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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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241AZ101 PUMP REMOVAL TROUGH ANALYSIS

September 29, 1995

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Author B. L. Coverdell

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

J L Julyk
J. L. Julyk Reviewer

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Author B. L. Coverdell

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☐	☐	☑	Mathematical derivations checked including dimensional consistency of results.
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James A Tuck
J. A. Tuck, Reviewer

29 Sept. 95
Date

CONTENTS

APPENDICES

FIGURES

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.

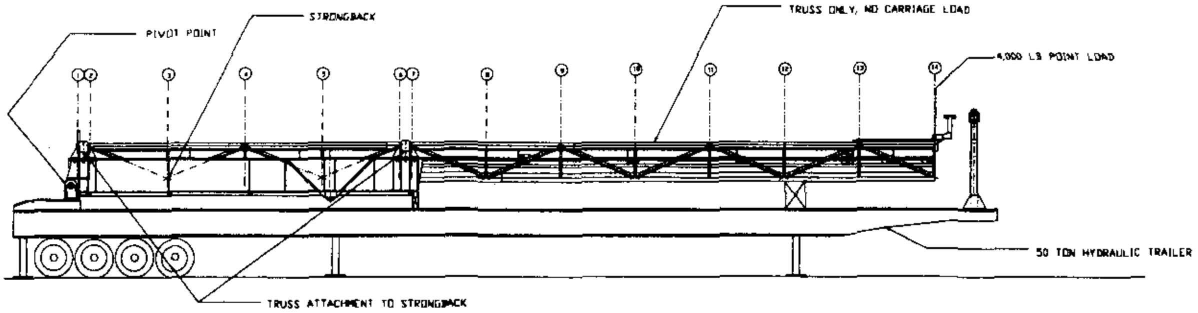
The scope of this task was to determine the structural adequacy of the 36 in. and 20 in. trough and the combined system of; the 241AZ101 trough, the carriage and the ERS-W320 hydraulic trailer system. Specific elements of this task were:

- 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.

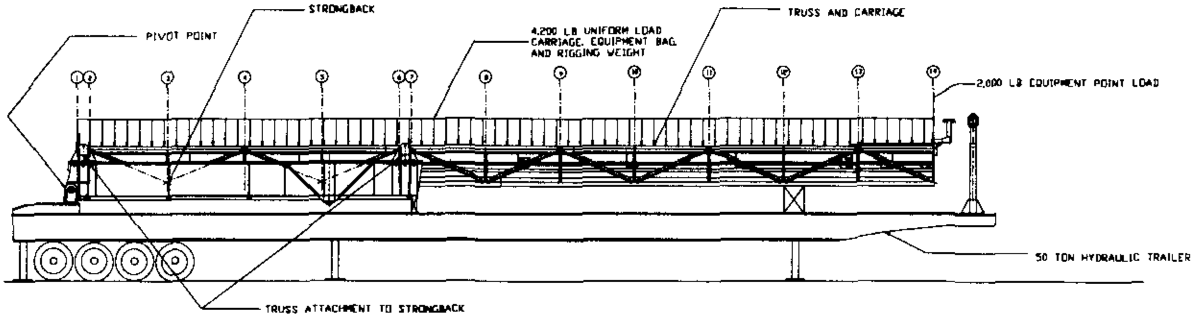
This design is in accordance with *Standard Architectural-Civil Design Criteria, Design Loads for Facilities* (DOE-RL 1993a) and is designated safety class 3. The design and fabrication is in accordance with the *Manual of Steel Construction* (AISC, 1989). The welding and weld inspection is in accordance 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 ¼ in. magnetic tape.



SIDE VIEW, 50 TON HYDRAULIC TRAILER WITH 20" OR 36" TRUSS
NO CARRIAGE, EQUIPMENT OR RIGGING
MAXIMUM EQUIVALENT LOADING = 4,000 LB POINT LOAD



SIDE VIEW, 50 TON HYDRAULIC TRAILER WITH 20' OR 36' TRUSS AND CARRIAGE

MAXIMUM LOAD DISTRIBUTION (NOTE: MAXIMUM CARRIAGE WHEEL LOAD IS 2,100 LB)

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, Indigo^2 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).

<u>A36 Structural Steel</u> F_y=36 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):

$F_b = F_t = F_a = ⅓F_y$ = 12 kip/in^2

Shear:

$F_v = 0.4 * F_y/2$ = 7.2 kip/in^2

Bearing:

$F_p = ⅓F_y$ = 12 kip/in^2

<u>A500 Structural Tubing</u> F_y=42 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):

$F_b = F_t = F_a = ⅓F_y$ = 14 kip/in^2

Shear:

$F_v = 0.4 * F_y/2$ = 8.4 kip/in^2

Bearing:

$F_p = ⅓F_y$ = 14 kip/in^2

<u>Connections</u>

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 tough 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/in^2 on effective area for A36 material and 8.4 kip/in^2 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 ½ x 1 ½ 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 x 4,000 lb = 5,000 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 $\mathrm{lbf/ft^2}$. 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 1.5*g* 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 1.5*g* 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 1.5*g* 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 wind[1] 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

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[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/in^2. 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/in^2 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/in^2. This is well below the allowable stress of 12,000 lbf/in^2 (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*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/ft^2 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 ¾ 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 toughs 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.

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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

ent: 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:
By:

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 carrage 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.

$V := 70 \cdot mph$ 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.

$q_z := 0.00256 \cdot \frac{lbf \cdot sec^2}{ft^4} \cdot K_z \cdot (I \cdot V)^2$ $q_z = 24.715 \cdot \frac{lbf}{ft^2}$ 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.

$h := 64 \cdot ft$ $D := 3 \cdot ft$ 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.

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

$F := q_z \cdot G_h \cdot C_f \cdot A_f$ $F = 7516 \cdot lbf$ Wind load to be applied to the AZ truss.

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

$P_l := p_z \cdot D$ $P_l = 9.79 \cdot \frac{lbf}{in}$ 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.

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

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ant: Westinghouse Hanford Company
ubject: 241AZ Truss Wind Analysis
Location: 200 E /

WO/Job No. C01909
Date: 06/28/95 **By:** B. L. Coverdell
Checked: 9/29/95 **By:**
Revised: **By:**

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

$q_z := 0.00256 \cdot \frac{\text{lbf} \cdot \text{sec}^2}{\text{ft}^4} \cdot K_z \cdot (I \cdot V)^2$ $q_z = 1.759 \cdot \frac{\text{lbf}}{\text{ft}^2}$ 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/ft^2 use 10 lbf/ft^2 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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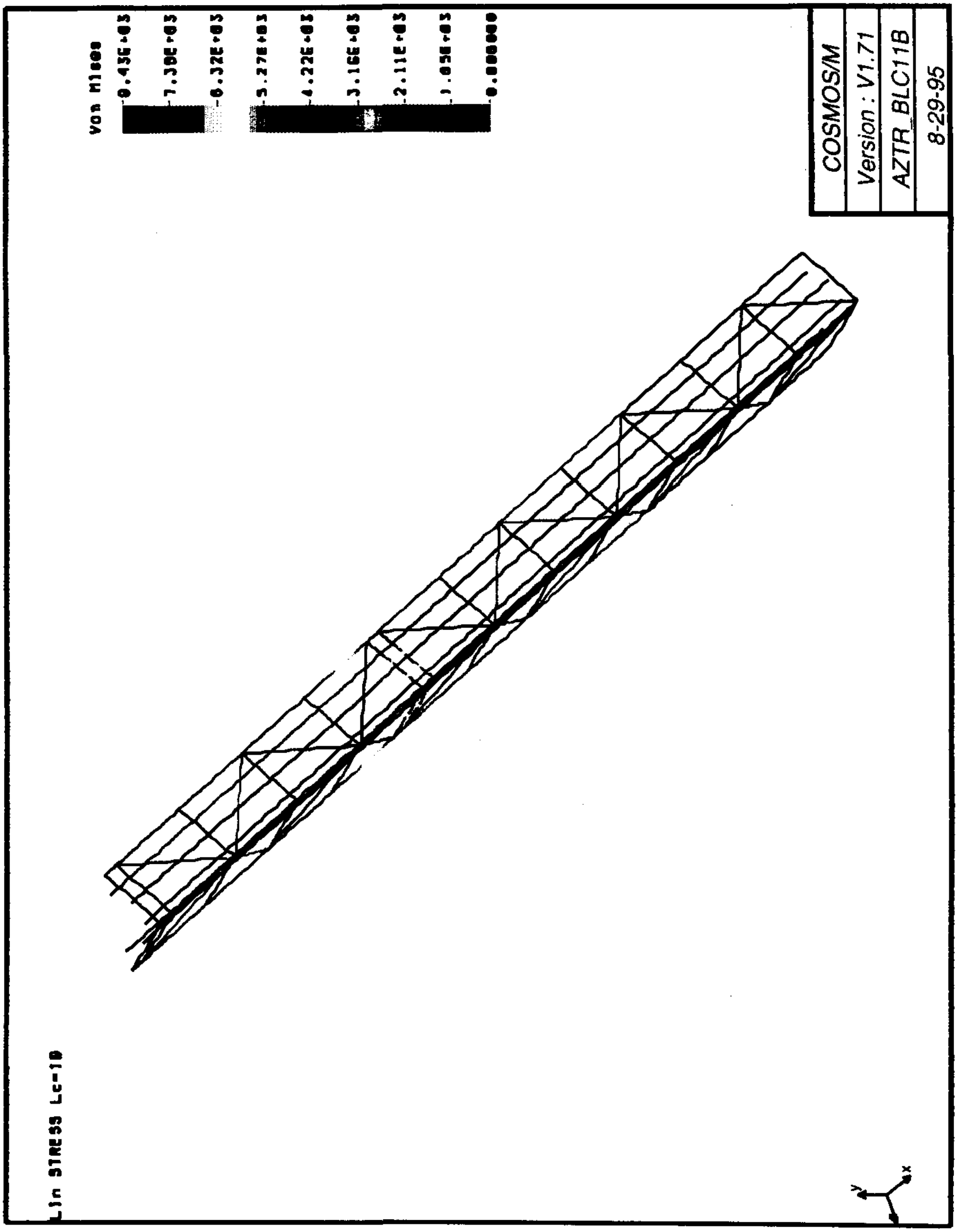
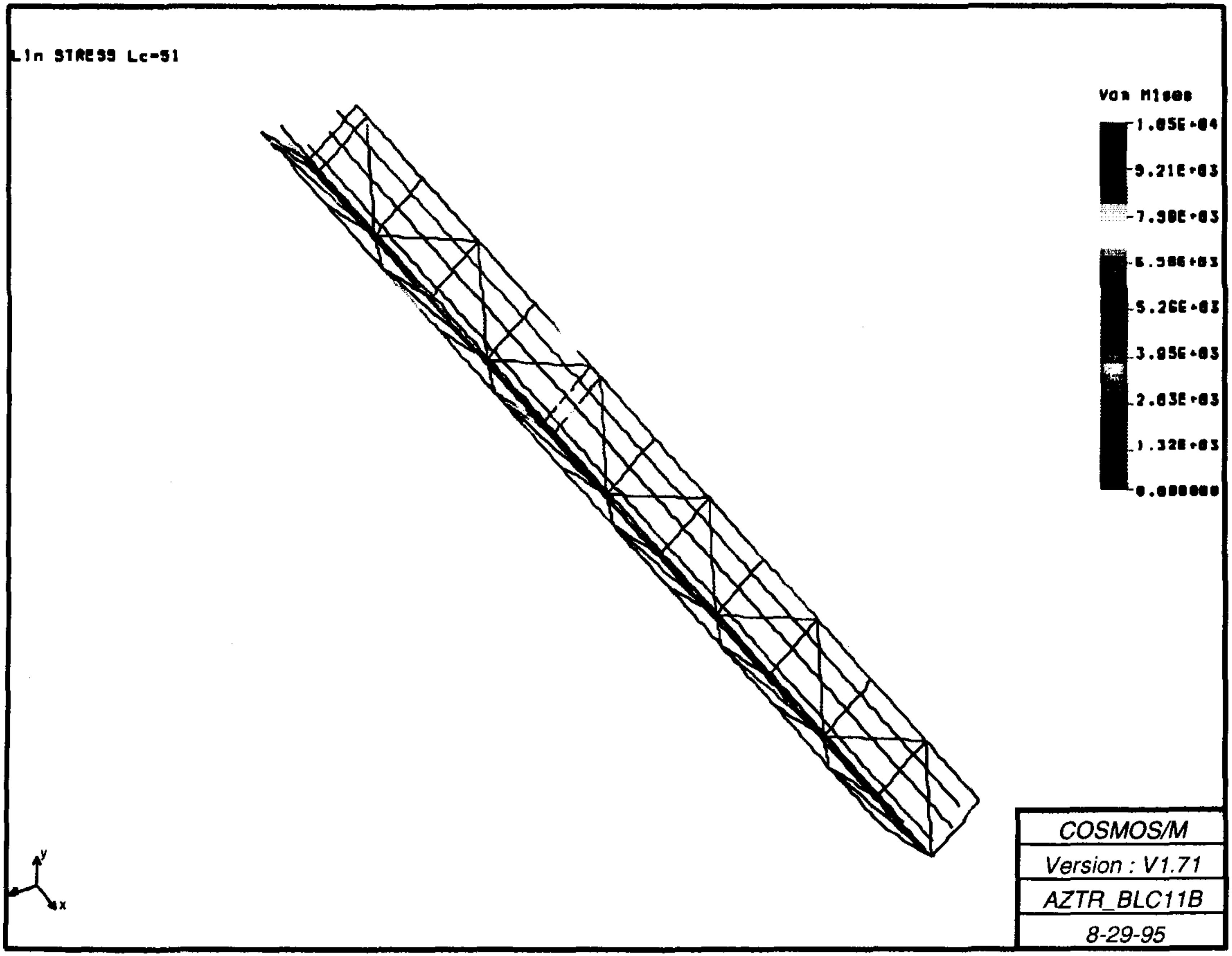
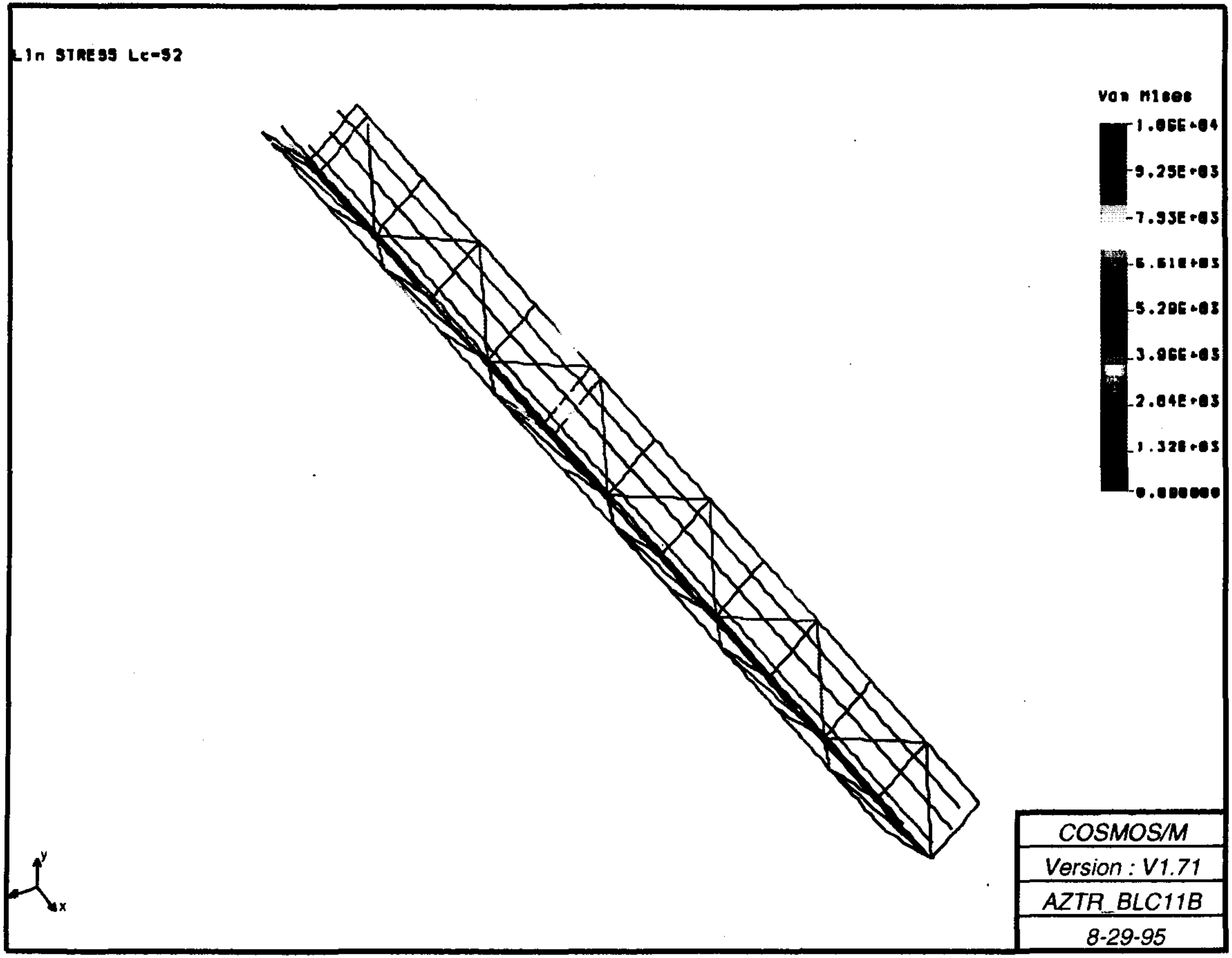


