BELOW-THE-HOOK LIFTING DEVICE
Engineering Note Cover Page

Lifting Device Numbers: ID #91

FNAL Site No.: — (if applicable) Div. Specific No.: — (if applicable) Asset No. — (if applicable)

ASME B30.20 Group: (check one)

- ☒ Group I Structural and Mechanical Lifting Devices
- ☐ Group II Vacuum Lifting Devices
- ☐ Group III Magnets, Close Proximity Operated
- ☐ Group IV Magnets, Remote Operated

Device Name or Description: CDF / COT FLIPPING FIXTURE

Device was: (check all applicable)

- ☐ Purchased from a Commercial Lifting Device Manufacturer
  mfg. name: —
- ☐ Designed and Built at Fermilab
- ☒ Designed by Fermilab and Built by a Vendor
  Assy drawing number: 2563.244-ME-339775
- ☐ Provided by a User or Other Laboratory
- ☐ Other. Describe: —

Engineering Note Prepared by: RAFAEL SILVA Date: 10/29/98

Engineering Note Reviewed by: BOB WOODS Date: 11/02/98

Lifting Device Data:

Capacity: 3,600 lb

Fixture Weight: 1,900 lb

Service: ☒ normal ☐ heavy ☐ severe (refer to B30.20 for definitions)

Duty Cycle: — 8, 16 or 24 hour rating (applicable to groups III, and IV)

Inspections Frequency: INSPECT BEFORE USE

Rated Load Test by FNAL (if applicable): Date: 11/12/98 Load: 4,700 lb

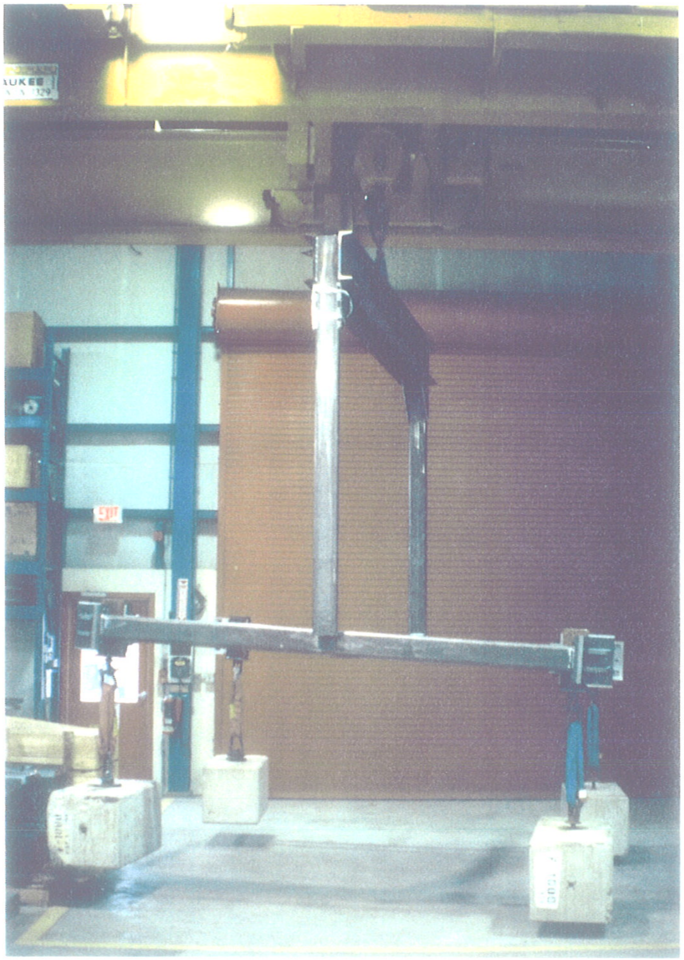
☐ Check if Load Test was by Vendor and attach the certificate.

Satisfactory Load Test Witnessed by: RAFAEL SILVA

Signature (of Load Test Witness): [signature]

Notes or Special Information:

FIXTURE TO BE USED ONLY FOR FLIPPING THE CDF/COT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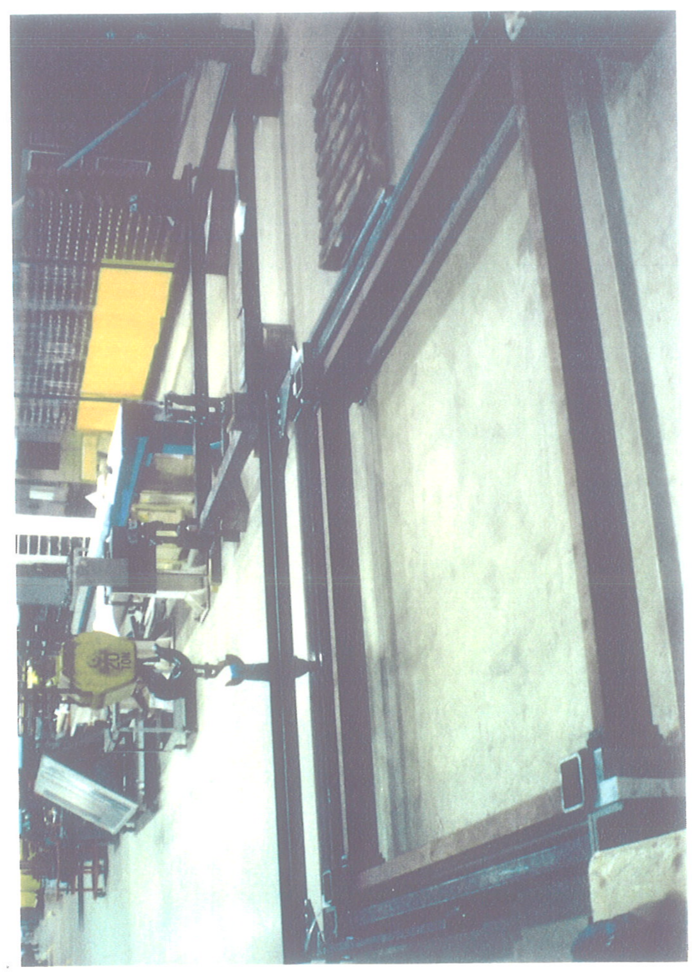


Fermilab

November 23, 1998

To: Win Baker, CDF Upgrade ES&H Review Committee Chair

From: Fritz Lange, CDF Mechanical Safety Subcommittee

Subject: Review of CDF COT Rotating Fixture and Support Stand

F Lange

The Safety Panel met with Rafael Silva on November 5 and November 13, 1998 to review a fixture that will be used to lift and rotate the Central Outer Tracker. In addition, the panel reviewed the design of a structure that will permanently support the Tracker after it has been rotated.

The panel agrees that, in principle, the design of both structures is sound and follows safe practices. The panel understands that, since the review took place, the flipping fixture has been load tested. The panel was not asked to review the procedure for using the fixture.

As is customary, the panel considers safe design practices, but does not offer formal opinions on the functionality of the design. Nor does it routinely check for arithmetic errors.

cc: R. Silva
J. Howell
A. Lee
R. Rucinski

Fermilab

CDF JHA/WORK PERMIT

JOB NAME: Flipping of the Central Outer Tracker
LOCATION: IB4 Building

EST. START DATE: 22NOV98 **EST. JOB DURATION** 1 day

WORK TO BE PERFORMED BY: CDF Personnel

RESPONSIBLE ENGINEER: Rafael Silva **PHONE:** 8311

PERSON IN CHARGE: Ken Schultz **PHONE:** 3377

DESCRIPTION OF WORK:

The goal is to reposition the COT from vertical to horizontal and place it into a fixture that will allow the installation of sense and field planes. This work consists of the following steps:

1) Move the COT assembly fixture (Gallows including the COT chamber) from the clean room into the crane area in IB4;
2) Disassemble parts of the Gallows to allow access to the COT;
3) Utilizing the Flipping Fixture (Lifting Device ID#91), extract the detector from the Gallows and turn it from the vertical to the horizontal position;
4) Place the COT onto the Rotation Fixture, then detach and remove the Flipping Fixture;
5) Move the Rotation Fixture with the COT back into the clean room.

Both the Flipping Fixture and the Rotation Fixture have been reviewed and approved by the CDF Mechanical Safety Committee.

Weight of components:
Gallows: 11,700 lb.
COT chamber: 3,600 lb.
Flipping Fixture: 1,900lb.
Rotation Fixture: 1,300 lb.

ASSOCIATED HAZARDS:

1) Standard hazards involved in rigging operations, which can result in injuries to personnel.
2) Expensive, critical object being moved as described above.
3) Could run out of time and not finish the job in 8 hours.

HAZARD MITIGATION:

1) All personnel involved in the lift will have the following Personal Protect Equipment (PPE); hard hats, safety shoes and gloves.
2) All crane and forklift operators are trained and qualified and all lifting equipment will be visually inspected prior to being used in this lift.
3) A pre-lift meeting will be held to coordinate the activities.
4) Experienced personnel will be conducting the operation as follows: The Person in Charge, Ken Schultz,, who has successfully performed similar operations involving conjunct use of the crane and forklift to perform a lift, will function as the crew foreman and will act as the primary crane and forklift operator. In the absence of Ken Schultz, the work will cease.
   Kourosh Taheri will function as a crew member and secondary crane operator.
   KC Kirksey, Jason Griffin and George Eddy will function as crew members, responsible for monitoring clearances, steadying the components with tag lines and bolting/unbolting parts of the assembly.
   At least one of the Physicist Project Managers (Aseet Mukherjee and Bob Wagner) will be present during this operation.
5) If the job looks like it will run over 8 hours, contact Rich Stanek who will approve the extra time or determine a safe and reasonable break point.

PREPARED BY: [signature] **DATE:** 11/20/98

APPROVED BY: [signature] **DATE:** 11/20/98

Is work being performed in close proximity to beams division equipment?

___Yes   _X__ No

Note: This work is being performed in the IB4 Building (which is owned by the Technical Division). The IB4 Building Manager, Art Paulson, has been informed that this work will be taking place.

CDF / COT Flipping Procedure

November 19th, 1998

Elaborated by Aseet Mukherjee, Ken Schultz, Rafael Silva, Rich Stanek and Bob Wagner.

Outside Clean Room (preliminary):

1. Sweep entire floor area from overhead door to the end of COT office space, before Gallows is removed from clean room.
2. Clean, position and prepare the Rotating Fixture.
3. Position and prepare the Flipping Fixture (Lifting Fixture ID#91).
4. Inspect all slings that will be used during the procedure.
5. Check operation of the IB4 crane and forklift.

Inside Clean Room:

4. Finish assembly and survey of structural components of COT. NOTE: Leave the 4x4x1/8 aluminum stiffeners in place on the chamber for added stability during flipping.
5. Detach and remove T-Bars, Angle Plates, Struts and related hardware from the top of the COT and from the upper octagon of the Gallows.
6. Install the Flipping Fixture spreader bars and hardware torquing the bolts up to 35 ft-lb.
7. Detach but do not remove all but two diametrically opposed T-Bars (#5 & #11) and related hardware from bottom of COT. Keep all T-Bars, Angle Plates, Struts, and related hardware attached to the bottom octagon of the Gallows (This allows the weight of the COT to be distributed to all T-Bars, while minimizing stresses induced by the Gallows to the COT chamber during movement).
8. Install dust covers.
9. Remove taper pins and bolts from all connections between the diagonal braces and the top octagon.
10. Remove taper pins from the connection between the lower diagonal braces and the bottom of the NE column of the Gallows.

11. Remove all bolts from the top of each column except for the outside corner bolts that should remain attached.
12. Install riser blocks for rollers on gallows.
13. Raise Gallows and detach columns from grouted base, removing grout from these areas.
14. Place G-10 plates on floor and place rollers under riser blocks.
15. Lower the Gallows on to rollers.
16. Move the Gallows out of the Clean Room. NOTE: Check clearances between Gallows and doorway as the assembly is moved (approximate clearance is 1.5 ").

<u>**Outside Clean Room:**</u>

NOTE: The removal of the top octagon involves the use of a conjunct lift using both the crane and forklift. This requires close coordination of the movements. A distant observer will be used to synchronize the movements so that the top octagon is kept level at all times during the lift.

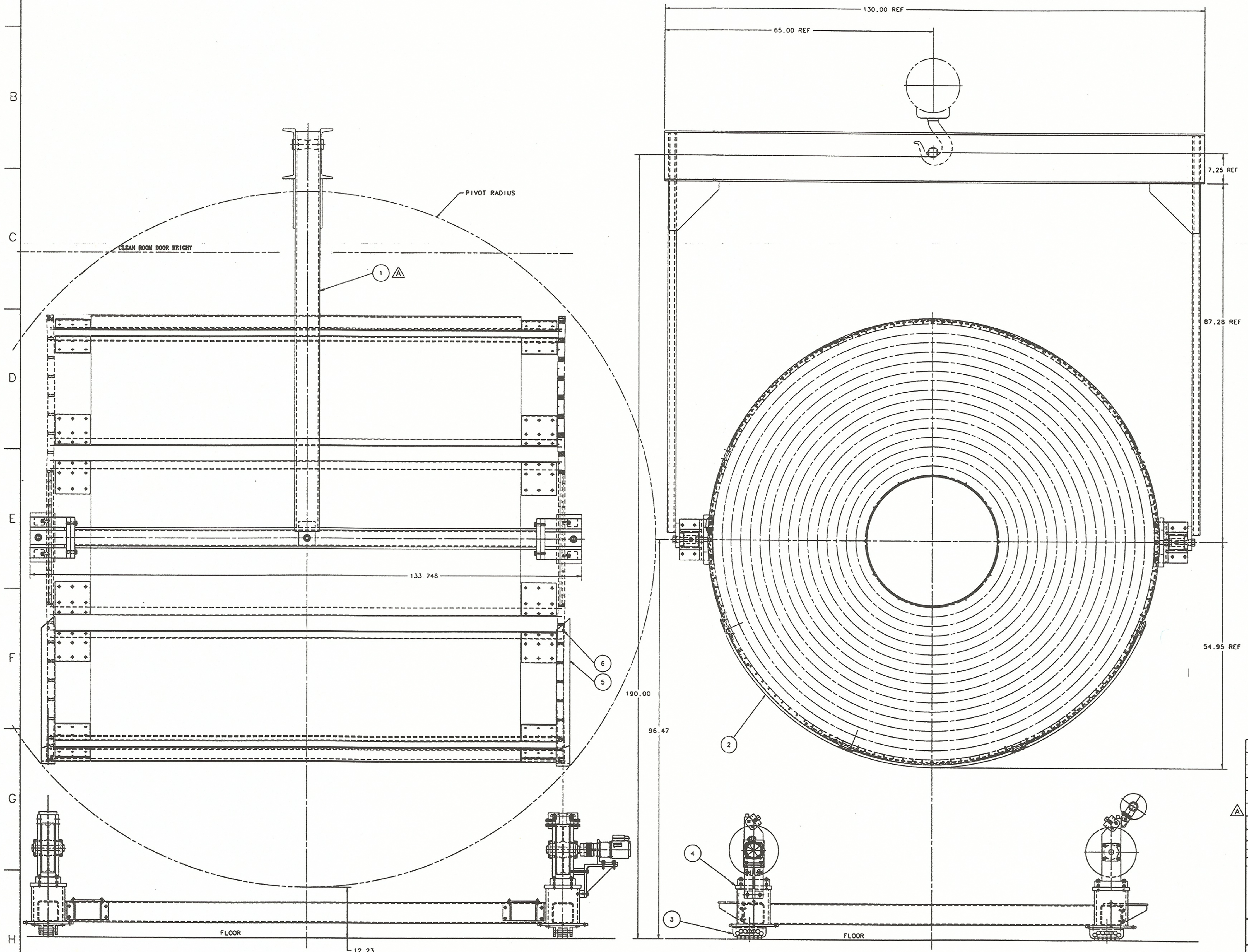
17. Position the forklift on the east side of the Gallows at the centerline of the cross bar. Spread forks apart to their furthest width (approximately 36"). Position forks to place load in contact with the mast, so that the full length of the forks is underneath the octagon. NOTE: This will help stabilize the load.
18. Attach slings to the corners of the west side of the Gallows to pick with the crane.
19. Remove four remaining bolts from the top octagon of Gallows and lift this piece to allow clearance for the next step (approximately 4").
20. Move the COT and Gallows assembly west (out from under top octagon) by attaching slings to the legs of the Gallows and pulling it out of the way. NOTE: Do not walk underneath the load of the top octagon.
21. Lower top octagon to the floor (using both the crane and forklift in a synchronized manner), then resling and lift with the crane only and place it at the north end of the building.
22. Attach slings and tag lines to NE column.
23. Remove bolts from the connection between the NE column, including the diagonal braces, and the bottom octagon. NOTE: Be careful to check stability of the column before it is fully detached.

24. Detach NE column and its diagonal braces from bottom octagon and remove with crane placing them in the same general location as top octagon.
25. Pick Flipping Fixture with the crane, attach it to spreader bars and lock them together to prevent rotation.
26. Remove the remaining bolts connecting the COT to the bottom T-Bars.
27. Check all rigging/fixturing to be sure all connections are properly made. Install tag lines to help steady the COT chamber during the lift.
28. Lift the COT to allow clearance for moving the remaining part of the Gallows out of the way. (Again, this is approximately 4") First move it to the center of the aisle and then outside through the overhead door. Position the COT in the proper orientation for flipping.
29. Install dust cover and supports on bottom of COT. Install 3 rail segments on each end of the COT centered between Flipping Fixture spreader bars.
30. Unlock spreader bars and flip COT slowly using tag lines to steady.
31. Position Rotation Fixture under COT and lower the COT onto it.
32. Detach spreader bars from Flipping Fixture and place Flipping Fixture in the same general location as top octagon.
33. Detach spreader bars from COT and place them out of the way.
34. Attach rollers and move the Rotation Fixture with COT back into the Clean Room, again checking clearances. However, there is quite a bit of clearance available in this orientation.

Back Inside Clean Room:

35. Position Rotation Fixture with COT in the Clean Room.
36. Place jacks (12 to screw jacks) underneath lift-brackets.
37. Raise Rotation Fixture with COT.
38. Remove rollers and lower Rotation Fixture with COT.

REV.	DESCRIPTION	DRAWN / APPROVED	DATE / DATE
A	REVISED ITEM #1. FLIPPING FIXTURE	PAT POLL	10/16/98



ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.
6	COML	5/8-11 UNC-3A X 1 LG. SOCKET HD CAP SCREW	32 TOTAL
5	MD-339238	TRACK	16 TOTAL
4	ME-339243	ROTATING FIXTURE ASSEMBLY	1
3	COML	HILLMAN ROLLER #5-OT	4
2		CENTRAL OPEN-CELL TRACKER (C.O.T.)	1
1 (A)	MD-339775	FLIPPING FIXTURE ASSEMBLY	1

PARTS LIST

UNLESS OTHERWISE SPECIFIED					
.XX	.XXX	ANGLES	ORIGINATOR	RAFAEL SILVA	8/26/97
±.06	±----	±----	DRAWN	R.F. SANDBERG	8/26/97
			CHECKED	R. SILVA	8/31/98
			APPROVED	R. SILVA	8/31/98

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5M-1982 STD'S.
4. ALL DIMENSIONS ARE IN INCHES.

XX √ MAX. ALL MACHINED SURFACES

USED ON

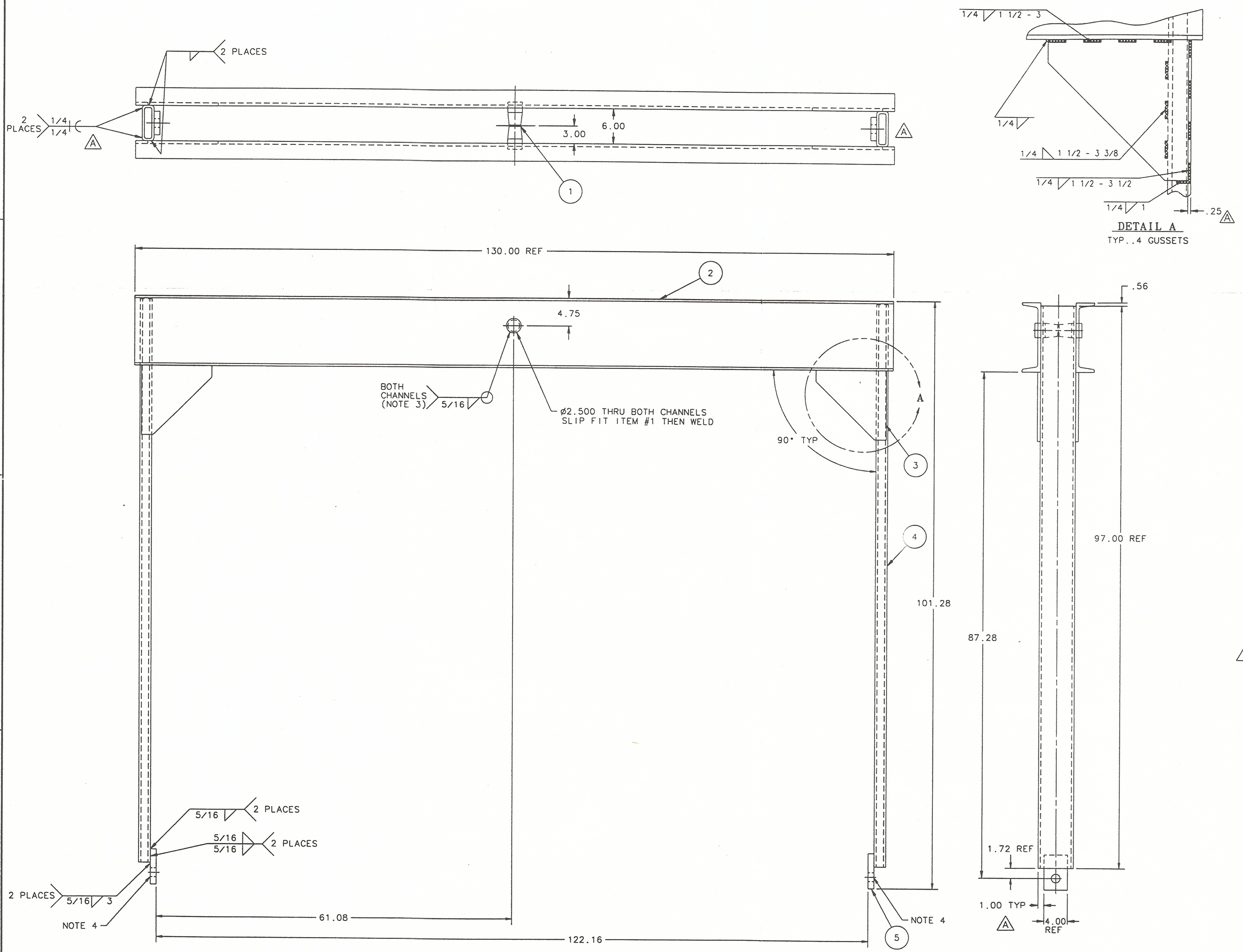
MATERIAL: SEE B.O.M.

