DISTRIBUTION SHEET

To	From	Page 1 of 1
Characterization Equipment	Structural Integrity Assessment	Date 02/21/95
Project Title/Work Order **STRESS ANALYSIS OF JACKS, FRAME AND BEARING CONNECTIONS AND DRILL ROD FOR CORE SAMPLER TRUCK #2 (WHC-SD-WM-ER-392, Rev. 0)**		EDT No. 608356 ECN No.

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
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L. L. Hyde	H5-58		X		
W. C. Miller	R1-30		X		
B. J. Niemi	X3-79		X		
K. V. Scott	H5-52		X		
J. L. Smalley	R1-17	X			
J. J. Verderber	S1-57		X		
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DISCLAIMER

FEB 2 8 1995 38 Sta.21

ENGINEERING DATA TRANSMITTAL

1. EDT 608356

2. To: (Receiving Organization) Characterization Equipment	3. From: (Originating Organization) Structural Integrity Assessment	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: Tank Farms	6. Cog. Engr.: H. H. Ziada	7. Purchase Order No.: N/A
8. Originator Remarks: For review and approval		9. Equip./Component No.: N/A
		10. System/Bldg./Facility: 200 Area Tank Farms
11. Receiver Remarks:		12. Major Assm. Dwg. No.: H-2-140308, H-2-91718, H-2-91702
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(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Impact Level	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	WHC-SD-WM-ER-392		0	STRESS ANALYSIS OF JACKS, FRAME AND BEARING CONNECTIONS, AND DRILL ROD FOR CORE SAMPLER TRUCK #2	Q	1	1	

16. KEY

Impact Level (F)	Reason for Transmittal (G)		Disposition (H) & (I)	
1, 2, 3, or 4 (see MRP 5.43)	1. Approval 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment	4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

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1	1	Cog.Eng. H. H. Ziada	[signature]	11-11-94	H5-52	OSTI (2)			L8-07		
1	1	Cog. Mgr. K. V. Scott	[signature]	11-11-94	H5-52						
1	1	QA J. J. Verderber	[signature]	12/5/94	S1-57						
1	1	Safety J. L. Smalley	[signature]	12/2/94	R1-17						
1	1	R. J. Blanchard	[signature]	12/2/94	R1-17						

18.	19.	20.	21. DOE APPROVAL (if required)
[signature] H. H. Ziada 11-11-94 Signature of EDT Originator Date	[signature] R. J. Blanchard 12/2/94 Authorized Representative Date for Receiving Organization	[signature] K. V. Scott 2/24/95 Cognizant/Project Engineer's Manager Date	Ltr. No. N/A [] Approved [] Approved w/comments [] Disapproved w/comments

RELEASE AUTHORIZATION

Document Number:	WHC-SD-WM-ER-392, Rev. 0
Document Title:	Stress Analysis of Jacks, Frame and Bearing Connections, and Drill Rod for Core Sampler Truck #2
Release Date:	02/27/95

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

APPROVED FOR PUBLIC RELEASE

WHC Information Release Administration Specialist:

V. L. Birkland 2/27/95
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SUPPORTING DOCUMENT	1. Total Pages 78

2. Title	3. Number	4. Rev No.
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5. Key Words	6. Author
Sampler truck, RMCST #2, stress analysis, jacks, drill rod, truck frame	Name: H. H. Ziada Hassan H. Ziada Signature Organization/Charge Code ~~7E650~~ 71430/N4XB1

7. Abstract

This document provides the stress analysis and evaluation of the jacks, bearing and frame connections, traverse slide assembly, and drill rod load capacity for the rotary mode core sampler truck #2 (RMCST #2).

8. RELEASE STAMP

A-6400-073 (08/94) WEF124

CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed STRESS ANALYSIS OF JACKS, FRAME AND BEARING CONNECTIONS, AND DRILL ROD FOR CORE SAMPLER TRUCK #2

Author D. A. Koehler
B. J. Niemi
F. R. Vollert

Document No. WHC-SD-WM-ER-392, Rev. 0

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

MANDATORY Software QA Log Number N/A

H. H. Ziada Hasan H. Ziada 11-11-94
Reviewer Date

CONTENTS

STRESS ANALYSIS OF JACKS, FRAME AND BEARING CONNECTIONS, AND DRILL ROD FOR CORE SAMPLER TRUCK #2

1.0 INTRODUCTION

This analysis evaluates the structural design adequacy of several components and connections for the rotary mode core sampler truck (RMCST) number 2. This analysis was requested by the Characterization Equipment Group (WHC 1994a). The components addressed in this report are listed below:

- Front jack assembly and connection to the truck chassis
- Rear jack assembly and connection to the truck chassis
- Center outrigger jacks and connection to the truck chassis
- Lower frame assembly and connection to the truck chassis
- Bolt connections for bearing plate assembly (for path of maximum load)
- Traverse slide brackets and mounting of the traverse jack cylinders
- Drill rod (failure loads).

The analyses of the front, rear, and center jacks appear in Appendix A. The analyses of the lower frame and the maximum load path through the bearing assembly appear in Appendix B. Appendix C contains the analysis of the traverse slide assembly. The drill rod analysis appears in Appendix D.

Analysis results led to design modifications to some components. All design modifications have been made that affect the safe normal operation of the truck; the remainder will be incorporated in the near future.

2.0 CONCLUSIONS AND RECOMMENDATIONS

Results of the analyses for operating loads show acceptable stresses in the components and connections when the design modifications are incorporated. The evaluation was performed in accordance with AISC 1989.

The front jack was completly redesigned. The new design appears in engineering change notice (ECN) number 615552 (WHC 1994b).

The jacks are not designed to support horizontal loads. Consequently, they have limited capacity for such loads. The analysis results show a horizontal load capacity not more than 5 percent of the vertical load (i.e., a total horizontal load of approximately 1,400 lbf). To ensure that horizontal loads do not exceed this limit, a sign should be posted on the truck warning workers not to impose any side loads. An alternative is to modify the design of the front and rear jacks to accommodate additional horizontal loading.

The existing drawings do not specify the grade or type of steel material used for the bolts and screws that connect the bearing assembly and the lower frame to the chassis. Accordingly, it is difficult to know what stress allowables to use in the stress evaluation. Analysis results recommend the use of SAE Grade 8 bolts (equivalent to ASTM A490) or equivalent. In addition, 5/8-in. bolts should be used instead of 1/2-in. bolts for the connection between the lower plate and the chassis. This design change appears in ECN number 615569 (WHC 1994c).

Moreover, the 12 screws (1/2-in. diameter) connecting the bearing mount to the lower frame are 15 percent overstressed when subjected to the longitudinal transportation acceleration of 3 *g*. It is not as easy to increase the size of these screws as it is to increase the size of the bolts between the lower plate and the chassis. However, the 3 *g* (WEC 1972) transportation acceleration is for highway transportation. The truck speed is limited to a maximum of 15 mi/h (WHC 1994d). Accordingly, the associated longitudinal transportation acceleration is expected to be much lower than 3 *g*. As long as this is the case, these screws should be acceptable in accordance with the AISC 1989 stress limits. Keeping the size of the screws unchanged, for the time being, does not affect safe normal operation of the truck. However, proper evaluation of the transportation loads requires that the actual accelerations applied on the truck be measured on Hanford roads at 15 mi/h.

3.0 MATERIALS AND ALLOWABLES

The materials are specified in the drawings (RHO 1981a-g), RHO 1988a and 1988b, WHC 1992, and WHC 1993a). The fillet weld material is E70XX.

The stress results of this analysis were evaluated in accordance with the design stress limits set out in AISC 1989.

4.0 CONFIGURATION AND LOADINGS

The configurations and dimensions of the components were taken from the drawings. The configuration of each component is provided in the appendices.

The operating loads consist of the weights of the components including the truck weight for the jacks and the 6,000-lbf maximum load imposed by the drill rod when it is jammed. The loads applied on each component are described in the appendices. The weight distributions of all components and the locations of centers of gravity are provided in WHC 1994a.

The dynamic loads are in accordance with the transportation (acceleration) design requirements defined by WEC 1972 (i.e., 2 *g* lateral, 3 *g* longitudinal, and 1 *g* vertical). These values provide consistency with other RMCST dynamic analyses (WHC 1993b).

5.0 STRESS ANALYSIS

The details of the stress analyses and evaluation of the individual components are presented in the appendices to this report. The static analyses of the jacks appear in Appendix A. Appendix B consists of the static and dynamic analyses of the lower frame assembly and its connections to the truck chassis, the dynamic analysis of the bearing assembly connections, and the maximum load path through the bearing assembly connections. The analyses of the traverse slide assembly and the drill rod appear in Appendices C and D, respectively. Table 1 summarizes the stresses in the critical locations of each component as determined by the analyses in the appendices.

6.0 REFERENCES

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

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Blodgett, O. W., 1982, *Design of Welded Structures*, James F. Lincoln Arc Welding Foundation, Cleveland, Ohio.

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RHO, 1981b, *Lower Frame and rotation Stop Assembly Core Sampler Truck*, Drawing Number H-2-91703, Rev. 3, Rockwell Hanford Operations, Richland, Washington.

RHO, 1981c, *Lower Frame Assembly Core Sampler Truck*, Drawing Number H-2-91704, Rev. 3, Rockwell Hanford Operations, Richland, Washington.

RHO, 1981d, *Lower Bearing Mount Core Sampler Truck*, Drawing Number H-2-91705, Rev. 2, Rockwell Hanford Operations, Richland, Washington.

RHO, 1981e, *Bearing Plate Core Sampler Truck*, Drawing Number H-2-91709, Rev. 2, Rockwell Hanford Operations, Richland, Washington.

RHO, 1981f, *Core Sampler Truck Switch Mounts, Stops, and Slide Bracket Details*, Drawing Number H-2-91711, Rev. 3, Rockwell Hanford Operations, Richland, Washington.

RHO, 1981g, *Core Sampler Truck Bed Assembly*, Drawing Number H-2-91702, Rev. 5, Rockwell Hanford Operations, Richland, Washington.

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WHC, 1993b, *Stress Evaluation for Grapple Hoist Mounting Support Assembly (Truck #2)*, Internal Memo CSA:DAK:ggb:93110, D. A. Koehler to J. C. Mast, Westinghouse Hanford Company, Richland, Washington.

WHC, 1994a, *Request Stress Analysis Be Performed to Support the Design Basis on the Rotary Mode Core Sample Truck #2 (RMCST #2)*, Internal Memo 9456856, J. L. Smalley to K. V. Scott, Westinghouse Hanford Company, Richland, Washington.

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WHC, 1994c, *Rotary Mode Development*, Engineering Change Notice, ECN 615569, Westinghouse Hanford Company, Richland, Washington.

WHC, 1994d, *Rollover Analysis of Rotary Mode Core Sampler Truck #2*, WHC-SD-WH-ER-391, Westinghouse Hanford Company, Richland, Washington.

Table 1: Stress Results Summary at Critical Locations.

Component	Location	Type of Stress	Calculated Stress (lbf/in^2)	Allowable Stress (lbf/in^2)	Design Margin[1] (DM)
Front jack[2] assembly (vertical load)	Bolts to chassis	shear	11,800	21,000	0.78
Center[2] outrigger assembly (vertical load)	Fillet weld (3/16 in.) between I-beam and plate	shear	8,053	14,800	0.84
	Tie-rod	tension	11,300	20,000	0.77
Rear jack[2] assembly (vertical load)	Fillet weld (3/16 in.) to chassis	shear	9,920	14,800	0.50
Bearing connections and lower frame	Bearing mount to lower frame screws (Grade 8)	shear	20,900	18,000	-0.14[3]
	Platform to bearing plate, 8 bolts (Grade 8)	shear	13,800	18,000	0.30
Traverse slide assembly	Stop bracket	shear	11,224	14,400	0.28
	Bolt (Grade 8)	tension	38,686	50,405	0.30
Drill rod[4] (failure load)	Recess at external thread	axial load	31,170 lbf	σ_u = 90,000 lbf/in^2	N/A
		torsional load	17,000 in-lbf	τ_u = 45,000 lbf/in^2	

(1) Design margin = $\frac{\text{Allowable Stress}}{\text{Calculated stress}} - 1.$

(2) Results of horizontal loads are not reported because they are limited to 5 percent of vertical loads.

(3) This negative margin is during transportation (dynamic) and does not affect the safe normal operation of the truck (see details in Section 2.0 and in Appendix B).

(4) These are drill-rod loads to failure (i.e., maximum axial load to ultimate tensile strength σ_u and maximum torsional load to ultimate shear strength τ_u) including initial tightening torque of 100 ft-lbf.

APPENDIX A

ANALYSES OF THE FRONT, REAR, AND CENTER OUTRIGGER JACKS
(Vertical and Horizontal Loads)

FRONT JACK ASSEMBLY STRUCTURAL EVALUATION

1.0 INTRODUCTION

For the core sample truck number 2 (truck 2) a stress analysis and structural evaluation have been conducted for the front jack mounting assembly connections to the truck chassis or frame. These two connections (or pair) are angle brackets fabricated from 1/2 in steel plate. They are full penetration welded to the jack assembly, and bolted (with 5/8 in. and 3/4 in. SAE Grade 8 bolts) to the front ends of the chassis longitudinal members. The connection configuration and design are shown by ECN 615552 (see sketches in Section 4.0 CALCULATIONS).

The vertical front jack load or force is 8,100 lb when deployed. This analysis also was required to presume a concurrent horizontal jack force equal to one half of the vertical force (or 4,050 lbf), and able to act in either the lateral and longitudinal direction. These forces could cause axial, shear, bending, and torsion in the connections to the truck 2 chassis.

2.0 SCOPE

The scope of the stress analysis and evaluation conducted for the front jack assembly connections to the truck 2 frame, in summary, is to assess the angle brackets and the bolt fasteners to the frame. The specific stresses and conditions determined and evaluated are:

The bending, and shear (direct and torsional) stresses in the angle brackets

The shear stress in the 5/8 in. and 3/4 in. bolts

The bearing stress from the bolts in the truck 2 chassis members

3.0 METHODOLOGY AND ACCEPTANCE CRITERIA

Typical methods for design stress analysis of structural steel members and their connections were used. The acceptance criteria for the angle bracket allowable stresses and bolt design limits were determined from AISC 1989.

4.0 CALCULATIONS

Stress Analyses Calculations

for

The Front Jack Assembly,

Core sample Truck Number 2

5.0 ANALYSIS RESULTS AND CONCLUSIONS

For the normal vertical load only on the front jack, the calculated bending and direct shear stresses in the angle brackets are 3,038 lbf/in^2 and 3,240 lbf/in^2, respectively. These values are low and well within their allowables, 22,000 lbf/in^2 bending and 10,800 lbf/in^2 shear. The corresponding bolt shear stresses are 11.8 $Kips/in^2$ and 10.4 $Kips/in^2$ for the 3/4 in. and 5/8 in. bolts, respectively. The allowable bolt shear stress is 21 $Kips/in^2$. The 3/4 in. bolts will apply 27.7 $Kips/in^2$ bearing stress at the holes in the chassis members (1/4 in. thickness). The chassis steel has an ultimate tensile strength (F_u) of 103 $Kips/in^2$, the maximum allowable full bearing stress is 1.5 F_u. The connections for the assembly to the chassis are adequately designed for the 8,100 lbf vertical front jack load acting alone.

The additional calculated stresses in the angle bracket for the 4,050 lbf horizontal load on the front jack are: 16,000 lbf/in^2 bending stress if this load is in the longitudinal direction, and 21,900 lbf/in^2 shear stress if this load is in the lateral direction. The potential combined horizontal and vertical load bending stress is 19,038 lbf/in^2 and remains below the allowable. However, the potential combination of shear stress is over 25,000 lbf/in^2, well over the allowable. Further, the calculated shear stress neglects the bolt holes in the brackets (nonconservative). The maximum potential additional shear stresses in the bolts 58.6 $Kips/in^2$ and 40.7 $Kips/in^2$ for the 5/8 in. and 3/4 in. bolts, respectively. Both are over the allowable. The combined shear stress in the 5/8 in. bolts for the vertical and horizontal loads exceeds the allowable by over a factor of 3. The maximum potential bearing stress applied by the 5/8 in. bolts at the holes in the truck chassis is 135.7 $Kips/in^2$, still under 1.5 F_u.

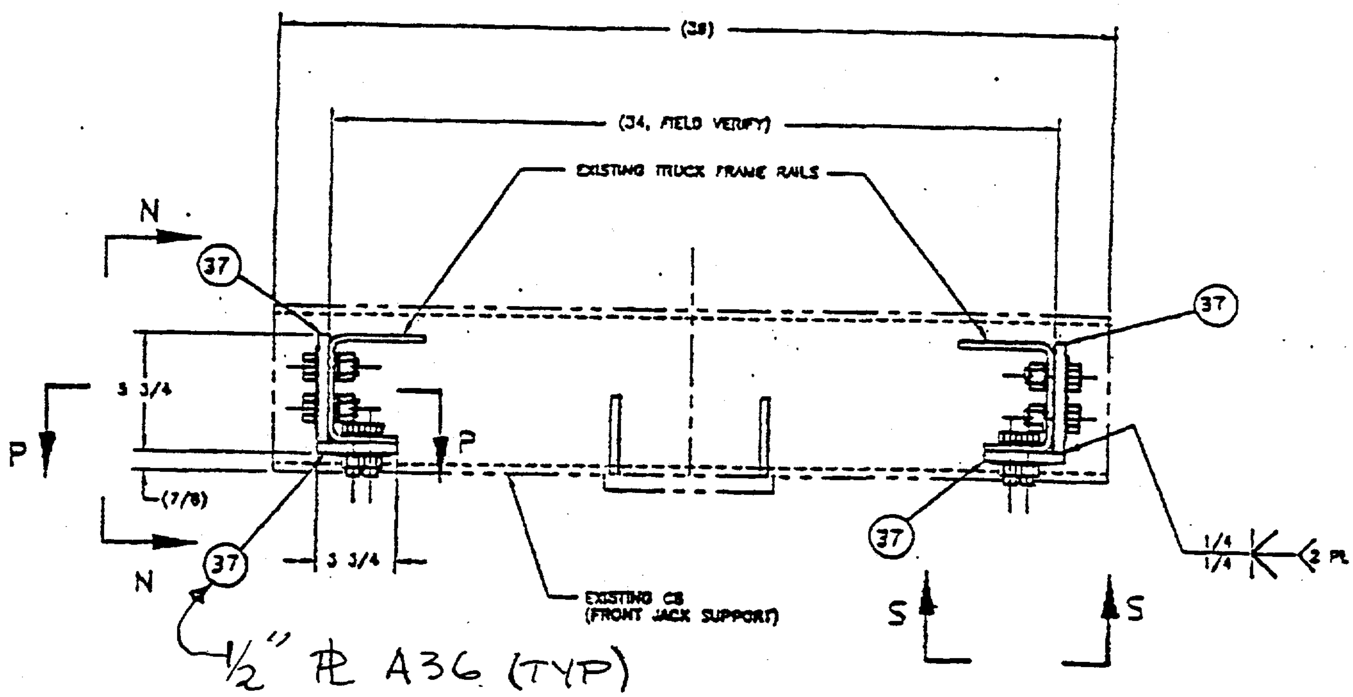
The horizontal front jack load the assembly connections to the chassis could resist is governed by the shear stress in the 5/8 in. bolts. The design allowable stress for these bolts limits this load to 9% of the 8,100 lbf vertical load or 730 lbf.