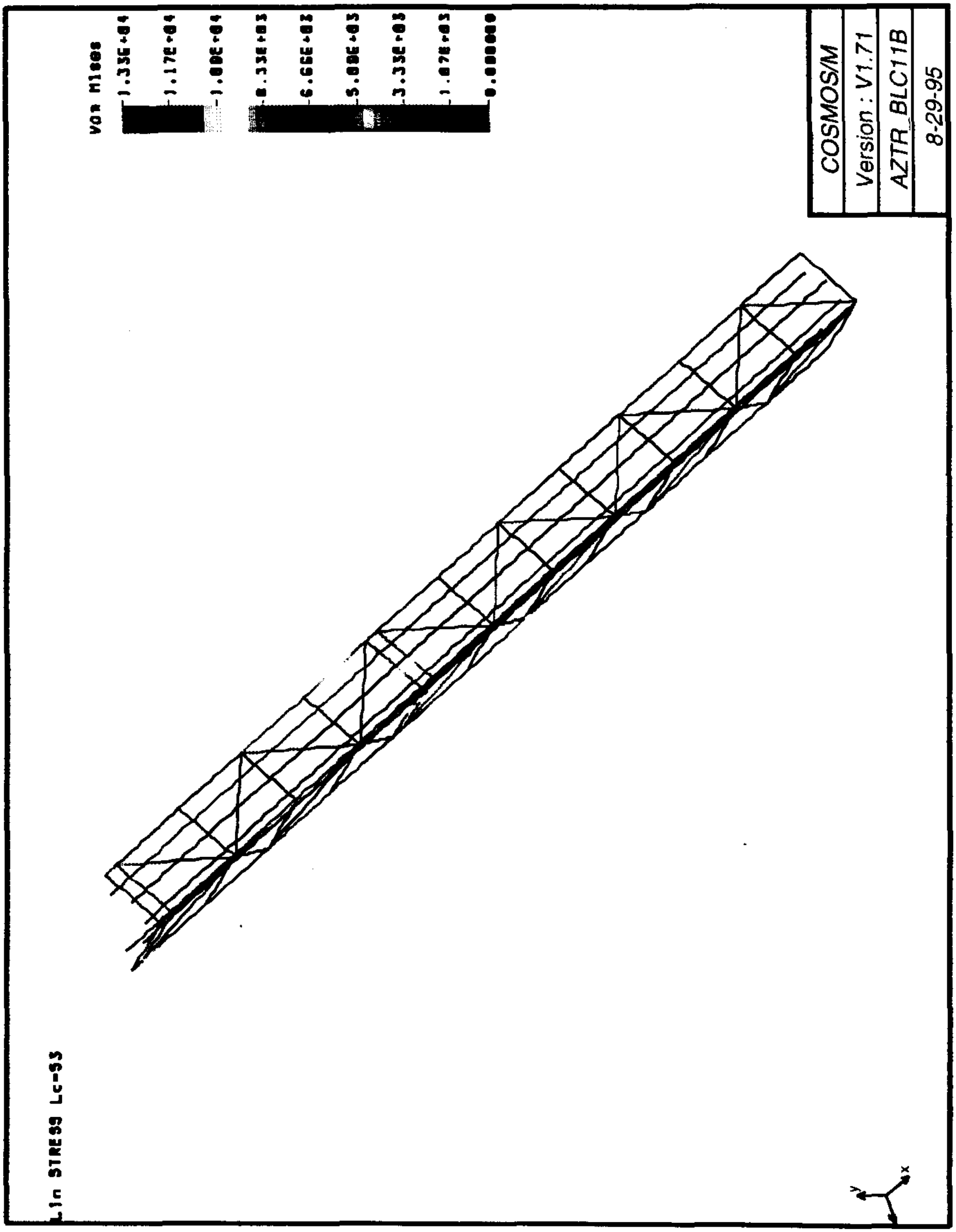
Maximum Von Mises Stress Plot Of Beam Members Only For Load Case 10



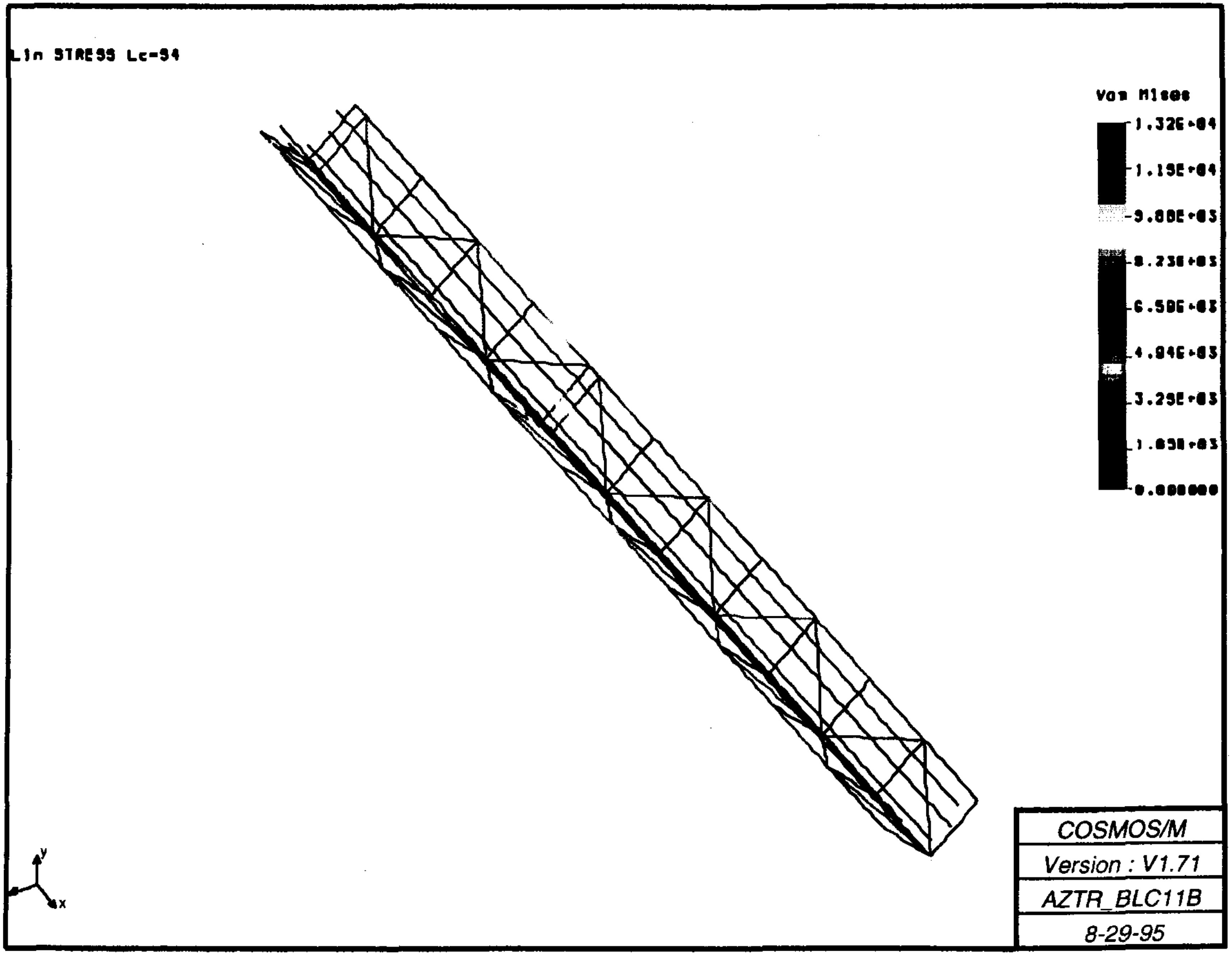
Maximum Von Mises Stress Plot Of Beam Members Only For Load Case 51