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

PPD/CDF/COT
FLIPPING ARRANGEMENT

SCALE	DRAWING NUMBER	SHEET NO.	REV.
1:8	2563.244-ME-339288	1 OF 1	A

REV.	DESCRIPTION	DRAWN / APPROVED	DATE / DATE
A	REPLACED CHANNEL WITH TUBING	PAT POLL	10/15/98



NOTES:

1. USE ONLY LOW HYDROGEN ELECTRODE.
2. MINIMUM BASE METALS TEMPERATURE FOR ALL WELDING SHALL BE 70° F.
3. MINIMUM BASE METALS TEMPERATURE FOR FOR WELDING OF ITEM 1 SHALL BE 150° F.
4. THESE TWO HOLES SHOULD BE ALIGNED AND LEVELED WITHIN ±.063.

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.
5	MB-339298	BEARING PLATE	2
4 (A)	COML	6 X 2 X 3/8 X 97.00 LG., STEEL RECT. TUBING ASTM A500, GR.B	2
3	MB-339299	GUSSET PLATE	4
2	COML	C12 X 3.170 X .510 X 30#/FT X 130.00 LG STEEL CHANNEL ASTM A 36	2
1	MB-339297	LIFTING PIN	1

PARTS LIST

UNLESS OTHERWISE SPECIFIED

.XX	.XXX	ANGLES
±.01	±.005	±----

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5M-1982 STD'S.
4. ALL DIMENSIONS ARE IN INCHES.

MAX. ALL MACHINED SURFACES

ORIGINATOR	RAFAEL SILVA	8/28/97
DRAWN	R.F.SANDBERG	8/28/97
CHECKED	R. SILVA	8/31/98
APPROVED	R. SILVA	8/31/98
USED ON	ME-339775	
MATERIAL	SEE B.O.M.	

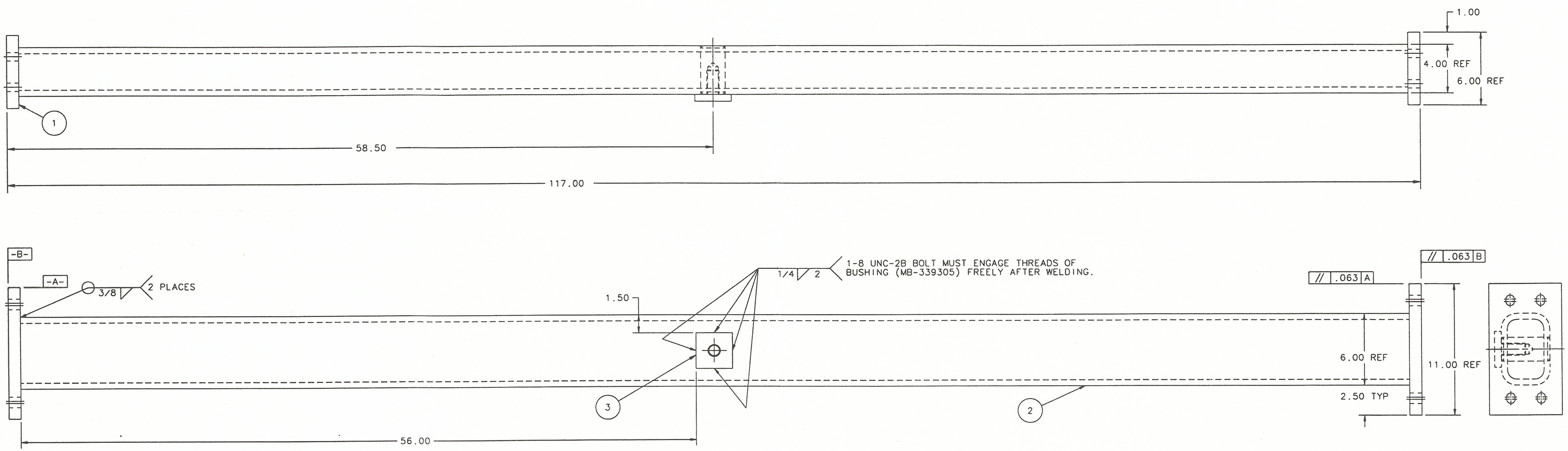
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

PPD/CDF/COT
COT FLIPPING FIXTURE
LIFTING ASSEMBLY

SCALE	DRAWING NUMBER	SHEET NO.	REV.
1:8	2563.244-MD-339295	1 OF 1	A

OCT 29 1998

REV.	DESCRIPTION	DRAWN / APPROVED	DATE / DATE



3	MB-330307	SHIM PLATE	1
2	MD-339304	SPREADER BAR WELDMENT	1
1	MB-339306	SPREADER BAR END PLATE	1
ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.

PARTS LIST

UNLESS OTHERWISE SPECIFIED		
.XX	.XXX	ANGLES
±.01	±.005	±----

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5M-1982 STD'S.
4. ALL DIMENSIONS ARE IN INCHES.

63 √ MAX. ALL MACHINED SURFACES

ORIGINATOR	RAFAEL SILVA	8/29/97
DRAWN	R.F.SANDBERG	8/29/97
CHECKED	R. SILVA	8/31/98
APPROVED	R. SILVA	8/31/98

USED ON: ME-339775

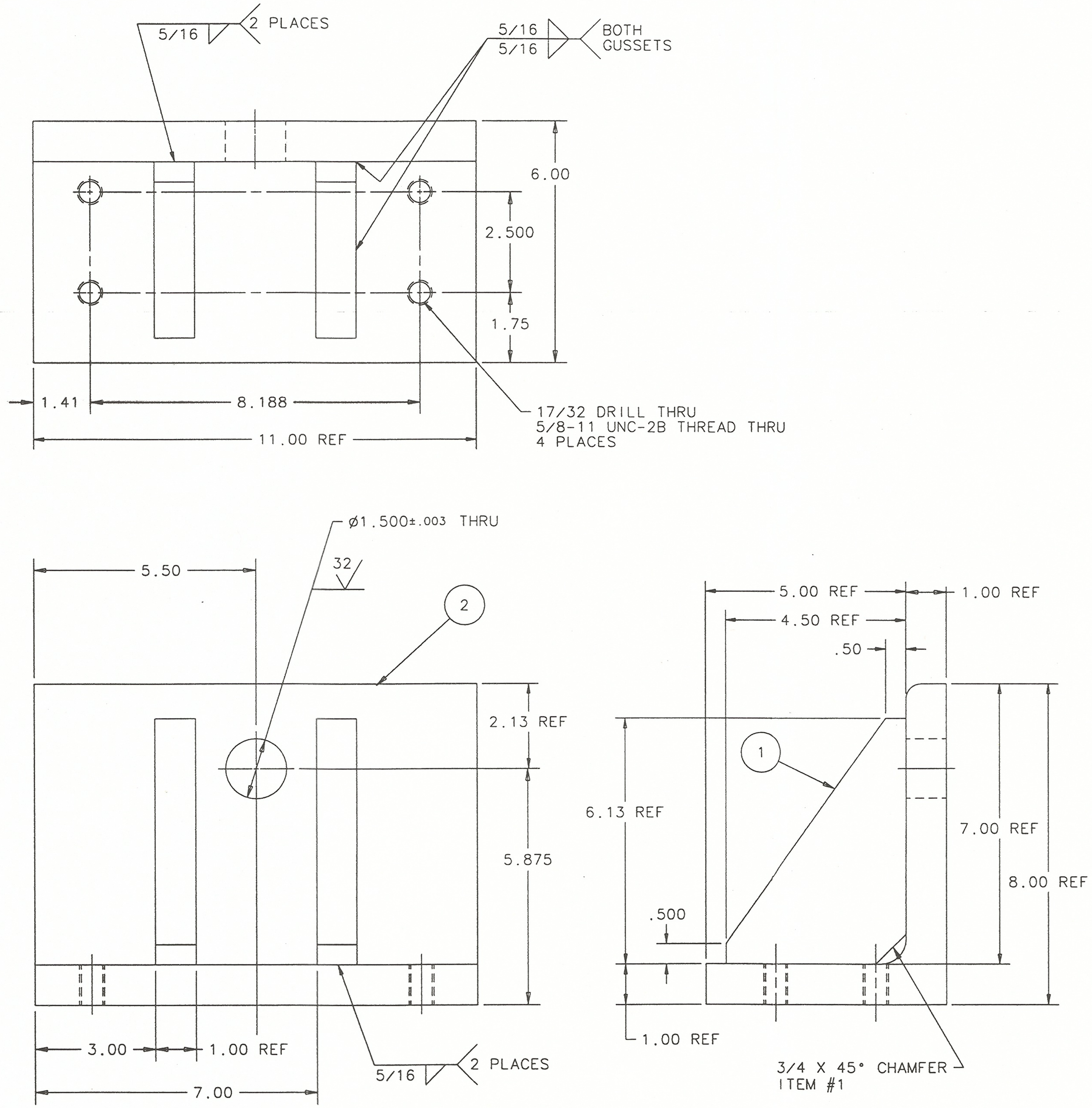
MATERIAL: SEE B.O.M.

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

PPD/CDF/COT
COT FLIPPING FIXTURE
SPREADER BAR ASSEMBLY

SCALE	DRAWING NUMBER	SHEET NO.	REV.
1:4	2563.244-MD-339301	1 OF 1	

REV.	DESCRIPTION	DRAWN / APPROVED	DATE / DATE



ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.
2	COML	L8 X 8 X 1 X 11.00 LG STEEL ANGLE ASTM A36	1
1	COML	1.00 X 4.50 X 6.13 LG STEEL FLAT ASTM A36	2

PARTS LIST

UNLESS OTHERWISE SPECIFIED					
.XX	.XXX	ANGLES	ORIGINATOR	RAFAEL SILVA	8/27/97
±.01	±.005	±----	DRAWN	R.F.SANDBERG	8/27/97
			CHECKED	R. SILVA	8/31/98
			APPROVED	R. SILVA	8/31/98

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5M-1982 STD'S.
4. ALL DIMENSIONS ARE IN INCHES.

63 MAX. ALL MACHINED SURFACES

USED ON: ME-339775

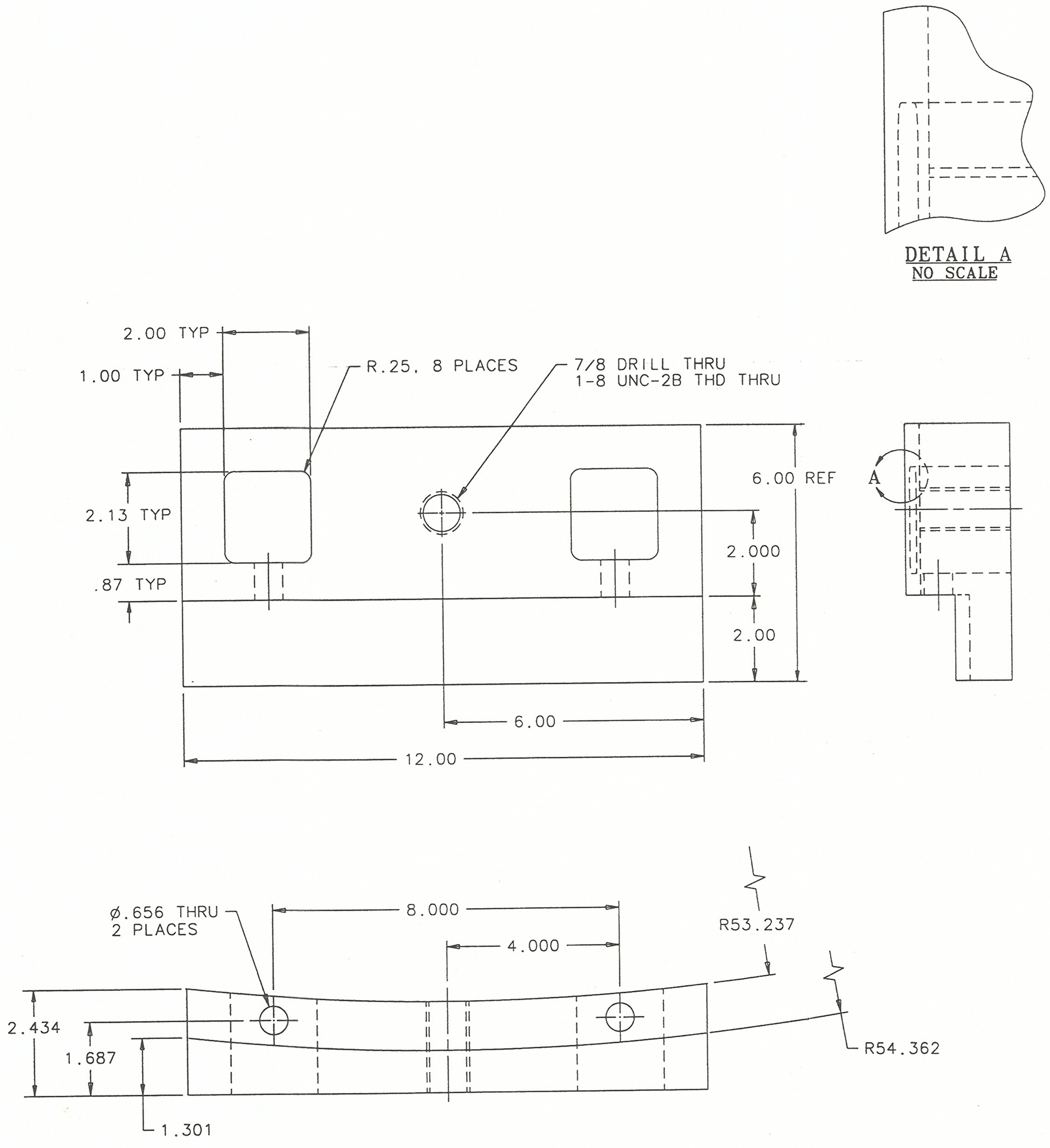
MATERIAL: SEE B.O.M.

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

PPD/CDF/COT
COT FLIPPING FIXTURE
CORNER SUPPORT BRACKET

SCALE	DRAWING NUMBER	SHEET NO.	REV.
1:2	2563.244-MC-339289	1 OF 1	

OCT 1 9 1998



REV.	DESCRIPTION	DRAWN / APPROVED	DATE / DATE

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.

PARTS LIST

UNLESS OTHERWISE SPECIFIED				
.XX	.XXX	ANGLES	ORIGINATOR	RAFAEL SILVA 8/27/97
± .01	±.005	±----	DRAWN	R.F. SANDBERG 8/27/97
			CHECKED	R. SILVA 8/27/98
			APPROVED	R. SILVA 8/27/98

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5M-1982 STD'S.
4. ALL DIMENSIONS ARE IN INCHES.

63 √ MAX. ALL MACHINED SURFACES

USED ON: ME-339288

MATERIAL: 6061-T651 ALUMINUM; 2.433 X 6.00 X 12 LG.

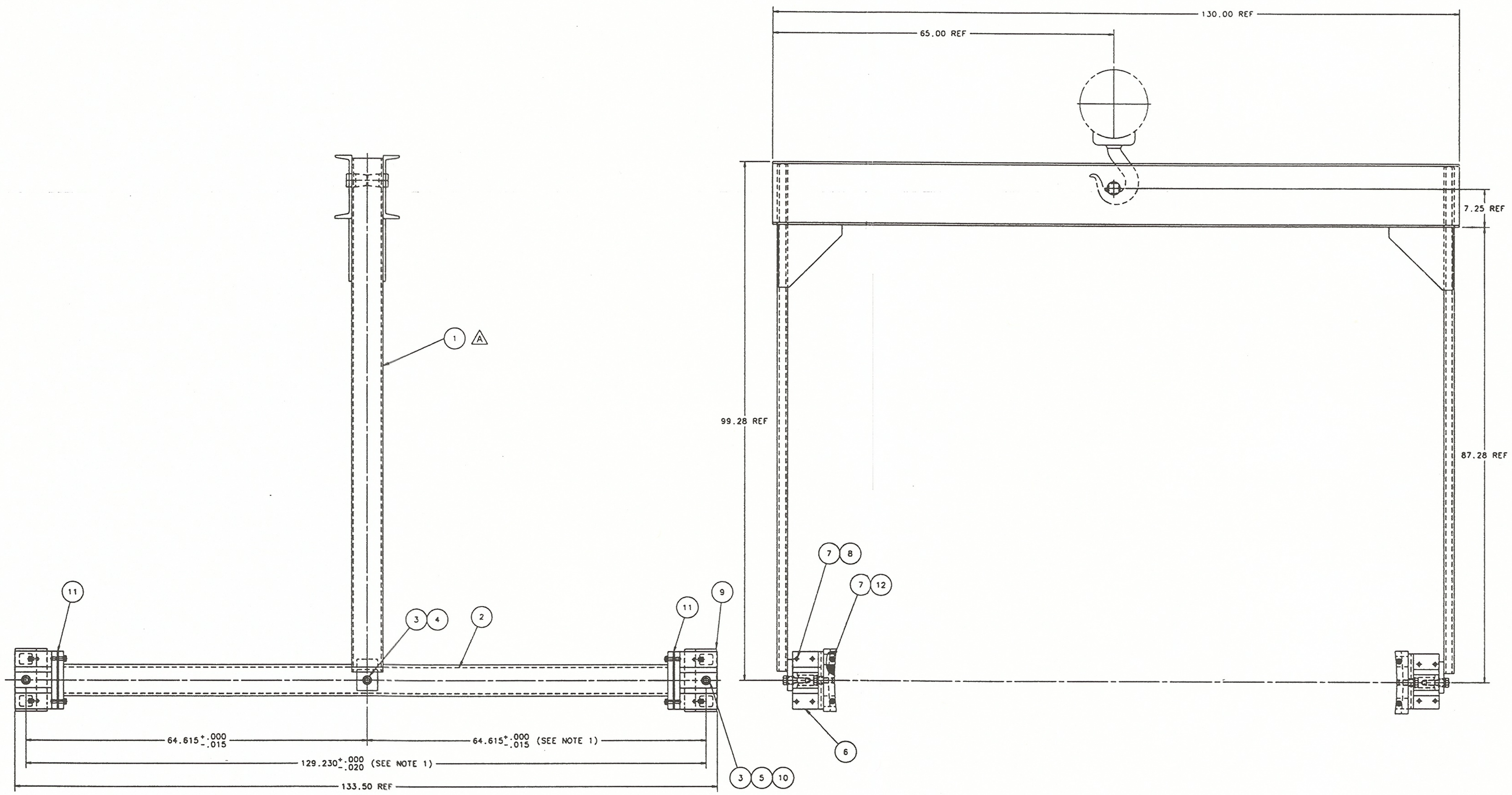
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

PPD/CDF/COT
COT FLIPPING FIXTURE
ENDPLATE MOUNTING SUPPORT

SCALE	DRAWING NUMBER	SHEET NO.	REV.
1:2	2563.244-MC-339290	1 OF 1	

OCT 19 1998

REV.	DESCRIPTION	DRAWN / APPROVED	DATE / DATE
A	REVISED ITEM #1. LIFTING ASSEMBLY	PAT POLL	10/16/98



NOTE:

1. ITEM 11 MAY BE MACHINED DOWN TO .188 THICK, IF NECESSARY TO KEEP DIMENSIONS 129.230 AND 64.615 WITHIN INDICATED TOLERANCES.

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.
12	COML	5/8-11 UNC-2A X 1.50 LG BLACK FINISH HEAVY HEX BOLT ASTM A325 TYPE 1 OR 2.	8
11	MB-339791	SPREADER BAR SHIM	4
10	COML	MCMASTER #5906K524. 1.00 I.D. X 2.00 O.D. X .125 THK BRONZE THRUST BEARING	4
9	MC-339290	ENDPLATE MOUNTING SUPPORT	4
8	COML	5/8-11 UNC-2A X 2.25 LG BLACK FINISH HEAVY HEX BOLT ASTM A325 TYPE 1 OR 2.	16
7	COML	5/8 LOCKWASHER	24
6	MC-339289	CORNER SUPPORT BRACKET	4
5	COML	1-8 UNC-2A X 3.50 LG BLACK FINISH HEAVY HEX BOLT ASTM A325 TYPE 1 OR 2.	4
4	COML	1-8 UNC-2A X 2.50 LG BLACK FINISH HEAVY HEX BOLT ASTM A325 TYPE 1 OR 2.	2
3	MB-339312	SWIVEL BUSHING	6
2	MD-339301	SPREADER BAR ASSEMBLY	2
1 (A)	MD-339295	LIFTING ASSEMBLY	1

PARTS LIST

UNLESS OTHERWISE SPECIFIED					
.XX	.XXX	ANGLES	DRAWN	R.F. SANDBERG	8/26/97
±.06	±----	±----	CHECKED	R. SILVA	9/01/98
			ORIGINATOR	RAFAEL SILVA	8/26/97
			APPROVED	R. SILVA	9/01/98

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5M-1982 STD'S.
4. ALL DIMENSIONS ARE IN INCHES.

XX √ MAX. ALL MACHINED SURFACES

USED ON: ME-339288

MATERIAL: SEE B.O.M.

