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7. Abstract

As part of the current Hanford mission of environmental cleanup, various long length equipment must be removed from highly radioactive waste tanks. The removal of equipment will utilize portions of the Equipment Removal System for Project W320 (ERS-W320), specifically the 50 ton hydraulic trailer system. Because the ERS-W320 system was designed to accommodate much heavier equipment it is adequate to support the dead weight of the trough, carriage and related equipment for 241AZ101 pump removal project. However, the ERS-W320 components when combined with the trough and its' related components must also be analyzed for overturning due to wind loads.

Two troughs were designed, one for the 20 in diameter carriage and one for the 36 in. diameter carriage. A proposed 52 in. trough was not designed and, therefore is not included in this document. In order to fit in the ERS-W320 strongback the troughs were design with the same widths. Structurally, the only difference between the two troughs is that more material was removed from the stiffener plates on the 36 in trough. The reduction in stiffener plate material reduces the allowable load. Therefore, only the 36 in. trough was analyzed.

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☒	☐	☐	Data checked for consistency with original source information as applicable.
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James A. Tuck
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Figure 1: Load chart for the 50 ton hydraulic trailer when used with the 36 in. and 20 in troughs. 2

1.0 INTRODUCTION

As part of the current Hanford mission of environmental cleanup, various long length equipment must be removed from highly radioactive waste tanks. The removal of equipment will utilize portions of the Equipment Removal System for Project W320 (ERS-W320), specifically the 50 ton hydraulic trailer system. Because the ERS-W320 system was designed to accommodate much heavier equipment it is adequate to support the dead weight of the trough, carriage and related equipment for the 241AZ101 pump removal project. However, the ERS-W320 components when combined with the trough and its' related components must also be analyzed for overturning due to wind loads.

Two troughs were designed, one for the 20 in. diameter carriage and one for the 36 in. diameter carriage. A proposed 52 in. trough was not designed and, therefore is not included in this document. In order to fit in the ERS-W320 strongback the troughs were design with the same widths. Structurally, the only difference between the two troughs is that more material was removed from the stiffener plates on the 36 in. trough. The reduction in stiffener plate material reduces the allowable load. Therefore, only the 36 in. trough was analyzed.

The scope of this task was to determine the structural adequacy of the 36 in. and 20 in. trough and the combined system of; the 241AZ101 trough, the carriage and the ERS-W320 hydraulic trailer system. Specific elements of this task were:

- Determine design loads.
- Determining the adequacy of structural members to support design loads.
- Evaluate welded connections for code compliance
- Evaluate connections between the trough and the strongback.
- Evaluate ERS-W320 hydraulic trailer system for overturning when combined with the lighter 241AZ101 equipment.
- Determine if coupling will occur between the trough's natural frequency and the excitation frequency due to wind (resonance).
- Evaluate the trough for transportation loads.

This design is in accordance with *Standard Architectural-Civil Design Criteria, Design Loads for Facilities* (DOE-RL 1993a) and is designated safety class 3. The design and fabrication is in accordance with the *Manual of Steel Construction* (AISC, 1989). The welding and weld inspection is in accordance with the *Structural Welding Code for Steel* (AWS 1994). The analysis of the structural components of the 241AZ101 troughs considers dead load and 125% of the live loads. An allowable stress of one-third yield is used for all critical structural components on the basis of requirements in DOE-RL 1993b. Adherence to DOE-RL 1993b is not a code requirement, however, this added factor of safety is appropriate.

2.0 SUMMARY OF RESULTS

The 20 in. and 36 in. trough shown on drawings H-2-83768 (WHC 1995b) and H-2-83769 (WHC 1995c) respectively, were found to be structurally adequate to accommodate the equipment removal efforts. The load chart in figure 1 shows the maximum possible loadings for the 241AZ101 equipment removal system. The allowable stresses were evaluated based on a safety factor of three applied to the yield stress of the material. Descriptions of the finite-element analyses as well as evaluations of the welds are contained in the appendices of this report. The input and output files for this model are archived on a 1/4 in. magnetic tape.

Figure 1: Load chart for the 50 ton hydraulic trailer when used with the 36 in. and 20 in troughs.

3.0 DISCUSSION

The purpose for the 241AZ101 trough is to allow an existing piece of equipment, the 50 ton hydraulic trailer system designed for project ERS-W320, to be used in the removal of smaller pieces of equipment. The trough is designed to maximize the strength to weight ratio by using structural tubing as the main structural members. Where additional strength is required solid bars are used. The analysis was performed using COSMOS/M finite-element analysis software (SRAC 1994) on a Silicon Graphics, Indigo² workstation. A three dimensional model was created using a combination of beam elements and four noded shell elements.

3.1 CONSTRAINTS

The constraints listed below are used to provide physical limitations on the geometry and functionality of the equipment. The **Double Shell Tank Retrieval Projects** group provided a set of functional requirements (see Appendix A). These are used as the following design criteria:

- Each trough must interface with the strongback shown on drawing H-2-83717 (WHC 1994a).
- Each trough must accommodate the loads outlined in the Internal Memo shown in Appendix A (the 52 in. trough design is excluded).

- Both troughs must interface with the 36 in diameter carriage and 20 in carriage shown on drawings H-2-83768 (WHC 1995b) and H-2-83769 (WHC 1995c) respectively.
- The trough must accommodate the installation of equipment during removal activities.

3.2 CRITERIA

The design criteria define the position on the allowable stresses used in the 241AZ101 36 in. and 20 in. trough designs. The troughs are designed to meet the requirements of DOE-RL 1993b, however, this document is vague on the practical application of the allowable stresses for use in analysis and design. DOE-RL 1993b specifies basic allowables of one-third of tensile yield strength only.

So that all design/analysis personnel use a consistent set of limits, the following interpretation of DOE-RL 1993b will be used for the structural analysis of the 241AZ101 troughs. For combined stresses, the AISC 1989 approach will be used (see Chapter H of AISC 1989).

A36 Structural Steel $F_y=36 \text{ kip/in}^2$

Bending (F_b), Tension (F_t) and Axial Compression (F_a - where buckling is not a concern and there are no bending moments):

$$F_b = F_t = F_a = \frac{1}{3}F_y = 12 \text{ kip/in}^2$$

Shear:

$$F_v = 0.4 * F_y / 2 = 7.2 \text{ kip/in}^2$$

Bearing:

$$F_p = \frac{1}{3}F_y = 12 \text{ kip/in}^2$$

A500 Structural Tubing $F_y=42 \text{ kip/in}^2$

Bending (F_b), Tension (F_t) and Axial Compression (F_a - where buckling is not a concern and there are no bending moments):

$$F_b = F_t = F_a = \frac{1}{3}F_y = 14 \text{ kip/in}^2$$

Shear:

$$F_v = 0.4 * F_y / 2 = 8.4 \text{ kip/in}^2$$

Bearing:

$$F_p = \frac{1}{3}F_y = 14 \text{ kip/in}^2$$

Connections

Note: The bolting of the trough to the strongback shall be performed in accordance with WHC-SD-W320-DA-003 (WHC 1994b).

Note: The bolting of the carriage to the trough shall be performed in accordance with WHC-SD-TP-ANAL-005 (WHC 1995d).

Bolts: Use AISC 1989 allowables divided by 2

Welds: 7.2 kip/in² on effective area for A36 material and 8.4 kip/in² on effective area for A500 tube steel (effective area = effective throat times the weld length)
Special case for fillet welds on A36 material only - check stress on the weld leg, not the weld throat (do not use the 0.707 factor to determine throat area).

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. Also, selecting allowables that are conservative is acceptable for the 241AZ101 pump removal project because it is new design; changes can be incorporated easily at the design stage.
- 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 used as the basis for structural steel allowables; instead, the allowables were developed exclusively 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. 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.

3.3 GEOMETRY

In order to achieve the best strength to weight ratio, AISC structural shapes in combination with stiffener plates located at regular intervals along the length of the trough were used. Several different sizes of either angle, structural tubing and bar are used to provide the needed strength (see drawings WHC 1995b and WHC 1995c). Structural tubing was used in most places, however, solid bars were used in areas of anticipated high stress. In the analysis the angle shapes and the two 2 1/2 x 1 1/2 x 3/16 in. tube steel back to back were also considered a structural component of the trough. This was done to ensure that they would be adequate supports for the carriage.

3.4 FINITE-ELEMENT MODEL

The finite-element model was generated using the finite-element code COSMOS/M. The name of the finite-element model generated is AZTR_BLC11B. This model uses two major element types; the four noded SHELL4T element and the three noded BEAM3D element. A linear elastic analysis was performed on the structure using the load cases and load cases combinations listed in Section 3.4.7.

3.4.1 DEAD WEIGHT

The dead weight of the trough in the horizontal and vertical position was determined by applying a gravitational acceleration in the global negative Y direction and the global negative X direction respectively. When the trough is in the horizontal position the reaction of the strongback on the trough is significant. The strongback tends to "open" the trough while the trough resists and has the tendency to act in the opposite direction, "closing". To model this effect, an existing FEA model of the strongback was used. The model was modified by placing a small beam between the two upper trough attachment points and applying the reaction forces from the strongback to the trough. After the FEA model was run for solution, the tensile stress in the added beam was determined. The forces induced in the beam was incorporated into the trough model as part of the dead weight load to simulate the opening of the strongback.

3.4.2 LIVE LOADS

Two live loads were considered; 1) The combination of a 4,200 lbf uniform load distributed over the length of the trough and a 2,000 lbf point load applied at the top end of the trough. 2) A 5,000 lbf point load applied at the top end of the trough.

The combination of the 4,200 lbf distributed load and the 2,000 lbf point load represents the weight of the 36 in. carriage, bagging, rigging and any extra equipment (see Appendix A). The 5,000 lbf point load at the top end of the trough represents the equivalent loading of a 4,200 lbf uniform load plus the 2,000 lbf point load at the top end of the trough. It is also used to represent the maximum rated point load of 4,000 lb at the top end of the trough. A 125% impact factor is used ($1.25 \times 4,000 \text{ lb} = 5,000 \text{ lbf}$) to verify that the trough is load tested for 5,000 lbf resulting in a 4,000 lbf load rating.

3.4.3 WIND LOAD

The most conservative method for calculating the wind load pressure distribution is to use the surface area of the carriage device. The calculations for determining the linear pressure load to apply to the FEA model are shown in Appendix B. From ASCE 1993, the minimum wind pressure loading was determined to be 10 lbf/ft². A linear pressure loading of 2.5 lbf/in was calculated and applied to the FEA model in two load cases over the entire 770.5 in. length of the trough. The first location was on the lower chord of the trough and the second location was on one of the upper chords of the trough.

3.4.4 SNOW LOAD

Since the trough and related equipment are not to be used during snow conditions, snow loading was not considered in this analysis.

3.4.5 SEISMIC LOAD

Seismic loads are not considered for the trough supporting the 36 in. carriage, its related equipment and the bag and rigging (see Appendix A) in the horizontal position. The reason for this is

that the 1.5g transportation load will govern. In the vertical position seismic loads are not considered due to the short period that the trough and related equipment will be vertical.

3.4.6 TRANSPORTATION LOAD

For transportation, the *Code of Federal Regulations* (DOT 1989) requires that a 1.5g acceleration be considered in the vertical, lateral and longitudinal directions. This load is applied to the horizontal trough and it will not be combined with any other loads, since, the trough is transported empty. Another consideration is that the horizontal trough is supported in three places; the lower strongback attachment point, the upper strongback attachment point and the top of the trough itself. However, in the FEA only the attachments to the strongback are modelled. This is conservative.

3.4.7 LOAD CASES AND LOAD CASE COMBINATIONS

ASCE 1993 specifies that structural steel equipment be checked for adequacy by applying several loads and load combinations. It was determined that the most conservative load case for both the horizontal and vertical load case is dead load + live load + wind (DL+LL+W). Below is a list of load cases and load case combination input into the FEA model AZTR_BLC11B:

- Load Case 1 Dead load of the horizontal trough represented by a -386.4 ft/s^2 acceleration in the global Y direction.
- Load Case 2 A 4,200 lb uniform live load represented by a line pressure of 5.45 lb/in. over the 770.5 in. length of the horizontal trough.
- Load Case 3 A 4,200 lb uniform live load represented by eleven 382 lb forces placed at equal intervals along the length of the horizontal trough (used to verify the results of Load Case 2).
- Load Case 4 A 2,000 lb vertical point load on the tip of the horizontal trough.
- Load Case 5 A 5,000 lb vertical point load on the tip of the horizontal trough
- Load Case 6 This is a 2.5 lb/in. line load used to represent wind on the 770.5 in. length of the lower chord of the trough.
- Load Case 7 This is a 2.5 lb/in. line load used to represent wind on the 770.5 in. length of the upper chord of the trough.
- Load Case 8 Dead load of the vertical trough represented by a -386.4 ft/s^2 acceleration in the global X direction.
- Load Case 9 Three 1,667 lb forces were used to represent the vertical load on the trough due to the test weight.
- Load Case 10 A 1.5g lateral acceleration used to represent a transportation load.
- Combination 51 Load Case 1 + Load Case 2 + Load Case 4 (dead load of trough + live load due to carriage + equipment load).
- Combination 52 Load Case 1 + Load Case 3 + Load Case 4 (dead load of trough + live load due to carriage + equipment load).
- Combination 53 Load Case 1 + Load Case 5 + Load Case 6 (dead load of trough + test weight live load + wind load on lower chord of trough).
- Combination 54 Load Case 1 + Load Case 5 + Load Case 7 (dead load of trough + test weight live load + wind load on upper chord of trough).
- Combination 55 Load Case 8 + Load Case 9 + Load Case 7 (dead load of trough + test weight live load + wind load on upper chord of trough all).

3.5 OVERTURNING

Wind on the vertical trough and carriage will result in an overturning moment. The overturning moment is resisted by the weight of the trailer, strongback, trough, carriage, bag, rigging and various other equipment. Since, the weight of the trough and its' associated equipment is significantly less than that of the ERS-W320 shipping container and mixer pump, the possibility of overturning was analyzed and is shown in Appendix F.

3.6 NATURAL FREQUENCY DETERMINATION

The trough was analyzed to determine if coupling of the natural frequency and an excitation frequency (resonance) could occur. The natural frequency of the trough was determined to be 4.15 hz (see Appendix G). The natural frequency was determined by creating a FEA model of the trough loaded with the 5,000 lb test weight. The test weight was included in the model and represented by a 5,000 lb mass. The ERS-W320 hydraulic trailer system has a 20 hz frequency design. This frequency is significantly high enough that it will not effect the frequency of the trough. For this reason, the boundary conditions modelling the trough attachment points to the strongback were modeled as fixed.