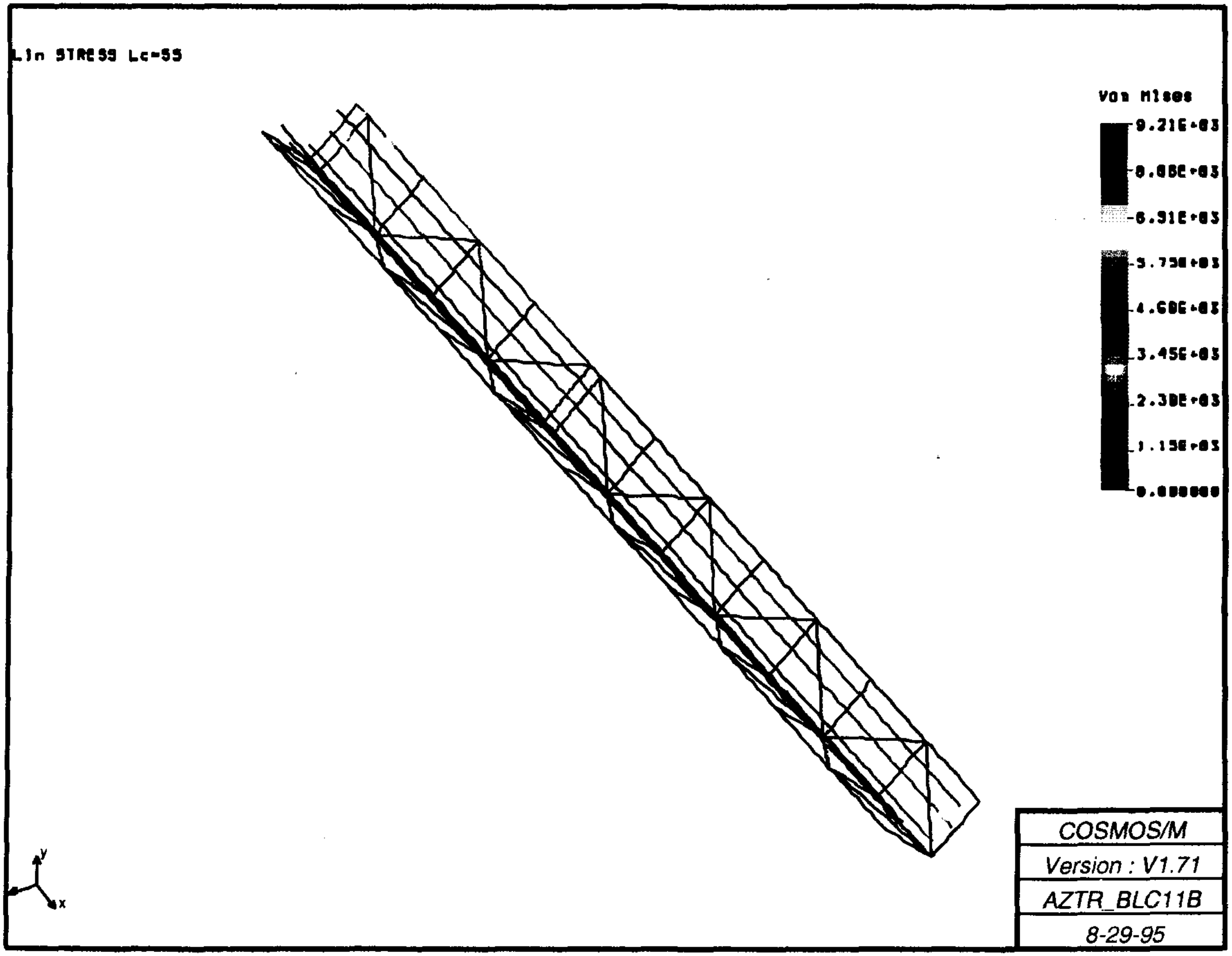
Maximum Von Mises Stress Plot Of Beam Members Only For Load Case 52



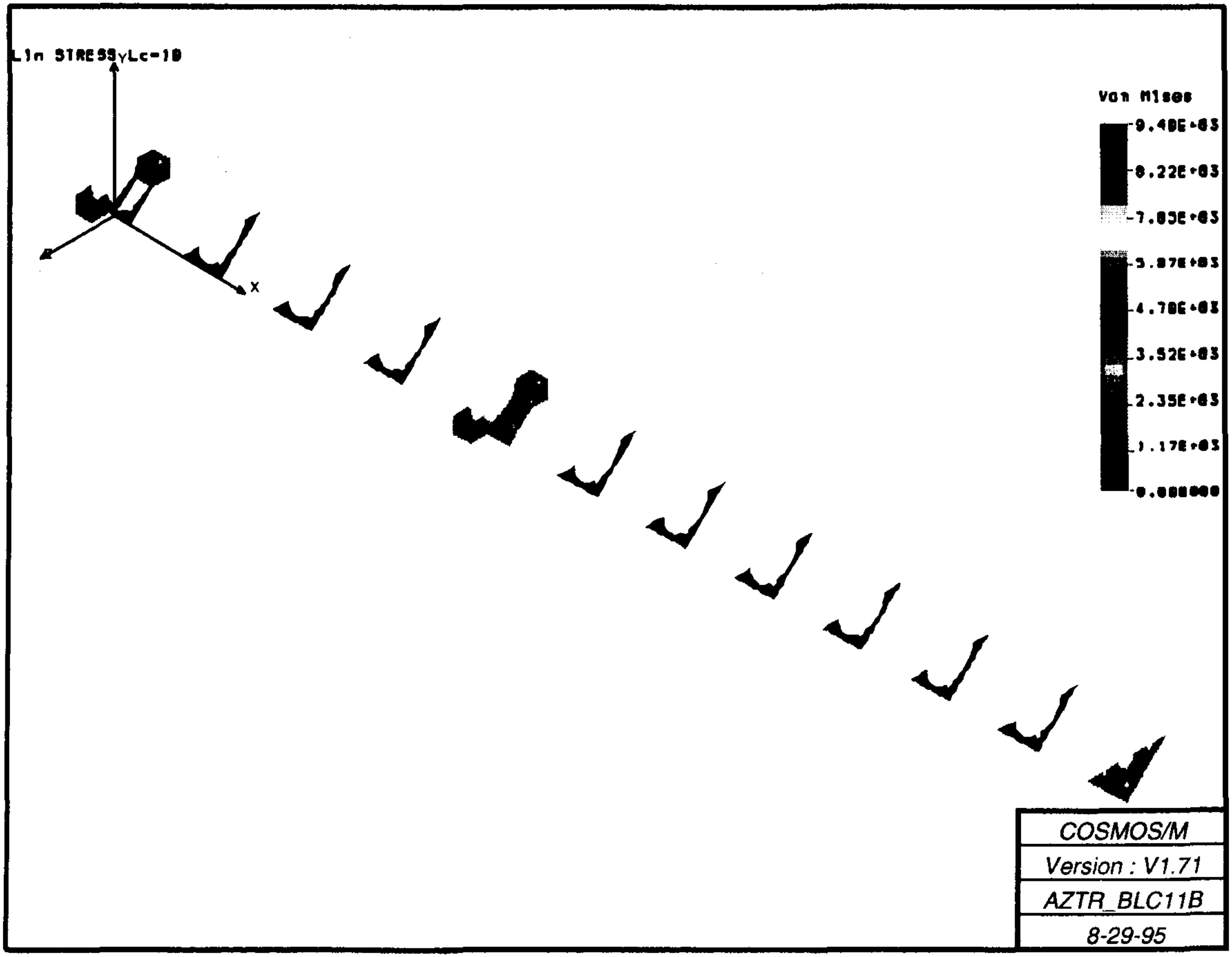
Maximum Von Mises Stress Plot Of Beam Members Only For Load Case 53



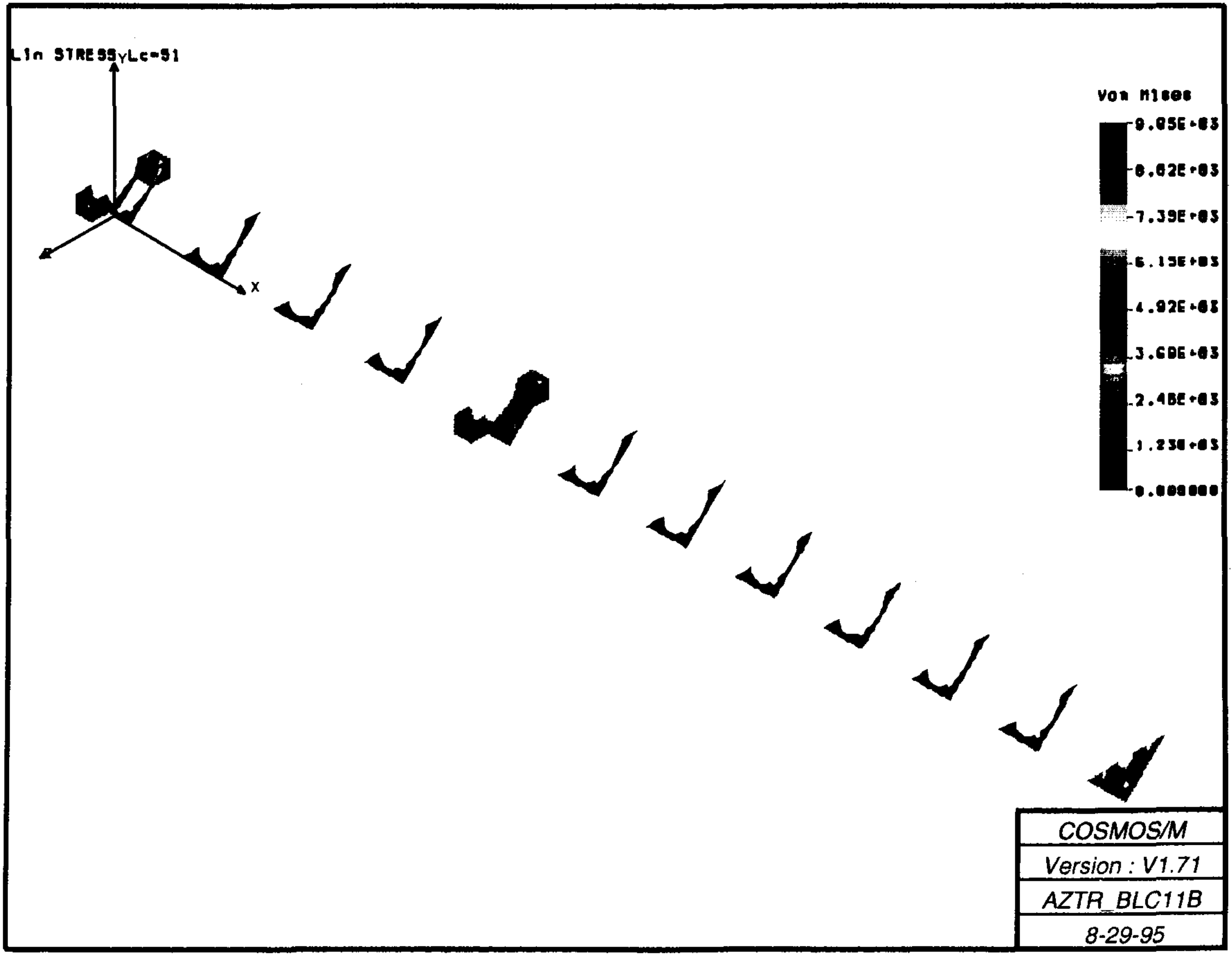
Maximum Von Mises Stress Plot Of Beam Members Only For Load Case 54



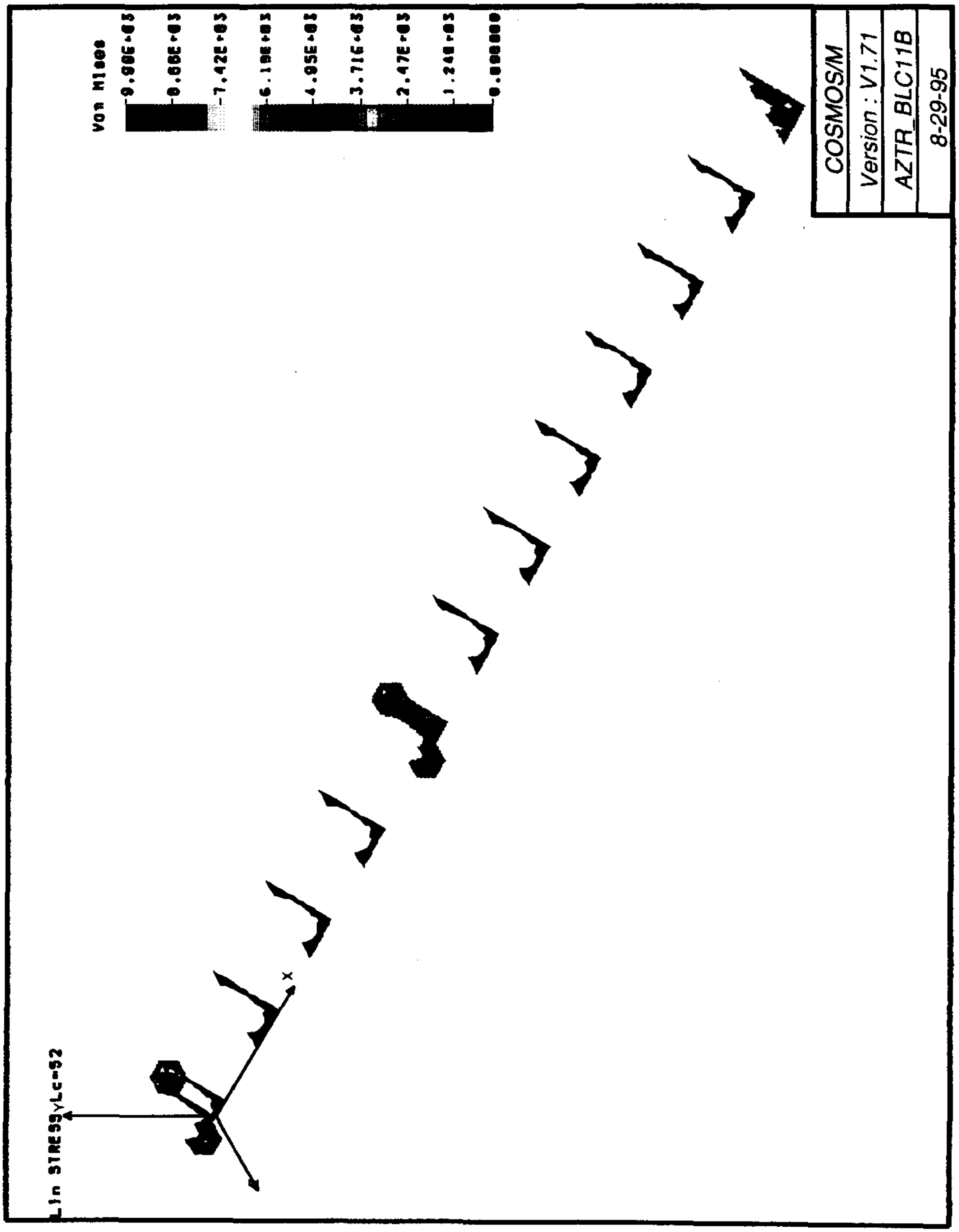
Maximum Von Mises Stress Plot Of Beam Members Only For Load Case 55