ANALYTICAL CALCULATIONS

Subject: FRONT JACK ASSEMBLY ATTACHMENTS TO CHASSIS, TRUCK 2
Originator: F.R. VOLLERT   Date: 10/4/94
Checker: Hasan H. Ziada   Date: 10-26-94

REF: ECN 615552, 9/30/94

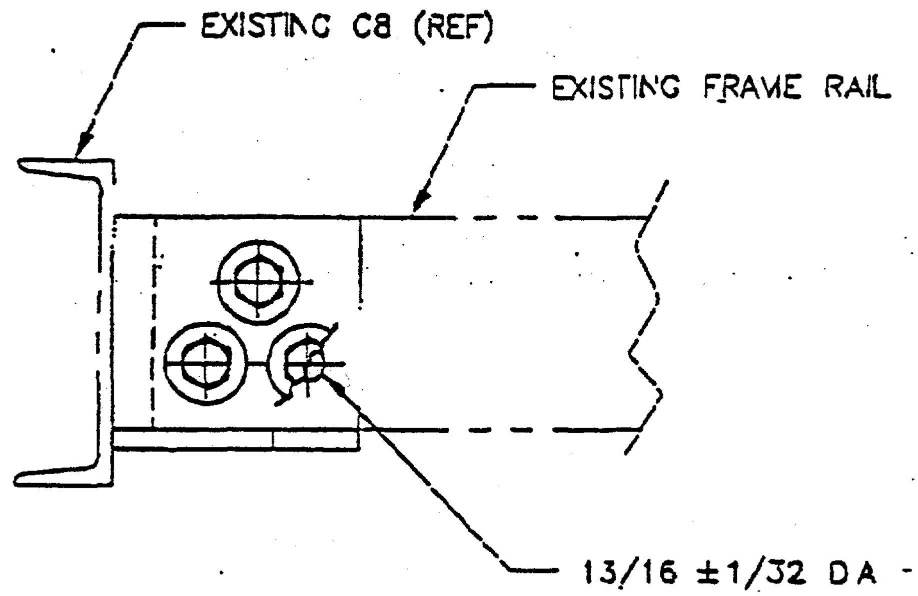
REQUIRED: STRESS ANALYSIS OF THE BOLTED AND WELDED CONNECTION FOR THE JACK ASSEMBLY TO THE FRONT ENDS OF THE TRUCK CHASSIS OR FRAME FOR: 8100 LB VERTICAL JACK LOAD AND FOR 1/2 (8100 LB) HORIZONTAL LOAD IN EITHER LATERAL OR LONGITUDINAL DIRECTION COMBINED WITH THE VERTICAL LOAD



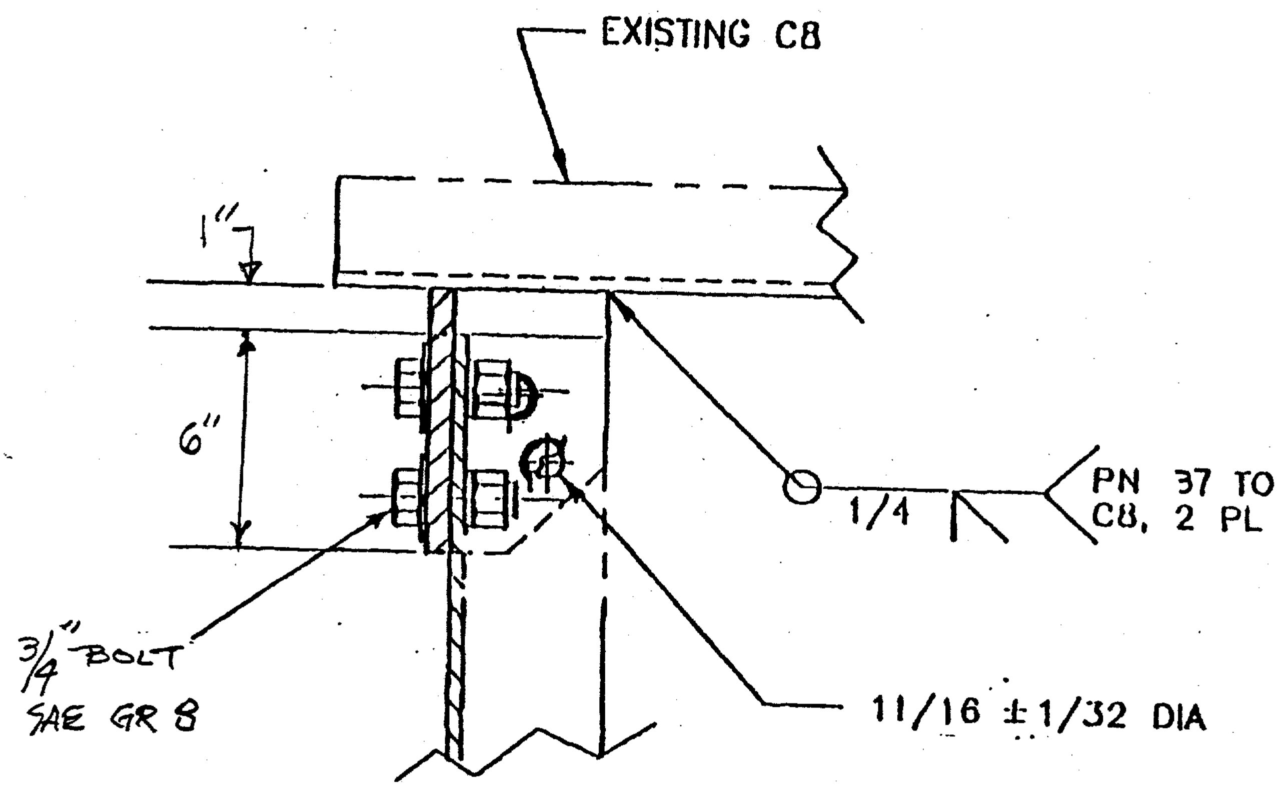
BD-6400-060.1 (07/93)

ANALYTICAL CALCULATIONS

Subject: FRONT JACK ASSEMBLY CONTINUED
Originator: F.R. VOLLERT Date: 10/4/94
Checker: Hasan H. Zieda Date: 10-26-94



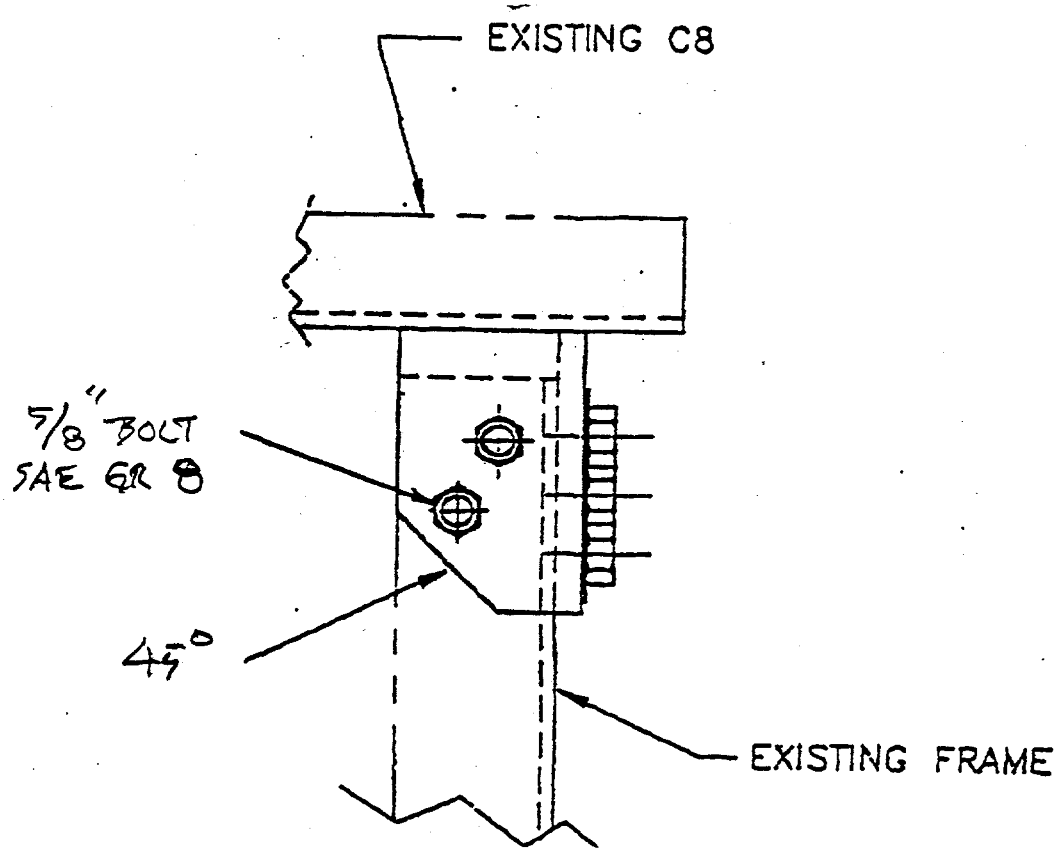
N - N



P-P

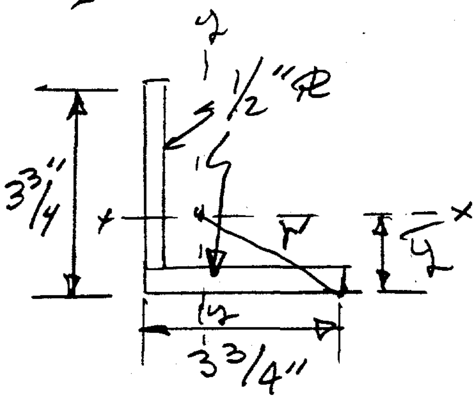
ANALYTICAL CALCULATIONS

Subject: FRONT JACK ASSEMBLY, CONTINUED
Originator: F. R. YOLCERT Date: 10/4/94
Checker: Homer H. Ziola Date: 10-26-94



S-S

CALCULATE SECTION PROPERTIES FOR 1/2" PL ANGLE BRACKET



$$AREA\ (A) = 3.75 \times 0.5 + 3.25 \times 0.5$$

$$A = 3.5\ in^2$$

$$\bar{y} = \frac{1.625 \times 2.125 + 1.875 \times 0.25}{3.5}$$

$$\bar{y} = 1.12''$$

$$I_{xx} = \frac{0.5 \times 3.25^3}{12} + 1.625(2.125 - 1.12)^2 + 1.875(1.12 - 0.25)^2$$

$I_{xx} = 4.5\ in^4$ $\qquad I_{yy} = 4.5\ in^4$ BY SYMMETRY

ANALYTICAL CALCULATIONS

Subject: FRONT JACK ASSEMBLY, CONTINUED
Originator: F.R. VOLLERT Date: 10/4/94
Checker: Hassan H. Zaki Date: 10-26-94

$$S_{xx} = S_{yy} = \frac{4.5}{1.12} = 4.0 \text{ IN}^3$$

$$J = I_{xx} + I_{yy} = 9.0 \text{ IN}^4, \quad r' = \sqrt{(1.12)^2 + (2.63)^2} = 2.86''$$

VERTICAL LOAD STRESSES IN BRACKET AT WELD TO EXISTING CB

$$\text{LOAD} = \frac{8100}{2} = 4050 \text{ LB/SIDE}$$

$$\text{SHEAR STRESS } f_v \approx \frac{3}{2} \times \frac{4050}{\frac{1}{2} \times 3.75} = 3240 \text{ PSI}$$

$$\text{BENDING STRESS } f_b = \frac{4050 \times 3}{4} = 3038 \text{ PSI}$$

ESTIMATED MOMENT ARM TO CENTER OF BOLT PATTERN ON FRAME = 3"

BOLT FORCES:

DIRECT SHEAR CARRIED BY TWO OF 3/4" BOLTS ONLY BASED ON PATTERN:

$$F_V = \frac{4.050^K}{2} = 2.0 \text{ K/} \tfrac{3}{4}'' \text{ BOLT}$$

BENDING COUPLE CARRIED BY TWO 5/8" BOLTS AND TWO 3/4" BOLTS, ARM ESTIMATE = $\frac{3.75''}{2}$

$$F_B = \frac{4.050^K \times 3}{2 \times \frac{3.75}{2}} = 3.2 \text{ K/BOLT (BOTH DIAM)}$$

BEARING STRESSES

1/4" t FOR TRUCK FRAME MEMBER ($F_u = 103$ KSI)

$$\text{For } \tfrac{5}{8}'' \text{ BOLT} \quad f_{Br} = \frac{3.2}{0.25 \times 0.625} = 20.5 \text{ KSI}$$

$$\text{For } \tfrac{3}{4}'' \text{ BOLT} \quad f_{Br} = \frac{3.2 + 2.0}{0.25 \times 0.75} = 27.7 \text{ KSI}$$

ANALYTICAL CALCULATIONS

Subject: FRONT JACK ASSEMBLY CONTINUED
Originator: F. R. VOLLERT Date: 10/4/94
Checker: Hasan H. Zink Date: 10-26-94

HORIZONTAL LOADS

$$H = \frac{8100}{2} \times \frac{1}{2} = 2025 \text{ LB / SIDE}$$

FULLY EXTENDED LN OF JACK RELATIVE TO THE INTERFACE OF THE MOUNTING PLATES IS 12 3/4" + 3/4" + 18" (STROKE) = 31.5"
(FROM LONGYEAR ENGINEERING DEPT 10/4/94)

MOMENT FROM HORIZONTAL EITHER DIRECTION

$$M_H = 2025^K \times 31.5 = 63.8 \text{ K-IN / BRACKET}$$

LONGITUDINAL DIRECTION

BENDING STRESS IN BRACKET

$$f_b = \frac{63.8^{K\text{-}IN}}{4} = 16 \text{ KSI}$$

DIRECT SHEAR IN BOLTS PRESUME 2-3/4" AND 2-5/8" BOLTS (4 TOTAL) CARRY:

$$F_{VH} = \frac{2050}{4} = 0.5 \text{ K/BOLT}$$

BENDING COUPLE 2 BOLTS EACH SIZE IBID

$$F_{VB} = \frac{63.8 \text{ K-IN}}{2 \times \frac{3.75}{2}} = 17.0 \text{ K/BOLT (TOO HIGH)}$$

BEARING STRESSES:

$$5/8'' \quad \frac{17.0K + 0.5K}{0.25 \times 0.625} = 112.0 \text{ KIPS/IN}^2$$

$$3/4'' \quad \frac{17.0 + 0.5}{0.25 \times 0.75} = 93.3 \text{ KIPS/IN}^2$$

ANALYTICAL CALCULATIONS

Subject FRONT JACK ASSEMBLY CONTINUED
Originator F.R. VOLLERT Date 10/4/94
Checker Hasan H. Zivk Date 10-26-94

LATERAL DIRECTION

TORSIONAL STRESS IN BRACKET (SHEAR)

$f_t = \frac{Mr}{J} = \frac{63.8\ K\text{-}IN \times 2.86}{9.0} = 20.3\ KSI$

DIRECT SHEAR IN BRACKET: TOTAL SHEAR =

$f_{VH} \approx \frac{3}{2} \times \frac{2.025}{\frac{1}{2} \times 3.75} = 1.6\ KSI \quad 1.6 + 20.3 = 21.9\ KIPS/IN^2$

ALLOWABLE SHEAR F_v = 0.30 F_u = 10.8 KIPS/IN² (ON NET SECTION)

DIRECT SHEAR IN BOLTS:

CARRIED BY BOTH 5/8" BOLTS ONLY

$F_v = \frac{2.025}{2} = 1.0K/BOLT$

TORSIONAL COUPLE 2 BOLTS EACH SIZE 18.0

17.0 K/BOLT (TOO HIGH) 5/8"⌀ $F_v = \frac{18}{0.307} = 58.6\ KIPS/IN^2$

BEARING STRESSES 18.0 3/4"⌀ $F_v = 18/0.442 = 40.7\ KIPS/IN^2$

5/8" BOLT $F_{br} = 18/0.25 \times 0.625 = 115.2\ KIPS/IN^2$

CONCLUSION: BOLTS IN JACK ASSY BRACKET GREATLY OVERLOADED BY HORIZONTAL LOADS PRESUMED (0.5 VERT LOAD)

ESTIMATE ACCEPTABLE HORIZONTAL LOAD COMBINED WITH VERTICAL

BOLT LOADS FROM VERTICAL LOAD;

3/4" BOLT $F_v = \frac{2.0^K + 3.2^K}{0.442 IN^2} = 11.8\ KIPS/IN^2$

(ALLOWABLE STD CONNECTIONS = 21 KIPS/IN²)

5/8" BOLT $F_v = \frac{3.2\ KIPS}{0.307 IN^2} = 10.4\ KIPS/IN^2$

CHASSIS COMBINED BEARING STRESS 5/8" BOLTS:

$F_{br} = 20.5 + 115.2 = 135.7\ KIPS/IN^2 < 1.5 F_u$

ANALYTICAL CALCULATIONS

Subject: FRONT JACK ASSEMBLY, CONTINUED
Originator: E.R. VOLLERT Date: 10/4/94
Checker: Hasan H. Zia Date: 10-26-94

BOLT LOADS FROM (0.5 x VERTICAL) HORIZONTAL LOAD

3/4" BOLT F_H = 0.5+17 = 17.5^K

5/8" BOLT F_H = 1.0+17.0 = 18 K

FOR 5/8" BOLT AVAILABLE CAPACITY = (21.0-10.4) 0.307 = 3.2^{KIPS}

$\frac{3.2}{18.0} \times 0.5 = 0.09$ ∴ 0.09 VERT IS ESTIMATED HORIZ CAPACITY

0.09 x 8100 = 729 lbf MAX

NOTE: THE 4 BOLT CONECTION BETWEEN THE JACK MOUTING PLATES NOT ANALYZED HERE FOR HORIZONTAL LOAD AND MOMENT ON JACK. VERTICAL JACK LOAD DOES NOT STRESS THESE 4 BOLTS. THE JACK AND ITS MOUNTING WOULD BE SUBJECT TO DOUBLE THE HORIZONTAL LOAD AND ASSOCIATED MOMENTS ON EACH FRAME BRACKET.

BD-6400-060.1 (07/93)

REAR AND CENTER AND CENTER JACK ASSEMBLIES STRUCTURAL EVALUATION

1.0 INTRODUCTION

For the core sample truck number 2 (truck 2) stress analyses and structural evaluations have been conducted for the rear and center jack assemblies and their connections to the truck chassis or frame. The main structural members for these assemblies are W 14 x 22 steel beams with end bolsters for mounting the jacks. The rear assembly has welded connections to the ends of the 2 longitudinal chassis members. The two center assemblies each have an end plate welded to the beam and bolted to the truck. There is a pair of 1 in. diameter tie rods between the center assemblies.

The vertical load on each of the rear assembly's 2 jacks is 13,000 lbf maximum. The analysis also was required to presume concurrent horizontal jack forces equal to one half of the vertical force (or 6,500 lbf) and able to act in either the lateral or longitudinal direction. The vertical load on the center jack is 10,000 lbf maximum and the concurrent vertical load on the other ranges from 1,000 lbf to 2,500 lbf. It was <u>not</u> required to presume horizontal loads on the center assembly jacks.

2.0 SCOPE

The scope of the stress analyses and evaluation conducted for the rear and center jack assemblies and their connections to the truck 2 chassis, in summary, is to assess all the structural members, components and connections in the load path from the mounting bolsters for the jacks to the truck chassis. The specific stresses and conditions determined and evaluated are:

The stresses in the bolsters and end plates, including welds and the mounting bolts for the jacks

The bending and shear stresses in the assembly W 14 x 22 beams

The stresses (including welds and bolts) in the attachments to the truck chassis

3.0 METHODOLOGY AND ACCEPTANCE CRITERIA

Typical methods for design stress analysis of structural steel members and their connections were used. The acceptance criteria for member allowable stresses, acceptable weld stress, and bolt force design limits were determined from AISC 1989. The analysis methods and criteria used include:

The bending and shear stresses for the beams were calculated presuming that they are simply supported or point loaded where the jacks are bolted to the mounting bolsters. The rear assembly is a simple beam with concentrated loads at the attachment points to the truck chassis. The center assemblies act as cantilever beams, fixed end supports are provided by the end plates bolted to the lower frame and the tie rods. The results were compared to the AISC allowables for compact sections.

For the bolsters and end plates, the web crippling potential, bolt stresses, and weld forces were analyzed and evaluated.

The rear assembly attachments to the chassis are 1/4 in. thick bracket plates fillet welded to the flanges and web on the inside of the W 14 x 22 beam and to one side of the chassis longitudinal members. The weld shear forces due to the concentrated loads at the attachments, and torsional moments caused by horizontal jack forces were calculated and compared to the AISC allowables.

The weld stress, bolt stress, and tie rod tension at the fixed ends of the center assemblies were calculated and evaluated with the AISC allowables.