3.7 EXCITATION FREQUENCY

Since resonance is being investigated in the trough structure, an induced vibration was determined. Vortex shedding due to a 15 mph wind¹ was determined to cause the only induced vibration in the trough. Vortex shedding is the periodic change in side pressure on a shape due to wind. When the sparse frame of the trough is compared to the large cylindrical shape of the carriage, the carriage will cause worse vortex shedding. For this reason, the carriage was considered as the only device causing vortex shedding.

For the given Reynolds number, an upper and lower bound exist for the excitation frequency (see Blevins 1977). Appendix G contains the hand calculations showing the range of the excitation frequency to be 1.8 hz to 2.8 hz.

4.0 RESULTS AND CONCLUSIONS

The results of this analysis show that the trough is structurally adequate for the equipment removal conditions evaluated. The input and output files for this model are backed up on the attached ¼ in. magnetic tape.

4.1 TROUGH STRUCTURAL MEMBERS

The structural members forming the trough are; structural tubing, bars, angle and stiffening plates located at intervals along the length of the trough. The first six von Mises stress plots in

¹ Tank Farms only operates in winds gusting to 15 mph or less.

Appendix C are of the beam shapes comprising the trough. The maximum stress from these first six plots is 13,300 lbf/in². This stress is in excess of the allowables described in Section 3.2., however, an AISC code evaluation on these beams shows that they are adequate to withstand the applied load combinations (see Section 4.2 and Appendix D). The remaining seven maximum von Mises stress plots in Appendix C are of the stiffeners and other plate members comprising the trough. The maximum stress from the remaining plots is 15,200 lbf/in² from load case 55. In this load case the maximum von Mises stress appears in the top stiffener plate of the trough when the trough is in the vertical position. This stress exceeds the allowable, however, it is due to the simplified way in which the 5,000 lbf test load was modeled. For this reason, the maximum stress in the top plate is discounted, resulting in a maximum stress of 4,590 lbf/in². This is well below the allowable stress of 12,000 lbf/in² (see the final stress plot in Appendix C).

4.2 AISC CODE EVALUATION

An AISC code evaluation was performed on all tube steel, bar, and angle members to determine their adequacy for bending, shear, axial tension, axial compression and stress interaction (see Appendix D). Bending, shear and axial tension stresses were determined using the proper forces and/or moments from the FEA model. Axial compression was determined by calculating the effective length ($k \cdot l/r$) and using tables within AISC 1989. Adequacy to resist stress interaction was determined using the interaction equation (see Chapter H of AISC 1989). All beams were determined to be adequate to the resultant stresses and interaction of stresses per AISC criteria.

4.3 WELD CONNECTION EVALUATION

The welds were sized and analyzed in accordance with the requirements of AWS D1.1 including Section 9. Using a spreadsheet developed in *Quattro Pro* (Borland 1994), each of the stress components (P/A, Ms/Ss, Mt/St) for each of the welded joints were input into the spreadsheet and a margin of safety calculated for each of the welds. The welds are appropriately sized and structurally adequate. The output for this spreadsheet can be found in Appendix E.

4.4 OVERTURNING ANALYSIS

The analysis in Appendix F determined that the ERS-W320 equipment when combined with the lighter, trough, carriage and related equipment in the vertical position will adequately resist an overturning moment due to 10 lb/ft² wind load.

4.5 FREQUENCY ANALYSIS

Comparison of the excitation frequency (1.8 to 2.8 hz) to the natural frequency (4.2 hz), shows that there will be no coupling of the two frequencies and, therefore, resonance will not occur.

4.6 TRANSPORTATION ANALYSIS

The trough is adequate to support its own dead weight during transportation as determined by load case 10 of the FEA.

4.7 BOLTED CONNECTION ANALYSIS

Comparison of the 25,000 lbf ERS-W320 design connection load (WHC 1995a, Page A-52) to the resultant reaction forces, from the FEA (Appendix I), shows that the four A325 bolts (ASTM 1995c) are adequate to connect the troughs to the ERS-W320 strongback.

Attachment of the carriage to the trough is described, analyzed and detailed in WHC 1995d. Also, the trough $\frac{3}{4}$ in. top plate is analyzed to determine its adequacy for connecting the carriage and trough assemblies.

5.0 REQUIREMENTS

Several requirements must be met for the combination of the ERS-W320 components to be safely used in conjunction with the 241AZ101 removal equipment. These requirements are:

- 15 mph is the maximum wind speed allowed when the 241AZ101 removal equipment is in the vertical position.
- The loads are not to exceed those specified on the load chart shown in Figure 1.
- The bolting sequence for attaching the trough to the strongback shall be performed similarly to the bolting sequence for attaching the 241C106 shipping container to the strongback (WHC 1994b).
- The maximum carriage wheel load is 2,100 lb per the calculations in Appendix H.
- Attachment of the troughs to the ERS-W320 strongback must be completed using four A325 structural steel bolts.
- The carriage must be bolted to the trough as specified in WHC 1995d.

6.0 REFERENCES

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- SRAC, 1994, *COSMOS/M*, Version 1.71, Structural Research and Analysis Corporations, Santa Monica, California. Note: *COSMOS/M* is a trademark of Structural Research and Analysis Corporation.
- Troitsky, M. S., 1982, *Tubular Steel Structures - Theory and Design*, James F. Lincoln Arc Welding Foundation, Cleveland, Ohio.
- UCRL-1990, *Design and Evaluation Guidelines for U.S. Department of Energy Facilities Subjected to Natural Phenomena Hazards*, UCRL-15910, University of California Research Laboratory, Livermore, California.

WHC, 1994a, *STRONGBACK*, drawing H-2-83717 Rev. 0, Sht. 1-13, Westinghouse Hanford Company, Richland, Washington.

WHC, 1994b, *Bolting Sequence for Attaching the Container to the Strongback*, WHC-SD-W320-DA-003, Westinghouse Hanford Company, Richland, Washington.

WHC, 1995a, *Structural Analysis of the Equipment Removal System for Tanks 241C106 and 241AY102*, WHC-SD-W320-DA-001, Westinghouse Hanford Company, Richland, Washington.

WHC, 1995b, *TROUGH ASSEMBLY 36 IN DIA X 64 FT LONG*, drawing H-2-83768 Rev. 0, Sht. 1-9, Westinghouse Hanford Company, Richland, Washington.

WHC, 1995c, *TROUGH ASSEMBLY 20 IN DIA X 64 FT LONG*, drawing H-2-83769 Rev. 0, Sht. 1-9, Westinghouse Hanford Company, Richland, Washington.

WHC, 1995d, *241AZ101 20 in. and 36 in. Carriage Assembly Analysis*, WHC-SD-TP-ANAL-005, Westinghouse Hanford Company, Richland, Washington.

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Appendix A: Internal Memo from DST Retrieval Projects to T. C. Mackey

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**Westinghouse
Hanford Company**

**Internal
Memo**

From: DST Retrieval Projects 7F520-MEM-94-09
Phone: 372-2682 R3-27
Date: November 29, 1994
Subject: PROJECT W-151, "TANK 101-AZ WASTE RETRIEVAL SYSTEM," REMOVAL
EQUIPMENT, TROUGH RE-DESIGN

To: T. C. Mackey

cc:	R. E. Clayton	R3-27	R. B. Pan	H5-53
	S. R. Crow	G2-03	J. E. Van Beek	R3-27
	K. D. Junt	S2-01	W-151 File	R3-27
	R. N. Kyle	S2-01	Project File	R1-28
	M. E. McKinney	R3-27	MEM File/LB	R3-27
	E. M. Nordquist	R3-27		

DST Retrieval Projects requests the services of Westinghouse Hanford Company (WHC) Structural to re-design the trough assemblies for the 20", 36", and 52" removal equipment systems.

SCOPE

The trough re-design shall proceed from the conceptualized approach and provide two troughs (20" and 36") which can be utilized with the Project W-320 tilt trailer and a 52" trough which can be used with the 101-SY tilt trailer. The troughs shall be designed to meet the following minimum load requirements:

SIZE	CARRIAGE WT.	EQUIPMENT WT.	BAG & RIGGING WT.	TOTAL
20"	2100 lbs	500 lbs	400 lbs	3000 lbs
36"	3700 lbs	2000 lbs	500 lbs	6200 lbs
52"	5600 lbs	14500 lbs	600 lbs	20700 lbs

WHC Structural is authorized to provide a trough design with increased load carrying capacity (closer to the maximum loads of the tilt trailer) provided the design is consistent with the conceptual approach (design of structure and type of material) and cost impacts are minimal.

WHC Structural shall provide a complete re-design of the trough assemblies. The re-design shall be documented with an Engineering Change Notice (ECN) and be a complete revision to the existing drawings. WHC Structural shall utilize the existing drawing numbers for the troughs.

SCHEDULE

WHC Structural is requested to initiate re-design of the trough assembly upon receipt of this letter. The trough re-design shall be split into two phases. The first phase shall provide the designs for the 20" and 36" troughs. The first phase re-design shall be completed by January 20, 1995

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Appendix B: Wind Load Calculations

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DESIGN ANALYSIS

Calc. No. _____

Revision 0

Page No. 1 of _____

Client: Westinghouse Hanford Company

Subject: 241AZ Truss Wind Analysis

Location: 200 E /

WO/Job No. C01909

Date: 06/28/95

Checked: 9/29/95

Revised:

By: B. L. Coverdell

By: [Signature]

By: [Signature]

PURPOSE:

Determine the effective wind load that on the AZ truss given that this is safety class 3 equipment.

ASSUMPTIONS:

All wind loading will be transmitted to the AZ truss via the 64 ft carriage.

DESCRIPTION:

Two load cases must be considered when analyzing the AZ truss; the truss in the lowered position and in then in the upright position

NOTE: The AZ truss has very little cross-sectional area, however, when the 64 ft carriage is in place it has a significant cross-section. The cross-sectional area of the 64 ft carriage will be used to determine the wind loading and that loading will be applied to the truss.

WIND CALCULATIONS FOR AZ TRUSS IN LOWER POSITION

Exposure category is C from DOE-RL 1993, Page 11.

$I = 1.07$ Importance factor from DOE-RL 1993, Page 11.

$V = 70 \text{ mph}$ Fastest wind speed from DOE-RL 1993, Page 11.

$K_z = 0.8$ Velocity pressure exposure coefficient from ASCE 7-93, Table 6, Page 12.

$q_z = 0.00256 \cdot \frac{\text{lb} \cdot \text{sec}^2}{\text{ft}^4} \cdot K_z \cdot (I \cdot V)^2$ $q_z = 24.715 \cdot \frac{\text{lb} \cdot \text{ft}}{\text{ft}^2}$ The velocity pressure from ASCE 1993, Page 11, Equation 3.

$G_h = 1.32$ Gust response factor from ASCE 7-93, Table 8, Page 15.

$h = 64 \text{ ft}$ $D = 3 \text{ ft}$ Respective height and length of the 64 ft carriage.

$\frac{h}{D} = 21.333$ Used to determine C_f in ASCE 1993, Table 12, Page 21.

$C_f = 1.2$ Force coefficient from ASCE 1993, Table 12, Page 21. NOTE: this value is conservative.

$A_f = h \cdot D$ $A_f = 192 \cdot \text{ft}^2$ Cross-sectional area of the carriage.

$F = q_z \cdot G_h \cdot C_f \cdot A_f$ $F = 7516 \cdot \text{lb} \cdot \text{ft}$ Wind load to be applied to the AZ truss.

$p_z = \text{if} \left(\frac{F}{h \cdot D} < 10 \cdot \frac{\text{lb} \cdot \text{ft}}{\text{ft}^2}, 10 \cdot \frac{\text{lb} \cdot \text{ft}}{\text{ft}^2}, \frac{F}{h \cdot D} \right)$ $p_z = 39.148 \cdot \frac{\text{lb} \cdot \text{ft}}{\text{ft}^2}$ If pressure less than $10 \text{ lb} \cdot \text{ft} / \text{ft}^2$ use $10 \text{ lb} \cdot \text{ft} / \text{ft}^2$ else use calculated pressure (ASCE 1993, Page 9, 6.4.2.1).

$P_l = p_z \cdot D$ $P_l = 9.79 \cdot \frac{\text{lb} \cdot \text{ft}}{\text{in}}$ The load per length of carriage. For use in the finite-element model.

WIND CALCULATIONS FOR AZ TRUSS IN UPRIGHT POSITION

Exposure category is C from DOE-RL 1993, Page 13.

$I = 1.07$ Importance factor from DOE-RL 1993, Page 13.

$V = 15 \text{ mph}$ Fastest operational wind speed with in Tank Farms. It should be noted that this is winds gusting to speed, not a continuous wind speed (conservative).

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DESIGN ANALYSIS

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Revision 0
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Client: Westinghouse Hanford Company
Subject: 241AZ Truss Wind Analysis
Location: 200 E /

WO/Job No. C01909
Date: 06/28/95
Checked: 9/29/95
Revised: _____

By: B. L. Coverdell
By: [Signature]
By: _____

$K_z = 1.24$ Velocity pressure exposure coefficient from ASCE 7-93, Table 6, Page 12.

$q_z = 0.00256 \cdot \frac{\text{lbf} \cdot \text{sec}^2}{\text{ft}^4} \cdot K_z \cdot (1 \cdot V)^2$ $q_z = 1.759 \cdot \frac{\text{lbf}}{\text{ft}^2}$ The velocity pressure from ASCE 1993, Page 11, Equation 3.

$G_h = 1.19$ Gust response factor from ASCE 7-93, Table 8, Page 15.

$h = 64 \cdot \text{ft}$ $D = 3 \cdot \text{ft}$ Respective height and length of the 64 ft carriage.

$\frac{h}{D} = 21.333$ Used to determine C_f in ASCE 1993, Table 12, Page 21.

$C_f = 1.2$ Force coefficient from ASCE 1993, Table 12, Page 21. NOTE: this value is conservative.

$A_f = h \cdot D$ $A_f = 192 \cdot \text{ft}^2$ Cross-sectional area of the carriage.

$F = q_z \cdot G_h \cdot C_f \cdot A_f$ $F = 482 \cdot \text{lbf}$ Wind load to be applied to the AZ truss.