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

PPD/CDF/COT

FLIPPING FIXTURE ASSEMBLY

SCALE	DRAWING NUMBER	SHEET NO.	REV.
1:8	2563.244-ME-339775	1 OF 1	A

OCT 19 1998

Fermilab	Particle Physics Division Engineering and Technical Teams

Engineering note number		Date	10/29/98

Experiment	**CDF / COT**
Project	COT Flipping Fixture
Author(s)	Rafael Silva (FNAL)
Reviewer(s)	Bob Woods (FNAL)
Abstract	Structural analysis of the COT Flipping Fixture.

Summary

1. Overview
2. Structural Analysis:
    - 2.1. Analysis Of Members
    - 2.2. Analysis Of Connections:
        - 2.2.1. Bolted Connections
        - 2.2.2. Welded Connections
3. Technical Specification For The Fabrication of CDF / COT Flipping Fixture
4. Load Test
5. Drawings

1. Overview

The CDF/COT detector is going to replace the CDF/CTC detector. The 3D drawing of the COT assembly and its main structural components - end plates, outer cylinder, and inner cylinder - can be seen in the COT Gallows Engineering Note.

The COT is assembled vertically in the structure called COT Gallows. After that, the detector has to be removed from the COT Gallows, turned 90 degrees, and placed on the COT Rotation fixture for the insertion of the sense and field planes.

The COT Flipping fixture is designed to lift the COT from the COT Gallows, rotate it 90 degrees and lower it to rest on the COT Rotation fixture.

The design started as a carbon copy of the CTC Flipping fixture and it was revised and updated to meet the current codes and specifications. Whenever applicable, the manufacturing of this fixture was required to meet or exceed the specifications and recommendations for fabrication of the AISC/ASD and AWS D1.1 codes. In addition, the most critical components were required to be non-destructivelly tested, as described in the Technical Specification For The Fabrication of CDF / COT Flipping Fixture attached.

Note: Throughout this note, except for the list of drawings, drawing numbers are referred only by their 3 last digits. For instance, drawing number 2563.244-ME-339288 is referred as dwg#288.

2. Structural Analysis

The COT Flipping fixture was design to meet the ANSI/ASME B30.20-1985 "Bellow-the-Hook Lifting Devices" standard and 1987 addenda. The two basic design recommendations of this standard and its addenda are:

- Minimum design factor of 3 over the rated load, based on yield strength (20-1.22, p.21) and
- Load test with 125% of the rated load (20-1.4.2, p.22).

2.1 Allowable stresses

The general design criteria adopted were the following:

Hand Calculations:

- *Stresses*:
  individual stress components should be in accordance with the most stringent of the following codes:
  - AA or AISC/ASD (whichever applicable)
  - ASME B30.20
- *Stability (if required)*:
  - AA or AISC/ASD (whichever applicable)

Finite Element Analysis:

- *Stresses*:
  Maximum Von Mises stresses (nodal averaging) < 1/3 of the Yield Strength (based on ASME B30.20).
- *Stability (if required)*:
  Buckling Load Factor (linear buckling) > 5 (see references below).

Published safety factors for buckling vary according to the application, but greater than 5 is confortably above some traditional references as, for instance, ASME sec. II, apendix 3, item 3-600 (c) (1), p.705, which addresses axial compression of thin cylinders - experimentally known to be one of the cases that most diverges from buckling theories - or AA, tb. 3.3.3, p.17, which covers aluminum structures.

Some cases, individually and specifically analyzed, may require different safety factors. The most severe loading condition happens during operation. The general philosophy in this note is to verify the stresses in the most critical members and connections only.

2.1. Loads and Analysis

The following are the estimated weight of the parts:

W_{COT} = 3,600 lb
$W_{Flipping}$ = 1,900 lb
W_{Total} = 5,500 lb

The following analysis is conservative and simplified. It is assumed that the structure has to withstand W_{Total}= 5,500 lb, plus 10% (550 lb) lateral loading. The next page contains a table summarizing all cases analyzed, and the calculations follow.

Summary Of Analysis Of Members Under Maximum Load				Min. Yield	Min. Tensile		Allowable				Max. stresses	Maximum / Allowable		SF
							Structural code			ASME				
Item	Drawing	Part	Material	Fy (ksi)	Fu (ksi)	Condition	Code	Item	(ksi)	(ksi)	(ksi)	ASME	AISC	(i.r.t. Fy)
a	dwg#289	Corner Supp. Bracket	A36 angle A36 plate	36.0	58.0	Von Mises (FEA)	-	-	-	12.0	5.4	***45%***	-	6.7
b	dwg#290	End Plate Mount. Supp.	6061-T651 plate	35.0	42.0	Von Mises (FEA)	-	-	-	11.7	6.8	***59%***	-	5.1
c	dwg#295	Lifting Assembly	A36 channels A500B tubing	36.0	58.0	Von Mises (FEA)	-	-	-	12.0	9.8	***82%***	-	3.7
d	dwg#297	Lifting Pin	A36 round	36.0	58.0	Bending Shear	AISC AISC	Eq. F2-1, p.5-48 Eq. F4-1, p.5-49	27.0 14.4	12.0 12.0	6.1 1.2	***51%*** ***10%***	23% 8%	5.9 30.0
e	dwg#298	Bearing Plate	A36 plate	36.0	58.0	Von Mises (FEA)	-	-	-	12.0	3.4	***28%***	-	10.6
f	dwg#304	Spreader Bar Weldment	A500B tubing	46.0	58.0	Von Mises (FEA) (Same as item c)	-	-	-	15.3	9.8	***64%***	-	4.7
g	dwg#305	Bushing	1215 round	60.0	78.0	Bending Shear	AISC AISC	Eq. F3-1, p.5-48 Eq. F4-1, p.5-49	39.6 24.0	20.0 20.0	3.9 2.3	***20%*** ***12%***	10% 10%	15.4 26.1
h	dwg#306	Spreader Bar End Plate	A36 plate	36.0	58.0	*Thickness (in)*	*AISC*	*p. 4-119 to 4-121*	*0.208*	-	*1.0*	-	*21%*	-
i	dwg#312	Pivot Bushing	UNS#C95400	32.0	85.0	Bending Shear Compression Combined	AISC AISC AISC AISC	Eq. F3-1, p.5-48 Eq. F4-1, p.5-49 Eq. E2-1, p.5-42 Eq. H1-1, p.5-54	21.1 12.8 19.1 1.00	10.7 10.7 10.7 -	1.2 3.3 6.5 0.40	***11%*** ***31%*** ***61%*** -	6% 26% 34% 40%	26.7 9.7 4.9 -

MEMBERS SUMMARY TABLE

Item: a

File: FEA_a.doc

F.E.A. of the COT Flipping Fixture - Corner Support Bracket

1. Parameters used

E = $10 \cdot 10^6$ psi

ν = 0.3

Geometry as defined by dwg#289.

2. Model

- Boundary conditions:	surfaces of 5/8-11 UNC-2B in dia. holes are restrained from translations.
- Loading:	2,750 lb (conservative) applied on surface of 1.5 in dia. hole. Loading was in plane parallel to *XZ* plane. Load was applied in the +X direction.
- Meshing:	free, approximate mesh size of 3/4 in.
- Elements:	Family: Solid, Order: Parabolic, Topology: Tetrahedron.
- Program:	SDRC I-DEAS Master Series v. 4.0 / Simulation.
- Analysis:	Linear Statics

3. Results

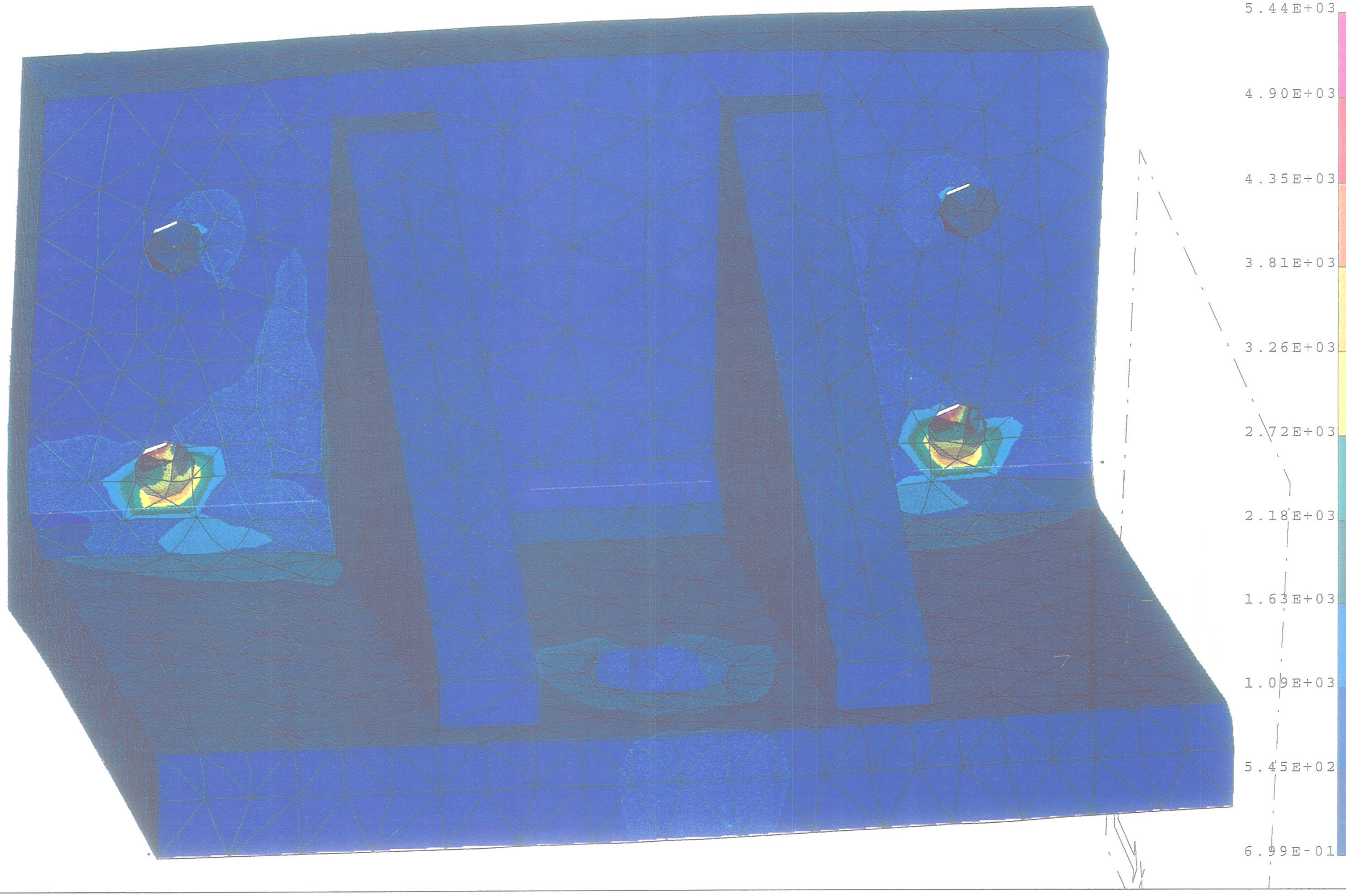
The maximum (Von Mises) stress is 5.4 ksi, which indicates a safety factor in relation to the yield strength of 6.7 when half of the full load is applied to the bracket. These stresses are also very localized.

This means that the member is ***OK*** .

/cadwhs_local/server02/ms_ra[illegible]el/flipp_frame_corner_sup.mf1

RESULTS: 3- B.C. 1,LOAD 1,STRESS_3
STRESS - VON MISES MIN: 6.99E-01 MAX: 5.44E+03
DEFORMATION: 1- B.C. 1,LOAD 1,DISPLACEMENT_1
DISPLACEMENT - MAG MIN: 0.00E+00 MAX: 5.19E-04
FRAME OF REF: PART

VALUE OPTION:ACTUAL



Item: b
File: FEA_b.doc

<u>F.E.A. of the COT Flipping Fixture - End Plate Mounting Support</u>

1. Parameters used

E = $10 \cdot 10^6$ psi
ν = 0.3

Geometry as defined by dwg#290.

2. Model

- Boundary conditions: surfaces of .656 dia. holes are restrained from translations.

- Loading: 2,750 lb (conservative) applied on surface of 1-8 UNC 2B hole. Refer to the meshed model picture for the orientation of the axes. Loading was always in plane parallel to <u>XZ</u> plane. Four cases were investigated, varying the direction of the load: in relation to the Z axis, loads were at 0°, 45°, 90° and 270°.

- Meshing: free, approximate mesh size of 3/4 in.

- Elements:
  Family: Solid,
  Order: Parabolic,
  Topology: Tetrahedron.

- Program: SDRC I-DEAS Master Series v. 4.0 / Simulation.

- Analysis: Linear Statics

3. Results

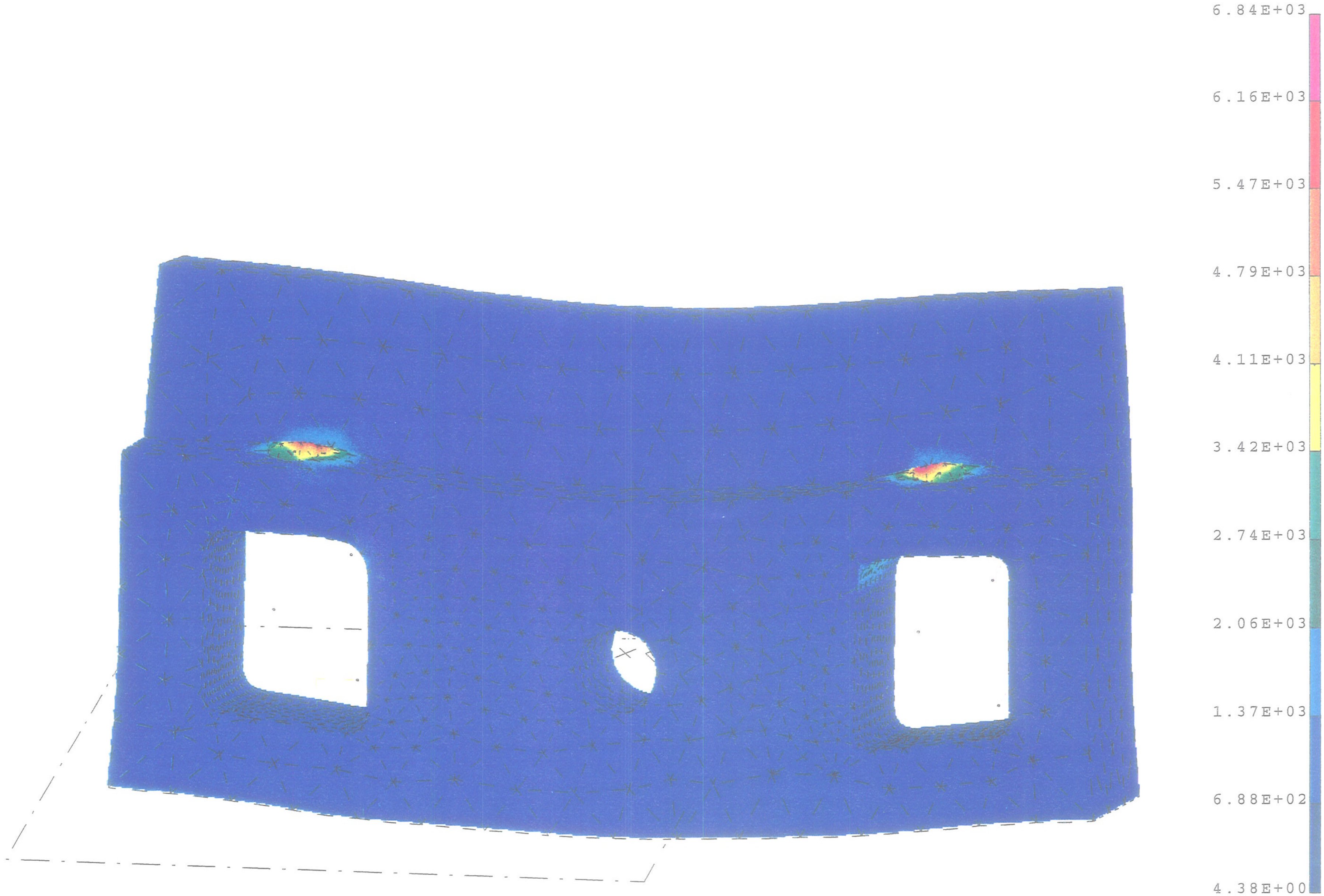
The maximum (Von Mises) stress from all four loading cases is 6.8 ksi, which indicates a safety factor in relation to the yield strength of 5.1 when half of the full load is applied to the support. These stresses are also very localized.

This means that the member is <u>***OK***</u>.

/cadwhs_local/server02/ms_rafael/flipp_ems1.mf1

RESULTS: 3- B.C. 1,LOAD 1,STRESS_3
STRESS - VON MISES MIN: 4.38E+00 MAX: 6.84E+03
DEFORMATION: 1- B.C. 1,LOAD 1,DISPLACEMENT_1
DISPLACEMENT - MAG MIN: 0.00E+00 MAX: 1.11E-03
FRAME OF REF: PART

VALUE OPTION:ACTUAL



Item: c

File: FEA_c.doc

F.E.A. of the COT Flipping Fixture - Lifting Assembly

1. Parameters used

E = $29 . 10^6$ psi

ν = 0.29

Geometry as defined by dwg#295.

2. Model

Four cases were analyzed, with different load conditions and constrains.

- Boundary conditions: The two ends of each spreader bar were constrained. One end was constrained in X, Y and Z (translations). The other end was constrained as shown in the table bellow.

Case	Other end of spreader bar constrains	Load direction	Load magnitude (lb)
1	X Y	"+Y"	5500
2	X Y	"+Y"	5500
		"+Z"	550
3	X Y	"+X"	550
		"+Y"	5500
4	X Y Z	"+X"	550
		"+Y"	5500

- Loading: Loads were applied to center of channels, in the direction and with the magnitude shown in the table above.

- Elements: Family: Beam,
  Order: Linear.

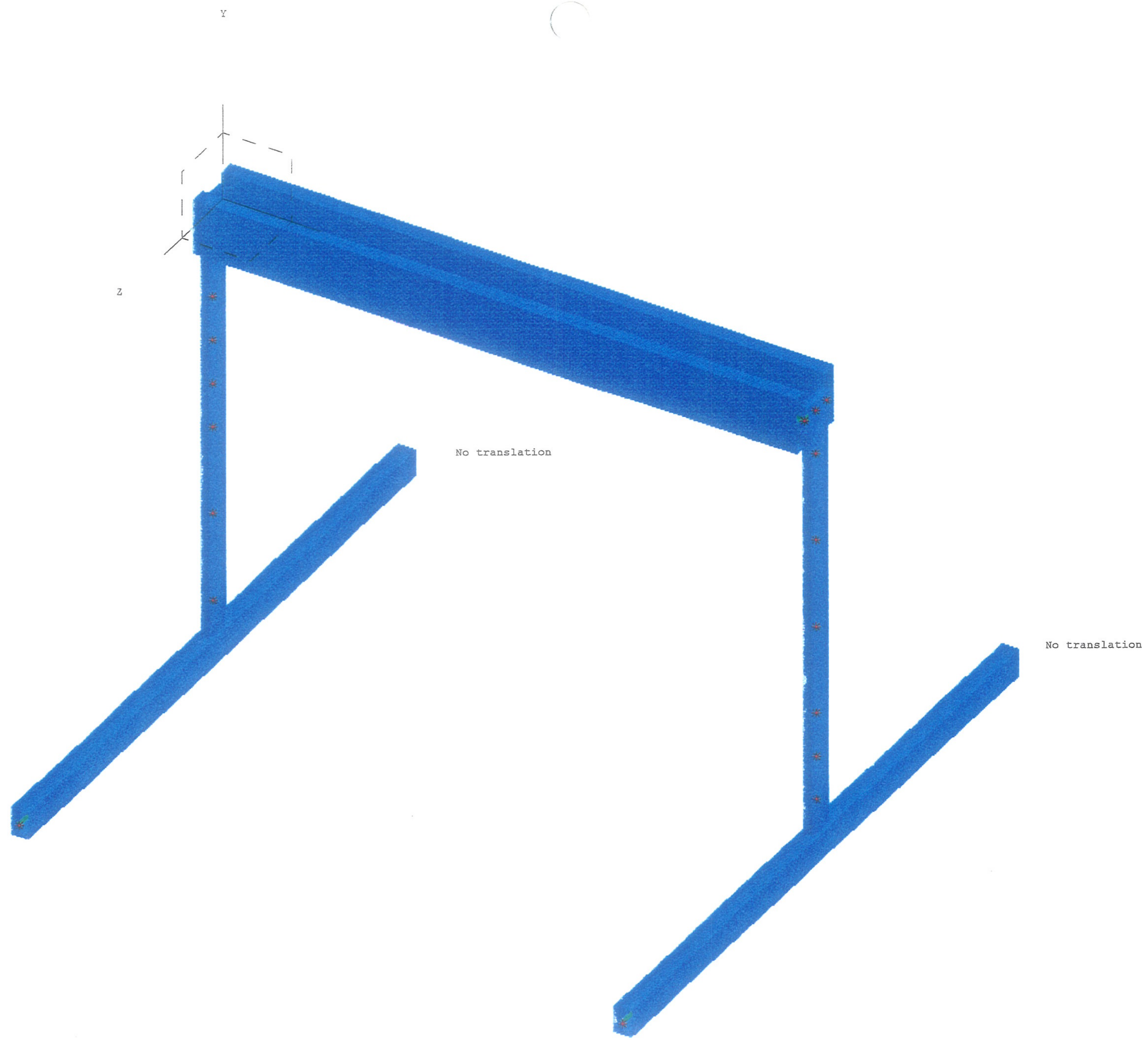
- Program: SDRC I-DEAS Master Series v. 4.0 / Simulation.

- Analysis: Linear Statics

3. Results

The maximum (Von Mises) stress from all four loading cases is 9.8 ksi, which indicates a safety factor in relation to the yield strength of 3.7 when the full load is applied in conjunction with a lateral load of 10% of the full load.

This means that the member is ***OK***.