4.0 CALCULATIONS

Stress Analyses Calculations

for

The Rear and Center Jack Assemblies,

Core sample Truck Number 2

(1) Drawing H-2-91718, 1403C8 (2) Doc. No. ____ (3) Page ____ of 1

(4) Building ____ (5) Rev. ____ (6) Job No. ____

(7) Subject Rear Jack Assembly

(8) Originator BJ Niemi Date 11-1-94

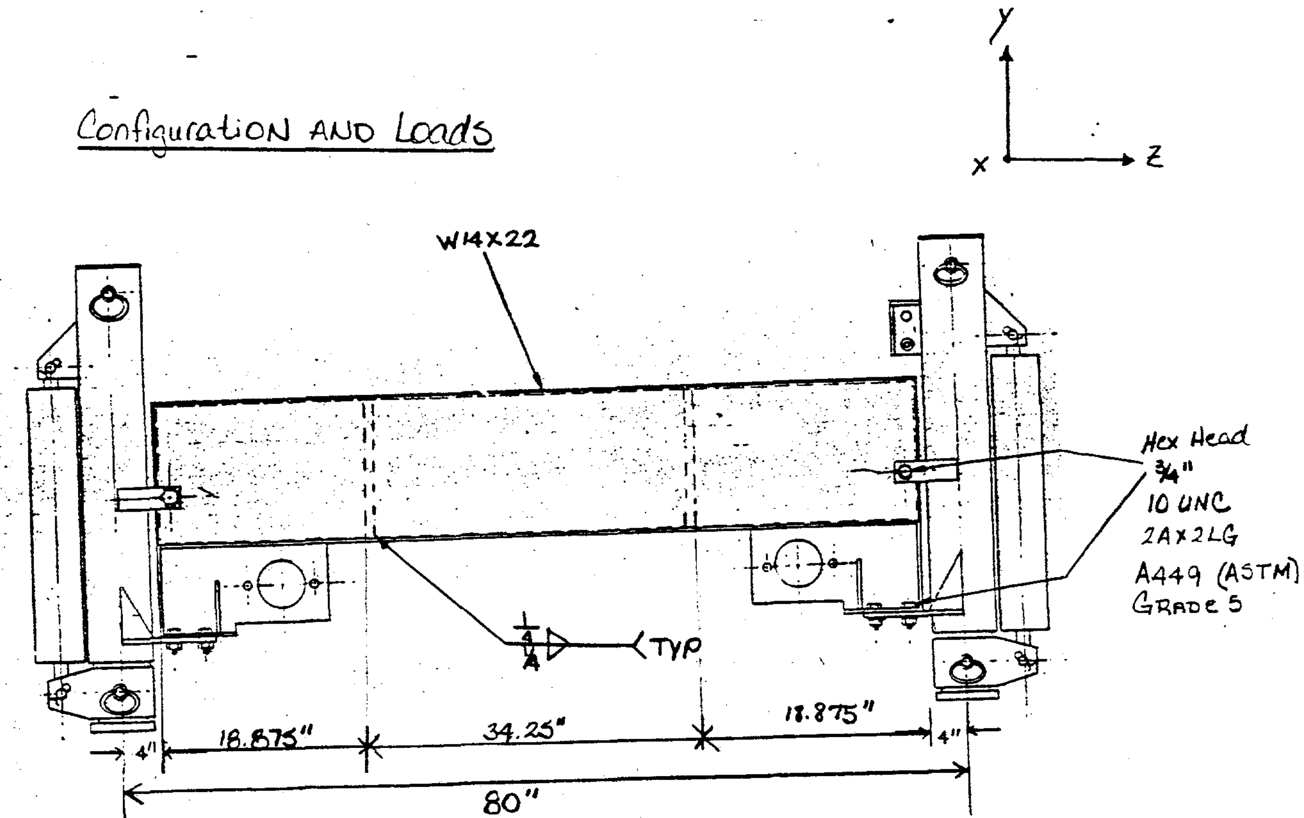
(9) Checker F.R. Vollert Date 11/11/94

REAR JACK

1.0 INTRODUCTION

The purpose of this ANAlysis is to determine if the REAR JACK Assembly design is Adequate for KNOWN LOADING CONditions.

2.0 Configuration AND Loads



NORMAL OPERATING LOADS

A) With platform rotated to the side, the REACTION Loads are 12 Kips & 6.5 Kips.

B) With platform extended to the rear, the Reaction Loads are 13 Kips AT EACH JACK including drill rod Maximum Loads.

CONFIGURATION

The wide FLANGE beam SECTION is welded To The Chassis AS shown Above.

3.0 Analysis for VERTICAL Loads

(1) Drawing H-2-91718, 140308 (2) Doc. No. ______ (3) Page ____ of ____

(4) Building ______ (5) Rev. ______ (6) Job No. ______

(7) Subject Rear Jack Assembly

(8) Originator BJ Niemi Date 11-1-94

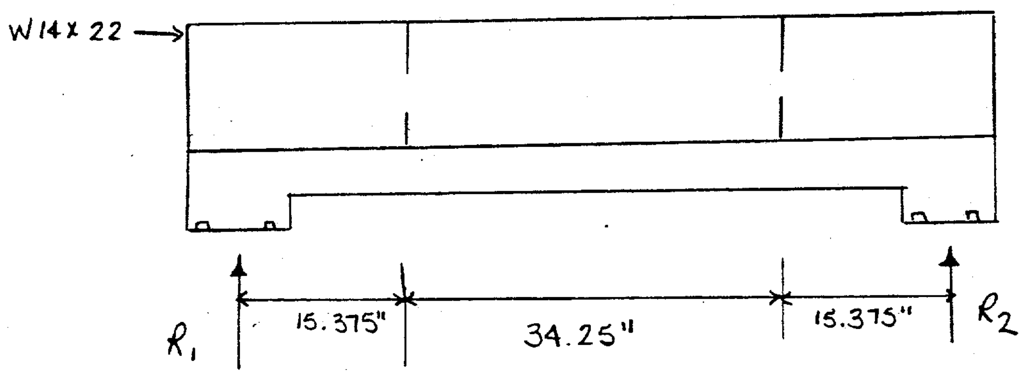
(9) Checker F.R. Vollert Date 11/11/94

(10)

3.1 Analysis of Rear Jack Assembly for Vertical Loads

Assume: 1) Loads are applied at ℄ of bolt holes in bolster.

2) Connecting plates from the jack are designed to carry the loads and are adequate to do so.



Case A $R_1 = 6.5$ K $R_2 = 12$ K

Case B $R_1 = 13$ K $R_2 = 13$ K

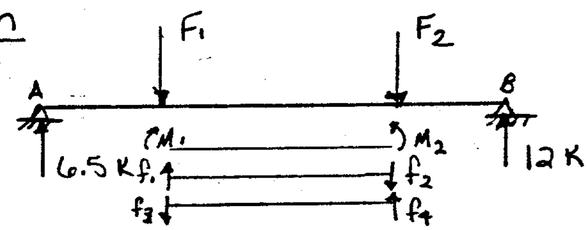
Max Moment (Case B) $= 13(15.375) = 200$ in·K

Check Bending Stress in Beam

$$f_b = \frac{M}{S} = \frac{200 \text{ in}\cdot K}{29 \text{ in}^3} \cong 7 \text{ KSI} < F_b \checkmark \text{ OKAY}$$

$$F_b = .66 F_y = .66(36 \text{ KSI}) = 23.8 \text{ KSI}$$

Check Shear Stress in Beam



$M_1 = 6.5(15.375) = 100$ in·K

$M_2 = 12(15.375) = 185$ in·K

$\Sigma M@A = 0$

$12(65) - f_2(49.625) - f_1(15.375) = 0$

$\Sigma F_y = 0$

$f_1 = 18.5 - f_2$

$f_1 = 4$ K & $f_2 = 14.5$ K

BD-6400-060.1 (12/87)

(1) Drawing H-2-91718 14C308 (2) Doc. No. ______ (3) Page ____ of ____

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(7) Subject Rear Jack Assembly

(8) Originator BJ Nierci Date 11-1-94

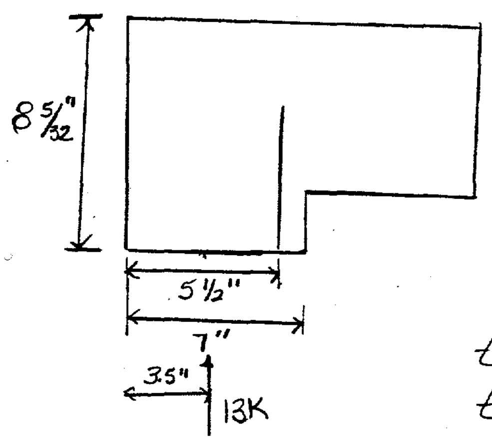
(9) Checker FRV Date 11/11/94

$$f_v = \frac{F_2}{td} = \frac{14.5K}{(13.74)(.230)} = 4.6KSI < F_v \checkmark \text{ OKAY}$$

$$F_v = .4\,F_y = 14.4KSI$$

Check Web Crippling Stress of 1/4" bolster plate

$d/2 = 4.07in$



AISC (1989)
When the concentrated load is applied at a distance less than d/2 from the end of the member:

$$13K \le 34 t_w^2 \left[1 + 3\left(\frac{N}{d}\right)\left(\frac{t_w}{t_f}\right)^{1.5}\right]\sqrt{F_{yw} t_f / t_w}$$

$t_w = 1/4"$ $N = 5\ 1/2"$ $F_{yw} = 36ksi$

$t_f = 1/4"$ $d = 8\ 5/32"$

$13K \le 38.5K$ ✓ Okay

BD-6400-060 [illegible]

DESIGN CALCULATION

(1) Drawing H-2-91718 14C308 (2) Doc. No. ______ (3) Page ____ of ____
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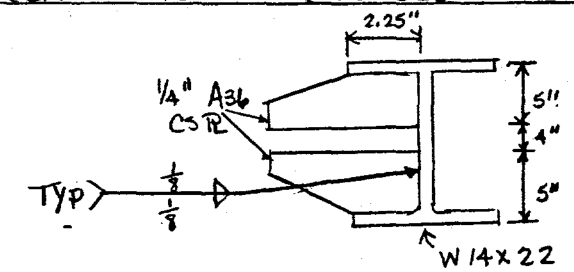
(7) Subject Rear Jack Assembly
(8) Originator CJ Niemi Date 11-1-94
(9) Checker FRV Date 11/11/94

Check Weld Shear Forces on Attachments to Chassis



Treating Weld as a line (Blodgett 1982)

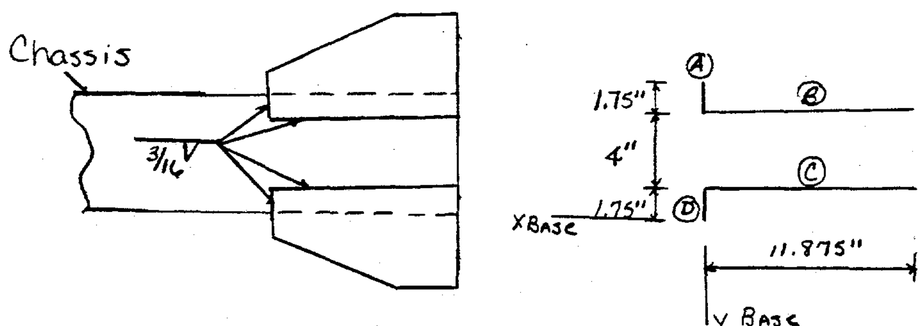
1/4" Plates To Beam

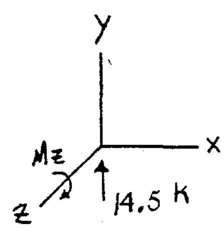
$A_w = 2(5+5) + 2(2.25+2.25) = 29 in$

$f_R = \frac{14.5K}{29} = 0.5$ K/in < Allowable $= (.3)(.707)(1/8)(70) = 1.85$ K/in ✓ OKAY

$t_w = \frac{.5}{(.3)(.707)(70)} = 0.034 in$

AISC (1989) requires 1/8" fillet weld which is adequate to carry the load.





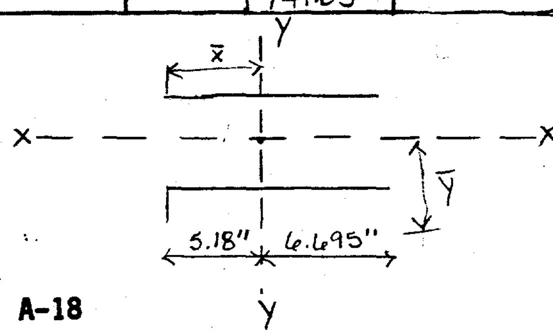
Member	$A_w = L$ (in)	Dist Y (in)	$M_y = L \cdot y$ (in^2)	$\bar{Y}$	Dist X in	$M_y = L \cdot X$ in^2	$\bar{X}$
A |	1.75	6.625	11.59	2.875	0	0	5.18
B ——	11.875	5.75	68.28	2	5.938	70.51	-.7575
C ——	11.875	1.75	20.78	-2	5.938	70.51	-.7575
D |	1.75	.875	1.53	-2.875	0	0	5.18
	27.25	—	102.19	—	—	141.03	

$\bar{y} = \frac{M_y}{A} = \frac{102.19}{27.25} = 3.75 in$

$\bar{X} = \frac{M_x}{A} = \frac{141.03}{27.25} = 5.18 in$

$r'^2 = 6.695^2 + 2^2$ $r' = 6.99 in$

$M_z = 14.5(6.695) = 97.08$ in·K.



DESIGN CALCULATION

(1) Drawing H-2-91718 14C308 (2) Doc. No. ______ (3) Page ____ of ____
(4) Building ______ (5) Rev. ______ (6) Job No. ______
(7) Subject Rear Jack Assembly
(8) Originator EJ Niemi Date 11-1-94
(9) Checker FRV Date 11/11/94

Member	$L\bar{y}^2$ in^3	$L\bar{x}^2$ in^3	$I_x = \frac{L^3}{12}$ (in^3)	I_y (in^3) $= \frac{L^3}{12}$
A |	14.46	46.96	.45	0
B —	47.5	6.82	0	139.5
C —	47.5	6.82	0	139.5
D |	14.46	46.96	.45	0
Σ	123.92	107.55	.89	279.09

$I_{xx} = I_x + L\bar{y}^2 = .89 + 123.92 = 124.81 in^3$

$I_{yy} = I_y + L\bar{x}^2 = 279.09 + 107.55 = 386.65 in^3$

$J_w = I_{xx} + I_{yy} = 511.45 in^3$

$f_R = \frac{14.5}{27.25} + \frac{97.07(6.99)}{511.45} = 1.86$ K/in $\left(\frac{1.860}{.1875} = 9,920 \text{ lb}_f/in^2\right)$
$< 14,800 \text{ lb}_f/in^2$ o.k.

$t_w = \frac{1.86}{14.80} = 0.125$ in < 3/16" ✓ okay

AISC (1989) requires 3/16" fillet weld, which is adequate for this loading condition.

Conclusion: The rear jack assembly design is adequate to carry this loading condition.

BD-6400-060 ...

DESIGN CALCULATION

WHC-SD-WM-ER-392
Rev. 0

(1) Drawing H-2-140309 (2) Doc. No. ______ (3) Page ____ of ____

(4) Building ______ (5) Rev. ______ (6) Job No. ______

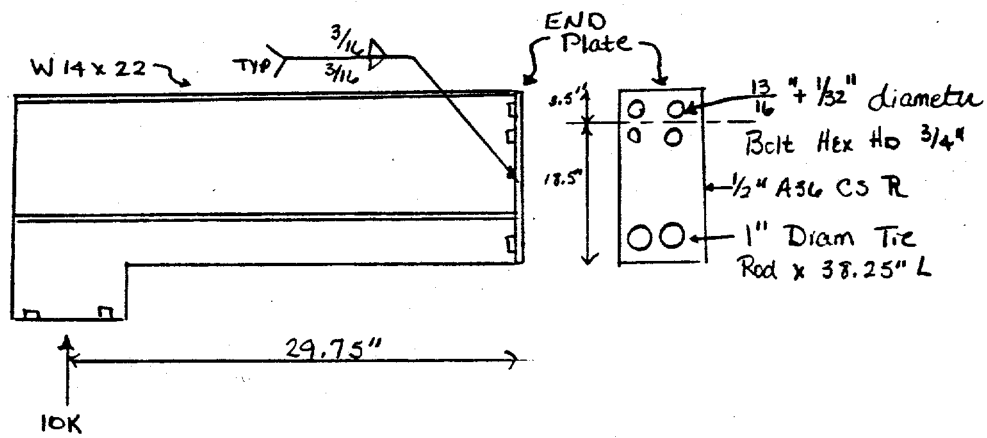
(7) Subject Center Jack Assembly

(8) Originator BJ Niemi Date 11-1-94

(9) Checker FRV Date 11/11/94

(10)

3.2 Center Jack Analysis for Vertical Loads



$M = P\ell = 10\,(29.75) \cong 298 \text{ in}\cdot\text{K}$

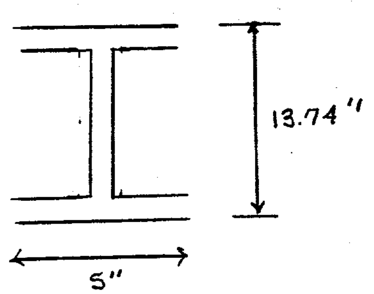
Check Bending Stress in Beam

$f_b = \frac{M}{S} = \frac{298 \text{ in}\cdot\text{K}}{29 \text{ in}^3} = 10 \text{ KSI} < F_p = .66 F_y = 23.8 \text{ KSI}$ ✓ OKAY

Check Shear Stress in Beam

$f_v = \frac{P}{td} = \frac{10}{13.74(.230)} = 3.16 \text{ KSI} < F_v = .4\,F_y = 14.4 \text{ KSI}$ ✓ OKAY

Check Weld stress of plate To Beam



$A_w = (2 \times 5) + 2(5 - .23) + 2[13.74 - (2 \times .335)] = 45.68 \text{ in}$

$S_w = 2bd + \frac{d^2}{3} = 200 \text{ in}^2$

$f_b = \frac{M}{S} = \frac{298}{200} = 1.49 \text{ K/in}$

$f_v = \frac{P}{A_w} = \frac{10}{45.68} = 0.219 \text{ K/in}$

$f_w = \sqrt{f_b^2 + f_v^2} = 1.51 \text{ K/in} < (.3)(.707)(70)(3/16) = 2.787 \text{ K/in}$ ✓ OKAY

$\left(\frac{1{,}510}{.1875} = 8{,}053 \text{ lb}_f/\text{in}^2 < 14{,}800 \text{ lb}_f/\text{in}^2\right)$

BD-6400-060.1 (12/87)

(1) Drawing *H-2- 140309* (2) Doc. No. ______ (3) Page ____ of ____

(4) Building ______ (5) Rev. ______ (6) Job No. ______

(7) Subject *Center Jack Assembly*

(8) Originator *B J Niemi* Date *11-1-94*

(9) Checker *FRV* Date *11/21/94*

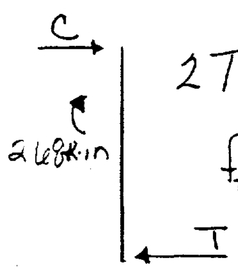
(10) Check bolted connection on End Plate (SAE GRADE 8)
with 1.0 K on opposite Center Jack

$M = 298 - 29.75 = 268.25 \text{ in} \cdot K$

$4T = \frac{268.25}{18.5} = 14.5 K$ $T = 3.6 K/\text{bolt} <$ allowable $23.9K$ ✓ Okay

Check Tie Rod Connection

Assume Tie Rods are in Tension, double headed, 2 Center jack Assembly



$2T = \frac{M}{18.5} = \frac{328}{18.5} = 17.7 K \Rightarrow T = 8.85 K/\text{rod}$

$f_t = \frac{T}{A} = \frac{8.85}{0.7854} = 11.3 \text{ KSI} < F_t = 20 \text{ KSI}$ ✓ Okay

Check for Web Crippling in bolster

Web crippling is okay by analysis of rear jack assembly (pg 3.)

(1) Drawing H-2-91718, 140308 (2) Doc. No. ______ (3) Page ___ of ___
(4) Building ______ (5) Rev. ______ (6) Job No. ______
(7) Subject Rear Jack Assembly
(8) Originator BJ Niemi Date 11-1-94
(9) Checker FRV Date 11/11/94

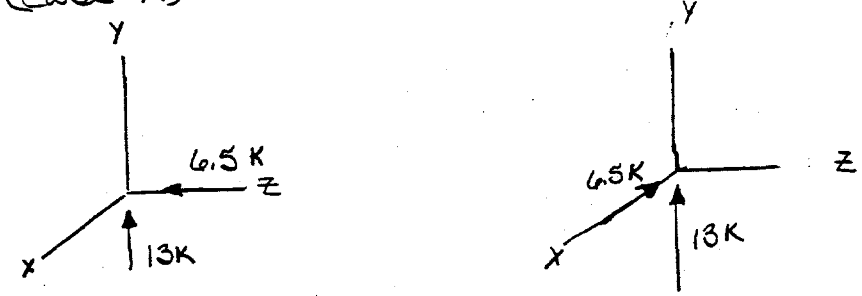
4.0 Analysis for Horizontal Loads

(10)

4.1 Analysis of Rear Jack Assembly under Applied Horizontal Loads.

The purpose of this analysis is to see how the rear jack assembly will perform if horizontal loading occurs. The horizontal jack load is presumed to be equal to 1/2 the vertical load and applies either longitudinally or laterally in combination with the vertical load.

(Case A) (Case B)



These forces correspond to the platform being extended to the rear of the truck. The jacks normally are extended only a few inches to barely raise the tires, however they could be extended to the maximum amount resulting in a distance of 34.125" to the bolted connection.