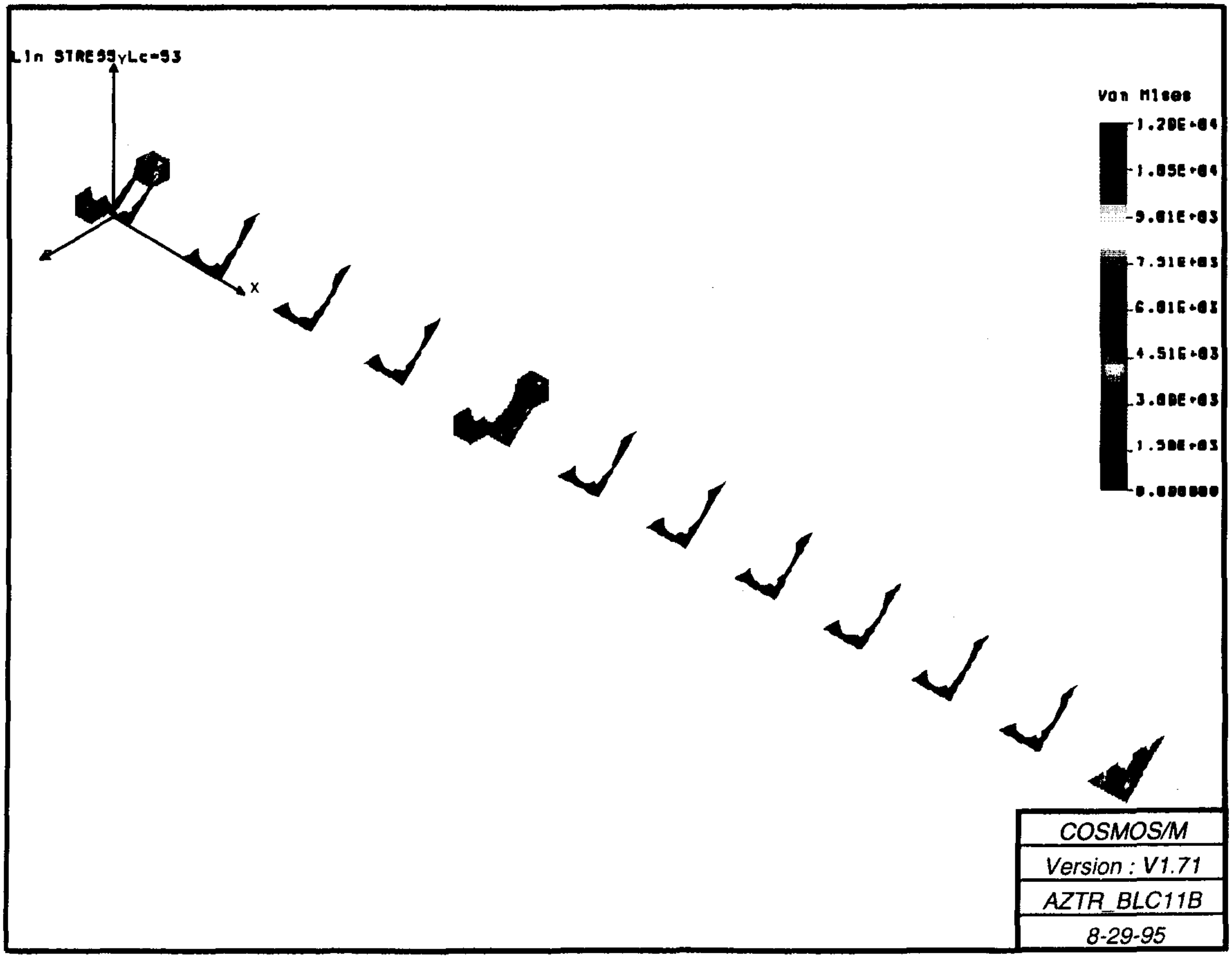
Maximum Von Mises Stress Plot Of Plate Members Only For Load Case 10



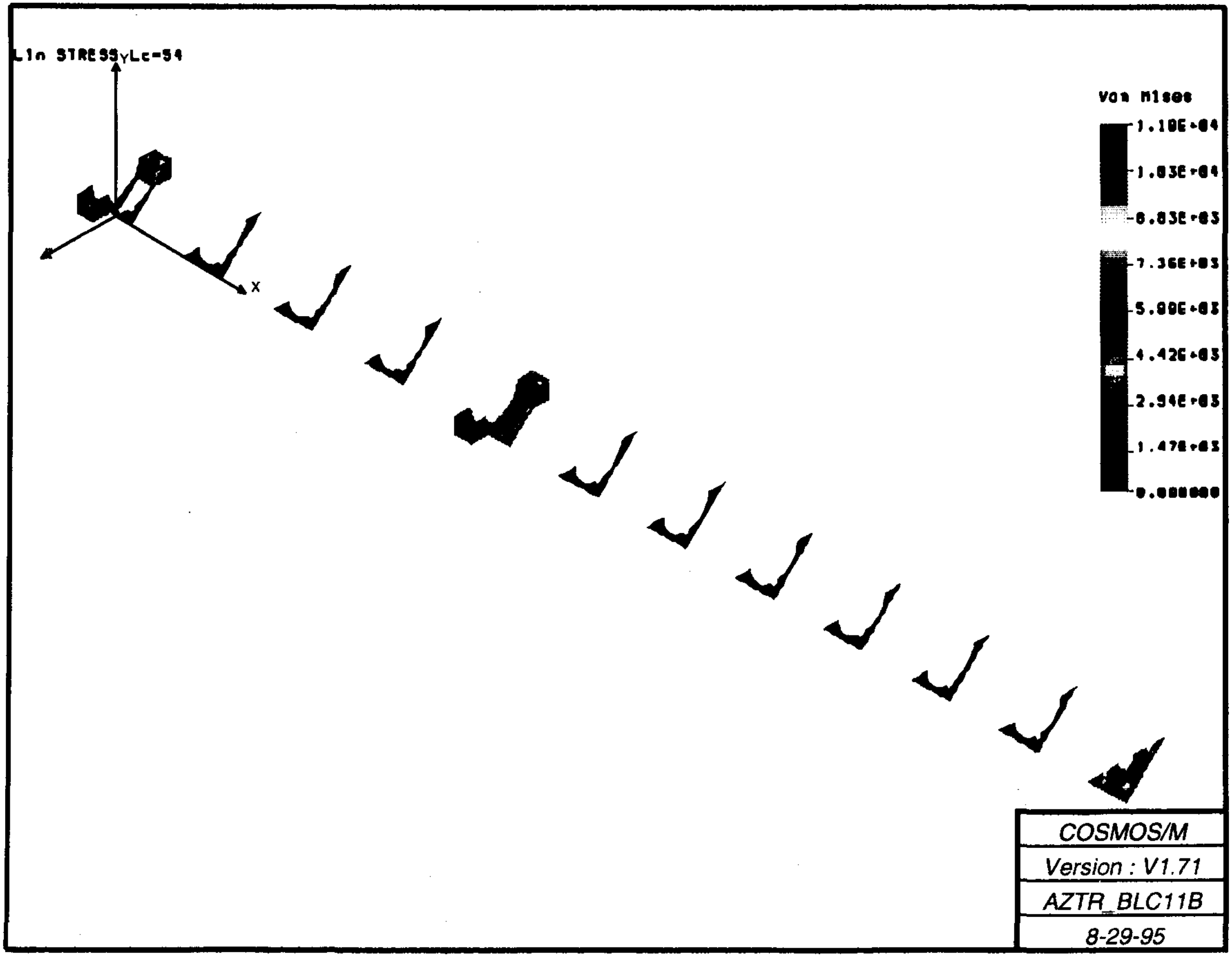
Maximum Von Mises Stress Plot Of Plate Members Only For Load Case 51



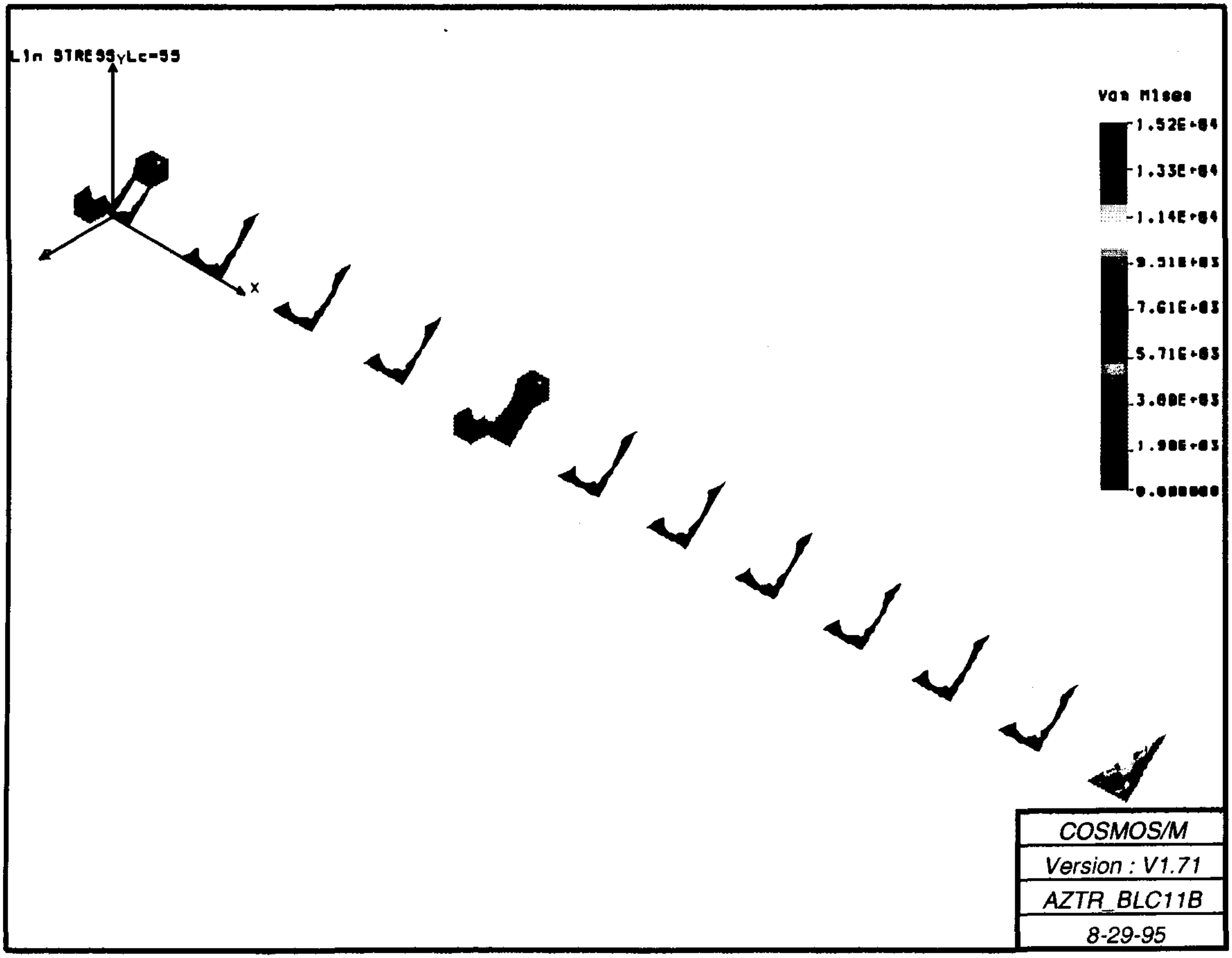
Maximum Von Mises Stress Plot Of Plate Members Only For Load Case 52