$p_z = \text{if} \left(\frac{F}{h \cdot D} < 10 \cdot \frac{\text{lbf}}{\text{ft}^2}, 10 \cdot \frac{\text{lbf}}{\text{ft}^2}, \frac{F}{h \cdot D} \right)$ $p_z = 10 \cdot \frac{\text{lbf}}{\text{ft}^2}$ If pressure less than 10 lbf/ft² use 10 lbf/ft² else use calculated pressure (ASCE 1993, Page 9, 6.4.2.1).

$P_l = p_z \cdot D$ $P_l = 2.5 \cdot \frac{\text{lbf}}{\text{in}}$ The load per length of carriage. For use in the finite-element model.

REFERENCES:

ASCE 1993, *Minimum Design Loads for Buildings and Other Structures*, Revision 7-93, American Society of Civil Engineers, New York, New York.

DOE-RL 1993, *Standard Arch-Civil Design Criteria*, DOE-RL-SDC 4.1 Revision 12, Westinghouse Hanford Company, Richland, Washington.

Appendix C: Finite-Element Analysis of 36 in. Trough

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Maximum Von Mises Stress Plot Of Beam Members Only For
Load Case 10

Maximum Von Mises Stress Plot Of Beam Members Only For
Load Case 51

Lin STRESS Lc-52

Von Mises

1.05E+04
9.25E+03
7.35E+03
5.51E+03
5.20E+03
3.86E+03
2.64E+03
1.32E+03
0.000000

COSMOS/M

Version : V1.71

AZTR_BLC11B

8-29-95

Maximum Von Mises Stress Plot Of Beam Members Only For
Load Case 52

Maximum Von Mises Stress Plot Of Beam Members Only For
Load Case 53

Lin STRESS LC=55

Von Mises
9.21E+03
0.00E+03
0.01E+03
0.75E+03
4.60E+03
3.45E+03
2.30E+03
1.15E+03
0.000000

COSMOS/M
Version : V1.71
AZTR BLC11B
8-29-95

Maximum Von Mises Stress Plot Of Beam Members Only For
Load Case 55

Maximum Von Mises Stress Plot Of Plate Members Only For
Load Case 10

Maximum Von Mises Stress Plot Of Plate Members Only For
Load Case 51

Maximum Von Mises Stress Plot of Plate Members Only For
Load Case 52

Maximum Von Mises Stress Plot Of Plate Members Only For
Load Case 53

Maximum Von Mises Stress Plot Of Plate Members Only For
Load Case 54

Maximum Von Mises Stress Plot Of Plate Members Only For
Load Case 55

Maximum Von Mises Stress Plot Of Plate Members Only For
Load Case 55 (Top Plate Removed)

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Appendix D: AISC Code Check

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ICF KAISER**HANFORD COMPANY****DESIGN ANALYSIS**

Calc. No. _____

Revision 0Page No. 1 ofClient: Westinghouse Hanford CompanyWO/Job No. C01909By: B. L. CoverdellBy: [Signature]By: [Signature]Subject: 241AZ Truss Buckling AnalysisDate: 06/28/95Checked: 7/19/95

Revised: _____

Location: 200 E /**PURPOSE:**

The calculations below determine the structural adequacy of the AISC shapes (AISC 1989) used in the construction of the 241AZ Truss.

ASSUMPTIONS:

$k = 1$ This value of k is conservative for this application (AISC 1989, Table C-C2.1). All columns are fixed at either end.

All forces and moments are taken from the finite-element model AZTR_BLC11B, (SRAC 1994). See the attached sheet listing the forces and moments. Due to the inability of the computer program to show whether the maximum axial force is compression or tension, it was assumed to be compressive. This is conservative.

$E = 30 \cdot 10^6 \text{ psi}$ The modulus of elasticity for all structural steel in this analysis.

$F_{y \text{ ts}} = 46000 \text{ psi}$ Yield stress for all structural tubing (ASTM A500, Gr. B).

$F_y = 36000 \text{ psi}$ Yield stress for all other sections (ASTM A36).

These calculations do not consider torsional buckling.

For simplicity, all sections are considered to be non-compact. This is conservative.

DESCRIPTION:

The actual axial forces and bending moments are taken from the finite-element model AZTR_BLC11B (SRAC 1993) and are used to determine the actual axial, shear and bending stress. The allowable stresses are then determined and compared to the actual stresses. All the stresses are then used in an interaction equation from AISC 1989.

CALCULATIONS:

TS 6" x 6" x 3/8" Real Constant #1 in the finite-element model

Properties of structural shape.

$S = 13.9 \text{ in}^3$ section modulus

$r_x = 2.27 \text{ in}$ radius of gyration about the x axis

$r_y = r_x$ radius of gyration about the y axis (square shape)

$l = 69.25 \text{ in}$ maximum column length

$A = 8.08 \text{ in}^2$ cross sectional area

Determine the allowable stresses on the beam.

$k \cdot l = 5.771 \text{ ft}$ effective length

$P_a = 201 \cdot 10^3 \text{ lbf}$ The allowable axial compressive load from AISC, 1989, page 3-42 using 6 for kl (no interpolation).

$F_a = \frac{P_a}{A}$ $F_a = 24876.238 \text{ psi}$ Allowable axial compressive stress of the column.

$F_v = 0.4 \cdot F_{y \text{ ts}}$ $F_v = 18400 \text{ psi}$ Allowable shear stress per AISC 1989, Page 5-49, F4-1.

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DESIGN ANALYSIS

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Client: Westinghouse Hanford Company

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By: B. L. Coverdell

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By: _____

$$F_{bx} = 0.60 \cdot F_y$$

$$F_{bx} = 27600 \text{ psi}$$

Allowable bending stress per AISC 1989, Page 5-48, F3-3.

$$F_{by} = F_{bx}$$

Conservative to use a value of 0.6 for bending about both axis.

Determine the actual shear, axial and bending stresses in the shape and compare them with the allowables.

Axial forces and bending moments on the beam. Determined from the finite-element model AZTR_BLC11B, SRAC, 1993.

$$F_r = 76444.9 \text{ lbf}$$

$$V_s = 1597.9 \text{ lbf}$$

$$V_t = 1665.2 \text{ lbf}$$

$$M_s = 26969 \text{ lbf-in}$$

$$M_t = 26093.7 \text{ lbf-in}$$

$$f_a = \frac{F_r}{A}$$

$$f_a = 9461.002 \text{ psi}$$

Maximum compressive stress in the beam.

$$f_v = \frac{\sqrt{V_s^2 + V_t^2}}{A}$$

$$f_v = 285.625 \text{ psi}$$

Maximum shear stress in the beam.

$$f_{bx} = \frac{M_t}{S}$$

$$f_{bx} = 1877.245 \text{ psi}$$

Maximum bending stress about major axis of beam.

$$f_{by} = \frac{M_s}{S}$$

$$f_{by} = 1940.216 \text{ psi}$$

Maximum bending stress about major axis of beam.

$$x = f_a \leq F_a$$

$$x = 1$$

$$x = f_v \leq F_v$$

$$x = 1$$

$$x = f_{bx} \leq F_{bx}$$

$$x = 1$$

$$x = f_{by} \leq F_{by}$$

$$x = 1$$

Since all the resultants equal 1 or true then the actual stresses are less than the allowables and, therefore, this section of calculations is adequate per AISC 1989.

Check interaction equation for compression.

$$\frac{f_a}{F_a} = 0.38$$

Since the resultant is greater than 0.15, use the equation H1-1 per AISC 1989, page 5-54.

$$F'_{ex} = \frac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\frac{k \cdot l}{r_x} \right)^2}$$

$$F'_{ex} = 165991.775 \text{ psi}$$

Euler stress for x axis bending divided by a factor of safety per AISC, page 5-54.

$$F'_{ey} = \frac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\frac{k \cdot l}{r_y} \right)^2}$$

$$F'_{ey} = 165991.775 \text{ psi}$$

Euler stress for y axis bending divided by a factor of safety per AISC, page 5-54.

$$C_{mx} = 0.85$$

Compression coefficient. Determined from AISC, page 5-55.

$$C_{my} = C_{mx}$$

Compression coefficient. Determined from AISC, page 5-55.

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Client: Westinghouse Hanford CompanySubject: 241AZ Truss Buckling AnalysisLocation: 200 E /

DESIGN ANALYSIS

WO/Job No. C01909Date: 06/28/95Checked: 7/19/95

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$$\frac{f_a}{F_a} + \frac{C_{mx} \cdot f_{bx}}{\left(1 - \frac{f_a}{F_{ex}}\right) \cdot F_{bx}} + \frac{C_{my} \cdot f_{by}}{\left(1 - \frac{f_a}{F_{ey}}\right) \cdot F_{by}} = 0.505$$

Since the resultant is less than or equal to 1, the beam is adequate to support the load per AISC 1989.

TS 4" x 4" x 3/8" Real Constant #2 in the finite-element model

Properties of structural shape.

$S = 5.35 \cdot \text{in}^3$ section modulus
 $r_x = 1.45 \cdot \text{in}$ radius of gyration about x axis.
 $r_y = r_x$ radius of gyration about y axis.
 $l = 69.25 \cdot \text{in}$ maximum column length
 $A = 5.08 \cdot \text{in}^2$ cross sectional area

Determine the allowable stresses on the beam.

$k \cdot l = 5.771 \cdot \text{ft}$ effective length
 $P_a = 115 \cdot 10^3 \cdot \text{lbf}$ The allowable axial compressive load from AISC, 1989, page 3-42 using 6 for kl (no interpolation).
 $F_a = \frac{P_a}{A}$ $F_a = 22637.795 \cdot \text{psi}$ Allowable axial compressive stress of the column.
 $F_v = 0.4 \cdot F_{yts}$ $F_v = 18400 \cdot \text{psi}$ Allowable shear stress per AISC 1989, Page 5-49, F4-1.
 $F_{bx} = 0.60 \cdot F_{yts}$ $F_{bx} = 27600 \cdot \text{psi}$ Allowable bending stress per AISC 1989, Page 5-48, F3-3.
 $F_{by} = F_{bx}$ Conservative to use a value of 0.6 for bending about both axis.

Determine the actual shear, axial and bending stresses in the shape and compare them with the allowables.

Axial forces and bending moments on the beam. Determined from the finite-element model AZTR_BLC11B, SRAC, 1993.

$F_r = 41495.4 \cdot \text{lbf}$ $V_s = 1332.7 \cdot \text{lbf}$ $V_t = 914.8 \cdot \text{lbf}$
 $M_s = 15971.6 \cdot \text{lbf} \cdot \text{in}$ $M_t = 9379.7 \cdot \text{lbf} \cdot \text{in}$

$f_a = \frac{F_r}{A}$ $f_a = 8168.386 \cdot \text{psi}$

Maximum compressive stress in the beam.

$f_v = \frac{\sqrt{V_s^2 + V_t^2}}{A}$ $f_v = 318.201 \cdot \text{psi}$

Maximum shear stress in the beam.

$f_{bx} = \frac{M_t}{S}$ $f_{bx} = 1753.215 \cdot \text{psi}$

Maximum bending stress about major axis of beam.

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HANFORD COMPANY

ent: Westinghouse Hanford Company

Subject: 241AZ Truss Buckling Analysis

Location: 200 E /

DESIGN ANALYSIS

WO/Job No. C01909

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Checked: 7/19/95

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By: B. L. Coverdell

By: [Signature]

By: [Signature]

$$f_{by} = \frac{M_s}{S} \quad f_{by} = 2985.346 \cdot \text{psi} \quad \text{Maximum bending stress about major axis of beam.}$$

$$x = f_a \leq F_a \quad x = 1 \quad x = f_v \leq F_v \quad x = 1$$

$$x = f_{bx} \leq F_{bx} \quad x = 1 \quad x = f_{by} \leq F_{by} \quad x = 1$$

Since all the resultants equal 1 or true then the actual stresses are less than the allowables and, therefore, this section of calculations is adequate per AISC 1989.

Check interaction equation for compression.

$$\frac{f_a}{F_a} = 0.361 \quad \text{Since the resultant is greater than 0.15, use the equation H1-1 per AISC 1989, page 5-54.}$$

$$F'_{ex} = \frac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\frac{k \cdot l}{r_x} \right)^2} \quad F'_{ex} = 67728.407 \cdot \text{psi} \quad \text{Euler stress for x axis bending divided by a factor of safety per AISC, page 5-54.}$$

$$F'_{ey} = \frac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\frac{k \cdot l}{r_y} \right)^2} \quad F'_{ey} = 67728.407 \cdot \text{psi} \quad \text{Euler stress for y axis bending divided by a factor of safety per AISC, page 5-54.}$$

$$C_{mx} = 0.85 \quad \text{Compression coefficient. Determined from AISC, page 5-55.}$$

$$C_{my} = C_{mx} \quad \text{Compression coefficient. Determined from AISC, page 5-55.}$$

$$\frac{f_a}{F_a} + \frac{C_{mx} \cdot f_{bx}}{\left(1 - \frac{f_a}{F'_{ex}} \right) \cdot F_{bx}} + \frac{C_{my} \cdot f_{by}}{\left(1 - \frac{f_a}{F'_{ey}} \right) \cdot F_{by}} = 0.527 \quad \text{Since the resultant is less than or equal to 1, the beam is adequate to support the load per AISC 1989.}$$

TS 4" x 2" x 5/16" Real Constant #3 & 4 in the finite-element model

Properties of structural shape.

$$S_x = 2.66 \cdot \text{in}^3 \quad \text{section modulus about major axis}$$

$$S_y = 1.71 \cdot \text{in}^3 \quad \text{section modulus about minor axis}$$

$$r_x = 1.31 \cdot \text{in} \quad \text{radius of gyration about x axis}$$

$$r_y = 0.743 \cdot \text{in} \quad \text{radius of gyration about y axis}$$

$$l = 81 \cdot \text{in} \quad \text{maximum column length}$$

$$A = 3.11 \cdot \text{in}^2 \quad \text{cross sectional area}$$

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HANFORD COMPANY

ent: Westinghouse Hanford Company
Subject: 241A2 Truss Buckling Analysis
Location: 200 E /

DESIGN ANALYSIS

WO/Job No. C01909
Date: 06/28/95
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Determine the allowable stresses on the beam.