ANALYTICAL CALCULATIONS

Subject: REAR JACK ASSEMBLY
Originator: F.R. VOLLERT — Date: 10/6/94
Checker: Hasan H. Zisla — Date: 11-2-94

HORIZONTAL LOADS ON BOLSTERS AND END PLATES

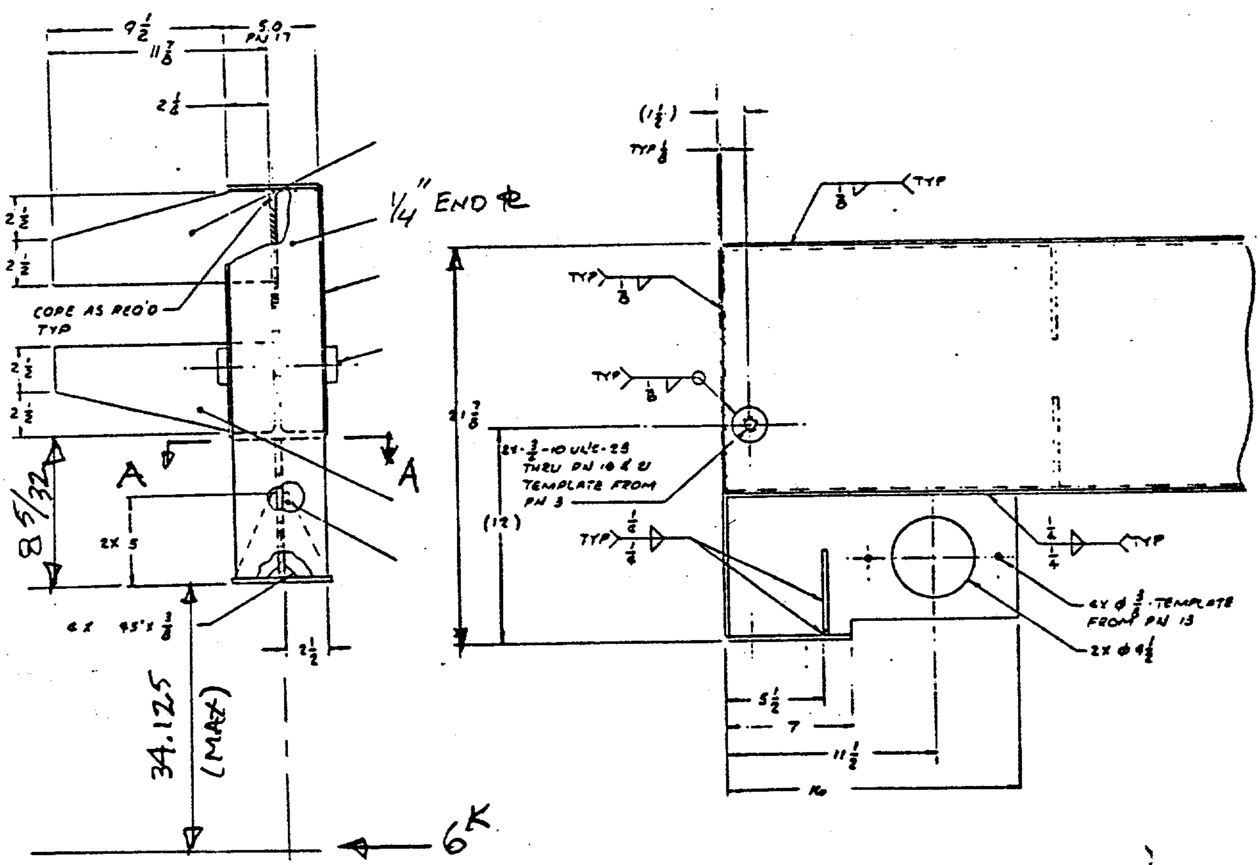
REF: H-2-91718 (SH 1,2)

REQUIRED:

STRESS ANALYSIS OF REAR JACK ASSEMBLY FOR HORIZONTAL LOAD ON END OF FULLY EXTENDED JACK IN EITHER LONGITUDINAL OR LATERAL DIRECTION COMBINED WITH VERTICAL LOAD
HORIZONTAL (PRESUMED) LOAD = 1/2 VERTICAL

$H = \frac{1}{2}\, 12^K = 6^K$ / JACK

FOR LONGITUDINAL DIRECTION CALCULATE STRESSES (SHEAR + BENDING) IN END PLATE 1/4" t × 5" w FOR W 14×22 SEE SKETCHES BELOW.



BD-6400-060.1 (07/93)

ANALYTICAL CALCULATIONS

Page ____ of ____

Subject: REAR JACK ASSEMBLY
Originator: F. R. VOLLERT Date: 10/6/94
Checker: Hasan H. Tiah Date: 11-2-94

$M_{A-A} = 6^K(34.125 + 8.156) = 253.7$ K-IN (HIGH)

$V_{A-A} = 6^K$ AND ≈ 0 KSI, VERTICAL LOAD STRESS

END PLATE ONLY IS EFFECTIVE FOR THESE IN THE LONGITUDINAL DIRECTION

$S = \frac{bd^2}{6} = \frac{1/4 \times 5^2}{6} = 1.04\ IN^3$

$f_b = \frac{253.7\ K\text{-}IN}{1.04} = 244$. TOO HIGH

$f_v = \frac{3}{2}\frac{6}{5 \times 0.25} = 7KSI$ LOW

IF $0.6F_y = 22KSI$ ALLOWABLE

ACCEPTABLE LONGITUDE LOAD $= \frac{22}{244} \times 6 = 0.5^K$

REMAINDER OF LOAD PATH FOR LONGITUDINAL LOAD MUCH MORE EFFECTIVE.

FOR LATERAL DIRECTION ATTACHMENT WELD FOR JACK MOUNTING PLATE 1/4" t × 6.5" W × 7" L SHOULD GOVERN

NOTE: 1/4" FILLET WELD SPECIFIED BUT ONLY 3/16" EFFECTIVE FOR 1/4" ℄ (AISC)

WELD LENGTH = 7" (2 SIDES) 6/16" = 3/8" SIZE

DIRECT SHEAR: (≈ 5400 LB/IN ALLOWED)

$F_{w,v} = \frac{6000}{7} = 857$ LB/IN

BENDING

$M = 6000 \times 34.125 = 204750$ IN-LB (HIGH)

$S_{weld} = \frac{7^2}{6} = 8.17\ IN^2$

$F_{w,B} = \frac{204750}{8.17} = 25061$ LB/IN TOO HIGH

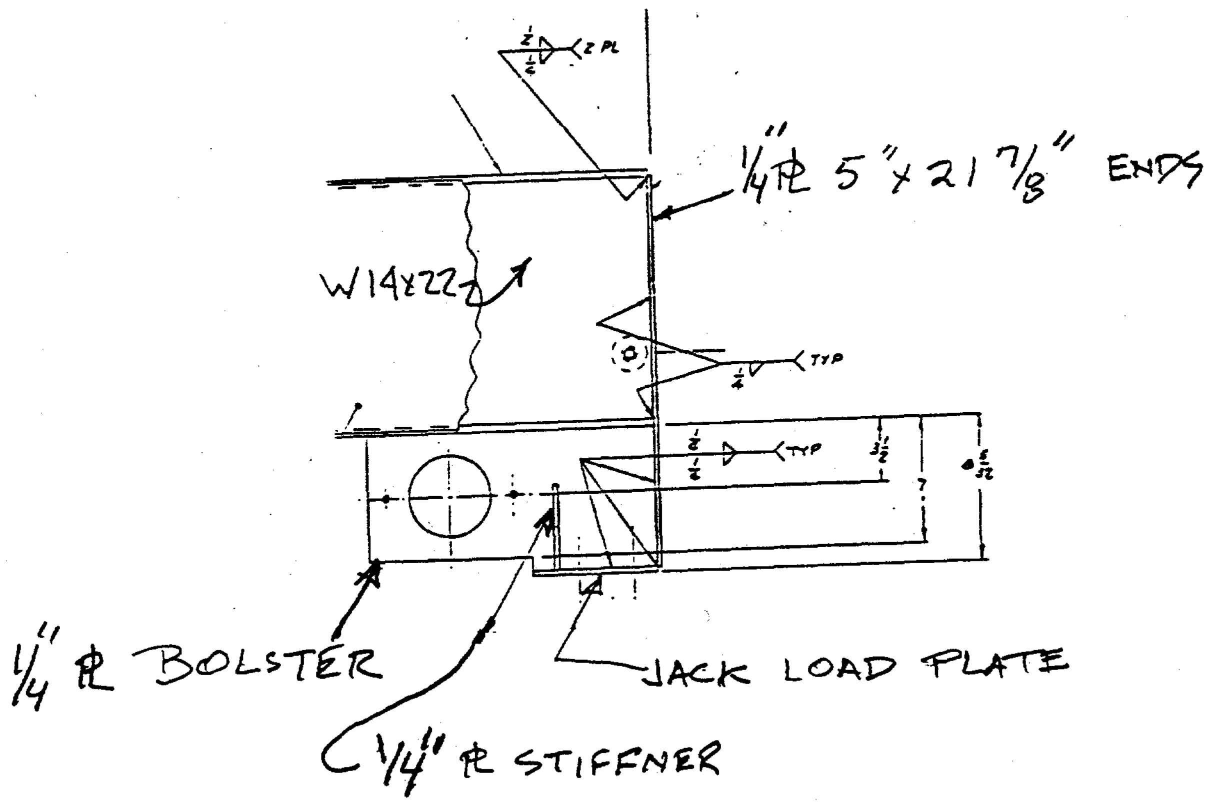
ALLOWABLE LATERAL $\lessapprox \frac{5400}{25061 + 857} \times 6^K = 1.25^K$

BD-6400-060.1 (07/93)

ANALYTICAL CALCULATIONS

Subject Rear Jack Assembly
Originator F.R. Vollert   Date 11/3/94
Checker Harm H. Zieh   Date 11-4-94

WELDS FOR 1/4" END PLATES TO W 14X22 WEB AND FLANGES



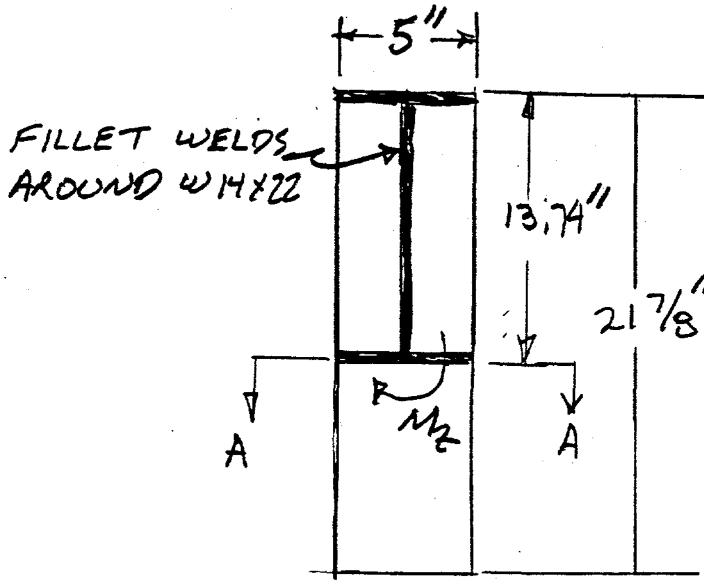
The 5 x 21-7/8 x 1/4 inches end plates are bolster components for the rear jack assembly, and are welded to the flanges and web at the ends of the W 14x22 beam. The main function of these plates is to stiffen the 16 in long 1/4 in plate bolsters which carry, in plane, the vertical jack loads. Horizontal, lateral loads on the jacks perpendicular to the end plates would also be resisted in plane by the bolsters (not the end plates). Horizontal, longitudinal loads on the jacks parallel to the end plates would be mainly resisted by the end plates. The force and moment this would apply to the end plates would generate shear stresses in the end plate welds to the W 14x22.

The 1/4 in thick end plates have limited capacity for in plane bending. To evaluate the welds to the W 14x22, this bending capacity of the end plate, and the strength of the welds for resisting the shear stress generated by this type of moment will be calculated and compared. Also, for reference, the direct shear capacity of the welds, without bending moment induced stresses, will be calculated.

ANALYTICAL CALCULATIONS

Subject: REAR JACK ASSEMBLY
Originator: F.R. VOLLERT Date: 11/3/94
Checker: Hazem H. Zidan Date: 11-4-94

END PLATE WELDS CONTINUED



CALCULATE IN PLANE BENDING STRENGTH (M_z) OF 1/4" PL AT A-A.

ALLOWABLE BENDING STRESS (F_B) = 0.6 FY = $0.6 \times 36 \approx 22 \frac{KIPS}{IN^2}$

$F_B = \frac{M_z}{S}$ $M_z = S \times 22 = \frac{1}{4}\frac{5^2}{6} \times 22 = 22.9$ IN KIPS

FOR WELD PRESUME 1/8" MINIMUM FILLET (UNDOUBLED)

$F_w = \frac{M_z r'}{J_w}$, $F_w = 1.8 \frac{KIPS}{IN}$ ALLOWED FOR 1/8 ▽

$J_w = \frac{d^3}{12} + \frac{b^3 + 3db^2}{6} = 408.7 \; IN^3$

$r' = \frac{1}{2}\sqrt{5^2 + 13.74^2} = 7.3''$

$M_z = \frac{F_w J_w}{r'} = \frac{1.8 \times 408.7}{7.3} =$ 100.8 IN-KIPS EXCEEDS PL BY FACTOR 4.4

FOR WELD DIRECT SHEAR STRENGTH = $F_w A_w = 1.8(10 + 13.74) = 42.7$ KIPS

BD-6400-060.1 (07/93)

DESIGN CALCULATION

(1) Drawing H-2-91718 14C308 (2) Doc. No. ______ (3) Page ____ of ____

(4) Building ______ (5) Rev. ______ (6) Job No. ______

(7) Subject Rear Jack Assembly

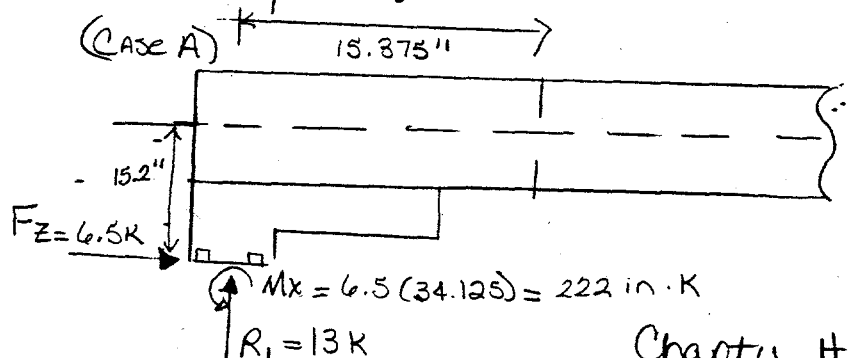
(8) Originator B.J. Nieri Date 11-1-94

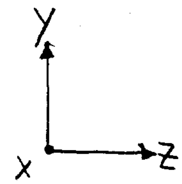
(9) Checker ERV Date 11/11/94

BEAM AND WELDS

Assume that loads are acting at ℄ of bolster bottom plate:

(CASE A)





(Case B)

$R_1 = 13K$

$F_x = 6.5K$

$M_z = 222$ in K

Chapter H
For members subjected to combined stresses: (AISC 1989)

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \le 1$$

Check Bending Stress in Beam

(CASE A)

$f_a = \frac{6.5}{6.49} = 1.0$ KSI $F_a = .6 F_y = 21.6$ KSI

$M_x = 13(15.375) + 222 + 6.5(15.2) = 521$ in·K

$f_{bx} = \frac{M_x}{S_x} = \frac{521}{29} = 17.95$ KSI

$F_{bx} = .66 F_y = 23.8$ KSI

$f_{by} = 0$

$\therefore \frac{1}{21.6} + \frac{17.95}{23.8} \le 1.0$

$0.802 \le 1.0$ ✓ OKAY

BD-6400-060

(1) Drawing H-2-91718, 14C3C8 (2) Doc. No. ________ (3) Page ____ of ____
(4) Building ________ (5) Rev. ________ (6) Job No. ________
(7) Subject Rear Jack Assembly
(8) Originator EJ Niemi Date 11-1-94
(9) Checker FRV Date 11/11/94

(10)

(Case B)

$fa = 0$

$Mx = 13(15.375) = 200 \text{ in}\cdot K$

$fbx = \frac{200}{29} = 6.89 \text{ KSI}$ $Fbx = .66\, Fy = 21.8 \text{ KSI}$

$My = 6.5(15.375) = 100 \text{ in K}$

$fby = \frac{100}{2.8} = 35.7 \text{ KSI}$ $Fby = .75\, Fy = 27 \text{ KSI}$

$\therefore \frac{6.89}{21.8} + \frac{35.7}{27} \geq 1.0$ This exceeds AISC (1989) limits.

$1.63 \geq 1.0$

<u>Check Beam for Shear</u>

(Case A)

$fv = \frac{P}{A} = \frac{13\text{ K}}{6.49 \text{ in}^2} = 2.0 \text{ KSI} < Fv = .4\, Fy = 14.4 \text{ KSI}$ ✓ OKAY

(Case B)

In this case, there is a shear component of 13K and also a torsional shear component.

$T = 6.5(15.2 + 34.125) = 321 \text{ in}\cdot\text{Kips}$

$fv = \frac{P}{A} + J$

(1) Drawing H-2-91715, 14C3C8 (2) Doc. No. ________ (3) Page ____ of ____
(4) Building ________ (5) Rev. ________ (6) Job No. ________
(7) Subject Rear Jack Assembly
(8) Originator RJ Niemi Date 11-1-94
(9) Checker FRV Date 11/11/94

(10)

torsional constant (W14X22) = 0.21

$\tau = (.21)(321) = 67.41 \text{ KSI}$

$f_V = 67.4 + \frac{6.5}{6.49} + \frac{13}{6.49} = 70.4 \text{ KSI} > F_V$

$F_V = .4\ F_y = 14.4 \text{ KSI}$

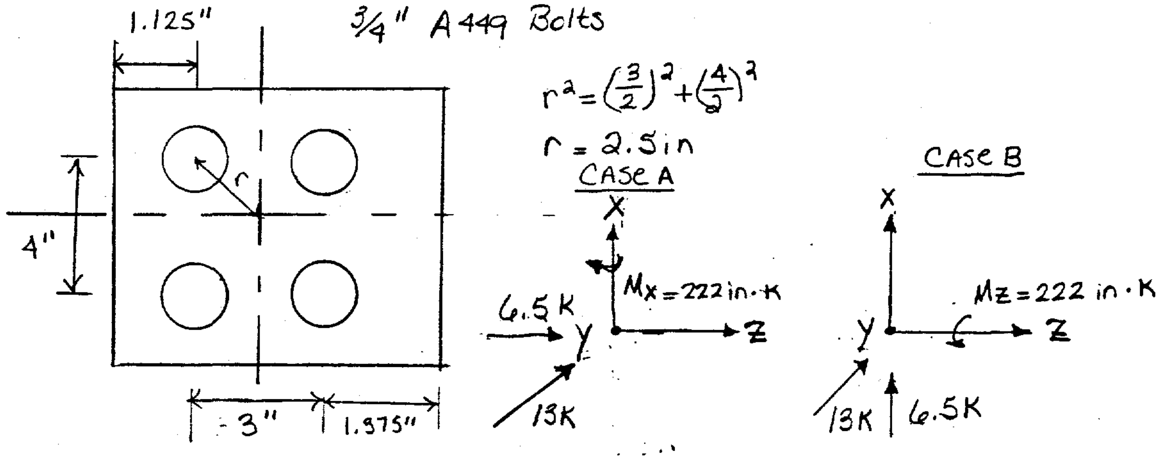
Shear Stress Exceeds AISC limits for this condition.

Check bolts in Bolster Mounting Plate

3/4" A449 Bolts

$r^2 = \left(\frac{3}{2}\right)^2 + \left(\frac{4}{2}\right)^2$

$r = 2.5 \text{ in}$



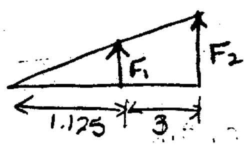
(1) Drawing H-2-91719, 14C308 (2) Doc. No. ______ (3) Page ______ of ______
(4) Building ______ (5) Rev. ______ (6) Job No. ______
(7) Subject Rear Jack Assembly
(8) Originator RJ Niemi Date 11-1-94
(9) Checker FRV Date 11/11/94

(10) (Case A+B)

Bolts in Shear & Tension

$V = \frac{6500}{4 \text{ bolts}} = 1625 \text{ lb/bolt}$

$f_v = \frac{V}{A} = \frac{1625 \text{ lbs}}{.4418 \text{ in}^2} = 3678 \frac{\text{lb}}{\text{in}^2} < F_v = .4(F_y) = 14.4 \text{ KSI}$ ✓ Okay



$F_1 \times 1.125 + F_2 \times 4.125 = 222$

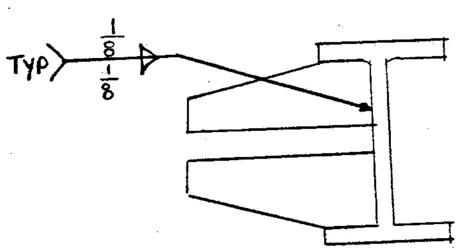
$F_1 = \frac{1.125}{4.125} F_2$

$2F_2 = 50.1 \text{K}$ $F_2 = 25.05 \text{ K/bolt}$

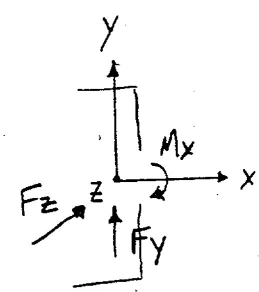
$f_t = \frac{25.05}{.4418} = 56.7 \text{KSI} > F_t = 40 \text{KSI}$

This exceeds the AISC (1989) limits.