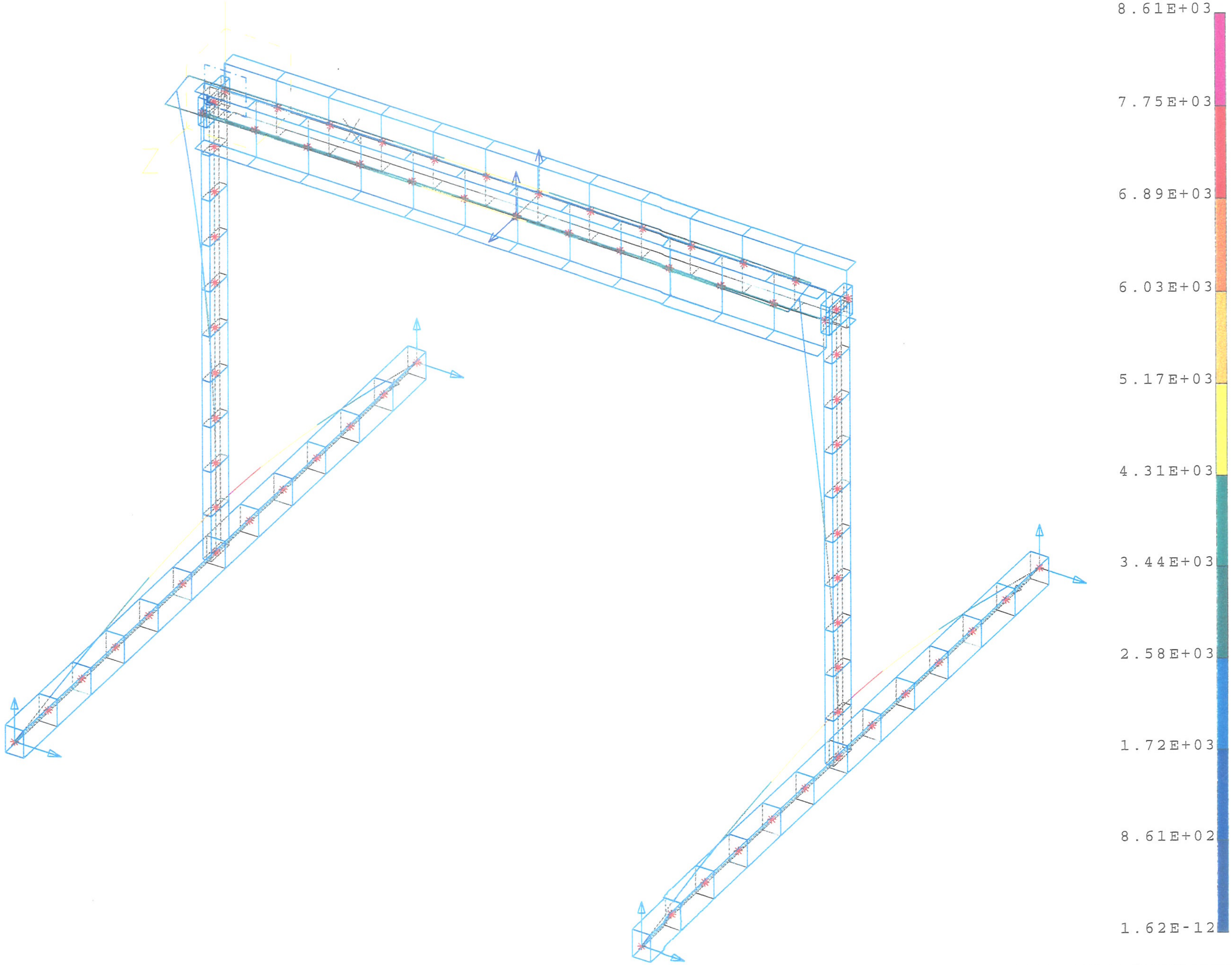

Y
Z
No translation
No translation

CASE 2

/cadwhs_local/server… /ms_rafael/flipp_frame

RESULTS: 3- B.C. 1,LOAD 1,STRESS_3
MAGNITUDE - MIN: 1.62E-12 MAX: 8.61E+03
Data component: VON MISES STRESS at maximum point

VALUE OPTION:ACTUAL

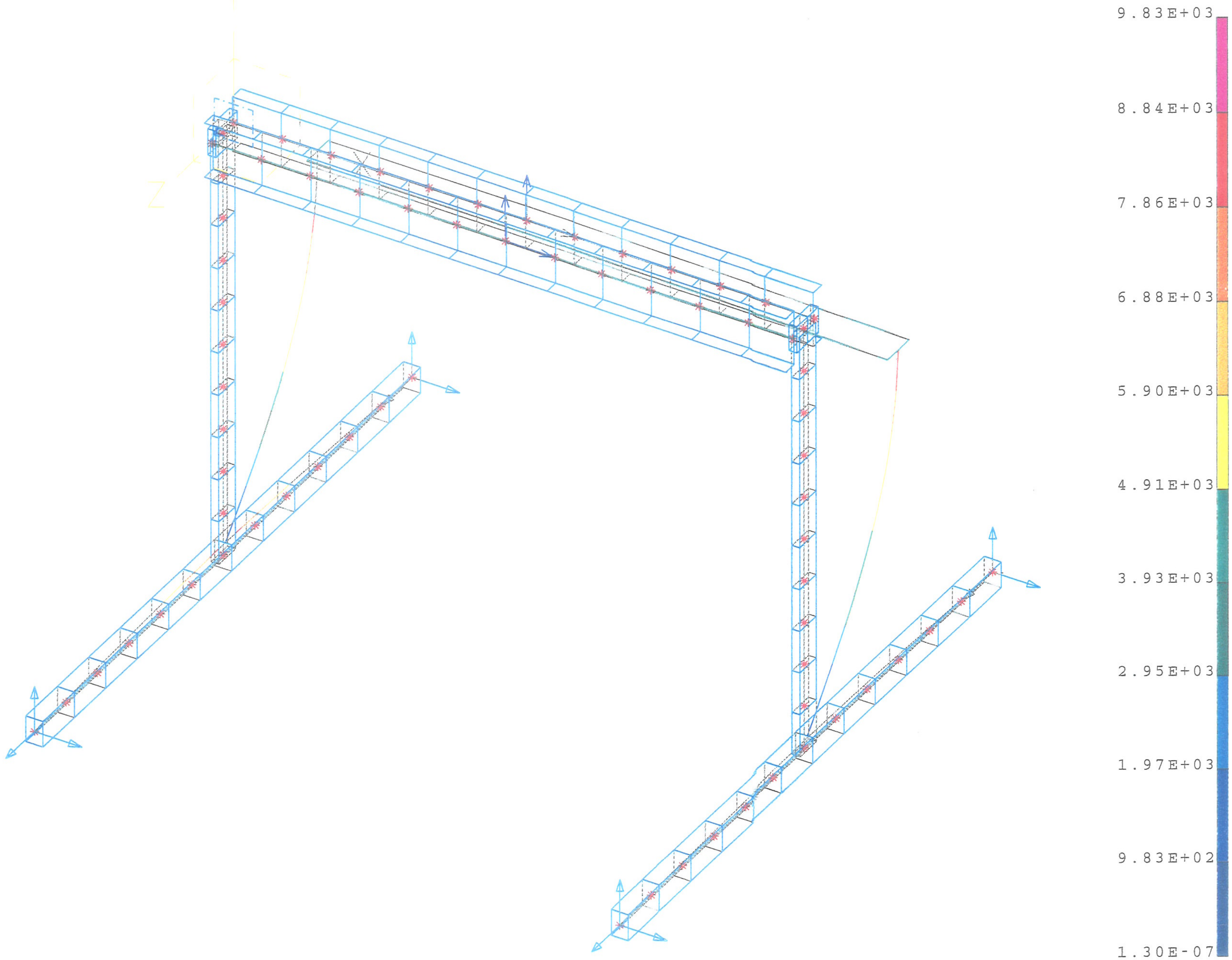


CASE 4

/cadwhs_local/server[illegible]/ms_rafael/flipp_frame

RESULTS: 3- B.C. 1,LOAD 1,STRESS_3
MAGNITUDE - MIN: 1.30E-07 MAX: 9.83E+03
Data component: VON MISES STRESS at maximum point

VALUE OPTION:ACTUAL



Item: d

File: F2.1_d.mcd

AISC/ASD Allowable Stresses (ksi)

AISC / ASD, 9th ed.P.5-48, sect. F2.1:

Weak axis bending of I-shaped members, solid bars and rectangular plates

Members with compact sections

Member: round bar

Yield strength of material:

$Fy := 36$

For bending (F2-1, p5-48):

$Fb := 0.75 \cdot Fy$

$Fb = 27.0$

For shear (F4, p.5-49):

$\frac{380}{\sqrt{Fy}} = 63.3$

Assuming $h/tw \le 380/\sqrt{Fy}$ (63.3) $\Rightarrow$ F4-1:

$Fv := .40 \cdot Fy$

$Fv = 14.4$

Item: d

File: C16_d.mcd

Maximum stresses

Member: Lifting Pin, dwg#297

Beam **fixed** at both ends, concentrated load at center

(AISC/ASD, case 16, p. 2-301)

Elastic modulus of material (psi):	$E := 29 \cdot 10^6$
Inertia moment of cross section (in^4):	$I := .785$
Cross-sectional area (in^2):	$A := 3.142$
Elastic section modulus (in^3):	$S := .785$
Span (in):	$l := 7.02$
Load (lb):	$P := 5500$
Yield Strength (ksi):	$Fy := 36.0$

$Mmax := \frac{P \cdot l}{8}$	(in-lb)	$Mmax = 4826$
$\Delta max := \frac{P \cdot l^3}{192 \cdot E \cdot I}$	(in)	$\Delta max = 0.0004$
$Vmax := \frac{P}{2}$	(lb)	$Vmax = 2750$
$\tau max := \frac{4}{3} \cdot \frac{Vmax}{A}$	(psi)	$\tau max = 1167$
$fv := \frac{\tau max}{1000}$	(ksi)	$fv = 1.2$
$\sigma max := \frac{Mmax}{S}$	(psi)	$\sigma max = 6148$
$fb := \frac{\sigma max}{1000}$	(ksi)	$fb = 6.1$

Item: e

File: FEA_e.doc

F.E.A. of the COT Flipping Fixture - Bearing Plate

1. Parameters used

E = 10 . 10^6 psi
v = 0.3

Geometry as defined by dwg#298.

2. Model

- Boundary conditions:	welded surfaces (see picture) are restrained from translations.
- Loading:	2,750 lb applied on surface of 1.5 in dia. hole, slightly (5/16 in) off center - to be conservative. Loading was in plane parallel to ***XY*** plane. Load was applied in the -*Y* direction.
- Meshing:	free, approximate mesh size of 1/4 in.
- Elements:	Family: Solid, Order: Parabolic, Topology: Tetrahedron.
- Program:	SDRC I-DEAS Master Series v. 4.0 / Simulation.
- Analysis:	Linear Statics

3. Results

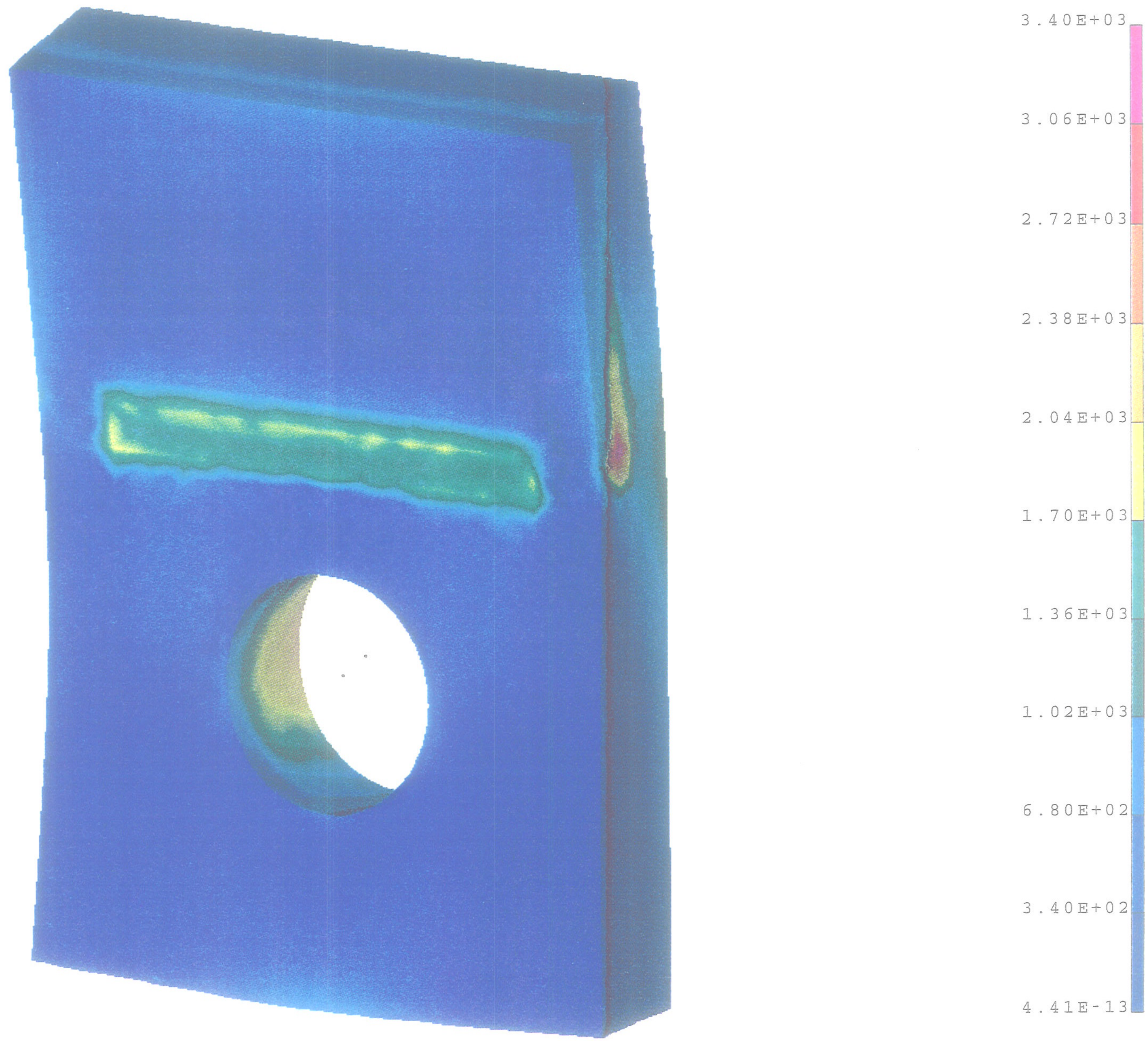
The maximum (Von Mises) stress is 3.4 ksi, which indicates a safety factor in relation to the yield strength of 10.6 when half of the full load is applied to the bracket. These stresses are also very localized.

This means that the member is ***OK***.

/cadwhs_local/server02/ms_ _fael/flipp_frame_bear_plate

RESULTS: 3- B.C. 1,LOAD 1,STRESS_3
STRESS - VON MISES MIN: 4.41E-13 MAX: 3.40E+03
DEFORMATION: 1- B.C. 1,LOAD 1,DISPLACEMENT_1
DISPLACEMENT - MAG MIN: 0.00E+00 MAX: 4.52E-04
FRAME OF REF: PART

VALUE OPTION:ACTUAL



Item: g

File: B5_g.mcd

Compactness

AISC/ASD, 9th ed., p.5-35 and 5-36, sect. B5.1.
Classification of steel sections:
Compact, Noncompact and Slender.
Description of the element:
Circular hollow sections in flexure.
Yield strength of material (ksi):

$Fy := 60$

Limiting Width-Thickness Ratios, Table B5.1, p.5-36.
- Compact:

$lwtc := \frac{3300}{Fy}$ $\qquad lwtc = 55.0$

Width-Thickness ratio:

$D := 2$

$t := .5$

$wtr := \frac{D}{t}$ $\qquad wtr = 4.0$

As wtr (4.0) < lwtc (55.0), the section is <u>Compact</u>.

Notes:
1. Compact section must have flanges continuosly connected to the web.
2. Stiffened elements are supported along two edges parallel to the direction of the compression force.
3. For compression members, K.l/r < 200 or the allowable is from E2-2.
4. For tension, K.l/r < 300, except for rods and members also under compression.

Item: g

File: F3.1_g.mcd

AISC/ASD Allowable Stresses (ksi)

AISC / ASD, 9th ed.P.5-48, sect. F3.1:
Bending of box members, rectangular tubes and circular tubes
Members with compact sections
Member: Assuming bushing as a 2 in od x 1/2 in wall tube.

Yield strength of material:

$Fy := 60$

For bending (F3.1, p5-48):

$Fb := 0.66 \cdot Fy$

$Fb = 39.6$

For shear (F4, p.5-49):

$h := 1.0$

$tw := .5$

$\frac{h}{tw} = 2.0$

$\frac{380}{\sqrt{Fy}} = 49.1$

As $h/tw\ (2.0) \le 380/\sqrt{Fy}\ (49.1) \Rightarrow$ F4-1:

$Fv := .40 \cdot Fy$

$Fv = 24.0$

Item: g

File: C26_g.mcd

Maximum stresses

Member: Bushing, dwg#305

Beam overhanging one support, concentrated load at end overhang (AISC/ASD, case 26, p. 2-305)

Elastic modulus of material (psi):	$E := 29 \cdot 10^6$
Inertia moment of cross section (in^4):	$I := .736$
Cross-sectional area (in^2):	$A := 2.356$
Elastic section modulus (in^3):	$S := .736$
Span (in):	$l := 4.0$
Overhang (in):	$a := 1.031$
Load (lb):	$P := 2750$
Yield Strength (ksi):	$Fy := 60.0$

$Mmax := P \cdot a$	(in-lb)	$Mmax = 2835$
$Vmax := P$	(lb)	$Vmax = 2750$
$\tau max := 2 \cdot \frac{Vmax}{A}$	(psi)	$\tau max = 2334$
$fv := \frac{\tau max}{1000}$	(ksi)	$fv = 2.3$
$\sigma max := \frac{Mmax}{S}$	(psi)	$\sigma max = 3852$
$fb := \frac{\sigma max}{1000}$	(ksi)	$fb = 3.9$

Item: h

File: EP_h.mcd

End Plate Flipping Fixture - spreader bar end plate thickness.
Four Tension Bolt End Plate Design.
In accordance to AISC/ASD, 9th ed., p.4-119 to 4-121.
Note: for flange and web dimensions, see definitions given on p.5-35, stiffened elements, items a (web height) and d (flange width).

Min. distance from bolt center to tension flange (in): $Pf := 1.096 \text{ in}$

Weld size (in) $w := .375 \text{ in}$

Bolt diameter (in): $db := .625 \text{ in}$

Depth of beam welded to end plate (in): $d := 6.00$

Flange width of beam connected to end plate (in): $bfb := 2.5$

Flange area of beam connected to end plate (in^2): $Af := 1.25$

Web area of beam connected to end plate (in^2): $Aw := 5.0$

End moment (in-kips): $M := \frac{2.750 \cdot 115.0}{8}$ so: $M = 39.5$

Constant Ca from page 4-119, conservatively: $Ca := 1.13$

Recommended minimum end plate width (in): $bp := bfb + 1$

Constant Cb from page 4-119: $Cb := \sqrt{\left(\frac{bfb}{bp}\right)}$ so: $Cb = 0.845$

Eff. bolt dist.: $Pe := Pf - \left(\frac{db}{4}\right) - (.707 \cdot w)$ so: $Pe = 0.675$

Constant αm from page 4-119:

$$\alpha m := Ca \cdot Cb \cdot \left(\frac{Af}{Aw}\right)^{\frac{1}{3}} \cdot \left(\frac{Pe}{db}\right)^{\frac{1}{4}}$$ so: $\alpha m = 0.613$

Force on tension flange (kips): $Ff := \frac{M}{d}$ so: $Ff = 6.6$

Effective moment from page 4-119 (in-kips):

$$Me := \frac{\alpha m \cdot Ff \cdot Pe}{4}$$ so: $Me = 0.7$

Required end plate thickness (in):

$$tp := \sqrt{\frac{6 \cdot Me}{27 \cdot bp}}$$ so: $tp = 0.208$

Item: i

File: B5_imcd

Compactness

AISC/ASD, 9th ed., p.5-35 and 5-36, sect. B5.1.
Classification of steel sections:
Compact, Noncompact and Slender.
Description of the element:
Circular hollow sections in axial compression.
Yield strength of material (ksi):

$Fy := 32$

Limiting Width-Thickness Ratios, Table B5.1, p.5-36.
- Compact:

$lwtc := \frac{3300}{Fy}$ $lwtc = 103.1$

Width-Thickness ratio:

$D := 1.484$

$t := .2105$

$wtr := \frac{D}{t}$ $wtr = 7.0$

As wtr (7.0) < lwtc (103.1), the section is **Compact**.

Notes:
1. Compact section must have flanges continuosly connected to the web.
2. Stiffened elements are supported along two edges parallel to the direction of the compression force.
3. For compression members, K.l/r < 200 or the allowable is from E2-2.
4. For tension, K.l/r < 300, except for rods and members also under compression.

Item: i

File: F3.1_i.mcd

AISC/ASD Allowable Stresses (ksi)

AISC / ASD, 9^{th} ed.P.5-48, sect. F3.1:
Bending of box members, rectangular tubes and circular tubes
Members with compact sections
Member: Assuming pivot bushing as a 1.484 in od x .2105 in wall tube.