$k \cdot l = 6.75 \cdot \text{ft}$	effective length	
$P_a = 36 \cdot 10^3 \cdot \text{lbf}$	The allowable axial compressive load from AISC, 1989, page 3-52 using 7 for $k \cdot l$ (no interpolation).	
$F_a = \frac{P_a}{A}$	$F_a = 11575.563 \cdot \text{psi}$	Allowable axial compressive stress of the column.
$F_v = 0.4 \cdot F_y$	$F_v = 18400 \cdot \text{psi}$	Allowable shear stress per AISC 1989, Page 5-49, F4-1.
$F_{bx} = 0.60 \cdot F_y$	$F_{bx} = 27600 \cdot \text{psi}$	Allowable bending stress per AISC 1989, Page 5-48, F3-3.
$F_{by} = F_{bx}$	Conservative to use a value of 0.6 for bending about both axis.	

Determine the actual shear, axial and bending stresses in the shape and compare them with the allowables.

Axial forces and bending moments on the beam. Determined from the finite-element model AZTR_BLC11B, SRAC, 1993.

$F_r = 17961.2 \cdot \text{lbf}$ $V_s = 178.3 \cdot \text{lbf}$ $V_t = 922.1 \cdot \text{lbf}$
 $M_s = 5435.3 \cdot \text{lbf} \cdot \text{in}$ $M_t = 5333.9 \cdot \text{lbf} \cdot \text{in}$

$f_a = \frac{F_r}{A}$	$f_a = 5775.305 \cdot \text{psi}$	Maximum compressive stress in the beam.
$f_v = \frac{\sqrt{V_s^2 + V_t^2}}{A}$	$f_v = 301.987 \cdot \text{psi}$	Maximum shear stress in the beam.
$f_{bx} = \frac{M_t}{S_x}$	$f_{bx} = 2005.226 \cdot \text{psi}$	Maximum bending stress about major axis of beam.
$f_{by} = \frac{M_s}{S_y}$	$f_{by} = 3178.538 \cdot \text{psi}$	Maximum bending stress about major axis of beam.
$x = f_a \leq F_a$	$x = 1$	$x = f_v \leq F_v$ $x = 1$
$x = f_{bx} \leq F_{bx}$	$x = 1$	$x = f_{by} \leq F_{by}$ $x = 1$

Since all the resultants equal 1 or true then the actual stresses are less then the allowables and, therefore, this section of calculations is adequate per AISC 1989.

Check interaction equation for compression.

$$\frac{f_a}{F_a} = 0.499$$

Since the resultant is greater than 0.15, use the equation H1-1 per AISC 1989, page 5-54.

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$$F'_{ex} = \frac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\frac{k \cdot l}{r_x} \right)^2}$$

$$F'_{ex} = 40406.103 \cdot \text{psi}$$

Euler stress for x axis bending divided by a factor of safety per AISC, page 5-54.

$$F'_{ey} = \frac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\frac{k \cdot l}{r_y} \right)^2}$$

$$F'_{ey} = 12998.164 \cdot \text{psi}$$

Euler stress for y axis bending divided by a factor of safety per AISC, page 5-54.

$$C_{mx} = 0.85$$

Compression coefficient. Determined from AISC, page 5-55.

$$C_{my} = C_{mx}$$

Compression coefficient. Determined from AISC, page 5-55.

$$\frac{f_a}{F_a} + \frac{C_{mx} \cdot f_{bx}}{\left(1 - \frac{f_a}{F'_{ex}} \right) \cdot F_{bx}} + \frac{C_{my} \cdot f_{by}}{\left(1 - \frac{f_a}{F'_{ey}} \right) \cdot F_{by}} = 0.747$$

Since the resultant is less than or equal to 1, the beam is adequate to support the load per AISC 1989.

TWO TS 2 1/2" x 1 1/2" 3/16" BACK TO BACK ON 1 1/2" SIDES Real Constant #7 in the finite-element model

Properties of built-up shape.

$$A = \left[1.5 \cdot \text{in} \cdot 2.5 \cdot \text{in} - \left(1.5 \cdot \text{in} - \frac{3}{8} \cdot \text{in} \right) \cdot \left(2.5 \cdot \text{in} - \frac{3}{8} \cdot \text{in} \right) \right]$$

$$A = 1.359 \cdot \text{in}^2$$

Cross-sectional area of a single TS.

$$l = 69.25 \cdot \text{in}$$

Length of column.

Determine the moment of inertia, section modulus and radius of gyration of the built-up shape.

$$d = \frac{1.5 \cdot \text{in}}{2}$$

$$d = 0.75 \cdot \text{in}$$

Distance to centroidal axis of a single TS to combined centroidal axis.

$$I_x = \frac{1.5 \cdot \text{in} \cdot (2.5 \cdot \text{in})^3}{12} - \frac{\left(1.5 \cdot \text{in} - \frac{3}{8} \cdot \text{in} \right) \cdot \left(2.5 \cdot \text{in} - \frac{3}{8} \cdot \text{in} \right)^3}{12}$$

$$I_x = 1.054 \cdot \text{in}^4$$

Moment of inertia for a single TS about the x axis.

$$I_y = \frac{2.5 \cdot \text{in} \cdot (1.5 \cdot \text{in})^3}{12} - \frac{\left(2.5 \cdot \text{in} - \frac{3}{8} \cdot \text{in} \right) \cdot \left(1.5 \cdot \text{in} - \frac{3}{8} \cdot \text{in} \right)^3}{12}$$

$$I_y = 0.451 \cdot \text{in}^4$$

Moment of inertia for a single TS about the y axis.

$$I_{x'} = 2 \cdot I_x$$

$$I_{x'} = 2.107 \cdot \text{in}^4$$

Combined moment of inertia for back to back TS's.

$$I_{y'} = 2 \cdot (I_y + A \cdot d^2)$$

$$I_{y'} = 2.431 \cdot \text{in}^4$$

Combined moment of inertia for back to back TS's.

$$S_{x'} = \frac{I_{x'}}{\frac{2.5 \cdot \text{in}}{2}}$$

$$S_{x'} = 1.686 \cdot \text{in}^3$$

section modulus about x axis

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$$S_{y'} = \frac{I_{y'}}{1.5 \cdot \text{in}}$$

$$S_{y'} = 1.621 \cdot \text{in}^3$$

section modulus about y axis

$$r_x = \sqrt{\frac{I_{x'}}{2 \cdot A}}$$

$$r_x = 0.88 \cdot \text{in}$$

The radius of gyration about the x axis for this beam.

$$r_y = \sqrt{\frac{I_{y'}}{2 \cdot A}}$$

$$r_y = 0.946 \cdot \text{in}$$

The radius of gyration about the y axis for this beam.

Determine the allowable stresses on the beam.

$$\frac{k \cdot l}{r_x} = 78.662$$

Slenderness ratio (used minimum radius of gyration).

$$F_a = 19210 \cdot \text{psi}$$

Allowable axial compressive stress of the column from AISC, 1989, page 3-17 using 79 for kl/r (no interpolation).

$$F_v = 0.4 \cdot F_{yts}$$

$$F_v = 18400 \cdot \text{psi}$$

Allowable shear stress per AISC 1989, Page 5-49, F4-1.

$$F_{bx} = 0.60 \cdot F_{yts}$$

$$F_{bx} = 27600 \cdot \text{psi}$$

Allowable bending stress per AISC 1989, Page 5-48, F3-3.

$$F_{by} = F_{bx}$$

True for a box member per AISC 1989.

Determine the actual shear, axial and bending stresses in the shape and compare them with the allowables.

Axial forces and bending moments on the beam. Determined from the finite-element model AZTR_BLC11B, SRAC, 1993.

$$F_r = 2252.4 \cdot \text{lbf}$$

$$V_s = 178.3 \cdot \text{lbf}$$

$$V_t = 7.1 \cdot \text{lbf}$$

$$M_s = 45.7 \cdot \text{lbf} \cdot \text{in}$$

$$M_t = 3464.7 \cdot \text{lbf} \cdot \text{in}$$

$$f_a = \frac{F_r}{2 \cdot A}$$

$$f_a = 828.469 \cdot \text{psi}$$

Maximum compressive stress in the beam.

$$f_v = \frac{\sqrt{V_s^2 + V_t^2}}{2 \cdot A}$$

$$f_v = 65.634 \cdot \text{psi}$$

Maximum shear stress in the beam.

$$f_{bx} = \frac{M_t}{S_x}$$

$$f_{bx} = 1302.519 \cdot \text{psi}$$

Maximum bending stress about major axis of beam.

$$f_{by} = \frac{M_s}{S_y}$$

$$f_{by} = 26.725 \cdot \text{psi}$$

Maximum bending stress about major axis of beam.

$$x = f_a \leq F_a$$

$$x = 1$$

$$x = f_v \leq F_v$$

$$x = 1$$

$$x = f_{bx} \leq F_{bx}$$

$$x = 1$$

$$x = f_{by} \leq F_{by}$$

$$x = 1$$

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Check interaction equation for compression.

$$\frac{f_a}{F_a} = 0.043$$

Since the resultant is less than 0.15, use the following equations per AISC, page 5-54.

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} = 0.091$$

Since the resultant is less than or equal to 1, the beam is adequate to support the load per AISC 1989.

ANGLE 2" x 2" x 1/4" Real Constant #9 in the finite-element model

Properties of structural shape.

$S_x = 0.247 \cdot \text{in}^3$	section modulus
$r_x = 0.609 \cdot \text{in}$	radius of gyration about x axis
$r_y = 0.609 \cdot \text{in}$	radius of gyration about y axis
$l = 69.25 \cdot \text{in}$	maximum column length
$A = 0.938 \cdot \text{in}^2$	cross sectional area

Determine the allowable stresses on the beam.

$$\frac{k \cdot l}{r_x} = 113.711 \quad \text{slenderness ratio}$$

$$F_a = 0.6 \cdot F_y \quad \text{Allowable axial compressive stress of the column from AISC, 1989, page 3-16 using 114 for } kl/r \text{ (no interpolation).}$$

$$F_v = 0.4 \cdot F_y \quad F_v = 14400 \cdot \text{psi} \quad \text{Allowable shear stress per AISC 1989, Page 5-49, F4-1.}$$

$$F_{bx} = 0.60 \cdot F_y \quad F_{bx} = 21600 \cdot \text{psi} \quad \text{Allowable bending stress per AISC 1989, Page 5-46, F1-5.}$$

$$F_{by} = F_{bx} \quad \text{True for an equal side angle.}$$

Determine the actual shear, axial and bending stresses in the shape and compare them with the allowables.

Axial forces and bending moments on the beam. Determined from the finite-element model AZTR_BLC11B, SRAC, 1993.

$$F_r = 3304.1 \cdot \text{lbf} \quad V_s = 431.4 \cdot \text{lbf} \quad V_t = 419.2 \cdot \text{lbf}$$

$$M_s = 2563.7 \cdot \text{lbf} \cdot \text{in} \quad M_t = 2638.8 \cdot \text{lbf} \cdot \text{in}$$

$$f_a = \frac{F_r}{A} \quad f_a = 3522.495 \cdot \text{psi} \quad \text{Maximum compressive stress in the beam.}$$

$$f_v = \frac{\sqrt{V_s^2 + V_t^2}}{A} \quad f_v = 641.287 \cdot \text{psi} \quad \text{Maximum shear stress in the beam.}$$

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$$f_{bx} = \frac{M_t}{S} \quad f_{bx} = 10683.401 \text{ psi} \quad \text{Maximum bending stress about major axis of beam.}$$

$$f_{by} = \frac{M_s}{S} \quad f_{by} = 10379.352 \text{ psi} \quad \text{Maximum bending stress about major axis of beam.}$$

$$x = f_a \leq F_a \quad x = 1 \quad x = f_v \leq F_v \quad x = 1$$

$$x = f_{bx} \leq F_{bx} \quad x = 1 \quad x = f_{by} \leq F_{by} \quad x = 1$$

Check interaction equation for compression.

Initial calculations on this structural shape showed that it will fail if the axial force is considered to be compression. In order to circumnavigate this problem the finite-element model was used to due an axial stress plot. This stress plot shows that the member in question is actually in tension not compression. The interaction equation for tension is used below.

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} = 1.138 \quad \text{The interaction equation exceeds 1, however, this member is not considered a prime structural member. For this reason, allow } F_{bx} \text{ and } F_{by} \text{ to be equal to the yield stress of the material.}$$

$$F_{bx} = F_y \quad F_{by} = F_y$$

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} = 0.748 \quad \text{Since the resultant is less than or equal to 1, the beam is adequate to support the load per AISC 1989.}$$

BAR 6" x 6" Real Constant #10 in the finite-element model.

Properties of bar shape.

$l = 69.25 \text{ in}$	maximum column length
$A = (6 \text{ in})^2$	$A = 36 \text{ in}^2$ cross sectional area
$I = \frac{(6 \text{ in})^4}{12}$	$I = 108 \text{ in}^4$ moment of inertia about either axis
$S = \frac{I}{\left(\frac{6 \text{ in}}{2}\right)}$	$S = 36 \text{ in}^3$ section modulus about either axis
$r_x = \sqrt{\frac{I}{A}}$	$r_x = 1.732 \text{ in}$ radius of gyration about x axis
$r_y = \sqrt{\frac{I}{A}}$	$r_y = 1.732 \text{ in}$ radius of gyration about y axis

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Determine the allowable stresses on the beam.

$$\frac{k \cdot l}{r_x} = 39.982$$

slenderness ratio

$$F_a = 19190 \text{ psi}$$

Allowable axial compressive stress of the column from AISC, 1989, page 3-16 using 40 for kl/r (no interpolation).

$$F_v = 0.4 \cdot F_y$$

$$F_v = 14400 \text{ psi}$$

Allowable shear stress per AISC 1989, Page 5-49, F4-1.

$$F_{bx} = .60 \cdot F_y$$

$$F_{bx} = 21600 \text{ psi}$$

Allowable bending stress per AISC 1989, Page 5-48, F2-2.

$$F_{by} = F_{bx}$$

This is a square bar.

Determine the actual shear, axial and bending stresses in the shape and compare them with the allowables.

