 31.7 \quad \text{OK. COMPACT SECTION}$$

DESIGN CALCULATION

WHC-SD-WM-DA-165
REV. 0

(1) Drawing _____ (2) Doc. No. _____ PAGE A-96
(4) Building _____ (5) Rev. _____ (6) _____
(7) Subject YOKE SUPPORT STEEL
(8) Originator J.V. EGGER Date 8/15/94
(9) Checker D.H. Zhang Date 10/27/94

(10)

$$\frac{76 b_f}{\sqrt{F_y}} = 12.7(5) = 63.5"$$

$$\frac{20,000}{(d/A_s) F_y} = \frac{20,000}{(5/5(6.25)) 36} = 139"$$

$$L_c = 63.5" \quad L_b = 33"$$

$$L_c > L_b \quad (\text{AISC F1.1})$$

$$F_b = 0.66 F_y = 24,000 \text{ psi}$$

$$F_b > f_b \quad \text{OK.}$$

CHECK AXIAL LOAD ON 1" ϕ PIPE

$$P = 4900 \text{ lb}$$

$$A = 0.494$$

$$f_a = \frac{4900}{0.494} = 9,920 \text{ psi}$$

$$K L / r = 126 \quad F_A = 9.87 \text{ ksi (AISC TABLES)}$$

$$\frac{2(L)}{0.421} < 126$$

$$L < 26.5" > 14.5" \quad \text{OK.}$$

Appendix B

Load Chart of the Equipment Removal System for Tank 241SY101.

CHART, 101SY

Appendix C

Finite-Element Analysis Models of the Following Equipment:

Shipping Container,
Strongback
&
Base Clevis

OVERVIEW

All analyses listed on page one of this document were completed using the finite-element analysis (FEA) software COSMOS/M version 1.70 on a Silicon Graphics Incorporated, Indigo. The input and output file for each FEA problem are located on the electronic media accompanying this document. All input files have the .GFM extension while the output files have the .OUT extension.

1. Shipping Container Finite-Element Analysis Models

a. Description of the FEA models SC06 and SC07

The models SC06 and SC07 are of the shipping container in the horizontal and vertical position respectively. Each of the FEA models have three primary load cases and one secondary load case combination. The three primary load cases are: dead weight, pump live load, and wind loading. The secondary load case is used to represent the linear addition of the three primary load cases.

The purpose of the models SC06 and SC07 is to determine the following:

- The maximum and minimum stresses in the inner and outer tubes of the shipping container,
- the maximum and minimum stresses in the shipping container to strongback attachment points,
- and the reaction forces at the four strongback attachment points.

The level of mesh refinement in this FEA model is adequate to determine the maximum and minimum stresses in both the inner and outer $\frac{3}{8}$ in. tube. It is also fine enough to determine the maximum and minimum stresses in the shipping container to strongback attachment points. The reaction force data for both SC06 and SC07 are listed in the Output Data Listing. For an over-all view of the model see the geometry plot on the following page.

SES MOS/M
Version : V1.70
SC06
8-27-94

2. Assumptions made to develop FEA models SC06 and SC07.
 1. The attachment points could be modeled by fixing the translational displacement boundary conditions.
 2. All welds are full length full penetration welds.
 3. The load chart accurately depicts the loading conditions for the shipping container.
3. Stress Plots
 1. Von Mises stress plot of complete SC06 model.
 2. Von Mises stress plot of center attachment points for SC06.
 3. Von Mises stress plot of complete SC07 model.
 4. Von Mises stress plot of center attachment point for SC07.

L1n STRESS Lc=51

Von Mises

GOSMOS/M

Version : V1.70

SC06

8-27-94

Lin STRESS Lc=51

Von Mises

5.99E+03
5.24E+03
4.49E+03
3.75E+03
3.00E+03
2.25E+03
1.50E+03
749.0000
0.000000

COSMOS/M

Version : V1.70

SC06

8-27-94

Lin STRESS Lc=51

COSMOS/M
Version : V1.70
SC07
8-26-94

Lin STRESS Lc=51

Von Mises

4.99E+03
4.37E+03
3.75E+03
3.12E+03
2.50E+03
1.87E+03
1.25E+03
624.0000
0.000000

COSMOS/M
Version : V1.70
SC07
8-26-94

d. Results for the FEA models SC06 and SC07.

The Von Mises stress plots for the models SC06 and SC07 show that the maximum nodal stress level in the inner and outer shells is 8.19 ksi. This stress is a stress concentration due to a point loading at a high load area. The overall maximum bending stress in the shipping container is approximately 5 ksi. The allowable stress for this design is 12 ksi. Based on the stress plots and assumptions the shipping container is adequate to support the maximum bending stress as designed.