Yield strength of material:

$Fy := 32$

For bending (F3.1, p5-48):

$Fb := 0.66 \cdot Fy$

$Fb = 21.1$

For shear (F4, p.5-49):

$h := 1.063$

$tw := .2105$

$$\frac{h}{tw} = 5.0$$

$$\frac{380}{\sqrt{Fy}} = 67.2$$

As h/tw (5.0) ≤ 380/√Fy (67.2) ⇒ F4-1:

$Fv := .40 \cdot Fy$

$Fv = 12.8$

Item: i

File: C15_i.mcd

Maximum stresses

Member: Pivot Bushing, dwg#312
Beam fixed at both ends - uniformly distributed load
(AISC/ASD, case 15, p. 2-301)

Elastic modulus of material (psi):	$E := 16 \cdot 10^6$
Inertia moment of cross section (in^4):	$I := .1754$
Cross-sectional area (in^2):	$A := .8422$
Elastic section modulus (in^3):	$S := .2364$
Span (in):	$l := 1.281$
Total load (lb):	$P := 2750$

$Mmax := \frac{P \cdot l}{12}$	(in-lb)	$Mmax = 294$
$\Delta max := \frac{P \cdot l^3}{384 \cdot E \cdot I}$	(in)	$\Delta max = 5.4 \cdot 10^{-6}$
$Vmax := \frac{P}{2}$	(lb)	$Vmax = 1375$
$\tau max := 2 \cdot \frac{Vmax}{A}$	(psi)	$\tau max = 3265$
$fv := \frac{\tau max}{1000}$	(ksi)	$fv = 3.3$
$\sigma max := \frac{Mmax}{S}$	(psi)	$\sigma max = 1242$
$fb := \frac{\sigma max}{1000}$	(ksi)	$fb = 1.2$

Item: i
File: E2_i.mcd

Allowable Stresses - Compression

AISC / ASD, 9th ed., p.5-42, sect. E2., allowable stresses:

COT Flipping Fixture - Pivot Bushing
Note: Material is Bronze instead of structural steel
K: Table C-C2.1, p.5-135:

$K := 1$ (conservative)

Mechanical properties of material (ksi):

$Fy := 32$ $\quad E := 16000$

Unbraced length of column - conservative (in):

$l := 1.281$

Governing radius of gyration (in):

$r := 0.456$

Allowable stresses (ksi):

$$Cc := \sqrt{\frac{2\cdot\pi^2\cdot E}{Fy}} \qquad Cc = 99.3 \qquad \frac{K\cdot l}{r} = 2.8$$

$$Fa1 := \frac{\left[1 - \left[\frac{\left(\frac{K\cdot l}{r}\right)^2}{2\cdot Cc^2}\right]\right]\cdot Fy}{\frac{5}{3} + \frac{3\cdot\left(\frac{K\cdot l}{r}\right)}{8\cdot Cc} - \frac{\left(\frac{K\cdot l}{r}\right)^3}{8\cdot Cc^3}} \qquad Fa1 = 19.1 \qquad \text{(E2-1)}$$

$$Fa2 := \frac{12\cdot\pi^2\cdot E}{23\cdot\left(\frac{K\cdot l}{r}\right)^2} \qquad Fa2 = 10440.1 \qquad \text{(E2-2)}$$

$$Fa := \text{if}\left[\left[\left(\frac{K\cdot l}{r}\right) > Cc\right], Fa2, Fa1\right]$$

This means that if (K.l/r) > Cc, Fa = Fa2, otherwise Fa =Fa1.

Hence: $Fa = 19.1$

Item: i

File: Comp_i.mcd

Maximum compressive stresses

COT Flipping Fixture - Pivot Bushing

Elastic modulus of material (psi): $E := 16 \cdot 10^{6}$

Cross-sectional area (in^2): $A := 0.842$

Total length of column - (in): $l := 1.281$ (conservative)

Load from screw torque [*] (lb): $P := 5500$

$\Delta max := \frac{P \cdot l}{E \cdot A}$ (in) $\Delta max = 5.2 \cdot 10^{-4}$

$\sigma c\_max := \frac{P}{A}$ (psi) $\sigma c\_max = 6532$

$fa := \frac{\sigma c\_max}{1000}$ (ksi) $fa = 6.5$

[*] Estimated load to prevent the opening of a gap between pivot bushing and its constrainers (spreader bar and bolt head).

Item: i

File: H1_i.mcd

AISC/ASD Allowable Stresses (ksi)

AISC / ASD, 9th ed.P.5-54, sect. H1:
Axial compression and bending
Pivot Bushing.

K: Table C-C2.1, p.5-135:

$K = 1$ (conservative)

Mechanical properties of material (ksi):

$Fy := 32$ $\qquad E := 16000$

Governing radius of gyration (in):

$r := 0.456$

Unbraced length of column (in):

$l := 1.281$

Combined Stresses:

$$Fe := \frac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\frac{K \cdot l}{r} \right)^2} \qquad Fe = 10440$$

$Cm := 1.0$ (conservative)

$$fa := 6.5 \qquad Fa := 19.1 \qquad \frac{fa}{Fa} = 0.34$$

$$fb := 1.2 \qquad Fb := 21.1$$

$$H1\_1 := \frac{fa}{Fa} + \frac{Cm \cdot fb}{\left(1 - \frac{fa}{Fe} \right) \cdot Fb} \qquad H1\_1 = 0.40$$

$$H1\_2 := \frac{fa}{(0.60 \cdot Fy)} + \frac{fb}{Fb} \qquad H1\_2 = 0.40$$

$$H1\_3 := \frac{fa}{Fa} + \frac{fb}{Fb} \qquad H1\_3 = 0.40$$

Equation H1-1 governs, and as $0.40 \le 1.00$, the member is ***OK***.

2.2. Analysis Of Connections:

Conservatively, to check the connections, fixed support will be assumed.

2.2.1. Welded Connections

All welds were sized to be equal or larger than the minimum size fillet weld or partial penetration groove weld from AWS D1.1 considering the parts to be joined. The next pages contain a summary of the welded joints analysis, drawings identifying all the welded joints and the calculations. The electrode specified for all welded joints is E7018.

To comply with the AISC/ASD code, the criteria adopted for determining the allowable stresses in the effective area of the welds, as long as Fu ≥ 1.2 x Fy and considering the use of matching weld metal [1], is:

Allowable Stresses In Welds	Complete Penetration Groove Weld	Partial Penetration Groove Weld	Fillet Weld	Plug and Slot Weld
Tension or Compression	0.60 x Fy	0.60 x Fy	0.60 x Fy	-
Shear	0.40 x Fy or 0.30 x Fw	0.40 x Fy or 0.30 x Fw	0.40 x Fy or 0.30 x Fw	0.40 x Fy or 0.30 x Fw

Fy = Min. Base Metal Yield Strength [2]
Fw = Nominal Weld Metal Tensile Strength [3]

Allowable Stresses In Welds Table

These values are intended to be a conservative interpretation of on AISC/ASD, Table J2.5, which contains the expression "Same as base metal", for the allowable stresses in tension and compression. This seems to allow a margin for ambiguity in its interpretation. For clarification, two additional references were also consulted.

[1] Matching weld metals as per AWS D1.1, Table 4.1, p. 70 to 73.
[2] For base metals mechanical properties, see Members Summary Table.
[3] Nominal weld metal tensile strength is equal or smaller than minimum weld metal tensile strength:
- E60XX: nominal = 60 ksi, min. yield = 50 ksi, min. tensile = 62 ksi;
- E70XX: nominal = 70 ksi, min. yield = 60 ksi, min. tensile = 72 ksi.

For prismatic members in tension, the AISC/ASD specifies the allowable stress in tension to be 0.60Fy on the gross area or 0.50 Fu on the effective area (D1). So, as long as $Fu \geq 1.2 \times Fy$, 0.60Fy on the effective area is conservative.

For beams and other flexural members, the AISC/ASD specifies the allowable stress in shear to be 0.40Fy (F4), as long as $h/t_w \leq 380/\sqrt{Fy}$ - and this can be assumed to be always true for any practical weld.

For compression however, the only consideration in the ASD manual seems to be about buckling (Chapter E), and that does not appear to be applicable to welds. The AISC/LFRD, Table J2.3, defines the allowable stresses in tension and compression to be the same.

A third reference, Salmon and Johnson, Steel Structures - Design and Behavior, 3rd ed., p. 245, states that:

"The allowable stresses for (1) shear on the effective area of all welds and (2) the tensile stress normal to the axis on the effective area of a partial penetration groove weld are equal to 0.30 times the electrode tensile strength. However, the stress in the adjacent base metal may not exceed 0.60Fy for tension and 0.40Fy for shear."

Hence, using 0.60Fy for tension and compression - when applicable - and the smaller of 0.30Fw and 0.40Fy for shear for all types of welds, appears to be a consistent and slightly conservative interpretation of the ASD manual.

It should be noted that shear is not combined with normal stresses in bending of *members* because these two kind of stresses are present in different parts of the members [4]. However, in *welds* under off-plane bending, both kinds of stresses may be present in the same region. So, they have to be vectorially added as shown in the numerical example number 5.19.2 from Salmon an Johnson, Steel Structures - Design and Behavior, 3rd ed., p.283 to 285. On page 284, is also stated that:

"[...] there is no indication in the LFRD tables that those tables should be used when the load is applied such as to cause moment and shear. Thus, it may be prudent to use a conservative elastic (vector) analysis."

On p.285, this numerical example uses the design strength based on shear stresses. This is the philosophy of the approach taken in this Engineering Note: for off-plane bending, the vector sum of shear and normal stresses has to be smaller than the allowable stresses for shear.

To also comply with the ANSI/ASME B30.20-1985 "Bellow-the-Hook Lifting Devices", the allowable stresses - normal and shear - are further reduced to 0.33Fy [5].

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[4] See Roark and Young, Formulas for Stress and Strain, 6th ed., p.97 and Shigley and Mischke, Mechanical Engineering Design, 5th ed., p.51.
[5] Note that $Fu \geq 1.2 \times Fy$ and weld metal matches base metal.

b. Limitations

Plug or slot welds may be used to transmit shear in lap joints or to prevent buckling of lapped parts and to join component parts of built-up members.

The diameter of the holes for a plug weld shall be not less than the thickness of the part containing it plus 5⁄16-in., rounded to the next larger odd 1⁄16-in., nor greater than 2¼ times the thickness of the weld metal.

The minimum c.-to-c. spacing of plug welds shall be four times the diameter of the hole.

The length of slot for a slot weld shall not exceed 10 times the thickness of the weld. The width of the slot shall be not less than the thickness of the part containing it plus 5⁄16-in., rounded to the next larger odd 1⁄16-in., nor shall it be larger than 2¼ times the thickness of the weld. The ends of the slot shall be semicircular or shall have the corners rounded to a radius not less than the thickness of the part containing it, except those ends which extend to the edge of the part.

The minimum spacing of lines of slot welds in a direction transverse to their length shall be 4 times the width of the slot. The minimum c.-to-c. spacing in a longitudinal direction on any line shall be 2 times the length of the slot.

The thickness of plug or slot welds in material 5⁄8-in. or less in thickness shall be equal to the thickness of the material. In material over 5⁄8-in. in thickness, the thickness of the weld shall be at least ½ the thickness of the material but not less than 5⁄8-in.

4. Design Strength

The design strength of welds shall be the lower value of ϕF_{BM} and ϕF_w, when applicable, where F_{BM} and F_w are the nominal strengths of the base material and the weld electrode material, respectively. The values of ϕ, F_{BM} and F_w and limitations thereon are given in Table J2.3.

5. Combination of Welds

If two or more of the general types of welds (groove, fillet, plug, slot) are combined in a single joint, the design strength of each shall be separately computed with reference to the axis of the group in order to determine the design strength of the combination.

6. Matching Steel

The choice of electrode for use with complete-penetration groove welds subject to tension normal to the effective area is dictated by the requirements for matching steels given in the AWS *Structural Welding Code—Steel* D1.1.

J3. BOLTS, THREADED PARTS AND RIVETS

1. High-strength Bolts

Except as otherwise provided in this Specification, use of high-strength bolts shall conform to the provisions of the *Specification for Structural Joints Using ASTM A325 or A490 Bolts*—1985, as approved by the Research Council on Structural Connections.

If required to be tightened to more than 50% of their minimum specified tensile strength, ASTM A449 bolts in tension and bearing-type shear connections shall have an ASTM F436 hardened washer installed under the bolt head, and the nuts shall meet

TABLE J2.3
Design Strength of Welds

Types of Weld and Stress[a]	Material	Resistance Factor ϕ	Nominal strength F_{BM} or F_w	Required Weld strength level[b,c]
Complete Penetration Groove Weld				
Tension normal to effective area	Base	0.90	F_y	"Matching" weld must be used.
Compression normal to effective area	Base	0.90	F_y	Weld metal with a strength level equal to or less than "matching" may be used.
Tension or compression parallel to axis of weld				
Shear on effective area	Base Weld electrode	0.90 0.80	$0.60F_y$ $0.60F_{EXX}$	
Partial Penetration Groove Welds				
Compression normal to effective area	Base	0.90	F_y	Weld metal with a strength level equal to or less than "matching" weld metal may be used.
Tension or compression parallel to axis of weld[d]				
Shear parallel to axis of weld	Base[e] Weld electrode	0.75	$0.60F_{EXX}$	
Tension normal to effective area	Base Weld Electrode	0.90 0.80	F_y $0.60F_{EXX}$	
Fillet Welds				
Shear on effective area	Base[e] Weld electrode	0.75	$0.60F_{EXX}$	Weld metal with a strength level equal to or less than "matching" weld metal may be used.
Tension or compression parallel to axis of weld[d]	Base	0.90	F_y	
Plug or Slot Welds				
Shear parallel to faying surfaces (on effective area)	Base[e] Weld Electrode	0.75	$0.60F_{EXX}$	Weld metal with a strength level equal to or less than "matching" weld metal may be used.

[a]For definition of effective area, see Sect. J2.
[b]For "matching" weld metal, see Table 4.1.1, AWS D1.1.
[c]Weld metal one strength level stronger than "matching" weld metal will be permitted.
[d]Fillet welds and partial-penetration groove welds joining component elements of built-up members, such as flange-to-web connections, may be designed without regard to the tensile or compressive stress in these elements parallel to the axis of the welds.
[e]The design of connected material is governed by Sect. J4.

is assumed to be carried equally by each segment of weld,

$$(R_n)_v = \frac{P}{A} = \frac{P}{2(1)L_w} = \frac{15.2}{2(1)10} = 0.76 \text{ kips/in.}$$

The tension component (horizontal) due to the moment Pe is

$$(R_n)_t = \frac{Mc}{I} = \frac{15.2(6)5}{166.7} = 2.74 \text{ kips/in.}$$

where $I = \frac{1}{12}\left[2(1)(10)^3\right] = 166.7 \text{ in.}^4$

The resultant force is

$$\text{Required } \phi R_n = \sqrt{(0.76)^2 + (2.74)^2} = 2.84 \text{ kips/in.}$$

The design strength of E70 electrode fillet weld is

$$\phi R_{nw} = \phi t_e(0.60 F_{EXX}) = 0.75(0.707)a(0.60)70 = 22.3a$$

and the fillet weld size a required is

$$\text{Required } a = \frac{2.84}{22.3} = 0.13 \text{ in., say } \frac{3}{16} \text{ in.}$$

(c) Use *LRFD Manual* [1.17] tables, p. 5-91. For weld using E70 electrodes,

$$a = e/L = 6/10 = 0.60$$
$$k = 0$$
$$\text{Find } C = 1.107$$

$$\text{Table value} = \phi P_n = CC_1DL = 1.107(1.0)(D)10 = 11.07D \text{ kips}$$

$$\text{Required } D = 15.2/11.07 = 1.4$$

$$\text{Required } a = 1.4/16 = 0.09 \text{ in., say } \tfrac{1}{8} \text{ in.}$$

The elastic (vector) method is as expected more conservative than the strength method represented by the LRFD Manual tables. The minimum desirable size to be used for this situation is probably $\frac{3}{16}$ in.

Use $\frac{3}{16}$-in. E70 fillet welds. ■

Design for Lines of Weld Subject to Bending Moment

Even when there are moderate returns at the top of lines of fillet weld, an estimate of the length required may be obtained by using the same approach as used to determine the number of bolts in a line in Sec. 4.12. In Fig. 4.12.9, R/p has units kips/in. which becomes ϕR_{nw}, the design strength at the top of the lines of weld.

For moment alone on one line of weld,

$$R = \frac{M}{S} = \frac{M}{\left(\frac{1}{6}L_w^2\right)} \text{ kips/in.} \tag{5.19.1}$$

Since the maximum value of R is ϕR_{nw}

$$\phi R_{nw} = \frac{6M}{L_w^2}$$

$$\text{Required } L_w = \sqrt{\frac{6M}{\phi R_{nw}}} \tag{5.19.2}$$

Equation 5.19.2 for welds corresponds to Eq. 4.12.28 for bolts. Since it is correct only for moment alone, R_{nw} should be entered as a reduced value to account for direct shear.

■ EXAMPLE 5.19.2

Determine the length L required to carry the load indicated in Fig. 5.19.4 when 75% of the load is live load and 25% is dead load. The weld to be used is $\frac{5}{16}$-in. E70 fillet weld. Use AISC Load and Resistance Factor Design.

SOLUTION

(a) Compute factored load P_u:

$$P_u = 1.2(0.25)40 + 1.6(0.75)40 = 60 \text{ kips}$$

(b) Estimate length of weld L required by using Eq. 5.19.2:

$$\phi R_{nw} = 0.75(a)(0.707)(0.60)70 = 22.3a \text{ kips/in.}$$
$$= 22.3(5/16) = 6.96 \text{ kips/in.}$$
$$M_u = 60(4) = 240 \text{ in.-kips per 2 lines of weld}$$

$$\text{Required } L \approx \sqrt{\frac{6M_u}{\phi R_{nw}}} = \sqrt{\frac{6(240/2)}{6(\text{est.})}} = 11 \text{ in.}$$

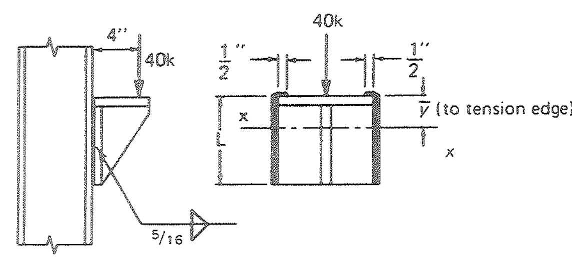


Figure 5.19.4 Example 5.19.2.

A reduced value of ϕR_{nw} has been used to account for the direct shear effect. Since the $\frac{1}{2}$-in. returns at the top add something; try $L = 10$ in.

(c) If the returns are neglected, the *LRFD Manual* [1.17] tables, p. 5-91, can be used to obtain an approximate result, as follows:

$$a = e/L = 4/10 = 0.40$$
$$k = 0$$
$$\text{Find } C = 1.549$$

$$\text{Table value} = \phi P_n = CC_1DL = 1.549(1.0)(a)10 = 15.49D \text{ kips}$$

$$\text{Required } D = 60/15.49 = 3.9$$

$$\text{Required } a = 3.9/16 = 0.24 \text{ in., say } \tfrac{1}{4} \text{ in.}$$

For $L = 8$ in.,

$$\text{Find } C = 1.299, \quad \text{required } a = 0.29 \text{ in.,} \quad \text{say } \tfrac{5}{16} \text{ in.}$$

(d) Elastic (vector) method. The actual weld configuration has the $\frac{1}{2}$-in. returns which make the center of gravity of the weld configuration lie closer to the top than the mid-depth assumed in part (c). Also, there is no indication in the LRFD tables that those tables should be used when the load is applied such as to cause moment and shear. Thus, it may be prudent to use a conservative elastic (vector) analysis.

Locate the center of gravity of the configuration,

$$\bar{y} = \frac{2(10)5}{2(10 + 0.5)} = \frac{100}{21} = 4.76 \text{ in.}$$

The direct shear component $(R_n)_v$ is computed assuming that none of the shear is carried by the returns,

$$(R_n)_v = \frac{P}{2L} = \frac{60}{2(10)} = 3.00 \text{ kips/in.}$$

The tension component due to the moment Pe is

$$I_x = \frac{2L^3}{12} + 2L(5 - 4.67)^2 + 2(0.5)(4.76)^2$$

$$= \frac{(10)^3}{6} + 20(0.24)^2 + (4.76)^2 = 190.5 \text{ in.}^3$$

$$(R_n)_t = \frac{60(4)4.76}{190.5} = 6.00 \text{ kips/in.}$$

The resultant force is

$$\text{Required } \phi R_n = \sqrt{(3.00)^2 + (6.00)^2} = 6.71 \text{ kips/in.}$$

The design strength of E70 electrode $\frac{5}{16}$-in. fillet weld is

$$\phi R_{nw} = \phi t_e(0.60F_{EXX})$$

$$= 0.75(0.707)(\tfrac{5}{16})(0.60)70 = 6.97 \text{ kips/in.}$$

The design strength ϕR_{nw} exceeds the 6.71 kips/in. required; thus, $L = 10$ in. is adequate.

Use $L = 10$ in. ■

Additional treatment of eccentric load on welds is to be found in Chapter 13 on connections.

SELECTED REFERENCES

5.1. K. Winterton. "A Brief History of Welding Technology," *Welding and Metal Fabrication*, November 1962; December 1962.

5.2. "100 Years of Metalworking—Welding, Brazing and Joining," *The Iron Age*, June 1955.

5.3. H. Carpmael. *Electric Welding and Welding Appliances*. London: D. Van Nostrand Company, 1920.

5.4. Preston M. Hall. "77 Years of Resistance Welding." *The Welding Engineer*, February 1954, 54–55; March 1954, 36–37; April 1954, 62–63.

5.5. W. L. Miskoe. "The Centenary of Modern Welding, 1885–1985—A Commemoration," *Welding Journal*, **65**, April 1986, 19–24.

5.6. D. W. Morgan. "Classification and Use of Mild Steel Covered Electrodes," *Welding Journal*, December 1976, 1035–1038.

5.7. E. Craig. "A Unique Mode of GMAW Transfer," *Welding Journal*, **66**, September 1987, 51–55.

5.8. K. A. Lyttle. "GMAW—A Versatile Process on the Move," *Welding Journal*, **62**, March 1983, 15–23.

5.9. V. R. Dillenbeck and L. Castagno. "The Effects of Various Shielding Gases and Associated Mixtures in GMA Welding of Mild Steel," *Welding Journal*, **66**, September 1987, 45–49. (See also letter from Nils Larson, Chairman, Committees C50 and A55, American Welding Society, and author's reply, **67**, March 1988, 6.)