Axial forces and bending moments on the beam. Determined from the finite-element model AZTR_BLC11B, SRAC, 1993.

$$F_r = 120987 \text{ lbf}$$

$$V_s = 1183 \text{ lbf}$$

$$V_t = 1222.8 \text{ lbf}$$

$$M_s = 64246.7 \text{ lbf-in}$$

$$M_t = 62143.9 \text{ lbf-in}$$

$$f_a = \frac{F_r}{A}$$

$$f_a = 3360.75 \text{ psi}$$

Maximum compressive stress in the beam.

$$f_v = \frac{\sqrt{V_s^2 + V_t^2}}{A}$$

$$f_v = 47.261 \text{ psi}$$

Maximum shear stress in the beam.

$$f_{bx} = \frac{M_t}{S}$$

$$f_{bx} = 1726.219 \text{ psi}$$

Maximum bending stress about major axis of beam.

$$f_{by} = \frac{M_s}{S}$$

$$f_{by} = 1784.631 \text{ psi}$$

Maximum bending stress about major axis of beam.

$$x = f_a \leq F_a$$

$$x = 1$$

$$x = f_v \leq F_v$$

$$x = 1$$

$$x = f_{bx} \leq F_{bx}$$

$$x = 1$$

$$x = f_{by} \leq F_{by}$$

$$x = 1$$

Check interaction equation for compression.

$$\frac{f_a}{F_a} = 0.175$$

Since the resultant is greater than 0.15, use the equation H1-1 per AISC 1989, page 5-54.

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$$F'_{ex} = \frac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\frac{k \cdot l}{r_x} \right)^2}$$

$$F'_{ex} = 96639.819 \cdot \text{psi}$$

Euler stress for x axis bending divided by a factor of safety per AISC, page 5-54.

$$F'_{ey} = \frac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\frac{k \cdot l}{r_y} \right)^2}$$

$$F'_{ey} = 96639.819 \cdot \text{psi}$$

Euler stress for y axis bending divided by a factor of safety per AISC, page 5-54.

$$C_{mx} = 0.85$$

Compression coefficient. Determined from AISC, page 5-55.

$$C_{my} = C_{mx}$$

Compression coefficient. Determined from AISC, page 5-55.

$$\frac{f_a}{F_a} + \frac{C_{mx} \cdot f_{bx}}{\left(1 - \frac{f_a}{F'_{ex}} \right) \cdot F_{bx}} + \frac{C_{my} \cdot f_{by}}{\left(1 - \frac{f_a}{F'_{ey}} \right) \cdot F_{by}} = 0.318$$

Since the resultant is less than or equal to 1, the beam is adequate to support the load per AISC 1989.

BAR 4" x 4" Real Constant #11 in finite-element model.

Properties of bar shape.

$$l = 67 \cdot \text{in}$$

maximum column length

$$A = (4 \cdot \text{in})^2$$

$$A = 16 \cdot \text{in}^2$$

cross sectional area

$$I = \frac{(4 \cdot \text{in})^4}{12}$$

$$I = 21.333 \cdot \text{in}^4$$

moment of inertia about either axis

$$S = \frac{I}{\left(\frac{4 \cdot \text{in}}{2} \right)}$$

$$S = 10.667 \cdot \text{in}^3$$

section modulus about either axis

$$r_x = \sqrt{\frac{I}{A}}$$

$$r_x = 1.155 \cdot \text{in}$$

radius of gyration about x axis

$$r_y = \sqrt{\frac{I}{A}}$$

$$r_y = 1.155 \cdot \text{in}$$

radius of gyration about y axis

Determine the allowable stresses on the beam.

$$\frac{k \cdot l}{r_y} = 58.024$$

slenderness ratio

$$F_a = 17620 \cdot \text{psi}$$

The allowable axial compressive stress from AISC, 1989, page 3-16 using 58 for kl/r (no interpolation).

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$$F_v = 0.4 \cdot F_y$$

$$F_v = 14400 \cdot \text{psi}$$

Allowable shear stress per AISC 1989, Page 5-49, F4-1.

$$F_{bx} = 0.60 \cdot F_y$$

$$F_{bx} = 21600 \cdot \text{psi}$$

Allowable bending stress per AISC 1989, Page 5-48, F2-2.

$$F_{by} = F_{bx}$$

True for a solid bar per AISC 1989.

Determine the actual shear, axial and bending stresses in the shape and compare them with the allowables.

Axial forces and bending moments on the beam. Determined from the finite-element model AZTR_BLC11B, SRAC, 1993.

$$F_r = 52855.4 \cdot \text{lb}$$

$$V_s = 1003.0 \cdot \text{lb}$$

$$V_t = 465.9 \cdot \text{lb}$$

$$M_s = 21676.1 \cdot \text{lb-in} \quad M_t = 18182.1 \cdot \text{lb-in}$$

$$f_a = \frac{F_r}{A}$$

$$f_a = 3303.463 \cdot \text{psi}$$

Maximum compressive stress in the beam.

$$f_v = \frac{\sqrt{V_s^2 + V_t^2}}{A}$$

$$f_v = 69.12 \cdot \text{psi}$$

Maximum shear stress in the beam.

$$f_{bx} = \frac{M_t}{S}$$

$$f_{bx} = 1704.572 \cdot \text{psi}$$

Maximum bending stress about major axis of beam.

$$f_{by} = \frac{M_s}{S}$$

$$f_{by} = 2032.134 \cdot \text{psi}$$

Maximum bending stress about major axis of beam.

$$x = f_a \leq F_a$$

$$x = 1$$

$$x = f_v \leq F_v$$

$$x = 1$$

$$x = f_{bx} \leq F_{bx}$$

$$x = 1$$

$$x = f_{by} \leq F_{by}$$

$$x = 1$$

Check interaction equation for compression.

$$\frac{f_a}{F_a} = 0.187$$

Since the resultant is greater than 0.15, use the equation H1-1 per AISC 1989, page 5-54.

$$F'_{ex} = \frac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\frac{k \cdot l}{r_x} \right)^2}$$

$$F'_{ex} = 45884.24 \cdot \text{psi}$$

Euler stress for x axis bending divided by a factor of safety per AISC, page 5-54.

$$F'_{ey} = \frac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\frac{k \cdot l}{r_y} \right)^2}$$

$$F'_{ey} = 45884.24 \cdot \text{psi}$$

Euler stress for y axis bending divided by a factor of safety per AISC, page 5-54.

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$$C_{mx} = 0.85$$

Compression coefficient. Determined from AISC, page 5-55.

$$C_{my} = C_{mx}$$

Compression coefficient. Determined from AISC, page 5-55.

$$\frac{f_a}{F_a} + \frac{C_{mx} \cdot f_{bx}}{\left(1 - \frac{f_a}{F_{ex}}\right) \cdot F_{bx}} + \frac{C_{my} \cdot f_{by}}{\left(1 - \frac{f_a}{F_{ey}}\right) \cdot F_{by}} = 0.346$$

Since the resultant is less than or equal to 1, the beam is adequate to support the load per AISC 1989.

TS 1 1/2" x 1 1/2" x 1/8" Real Constant #12 in the finite-element model.

Properties of structural shape.

$$l = 69.25 \cdot \text{in} \quad \text{maximum column length}$$

$$A = (1.5 \cdot \text{in})^2 - (1.5 \cdot \text{in} - 0.25 \cdot \text{in})^2 \quad A = 0.688 \cdot \text{in}^2 \quad \text{cross sectional area}$$

$$I = \frac{(1.5 \cdot \text{in})^4 - (1.5 \cdot \text{in} - 0.25 \cdot \text{in})^4}{12} \quad I = 0.218 \cdot \text{in}^4$$

$$S = \frac{I}{\left(\frac{1.5 \cdot \text{in}}{2}\right)} \quad S = 0.291 \cdot \text{in}^3 \quad \text{section modulus about either axis}$$

$$r_x = \sqrt{\frac{I}{A}} \quad r_x = 0.564 \cdot \text{in} \quad \text{radius of gyration}$$

$$r_y = \sqrt{\frac{I}{A}} \quad r_y = 0.564 \cdot \text{in} \quad \text{radius of gyration}$$

Determine the allowable stresses on the beam.

$$\frac{k \cdot l}{r_y} = 122.859 \quad \text{slenderness ratio}$$

$$F_a = 9870 \cdot \text{psi} \quad \text{Allowable axial compressive stress of the column from AISC, 1989, page 3-17 using 123 for } kl/r \text{ (no interpolation).}$$

$$F_v = 0.4 \cdot F_y \quad F_v = 18400 \cdot \text{psi} \quad \text{Allowable shear stress per AISC 1989, Page 5-49, F4-1.}$$

$$F_{bx} = 0.60 \cdot F_y \quad F_{bx} = 27600 \cdot \text{psi} \quad \text{Allowable bending stress per AISC 1989, Page 5-49, F3-3, conservative.}$$

$$F_{by} = F_{bx} \quad \text{Square box.}$$

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Determine the actual shear, axial and bending stresses in the shape and compare them with the allowables.

Axial forces and bending moments on the beam. Determined from the finite-element model AZTR_BLC11B, SRAC, 1993.

$$F_r = 664.8 \cdot \text{lb} \cdot \text{f}$$

$$V_s = 276.5 \cdot \text{lb} \cdot \text{f}$$

$$V_t = 126.8 \cdot \text{lb} \cdot \text{f}$$

$$M_s = 785.7 \cdot \text{lb} \cdot \text{f} \cdot \text{in}$$

$$M_t = 1693.8 \cdot \text{lb} \cdot \text{f} \cdot \text{in}$$

$$f_a = \frac{F_r}{A} \quad f_a = 966.982 \cdot \text{psi}$$

Maximum compressive stress in the beam.

$$f_v = \frac{\sqrt{V_s^2 + V_t^2}}{A} \quad f_v = 442.456 \cdot \text{psi}$$

Maximum shear stress in the beam.

$$f_{bx} = \frac{M_t}{S} \quad f_{bx} = 5815.969 \cdot \text{psi}$$

Maximum bending stress about major axis of beam.

$$f_{by} = \frac{M_s}{S} \quad f_{by} = 2697.843 \cdot \text{psi}$$

Maximum bending stress about minor axis of beam.

$$x = f_a \leq F_a \quad x = 1$$

$$x = f_v \leq F_v \quad x = 1$$

$$x = f_{bx} \leq F_{bx} \quad x = 1$$

$$x = f_{by} \leq F_{by} \quad x = 1$$

Check interaction equation for compression.

$$\frac{f_a}{F_a} = 0.098$$

Since the resultant is less than 0.15, use the following equations per AISC, page 5-54.

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} = 0.406$$

Since the resultant is less than or equal to 1, the beam is adequate to support the load per AISC 1989.

BAR 4" x 2" Real Constant #13 in the finite-element model.

Properties of bar.

$$A = 4 \cdot \text{in} \cdot 2 \cdot \text{in}$$

$$A = 8 \cdot \text{in}^2$$

cross sectional area

$$l = 67 \cdot \text{in}$$

maximum column length

Determine moment of inertia and section modulus.

$$I_x = \frac{2 \cdot \text{in} \cdot (4 \cdot \text{in})^3}{12}$$

$$I_x = 10.667 \cdot \text{in}^4$$

moment of inertia about major axis

$$I_y = \frac{4 \cdot \text{in} \cdot (2 \cdot \text{in})^3}{12}$$

$$I_y = 2.667 \cdot \text{in}^4$$

moment of inertia about minor axis

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DESIGN ANALYSIS

Calc. No. _____

Revision 0

Page No. 15 of

Client: Westinghouse Hanford Company

WO/Job No. C01909

Subject: 241AZ Truss Buckling Analysis

Date: 06/28/95

By: B. L. Coverdell

Checked: 7/19/95

By: [Signature]

Revised: _____

By: [Signature]

Location: 200 E /

$$S_x = \frac{I_x}{\left(\frac{4 \cdot \text{in}}{2}\right)}$$

$$S_x = 5.333 \cdot \text{in}^3$$

section modulus about major axis

$$S_y = \frac{I_y}{\left(\frac{2 \cdot \text{in}}{2}\right)}$$

$$S_y = 2.667 \cdot \text{in}^3$$

section modulus about minor axis

$$r_x = \sqrt{\frac{I_x}{A}}$$

$$r_x = 1.155 \cdot \text{in}$$

radius of gyration

$$r_y = \sqrt{\frac{I_y}{A}}$$

$$r_y = 0.577 \cdot \text{in}$$

radius of gyration

Determine the allowable stresses on the beam.

$$\frac{k \cdot l}{r_y} = 116.047$$

slenderness ratio

$$F_a = 10850 \cdot \text{psi}$$

Allowable axial compressive stress of the column from AISC, 1989, page 3-16 using 116 for kl/r (no interpolation).

$$F_v = 0.4 \cdot F_y$$

$$F_v = 14400 \cdot \text{psi}$$

Allowable shear stress per AISC 1989, Page 5-49, F4-1.

$$F_{bx} = 0.6 \cdot F_y$$

$$F_{bx} = 21600 \cdot \text{psi}$$

Allowable bending stress per AISC 1989, Page 5-48, F2-2.

$$F_{by} = F_{bx}$$

Rectangular solid member.

Determine the actual shear, axial and bending stresses in the shape and compare them with the allowables.

Axial forces and bending moments on the beam. Determined from the finite-element model AZTR_BLC11B, SRAC, 1993.

$$F_r = 14744.8 \cdot \text{lbf}$$

$$V_s = 5258.4 \cdot \text{lbf}$$

$$V_t = 2325.0 \cdot \text{lbf}$$

$$M_s = 7624.3 \cdot \text{lbf} \cdot \text{in}$$

$$M_t = 42070.2 \cdot \text{lbf} \cdot \text{in}$$

$$f_a = \frac{F_r}{A}$$

$$f_a = 1843.1 \cdot \text{psi}$$

Maximum compressive stress in the beam.

$$f_v = \frac{\sqrt{V_s^2 + V_t^2}}{A}$$

$$f_v = 718.684 \cdot \text{psi}$$

Maximum shear stress in the beam.

$$f_{bx} = \frac{M_t}{S_x}$$

$$f_{bx} = 7888.163 \cdot \text{psi}$$

Maximum bending stress about major axis of beam.