The Von Mises Stress plots of the shipping container upper attachment points show that the maximum nodal stress for this section is 5.99 ksi. From these two stress plots and knowing that the maximum allowable stress is 12 ksi, the shipping container connections are adequate as designed.

The maximum reaction forces for this model are listed below in the Output Data Listing. This data is used as force boundary conditions on the strongback FEA models.

e. Output Data Listing

Below is listing of reaction forces from load case 51 for the shipping container FEA models SC06 and SC07.

i. Reaction Forces for SC06.OUT.

Node	Csid	RFX	RFY	RFZ
10262	0	2.687e+04	1.177e+02	-2.761e+03
10265	0	2.705e+04	-5.967e+01	3.064e+03
15314	0	2.452e+04	-	-3.849e+03
15315	0	-	-1.021e+02	6.752e+02
15316	0	-	-	5.463e+03
15330	0	-	-	3.002e+02
15345	0	2.775e+04	-	-4.557e+03
15346	0	-	4.405e+01	6.033e+02
15347	0	-	-	5.829e+03
15365	0	-	-	3.177e+02

ii. Reaction Forces for SC07.OUT.

Node	Csid	RFX	RFY	RFZ
10262	0	2.687e+04	1.177e+02	-2.761e+03
10265	0	2.705e+04	-5.967e+01	3.064e+03

15314	0	2.452e+04	-	-3.849e+03
15315	0	-	-1.021e+02	6.752e+02
15316	0	-	-	5.463e+03
15330	0	-	-	3.002e+02
15345	0	2.775e+04	-	-4.557e+03
15346	0	-	4.405e+01	6.033e+02
15347	0	-	-	5.829e+03
15365	0	-	-	3.177e+02

On the following six pages are plots showing the displacement boundary conditions for both FEA models. The plots are:

- SC06 fixed translational boundary conditions at shipping container base.
Upper SC06 fixed translational boundary conditions on the positive Z-direction side of the FEA model.
Upper SC06 fixed translational boundary conditions on the negative Z-direction side of the FEA model.
- SC07 fixed translational boundary conditions at shipping container base.
Upper SC07 fixed translational boundary conditions on the positive Z-direction side of the FEA model.
Upper SC07 fixed translational boundary conditions on the negative Z-direction side of the FEA model.

COSMOS/M
Version : V1.70
SC06
8-27-94

COSMOS/M
Version : V1.70
SC06
8-27-94

R13

AS 314
AS 315
AS 316
AS 317

R14

COSMOS/M
Version : V1.70
SC06
8-27-94

R15

R16

COSMOS/M
Version : V1.70
SC07
8-27-94

COSMOS/M
Version : V1.70
SC07
8-27-94

R13

45315
45314
45316
45330

R14

COSMOS/M
Version : V1.70
SC07
8-27-94

R15

R16

2. Independent Review Checklist(s) and Software Report Form(s)

CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed Cosmos/M Finite-Element models SC06 and SC07Author B. L. Coverdell

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 94-047S. Burgess *S. Burgess*
Reviewer9/26/94
Date

ENGINEERING ANALYSIS SOFTWARE REPORT FORM

August 25, 1994

DATE ANALYSIS PERFORMED

94-D47

SOFTWARE LOG NUMBER

SOFTWARE APPLICATION: COSMOS/M ver. 1.70 on a Silicon Graphics Incorporated.
Indigo (CEA3).

B. L. Coverdell

9-26-94

B. L. Coverdell, Equipment Stress Analysis, ANALYST DATE

R. B. Pan

10/31/94

R. B. Pan, Equipment Stress Analysis, MANAGER DATE

DESCRIPTION OF ANALYSIS:

This analysis was performed using the finite-element software COSMOS/M version 1.70 on a Silicon Graphics Incorporated, Indigo (CEA3). A static analysis was performed using the SHELL4 element type.

The models SC06 and SC07 are of the shipping container in the horizontal position and vertical position respectively. Each of the FEA models have three primary load cases and one secondary load case combination. The three primary load cases are: dead weight, pump live load, and wind loading. The secondary load case is used to represent the linear addition of the three primary load cases.

The purpose of the models SC06 and SC07 is to determine the reaction forces at the four strongback attachment points. The models were also used to determine the maximum and minimum stress in the inner and outer tubes of the shipping container. It was also used to determine the maximum and minimum stresses in the attachment points of the shipping container to the strongback.

J. S. Burgess

9/26/94

J. S. Burgess, Equipemnt Stress Analysis, REVIEWER

DATE

2. Strongback Finite-Element Models

a. Description of the FEA models SB01C and SB02A.