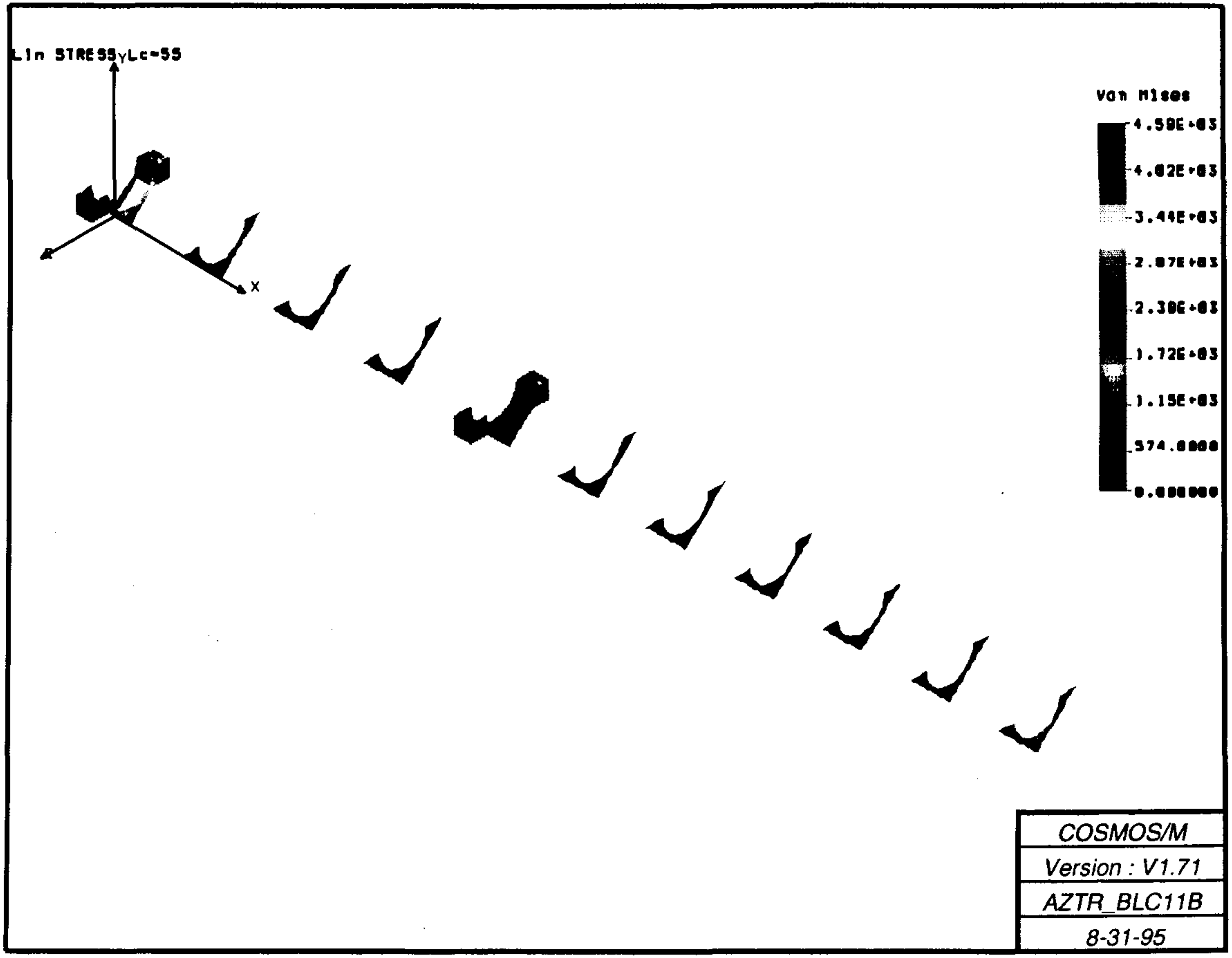
Maximum Von Mises Stress Plot Of Plate Members Only For Load Case 53



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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DESIGN ANALYSIS

Calc. No.

Revision 0

Page No. 1 of

ent: Westinghouse Hanford Company

oject: 241AZ Truss Buckling Analysis

Location: 200 E /

WO/Job No. C01909

Date: 06/28/95

Checked: 7/19/95

Revised:

By: B. L. Coverdell

By:

By:

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.

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

$Fy_{ts} := 46000 \cdot \mathrm{psi}$ Yield stress for all structural tubing (ASTM A500, Gr. B).

$Fy := 36000 \cdot \mathrm{psi}$ 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.

$S := 13.9 \cdot \mathrm{in}^3$ section modulus

$r_x := 2.27 \cdot \mathrm{in}$ radius of gyration about the x axis

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

$l := 69.25 \cdot \mathrm{in}$ maximum column length

$A := 8.08 \cdot \mathrm{in}^2$ cross sectional area

Determine the allowable stresses on the beam.

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

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

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

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

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HANFORD COMPANY **DESIGN ANALYSIS**

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ent: Westinghouse Hanford Company
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Checked: 7/19/95
By:
Location: 200 E /
Revised:
By:

$F_{bx} := 0.60 \cdot Fy_{ts}$ $F_{bx} = 27600 \cdot psi$ 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.

$F_r := 76444.9 \cdot lbf$ $V_s := 1597.9 \cdot lbf$ $V_t := 1665.2 \cdot lbf$

$M_s := 26969 \cdot lbf \cdot in$ $M_t := 26093.7 \cdot lbf \cdot in$

$f_a := \frac{F_r}{A}$ $f_a = 9461.002 \cdot psi$ Maximum compressive stress in the beam.

$f_v := \frac{\sqrt{V_s^2 + V_t^2}}{A}$ $f_v = 285.625 \cdot psi$ Maximum shear stress in the beam.

$f_{bx} := \frac{M_t}{S}$ $f_{bx} = 1877.245 \cdot psi$ Maximum bending stress about major axis of beam.

$f_{by} := \frac{M_s}{S}$ $f_{by} = 1940.216 \cdot psi$ Maximum bending stress about major axis of beam.

$x := f_a \le F_a$ $x = 1$ $x := f_v \le F_v$ $x = 1$

$x := f_{bx} \le F_{bx}$ $x = 1$ $x := f_{by} \le F_{by}$ $x = 1$

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.

$\frac{f_a}{F_a} = 0.38$ Since the resultant is greater than 0.15, use the equation H1-1 per AISC 1989, page 5-54.

$F'_{ex} := \frac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\frac{k \cdot l}{r_x}\right)^2}$ $F'_{ex} = 165991.775 \cdot psi$ Euler stress for x axis bending divided by a factor of safety per AISC, page 5-54.

$F'_{ey} := \frac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\frac{k \cdot l}{r_y}\right)^2}$ $F'_{ey} = 165991.775 \cdot psi$ 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.

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

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.

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

Determine the allowable stresses on the beam.

$k \cdot l = 5.771 \cdot ft$	effective length	
$P_a := 115 \cdot 10^3 \cdot lbf$	The allowable axial compressive load from AISC, 1989, page 3-42 using 6 for kl (no interpolation).	
$F_a := \frac{P_a}{A}$	$F_a = 22637.795 \cdot psi$	Allowable axial compressive stress of the column.
$F_v := 0.4 \cdot Fy_{ts}$	$F_v = 18400 \cdot psi$	Allowable shear stress per AISC 1989, Page 5-49, F4-1.
$F_{bx} := 0.60 \cdot Fy_{ts}$	$F_{bx} = 27600 \cdot psi$	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.

$F_r := 41495.4 \cdot lbf$ $V_s := 1332.7 \cdot lbf$ $V_t := 914.8 \cdot lbf$

$M_s := 15971.6 \cdot lbf \cdot in$ $M_t := 9379.7 \cdot lbf \cdot in$

$f_a := \frac{F_r}{A}$	$f_a = 8168.386 \cdot psi$	Maximum compressive stress in the beam.
$f_v := \frac{\sqrt{V_s^2 + V_t^2}}{A}$	$f_v = 318.201 \cdot psi$	Maximum shear stress in the beam.
$f_{bx} := \frac{M_t}{S}$	$f_{bx} = 1753.215 \cdot psi$	Maximum bending stress about major axis of beam.

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HANFORD COMPANY **DESIGN ANALYSIS**

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ent: Westinghouse Hanford Company
ubject: 241AZ Truss Buckling Analysis
Location: 200 E /

WO/Job No. C01909
Date: 06/28/95
Checked: 7/19/95
Revised:

By: B. L. Coverdell
By:
By:

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

$x := f_a \le F_a \quad x = 1 \qquad x := f_v \le F_v \quad x = 1$

$x := f_{bx} \le F_{bx} \quad x = 1 \qquad x := f_{by} \le F_{by} \quad x = 1$

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.

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

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

$F'_{ey} := \dfrac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\dfrac{k \cdot l}{r_y}\right)^2}$ $\quad F'_{ey} = 67728.407 \cdot psi$ 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.

$$\frac{f_a}{F_a} + \frac{C_{mx} \cdot f_{bx}}{\left(1 - \dfrac{f_a}{F'_{ex}}\right) \cdot F_{bx}} + \frac{C_{my} \cdot f_{by}}{\left(1 - \dfrac{f_a}{F'_{ey}}\right) \cdot F_{by}} = 0.527$$

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.

$S_x := 2.66 \cdot in^3$	section modulus about major axis
$S_y := 1.71 \cdot in^3$	section modulus about minor axis
$r_x := 1.31 \cdot in$	radius of gyration about x axis
$r_y := 0.743 \cdot in$	radius of gyration about y axis
$l := 81 \cdot in$	maximum column length
$A := 3.11 \cdot in^2$	cross sectional area

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Determine the allowable stresses on the beam.

$k \cdot l = 6.75 \cdot ft$	effective length
$P_a := 36 \cdot 10^3 \cdot lbf$	The allowable axial compressive load from AISC, 1989, page 3-52 using 7 for kl (no interpolation).

$F_a := \frac{P_a}{A}$	$F_a = 11575.563 \cdot psi$	Allowable axial compressive stress of the column.
$F_v := 0.4 \cdot Fy_{ts}$	$F_v = 18400 \cdot psi$	Allowable shear stress per AISC 1989, Page 5-49, F4-1.
$F_{bx} := 0.60 \cdot Fy_{ts}$	$F_{bx} = 27600 \cdot psi$	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.

$F_r := 17961.2 \cdot lbf$ $V_s := 178.3 \cdot lbf$ $V_t := 922.1 \cdot lbf$

$M_s := 5435.3 \cdot lbf \cdot in$ $M_t := 5333.9 \cdot lbf \cdot in$

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

$x := f_a \le F_a$ $x = 1$ $x := f_v \le F_v$ $x = 1$

$x := f_{bx} \le F_{bx}$ $x = 1$ $x := f_{by} \le F_{by}$ $x = 1$

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.

$F'_{ex} := \dfrac{12\cdot\pi^2\cdot E}{23\cdot\left(\dfrac{k\cdot l}{r_x}\right)^2}$ $\quad F'_{ex} = 40406.103\cdot psi$ Euler stress for x axis bending divided by a factor of safety per AISC, page 5-54.

$F'_{ey} := \dfrac{12\cdot\pi^2\cdot E}{23\cdot\left(\dfrac{k\cdot l}{r_y}\right)^2}$ $\quad F'_{ey} = 12998.164\cdot psi$ 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.

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

$A := \left[1.5\cdot in\cdot 2.5\cdot in - \left(1.5\cdot in - \frac{3}{8}\cdot in\right)\cdot\left(2.5\cdot in - \frac{3}{8}\cdot in\right)\right]$ $\quad A = 1.359\cdot in^2$ Cross-sectional area of a single TS.

$l := 69.25\cdot in$ Length of column.

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

$d := \dfrac{1.5\cdot in}{2}$ $\quad d = 0.75\cdot in$ Distance to centroidal axis of a single TS to combined centroidal axis.

$I_x := \dfrac{1.5\cdot in\cdot(2.5\cdot in)^3}{12} - \dfrac{\left(1.5\cdot in - \frac{3}{8}\cdot in\right)\cdot\left(2.5\cdot in - \frac{3}{8}\cdot in\right)^3}{12}$ $\quad I_x = 1.054\cdot in^4$ Moment of inertia for a single TS about the x axis.

$I_y := \dfrac{2.5\cdot in\cdot(1.5\cdot in)^3}{12} - \dfrac{\left(2.5\cdot in - \frac{3}{8}\cdot in\right)\cdot\left(1.5\cdot in - \frac{3}{8}\cdot in\right)^3}{12}$ $\quad I_y = 0.451\cdot in^4$ Moment of inertia for a single TS about the y axis.

$I_{x'} := 2\cdot I_x$ $\quad I_{x'} = 2.107\cdot in^4$ Combined moment of inertia for back to back TS's.

$I_{y'} := 2\cdot\left(I_y + A\cdot d^2\right)$ $\quad I_{y'} = 2.431\cdot in^4$ Combined moment of inertia for back to back TS's.

$S_{x'} := \dfrac{I_{x'}}{\dfrac{2.5\cdot in}{2}}$ $\quad S_{x'} = 1.686\cdot in^3$ section modulus about x axis

$S_{y'} := \frac{I_{y'}}{1.5 \cdot in}$ $S_{y'} = 1.621 \cdot in^3$ section modulus about y axis

$r_x := \sqrt{\frac{I_{x'}}{2 \cdot A}}$ $r_x = 0.88 \cdot in$ The radius of gyration about the x axis for this beam.