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Client: Westinghouse Hanford Company

Subject: 241AZ Truss Buckling Analysis

Location: 200 E /

DESIGN ANALYSIS

WO/Job No. C01909

Date: 06/28/95

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Revised:

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By: [Signature]

$$f_{by} = \frac{M_s}{S_y}$$

$$f_{by} = 2859.113 \cdot \text{psi}$$

Maximum bending stress about major axis of beam.

$$x = f_a \leq F_a$$

$$x = 1$$

$$x = f_v \leq F_v$$

$$x = 1$$

$$x = f_{bx} \leq F_{bx}$$

$$x = 1$$

$$x = f_{by} \leq F_{by}$$

$$x = 1$$

Check interaction equation for compression.

$$\frac{f_a}{F_a} = 0.17$$

Since the resultant is greater than 0.15, use the equation H1-1 per AISC 1989, page 5-54.

$$F'_{ex} = \frac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\frac{k \cdot l}{r_x} \right)^2}$$

$$F'_{ex} = 45884.24 \cdot \text{psi}$$

Euler stress for x axis bending divided by a factor of safety per AISC, page 5-54.

$$F'_{ey} = \frac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\frac{k \cdot l}{r_y} \right)^2}$$

$$F'_{ey} = 11471.06 \cdot \text{psi}$$

Euler stress for y axis bending divided by a factor of safety per AISC, page 5-54.

$$C_{mx} = 0.85$$

Compression coefficient. Determined from AISC, page 5-55.

$$C_{my} = C_{mx}$$

Compression coefficient. Determined from AISC, page 5-55.

$$\frac{f_a}{F_a} + \frac{C_{mx} \cdot f_{bx}}{\left(1 - \frac{f_a}{F'_{ex}} \right) \cdot F_{bx}} + \frac{C_{my} \cdot f_{by}}{\left(1 - \frac{f_a}{F'_{ey}} \right) \cdot F_{by}} = 0.627$$

Since the resultant is less than or equal to 1, the beam is adequate to support the load per AISC 1989.

RESULTS AND CONCLUSIONS:

The calculations combined with the finite-element model AZTR_BLC11B determined that all structural shapes and bars are adequate per AISC 1989.

REFERENCES:

AISC, 1989, *Manual of Steel Construction*, 9th Edition, American Institute of Steel Construction, Chicago, Illinois.

SRAC, 1993, *COSMOS/M*, Version 1.71, Structural Research and Analysis Corporations, Santa Monica, California.

MAXIMUM FORCES AND MOMENTS

per COSMOS/M model AZTR_BLC11B

WHC-SD-WM-DA-205
Rev. 0

JJG 7/19/91

REAL CONSTANT #1

* Selection List 1	Load case 53	Top Face
Elem FR		
306 76444.9		
* Selection List 1	Load case 53	Top Face
Elem VS		
2 1597.94		
* Selection List 1	Load case 53	Top Face
Elem VT		
2 1665.21		
* Selection List 1	Load case 53	Top Face
Elem MS		
142 26969		
* Selection List 1	Load case 53	Top Face
Elem MT		
142 26093.7		

REAL CONSTANT #2

* Selection List 1	Load case 53	Top Face
Elem FR		
155 41495.4		
* Selection List 1	Load case 53	Top Face
Elem VS		
1670 1332.7		
* Selection List 1	Load case 53	Top Face
Elem VT		
1655 914.75		
* Selection List 1	Load case 53	Top Face
Elem MS		
178 15971.6		
* Selection List 1	Load case 53	Top Face
Elem MT		
393 9379.66		

REAL CONSTANT #3 & 4

* Selection List 1	Load case 53	Top Face
Elem FR		
230 17961.2		
* Selection List 1	Load case 53	Top Face
Elem VS		
1452 1131.86		
* Selection List 1	Load case 53	Top Face
Elem VT		
1439 922.078		
* Selection List 1	Load case 53	Top Face
Elem MS		
1201 5435.27		
* Selection List 1	Load case 53	Top Face
Elem MT		
1277 5333.93		

REAL CONSTANT #7

* Selection List 1	Load case 53	Top Face
Elem FR		
2513 2252.35		
* Selection List 1	Load case 53	Top Face
Elem VS		
2441 178.318		
* Selection List 1	Load case 53	Top Face
Elem VT		
2440 7.08987		
* Selection List 1	Load case 53	Top Face
Elem MS		
2440 45.7269		
* Selection List 1	Load case 53	Top Face
Elem MT		
2492 3464.73		

REAL CONSTANT #9

* Selection List 1	Load case 53	Top Face
Elem FR		
2751 3304.13		
* Selection List 1	Load case 53	Top Face
Elem VS		
2713 431.393		
* Selection List 1	Load case 53	Top Face
Elem VT		
2577 419.167		
* Selection List 1	Load case 53	Top Face
Elem MS		
2577 2563.69		
* Selection List 1	Load case 53	Top Face
Elem MT		
2713 2638.75		

REAL CONSTANT #10

* Selection List 1	Load case 53	Top Face
Elem FR		
143 120987		
* Selection List 1	Load case 53	Top Face
Elem VS		
261 1183		
* Selection List 1	Load case 53	Top Face
Elem VT		
261 1222.75		
* Selection List 1	Load case 53	Top Face
Elem MS		
260 64246.7		
* Selection List 1	Load case 53	Top Face
Elem MT		
260 62143.9		

REAL CONSTANT #11

* Selection List 1	Load case 53	Top Face
Elem FR		
1678 52855.4		
* Selection List 1	Load case 53	Top Face
Elem VS		
1683 1003.04		
* Selection List 1	Load case 53	Top Face
Elem VT		
273 465.895		
* Selection List 1	Load case 53	Top Face
Elem MS		
273 21676.1		
* Selection List 1	Load case 53	Top Face
Elem MT		
1683 18182.1		

REAL CONSTANT #12

* Selection List 1	Load case 53	Top Face
Elem FR		
2895 664.788		
* Selection List 1	Load case 53	Top Face
Elem VS		
2849 276.458		
* Selection List 1	Load case 53	Top Face
Elem VT		
2848 126.785		
* Selection List 1	Load case 53	Top Face
Elem MS		
2849 785.662		
* Selection List 1	Load case 53	Top Face
Elem MT		
2848 1693.79		

MAXIMUM FORCES AND MOMENTS
per COSMOS/M model AZTR_BLC11B

WHC-SD-WM-DA-205
Rev. 0

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REAL CONSTANT #13

* Selection List 1	Load case 53	Top Face
Elem FR		
7875 14744.8		
* Selection List 1	Load case 53	Top Face
Elem VS		
7899 5258.44		
* Selection List 1	Load case 53	Top Face
Elem VT		
7889 2324.95		
* Selection List 1	Load case 53	Top Face
Elem MS		
751 7624.26		
* Selection List 1	Load case 53	Top Face
Elem MT		
7980 42070.2		

Appendix E: Weld Evaluation

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It should be noted that all welds have been analyzed per Troitsky 1982, however all welds are either full penetration or a prequalified weld. These welds will develop the full strength of the base metals being connected. For this reason, all welds are adequate if the base metals are adequate.

Elem	P/A	MS/BS	MT/ST	sigma _h	δ	b	h	h ₀	ex	D	te	P/A (adj)	sigma _h y	h ₀	Q _{max}	U	G ₂	gamma	h ₀ m	Kg	actual punching shear	h ₀	h ₀ ref	MS
1	2174.835	159.1710	428.3914	785.3774	2	4	0.3125	30.3	3.864104	4	0.375	12000	30000	1	2.460783	0.8	0.82	5.333333	25758.9	1.327351	2.26012	1783.512	13.44441	
2	524.2252	581.0711	261.1546	984.48	2	4	0.3125	30.3	3.864104	4	0.375	12000	30000	1	2.460783	0.8	0.82	5.333333	25758.9	1.327351	2.26012	2061.791	11.40049	
103	4294.8716	899.5493	266.7325	1072.201	2	4	0.3125	30.3	3.864104	4	0.375	12000	30000	1	2.460783	0.8	0.82	5.333333	25758.9	1.327351	2.26012	1783.512	13.48596	
130	5378.195	395.5724	260.5324	482.78	2	4	0.3125	30.3	3.864104	4	0.375	12000	30000	1	2.460783	0.8	0.82	5.333333	25758.9	1.327351	2.26012	1801.159	12.60072	
203	7004.477	538.8848	687.0900	971.9345	2	4	0.3125	30.3	3.864104	4	0.375	12000	30000	1	2.460783	0.8	0.82	5.333333	25758.9	1.327351	2.26012	2240.131	8.40078	
231	6487.178	658.7681	642.8002	920.5274	2	4	0.3125	30.3	3.864104	4	0.375	12000	30000	1	2.460783	0.8	0.82	5.333333	25758.9	1.327351	2.26012	2260.787	9.744529	
583	2355.747	240.7702	163.8314	502.2282	2	4	0.3125	30.3	3.864104	4	0.375	12000	30000	1	2.460783	0.8	0.82	5.333333	25758.9	1.327351	2.26012	621.2270	26.30149	
597	575.0486	107.8897	60.03504	139.8023	2	4	0.3125	30.3	3.864104	4	0.375	12000	30000	1	2.460783	0.8	0.82	5.333333	25758.9	1.327351	2.26012	233.8179	108.1217	
624	3919.085	248.0343	304.4913	437.5528	2	4	0.3125	30.3	3.864104	4	0.375	12000	30000	1	2.460783	0.8	0.82	5.333333	25758.9	1.327351	2.26012	1514.797	18.49243	
638	1559.891	70.7469	152.1506	167.0756	2	4	0.3125	30.3	3.864104	4	0.375	12000	30000	1	2.460783	0.8	0.82	5.333333	25758.9	1.327351	2.26012	555.8097	45.33239	
653	2355.544	241.9356	182.478	503.0384	2	4	0.3125	30.3	3.864104	4	0.375	12000	30000	1	2.460783	0.8	0.82	5.333333	25758.9	1.327351	2.26012	621.3311	26.49435	
777	9477.840	108.8228	88.77483	138.8958	2	4	0.3125	30.3	3.864104	4	0.375	12000	30000	1	2.460783	0.8	0.82	5.333333	25758.9	1.327351	2.26012	224.1175	109.0265	
804	3818.805	247.7582	365.073	457.0718	2	4	0.3125	30.3	3.864104	4	0.375	12000	30000	1	2.460783	0.8	0.82	5.333333	25758.9	1.327351	2.26012	1315.066	18.58768	
884	1559.885	67.54837	152.0032	166.8781	2	4	0.3125	30.3	3.864104	4	0.375	12000	30000	1	2.460783	0.8	0.82	5.333333	25758.9	1.327351	2.26012	555.8097	45.33449	

Section 10.5.1: Local or "punching" shear failure (Bottom Tube -> 2nd Stud)

Elem	P/A	MS/SS	MT/ST	sigma b	sigma y	branch	theta	Info	ax	D	mean	IC	P/A (lb)	sigma y	beta	Chord	U	CF	gamm	tau all	IC	KB	tau act	MS
708	743.8149	2049.857	1031.602	3041.390	30000	2	4	0.25	90	2	0	0.375	12000	36000	0.69087	1.125	0.00413	1	0	0.4375	1	1	2503.543	2.433514
720	364.9548	2546.192	1005.248	3000.000	30000	2	4	0.25	90	2	0	0.375	12000	36000	0.69087	1.125	0.00413	1	0	0.4375	1	1	2248.849	2.760085
732	522.8574	1233.06	1238.414	2377.411	30000	2	4	0.25	90	2	0	0.375	12000	36000	0.69087	1.125	0.043271	1	0	0.4375	1	1	1933.332	3.304277
751	550.2704	1554.224	891.1649	1833.355	36000	2	4	0.25	90	2	0	0.375	12000	36000	0.69087	1.125	0.043565	1	0	0.4375	1	1	1502.411	4.298549
764	892.9468	917.0002	2223.106	2414.284	36000	2	4	0.25	90	2	0	0.375	12000	36000	0.69087	1.125	0.021357	1	0	0.4375	1	1	1209.836	5.974098
781	182.9468	917.0002	2223.106	2414.284	36000	2	4	0.25	90	2	0	0.375	12000	36000	0.69087	1.125	0.021357	1	0	0.4375	1	1	1106.576	6.811114
800	125.4481	1129.154	267.071	1160.097	36000	2	4	0.25	90	2	0	0.375	12000	36000	0.69087	1.125	0.010239	1	0	0.4375	1	1	850.0003	8.833548
817	308.1959	970.1024	522.0405	887.3567	36000	2	4	0.25	90	2	0	0.375	12000	36000	0.69087	1.125	0.010457	1	0	0.4375	1	1	867.4449	8.726843
831	310.2023	698.2177	578.3321	887.4201	36000	2	4	0.25	90	2	0	0.375	12000	36000	0.69087	1.125	0.025483	1	0	0.4375	1	1	787.1817	9.564002
848	53.1154	323.3684	272.3718	503.4055	36000	2	4	0.25	90	2	0	0.375	12000	36000	0.69087	1.125	0.024425	1	0	0.4375	1	1	371.0442	21.74172
868	51.8371	435.7989	270.7629	513.8993	36000	2	4	0.25	90	2	0	0.375	12000	36000	0.69087	1.125	0.004304	1	0	0.4375	1	1	317.8354	21.78353
1017	118.8518	727.720	251.242	2748.78	36000	2	4	0.25	90	2	0	0.375	12000	36000	0.69087	1.125	0.009748	1	0	0.4375	1	1	1910.494	3.410398
1044	115.8413	2652.728	238.0553	2607.019	36000	2	4	0.25	90	2	0	0.375	12000	36000	0.69087	1.125	0.006537	1	0	0.4375	1	1	1855.108	3.548257

Bar->Stud

Section 10.5.1: Local or "punching" shear failure (Top Tube -> 2nd Stud)