Check weld shear forces on Attachments to Chassis

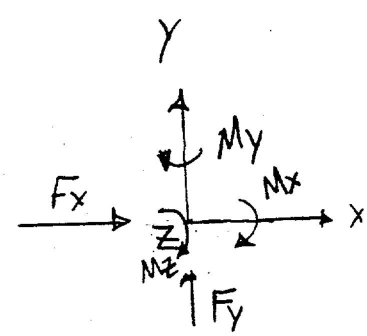


(From Pg 4)
$A_w = 29 \text{in}$
$S_w = \frac{2bd + d^2}{3} = 86.33 \text{in}^2$



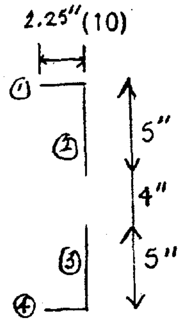
(Case A)
$M_x = 521 \text{ in}\cdot\text{K}$ (pg 13)
$F_z = 6.5\text{K}$
$F_y = 13\text{K}$

(Case B)
$M_x = 200 \text{ in}\cdot\text{K}$ (pg 13)
$F_y = 13\text{K}$
$F_x = 6.5\text{K}$
$M_y = 100 \text{ in}\cdot\text{K}$
$M_z = 321 \text{ in}\cdot\text{K}$



DESIGN CALCULATION

(1) Drawing H-2-91718, 14C3C8 (2) Doc. No. ______ (3) Page ___ of ___
(4) Building ______ (5) Rev. ______ (6) Job No. ______
(7) Subject Rear Jack Assembly
(8) Originator RJ Niemi Date 11-1-94
(9) Checker FRV Date 11/11/94



Member	$A_w = L$	Dist y	Dist x	$M_x = L \cdot y$	$M_y = L \cdot x$	$\bar{x}$	$\bar{y}$	$L \cdot \bar{y}^2$	$L \cdot \bar{x}^2$	I_{xx}	I_{yy}
① —	2.25	1.125	14	2.53	31.5	0.77	-7	110.25	1.33	0	0.95
② |	5	0	11.5	0	57.5	0.35	-4.5	101.25	.6125	10.42	0
③ |	5	0	2.5	0	12.5	0.35	4.5	101.25	.6125	10.42	0
④ —	2.25	1.125	0	2.53	0	0.77	7	110.25	1.33	0	0.95
	14.5	—	—	5.06	101.5	—	—	423.0	3.88	21.84	1.90

$$\bar{I}_{xx} = \Sigma L\bar{y}^2 + 2 I_{xx} = 444.84 \text{ in}^3$$

$$\bar{I}_{yy} = \Sigma L\bar{x}^2 + I_{yy} = 5.78 \text{ in}^3$$

$$J = \bar{I}_{xx} + \bar{I}_{yy} = 450.62 \text{ in}^3$$

$$r' = \sqrt{7^2 + (2.25 - 0.35)^2} = 7.25$$

$$N_x = \frac{M_y}{A} = \frac{101.5}{14.5} = 7$$

$$N_y = \frac{M_x}{A} = \frac{5.06}{14.5} = 0.35$$

(CASE A)

$$f_1 = \frac{F_z}{A_w} = \frac{6.5}{14.5} = 0.45 \text{ K/in}$$

$$f_2 \quad \frac{F_y}{A_w} = \frac{13}{14.5} = 0.90 \text{ K/in}$$

$$f_w = \sqrt{f_1^2 + f_2^2} = 1.0 \text{ K/in} < \text{allowable } (.3)(.707)(70)\left(\tfrac{2}{8}\right) = 3.70 \text{ K/in} \checkmark$$

OKAY

(CASE B)

$$f_1 = \frac{F_y}{A_w} = \frac{13}{14.5} = 0.90 \text{ K/in}$$

$$f_2 = \frac{F_x}{A_w} = \frac{6.5}{14.5} = 0.45 \text{ K/in}$$

$$f_3 = \frac{M_z r'}{J} = \frac{321(7.25)}{450.62} = 5.16 \text{ K/in} > \text{allowable} = 3.70 \text{ K/in}$$

This exceeds AISC (1989) limits.

BD-6400-060.1 (12/87)

(1) Drawing H-2-91715, 14C308 (2) Doc. No. ______ (3) Page ______ of ______

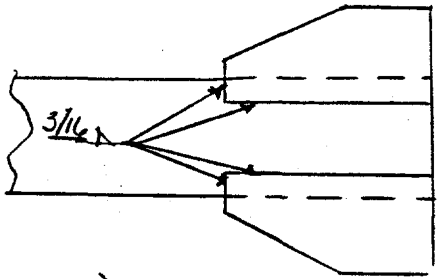
(4) Building ______ (5) Rev. ______ (6) Job No. ______

(7) Subject Rear Jack Assembly

(8) Originator RJ Niemi Date 11-1-94

(9) Checker FR✓ Date 11/11/94

(10)

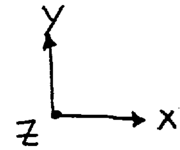


From analysis on Pg 5

$J_w = 511.45\ in^3$

$A_w = 27.25\ in$

$r' = 6.99''$



(Case A)

$M_x = 253\ in \cdot K$

$F_z = 6.5K$

$F_y = 13K$

$M_z = 97.07\ in \cdot K$

(Case B)

$M_z = 418.07\ in \cdot K$

$F_y = 13K$

$F_x = 6.5K$

(Case A)

$$f_1 = \frac{f_z}{A_w} + \frac{M_z r'}{J} = \frac{6.5}{27.25} + \frac{97.07(6.99)}{511.45} = 1.48\ K/in$$

$$f_2 = \frac{f_y}{A_w} = \frac{13}{27.25} = 0.477\ K/in$$

$$f_R = \sqrt{f_1^2 + f_2^2} = 1.55\ K/in < \text{Allowable } (.3)(.707)(70)(3/16) = 2.78\ K/in$$

(Case B)

$$f_1 = \frac{F_y}{A_w} = \frac{13}{27.25} = 0.477\ K/in$$

$$f_2 = \frac{F_x}{A_w}\ \frac{6.5}{27.25} = 0.239\ K/in$$

$$f_3 = \frac{M_z r'}{J} = \frac{418.07(6.99)}{511.45} = 5.17\ K/in > 2.78\ K/in$$

This exceeds AISC allowable

BD-6400-060.1 (12.87)

5.0 ANALYSIS RESULTS AND CONCLUSIONS

For normal vertical loads only on the rear jacks, all the stresses in the rear assembly and the connections to the chassis are within the allowables. The vertical jack loads are governed by the force or stress in the 3/16 in. fillet welds to the truck chassis. The allowable maximum value is 2.78 Kips/in. The calculated value for the normal vertical loads is 1.86 Kips/in. (about a 1.5 safety margin).

The bolsters on the rear jack assembly highly limit the horizontal load capacity. A 500 lbf horizontal rear jack load in the truck longitudinal direction will over stress the 1/4 in. thick bolster end plates in bending. A 1,250 lbf horizontal jack load in the lateral direction will over stress the attachment weld for the jack mounting plates on the bolsters. The other components potentially over stressed by the horizontal loads used for this analysis include: the main W 14 x 22 beam would be over stressed both the bending and torsional shear, the mounting bolts for the jacks to the bolsters would be over loaded, and there would be excessive stresses in the attachment welds to the truck chassis.

The center jack assemblies are within the allowable stresses for the given vertical loads. The loads are governed by the tensile stress or load in the 2 tie rods. The load from both center jacks to the tie rods directly add together. The tie rod tension stress for the given loads is 11.3 Kips/in^2. The allowable is 20 Kips/in^2, the safety margin is 1.77. When the vertical load on one center jack exceeds that on the opposite jack (the case considered) the tie rod loads will cause a moment on the opposite assembly and put tension in the 3/4 in. mounting bolts to the truck. For this case the bolt tension is 3.6 Kips/bolt. The allowable for these (replacement SAE Grade 8) 3/4 in. bolts is 23.9 Kips/bolt.

APPENDIX B

ANALYSES OF LOWER FRAME ASSEMBLY AND THE MAXIMUM LOAD PATH THROUGH THE BEARING ASSEMBLY

1.0 INTRODUCTION

For the core sample truck number 2 (truck 2) stress analyses and structural evaluations have been conducted for the lower frame, and the 4 sets of bolts which attach the rotating platform and bearing system to the lower frame. The lower frame is supported full length on 2 inch thick lumber spacers which sit on top of the truck chassis (or frame) longitudinal members. The lower frame is attached to the chassis and held on the spacers with 6 welded and bolted clip angle connections (3 for each longitudinal member). The lower frame configuration and attachment to the chassis are shown by drawings H-2-91703 and H-2-140308. The 4 sets of bolts are shown on drawings H-2-91703, 91704, 91705, 91708, 91709, and 91711 (See sketches in Section 4.0 CALCULATIONS).

The estimated weight of the rotating platform and equipment is 15,210 lbf. The drill string potentially applies a 6,000 lbf vertical load on the platform. The location of this load could result in a 526,500 in-lbf overturning moment which must be resisted by the 4 sets of attachment bolts for the platform and bearing system. The lower frame connections to the chassis, and the attachment bolts for the rotating platform and bearing system are subject to potential transportation forces of 1.0 g, 2.0 g, and 3.0 g vertical, lateral, and longitudinal, respectively.

2.0 SCOPE

The scope of the stress analyses and structural evaluations conducted for the lower frame and attachments, in summary, is to assess: the lower frame for the weight of the rotating platform, the clip angle connections to the truck chassis for the horizontal transportation loads, and the bolt sets for attaching the platform and bearing system for the drill string overturning moment and the transportation loads. The specific stresses and conditions determined and evaluated are:

The web crippling or compressive bearing stress in the lower frame longitudinal members

The bending stress in the lower frame longitudinal members, neglecting the support by the lumber spacers

The bolt forces or stresses and weld stresses in the clip angle connections to the chassis

The bolt forces or stresses in the 4 sets of bolts which attach the platform and bearing system to the lower frame

3.0 METHODOLOGY AND ACCEPTANCE CRITERIA

Typical methods for design stress analysis of structural steel members, and their connections were used. The acceptance criteria for member allowable stresses, acceptable weld stress, and bolt force design limits were determined from AISC 1989. Certain design details and bolt specifications have been reviewed for conformance with the appropriate technology, accepted normal practice, and AISC 1989 provisions. In summary, the specific analysis methods and criteria used are:

To evaluate the web crippling potential for the longitudinal members, the maximum AISC 1989 allowable bearing load on the members was determined and compared to the maximum estimated load.

The maximum bending stress in the longitudinal members was conservatively calculated presuming that each member is supported between only 2 of the clip angle connections in simple bending. The results were compared to the AISC 1989 allowable bending stress for compact sections.

The maximum weld stresses and bolt loads in the clip angle connections were calculated presuming the 3.0 g transportation forces are equally distributed to the 6 connections. The weld stresses were compared to allowable values determined using AISC 1989. The existing 1/2 in diameter bolts, based on their design specification, are deficient. The bolt shear load due to transportation forces was calculated. Then it was determined that 5/8 in diameter SAE Grade 8 replacement bolts would have sufficient strength.

The 4 sets of bolts attaching the rotating platform and the bearing to the lower frame are in series. Therefore, the bolt loads were calculated for each set alone resisting the total overturning moment due to the potential 6,000 lbf load on the drill string, and the 3.0 g transportation loads. The bolt design specifications and other details were the bases to determine the allowable bolt loads using AISC 1989.

4.0 CALCULATIONS

Stress Analyses Calculations

for

The Lower Frame and Attachments,

Core sample Truck Number 2

ANALYTICAL CALCULATIONS

Subject: LOWER FRAME CORE SAMPLE TRUCK NUMBER 2
Originator: E. R. VOLLERT Date: 9/27/94
Checker: H H-Zink Date: 10-25-94

REF: DWGS H-2-91703, H40308 (SH 1-3)

DISCUSSION:

THE MAJOR LOAD ON THIS FRAME IS THE ROTATING PLATFORM AND EQUIPMENT ITEMS THEREON. THE BEARING ℄ MOUNT IS THE LOCATION WHERE THIS LOAD IS APPLIED TO THE FRAME (DWGS H-2-91702, 04, 05) THE STATIONARY PLATFORM (ABOUT 250 LB) IS ON THE LOWER FRAME FORWARD OF THE BEARING MOUNT EACH SIDE OR LONGITUDINAL MEMBER OF THIS FRAME IS ATTACHED TO THE TRUCK CHASSIS BY 3 WELDED AND BOLTED CLIP ANGLES. THE LONGITUDINAL MEMBERS BEAR ON FULL LENGTH LUMBER SPACERS BETWEEN THEM AND THE CHASSIS. STRESSES IN THE LOWER FRAME WILL BE LOW AND THE ANALYSIS TO SHOW THEM ACCEPTABLE FOLLOWS. THE BOLTS USED IN THE CLIP ANGLE ATTACHMENTS TO THE CHASSIS SHOULD BE REPLACED WITH 5/8 HEX, SAE GRADE 8 BOLTS. THE 4 SETS OF BOLTS ATTACHING THE ROTATING PLATFORM & BEARING ASSEMBLY SHOULD BE REPLACED WITH SAE GRADE 8 SAME TYPE + SIZE BOLTS.

THE STRESS CONDITIONS ANALYZED AND EVALUATED ARE:

WEB CRIPLING OR BEARING STRESS, LONGITUDINAL MEMBERS LOWER FRAME

BENDING, LONGITUDINAL MEMBERS, NEGLECT SPACERS

BOLTS, UPDATE DESIGN SIZE AND SPECIFICATION EVALUATE HORIZONTAL SHEAR LOADS

CLIP ANGLE WELD STRESS DUE TO HORIZONTAL LOADS.

FORCES OR STRESSES IN THE 4 SETS OF BOLTS (LOADED IN SERIES) ATTACHING BEARING MOUNT, BEARING, BEARING PLATE, AND ROTATING PLATFORM FRAME TO LOWER FRAME

ANALYTICAL CALCULATIONS

Subject LOWER FRAME, TRUCK 2
Originator F.R. VOLLERT Date 9/20/94
Checker Hassan H. Tisla Date 10-25-94

Lower Frame To Chassis

WEB CRIPLING STRESS, LONGITUDINAL MEMBERS

THE BEARING MOUNT IS 2" THICK PL

BEARING LENGTH / SIDE ≥ 24"

PRESUME ENTIRE ROTATING PLATFORM WEIGHT BEARS ON 1 SIDE (15210 LB)

MAX LOAD INTERIOR = $0.75 F_y t (N+k)$ (AISC 1.10)

LET $k = \phi$, $N = 24"$, $F_y = 36$ KSI, $t = 0.325"$

t = WEB THICKNESS MC 10 x 31.9

IL = $0.75 \times 36 \times 0.325 \times 24 = 210.6^K > 15.21K$, OK

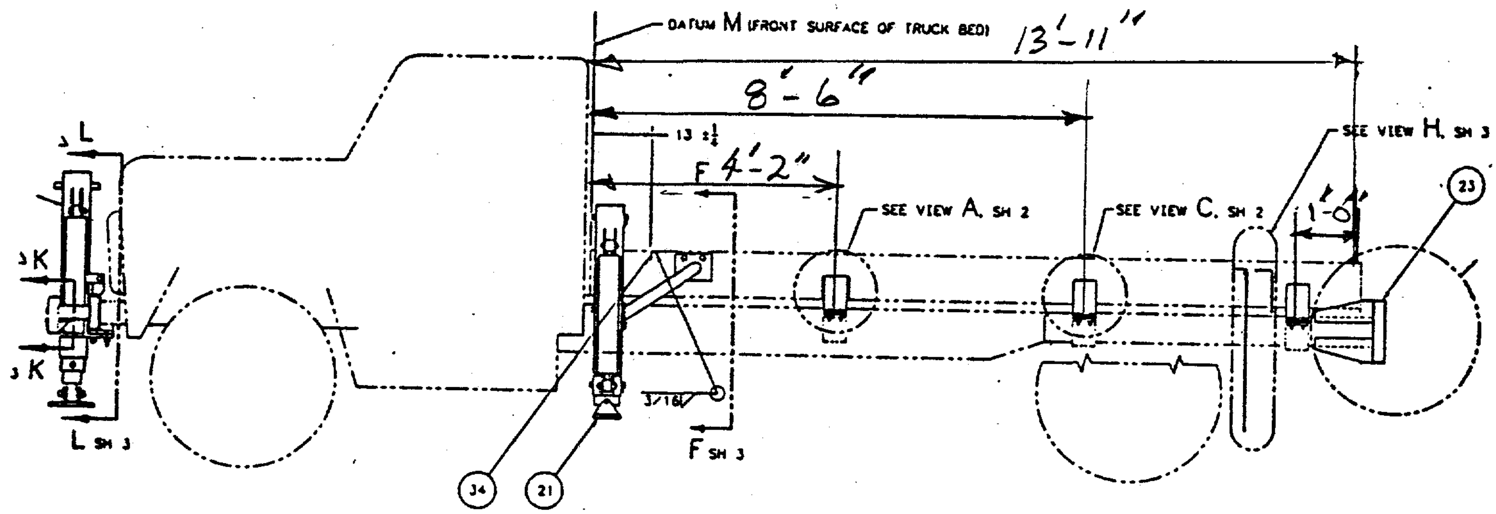
BENDING STRESS, LONGITUDINAL MEMBERS

THE LONGITUDINAL FRAME MEMBERS ARE EACH ATTACHED TO THE TRUCK CHASSIS WITH 3 CLIP ANGLE CONNECTIONS THE LOCATIONS AND SPACING OF THESE ATTACHMENTS ARE NOT IDENTICAL FOR LEFT AND RIGHT (SEE SKETCHES NEXT PAGE) THESE MEMBERS SHOULD EXPIERIENCE LITTLE BENDING FROM VERTICAL LOADS BECAUSE THEY BEAR FULL LENGTH ON LUMBER SPACERS BETWEEN THE MEMBERS AND CHASSIS.

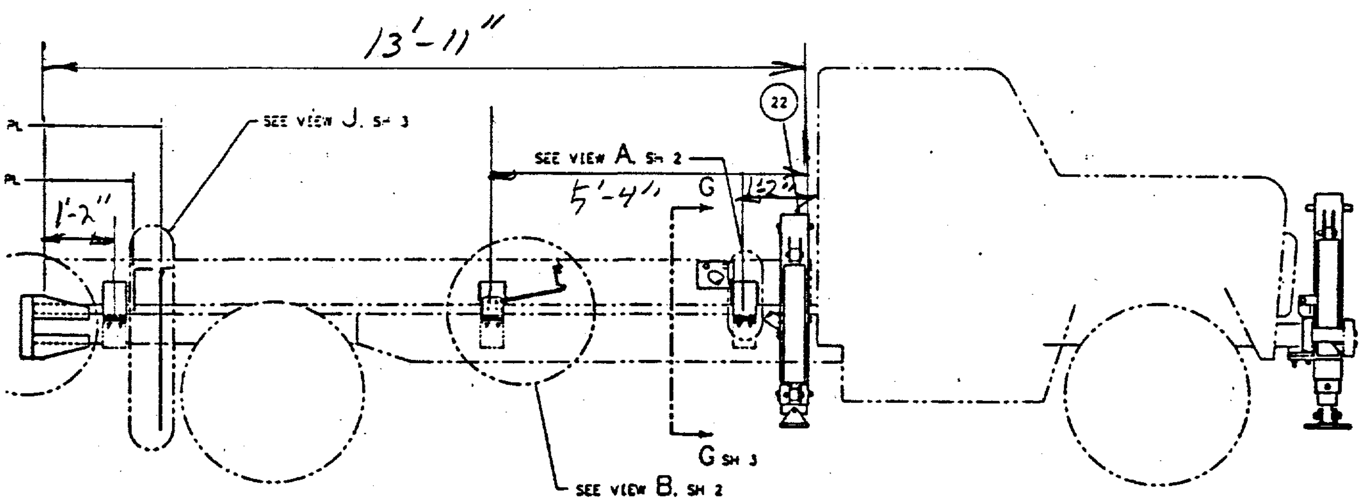
ON THE RIGHT SIDE, THE BEARING MOUNT PLATE WITH THE MAJOR LOAD IS BETWEEN 2 OF THE CLIP ANGLE ATTACHMENTS. IT IS CONSERVATIVELY PRESUMED THAT THE TOTAL MOUNT PLATE VERTICAL LOAD ACTS ON THE RIGHT SIDE, AND THE FRAME MEMBER ACTS IN SIMPLE BENDING BETWEEN THE 2 ATTACHMENT POINTS.