$r_y := \sqrt{\frac{I_{y'}}{2 \cdot A}}$ $r_y = 0.946 \cdot in$ 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).

$F_a := 19210 \cdot psi$ Allowable axial compressive stress of the column from AISC, 1989, page 3-17 using 79 for kl/r (no interpolation).

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

$F_{bx} := 0.60 \cdot Fy_{ts}$ $F_{bx} = 27600 \cdot psi$ 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.

$F_r := 2252.4 \cdot lbf$ $V_s := 178.3 \cdot lbf$ $V_t := 7.1 \cdot lbf$

$M_s := 45.7 \cdot lbf \cdot in$ $M_t := 3464.7 \cdot lbf \cdot in$

$f_a := \frac{F_r}{2 \cdot A}$ $f_a = 828.469 \cdot psi$ Maximum compressive stress in the beam.

$f_v := \frac{\sqrt{V_s^2 + V_t^2}}{2 \cdot A}$ $f_v = 65.634 \cdot psi$ Maximum shear stress in the beam.

$f_{bx} := \frac{M_t}{S_x}$ $f_{bx} = 1302.519 \cdot psi$ Maximum bending stress about major axis of beam.

$f_{by} := \frac{M_s}{S_y}$ $f_{by} = 26.725 \cdot psi$ Maximum bending stress about major axis of beam.

$x := f_a \le F_a$ $x = 1$ $x := f_v \le F_v$ $x = 1$

$x := f_{bx} \le F_{bx}$ $x = 1$ $x := f_{by} \le F_{by}$ $x = 1$

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.

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

Determine the allowable stresses on the beam.

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

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

$F_v := 0.4 \cdot Fy$ $F_v = 14400 \cdot psi$ Allowable shear stress per AISC 1989, Page 5-49, F4-1.

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

$F_{by} := F_{bx}$ 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.

$F_r := 3304.1 \cdot lbf$ $V_s := 431.4 \cdot lbf$ $V_t := 419.2 \cdot lbf$

$M_s := 2563.7 \cdot lbf \cdot in$ $M_t := 2638.8 \cdot lbf \cdot in$

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

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

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$$f_{bx} := \frac{M_t}{S} \qquad f_{bx} = 10683.401 \cdot psi$$

Maximum bending stress about major axis of beam.

$$f_{by} := \frac{M_s}{S} \qquad f_{by} = 10379.352 \cdot psi$$

Maximum bending stress about major axis of beam.

$x := f_a \le F_a \qquad x = 1 \qquad x := f_v \le F_v \qquad x = 1$

$x := f_{bx} \le F_{bx} \qquad x = 1 \qquad x := f_{by} \le F_{by} \qquad x = 1$

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.

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} = 1.138$$

The interaction equation exceeds 1, however, this member is not considered a prime structural member. For this reason, allow F_{bx} and F_{by} to be equal to the yield stress of the material.

$F_{bx} := Fy \qquad F_{by} := Fy$

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} = 0.748$$

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.

$l := 69.25 \cdot in$ maximum column length

$A := (6 \cdot in)^2 \qquad A = 36 \cdot in^2$ cross sectional area

$I := \frac{(6 \cdot in)^4}{12} \qquad I = 108 \cdot in^4$ moment of inertia about either axis

$S := \frac{I}{\left(\frac{6 \cdot in}{2}\right)} \qquad S = 36 \cdot in^3$ section modulus about either axis

$r_x := \sqrt{\frac{I}{A}} \qquad r_x = 1.732 \cdot in$ radius of gyration about x axis

$r_y := \sqrt{\frac{I}{A}} \qquad r_y = 1.732 \cdot in$ *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

$F_a := 19190 \cdot psi$ Allowable axial compressive stress of the column from AISC, 1989, page 3-16 using 40 for kl/r (no interpolation).

$F_v := 0.4 \cdot Fy$ $F_v = 14400 \cdot psi$ Allowable shear stress per AISC 1989, Page 5-49, F4-1.

$F_{bx} := .60 \cdot Fy$ $F_{bx} = 21600 \cdot psi$ 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.

$F_r := 120987 \cdot lbf$ $V_s := 1183 \cdot lbf$ $V_t := 1222.8 \cdot lbf$

$M_s := 64246.7 \cdot lbf \cdot in$ $M_t := 62143.9 \cdot lbf \cdot in$

$f_a := \frac{F_r}{A}$ $f_a = 3360.75 \cdot psi$ Maximum compressive stress in the beam.

$f_v := \frac{\sqrt{V_s^2 + V_t^2}}{A}$ $f_v = 47.261 \cdot psi$ Maximum shear stress in the beam.

$f_{bx} := \frac{M_t}{S}$ $f_{bx} = 1726.219 \cdot psi$ Maximum bending stress about major axis of beam.

$f_{by} := \frac{M_s}{S}$ $f_{by} = 1784.631 \cdot psi$ Maximum bending stress about major axis of beam.

$x := f_a \le F_a$ $x = 1$ $x := f_v \le F_v$ $x = 1$

$x := f_{bx} \le F_{bx}$ $x = 1$ $x := f_{by} \le F_{by}$ $x = 1$

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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$$F'_{ex} := \frac{12\cdot\pi^2\cdot E}{23\cdot\left(\frac{k\cdot l}{r_x}\right)^2} \qquad F'_{ex} = 96639.819\cdot psi$$

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

$$F'_{ey} := \frac{12\cdot\pi^2\cdot E}{23\cdot\left(\frac{k\cdot l}{r_y}\right)^2} \qquad F'_{ey} = 96639.819\cdot psi$$

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.

$l := 67\cdot in$ *maximum column length*

$A := (4\cdot in)^2$ $\quad A = 16\cdot in^2$ cross sectional area

$I := \frac{(4\cdot in)^4}{12}$ $\quad I = 21.333\cdot in^4$ *moment of inertia about either axis*

$S := \frac{I}{\left(\frac{4\cdot in}{2}\right)}$ $\quad S = 10.667\cdot in^3$ section modulus about either axis

$r_x := \sqrt{\frac{I}{A}}$ $\quad r_x = 1.155\cdot in$ radius of gyration about x axis

$r_y := \sqrt{\frac{I}{A}}$ $\quad r_y = 1.155\cdot in$ radius of gyration about y axis

Determine the allowable stresses on the beam.

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

$F_a := 17620\cdot psi$ The allowable axial compressive stress from AISC, 1989, page 3-16 using 58 for kl/r (no interpolation.

$F_v := 0.4 \cdot Fy$ $\quad F_v = 14400 \cdot psi$ Allowable shear stress per AISC 1989, Page 5-49, F4-1.

$F_{bx} := 0.60 \cdot Fy$ $\quad F_{bx} = 21600 \cdot psi$ 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.

$F_r := 52855.4 \cdot lbf$ $\quad V_s := 1003.0 \cdot lbf$ $\quad V_t := 465.9 \cdot lbf$

$M_s := 21676.1 \cdot lbf \cdot in$ $\quad M_t := 18182.1 \cdot lbf \cdot in$

$f_a := \dfrac{F_r}{A}$ $\quad f_a = 3303.463 \cdot psi$ Maximum compressive stress in the beam.

$f_v := \dfrac{\sqrt{V_s^2 + V_t^2}}{A}$ $\quad f_v = 69.12 \cdot psi$ Maximum shear stress in the beam.

$f_{bx} := \dfrac{M_t}{S}$ $\quad f_{bx} = 1704.572 \cdot psi$ Maximum bending stress about major axis of beam.

$f_{by} := \dfrac{M_s}{S}$ $\quad f_{by} = 2032.134 \cdot psi$ Maximum bending stress about major axis of beam.

$x := f_a \le F_a$ $\quad x = 1$ $\qquad x := f_v \le F_v$ $\quad x = 1$

$x := f_{bx} \le F_{bx}$ $\quad x = 1$ $\qquad x := f_{by} \le F_{by}$ $\quad x = 1$

Check interaction equation for compression.

$\dfrac{f_a}{F_a} = 0.187$ Since the resultant is greater than 0.15, use the equation H1-1 per AISC 1989, page 5-54.

$F'_{ex} := \dfrac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\dfrac{k \cdot l}{r_x}\right)^2}$ $\quad F'_{ex} = 45884.24 \cdot psi$ Euler stress for x axis bending divided by a factor of safety per AISC, page 5-54.

$F'_{ey} := \dfrac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\dfrac{k \cdot l}{r_y}\right)^2}$ $\quad F'_{ey} = 45884.24 \cdot psi$ 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.

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

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.

$l := 69.25 \cdot in$ maximum column length

$A := (1.5 \cdot in)^2 - (1.5 \cdot in - 0.25 \cdot in)^2$ $A = 0.688 \cdot in^2$ cross sectional area

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

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

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

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

Determine the allowable stresses on the beam.

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

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

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

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

$F_{by} := F_{bx}$ 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.

$F_r := 664.8 \cdot \mathrm{lbf}$ $V_s := 276.5 \cdot \mathrm{lbf}$ $V_t := 126.8 \cdot \mathrm{lbf}$

$M_s := 785.7 \cdot \mathrm{lbf} \cdot \mathrm{in}$ $M_t := 1693.8 \cdot \mathrm{lbf} \cdot \mathrm{in}$

$$f_a := \frac{F_r}{A} \qquad f_a = 966.982 \cdot \mathrm{psi}$$

Maximum compressive stress in the beam.

$$f_v := \frac{\sqrt{V_s^2 + V_t^2}}{A} \qquad f_v = 442.456 \cdot \mathrm{psi}$$

Maximum shear stress in the beam.

$$f_{bx} := \frac{M_t}{S} \qquad f_{bx} = 5815.969 \cdot \mathrm{psi}$$

Maximum bending stress about major axis of beam.

$$f_{by} := \frac{M_s}{S} \qquad f_{by} = 2697.843 \cdot \mathrm{psi}$$

Maximum bending stress about major axis of beam.

$x := f_a \le F_a$ $x = 1$ $x := f_v \le F_v$ $x = 1$

$x := f_{bx} \le F_{bx}$ $x = 1$ $x := f_{by} \le F_{by}$ $x = 1$

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.

$A := 4 \cdot \mathrm{in} \cdot 2 \cdot \mathrm{in}$ $A = 8 \cdot \mathrm{in}^2$ cross sectional area

$l := 67 \cdot \mathrm{in}$ maximum column length

Determine moment of inertia and section modulus.

$$I_x := \frac{2 \cdot \mathrm{in} \cdot (4 \cdot \mathrm{in})^3}{12} \qquad I_x = 10.667 \cdot \mathrm{in}^4$$

moment of inertia about major axis

$$I_y := \frac{4 \cdot \mathrm{in} \cdot (2 \cdot \mathrm{in})^3}{12} \qquad I_y = 2.667 \cdot \mathrm{in}^4$$

moment of inertia about minor axis

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$S_x := \dfrac{I_x}{\left(\dfrac{4\cdot in}{2}\right)}$ $S_x = 5.333\cdot in^3$ section modulus about major axis

$S_y := \dfrac{I_y}{\left(\dfrac{2\cdot in}{2}\right)}$ $S_y = 2.667\cdot in^3$ section modulus about minor axis

$r_x := \sqrt{\dfrac{I_x}{A}}$ $r_x = 1.155\cdot in$ radius of gyration

$r_y := \sqrt{\dfrac{I_y}{A}}$ $r_y = 0.577\cdot in$ radius of gyration

Determine the allowable stresses on the beam.

$\dfrac{k\cdot l}{r_y} = 116.047$ slenderness ratio

$F_a := 10850\cdot psi$ Allowable axial compressive stress of the column from AISC, 1989, page 3-16 using 116 for kl/r (no interpolation).

$F_v := 0.4\cdot Fy$ $F_v = 14400\cdot psi$ Allowable shear stress per AISC 1989, Page 5-49, F4-1.

$F_{bx} := 0.6\cdot Fy$ $F_{bx} = 21600\cdot psi$ 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.

$F_r := 14744.8\cdot lbf$ $V_s := 5258.4\cdot lbf$ $V_t := 2325.0\cdot lbf$

$M_s := 7624.3\cdot lbf\cdot in$ $M_t := 42070.2\cdot lbf\cdot in$

$f_a := \dfrac{F_r}{A}$ $f_a = 1843.1\cdot psi$ Maximum compressive stress in the beam.

$f_v := \dfrac{\sqrt{{V_s}^2 + {V_t}^2}}{A}$ $f_v = 718.684\cdot psi$ Maximum shear stress in the beam.

$f_{bx} := \dfrac{M_t}{S_x}$ $f_{bx} = 7888.163\cdot psi$ Maximum bending stress about major axis of beam.

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HANFORD COMPANY **DESIGN ANALYSIS**

Calc. No.
Revision 0
Page No. 16 of

ent: Westinghouse Hanford Company
bject: 241AZ Truss Buckling Analysis
Location: 200 E /

WO/Job No. C01909
Date: 06/28/95
Checked: 7/19/95
Revised:

By: B. L. Coverdell
By:
By:

$f_{by} := \dfrac{M_s}{S_y}$ $f_{by} = 2859.113 \cdot psi$ Maximum bending stress about major axis of beam.