Model Results (100,000 of 224,000)																									
Elem	P/A	MS/SS	MT/ST	sigma b	theta	ax	D	IC	P/A (lb)	sigma y	branch		1/2ae info		msh		adverse punching shear		shear		IC	actual punching shear	KB	tau act	MS
											b	q	tb	ts	beta	Chord	U	CF	gamma	tau all					
722	54.80035	1700.051	427.2534	1440.342	2	2	4	0.375	12000	36000	0.8975	1.875	0.004717	1	0	0.533333	14400	1	0	0.533333	14400	1	1	602.8955	22.88473
1443	34.43511	1385.053	877.3774	1640.07	2	2	4	0.375	12000	36000	0.8975	1.875	0.002688	1	0	0.533333	14400	1	0	0.533333	14400	1	1	558.2417	24.79528
1462	78.48419	1305.072	1059.432	1040.355	2	2	4	0.375	12000	36000	0.8975	1.875	0.006822	1	0	0.533333	14400	1	0	0.533333	14400	1	1	568.0083	23.53982
1478	73.95045	1258.125	1052.182	1640.887	2	2	4	0.375	12000	36000	0.8975	1.875	0.005183	1	0	0.533333	14400	1	0	0.533333	14400	1	1	571.8124	24.1919
1490	896.1103	843.8414	2222.107	2414.249	2	2	4	0.375	12000	36000	0.8975	1.875	0.074078	1	0	0.533333	14400	1	0	0.533333	14400	1	1	1103.453	12.04094
1491	892.9468	917.0002	2223.106	2414.284	2	2	4	0.375	12000	36000	0.8975	1.875	0.074413	1	0	0.533333	14400	1	0	0.533333	14400	1	1	1102.413	12.08225
1518	20.81347	1489.316	190.0718	1501.584	2	2	4	0.375	12000	36000	0.8975	1.875	0.001734	1	0	0.533333	14400	1	0	0.533333	14400	1	1	507.4693	27.37031
1532	20.72007	1482.188	192.0713	1474.78	2	2	4	0.375	12000	36000	0.8975	1.875	0.001727	1	0	0.533333	14400	1	0	0.533333	14400	1	1	498.4098	27.08058
1548	548.0173	639.860	250.2714	487.0743	2	2	4	0.375	12000	36000	0.8975	1.875	0.047353	1	0	0.533333	14400	1	0	0.533333	14400	1	1	411.3339	33.4198
1547	547.4742	638.9833	250.4929	675.1982	2	2	4	0.375	12000	36000	0.8975	1.875	0.047265	1	0	0.533333	14400	1	0	0.533333	14400	1	1	412.2478	33.7818
1574	10.3772	558.2929	41.83335	558.8498	2	2	4	0.375	12000	36000	0.8975	1.875	0.001553	1	0	0.533333	14400	1	0	0.533333	14400	1	1	162.7482	73.70849
1588	16.2627	548.5784	43.18311	548.28	2	2	4	0.375	12000	36000	0.8975	1.875	0.001522	1	0	0.533333	14400	1	0	0.533333	14400	1	1	188.4878	75.25197
1602	952.9003	215.8208	232.0285	317.106	2	2	4	0.375	12000	36000	0.8975	1.875	0.049042	1	0	0.533333	14400	1	0	0.533333	14400	1	1	260.5555	48.94588
1603	51.8035	233.2733	234.8227	331.0695	2	2	4	0.375	12000	36000	0.8975	1.875	0.049884	1	0	0.533333	14400	1	0	0.533333	14400	1	1	284.29	47.83132
1630	32.81384	1424.321	168.4705	1434.448	2	2	4	0.375	12000	36000	0.8975	1.875	0.002724	1	0	0.533333	14400	1	0	0.533333	14400	1	1	489.074	28.42459
1631	33.19148	1445.078	174.5002	1458.574	2	2	4	0.375	12000	36000	0.8975	1.875	0.002785	1	0	0.533333	14400	1	0	0.533333	14400	1	1	498.255	28.01724

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Weld Analysis (continued)

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Appendix F: Overturning Analysis

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**KAISER ENGINEERS
HANFORD**

Calc. No. N/A

Revision 0

Page No. of

DESIGN ANALYSIS

Client Westinghouse

WO/Job No. C01909

Subject 241 AZ Trough Analysis

Date 9/27/95

By Mark Axup

Checked 9/28/95

By *Thomas Petersen*

Location 200 E

Revised

By

OVERTURNING WIND CALCULATION FOR 50 TON HYDRAULIC TRAILER**OBJECTIVE:**

Check adequacy of trussed structure (trough) against overturning due to wind for the following two load cases:

1. Strongback and 36" truss in vertical position without carriage.
2. Strongback and 36" truss in vertical position without carriage but with a 5000 lb. load concentrated at top and offset 1 foot.

Overturning wind calculations have originally been done by Jordan Engineering for the 50 ton hydraulic trailer carrying a solid 4.5 ft. dia. cylinder in the vertical position. The design wind pressure, without the force coefficient C_f , was 10 psf. which conservatively corresponds with a 45 mph wind for safety class 3 structure in exposure category C as shown below. A 45 mph wind is the maximum allowable wind speed for operation of the trailer as stated in section 2.2 of the Westinghouse Hydraulic Trailer Operation Manual, vendor information manual no. 22642.

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

See (Eq.3), ASCE 7-93

where

$$I = 1.07$$

$$V = 45$$

$$K_z = 1.29 @ 80 \text{ ft.}$$

$$q_z = 7.66 \text{ psf use } 10.0 \text{ psf}$$

The Jordan Engineering overturning calculations are contained in Westinghouse 50 Ton Hydraulic Trailer, Final Submittal Specification WHC-S-0256, Rev. 2, vendor information manual no. 22642. These pages are also duplicated and included in this calculation as pages F-5 through F-7.

This calculation will qualify the above two load cases using the same trailer dimensions as per the original calculation by Jordan Engineering. The design wind load of 10 psf. will be modified in accordance with the wind analysis method contained in ASCE 7-93 to reflect the unique structural geometry of the trussed trough as shown on drawings H-2-83768 shts. 1-9.

Design loading:

Weight of trailer + strongback

See page F-6

$$35,000 + 15,000 = 50,000 \text{ lbs.}$$

Weight of 36" truss = 10,640 lbs.

See CC:Mail message from Tom Mackey, page F-8

ASCE 7-93 design wind pressures.

$$F = q_z G_h C_f A_f$$

See "Other Structures", table 4

$$q_z G_h = 10 \text{ psf.}$$

As stated above.

C_f is determined from table 15 for trussed triangular towers and is a function of the ratio of the solid area to gross area of tower face.

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Page No. of

DESIGN ANALYSISClient Westinghouse
Subject 241 AZ Trough Analysis

WO/Job No. C01909

Date 9/27/95

Checked 9/28/95

Revised

By Mark Axup

By *Shirley Peterson*

By

Location 200 E

Wind Overturning Analysis: (Cont'd.)

Conservatively, check ratio of solids to gross for truss as depicted on view C, sht. 3 of H-2-83768. For members shown with an asterisk, (*), see section B, sht. 5.

Typical section between col. lines spaced at approx. 5'-9" consists of the following members. Approximate depth of truss is 3'-9".

Member Description	Area (ft. ²)
TS 4x4x ³ / ₈ x5'-9" (horizontal)	1.917
TS 6x6x ³ / ₈ x5'-9" (horizontal)	2.875
TS 4x2x ¹ / ₄ x3'-4" (vertical)	0.556
TS 4x2x ⁵ / ₁₆ x7'-0" (diagonal)	1.167
*TS 1 ¹ / ₂ x1 ¹ / ₂ x ¹ / ₈ x5'-6" (rotated 45 deg.)	0.972
*TS 2 ¹ / ₂ x1 ¹ / ₂ x ³ / ₁₆ x5'-6" (doubled, rotated 45 deg.)	1.789
*L 2x2x ¹ / ₄ x5'-6" (rotated 45 deg.)	1.296
Total	10.573

$$\text{Gross Area} = 5.75 \times 3.75 = 21.562 \text{ ft.}^2$$

$$\frac{\text{Solid Area}}{\text{Gross Area}} = \frac{10.573}{21.562} = 0.49 \quad \text{Therefore, from table 15, } C_f = 1.7$$

A review of original wind overturning calculations by Jordan Engineering shows that the basic wind pressure of 10 psf was modified (multiplied) by force coefficients of 1.0 for the upper circular part of the cannister and 1.4 for the lower portion including the strongback. This calculation will use the same methodology and conservatively use $C_f = 1.7$ for the entire length of the raised vertical trough. For the strongback, use $C_f = 1.05$ (interpolating from table 12)

Length of strongback = 24.5 ft.

Length of trough extending past strongback = 39.0 ft.

Extension of outriggers from center of trailer = 8.0 ft.

$$\text{Top wind load area} = 3.75 \times 39.0 \times 0.49 = 71.66 \text{ ft}^2$$

$$\text{Bottom wind load area} = 7.43 \times 24.5 \times 1.0 = 182.1 \text{ ft}^2$$

$$\text{Top wind load} = 71.66 \times 10.0 \times 1.7 = 1218.26 \text{ lbs.}$$

$$\text{Bottom wind load} = 182.1 \times 10.0 \times 1.05 = 1912.05 \text{ lbs.}$$

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Calc. No. N/A

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DESIGN ANALYSISClient Westinghouse
Subject 241 AZ Trough Analysis

WO/Job No. C01909

Date 9/27/95

By Mark Axup

Checked 9/28/95

By *Shirley Peterson*

Location 200 E

Revised

By

Wind Overturning Analysis: (Cont'd.)**Check Load Cases:****Load Case 1**Wind OT moment = $(1218.26 \times 51.5) + (1912.05 \times 19.75) = 100,503.4 \text{ ft-lbs.}$ Dead weight resisting moment = $(50,000 + 10,640) \times 8.0 = 485,120.0 \text{ ft-lbs.}$ F.S. against overturning = $\frac{485,120.0}{100,503.4} = 4.83$ **Load Case 2**OT moment (wind + offset load) = $100,503.4 + 5000.0 \times 1.0 = 105,503.4 \text{ ft-lbs.}$ Dead weight resisting moment = $485,120.0 + 5000.0 \times 7.0 = 520,120.0 \text{ ft-lbs.}$ F.S. against overturning = $\frac{520,120.0}{105,503.4} = 4.93$

**OVERTURNING DUE TO WIND
LOADING WITH THE STRONG BACK
IN THE VERTICAL POSITION**

SUM F_y = ORL-25200 LBS (62' TRANSPORT ASSY.)-15000 LBS (STRONG BACK ASSY)-35,000 LBS TRAILER ASSY=0

ORL=OUTRIGGER LOADING VERTICAL= 75,200 LBS.

ASSUME THAT EACH SIDE IS EQUAL SO THAT EACH SET OF OUTRIGGERS SEES 1/2 ORL OR 37,600 LBS.

THE TOP LOAD OF 6500 LBS. WAS REMOVED FOR THIS CALCULATION

TRAILER OVERTURNING FORCE DIAGRAM

USE PAGE 50&51 FOR OUTRIGGER LOADING

WIND LOADS USED ARE AS FOLLOWS

TOP WIND LOAD AREA = 4.5 FT. X 39' = 175.5 sq.ft.

BOTTOM WIND LOAD AREA = 5.58' X 24.5' = 136.7 sq.ft.

TOP WIND LOAD = 175.5 sq.ft. x 10 lb/sq.ft. = 1755 lbs.

BOTTOM WIND LOAD = 136.7 sq.ft. x 14 lbs./sq. ft. = 1913 lbs

SUM OF THE MOMENTS ABOUT THE OFF SIDE OUTRIGGER

TRL=TRAILER LOAD (lbs.)

SB = STRONG BACK LOAD (lbs.)

TP = TRANSPORT ASSY 62' (lbs.)

WLT= WIND LOAD AT THE TOP OF THE TRANSPORT ASSY. (lbs.)

WLB = WIND LOAD AT THE BOTTOM OF THE ASSY. (lbs.)

DIST1= DISTANCE FROM THE FOOT OF THE OUTRIGGER TO THE
PERPENDICULAR OF THE CG OF TRL,SB,AND TP.(in.)

DIST2 = DISTANCE FROM THE OUTRIGGER FOOT TO THE
PERPENDICULAR OF THE REACTION FORCE FROM THE TOP WIND LOAD
REACTION (lbs.)

DIST3 = DISTANCE FROM THE OUTRIGGER FOOT TO THE
PERPENDICULAR OF THE BOTTOM LOAD REACTION(in.)

OVM = OVER TURN MOMENT

WM = WIND MOMENT

OVM = DIST1 * (TRL+SB+TP) = 96 *(35000 + 15000 +25200) = 7,219,200 in-lbs.

WM = DIST2*WLT +DIST3*WLB = 618*-1755 +237*-1950 = 1,546,740 in-lbs.

SHOWS THAT "FACTOR OF SAFTEY FOR OVERTURNING"

F.S.O.T. =7,219,200/1,546,740 = 4.67 TO 1

Author: Thomas C Mackey at ~WHC396
Date: 8/18/95 7:14 AM
Priority: Normal
TO: Bradford L Coverdell at ~WHC240
? : John L Julyk at ~KEH16
: Mark D Axup at ~KEH16
C: Richard N Kyle at ~WHC239
CC: Kenneth D Junt at ~WHC339
CC: Thomas C Mackey
CC: Theresa K Peterson at ~KEH7
Subject: 101-AZ Truss Weight

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

FYI

The weight of the subject 20" truss (trough) is 11,960#.
The weight of the 36" is 10,640#.

These are the weights painted on the equipment.

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Appendix G: Frequency Analysis

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INTRODUCTION

This set of calculations is used to determine the adequacy of the trough to resist the effects resonance due to vortex shedding.

SUMMARY OF RESULTS

From the FEA model it was determined that the natural frequency of the loaded trough is 4.2 hz. Hand calculations show that the driving frequency due to vortex shedding will range between 1.8 and 2.8 hz. The driving frequency range is due to the transition between laminar and turbulent flow.

DESCRIPTION

The trough is a 64 ft long device used in the process of removing equipment from highly radioactive waste tanks. It was deemed possible for resonance due to vortex shedding to occur. For this reason, a FEA model of the loaded trough was created to determine its' natural frequency. Hand calculation were used to determined the driving frequency due to vortex shedding. The two frequencies are then compared to determine if resonance could occur.