ANALYTICAL CALCULATIONS

Subject: LOWER FRAME, TRUCK 2
Originator: F. R. VOLLERT Date: 9/27/94
Checker: Hassan H. Ziada Date: 10-25-94



LEFT SIDE ELEVATION



RIGHT SIDE ELEVATION

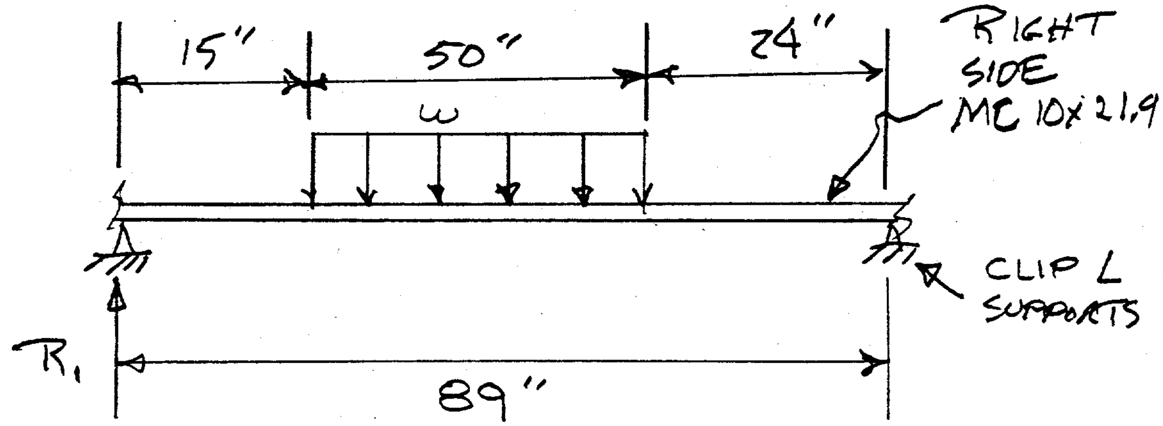
REF: H-2-140308

ANALYTICAL CALCULATIONS

Subject: LOWER FRAME TRUCK 2

Originator: F.R. VOLLERT Date: 9/27/94

Checker: Hassan H. Tirda Date: 10-25-94



$w = \frac{15210 \text{ LB}}{50''} = 304.2 \text{ LB/IN}$

$R_1 = \frac{50 \times w}{2 \times 89}(2 \times 24 + 50) = 8374 \text{ LB}$

$M_{MAX} \approx 8374\left(15 + \frac{8374}{2 \times 304.2}\right) + \left(\frac{21.9 \times 89^2}{8}\right)^* = 262855 \text{ IN-LB}$

$f_b = \frac{M}{S} = \frac{262855 \text{ IN LB}}{19.7 \text{ IN}^3} = 13343 \text{ LB/IN}^2 < 0.60 F_y$ OK

$0.60 F_y = 0.60 \times 36 = 22 \frac{\text{KIPS}}{\text{IN}^2}$

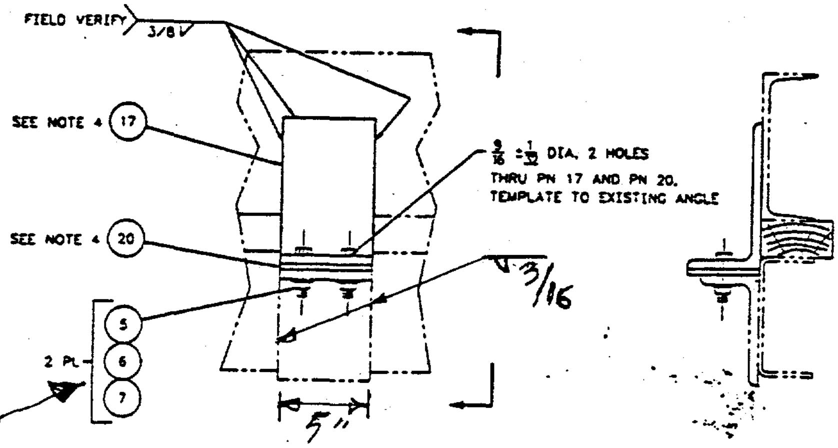
* DUE TO WEIGHT OF MC 10x21.9

BD-6400-060.1 (07/93)

ANALYTICAL CALCULATIONS

Subject LOWER FRAME, TRUCK 2
Originator F.R. VOLLERT Date 9/27/94
Checker Hassan H. Tirdu Date 10-25-94

BOLTS, CLIP ANGLE ATTACHMENTS



1/2", BOLTS, SST SPECIFIED ON H-2-140308

SIZE SHOULD BE 5/8 IN MIN FOR THIS USE

SST IS DISSIMILAR METAL, ALLOY UNKNOWN.

MAX SHEAR FORCE ON BOLTS DUE TO 3.0 g LONGITUDINAL TRANSPORTATION FORCE

$F_V = 3.0g \times (15210 + 250 + 850) = 48930$ LB

6 ATTACHMENTS × 2 BOLTS/ATTACH = 12 BOLTS

BOLT SHEAR $= \frac{48930}{12} = 4036$ LB/BOLT

USE SAE GRADE 8 BOLTS, EQUIVALENT TO ASTM A490, FOR SINGLE SHEAR, STD HOLE SIZE FRICTION TYPE CONNECTION $F_V = 6.44 \frac{KIP}{BOLT}$ DESIGN LOAD 5/8" Φ

SAE GR 8, 5/8 BOLTS OK

BD-6400-060.1 (07/93)

ANALYTICAL CALCULATIONS

Subject: LOWER FRAME, TRUCK 2
Originator: FR VOLLERT Date: 9/28/94
Checker: Harry H. [illegible] Date: 10-25-94

CLIP ANGLE WELDS

A 8 × 4 × 1/2 ON LOWER FRAME

LENGTH OF 3/8 FILLET = $l_{w1} = 5'' + 2(8-1-1\frac{5}{8})$

$l_w = 15.75''$ / CLIP ANGLE

MAX SHEAR FORCE ON CLIP FROM 3 g FORCE

$F/_{CLIP} = \frac{48930}{6} = \frac{8155\ LB}{ANGLE}$

WELD SHEAR / UNIT LENGTH $= \frac{8155\ LB}{15.75\ IN} = 518 \frac{LB}{IN}$

OK FOR 3/8 FILLET (5.4 KIPS/IN ALLOWABLE)

A 6 × 3 1/2 × 5/16 ON CHASSIS, 3/16" FILLET
LENGTH OF FILLET = 2 × 6" = 12" / CLIP
} FIELD MEASURED 9/28/94

WELD SHEAR / UNIT LENGTH $= \frac{8155}{12} = 680\ LB/IN$

OK FOR 3/16" FILLET (2.7 KIPS/IN ALLOWABLE)

BD-6400-060.1 (07/93)

ANALYTICAL CALCULATIONS

Subject: LOWER FRAME, TRUCK 2
Originator: F.R. VOLLERT Date: 9/28/94
Checker: Hasan H-Zia Date: 10-25-94

PLATFORM + BEARING ASSEMBLY ATTACHMENT BOLTS (TRANSPORTATION FORCES)

THE BEARING MOUNT IS ATTACHED WITH 12-1/2" Φ SCREWS INSTALLED THROUGH 5/8" DIA HOLES IN THE TOP FLANGES OF LOWER FRAME MEMBERS INTO THREADED HOLES (MATCHING) IN THE BEARING MOUNT, THE SCREWS ARE ASTM A 449

SHEAR FORCE / SCREW = $\frac{48.93 \text{ KIPS}}{12} = 4.1 \text{ KIPS}$

SHEAR STRESS = $\frac{4.1}{0.196} = 20.9 \frac{KIP}{IN^2}$

DETERMINE ALLOWABLE ~~SHEAR~~ : 0.63" DIA HOLES FOR 1/2" BOLTS (H-2-91703) ARE OVERSIZED

FOR FRICTION OVERSIZE HOLE CONNECTION
FOR A490 ALLOWABLE $F_V = 18 \text{ KIPS/IN}^2$, $\frac{18}{150} = 0.12 F_u$
FOR A449 $F_v = 0.12 \times 120 = 14.4 \text{ KIPS/IN}^2 < 20.9 \text{ KIPS/IN}^2$
BOLTS WOULD BE OVERLOADED
LONGITUDINAL ACCELERATION LIMIT WOULD BE:

$\frac{3g}{20.9} = \frac{A}{14.4}$ $A = 0.69 \times 3 = 2g$

BEARING ATTACHED TO BEARING MOUNT WITH 24-1/2" COMMERCIAL CS SCREWS REF H-2-91704, 91705, 91711
PRESUME A 307 AND 10 KIPS/IN2 ALLOWABLE SHEAR STRESS.

BOLT STRESS = $\frac{48.93}{24 \times 0.196} = 10.4 \frac{KIP}{IN^2}$ ≈ 4% OVERLOAD

NOTE: HOLES ≈ 0.60" FOR 1/2" BOLTS (H-2-91705) OVERSIZED

BEARING ℄ 1 1/4" t FOR THE PLATFORM ATTACHED WITH 18-5/8" COMMERCIAL CS SCREWS THROUGH THE BEARING INTO THREADED HOLES IN THE BEARING ℄.
PRESUME A307 AND 10 KIPS/IN2 ALLOWABLE SHEAR STRESS

BOLT STRESS = $\frac{48.93}{18 \times 0.307} = 8.8 \frac{KIPS}{IN^2} < 10 \text{ KIPS/IN}^2$

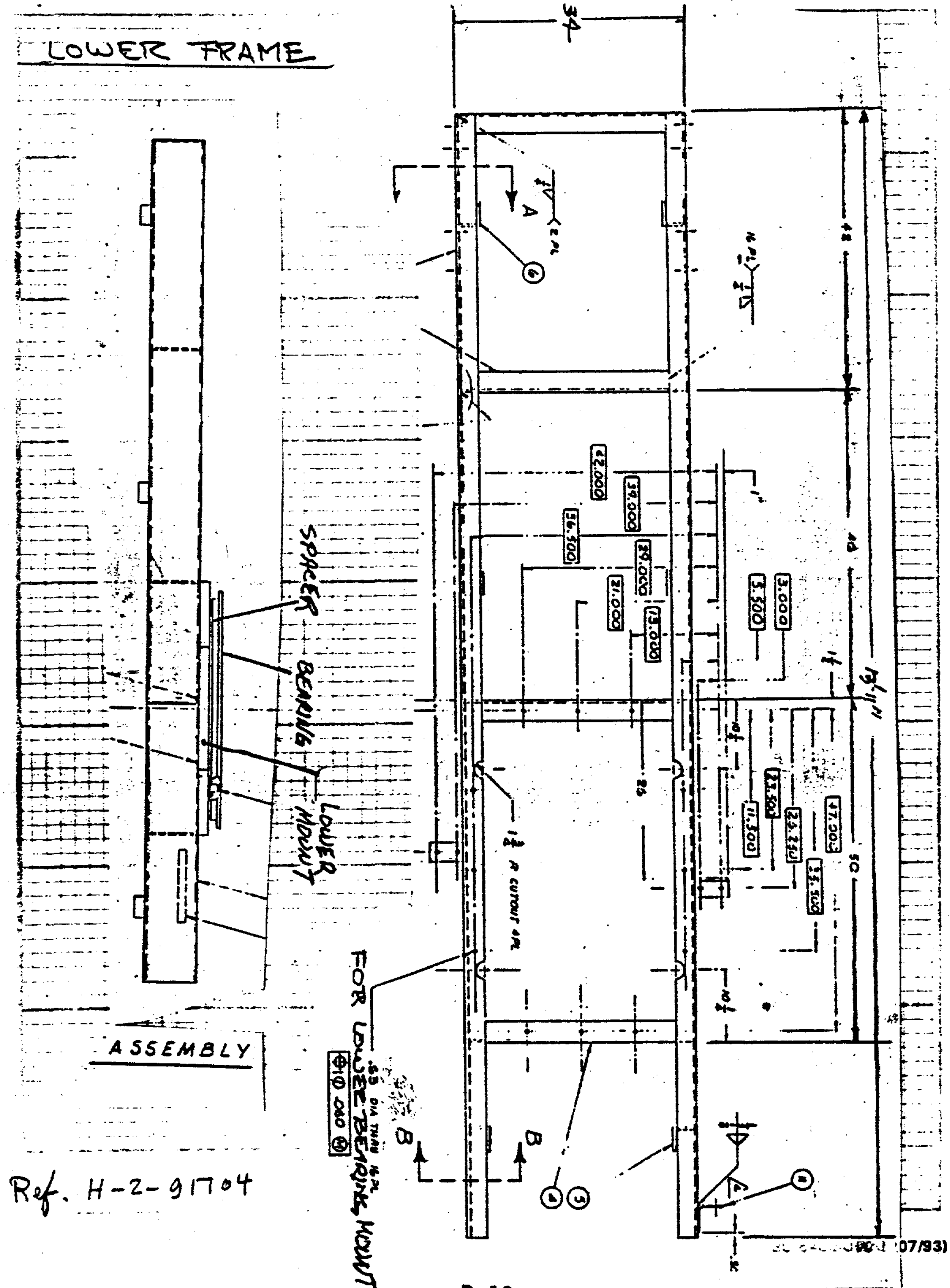
NOTE: HOLES = 11/16 FOR 5/8" BOLTS (VENDOR INFO) ARE STANDARD.

ANALYTICAL CALCULATIONS

Subject: LOWER FRAME TRUCK 2

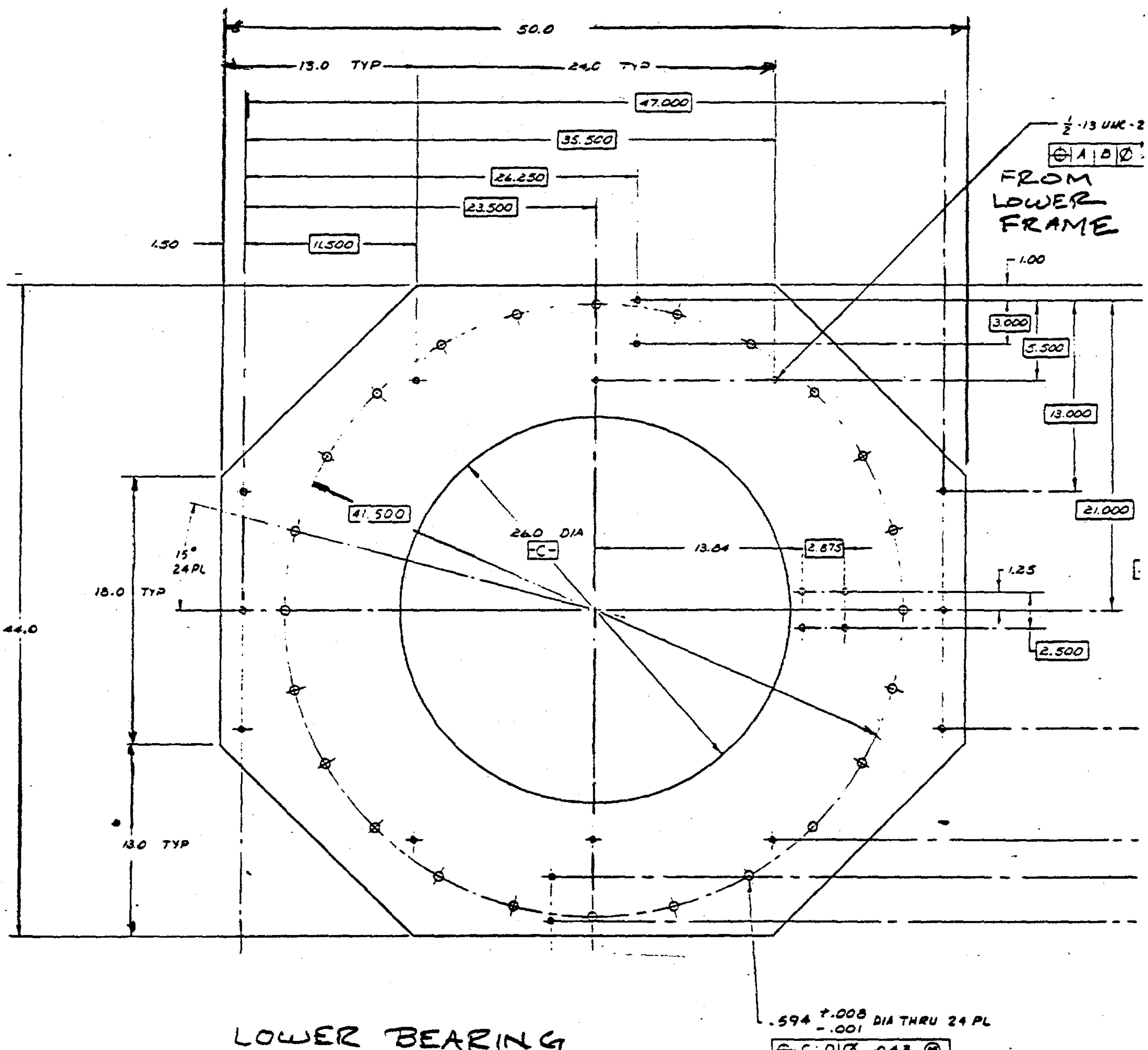
Originator: F.R. Vollert Date: 11/2/94

Checker: Harold H. Tish Date: 11-4-94



ANALYTICAL CALCULATIONS

Subject LOWER FRAME, TRUCK 2
Originator E.R. VOLLERT Date 11/2/94
Checker Hasan H. Zaki Date 11-4-94



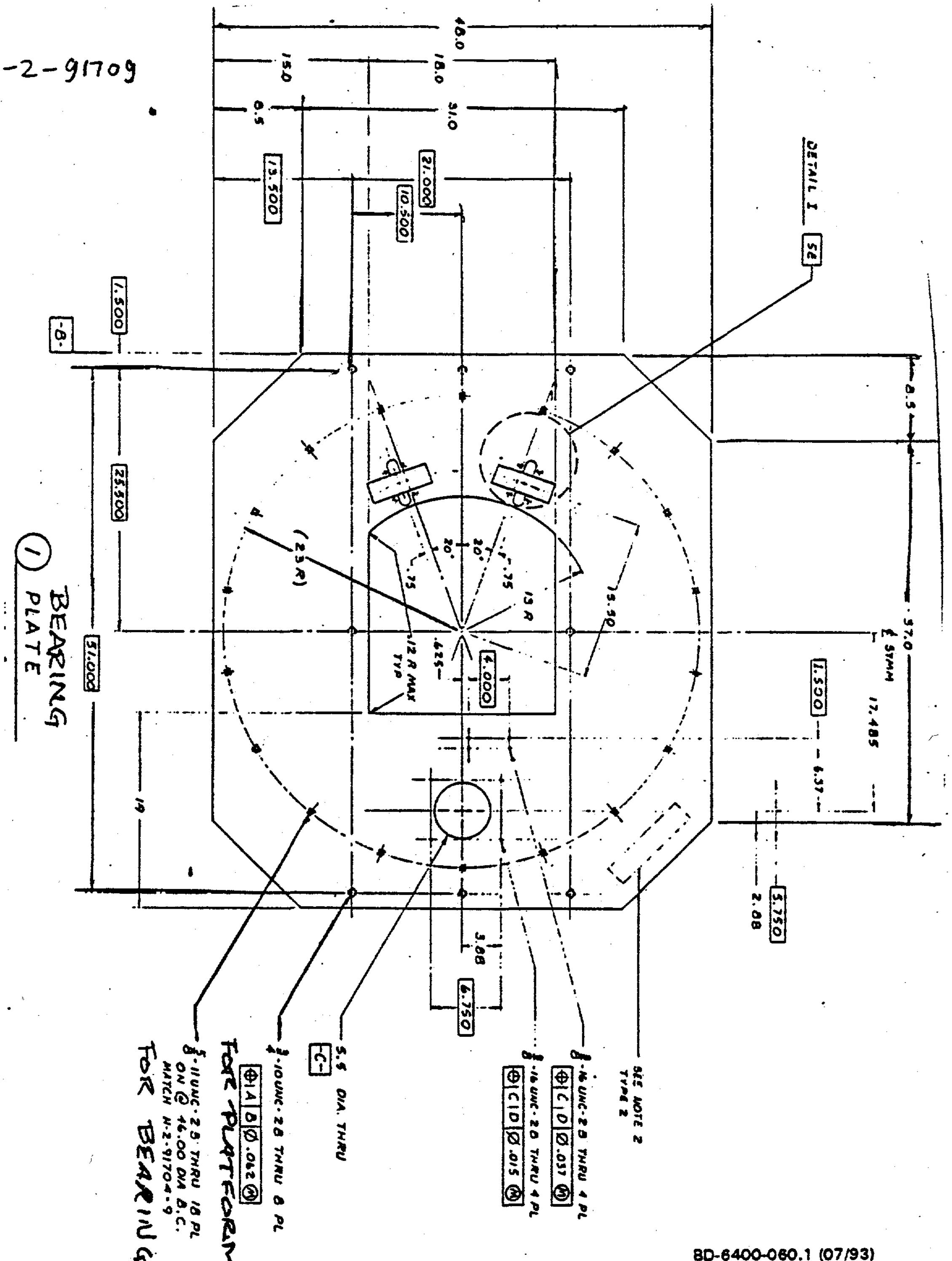
LOWER BEARING MOUNTING PLATE

Ref. H-2-91705

ANALYTICAL CALCULATIONS

Subject: Lower Frame, Truck 2
Originator: E.R. Vollert   Date: 11/2/94
Checker: Hasan H. Zink   Date: 11-4-94