$x := f_a \le F_a$ $x = 1$ $x := f_v \le F_v$ $x = 1$

$x := f_{bx} \le F_{bx}$ $x = 1$ $x := f_{by} \le F_{by}$ $x = 1$

Check interaction equation for compression.

$\dfrac{f_a}{F_a} = 0.17$ Since the resultant is greater than 0.15, use the equation H1-1 per AISC 1989, page 5-54.

$F'_{ex} := \dfrac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\dfrac{k \cdot l}{r_x}\right)^2}$ $F'_{ex} = 45884.24 \cdot psi$ Euler stress for x axis bending divided by a factor of safety per AISC, page 5-54.

$F'_{ey} := \dfrac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\dfrac{k \cdot l}{r_y}\right)^2}$ $F'_{ey} = 11471.06 \cdot psi$ 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.

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

7/14/93

```
               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

7/19/95

```
                  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.

Section 10.5.1: Local or "punching" shear failure ([illegible] -> Truss Tube).

Bar->Truss

	Model Results				Tube Info									allowable punching shear						actual punching shear			
Elem	P/A	MS/SS	MT/ST	sigma b	a	b	tb	theta	ax	D	tc	P/A (all)	sigma y	beta	Qbeta	U	Qf	gamma	tau all	Ka	Kb	tau act	MS
88	4722.132	1336.267	118.454	1341.507	2	4	0.3125	30.3	3.964104	6	0.375	12000	36000	0.666667	1.125	0.393511	1	8	8437.5	1.327351	2.26012	1990.37	3.239182
89	5807.573	352.378	358.8231	502.7731	2	4	0.3125	30.3	3.964104	6	0.375	12000	36000	0.666667	1.125	0.483964	0.978018	8	8252.025	1.327351	2.26012	2024.933	3.075208
116	4302.414	1756.055	50.4411	1756.779	2	4	0.3125	30.3	3.964104	6	0.375	12000	36000	0.666667	1.125	0.358534	1	8	8437.5	1.327351	2.26012	2010.539	3.196635
117	5370.898	256.0948	377.9065	456.5079	2	4	0.3125	30.3	3.964104	6	0.375	12000	36000	0.666667	1.125	0.447558	0.996221	8	8405.614	1.327351	2.26012	1869.494	3.496197
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582	4423.868	528.1965	327.6917	621.5894	2	4	0.3125	30.3	3.964104	6	0.375	12000	36000	0.666667	1.125	0.368656	1	8	8437.5	1.327351	2.26012	1630.452	4.174945
598	2548.249	218.5927	240.3173	324.8617	2	4	0.3125	30.3	3.964104	6	0.375	12000	36000	0.666667	1.125	0.212354	1	8	8437.5	1.327351	2.26012	928.9409	8.102522
610	587.8807	404.1253	222.5876	461.3606	2	4	0.3125	30.3	3.964104	6	0.375	12000	36000	0.666667	1.125	0.047322	1	8	8437.5	1.327351	2.26012	349.8796	23.10655
611	3625.583	431.9092	116.1441	447.2527	2	4	0.3125	30.3	3.964104	6	0.375	12000	36000	0.666667	1.125	0.302132	1	8	8437.5	1.327351	2.26012	1313.315	5.424564
625	1587.158	249.8445	98.20567	268.2863	2	4	0.3125	30.3	3.964104	6	0.375	12000	36000	0.666667	1.125	0.130597	1	8	8437.5	1.327351	2.26012	595.312	13.17324
652	4424.332	531.5021	327.2741	624.1817	2	4	0.3125	30.3	3.964104	6	0.375	12000	36000	0.666667	1.125	0.368694	1	8	8437.5	1.327351	2.26012	1631.555	4.171447
666	2548.447	221.2841	238.8284	326.1724	2	4	0.3125	30.3	3.964104	6	0.375	12000	36000	0.666667	1.125	0.212371	1	8	8437.5	1.327351	2.26012	927.4868	8.097165
680	569.9434	411.131	221.1598	466.8406	2	4	0.3125	30.3	3.964104	6	0.375	12000	36000	0.666667	1.125	0.047495	1	8	8437.5	1.327351	2.26012	352.6599	22.92532
681	3626.103	431.0242	115.8962	446.3337	2	4	0.3125	30.3	3.964104	6	0.375	12000	36000	0.666667	1.125	0.302175	1	8	8437.5	1.327351	2.26012	1313.14	5.425437
695	1567.483	250.5863	96.11453	269.1098	2	4	0.3125	30.3	3.964104	6	0.375	12000	36000	0.666667	1.125	0.130624	1	8	8437.5	1.327351	2.26012	595.7257	13.1634

Section 10.5.1: Local or "punching" shear failure (Top Tube -> Truss Tube).

	Model Results				Tube info									allowable punching shear						actual punching shear			
Elem	P/A	MS/SS	MT/ST	sigma b	a	b	tb	theta	ax	D	tc	P/A (all)	sigma y	beta	Qbeta	U	Qf	gamma	tau all	Ka	Kb	tau act	MS
75	4714.835	859.1219	428.8014	786.3774	2	4	0.3125	30.3	3.964104	4	0.375	12000	36000	1	2.488783	0.8	0.92	5.333333	25758.9	1.327351	2.26012	1783.312	13.44441
102	5815.071	524.3252	281.1348	594.94	2	4	0.3125	30.3	3.964104	4	0.375	12000	36000	1	2.488783	0.8	0.92	5.333333	25758.9	1.327351	2.26012	2061.291	11.49649
103	4294.816	969.5493	290.7325	1012.201	2	4	0.3125	30.3	3.964104	4	0.375	12000	36000	1	2.488783	0.8	0.92	5.333333	25758.9	1.327351	2.26012	1733.63	13.85836
130	5378.195	385.5734	290.5334	482.78	2	4	0.3125	30.3	3.964104	4	0.375	12000	36000	1	2.488783	0.8	0.92	5.333333	25758.9	1.327351	2.26012	1861.556	12.69021
203	7004.477	536.6846	687.0699	871.8345	2	4	0.3125	30.3	3.964104	4	0.375	12000	36000	1	2.488783	0.8	0.92	5.333333	25758.9	1.327351	2.26012	2540.131	9.140776
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231	6497.176	658.7881	642.9602	920.5274	2	4	0.3125	30.3	3.964104	4	0.375	12000	36000	1	2.488783	0.8	0.92	5.333333	25758.9	1.327351	2.26012	2397.397	9.744529
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583	2555.747	240.7702	183.8314	302.9282	2	4	0.3125	30.3	3.964104	4	0.375	12000	36000	1	2.488783	0.8	0.92	5.333333	25758.9	1.327351	2.26012	921.2278	26.96149
597	575.8466	107.8897	89.03304	139.8823	2	4	0.3125	30.3	3.964104	4	0.375	12000	36000	1	2.488783	0.8	0.92	5.333333	25758.9	1.327351	2.26012	233.9129	109.1217
624	3618.085	248.0343	384.4913	457.5528	2	4	0.3125	30.3	3.964104	4	0.375	12000	36000	1	2.488783	0.8	0.92	5.333333	25758.9	1.327351	2.26012	1314.737	18.59243
638	1559.861	70.7468	152.3506	167.9756	2	4	0.3125	30.3	3.964104	4	0.375	12000	36000	1	2.488783	0.8	0.92	5.333333	25758.9	1.327351	2.26012	555.9568	45.33239
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653	2555.944	241.9356	182.478	303.0384	2	4	0.3125	30.3	3.964104	4	0.375	12000	36000	1	2.488783	0.8	0.92	5.333333	25758.9	1.327351	2.26012	921.3311	26.95835
667	577.4409	106.8228	88.77463	138.8958	2	4	0.3125	30.3	3.964104	4	0.375	12000	36000	1	2.488783	0.8	0.92	5.333333	25758.9	1.327351	2.26012	234.1175	109.0255
694	3618.605	247.7582	385.1673	457.9716	2	4	0.3125	30.3	3.964104	4	0.375	12000	36000	1	2.488783	0.8	0.92	5.333333	25758.9	1.327351	2.26012	1315.056	18.58768
708	1559.985	67.54837	152.7052	166.9781	2	4	0.3125	30.3	3.964104	4	0.375	12000	36000	1	2.488783	0.8	0.92	5.333333	25758.9	1.327351	2.26012	555.6937	45.35449

Weld Analysis

Section 10.5.1: Local or "punching" shear failure (Bottom Tube -> 2x4 Studs).

Bar->Stud

Model Results						branch		Tube Info		main				allowable punching shear						actual punching shear			
Elem	P/A	MS/SS	MT/ST	sigma b	a	b	tb	theta	ax	D	tc	P/A (all)	sigma y	beta	Qbeta	U	Qf	gamma	tau all	Ka	Kb	tau act	MS
709	743.9149	2859.857	1035.602	3041.399	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.061993	1	8	8437.5	1	1	2523.543	2.343514
723	384.9548	2546.192	1605.248	3009.988	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.030413	1	8	8437.5	1	1	2249.949	2.750065
737	522.8574	1733.88	1628.414	2377.141	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.043571	1	8	8437.5	1	1	1933.332	3.364227
751	550.2704	1554.236	961.7849	1838.355	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.045856	1	8	8437.5	1	1	1592.417	4.298549
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1421	61.61026	3209.854	1168.708	3415.61	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.005134	1	8	8437.5	1	1	2318.28	2.639552
1435	50.23832	2958.73	1189.511	3185.916	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.004187	1	8	8437.5	1	1	2157.436	2.910892
1449	193.5747	2922.98	1321.323	3207.758	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.016131	1	8	8437.5	1	1	2287.555	2.720868
1463	200.3961	2935.74	1240.871	3167.136	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.0167	1	8	8437.5	1	1	2258.358	2.736125
1477	236.75	1541.864	142.9854	1548.48	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.019696	1	8	8437.5	1	1	1191.487	6.08149
1504	239.4411	1570.808	119.0447	1575.312	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.019953	1	8	8437.5	1	1	1209.836	5.974068
1505	256.2883	1234.729	826.4489	1384.555	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.021357	1	8	8437.5	1	1	1093.895	6.713261
1519	257.8651	1259.594	622.4521	1404.999	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.021489	1	8	8437.5	1	1	1106.576	6.611114
1533	126.3481	1129.554	287.071	1160.697	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.010529	1	8	8437.5	1	1	858.0303	8.833568
1560	125.4807	1146.246	281.4547	1175.687	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.010457	1	8	8437.5	1	1	867.4449	8.726843
1561	308.1959	870.1024	582.0405	987.5857	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.025683	1	8	8437.5	1	1	797.1877	9.584082
1575	310.2023	886.2177	578.3321	997.4201	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.02585	1	8	8437.5	1	1	805.0816	9.480305
1589	53.11584	423.3584	272.3718	503.4055	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.004426	1	8	8437.5	1	1	371.0142	21.74172
1616	51.65371	436.7689	270.7869	513.8995	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.004304	1	8	8437.5	1	1	377.0354	21.37853
1617	116.9518	2737.229	251.842	2748.79	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.009746	1	8	8437.5	1	1	1910.494	3.416396
1644	115.8413	2656.228	239.6653	2667.018	2	4	0.25	90	2	6	0.375	12000	36000	0.666667	1.125	0.009637	1	8	8437.5	1	1	1855.108	3.548257

Section 10.5.1: Local or "punching" shear failure (Top Tube -> 2x4 Studs).

Bar->Stud

Model Results						branch		Tube Info		main				allowable punching shear						actual punching shear			
Elem	P/A	MS/SS	MT/ST	sigma b	a	b	tb	theta	ax	D	tc	P/A (all)	sigma y	beta	Qbeta	U	Qf	gamma	tau all	Ka	Kb	tau act	MS
722	56.60065	1790.057	427.2836	1840.342	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.004717	1	5.333333	14400	1	1	632.3141	21.77349
736	769.2133	1484.076	1414.383	2050.112	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.064101	1	5.333333	14400	1	1	839.7752	14.32281
750	76.81247	682.3826	215.3004	715.5419	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.006401	1	5.333333	14400	1	1	264.1161	53.52106
764	638.3284	123.8112	1256.113	1262.2	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.053194	1	5.333333	14400	1	1	633.5093	21.73053
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1434	43.00948	1497.903	934.8281	1765.877	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.003584	1	5.333333	14400	1	1	602.8955	22.88473
1448	34.65511	1385.655	877.3774	1640.07	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.002888	1	5.333333	14400	1	1	558.2417	24.79528
1462	79.46419	1305.072	1059.432	1680.955	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.006622	1	5.333333	14400	1	1	586.8063	23.53962
1476	73.95045	1259.152	1052.182	1640.887	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.006163	1	5.333333	14400	1	1	571.6124	24.1919
1490	896.1103	943.8414	2222.107	2414.249	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.074676	1	5.333333	14400	1	1	1103.453	12.04994
1491	892.9568	917.6002	2233.109	2414.284	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.074413	1	5.333333	14400	1	1	1102.413	12.06225
1518	20.81387	1489.516	190.0718	1501.594	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.001734	1	5.333333	14400	1	1	507.4693	27.3761
1532	20.72987	1462.198	192.0763	1474.78	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.001727	1	5.333333	14400	1	1	498.4968	27.88686
1546	568.0173	639.869	250.2774	687.0743	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.047335	1	5.333333	14400	1	1	418.3638	33.4196
1547	567.5472	626.8633	250.8629	675.1982	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.047298	1	5.333333	14400	1	1	414.2478	33.7618
1574	18.39772	558.2959	41.68335	559.8498	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.001533	1	5.333333	14400	1	1	192.7492	73.70649
1588	18.2627	546.5784	43.18311	548.28	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.001522	1	5.333333	14400	1	1	188.8478	75.25197
1602	552.9803	215.6208	232.6255	317.186	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.046082	1	5.333333	14400	1	1	290.0555	48.64568
1603	551.8035	233.2733	234.8227	331.0866	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.045984	1	5.333333	14400	1	1	294.29	47.93132
1630	32.81394	1424.521	168.4705	1434.448	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.002734	1	5.333333	14400	1	1	489.0674	28.44259
1631	33.19148	1445.078	174.5002	1455.574	2	3.99	0.125	90	2	4	0.375	12000	36000	0.9975	1.875	0.002766	1	5.333333	14400	1	1	498.255	28.01734

Weld Analysis (continued)

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Appendix F: Overturning Analysis

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KAISER ENGINEERS HANFORD

DESIGN ANALYSIS

ient Westinghouse	WO/Job No. C01909	Calc. No. N/A Revision 0 Page No. of
Subject 241 AZ Trough Analysis	Date 9/27/95	By Mark Axup
	Checked 9/28/95	By Theresa Peterson
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 ft.