5.10. AWS. *Welding Handbook*, 7th ed., Vols. 2 and 3. Miami, FL: American Welding Society, 1978, 1980.

5.11. ______. "Office Building Columns Field Spliced with Self-Shielded Welding Wire," *Welding Journal*, **65**, October 1986, 53–54.

5.12. ______. "Self-Shielded FCAW Speeds High-Rise Construction," *Welding Journal*, **63**, April 1984, 47–49.

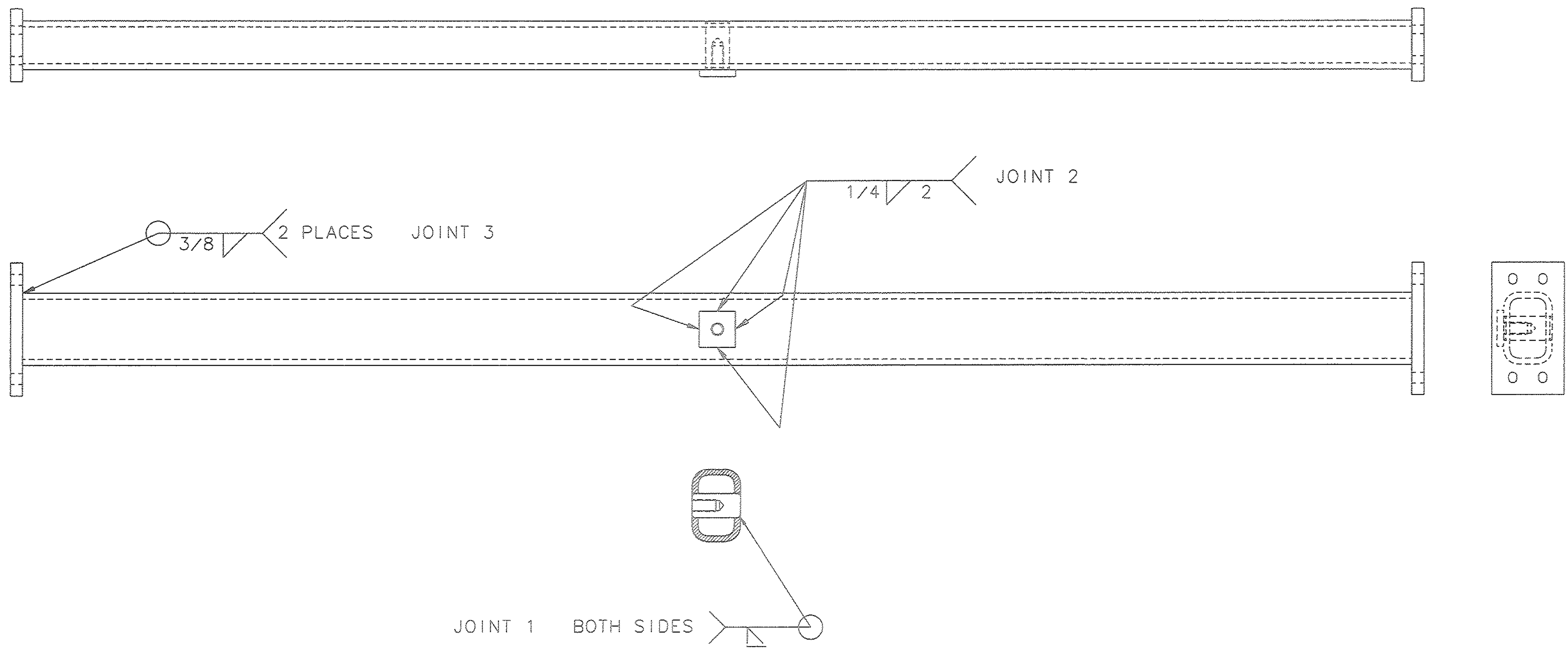
5.13. ______. "Self-Shielded FCA Welding is a Breeze in the Windy City," *Welding Journal*, **67**, March 1988, 47–48.

5.14. A. Raman. "Electroslag Welds: Problems and Cures," *Welding Journal*, **60**, December 1981, 17–21.

5.15. C. G. Schilling and K. H. Klippstein. "Tests of Electroslag-Welded Bridge Girders," *Welding Journal*, **60**, December 1981, 23–30.

Summary Of Analysis Of Welded Joints							
Joint	#	1	2	3	4	5	6
Joint Type	-	Edge	Lap	Tee	Tee	Tee	Lap
Weld Type	-	PPGW	Fillet	Fillet	Fillet	Fillet (*)	Fillet
Base Metals Min. Yield	Fy (ksi)	46	36	36	36	36	36
Base Metals Min. Yield x	0.33	15.18	11.88	11.88	11.88	11.88	11.88
Depth or leg	(in)	3/16	1/4	3/8	5/16	1/4	5/16
Eff. Throat	(in)	0.063	0.177	0.265	0.221	0.177	0.221
Length	(in)	5.89	8.00	18.21	8.47	24.88	11.56
Rw	(kips/in)	**0.95**	**2.10**	**3.15**	**2.63**	**2.10**	**2.63**
Bending axis	-	-	-	x	x	z	-
I	(in4)	-	-	94.6	8.8	336.4	-
cmax	(in)	-	-	3.125	1.350	6.196	-
I/cmax	(in3)	-	-	30.27	6.50	54.29	-
csec	(in)	-	-	-	-	0.917	-
I/csec	(in3)	-	-	-	-	366.8	-
Shear load	(kips)	3.46	2.75	1.38	2.75	1.38	2.75
Shear stress	(kips/in)	**0.59**	**0.34**	0.08	0.32	0.06	**0.24**
Moment max.	(kips-in)	-	-	39.50	5.50	44.69	-
Max. Bending stress	(kips/in)	-	-	1.30	0.85	0.82	-
Secondary Bending stress	(kips/in)	-	-	-	-	0.12	-
Vector Sum	(kips/in)	-	-	**1.31**	**0.91**	**0.84**	-
SF l.r.t. base metal yield strength	-	***4.9***	***18.5***	***7.3***	***8.8***	***7.6***	***33.4***
(*) Combination of FBGW (Eff.throat=.234") and fillet, conservatively assumed to be all fillet.							

WELDS SUMMARY TABLE



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Welded Joint: 1

File: Joint1.mcd

Calculation in accordance to Steel Structures - Design and Behavior,
Salmon and Johnson, 3rd ed., Harper Collins Publishers, and
this note's Allowable Stresses In Welds Table,
Elastic Vector Analysis.
Load: from item "g" (case 26, p.305).
Allowable Stresses in Partial Penetration Groove Welds:
ASD based: Tension and compression : 0.60 x Fy;
Shear: smaller between 0.30 x Fw and 0.40 x Fy;
ASME B30.20: All: 0.33 x Fy.

Nominal tensile strength of weld metal (ksi):	$Fw := 70$	
Yield strength of base metal (ksi):	$Fy := 46$	
0.60 x Fy (ksi):	$Fb := 0.60 \cdot Fy$	$Fb = 27.6$
0.40 x Fy (ksi):	$Fsb := 0.40 \cdot Fy$	$Fsb = 18.4$
0.30 x Fw (ksi):	$Fsw := 0.30 \cdot Fw$	$Fsw = 21.0$
0.33 x Fy (ksi):	$Fa := 0.33 \cdot Fy$	$Fa = 15.2$
Effective throat with α=45°, te=(d-1/8) (in):	$te := .063$	
Allowable resistance (kips/in):	$Rw := te \cdot Fa$	$Rw = 0.96$
Max. shear load (kips):	$P := \frac{2.75}{4} \cdot (4 + 1.031)$	$P = 3.46$
Length (in):	$L := 5.89$	

$$Shear := \frac{P}{L}$$

So:

$Shear = 0.59$ kips/in

As 0.59 kips/in < 0.96 kips/in ⇒ Weld is *OK*.

Welded Joint: 2

File: Joint2.mcd

Calculation in accordance to Steel Structures - Design and Behavior,
Salmon and Johnson, 3rd ed., Harper Collins Publishers, and
this note's Allowable Stresses In Welds Table,
Elastic Vector Analysis.
Allowable Stresses in Fillet Welds:
ASD based: Tension and compression : 0.60 x Fy;
Shear: smaller between 0.30 x Fw and 0.40 x Fy;
ASME B30.20: All: 0.33 x Fy.

Size of fillet weld (in):	$l := \frac{1}{4}$	
Nominal tensile strength of weld metal (ksi):	$Fw := 70.0$	
Yield strength of base metal (ksi):	$Fy := 36.0$	
0.60 x Fy (ksi):	$Fb := 0.60 \cdot Fy$	$Fb = 21.6$
0.40 x Fy (ksi):	$Fsb := 0.40 \cdot Fy$	$Fsb = 14.4$
0.30 x Fw (ksi):	$Fsw := 0.30 \cdot Fw$	$Fsw = 21.0$
0.33 x Fy (ksi):	$Fa := 0.33 \cdot Fy$	$Fa = 11.9$
Effective throat with (in):	$te := \frac{\sqrt{2}}{2} \cdot l$	$te = 0.177$
Allowable resistance (kips/in):	$Rw := te \cdot Fa$	$Rw = 2.1$
Shear load (kips):	$P := 2.750$	
Length (in):	$L := 8.0$	

$Shear := \frac{P}{L}$,so: $Shear = 0.34$ kips/in

As 0.34 kips/in < 2.1 kips/in ⇒ Weld is ***OK***.

Welded Joint: 3

File: Joint3.mcd

Calculation in accordance to Steel Structures - Design and Behavior, Salmon and Johnson, 3rd ed., Harper Collins Publishers, and this note's Allowable Stresses In Welds Table, Elastic Vector Analysis.
Allowable Stresses in Fillet Welds:
ASD based: Tension and compression : 0.60 x Fy;
Shear: smaller between 0.30 x Fw and 0.40 x Fy;
ASME B30.20: All: 0.33 x Fy.

Size of fillet weld (in):	$l := \frac{3}{8}$	
Nominal tensile strength of weld metal (ksi):	$Fw := 70.0$	
Yield strength of base metal (ksi):	$Fy := 36.0$	
0.60 x Fy (ksi):	$Fb := 0.60 \cdot Fy$	$Fb = 21.6$
0.40 x Fy (ksi):	$Fsb := 0.40 \cdot Fy$	$Fsb = 14.4$
0.30 x Fw (ksi):	$Fsw := 0.30 \cdot Fw$	$Fsw = 21.0$
0.33 x Fy (ksi):	$Fa := 0.33 \cdot Fy$	$Fa = 11.9$
Effective throat with (in):	$te := \frac{\sqrt{2}}{2} \cdot l$	$te = 0.265$
Allowable resistance (kips/in):	$Rw := te \cdot Fa$	$Rw = 3.15$
Shear load (kips):	$P := 1.375$	
Bending laod (kpis-in):	$M := 39.5$	
Length (in):	$L := 18.21$	
Mom. of inertia / 1 in wide weld (in^4):	$I := 94.6$	
Max. dist. to center of eff. throat (in):	$cmax := 3.125$	

$Shear := \frac{P}{L}$ so $Shear = 0.08$ kips/in

$Bending := \frac{M}{\left(\frac{I}{cmax}\right)}$ so $Bending = 1.30$ kips/in

Vector sum R is:

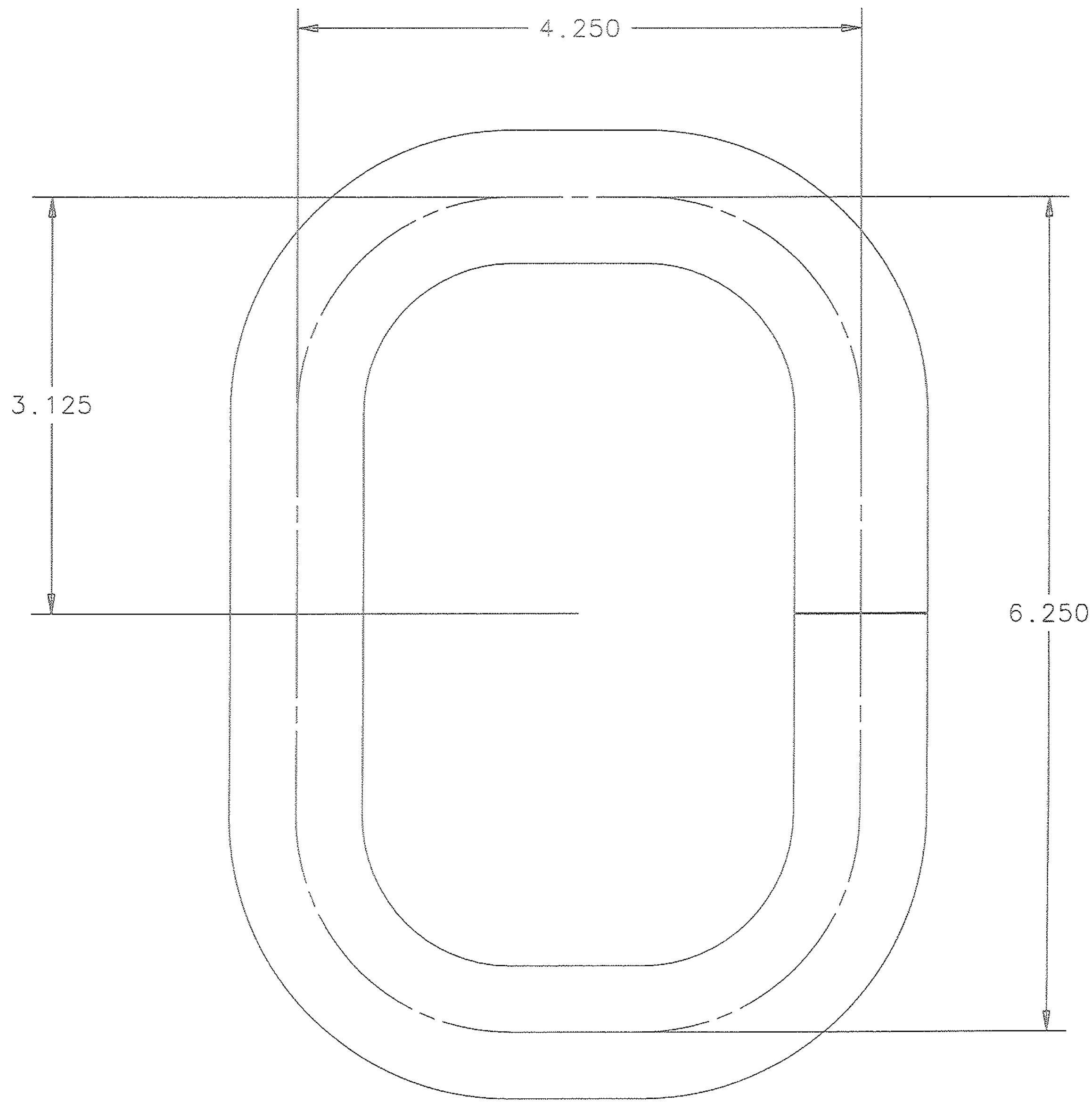
$$Vector\_sum := \sqrt{Shear^2 + Bending^2}$$

so:

$Vector\_sum = 1.31$ kips/in

As 1.31 kips/in < 3.15 kips/in ⇒ Weld is ***OK***.

Joint 3



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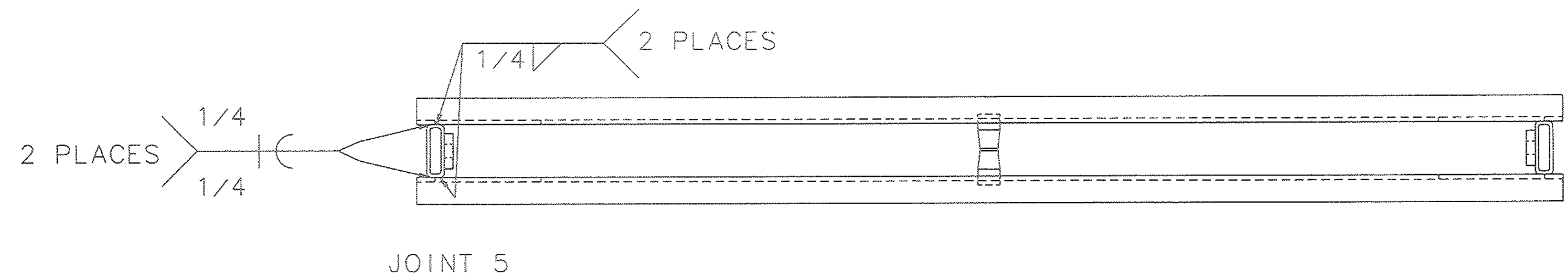

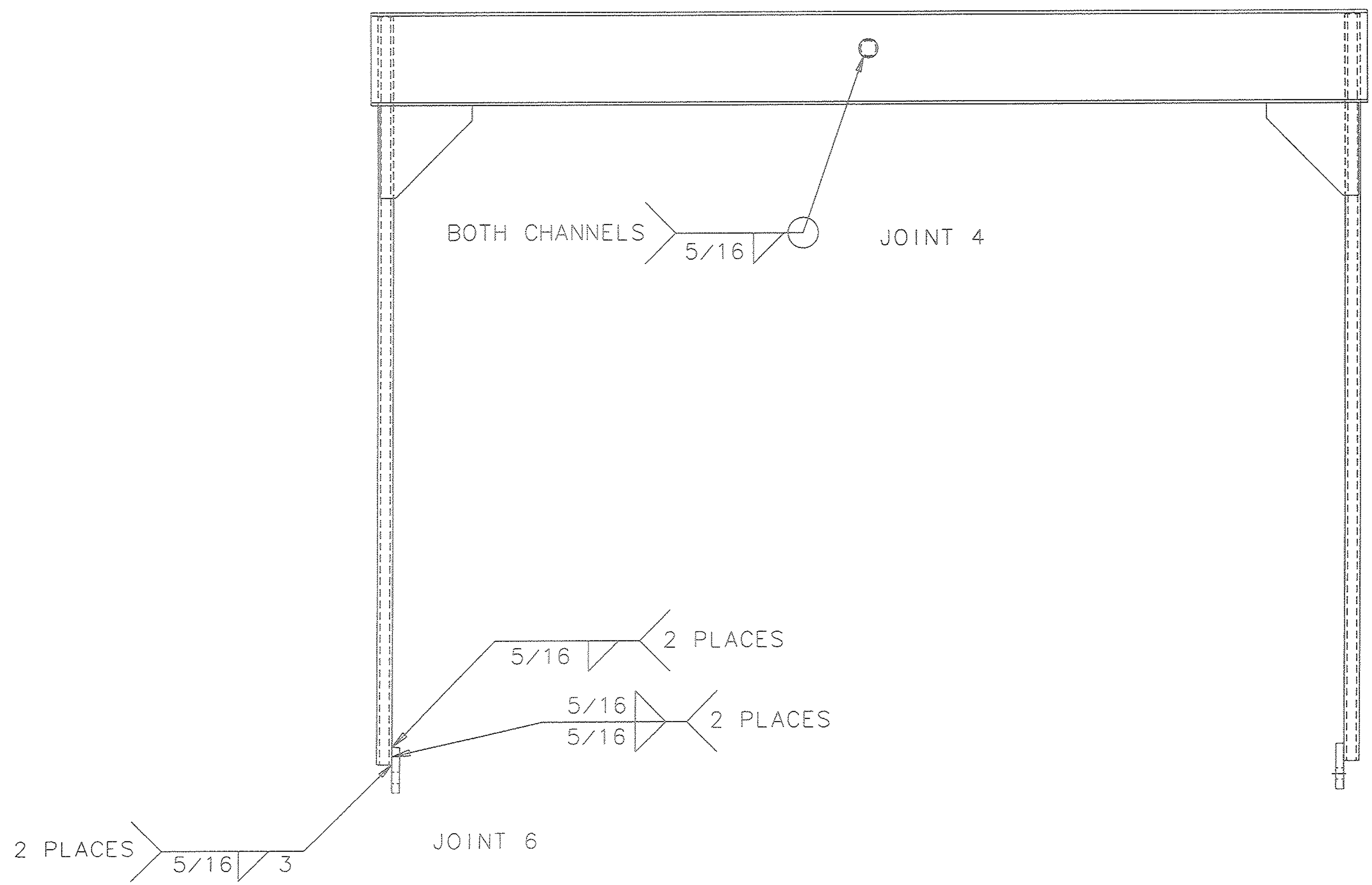

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Welded Joint: 4

File: Joint4.mcd

Calculation in accordance to Steel Structures - Design and Behavior,
Salmon and Johnson, 3rd ed., Harper Collins Publishers, and
this note's Allowable Stresses In Welds Table,
Elastic Vector Analysis.
Allowable Stresses in Fillet Welds:
ASD based: Tension and compression : 0.60 x Fy;
Shear: smaller between 0.30 x Fw and 0.40 x Fy;
ASME B30.20: All: 0.33 x Fy.

Size of fillet weld (in):	$l := \frac{5}{16}$	
Nominal tensile strength of weld metal (ksi):	$Fw := 70.0$	
Yield strength of base metal (ksi):	$Fy := 36.0$	
0.60 x Fy (ksi):	$Fb := 0.60 \cdot Fy$	$Fb = 21.6$
0.40 x Fy (ksi):	$Fsb := 0.40 \cdot Fy$	$Fsb = 14.4$
0.30 x Fw (ksi):	$Fsw := 0.30 \cdot Fw$	$Fsw = 21.0$
0.33 x Fy (ksi):	$Fa := 0.33 \cdot Fy$	$Fa = 11.9$
Effective throat with (in):	$te := \frac{\sqrt{2}}{2} \cdot l$	$te = 0.221$
Allowable resistance (kips/in):	$Rw := te \cdot Fa$	$Rw = 2.63$
Shear load (kips):	$P := 2.75$	
Bending laod (kpis-in):	$M := 5.5$	
Length (in):	$L := 8.47$	
Mom. of inertia / 1 in wide weld (in^4):	$I := 8.77$	
Max. dist. to center of eff. throat (in):	$cmax := 1.35$	

$Shear := \frac{P}{L}$ so $Shear = 0.32$ kips/in

$Bending := \frac{M}{\left(\frac{I}{cmax}\right)}$ so $Bending = 0.85$ kips/in

Vector sum R is:

$$Vector\_sum := \sqrt{Shear^2 + Bending^2}$$

so:

$Vector\_sum = 0.91$ kips/in

As 0.91 kips/in < 2.63 kips/in ⇒ Weld is ***OK***.