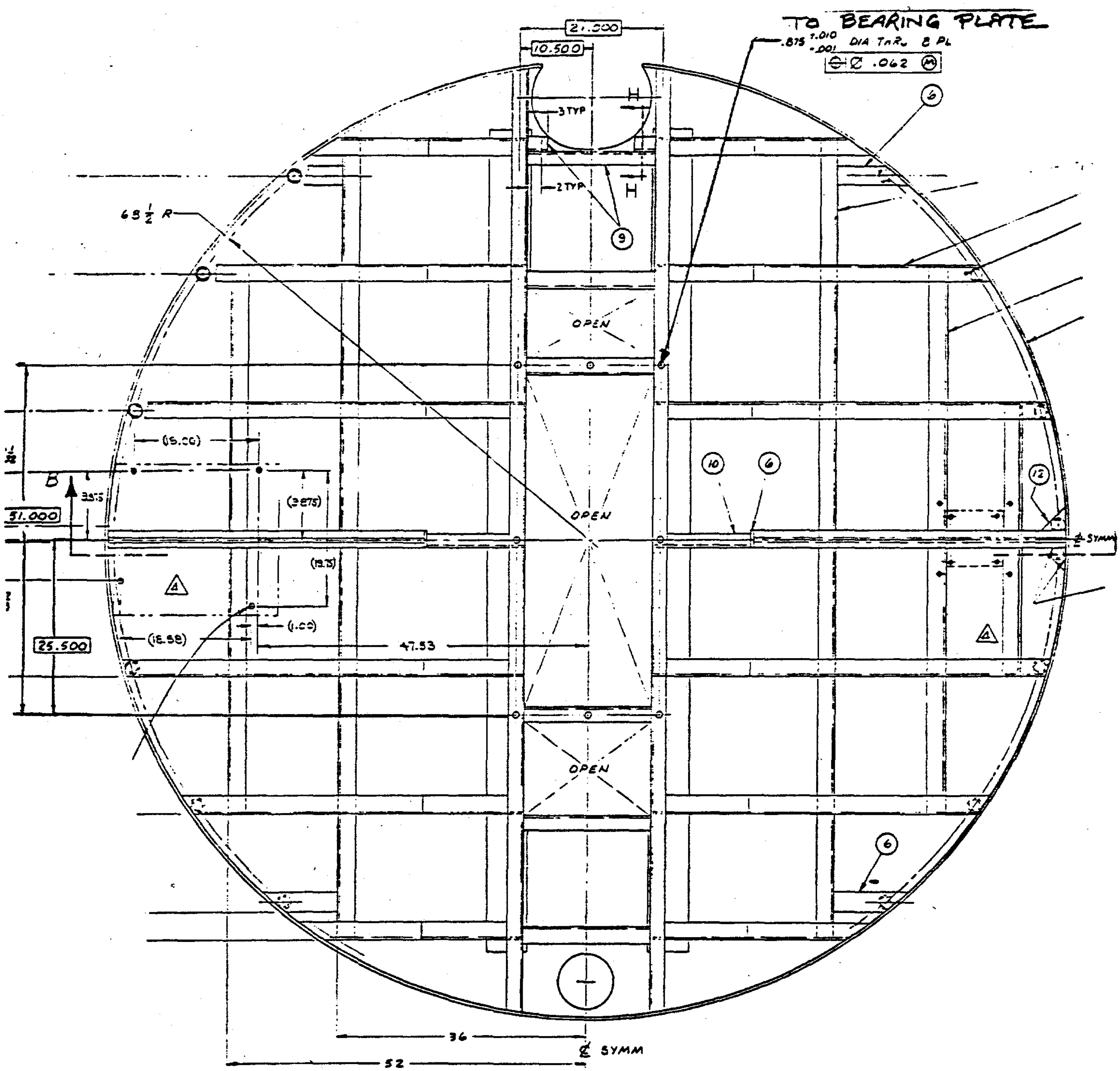
Rf. H-2-91709



BD-6400-060.1 (07/93)

ANALYTICAL CALCULATIONS

Subject: LOWER FRAME, TRUCK 2
Originator: F.R. VOLLERT Date: 11/2/94
Checker: Hasan H. Zahn Date: 11-4-94



BOTTOM VIEW
ROTATING PLATFORM FRAME

Ref. H-291708

ANALYTICAL CALCULATIONS

Subject LOWER FRAME, TRUCK 2
Originator F.R. VOLLERT Date 9/30/94
Checker Hasan H. Zirh Date 10-25-94

BOLTS ATTACHING ROTATING PLATFORM FRAME TO BEARING PLATE
REF: H-2-91707, 91708, 91709
8-3/4" COMMERCIAL CS BOLTS THREADED INTO BEARING PLATE
PRESUME A 307 AND 10 KIPS/IN² ALLOWABLE SHEAR STRESS

$$\text{BOLT STRESS} = \frac{48.93}{8 \times 0.442} = 13.8\ \frac{KIPS}{IN^2} > 10\ KIPS/IN^2$$

NOTE: HOLES FOR 3/4" BOLTS ARE 0.875" (H-2-91708) OVERSIZED
SAE GRADE 8 BOLTS, (EQUIVALENT TO ASTM A490) WOULD HAVE ALLOWABLE SHEAR STRESS OF 19 KIPS/IN²

RECOMMENDATION: REPLACE ALL BOLTS IN THE 4 SETS FOR PLATFORM AND BEARING ASSEMBLY WITH SAE GRADE 8 (SAME TYPE AND SIZE) BOLTS.

NOTE:
FOR 12-1/2" BOLTS REPLACED WITH GRADE 8, SAE AND $F_v = 18$ KIPS/IN² WOULD REMAIN OVERSTRESSED AT 3g LONGITUDINAL ACCELERATION, HOWEVER

$$A = \frac{18}{20.9} \times 3 = 2.6g \;,\; 13\% < 3.0g$$

Table1 includes the stress results for the existing bolts and Table 2 shows the stress results for Grade 8 bolts.

BD-6400-060.1 (07/93)

ANALYTICAL CALCULATIONS

Subject: Lower Frame Truck 2
Originator: E.R. Vollert Date: 10/11/94
Checker: Hassan H. Tirda Date: 10-25-94

OVERTURNING MOMENT ON BEARING ASSEMBLY

THE DRILL STRING HAS A POTENTIAL 6000 LB VERTICAL LOAD. THIS COULD OCCUR WHEN THE STRING IS LOCATED TO THE REAR OF THE TRUCK 18" OUTBOARD OF THE ROTATING PLATFORM AND COINCIDENT WITH THE TRUCK /LOWER FRAME LONGITUDINAL CENTERLINE. THE ECCENTRICITY WOULD DEVELOP A MOMENT ABOUT THE VERTICAL CENTER AXIS OF THE BEARING WHICH WILL LOAD OR STRESS THE 4 SETS OF BOLTS BETWEEN THE LOWER FRAME AND THE PLATFORM FRAME. THE ANALYSIS TO DETERMINE AND EVALUATE THESE BOLT LOADS FOLLOWS:

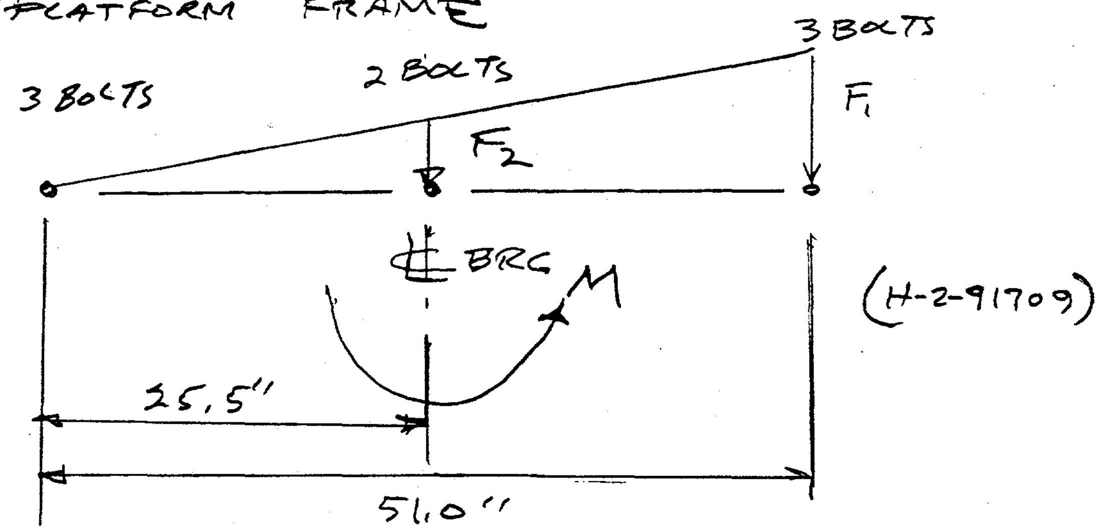
MOMENT (M) ABOUT ℄ BEARING $= 6^K (e_l)$

ECCENTRICITY $(e_l) = 18'' + \frac{11'-7\frac{1}{2}''}{2}$ (H-2-91708)

$e_l = 7.3125'$

$M = 6 \times 7.3125 \times 12 = 526.5$ IN KIPS

8 - 3/4" COMMERCIAL C.S. BOLT ARRAY IN PLATFORM FRAME



$F_2 = \frac{F_1}{2}$ (ASSUME LINEAR ELASTIC)

$M = 25.5\,F_2 + 51.0\,F_1 = \frac{25.5}{2}F_1 + 51.0\,F_1 = 63.75\,F_1$

$F_1 = 526.5 / 63.75 = 8.26$ KIPS

ANALYTICAL CALCULATIONS

Subject ____________________

Originator F.R. Vollert Date 10/1/94

Checker Hassan H Zaki Date 10-25-94

$(\text{BOLT LOAD})_1 = \frac{F_1}{3\text{ BOLTS}} = \frac{8.26}{3} = 2.75$ KIPS/BOLT

$(\text{BOLT LOAD})_2 = \frac{F_2}{2} = \frac{8.26}{4} = 2.06$ KIPS/BOLT

TENSION STRESS $(f_t) = \frac{F}{A_B}$

$f_t = \frac{2.75 \text{ KIPS}}{0.442 \text{ IN}^2} = 6.22 \text{ KIPS/IN}^2$ VS $F_t = 20 \text{ KIPS/IN}^2$ ALLOWABLE. IF A 307 PRESUMED

18 - 5/8" COMMERCIAL C.S. 46.0" DIA BOLT CIRCLE

ANALYSIS METHOD TO DETERMINE BOLT LOAD OR STRESS DUE TO MOMENT ABOUT BOLT CIRCLE!, TREAT AS EQUIVALENT THIN RING OF EQUAL MEAN DIA (d_m) AND THICKNESS (t) WHERE

$t = \frac{N_b A_b}{\pi d_m}$ BENDING STRESS $= f_b = \frac{M d_m/2}{I}$

I FOR EQUIVALENT RING $= \pi r_m^3 t = \frac{\pi d_m^3 t}{8}$

$t = \frac{18 \times 0.307}{\pi \times 46} = 0.04$ IN

$I = \frac{\pi \times 46^3 \times 0.04}{8} = 1529.0 \text{ IN}^4$

$f_b = \frac{526.5 \times 46/2}{1529.0} = 7.9 \text{ KIPS/IN}^2$

$F_b = 20 \text{ KIPS/IN}^2$ ALLOWABLE IF A 307 PRESUMED

ANALYTICAL CALCULATIONS

Subject: LOWER FRAME, TRUCK 2

Originator: E.R. VOLLERT Date: 10/1/94

Checker: Hassan H. Zeitoun Date: 10-25-94

24 - 1/2" COMMERCIAL C.S. 41.5" DIA BOLT CIRCLE

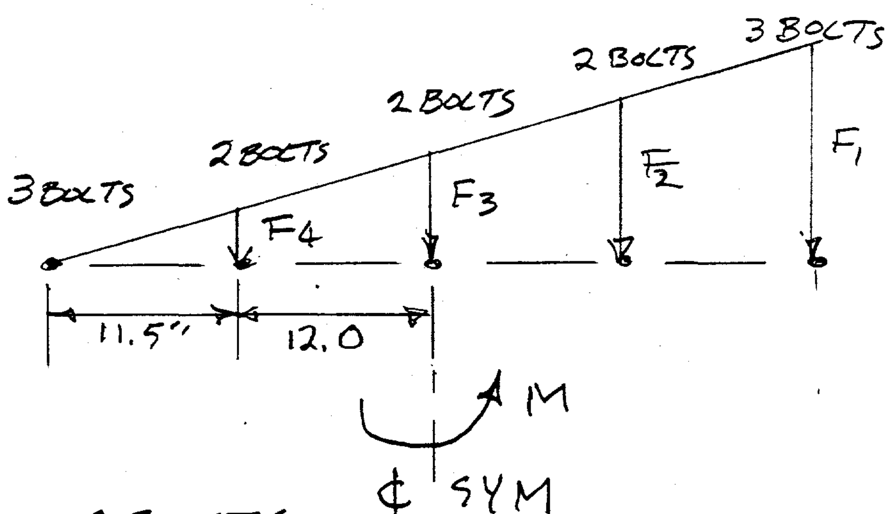
$$t = \frac{24 \times 0.196}{\pi \times 41.5} = 0.04"$$

$$\bar{I} = \frac{\pi \times 41.5^3 \times 0.04}{8} = 1122.7\ IN^4$$

$$f_b = \frac{526.5 \times 41.5/2}{1122.7} = 9.7\ KIPS/IN^2$$

$F_b = 20\ KIPS/IN^2$ IF A307 PRESUMED

12 - 1/2" A 449 BOLT ARRAY IN LOWER FRAME
H-2-91703, 91705



BY LINEAR ELASTIC AND SYMMETRY

$$F_2 = \frac{35.5}{47.0} F_1, \quad F_3 = \frac{23.5}{47.0} F_1, \quad F_4 = \frac{11.5}{47.0} F_1$$

$$M = \frac{1}{47}\left(47^2 + 35.5^2 + 23.5^2 + 11.5^2\right) F_1 = 526.5$$

$F_1 = 6.0^K$ OR $2K$/BOLT $F_2 = 4.5^K$ OR 2.25 KIPS/BOLT

MAX BOLT STRESS $(f_t) = \frac{2.25^K}{0.196\ IN^2} = 11.5\ KIPS/IN^2$

$F_T = 40\ KIPS/IN^2$ FOR A 449

5.0 ANALYSIS RESULTS

5.1 LOWER FRAME LONGITUDINAL MEMBERS

The longitudinal members of the lower frame are structural steel channels, MC 10x21.9. The AISC 1989 allowable bearing loads on the flanges, based on web crippling, is a function of the thickness and bearing length for the plate which applies the load. These dimensions for the plate on the lower frame are 2 inches and 50 inches, respectively. The calculated allowable bearing load for each longitudinal member is 210.6 Kips. The total estimated weight of the rotating platform and equipment is 15.2 Kips. The bearing load compressive stress in the longitudinal member is comfortably within AISC 1989 limits for web crippling.

The maximum bending stress for the longitudinal members was calculated conservatively assuming that the total weight of the rotating platform is supported on one member only, and that it is supported by only 2 of the clip angle connections to the truck chassis in simple bending. The AISC 1989 allowable bending stress is 60% of the minimum yield stress (F_y = 36,000 lbf/in^2). The calculated bending stress is 13,343 lbf/in^2, about 37% F_y.

Each clip angle connection has 2 bolts. The bolts are specified as stainless steel, size 1/2 in. This specification is deficient for determining allowable bolt loads. Further, stainless steel is a dissimilar metal to the structural steel lower frame and chassis. For the 3.0 g maximum potential transportation force on truck 2 distributed equally to these connections, the calculated bolt shear load is about 4.0 Kips. The clip angle bolts should be replaced with 5/8 in SAE Grade 8 bolts (steel similar to the frame and chassis). The AISC 1989 allowable shear load for these replacement bolts would exceed 6 Kips.

Each clip angle connection is fillet welded to the longitudinal members of the lower frame and the truck 2 chassis. Both welds must resist the total horizontal transportation force at each connection. The welds to the truck chassis govern. These are 12 in total length, 3/16 in fillet welds. The calculated maximum shear stress or force in the welds is 680 lbf/in. The AISC 1989 allowable stress for a 3/16 in fillet weld is 2,700 lbf/in.

5.2 ROTATING PLATFORM AND BEARING SYSTEM ATTACHMENT BOLT SETS

There are 4 sets of bolts required to attach the rotating platform and its bearing system to the lower frame. Briefly, these are:

An array of 12 ASTM A449 1/2 in. diameter screws attaching the bearing mount to the lower frame,

A 41.5 in diameter circle of 24 commercial carbon steel 1/2 in. diameter screws attaching the (rotating platform) bearing to the bearing plate,

A 46.0 in diameter circle of 18 commercial carbon steel 5/8 in. diameter screws to attach the (top) bearing plate, and

An array of 8 commercial carbon steel 3/4 in. diameter bolts attaching the rotating platform frame to the (top) bearing plate.

All of these bolt sets were presumed to be linear elastic. The horizontal transportation loads were assumed to be equally distributed to the bolts in each set. The potential overturning moment from the drill string was assumed to act about the center of the bolt circles, and (conservatively) tends to rotate the bolt arrays about the outside row of bolts. The bolt shear and tension forces from these demands can be readily calculated. However, 3 of the bolt sets are specified as commercial carbon steel. This specification is deficient for determining the allowable bolt loads. Therefore, to have a design comparison value for the calculated bolt loads, the AISC 1989 allowable loads for ASTM A307 (low strength) bolts were determined.

The calculated bolt stresses with allowable values for comparison are given in Table 1. The allowable for the commercial carbon steel bolts presume that the materials conform to or exceed ASTM A307. The bolt tension stresses for all 4 sets due to the drill string overturning moment are comfortably within the given allowable. The calculated bolt shear stresses due to the transportation forces exceed the given allowable for the 1/2 in. and 5/8 in. bolt arrays. Based on the need to presume the material specification and design allowable for 3 of these bolt sets, and that the other set of 1/2 in. A449 bolts would be over stressed resisting the given transportation forces, The bolts in all 4 of these sets should be replaced with SAE Grade 8 bolts.

In Table 2, the calculated bolt stresses are compared to the allowables for SAE Grade 8 bolts. Only the 12 - 1/2 in. bolt array would remain over stressed by the 3 g maximum transportation force. These bolts would remain within the design allowable shear stress under a 2.6 g horizontal transportation force, about 13% less than 3 g.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The lower frame structural steel channel members are supported so that little or no bending stresses can develop. With conservative assumptions, the maximum calculated bending stress in the longitudinal members due to vertical load is 13,343 lbf/in^2. This is 37% F_y, 60% F_y is acceptable.

The bearing loads in the top flanges of the lower frame channels put compressive stress in the webs. This stress, conservatively calculated, is within the AISC limit for precluding web crippling.

It is recommended that the 12 - 1/2 in. bolts (those readily accessible) in the clip angle attachments between the lower frame and the truck 2 chassis be replaced with 5/8 in. Hex bolts, SAE Grade 8. The existing bolts could be a dissimilar metal and it is not possible to determine an allowable shear load for them to compare with the potential 3 g transportation force.

The fillet welds for the clip angle attachments between the lower frame and truck 2 chassis have sufficient throat sizes and lengths to resist the potential 3 g transportation force.

There are 4 sets of bolts (loaded in series) which attach the bearing mount, bearing, bearing plate, and rotating platform frame to the lower frame. The conclusions from the evaluation of each set are summarized below:

The array of 12 1/2 in. bolts or screws, ASTM A449, attaching the bearing mount to the lower frame would be about 1/3 over the design allowable shear stress due to the potential 3 g transportation force. If readily accessible, it is recommended that these bolts be replaced with 1/2 in. bolts, SAE Grade 8. Table 2 shows the allowable shear stress in the replacement high strength bolts would still be exceeded if the transportation force is over 2.6 g (about 13% less than 3 g). Given that the 3 g horizontal transportation force is just remotely possible, the resulting stress in the bolts should not cause shear rupture, the design allowable stresses are for continuous duty (conservative), and either additional bolts or larger size bolts would be needed to lower the potential stresses (a major and impractical design modification), the recommendation for SAE Grade 8 1/2 in. bolts remains acceptable.