The two FEA models SB01C and SB02A use the reaction forces developed by the FEA models SC06 and SC07 respectively. Therefore, SB01C represents the strongback loaded in the horizontal position and SB02A represents the strongback loaded in the vertical position. On the following page is an overall view of the FEA model SB01C. This view shows nodal points used to load both FEA models.

The purpose of the two FEA models is to determine the maximum and minimum stress levels in the strongback. The model will also be used to determine the reaction forces at the fixed boundary condition locations. These locations are at the hydraulic beam and base clevis. For an overall view of the FEA model, see the geometry plot on the following page.

Both of the FEA models have two primary load cases: dead weight and live load (the reaction forces from either SC06 or SC07). Each FEA model also has one secondary load case. This secondary load case is the linear combination of the two primary load cases.

b. Assumptions made to develop FEA models SB01C and SB02A.

- i. The reaction forces from the FEA models SC06 and SC07 are correct.
- ii. The base clevis and hydraulic beam clevis are modeled only to load the model.
- iii. All welds are full length full penetration welds.
- iv. The load chart accurately depicts the loading conditions for the strongback.
- v. The hydraulic clevises are modeled only to transfer loads to the strongback.

COSMOS/M
Version : V1.70
SB01C
8-29-94

- c. Stress Plots of FEA models SB01C and SB02A.
 - i. Shell element Von Mises stress plot for SB01C.
 - ii. Beam element Von Mises stress plot for SB01C.
 - iii. Shell element Von Mises stress plot for SB02A.
 - iv. Beam element Von Mises stress plot for SB02A.

Lin STRESS Lc-51

COSMOS/M
Version : V1.70
SB01C
8-25-94

Lin STRESS Lc-51

Von Mises
9.46E+03
7.40E+03
6.34E+03
5.28E+03
4.23E+03
3.17E+03
2.11E+03
1.06E+03
0.000000

COSMOS/M
Version : V1.70
SB02A
8-29-94

Lin STRESS Lc-51

von Mises

3.20E+03
2.87E+03
2.46E+03
2.03E+03
1.64E+03
1.23E+03
0.020.0000
0.010.0000
0.000000

COSMOS/M

Version : V1.70

SB02A

8-29-94

d. Results for the FEA models SB01C and SB02A.

From the Von Mises stress plots of SB01C it can be seen that the maximum stress in the shell elements is 13.0 ksi and the maximum Von Mises stress in the beam elements is 3.84 ksi. The stress in the shell elements is greater than the allowable stress of 12.0 ksi. This high stress occurs in a small area next to a perpendicular set of elements. Since it concerns such a small area and so few elements are involved the strongback is adequate to support the horizontal loading.

The Von Mises stress plots of the strongback in the vertical position (SB02A) show that the maximum stress is 8.46 ksi. This stress is below the allowable stress of 12 ksi. For this reason, the strongback is adequate to support the loads imposed by being positioned vertically.

e. Output Data Listing for SB01C and SB02A.

Below is a listing of the reaction forces from SB01C and SB02A. This data is used as force boundary conditions in other FEA models.

i. Reaction forces from SB01C.OUT.

Node	Csid	RFX	RFY	RFZ
7622	0	-	-1.364e+04	-1.512e+03
7623	0	-	-	-1.648e+02
7624	0	-	-	2.332e+03
7625	0	-	-	3.465e+03
7626	0	-	-	3.708e+03
7627	0	-	-	3.423e+03
7628	0	-	-	1.753e+03
7629	0	-	-	-5.098e+02
7630	0	-	-	-1.569e+03
7631	0	-7.729e+04	-	-2.805e+03
7632	0	-	-	-2.439e+03
7633	0	-	-	-2.398e+03
8014	0	-5.041e+04	-	2.501e+03
8015	0	-	-	3.354e+03
8030	0	-	-	-2.642e+03
8032	0	-	-	-2.540e+03

8033	0	-	-	-1.779e+03
8035	0	-	-1.221e+04	1.324e+03
8036	0	-	-	2.018e+02
8037	0	-	-	2.647e+03
8038	0	-	-	2.364e+03
8039	0	-	-	-4.825e+02
8044	0	-	-	-1.796e+03
8045	0	-	-	-1.354e+03
9888	0	5.194e+04	-	-
10095	0	7.591e+04	-	-

ii. Reaction forces from SB02A.OUT.