$q_z = 7.66$ psf use 10.0 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 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

$q_z G_h = 10$ 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.

KAISER ENGINEERS
HANFORD

DESIGN ANALYSIS

ient Westinghouse		**Calc. No.** N/A	
		Revision 0	
		Page No.	**of**
	WO/Job No. C01909		
Subject 241 AZ Trough Analysis	**Date** 9/27/95	**By** Mark Axup	
	Checked 9/28/95	**By** Theresa Peterson	
Location 200 E	**Revised**	**By**	

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

Gross Area = 5.75 x 3.75 = 21.562 ft.^{2}

$\frac{\text{Solid Area}}{\text{Gross Area}} = \frac{10.573}{21.562} = 0.49$ 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.

Top wind load area = 3.75 x 39.0 x 0.49 = 71.66 ft^2

Bottom wind load area = 7.43 x 24.5 x 1.0 = 182.1 ft^2

Top wind load = 71.66 x 10.0 x 1.7 = 1218.26 lbs.

Bottom wind load = 182.1 x 10.0 x 1.05 = 1912.05 lbs.

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Subject 241 AZ Trough Analysis	**Date** 9/27/95 **By** Mark Axup
	Checked 9/28/95 **By** Theresa Peterson
Location 200 E	**Revised** **By**

Wind Overturning Analysis: (Cont'd.)

Check Load Cases:

Load Case 1

Wind OT moment = (1218.26 x 51.5) + (1912.05 x 19.75) = 100,503.4 ft-lbs.

Dead weight resisting moment = (50,000 + 10,640) x 8.0 = 485,120.0 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 x 1.0 = 105,503.4 ft-lbs.

Dead weight resisting moment = 485,120.0 + 5000.0 x 7.0 = 520,120.0 ft-lbs.

F.S. against overturning = $\frac{520,120.0}{105,503.4}$ = 4.93

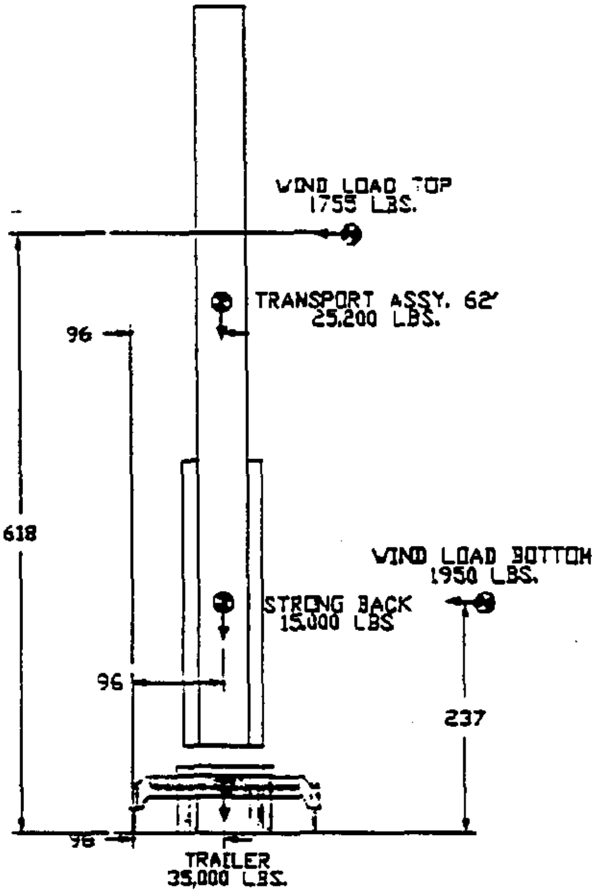
OVERTURNING DUE TO WIND LOADING WITH THE STRONG BACK IN THE VERTICAL POSITION

SUM Fy = 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.

TCM

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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.

```
*****************************************************************
*****************************************************************
**                                                             **
**                                                             **
**  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:                        **
**      STRUCTURAL  RESEARCH  AND  ANALYSIS  CORPORATION       **
**                2951 28TH STREET SUITE 1000                  **
**            SANTA MONICA,   CALIFORNIA    90405              **
**                TEL. NO.   (310)  452-2158                   **
**               COPYRIGHT  1988   S. R. A. C.                 **
**                                                             **
*****************************************************************
*****************************************************************

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


  C O N T R O L   I N F O R M A T I O N
   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 AODITION 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

  T O T A L   S Y S T E M   D A T A
   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

    ----------------------------------------------------------------------
    |             M A S S   M O M E N T   I N F O R M A T I O N           |
    |---------------------------------------------------------------------|
    |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   |
---------------------------------------------------------------------



S O L U T I O N   P A R A M E T E R S
 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


S U B S P A C E   I T E R A T I O N


  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


  F R E Q U E N C Y   A N A L Y S I S
                 by
  S U B S P A C E   A L G O R I T H M


    FREQUENCY        FREQUENCY        FREQUENCY       PERIOD
     NUMBER          (RAD/SEC)      (CYCLES/SEC)    (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


   S O L U T I O N   T I M E     L O G  (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 0
Page No. 1 of

ent: Westinghouse Hanford Company
ubject: 241AZ Truss Analysis
Location: 200 E /

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

By: B. L. Coverdell
By:
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

$V_o := 15 \cdot \mathrm{mph}$	Maximum wind velocity that the trough and carriage will be rotated into the vertical position.	
$d := 28 \cdot \mathrm{in}$	Diameter of the carriage.	
$\rho := 0.00234 \cdot 32.2 \cdot \dfrac{\mathrm{lb}}{\mathrm{ft}^3}$	Density of air at standard temperature and pressure (converted from slugs to pounds-mass).	
$\mu := 3.78 \cdot 10^{-7} \cdot \dfrac{\mathrm{lbf} \cdot \mathrm{sec}}{\mathrm{ft}^2}$	Viscosity of air at standard temperature and pressure.	
$Re := \dfrac{V_o \cdot d \cdot \rho}{\mu}$	$Re = 3.18 \cdot 10^5$	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	
$n := \dfrac{S \cdot V_o}{d}$		
$n = \begin{pmatrix} 1.791 \\ 2.829 \end{pmatrix} \cdot \mathrm{hz}$	The range of excitation frequency.	

RESULTS AND CONCLUSIONS:

The range of excitatation 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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HANFORD COMPANY

DESIGN ANALYSIS

Calc. No.
Revision 0
Page No. 1 of

ent: Westinghouse Hanford Company
ubject: 241AZ Trough Analysis
Location: 200 E /

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

By: B. L. Coverdell
By:
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:

$L := 69.25 \cdot in$	Maximum length of tube steel to be analyzed (WHC 1995a and WHC 1995b).	
$c := \frac{2.5 \cdot in}{2}$	Distance to outer fiber (WHC 1995a and WHC 1995b).	
$I_{xx} := 2.107 \cdot in^4$	Moment of inertia about loaded axis (Appendix D, Page D-1).	
$\sigma := 0.6 \cdot 36000 \cdot psi$	$\sigma = 2.16 \cdot 10^4 \cdot psi$	The maximum allowable stress in the tubular section per AISC 1989.
$M_{max} := \frac{\sigma \cdot I_{xx}}{c}$	$M_{max} = 3.641 \cdot 10^4 \cdot in \cdot lbf$	The maximum allowable bending moment in the beam.
$P_{max} := \frac{8 \cdot M_{max}}{L}$	$P_{max} = 4.206 \cdot 10^3 \cdot lbf$	The maximum allowable point load (carriage wheel load) in a beam fixed at either end per AISC 1989, page 3-125.
$\frac{P_{max}}{2} = 2.103 \cdot 10^3 \cdot lbf$	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.

Appendix I: Connection Calculations

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

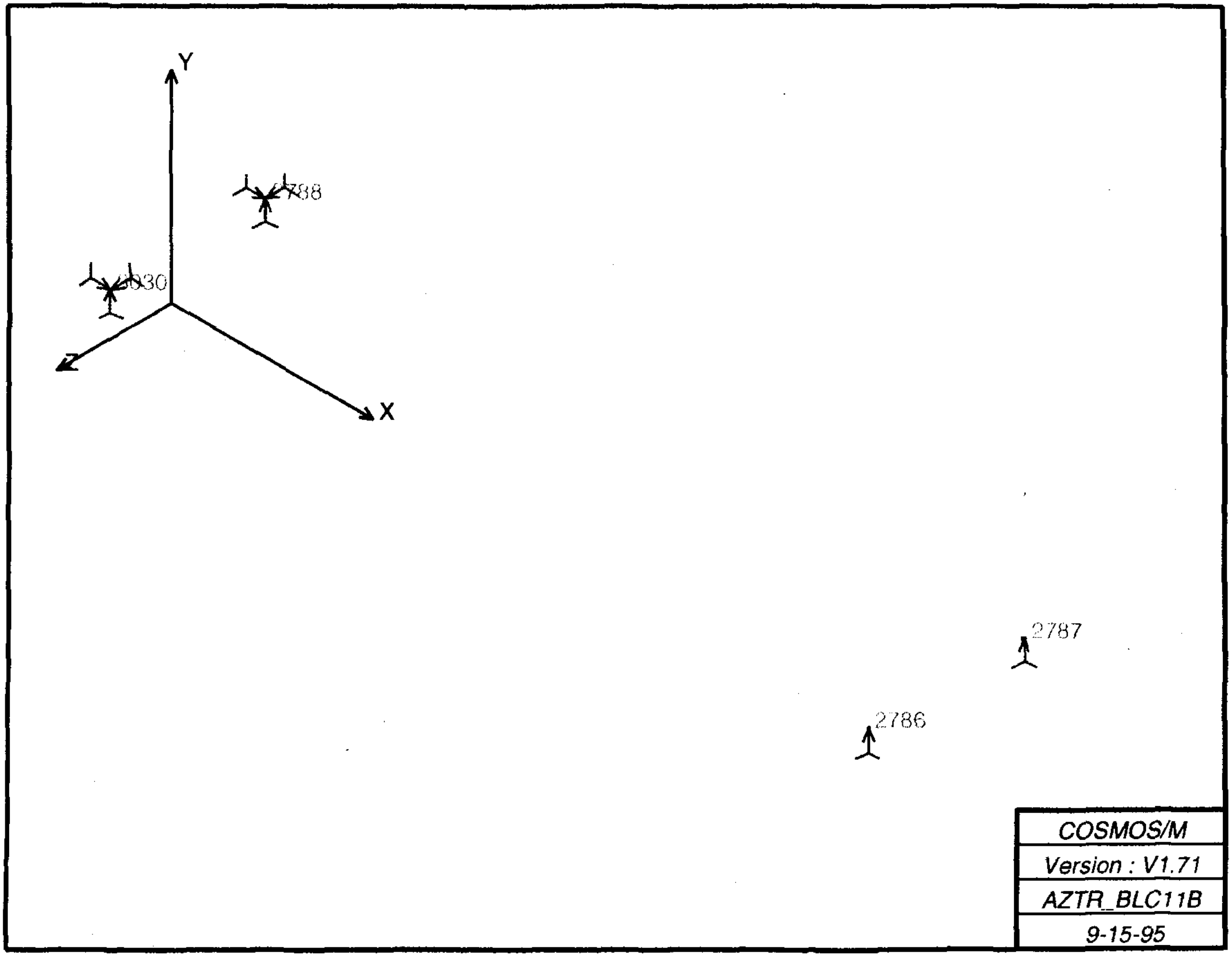
From the FEA model output contained in this appendix, the maximum tensile load is 7,500 lbf and the maximum shear load is 20,600 lbf.

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    -          -          -
```