Welded Joint: 5

File: Joint5.mcd

Calculation in accordance to Steel Structures - Design and Behavior,
Salmon and Johnson, 3rd ed., Harper Collins Publishers, and
this note's Allowable Stresses In Welds Table,
Elastic Vector Analysis.
Allowable Stresses in Fillet Welds:
ASD based: Tension and compression : 0.60 x Fy;
Shear: smaller between 0.30 x Fw and 0.40 x Fy;
ASME B30.20: All: 0.33 x Fy.
This is a combination of flare bevel groove weld, with effective throat of .234 in and a 1/4 in fillet weld. For simplicity and being conservative, it was assumed a 1/4 in fillet weld all around.

Size of fillet weld (in):	$l := \frac{1}{4}$	
Nominal tensile strength of weld metal (ksi):	$Fw := 70.0$	
Yield strength of base metal (ksi):	$Fy := 36.0$	
0.60 x Fy (ksi):	$Fb := 0.60 \cdot Fy$	$Fb = 21.6$
0.40 x Fy (ksi):	$Fsb := 0.40 \cdot Fy$	$Fsb = 14.4$
0.30 x Fw (ksi):	$Fsw := 0.30 \cdot Fw$	$Fsw = 21.0$
0.33 x Fy (ksi):	$Fa := 0.33 \cdot Fy$	$Fa = 11.9$
Effective throat with (in):	$te := \frac{\sqrt{2}}{2} \cdot l$	$te = 0.177$
Allowable resistance (kips/in):	$Rw := te \cdot Fa$	$Rw = 2.10$
Shear load (kips):	$P := 1.375$	
Bending laod (kpis-in):	$M := 44.6875$	
Length (in):	$L := 24.88$	
Mom. of inertia / 1 in wide weld (in^4):	$I := 336.4$	
Max. dist. to center of eff. throat (in):	$cmax := 6.196$	
Sec. dist. to center of eff. throat (in):	$csec := 0.917$	

$Shear := \frac{P}{L}$ so $Shear = 0.06$ kips/in

$X\_Bending := \frac{M}{\left(\frac{I}{cmax}\right)}$ so $X\_Bending = 0.82$ kips/in

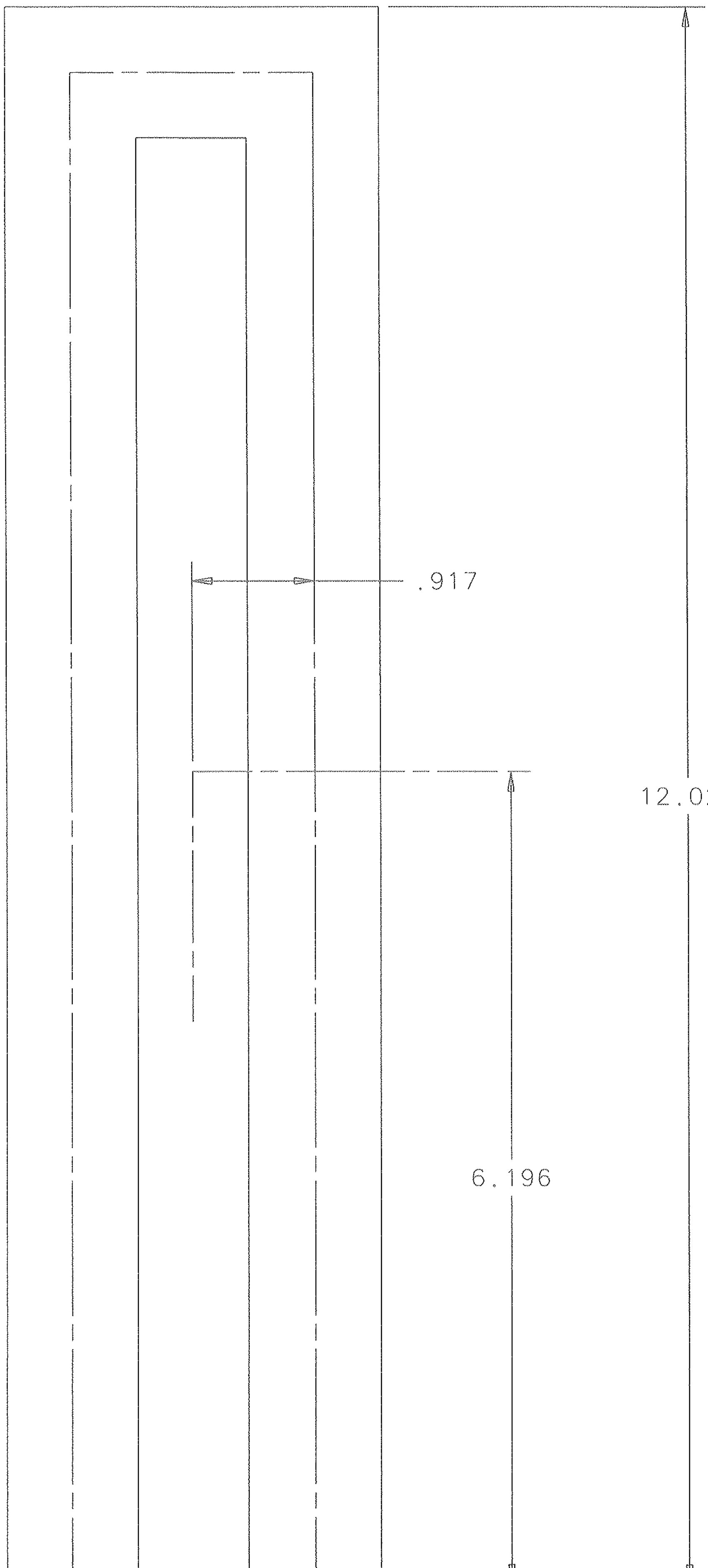
$Y\_Bending := \frac{M}{\left(\frac{I}{csec}\right)}$ so $Y\_Bending = 0.12$ kips/in

Vector sum R is:

$$Vector\_sum := \sqrt{(Shear + Y\_Bending)^2 + X\_Bending^2}$$ so:

$Vector\_sum = 0.84$ kips/in

As 0.84 kips/in < 2.10 kips/in ⇒ Weld is ***OK***.



Joint 5

Area=2.48800e+01
Xcg=9.17020e+00
Ycg=9.13923e+00
Ixcg=3.14220e+02
Iycg=2.22580e+01
Ixycg=-1.17240e-13
Ixor=2.39234e+03
Iyor=2.11448e+03
Ixyor=2.08516e+03
Kxcg=3.55379e+00
Kycg=9.45840e-01
Kxor=9.80587e+00
Kyor=9.21885e+00
Ixprin=2.22580e+01
Iyprin=3.14220e+02
Ipolar=3.36478e+02

Welded Joint: 6

File: Joint6.mcd

Calculation in accordance to Steel Structures - Design and Behavior,
Salmon and Johnson, 3rd ed., Harper Collins Publishers, and
this note's Allowable Stresses In Welds Table,
Elastic Vector Analysis.
Allowable Stresses in Fillet Welds:
ASD based: Tension and compression : 0.60 x Fy;
Shear: smaller between 0.30 x Fw and 0.40 x Fy;
ASME B30.20: All: 0.33 x Fy.

Size of fillet weld (in):	$l := \frac{5}{16}$	
Nominal tensile strength of weld metal (ksi):	$Fw := 70.0$	
Yield strength of base metal (ksi):	$Fy := 36.0$	
0.60 x Fy (ksi):	$Fb := 0.60 \cdot Fy$	$Fb = 21.6$
0.40 x Fy (ksi):	$Fsb := 0.40 \cdot Fy$	$Fsb = 14.4$
0.30 x Fw (ksi):	$Fsw := 0.30 \cdot Fw$	$Fsw = 21.0$
0.33 x Fy (ksi):	$Fa := 0.33 \cdot Fy$	$Fa = 11.9$
Effective throat with (in):	$te := \frac{\sqrt{2}}{2} \cdot l$	$te = 0.221$
Allowable resistance (kips/in):	$Rw := te \cdot Fa$	$Rw = 2.63$
Shear load (kips):	$P := 2.750$	
Length (in):	$L := 11.56$	

$Shear := \frac{P}{L}$,so: $Shear = 0.24$ kips/in

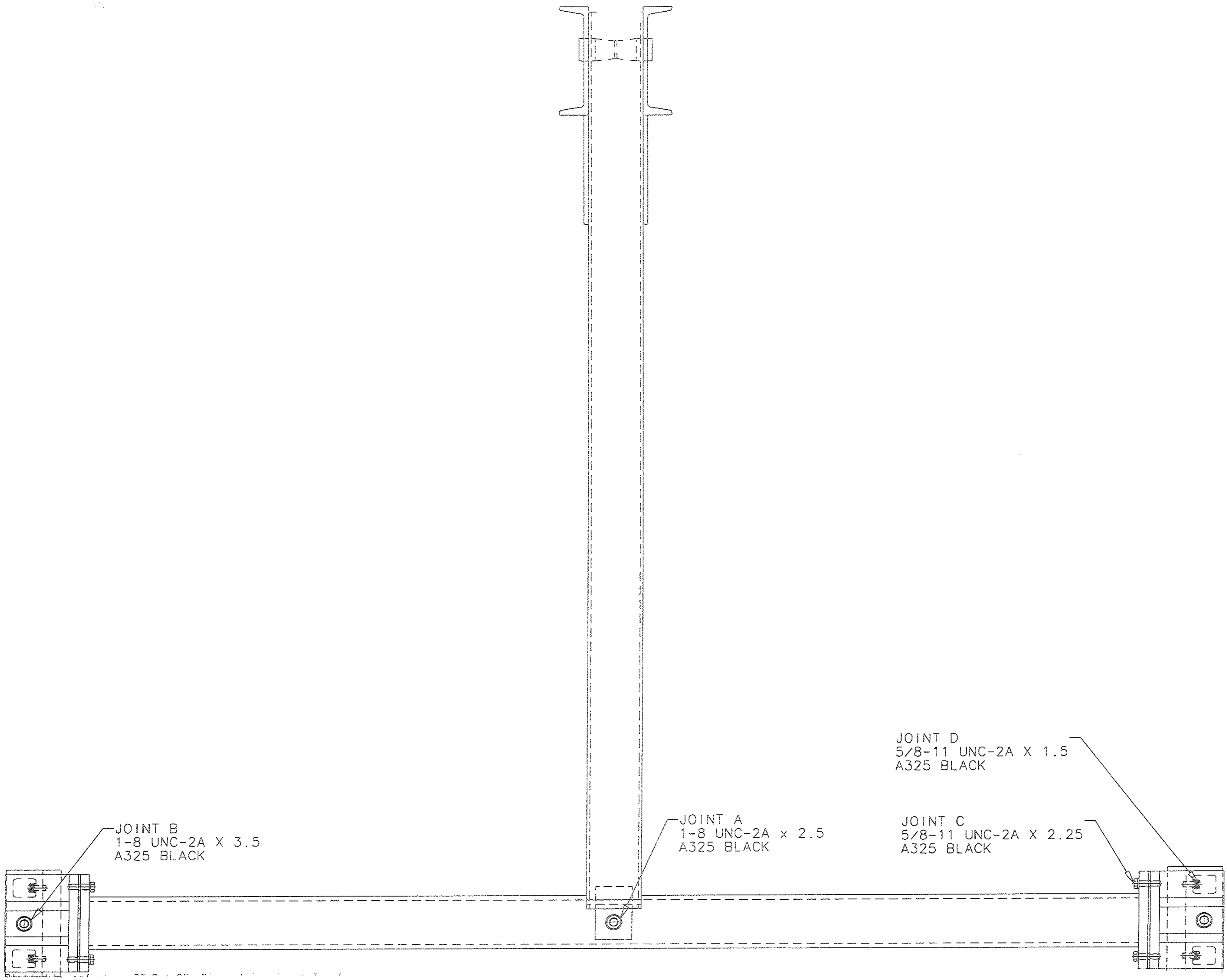
As 0.24 kips/in < 2.63 kips/in ⇒ Weld is *OK*.

2.2.2. Bolted Connections

There are 4 kinds of bolted connections, joints A to D. The next pages contain a summary of the bolted joints analysis, a drawing identifying all the bolted joints and the calculations.

Summary Of Analysis Of Bolted Joints					
Joit	#	A	B	C	D
Connection Type	-	Bearing	Bearing	Slip-critical	Bearing
Threads Excluded From Shear Plane	-	No	No	No	No
Bolt Material Specification	-	ASTM A325	ASTM A325	ASTM A325	ASTM A325
Bolt Tensile Strength	Fub (ksi)	120	120	120	120
Nominal Bolt Diameter	(in)	1	1	5/8	5/8
Bolt Area	(in2)	0.785	0.785	0.307	0.307
Tapped Material Specification	-	ASTM A108 Gr.1215	6061-T651	ASTM A36	6061-T651
Tapped Material Yield Strength	Fy (ksi)	60.0	35.0	36.0	35.0
Desirable Thread Engagement	(in)	-	-	0.639	-
Actual Thread Engagement	(in)	-	-	1.000	-
Torque Required	lb-ft	-	-	218	-
Excentricity (In Plane / Off Plane)	-	-	-	Off	-
Shear Load Per Bolt	(kips)	2.8	2.8	-	1.4
Shear Stress	(ksi)	3.5	3.5	-	4.5
Shear Load Excentricity	(in)	-	-	-	-
Moment From Shear Load	(kips-in)	-	-	-	-
Tension Load	(kips)	-	-	2.75	-
Tension Load Excentricity	(in)	-	-	57.5	-
Moment From Tension Load	(kips-in)	-	-	39.5	-
Allowable Shear Stress (ASD Tb. J3.2)	(ksi)	21.0	21.0	-	21.0
Allowable Shear Load (Rs)	(kips)	16.5	16.5	-	6.4
Allowable Tension Stress (ASD Tb. J3.2)	(ksi)	-	-	44.0	-
Allowable Tension Load (Rt)	(kips)	-	-	13.5	-
Number Of Columns (m)	#	-	-	2	-
Column Spacing (g)	(in)	-	-	2.5	-
Row Spacing (p)	(in)	-	-	8.188	-
Estimated Number Of Rows	#	-	-	1.04	-
Number Of Rows (n)	#	-	-	2	-
cx	(in)	-	-	-	-
cy	(in)	-	-	-	-
Ix	(in4)	-	-	-	-
Iy	(in4)	-	-	-	-
J	(in4)	-	-	-	-
ea	(in)	-	-	-	-
ee	(in)	-	-	-	-
fsx	(ksi)	-	-	-	-
fsy	(ksi)	-	-	-	-
fbx	(ksi)	-	-	-	-
fby	(ksi)	-	-	-	-
fr	(ksi)	-	-	-	-
Σy2	(in2)	-	-	67.0	-
Tm	(kips)	-	-	2.4	-
Ratio Resultant / Allowable (%)	-	17%	17%	18%	21%
SF i.r.t. Bolt Tensile Strength	-	***34.3***	***34.3***	***15.3***	***26.8***

BOLTS SUMMARY TABLE


JOINT D
5/8-11 UNC-2A X 1.5
A325 BLACK
JOINT B
1-8 UNC-2A X 3.5
A325 BLACK
JOINT A
1-8 UNC-2A x 2.5
A325 BLACK
JOINT C
5/8-11 UNC-2A X 2.25
A325 BLACK

Bolted Joint: A

File: JointA.mcd

Calculations in accordance to Structural Engineering Handbook, 3rd ed., Chapter 8, McGraw-Hill, and AISC/ASD, Chapter J.
Shear, Structural Engineering Handbook, p.8-65.

- Bearing Connection;
- Size of holes: 1.063 in;
- Direction of load relative to larger axis of hole: N/A;
- Threads not excluded from shear planes;
- Bolt specification: ASTM A 325.

Allowable Tension Stress, ASD, Tb. J3.2, p.5-73 (ksi): $Ft := 21.0$

Bolt size (in): $d := 1$

Bolt area (in^2): $A := \left(\frac{\pi}{4}\right) \cdot d^2$ $A = 0.785$

Allowable load (kips): $R := Ft \cdot A$ $R = 16.5$

Load (kips): $L := 2.75$

Number of bolts: $n := 1$

Load per bolt (kips): $s := \frac{L}{n}$ $s = 2.8$

R (16.5) > s (2.8) so bolts are *OK*.

Bolted Joint: B

File: JointB.mcd

Calculations in accordance to Structural Engineering Handbook, 3rd ed., Chapter 8, McGraw-Hill, and AISC/ASD, Chapter J.
Shear, Structural Engineering Handbook, p.8-65.

- Bearing Connection;
- Size of holes: 1.063 in;
- Direction of load relative to larger axis of hole: N/A;
- Threads not excluded from shear planes;
- Bolt specification: ASTM A 325.

Allowable Tension Stress, ASD, Tb. J3.2, p.5-73 (ksi): $Ft := 21.0$

Bolt size (in): $d := 1$

Bolt area (in^2): $A := \left(\frac{\pi}{4}\right)\cdot d^2$ $A = 0.785$

Allowable load (kips): $R := Ft \cdot A$ $R = 16.5$

Load (kips): $L := 2.75$

Number of bolts: $n := 1$

Load per bolt (kips): $s := \frac{L}{n}$ $s = 2.8$

R (16.5) > s (2.8) so bolts are *OK*.

Bolted Joint: C

File: JointC.mcd

Calculations in accordance to Structural Engineering Handbook, 3rd ed., Chapter 8, McGraw-Hill, and AISC/ASD, Chapter J.
Off Plane Bending, Structural Engineering Handbook, p.8-68.

- Slip-critical Connection;
- Size of holes: short-slot 11/16 x 7/8;
- Direction of load relative to larger axis of hole: parallel;
- Threads not excluded from shear planes;
- Bolt specification: ASTM A 325.

Allowable Tension Stress, ASD, Tb. J3.2, p.5-73 (ksi): $Ft := 44.0$

Bolt size: $d := \frac{5}{8}$ Bolt area (in^2): $A := \left(\frac{\pi}{4}\right)\cdot d^2$ $A = 0.307$

Allowable load (kips): $R := Ft\cdot A$ $R = 13.5$

Bending moment, from calculations of item h (in-kips): $M := 39.5$

Number of columns: $m := 2$

Vertical spacing between bolts (in): $p := 8.188$

Horizontal spacing between bolts (in): $g := 2.5$

Estimated number of rows: $n := \sqrt{\frac{6\cdot M}{p\cdot m\cdot R}}$ $n = 1.04$

Number of rows: $n := 2$

C.G.: $xcg := \frac{g}{2}\cdot(m-1)$ $xcg = 1.25$ $ycg := \frac{p}{2}\cdot(n-1)$ $ycg = 4.094$

Calculation of Σy^2: $buf := \frac{n-1}{2}$

$int := floor(buf)$ $int = 0.00$ $frac := (buf - int)$ $frac = 0.50$

$k := if((frac = 0), int, (int + 1))$ $k = 1.00$

$$\Sigma y2 := 2\cdot m\cdot \sum_{j=1}^{k} ((j - frac)\cdot p)^2 \qquad \Sigma y2 = 67.0$$

Max. tension on bolt (kips): $Tm := \frac{M\cdot ycg}{\Sigma y2}$ $Tm = 2.4$

R (13.5) > Tm (2.4) so bolts are ***OK***.

Joint: C

File: T_C.mcd

Torque Required

The calculations are based on the methodology presented by Shigley & Mischke, Chapter 8.
For permanent connections, the pre-load is based on ASD recommendations (Table 4, p.5-274) of tension required of 70% of tensile strength plus 5% for torque wrenches (total of 78.5%).
For reusable connections, the pre-load is based on Shigley & Mischke, Chapter 8, p. 349, equations 8-25 or 8-26, representing 75% of the proof load or, in the abscence of that, 85% of the yield strength.

Type of connection assumed in this case: **Reusable**.

Bolt Tensile/**Proof**/Yield Stress (ksi):	$Fb := 85$	
Req. Bolt Tension, ASD/**Shigley** (ksi):	$Rb := .75 \cdot Fb$	$Rb = 63.8$
Torque Factor, (Zn=.2,**Blk=.3**), p.347:	$K := .30$	
Major Screw Diameter (in):	$d := \frac{5}{8}$	
Pitch (threads/in):	$n := 11$	
Grip Threaded Length (in):	$lt := 1.00$	
Grip Unthreaded Length (in):	$ld := 1.00$	
Bolt Elastic Modulus (ksi):	$Eb := 2.9 \cdot 10^4$	
External Tensile Load (kips):	$P := 2.4$	
Threaded Member Elastic Modulus (ksi):	$Et := 2.9 \cdot 10^4$	
Threaded Member Thickness (in):	$tt := 1.00$	
Unthreaded Member Elastic Modulus (ksi):	$Eu := 2.9 \cdot 10^4$	
Unthreaded Member Thickness (in):	$tu := 1.0$	
Washer Diameter [D≅1.5xd] (in):	$D := 1.5 \cdot d$	$D = 0.938$
Half-Apex Angle (°):	$a := 30$	

$\alpha := \frac{\pi}{180} \cdot a$ $\quad \alpha = 0.524$ $\qquad Ad := \frac{\pi}{4} \cdot d^2$ $\quad Ad = 0.307$

$At := .7854 \cdot \left(d - \frac{.9743}{n}\right)^2$ $\quad At = 0.226$ $\qquad kb := \frac{Ad \cdot At \cdot Eb}{Ad \cdot lt + At \cdot ld}$ $\quad kb = 3.77 \cdot 10^3$

$$kt := \frac{\pi \cdot Et \cdot d \cdot \tan(\alpha)}{\ln\left[\left[\frac{(2 \cdot tt \cdot \tan(\alpha) + D - d) \cdot (D + d)}{(2 \cdot tt \cdot \tan(\alpha) + D + d) \cdot (D - d)}\right]\right]} \qquad ku := \frac{\pi \cdot Eu \cdot d \cdot \tan(\alpha)}{\ln\left[\left[\frac{(2 \cdot tu \cdot \tan(\alpha) + D - d) \cdot (D + d)}{(2 \cdot tu \cdot \tan(\alpha) + D + d) \cdot (D - d)}\right]\right]}$$

$kt = 33100.46$ $\qquad ku = 33100.46$

$KM := \frac{1}{\frac{1}{kt} + \frac{1}{ku}}$ $\quad KM = 1.66 \cdot 10^4$ $\qquad C := \frac{kb}{kb + KM}$ $\quad C = 0.186$

Total Bolt Load from Req. Bolt Tension (kips):	$Fb := Rb \cdot At$	$Fb = 14.4$
Preload - Clamping Force (kips):	$Fi := Fb - C \cdot P$	$Fi = 14.0$
Torque Required (ft-lb):	$T := \frac{K \cdot Fi \cdot 1000 \cdot d}{12}$	$T = 218$

Joint: C

File: Th_C.mcd

Minimum thread engagement

Machinery's Handbook, 24th ed., p.1324. Data required: p.1544-1566.
Minimum thread engagement to assure failure on externally threaded part.
COT Flipping Fixture.