Node	Csid	RFX	RFY	RFZ
7622	0	-	1.117e+04	1.461e+03
7623	0	-	-	2.391e+03
7624	0	-	-	2.656e+03
7625	0	-	-	1.734e+03
7626	0	-	-	1.620e+03
7627	0	-	-	-1.067e+03
7628	0	-	-	-2.140e+03
7629	0	-	-	-2.618e+03
7630	0	-	-	-2.283e+03
7631	0	2.944e+04	-	-1.226e+03
7632	0	-	-	-8.346e+02
7633	0	-	-	6.401e+02
8014	0	6.973e+04	-	1.647e+03
8015	0	-	-	3.767e+03
8030	0	-	-	-4.017e+03
8032	0	-	-	-3.092e+03
8033	0	-	-	-9.519e+02
8035	0	-	1.018e+04	3.168e+03
8036	0	-	-	2.010e+03
8037	0	-	-	4.330e+03
8038	0	-	-	1.293e+03
8039	0	-	-	-3.133e+03
8044	0	-	-	-4.170e+03
8045	0	-	-	-4.832e+02
9888	0	-1.320e+04	-	-
10095	0	2.102e+04	-	-

3. Independent Review Checklist(s) and Software Report Form(s)

CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed Cosmos/M Finite-Element models of SB01C and SB02A

Author B. L. Coverdell

<u>Yes</u>	<u>No</u>	<u>N/A</u>	
☒	☐	☐	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. 94-048

J. S. Burgess *JS Burgess*
Reviewer

9/26/94
Date

ENGINEERING ANALYSIS SOFTWARE REPORT FORM

August 29, 1994
DATE ANALYSIS PERFORMED

94-048
SOFTWARE LOG NUMBER

SOFTWARE APPLICATION: COSMOS/M ver. 1.70 on a Silicon Graphics Incorporated.
Indigo (CEA3).

B. L. Coverdell 9-26-94
B. L. Coverdell, Equipment Stress Analysis, ANALYST DATE

R. B. Pan 10/31/94
R. B. Pan, Equipment Stress Analysis, MANAGER DATE

DESCRIPTION OF ANALYSIS:

This analysis was performed using the finite-element software COSMOS/M version 1.70 on a Silicon Graphics Incorporated, Indigo (CEA3). A static analysis was performed using the SHELL4 and BEAM3D element types.

The purpose of the two FEA models is to determine the maximum and minimum stress levels in the strongback. The model will also be used to determine the reaction forces at the fixed boundary condition locations. These locations are at the hydraulic beam and base clevis. For an over-all view of the FEA model, see the geometry plot on the following page.

Both of the FEA models have two primary load cases: dead weight and live load (the reaction forces from either SC06 or SC07). Each FEA model also has one secondary load case. This secondary load case is the linear combination of the two primary load cases.

J. S. Burgess 9/26/94
J. S. Burgess, Component Structural Analysis, REVIEWER DATE

3. BCLEV01 FEA model

a. Description of the FEA model BCLEV01.

The model BCLEV01 was developed to determine the maximum stresses in the base clevis. Reaction force output from both of the strongback FEA models was checked to determine the maximum load on the base clevis. This output is listed on the following two pages. The maximum load on the base clevis was determined to be 80 kips. at 10^0 up from the horizontal. An overall geometry plot of the FEA model is also on the following pages.

The design criteria for this project was stated as a factor of three on the yield stress, resulting in an allowable stress of 12 ksi. As an added factor of safety all live loads were increase by 25%. The design basis wind loading used on this project was determined to be 12 lb/in².

Assumptions made in the development of the FEA model BCLEV01.

- i. The reaction forces from SB01C.OUT and SB02A.OUT are valid.
- ii. All welds are all full length, full penetration welds.
- iii. The X and Y components of the strongback reaction forces could be combined using square root of the sum of the squares.

SB01C 1st set of nodes.

PAGE C-33a

Node	Csid	RFX	RFY	RFZ
7622	0 -		-1.36E+04	-1.51E+03
7623	0 -	-		-1.65E+02
7624	0 -	-		2.33E+03
7625	0 -	-		3.47E+03
7626	0 -	-		3.71E+03
7627	0 -	-		3.42E+03
7628	0 -	-		1.75E+03
7629	0 -	-		-5.10E+02
7630	0 -	-		-1.57E+03
7631	0	-7.73E+04 -		-2.81E+03
7632	0 -	-		-2.44E+03
7633	0 -	-		-2.40E+03
			RFZ summation	3.28E+03

Determine the resultant force and angle in the X-Y plane.

78484 lb.

10 deg.

SB01C 2nd set of nodes.