RESULTS/CONCLUSIONS

From comparison of the trough natural frequency (4.2 hz) to the driving frequency due to vortex shedding (1.8 to 2.8 hz), it is apparent that they are far enough apart to preclude resonance.


```

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*****
**
**
** CCCC 0000 SSSS M M 0000 SSSS / M M **
** C 0 0 S MM MM 0 0 S / MM MM **
** C 0 0 SSSS M M M M 0 0 SSSS / M M M M **
** C 0 0 S M M M 0 0 S / M M M **
** CCCC 0000 SSSS M M 0000 SSSS / M M **
**
**
**
**          VERSION: 1.71
**        DISTRIBUTED BY:
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**
*****
*****

```

Licensed to :
 Problem name: AZTR_BLC11B_FREQ
 Date : 08/24/1995 Time: 07:13:26
 Title :
 |
 Subtitle :

CONTROL INFORMATION

```

NUMBER OF LOAD CASES . . . . . (NLCASE) = 1
SOLUTION MODE . . . . . (MODEX) = 2
  EQ. 0, STATIC ANALYSIS
  EQ. 1, BUCKLING ANALYSIS
  EQ. 2, DYNAMIC ANALYSIS
THERMAL LOADING FLAG . . . . . (ITHERM) = 0
  EQ. 0, NO THERMAL EFFECTS CONSIDERED
  EQ. 1, ADD TEMPERATURE EFFECT
GRAVITY LOADING FLAG . . . . . (IGRAV) = 0
  EQ. 0, NO GRAVITY LOADING CONSIDERED
  EQ. 1, ADD GRAVITY LOADING EFFECT
CENTRIFUGAL LOADING FLAG . . . . . (ICNTRF) = 0
  EQ. 0, NO CENTRIFUGAL LOADING CONSIDERED
  EQ. 1, ADD CENTRIFUGAL LOADING EFFECT
IN-PLANE STIFFENING FLAG . . . . . (INPLN) = 0
  EQ. 0, NO IN-PLANE EFFECTS CONSIDERED
  EQ. 1, IN-PLANE EFFECTS CONSIDERED

```

SOFT SPRING ADDITION FLAG (ISOFT) = 0
 EQ. 0, NO SOFT SPRING OPTION
 EQ. 1, SOFT SPRING ADDED

SAVE DECOMPOSED STIFFNESS MATRIX FLAG . . . (ISAVK) = 0
 EQ. 0, DO NOT SAVE DECOMPOSED K
 EQ. 1, SAVE DECOMPOSED K

FORM STIFFNESS MATRIX FLAG (IFORMK) = 0
 EQ. 0, FORM STIFFNESS MATRIX
 EQ. 1, USE EXIST DECOMPOSED STIFFNESS MATRIX

TOTAL SYSTEM DATA

NUMBER OF EQUATIONS (NEQ) = 43640
 NUMBER OF MATRIX ELEMENTS (NWK) = 25917887
 MAXIMUM HALF BANDWIDTH (MK) = 1794
 MEAN HALF BANDWIDTH (MM) = 593
 NUMBER OF ELEMENTS (NUME) = 7999
 NUMBER OF NODAL POINTS (NUMNP) = 7281
 ADJUSTED BLOCK SIZE (MTBLK) = 372049
 NUMBER OF STIFFNESS BLOCKS (NBLK) = 70

MAXIMUM DIAGONAL STIFFNESS MATRIX VALUE = 0.926177E+10 (40693)
 MINIMUM DIAGONAL STIFFNESS MATRIX VALUE = 0.110997E+06 (8575)

1

MASS MOMENT INFORMATION					
MASS	0.299103E+02	VOLUME	0.409744E+05	WEIGHT	0.000000E+00
MASS MOMENT OF INERTIA W.R.T. C.G.					
IX	0.154052E+05	IY	0.136532E+07	IZ	0.135834E+07
MASS PRODUCT OF INERTIA W.R.T. C.G.					
PXY	0.286927E+04	PXZ	-0.243830E-02	PYZ	-0.265892E-01
RADII OF GYRATION W.R.T. C.G.					
RX	0.226946E+02	RY	0.213652E+03	RZ	0.213105E+03
CENTER OF GRAVITY					
CGx	0.349781E+03	CGy	0.153938E+02	CGz	0.521111E-06
PRINCIPAL MASS MOMENT OF INERTIA					

P1	0.136533E+07	P2	0.135834E+07	P3	0.153991E+05
PRINCIPAL RADII OF GYRATION					
R1	0.213652E+03	R2	0.213105E+03	R3	0.226901E+02
PRINCIPAL AXES (DIRECTION COSINES IN ROWS W.R.T C.G)					
N_11	0.212550E-02	N_12	-0.999998E+00	N_13	-0.380677E-05
N_21	-0.855476E-05	N_22	0.400484E-02	N_23	0.999992E+00
N_31	-0.999990E+00	N_32	-0.212548E-02	N_33	-0.424487E-07

SOLUTION PARAMETERS

NUMBER OF EIGENVALUES.	(NFR)=	5
MASS TYPE: 1-LUMPED,2-CONSISTENT. . . .	(MASS)=	1
MODE SHAPE PRINT FLAG.	(MPRNT)=	0
INTERMEDIATE SOLUTION PRINT FLAG	(IFPR)=	0
STURM SEQUENCE CHECK FLAG.	(IFSS)=	0
MAXIMUM NUMBER OF ITERATIONS	(ITMAX)=	16
FREQUENCY SHIFT FLAG	(IFRSH)=	0
FREQUENCY SHIFT.	(FRSH)=	0.0000000E+00
CONVERGENCE TOLERANCE.	(RTOL)=	0.1000000E-04
COMPOSITE MODAL DAMPING CALC. FLAG . . .	(IMDC)=	0
MODAL ACCELERATION FLAG.	(IMAM)=	0

SUBSPACE ITERATION

ITERATION	NUMBER	1
ITERATION	NUMBER	2
ITERATION	NUMBER	3
ITERATION	NUMBER	4
ITERATION	NUMBER	5

ITERATION NUMBER 6

ITERATION NUMBER 7

CONVERGENCE REACHED FOR RTOL 0.1000E-04

FREQUENCY ANALYSIS
by
SUBSPACE ALGORITHM

FREQUENCY NUMBER	FREQUENCY (RAD/SEC)	FREQUENCY (CYCLES/SEC)	PERIOD (SECONDS)
1	0.2610489E+02	0.4154722E+01	0.2406900E+00
2	0.2762723E+02	0.4397010E+01	0.2274273E+00
3	0.5331185E+02	0.8484845E+01	0.1178572E+00
4	0.8672043E+02	0.1380198E+02	0.7245335E-01
5	0.1205615E+03	0.1918796E+02	0.5211601E-01

SOLUTION TIME	LOG (sec)
INPUT PHASE	19
ASSEMBLAGE OF THE STIFFNESS MATRIX	54
ASSEMBLAGE OF THE MASS MATRIX	0
DECOMPOSITION OF THE STIFFNESS MATRIX	2312
EIGENVALUE SOLUTION	1858
OUTPUT PHASE	13
TOTAL SOLUTION TIME	4256

ICF KAISER**HANFORD COMPANY****DESIGN ANALYSIS**

Calc. No. _____

Revision 0Page No. 1 ofClient: Westinghouse Hanford CompanySubject: 241AZ Truss AnalysisLocation: 200 E /WO/Job No. C01909Date: 06/28/95Checked: 9/29/95

Revised: _____

By: B. L. CoverdellBy: 88

By: _____

PURPOSE:

This section of calculations is used to determine the excitation frequency of the container due to wind.

CONSIDERATIONS:

- 1) Vortex shedding off the cylindrical carriage is worse off the sparse frame of the trough.

DESCRIPTION:

The excitation frequency due to wind on the trough and cylindrical carriage assembly is caused by vortex shedding. Vortex shedding causes a periodic change in side pressure on the cylindrical carriage. The equations determining the frequency of the change in side pressure were determined from Blevins 1977.

CALCULATIONS

$V_o = 15 \text{ mph}$ Maximum wind velocity that the trough and carriage will be rotated into the vertical position.

$d = 28 \text{ in}$ Diameter of the carriage.

$\rho = 0.00234 \cdot 32.2 \cdot \frac{\text{lb}}{\text{ft}^3}$ Density of air at standard temperature and pressure (converted from slugs to pounds-mass).

$\mu = 3.78 \cdot 10^{-7} \cdot \frac{\text{lb} \cdot \text{sec}}{\text{ft}^2}$ Viscosity of air at standard temperature and pressure.

$Re = \frac{V_o \cdot d \cdot \rho}{\mu}$ $Re = 3.18 \cdot 10^5$ Reynolds number.

$S = \begin{pmatrix} .19 \\ .3 \end{pmatrix}$ Strouhal numbers determined from the graph of Reynolds number versus Strouhal number on page 15 of Blevins 1977. Due to the spread of data, the strouhal number has an upper and lower bound

$$n = \frac{S \cdot V_o}{d}$$

$n = \begin{pmatrix} 1.791 \\ 2.829 \end{pmatrix} \cdot \text{hz}$ The range of excitation frequency.

RESULTS AND CONCLUSIONS:

The range of excitation frequencies combined with the natural frequency output from the finite element analysis model AZTR_BLC11B_FREQ shows that resonance should not occur.

REFERENCES:

Blevins R. D., 1977, *Flow-Induced Vibration*, Van Norstrand Reinhold and Company, New York, New York.

Appendix H: Carriage Maximum Wheel Load Calculations

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ICF KAISER

HANFORD COMPANY

DESIGN ANALYSIS

Calc. No. _____

Revision 0

Page No. 1 of _____

Client: Westinghouse Hanford Company

Subject: 241AZ Trough Analysis

Location: 200 E /

WO/Job No. C01909

Date: 06/28/95

Checked: 9/29/95

Revised: _____

By: B. L. Coverdell

By: [Signature]

By: _____

PURPOSE:

This set of calculations determines the maximum allowable carriage wheel load on the two 2 1/2 x 1 1/2 x 3/16 TS.

CALCULATIONS:

$L = 69.25 \text{ in}$ Maximum length of tube steel to be analyzed (WHC 1995a and WHC 1995b).

$c = \frac{2.5 \text{ in}}{2}$ Distance to outer fiber (WHC 1995a and WHC 1995b).

$I_{xx} = 2.107 \text{ in}^4$ Moment of inertia about loaded axis (Appendix D, Page D-1).

$\sigma = 0.6 \cdot 36000 \text{ psi}$ $\sigma = 2.16 \cdot 10^4 \text{ psi}$ The maximum allowable stress in the tubular section per AISC 1989.

$M_{\max} = \frac{\sigma \cdot I_{xx}}{c}$ $M_{\max} = 3.641 \cdot 10^4 \text{ in-lbf}$ The maximum allowable bending moment in the beam.

$P_{\max} = \frac{8 \cdot M_{\max}}{L}$ $P_{\max} = 4.206 \cdot 10^3 \text{ lbf}$ The maximum allowable point load (carriage wheel load) in a beam fixed at either end per AISC 1989, page 3-125.

$\frac{P_{\max}}{2} = 2.103 \cdot 10^3 \text{ lbf}$ If an added factor-of-safety of 2 is preferred, then the maximum wheel load is 2100 lbf.

RESULTS AND CONCLUSIONS:

The 2 1/2 x 1 1/2 x 3/16 TS is adequate to support a maximum carriage wheel load of 2100 lbf.

REFERENCES:

AISC, 1989, *Manual of Steel Construction*, Ninth Edition, American Institute of Steel Construction, Chicago, Illinois.

WHC, 1995a, *Trough Assembly 36 in. Dia. x 64 ft Long*, drawing H-2-83768 Rev 0, Westinghouse Hanford Company, Richland, Washington.

WHC, 1995b, *Trough Assembly 20 in. Dia. x 64 ft Long*, drawing H-2-83769 Rev 0, Westinghouse Hanford Company, Richland, Washington.

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Appendix I: Connection Calculations

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INTRODUCTION

The data in this appendix is used to determine the maximum reaction force by the loaded trough on the strongback. The reaction force data is then used to determine the adequacy of the four 1 in A325 bolts.

SUMMARY OF RESULTS

From the FEA model output contained in this appendix, the maximum tensile load is 7,500 lbf and the maximum shear load is 20,600 lbf.

DESCRIPTION

The plot on the following page shows the nodes and the displacement boundary conditions applied to the FEA model AZTR_BLC11B. The displacement boundary conditions located closest to the origin represent the lower attachment points of the trough and those farthest away from the origin represent the upper attachments points. The plot is used to inform the reader as to the location of the reaction forces listed on the following pages. The reaction force listing output was used to determine the maximum force on the bolts. From this output it was quickly determined that any applied loading by the trough is less than that applied by the 241C106 shipping container.

RESULTS/CONCLUSIONS

The comparison of the reaction forces contained in this document to the ERS-W320 design connection load shows that the four A325 bolts are adequate to connect the trough to the strongback.

Plot of Reaction Forces and Respective Nodes

Reaction Forces from Load Case 10

Node	Csid	RFX	RFY	RFZ	RMX	RMY	RMZ
2786	0	-	1.03e+04	0.00e+00	-	-	-
2787	0	-	1.03e+04	0.00e+00	-	-	-
2788	0	5.12e-06	-1.63e+03	2.35e+03	-	-	-
3030	0	-5.03e-06	-1.63e+03	-2.35e+03	-	-	-

Reaction Forces from Load Case 51

Node	Csid	RFX	RFY	RFZ	RMX	RMY	RMZ
2786	0	-	1.17e+04	0.00e+00	-	-	-
2787	0	-	1.29e+04	0.00e+00	-	-	-
2788	0	1.23e+04	-3.79e+03	5.20e+03	-	-	-
3030	0	-1.23e+04	-2.97e+03	-3.27e+03	-	-	-

Reaction Forces from Load Case 52

Node	Csid	RFX	RFY	RFZ	RMX	RMY	RMZ
2786	0	-	1.17e+04	0.00e+00	-	-	-
2787	0	-	1.29e+04	0.00e+00	-	-	-
2788	0	1.23e+04	-3.84e+03	5.26e+03	-	-	-
3030	0	-1.23e+04	-3.02e+03	-3.34e+03	-	-	-

Reaction Forces from Load Case 53

Node	Csid	RFX	RFY	RFZ	RMX	RMY	RMZ
2786	0	-	1.33e+04	0.00e+00	-	-	-
2787	0	-	1.36e+04	0.00e+00	-	-	-
2788	0	1.23e+04	-5.70e+03	7.17e+03	-	-	-
3030	0	-1.23e+04	-4.68e+03	-5.25e+03	-	-	-

Reaction Forces from Load Case 54

Node	Csid	RFX	RFY	RFZ	RMX	RMY	RMZ
2786	0	-	1.29e+04	0.00e+00	-	-	-
2787	0	-	1.41e+04	0.00e+00	-	-	-
2788	0	1.23e+04	-5.60e+03	7.26e+03	-	-	-
3030	0	-1.23e+04	-4.78e+03	-5.34e+03	-	-	-

Reaction Forces from Load Case 55

Node	Csid	RFX	RFY	RFZ	RMX	RMY	RMZ
2786	0	-	-5.03e+02	0.00e+00	-	-	-
2787	0	-	7.15e+02	0.00e+00	-	-	-
2788	0	2.06e+04	-5.16e+02	1.40e+03	-	-	-
3030	0	-4.06e+03	3.04e+02	5.24e+02	-	-	-