The rotating platform bearing is attached top and bottom, respectively, with a ring of 18 - 5/8 in. carbon steel bolts, and a ring of 24 - 1/2 in. carbon steel bolts. Presuming that these bolts are ASTM A307 or better, the 5/8 in. bolts would be within the design allowable shear stress due to the potential 3 g transportation force, while the 1/2 in. bolts would be about 4% over stressed. On the basis it is necessary to presume the design allowable, if readily accessible, it is recommended that these bolts (both rings) be replaced with same size SAE Grade 8 bolts.

The array of 8 - 3/4 in. carbon steel bolts attaching the bearing plate and rotating platform frame, if readily accessible, should be replaced with 3/4 in. SAE Grade 8 bolts. With the relatively conservative presumption of ASTM A307 for the existing bolts, the potential 3 g transportation shear stress is about 38% over the allowable. Thus, bolt replacement will assure that the bolt design allowable shear stress is within the potential value.

The stresses or loads on these bolts due to the potential eccentric vertical 6,000 lbf load on the drill string could approach 1/2 the presumed allowable. Based on the need to presume most of the bolt materials and allowable loads, no exceptions are provided to the above recommendations for bolt replacements. With or without bolt replacements, these bolt sets and installation details have not been rated for continuous duty under the 6,000 lbf drill string load and potential overturning moment.

Table 1. Bolt stresses, rotating platform and bearing attachment to lower frame

Bolt Set Description	Bolt Diameter (in)	Material	Transportation Loads, Shear (KIP/in^2)		Overturning Loads, Tension (KIP/in^2)	
			Calculated	Allowable	Calculated	Allowable
12 screws for bearing mount to lower frame	1/2	A449	20.9	14.4	11.5	40.0
24 screws for bearing to its mount	1/2	A307 *	10.4	10.0	9.7	20.0
18 screws for attaching (top) bearing plate	5/8	A307 *	8.8	10.0	7.9	20.0
8 bolts for platform to bearing plate	3/4	A307 *	13.8	10.0	6.2	20.0

* Assumed for Commercial Carbon Steel

Table 2. Bolt stresses versus SAE Grade 8 allowables, rotating platform and bearing attachment to lower frame

Bolt Set Description	Bolt Diameter (in)	Material	Transportation Loads, Shear (KIP/in^2)		Overturning Load, Tension (KIP/in^2)	
			Calculated	Allowable	Calculated	Allowable
12 screws for bearing mount to lower frame	1/2	SAE Grade 8	20.9	18.0	11.5	54.0
24 screws for bearing to its mount	1/2	SAE Grade 8	10.4	18.0	9.7	54.0
18 screws for attaching (top) bearing plate	5/8	SAE Grade 8	8.8	18.0	7.9	54.0
8 bolts for platform to bearing plate	3/4	SAE Grade 8	13.8	18.0	6.2	54.0

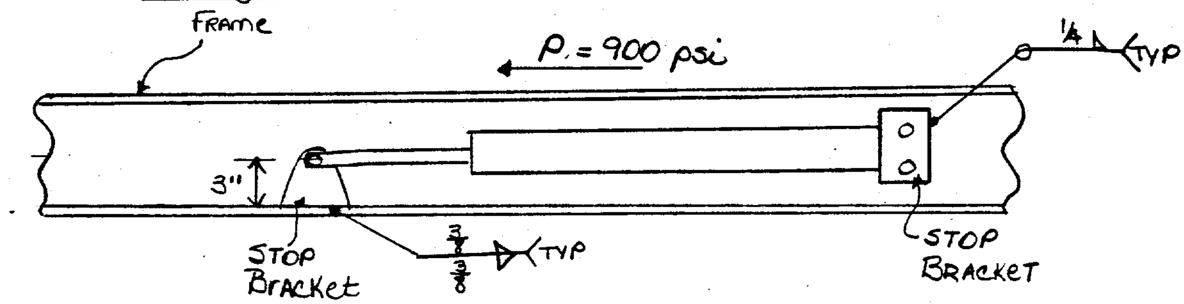
APPENDIX C

ANALYSIS OF THE TRANSVERSE SLIDE ASSEMBLY

(1) Drawing H-2-91711, 91702 (2) Doc. No. ______ (3) Page 1 of ____
(4) Building N/A (5) Rev. ______ (6) Job No. ______
(7) Subject Traverse Cylinder
(8) Originator BJ Niemi Date 10-26-94
(9) Checker Hrese H. Zich Date 11-3-94

(10) 1.0 Introduction: The Following Analysis is For The connections of The Traverse Cylinder To The upper Frame.

2.0 Configuration & Loads

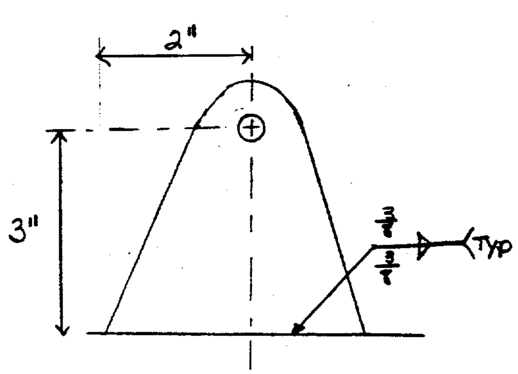


Inside Diam of Cylinder = 2 1/2"
Pressure = 900 psi

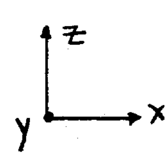
Materials: Assume 70E Electrode For Welds
A36 Carbon Steel

Find: Check the design of the stop brackets including welds, bolts and plates.

2.1) Front Stop Bracket



PL = 0.62"
R = 0.62"
Diameter of Hole = 0.765"



BD-6400-060.1 (12/87)

DESIGN CALCULATION

(1) Drawing H-2-91711, 91702 (2) Doc. No. ______ (3) Page 2 of ____

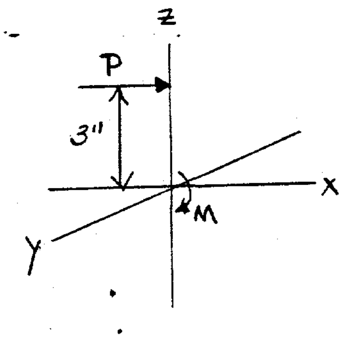
(4) Building ______ (5) Rev. ______ (6) Job No. ______

(7) Subject Traverse Cylinder

(8) Originator BJ Niemi Date 10-26-94

(9) Checker Hassan H. Zaidi Date 11-3-94

(10)



Determine P + M

Area of Cylinder $= \frac{\pi d^2}{4} = \frac{\pi 2.5^2}{4} = 4.91 \text{ in}^2$

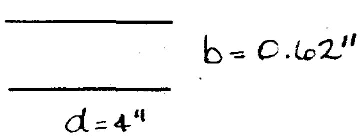
$\sigma_{cyl} = 900 \text{ psi} = \frac{P}{A}$

$P = 900 \frac{\text{lb}}{\text{in}^2} \times 4.91 \text{ in}^2 = 4419 \text{ lbs}$

$M = P \times 3 = 13,257 \text{ in} \cdot \text{Lbf}$

A. Check Weld

Geometry of Weld



Properties of weld

Blodgett 1982

$A_w = 2(4) = 8 \text{ in}$

$S_w = \frac{d^2}{3} = 5.33 \text{ in}^2$

Find Resultant Force (f_R) on Weld

$f_1 = \frac{M}{S_w} = \frac{13,257 \text{ in} \cdot \text{lb}}{5.33 \text{ in}^2} = 2487 \text{ lbf/in}$

$f_2 = \frac{P}{A_w} = \frac{4419}{8} = 552 \text{ lbf/in}$

$f_R = \sqrt{f_1^2 + f_2^2} = 2548 \text{ lbf/in}$

Determine weld size (ω)

$\omega = \frac{f_R}{f_{Allow}} = \frac{2548}{(.3)(.707)(70,000)} = 0.172 \text{ in} < 3/8''$

BD-6400-060.1 (12/87)

(1) Drawing H-2-91711, 91702 (2) Doc. No. ______ (3) Page 3 of ____

(4) Building ______ (5) Rev. ______ (6) Job No. ______

(7) Subject Traverse Cylinder

(8) Originator B J Niemi Date 10-26-94

(9) Checker [signature] Date 11-3-94

(10)

Code Requirments

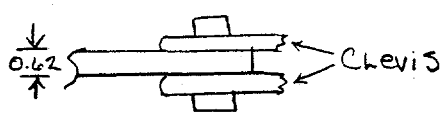
Based on the thicker of the 2 parts, AISC code requires 5/16" fillet < 3/8", therefore this weld meet AISC specs.

B. Check Plate

Bearing Stress

using projected area to check for bearing failure

$$A = td = 0.62 \times .765\,in = 0.474\,in^2$$



$$\sigma_{plate} = \frac{P}{A} = \frac{4419}{0.474} = 9322\ lb_f/in^2 < F_p$$

$$F_p = 0.9\,F_y = 0.9(36{,}000) = 32{,}400\ lb_f/in^2$$ ✓ OKAY

∴ This plate meets AISC specs for bearing strength.

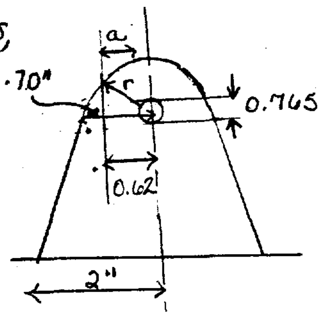
BD-6400-060.1 (12.87)

(1) Drawing H-2-91711, 91702 (2) Doc. No. ______ (3) Page 4 of ____
(4) Building ______ (5) Rev. ______ (6) Job No. ______
(7) Subject Traverse Cylinder
(8) Originator BJ Niemi Date 10-26-94
(9) Checker Hassan H. Ziada Date 11-3-94

(10)

C) Check Shear of Plate (Plate is in double shear)

Used drawings, Nuleno + Natico to get distance from ℄ to edge.



a = distance to edge from bolt Hole.

$$a = 0.70 - \frac{0.765}{2} = 0.3175 \text{ in}$$

Assume:
The entire bolt load acts perpendicular to the nearest edge, the shear area is based on the closest distance from the edge to the bolt.

Therefore: The Shear area (A) = 2at

$$A = 2 \times 0.3175 \times 0.62 = 0.3937 \text{ in}^2$$

$$F_v = 0.40\, F_y = 0.4\,(36{,}000) = 14{,}400 \text{ lb/in}^2$$

$$f_v = \frac{P}{A} = \frac{4419}{0.3937} = 11{,}224 \text{ lb}_f/\text{in}^2 < F_v = 14{,}400 \text{ lb}_f/\text{in}^2$$

∴ This plate meets AISC specs for shear in this loading condition.

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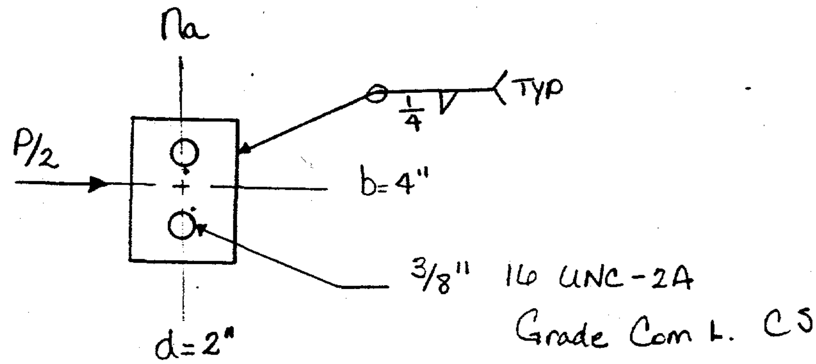
(7) Subject Traverse Cylinder

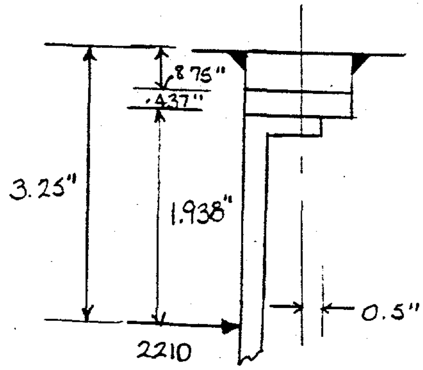
(8) Originator B J Niemi Date 10-26-94

(9) Checker Hassan H. Tirah Date 11-3-94

(10)

2.2 Back Stop Bracket





Properties of Side Weld

$$S_w = \frac{d}{3}(3b+d)$$

$$= \frac{2}{3}(3 \times 4 + 2) = 9.33\,in^2$$

$$A = 2(2) + 2(4) = 12\,in$$

Assume the load is equally divided between the two brackets.

$$Load/bracket = \frac{4419}{2} = 2210\ lbf$$

$$Moment = 2210 \times 3.25 = 7183\ in \cdot lbf$$

A) Check side weld

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(9) Checker Hasan H. Zia Date 11-3-94

(10)

Determine f_R

① $f_b = \frac{M}{S_w} = \frac{7183}{9.33} = 770$ lbf

② $f_v = \frac{P}{A} = \frac{2210}{12} = 184$ lbf

③ $f_R = \sqrt{f_b^2 + f_v^2} = 792$ lbf

Find weld size (ω)

$$\omega = \frac{f_R}{f_{Allow}} = \frac{792}{(.3)(.707)(70{,}000)} = 0.053 \text{ in} < 0.25$$

Summary

¼" fillet weld meets AISC specs for this loading condition.

B) Check Bolts

Assume: A325 material

Tension load per bolt:

$2210 \times 1.938 = 2\,T_1 \times 0.5$

$T_1 = 4283$ lbf

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(8) Originator B.J. Niemi Date 10-21-94

(9) Checker Hassan H. Zink Date 11-3-94

(10)

c) Shear load per bolt:

$$V_1 = \frac{2210}{2} = 1105 \text{ lbf}$$

The bolts carry shear & tension load. Assume the threads are included in the shear plane.

$$\text{Nominal Area} = \frac{\pi d^2}{4} = \frac{\pi \left(\frac{3}{8}\right)^2}{4} = 0.1104 \text{ in}^2$$

$$\text{Shear stress: } f_v = \frac{V_1}{A_n} = \frac{1105}{.1104} = 10{,}005 \text{ lbf/in}$$

$$\text{Allowable tension} = \sqrt{(44{,}000)^2 - 4.39 f_v^2} = 38{,}686 \text{ lbf/in}^2$$

AISC (1989)

$$\text{Tensile stress: } f_t = \frac{T_1}{A} = \frac{4282.98}{.1104} = 38{,}795 \cong 38{,}686$$

This is very close, but lets check using A490 bolts. (SAE GRADE 8)

$$\text{Allowable tension} = \sqrt{(54{,}000)^2 - 3.75(f_v^2)} = 50{,}405 \text{ lbf/in}^2$$

$$\text{Design Margin, DM} = \frac{50{,}405}{38{,}686} = 0.3$$

Summary:

Recommend using SAE GRADE 8 bolts or equivalent material to meet AISC specs for this loading condition.

APPENDIX D

DRILL ROD FAILURE LOADS ANALYSIS

DESIGN CALCULATION

(1) Drawing ______ (2) Doc. No. ______ (3) Page 1 of 4
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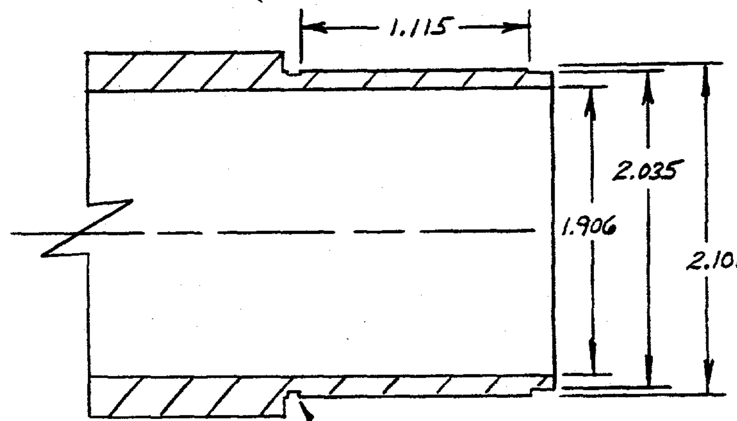
(9) Checker Hasan H. Tirta Date 11-4-94

(10)

Drill Rod

Threads

4 TPI
RH 5° MOD SQR



Case 1: Initial Tightening Torque = 600 in-lbf.

Tensile load on critical area due to initial tightening of joint,

$$T = \frac{F_1 d_m}{2}\left(\frac{l + \pi \mu d_m \sec\alpha}{\pi d_m - \mu l \sec\alpha}\right)$$

where
- T = applied torque (600 in-lbf)
- d_m = mean diameter of thread (2.068 in.)
- l = lead of thread (0.25 in.)
- μ = coefficient of static friction (.20)
- α = 1/2 the thread angle (2.5°)
- F_1 = axial load at critical area

Solving for axial load,

$$F_1 = \frac{2(600 \text{ in-lbf})}{2.068 \text{ in.}}\left(\frac{\pi(2.068 \text{ in.}) - 0.20(0.25 \text{ in.})\sec 2.5°}{0.25 \text{ in.} + \pi(.20)(2.068 \text{ in.})\sec 2.5°}\right)$$

$$= 580.27\,(6.447 / 1.551)$$

$$= 2{,}412 \text{ lbf.}$$

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(7) Subject Core Sampling Truck No. 2 Drill Rod

(8) Originator Duane Koehler *Duane Koehler* Date 10/19/94

(9) Checker Hassan H. Zeid Date 11-4-94

(10)

Material

Yield Strength, $\sigma_y = 76{,}000\ lbf/in^2$
Ultimate Strength, $\sigma_u = 90{,}000\ lbf/in^2$

Rod pull to yield,

Cross-sectional area at critical point, $A = \frac{\pi}{4}(2.035^2 - 1.906^2)$
$= 0.40\ in^2$

$F_2 = \sigma_y \cdot A = 76{,}000 \cdot 0.40 = 30{,}400\ lbf.$

where F_2 = axial load on critical area at yield

$F_y = F_2 - F_1 = 30{,}400 - 2{,}412 = \boxed{27{,}988\ lbf.}$

where F_y = axial load on rod to yield critical area after initial tightening of joint.

Rod pull to failure,

$F_3 = \sigma_u \cdot A = 90{,}000 \cdot 0.40 = 36{,}000\ lbf$

where F_3 = axial load on critical area at failure

$F_u = F_3 - F_1 = 36{,}000 - 2{,}412 = \boxed{33{,}588\ lbf.}$

where F_u = axial load on rod to fail critical area after initial tightening of joint

(1) Drawing ______ (2) Doc. No. ______ (3) Page 3 of 4

(4) Building ______ (5) Rev. ______ (6) Job No. ______

(7) Subject Core Sampling Truck No. 2 Drill Rod

(8) Originator Duane Koehler [signature] Date 10/20/94

(9) Checker [signature] Date 11-4-94

(10)

Torque to yield,

Assume plane stress at critical area.

$$\tau_y = \sqrt{\frac{1}{4}\sigma_j^2 + \tau_a^2}$$

where τ_y = yield strength of material in shear

σ_j = tensile stress at critical area due to tightening of joint

τ_a = shear stress applied to critical area by twisting drill rod

$$\tau_a = \frac{Tr}{J} = \frac{T(1.018)}{\frac{\pi}{32}(2.035^4 - 1.906^4)} = 2.624\ T$$

where T = applied torque to drill rod

$$\sigma_j = \frac{F_i}{A} = \frac{2{,}412\ lbf}{0.40\ in^2} = 6{,}030\ lbf/in^2$$

$$\tau_y = \sqrt{\frac{1}{4}(6{,}030)^2 + (2.624\ T_y)^2} = \frac{1}{2}(76{,}000)$$

$$T_y = 14{,}436\ in\text{-}lbf = \boxed{1{,}203\ ft\text{-}lbf}$$

Torque to failure,

$$\tau_u = \sqrt{\frac{1}{4}(6{,}030)^2 + (2.624\ T_u)^2} = \frac{1}{2}(90{,}000)$$

$$T_u = 17{,}111\ in\text{-}lbf = \boxed{1{,}426\ ft\text{-}lbf.}$$

DESIGN CALCULATION

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(7) Subject Core Sampling Truck No. 2 Drill Rod
(8) Originator Duane Koehler *Duane Koehler* Date 11/7/94
(9) Checker *Hassan H. Tiwla* Date 11-4-94

(10)

Case 2: Initial Tightening Torque = 1200 in-lbf.

Repeating calculations in Case 1 for $T = 1200$ in-lbf.,

$F_1 = 4{,}824$ lbf.

$F_y = 30{,}400 - 4{,}824 = 25{,}576$ lbf.

$F_u = 36{,}000 - 4{,}824 = 31{,}176$ lbf.

$\sigma_j = 4{,}824/0.4 = 12{,}060$ lbf/in^2

$\tau_y = 14{,}298$ in-lbf $= 1{,}191$ ft-lbf

$\tau_u = 16{,}995$ in-lbf $= 1{,}416$ ft-lbf.