Node	Csid	RFX	RFY	RFZ
8014	0	-5.04E+04 -		2.50E+03
8015	0 -	-		3.35E+03
8030	0 -	-		-2.64E+03
8032	0 -	-		-2.54E+03
8033	0 -	-		-1.78E+03
8035	0 -		-1.22E+04	1.32E+03
8036	0 -	-		2.02E+02
8037	0 -	-		2.65E+03
8038	0 -	-		2.36E+03
8039	0 -	-		-4.83E+02
8044	0 -	-		-1.80E+03
8045	0 -	-		-1.35E+03
			RFZ summation	1.80E+03

Determine the resultant force and angle in the X-Y plane.

51868 lb.

14 deg.

SB02A 1st set of nodes.

PAGE C-33b

Node	Csid	RFX	RFY	RFZ
7622	0 -		1.12E+04	1.46E+03
7623	0 -	-		2.39E+03
7624	0 -	-		2.66E+03
7625	0 -	-		1.73E+03
7626	0 -	-		1.62E+03
7627	0 -	-		-1.07E+03
7628	0 -	-		-2.14E+03
7629	0 -	-		-2.62E+03
7630	0 -	-		-2.28E+03
7631	0	2.94E+04 -		-1.23E+03
7632	0 -	-		-8.35E+02
7633	0 -	-		6.40E+02
			RFZ summation	3.34E+02

Determine the resultant force and angle in the X-Y plane.

31488 lb.

23 deg.

SB02A 1st set of nodes.

Node	Csid	RFX	RFY	RFZ
8014	0	6.97E+04 -		1.65E+03
8015	0 -	-		3.77E+03
8030	0 -	-		-4.02E+03
8032	0 -	-		-3.09E+03
8033	0 -	-		-9.52E+02
8035	0 -		1.02E+04	3.17E+03
8036	0 -	-		2.01E+03
8037	0 -	-		4.33E+03
8038	0 -	-		1.29E+03
8039	0 -	-		-3.13E+03
8044	0 -	-		-4.17E+03
8045	0 -	-		-4.83E+02
			RFZ summation	3.68E+02

Determine the resultant force and angle in the X-Y plane.

70469 lb.

8 deg.

COSMOS/M
Version : V1.70
BCLEV01
9-26-94

c. Overall stress plot of BCLEV01

c. Results of BLCEV01 FEA model.

From the Von Mises stress plot on the following page it can be seen that the maximum stress in the base clevis is approximately 24 ksi. This stress is significantly above the allowable stress. The maximum stresses are located in two places one of which is around the lug hole the other is at the intersection the lug plate and base plate. The loading around the lug hole is due to the point loading. This loading is unrealistic for stress determination around the lug hole. When the maximum stresses at the intersection of the lug plate and base plate are plotted only four elements are at or above 12 ksi. The lack of high stress elements combined with the conservativeness of the loading shows that the base clevis is adequate for it's intended purpose.

d.. Output Data Listing for BCLEV01

(NONE)

L1n STRESS Lc=1

Von Mises

COSMOS/M
Version: V1.70
BCLEV01
9-26-94

C-37

f. Independent Review Checklist and Software Report Form

CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed Cosmos/M Finite-Element models BCLEV01

Author B. L. Coverdell

<u>Yes</u>	<u>No</u>	<u>N/A</u>	
☒	☐	☐	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 94-049

J. S. Burgess *J. S. Burgess*
Reviewer

7/28/97
Date

ENGINEERING ANALYSIS SOFTWARE REPORT FORM

August 31, 1994

DATE ANALYSIS PERFORMED

94-649

SOFTWARE LOG NUMBER

SOFTWARE APPLICATION: COSMOS/M ver. 1.70 on a Silicon Graphics Incorporated.
Indigo (CEA3).

B. L. Coverdell9-26-94

B. L. Coverdell, Equipment Stress Analysis, ANALYST DATE

R. B. Pan10/31/94

R. B. Pan, Equipment Stress Analysis, MANAGER DATE

DESCRIPTION OF ANALYSIS:

This analysis was performed using the finite-element software COSMOS/M version 1.70 on a Silicon Graphics Incorporated, Indigo (CEA3). A static analysis was performed using the SHELL4T element type.

The model BCLEV01 was developed to determine the maximum stresses in the base clevis. Reaction force output from both of the strongback FEA models was checked to determine the maximum load on the base clevis. From the calculations on the following page it can be seen that the maximum loading is 78,000 lb. at approximately 10^0 up from the horizontal. An over-all geometry plot of the FEA model is also on the following pages.

J. S. Burgess7/26/94.

J. S. Burgess, Equipment Stress Analysis, REVIEWER

DATE

Appendix D

Tape for the COSMOS/M 1.70 Input Files