Internal thread (ASTM A36):

Basic major diameter (in) : $D := \frac{5}{8}$

Pitch (threads/in): $n := 11$

Max. minor diameter (in): $Kn := .5460$

Max. pitch diameter (in): $En := .5732$

Min. tensile strenth (ksi): $\sigma i := 58$

External thread (ASTM A 325):

Min. major diameter (in): $Ds := .6113$

Min. pitch diameter (in): $Es := .5589$

Max. tensile strength (ksi): $\sigma e := 120$

Hence:

$$Ats := .7854 \cdot \left(D - \frac{.9743}{n}\right)^2$$ so: $Ats = 0.226$

$$Ath := \pi \cdot \left(\frac{Es}{2} - \frac{.16238}{n}\right)^2$$ so: $Ath = 0.220$

$$At := \text{if}((\sigma e > 100), Ath, Ats)$$ so: $At = 0.220$

$$Le := \frac{2 \cdot At}{\pi \cdot Kn \cdot (.5 + (.57735 \cdot n \cdot (Es - Kn)))}$$ so: $Le = 0.441$

$$As := \pi \cdot n \cdot Le \cdot Kn \cdot \left[\frac{1}{2 \cdot n} + .57735 \cdot (Es - Kn)\right]$$ so: $As = 0.440$

$$An := \pi \cdot n \cdot Le \cdot Ds \cdot \left[\frac{1}{2 \cdot n} + .57735 \cdot (Ds - En)\right]$$ so: $An = 0.628$

$$J := \frac{As \cdot \sigma e}{An \cdot \sigma i}$$ so: $J = 1.449$

$$Q := J \cdot Le$$ so: $Q = 0.639$

$$Engagement := \text{if}((J > 1), Q, Le)$$ so: $Engagement = 0.639$

Bolted Joint: D

File: JointD.mcd

Calculations in accordance to Structural Engineering Handbook, 3rd ed., Chapter 8, McGraw-Hill, and AISC/ASD, Chapter J.
Shear, Structural Engineering Handbook, p.8-65.

- Bearing Connection;
- Size of holes: 21/32 in;
- Direction of load relative to larger axis of hole: N/A;
- Threads not excluded from shear planes;
- Bolt specification: ASTM A 325.

Allowable Tension Stress, ASD, Tb. J3.2, p.5-73 (ksi): $Ft := 21.0$

Bolt size (in): $d := \frac{5}{8}$

Bolt area (in^2): $A := \left(\frac{\pi}{4}\right) \cdot d^2$ $A = 0.307$

Allowable load (kips): $R := Ft \cdot A$ $R = 6.4$

Load (kips): $L := 2.75$

Number of bolts: $n := 2$

Load per bolt (kips): $s := \frac{L}{n}$ $s = 1.4$

R (6.4) > s (1.4) so bolts are ***OK***.

3. Technical Specification For The Fabrication Of The CDF / COT Flipping Fixture

Technical Specification for

CDF / COT Flipping Fixture Assembly W.B.S. 1.7.1.6.1

1. Assembly

Assembly as detailed on Fermi National Accelerator Laboratory PPD/CDF/COT drawing number 2563.244-ME-339775, *COT Flipping Fixture Assembly*, and all items and drawings called out therein:

- Item 1, drawing 2563.244-MD-339295, *Lifting Assembly*, qty. 1,
- Item 2, drawing 2563.244-MD-339301, *Flipping Spreader Bar Assembly*, qty. 2,
- Item 3, drawing 2563.244-MB-339312, *Swivel Bushing*, qty. 6,
- Item 4, 1-8 UNC 2A x 2.5 Black Finish Heavy Hex Bolt ASTM A325 Type 1 or 2, qty. 2,
- Item 5, 1-8 UNC 2A x 3.5 Black Finish Heavy Hex Bolt ASTM A325 Type 1 or 2, qty. 4,
- Item 6, drawing 2563.244-MC-339289, *Corner Support Bracket*, qty. 4,
- Item 7, 5/8 Black Finish Carbon Steel Lockwasher, qty.24,
- Item 8, 5/8-11 UNC 2A x 2.25 Black Finish Heavy Hex Bolt ASTM A325 Type 1 or 2, qty. 16,
- Item 9, drawing 2563.244-MC-339290, *Endplate Mounting Support*, qty. 4.
- Item 10, Bronze Thrust Bearing, 1"ID x 2"OD x 1/8"thick, McMaster Carr # 5906K524, qty. 4,
- Item 11, drawing 2563.244-MB-339791, *Spreader Bar Shim*, qty. 4.
- Item 12, 5/8-11 UNC 2A x 1.5 Black Finish Heavy Hex Bolt ASTM A325 Type 1 or 2, qty. 8.

Drawings with stamp "Approved for fabrication" will be issued on contract award.

2. Fabrication

All structural steel parts shall be fabricated in strict accordance with the *Code of Standard Practice for Steel Buildings and Bridges* of the American Institute of Steel Construction (AISC), 1986, unless otherwise noted in any of the contractual documents.

All welds shall be in strict accordance with the Structural Welding Code - Steel, of the American Welding Society, *AWS D1.1-92*, unless otherwise noted in any of the contractual documents.

The following items:
Item 4, 1-8 UNC 2A x 3.5 Black Finish Heavy Hex Bolt ASTM A325 Type 1 or 2, qty. 2,
item 5, 1-8 UNC 2A x 3 Black Finish Heavy Hex Bolt ASTM A325 Type 1 or 2, qty. 4,
item 12, 5/8-11 UNC 2A x 1.5 Black Finish Heavy Hex Bolt ASTM A325 Type 1 or 2, qty. 8,
item 9, drawing 2563.244-MC-339290, *Endplate Mounting Support*, qty. 4 and
Lifting Pin, drawing number 2563.244-MB-339297, qty.1,
must be uniquely identified and certified to have been inspected as follows:

- Magnetic Particles according to ASTM E1444/94 and Addenda with no relevant linear indication;
- X-Ray (or Gamma Ray) according to ASTM E94/93 and ASTM E142/92 with no internal defects allowed or, for item 9, ultrasonic testing according to ASTM E388/95 with no internal reflections with response greater than a 3/64" flat bottom hole.

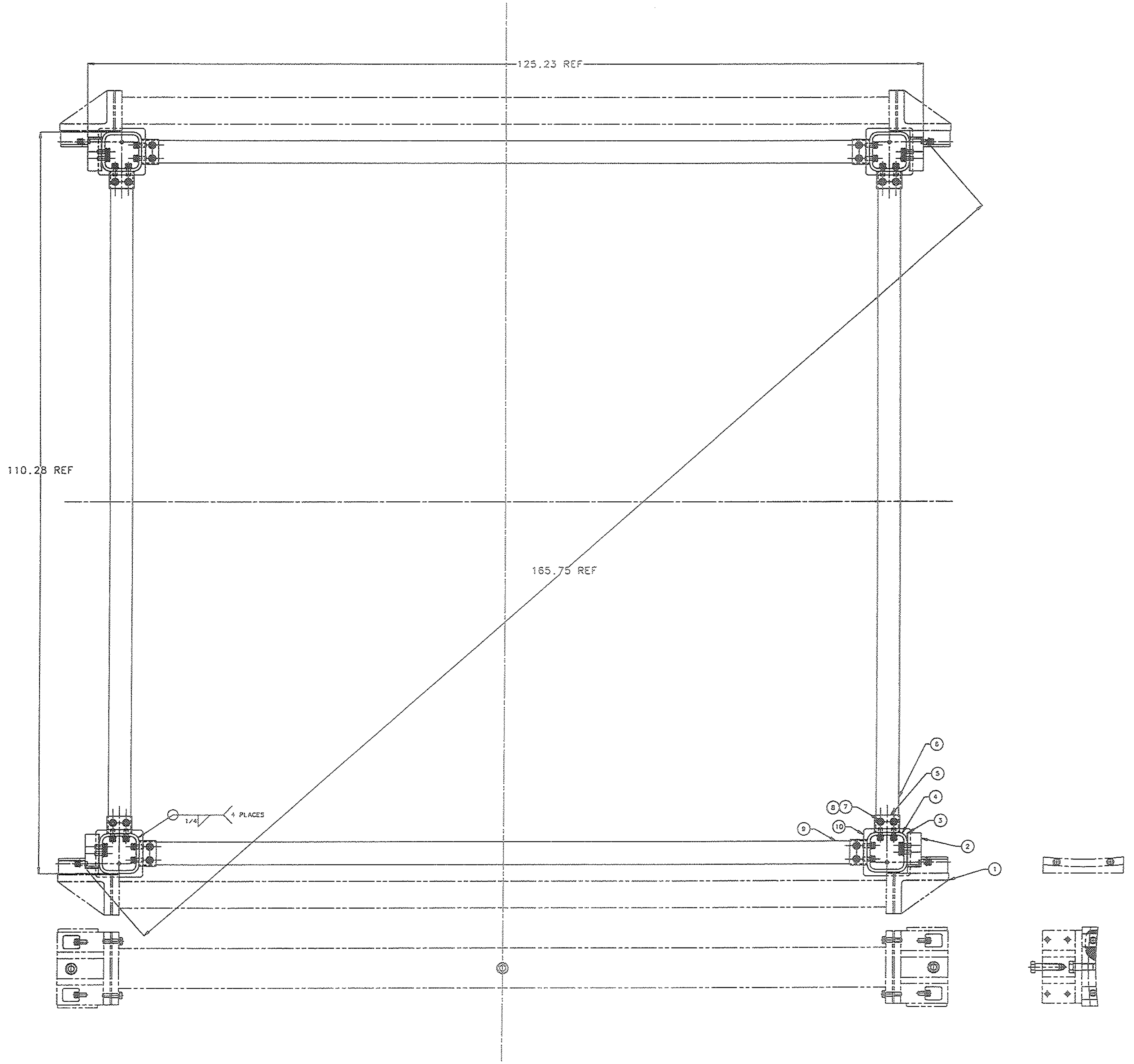
3. Surface Condition

The steel parts may be painted by Fermilab on site and they should be delivered ready to accept primer. Except for threads of tapped holes, all not concealed parts of the assembly shall be:

- thoroughly *cleaned* of all scale, rust and dirt per specifications of the Steel Structure Painting Council (SSPC) "Surface Preparation Specification No. 3, (SP-3), Power Tool Cleaning";
- thoroughly *cleaned* of all oil, grease, salts, and contaminants per specifications of the Steel Structure Painting Council (SSPC) "Surface Preparation Specification No. 1, (SP-1), Solvent Cleaning";
- properly wrapped and packed in order to preserve the cleanliness obtained with the above mentioned cleaning processes and to minimize rust formation.

4. Load Test

The Flipping fixture will be load tested at 125% of the operational load (3,600 lb) so the load test will be at least 4,500 lb. To prevent the application of torques and moments that are not present during operation (due to the rigidity of the COT itself) but that would appear by simply hanging weights from the End Plate Mounting Support, a frame will be built and attached to the Flipping Fixture. The test frame is shown in the drawing next page.



ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.
10	10	TUBING END PLATE	4
9	9	LONG I-BEAM	2
8	COMMERCIAL	5/8 SPRING WASHER	34
7	COMMERCIAL	5/8-11 UNC 2B STEEL ALLEN SHCS	64
6	6	SHORT I-BEAM	2
5	5	ANGLE	16
4	4	TUBING	4
3	3	SHIM	4
2	2	ADAPTER PLATE	4
1	ME - 339773	FLIPPING FIXTURE	1

PARTS LIST

UNLESS OTHERWISE SPECIFIED					
.XX	.XXX	ANGLES	ORIGINATOR	Rafael	09/30/98
± —	± —	± —	DRAWN	Rafael	08/30/98
			CHECKED	Rafael	09/30/98
			APPROVED	Rafael	09/30/98

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5M-1982 STD.
4. ALL DIMENSIONS ARE IN INCHES.

MAX. ALL MACHINED SURFACES

USED ON: —

MATERIAL: —

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

PPD/ETT

COT Flipping Fixture Test Frame Assembly

SCALE	DRAWING NUMBER	SHEET NO	REV
—	—	1 OF 1	—

REV.		DRAWN	DATE
		APPROVED	DATE

5. Drawings

Drawing Number:	Title:
2563.244-ME-339288	PPD/CDF/COT Flipping Arrangement
2563.244-ME-339775	PPD/CDF/COT Flipping Fixture Assembly
2563.244-MC-339289	PPD/CDF/COT Flipping Fixture Corner Support Bracket
2563.244-MC-339290	PPD/CDF/COT Flipping Fixture End Plate Mounting Support
2563.244-MD-339295	PPD/CDF/COT Flipping Fixture Lifting Assembly
2563.244-MB-339297	PPD/CDF/COT Flipping Fixture Lifting Pin
2563.244-MB-339298	PPD/CDF/COT Flipping Fixture Bearing Plate
2563.244-MB-339299	PPD/CDF/COT Flipping Fixture Gusset Plate
2563.244-MD-339301	PPD/CDF/COT Flipping Fixture Spreader Bar Assembly
2563.244-MD-339304	PPD/CDF/COT Flipping Fixture Spreader Bar Weldment
2563.244-MB-339305	PPD/CDF/COT Flipping Fixture Bushing
2563.244-MB-339306	PPD/CDF/COT Flipping Fixture Spreader Bar End Plate
2563.244-MB-339307	PPD/CDF/COT Flipping Fixture Shim Plate
2563.244-MB-339312	PPD/CDF/COT Flipping Fixture Pivot Bushing
2563.244-MB-339791	PPD/CDF/COT Flipping Fixture Spreader Bar Shim

DB

DILL BROTHERS, INC.

3401 20TH STREET
ZION, ILLINOIS 60099-1492
(847) 746-8323-25

FAX: (847)746-0163

Lake County's Finest Fabricating and Machining Servicenter
CNC · NC · TURNING · BORING · MILLING · VMC

FACSIMILE TRANSMITTAL
****

TO: FERMILAB

ATTN: R. SILVA

FAX # 1-630-840-3694

SUBJECT: CERTIFICATIONS

MESSAGE: PAGES 1-3 ARE FOR THE BOLT SHIPPING TODAY. PAGES 4-7 ARE FOR THE BALANCE OF THE HARDWARE - NOTE - THE 16PC QTY. DID NOT REQUIRE TESTING & WAS NOT SHIPPED (THEY WERE TOO SHORT, REF. OUR TELECON OF LAST WEEK, THEY WERE REPLACED WITH THE PROPER LENGTH BOLTS). PAGES 8 & 9 ARE FOR THE ALUMINUM BLOCKS. PAGES 10 + 11 ARE FOR THE STEEL PIN.

THANKS

FROM: D. MORGAN DATE: 11-10-98

PAGES 11 + COVER

DOCUMENT OF CERTIFICATION

MAGNETIC INSPECTION LABORATORY, INC.
1401 GREENLEAF AVENUE
ELK GROVE VILLAGE, IL 60007-5536
(847) 437-4488 FAX (847) 437-4538
NONDESTRUCTIVE TESTING • PRECISION WELDING • METAL FINISHING

JOB NUMB
1925..

CUSTOMER NUMBER	SOLD TO	SHIP TO
40418	DILL BROTHERS, INC. 3401 - 20TH STREET ZION IL 60099-1492	DILL BROTHERS, INC. 3401 20TH STREET ZION

CUSTOMER P.O. NUMBER	DATE RECEIVED	DATE SHIPPED	SHIP VIA	PPD	COLL
1690	11/05/98	11/10/98			

NO CTNS.	PART NUMBER OR DESCRIPTION
001	2563.244ME-33975-4 HEX BOLT

PIECES	WEIGHT	PROCESS	DESCRIPTION
* * * * * *	* * * * * *	* *	DOCUMENT OF CERTIFICATION * * * * * * * *
2			PAGE 1 OF 2
		BGB	BLAST-GLASS BEAD MEDIA TYPE: GLASS BEAD TIME: 10 MIN PRESSURE: 80 PSI
		MPI	MAGNETIC PARTICLE INSPECTION PER ASTM E1444-94A WET,FLUORESCENTVENT INDICATION AMPS CIRC: 600 AMPS LONG: 4500 RESULTS: 1 PC ACCEPTED AND 1 PC REJECTED FOR CRACK
		RDG	RADIOGRAPHY/X-RAY INSPECT PER ASTM E94/93 & ASTM E142/92 LOG#: L007 VIEWS: 2 FILM: 1 (4.5 X 10) 1 PC INSPECTED RESULTS: 1 PC ACCEPTED
		MSS	MISC SERVICES - CHEM SERVICE BLACK OXIDE PER PO (1 PC ONLY)
			THIS IS TO CERTIFY THAT THE ITEMS WERE PROCESSED UNDER THE AFOREMENTIONED P.O. AND THAT THE PROCESS CONFORMS TO THE APPLICABLE SPECIFICATIONS. RECORDS ARE ON FILE IN THE

CONTINUED ON NEXT PAGE

(1)

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MAGNETIC INSPECTION LABORATORY, INC.
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ELK GROVE VILLAGE, IL 60007-5536
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NONDESTRUCTIVE TESTING • PRECISION WELDING • METAL FINISHING

JOB NUMBER
10.95[illegible]

CUSTOMER NUMBER
40418

SOLD TO
DILL BROTHERS, INC.
3401 - 20TH STREET
ZION IL 60099-1492

SHIP TO
DILL BROTHERS, INC.
3401 - 20TH STREET
ZION IL [illegible]

CUSTOMER P.O. NUMBER	DATE RECEIVED		DATE SHIPPED	SHIP VIA	PPD	COLL	SL
1690	11/05/98		11/10/98				

NO. CTNS.	PART NUMBER OR DESCRIPTION
001	2563.244ME-33975-4 HEX BOLT

PIECES	WEIGHT	PROCESS	DESCRIPTION
* * * * * *	* * * * *	* * *	DOCUMENT OF CERTIFICATION * * * * * * * * * PAGE 2 OF 2 CERTIFICATION DEPARTMENT.

TECHNICIAN (S) SIGNATURE (S) D Chiovarie V Vijon R Bachner D Chiovarie

	D CHIOVARIE	V VIJON	R BACHNER	D CHIOVARIE
MIL-STD-410/SNT-TC-1A LVL II EXP DATE	N/A	7/2/2001	4/1/2001	N/A

(2)

ORIGINAL

(3)

MAGNETIC INSPECTIO. LABORATORY, INC.

1401 Greenleaf Ave. Elk Grove Village, IL 60007-5536
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NONDESTRUCTIVE TESTING • PRECISION WELDING • METAL FINISHING

CASTING CERTIFICATION/REPORT

PAGE 1 OF 1

DATE: 11/10/98

CUSTOMER: DILL BROTHERS	P.O. NO.: 1690	SPECIFICATION: ASTM E94-93 AND ASTM E142-92
PART NO.: 2563-244MB-33975-4	CLASSIFICATION:	JOB NO.: 102953
PART NAME: HEX BOLT	MATERIAL TYPE: STL	LOG NO.: L007

FILM USED: NO 1 SIZE 4.5X10 NO ____ SIZE ____ NO ____ SIZE ____ NO ____ SIZE ____

NO. OF PARTS RECEIVED:	NO. OF PARTS X-RAYED:	NO. OF PARTS ACCEPTED:	NO. OF PARTS REJECTED:
1	1	1	0

VIEWS: 2

SERIAL NUMBER:	ACCEPT	REJECT	SHRINKAGE SPONGE	SHRINKAGE FEATHERY	SHRINKAGE CAVITY	SHRINKAGE DENDRITIC	SHRINKAGE FIHAMENTARY	GAS HOLES	GAS POROSITY	SEGREGATION	FOREIGN MAT'L LESS DENSE	FOREIGN MAT'L MORE DENSE	CRACK	COLD SHUT	HOT TEAR	MISRUN	CORE SHIFT	COLUMNAR	MOTTLED	SURFACE	REMARKS
1	X								-												

INTERPRETER: [signature] | STAMP RT-3 | ASNT-TC-1A LEVEL II/III: II | EXPIRATION DATE: 4/1/2001

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NONDESTRUCTIVE TESTING • PRECISION WELDING • METAL FINISHING

JOB NUMBER
102677

CUSTOMER NUMBER	SOLD TO	SHIP TO
40418	DILL BROTHERS, INC. 3401 - 20TH STREET ZION IL 60099-1492	DILL BROTHERS, INC. 3401 - 20TH STREET ZION IL 60099-1492

CUSTOMER P.O. NUMBER	DATE RECEIVED		DATE SHIPPED	SHIP VIA	PPD	COLL	SLSM
1684	10/30/98		11/4/98				

NO. CTNS.	PART NUMBER OR DESCRIPTION
001	MULTI

PIECES	WEIGHT	PROCESS	DESCRIPTION
* * * * * *	* * * * *	* * *	DOCUMENT OF CERTIFICATION * * * * * * * * * *
30			PAGE 1 OF 2
		BGB	BLAST-GLASS BEAD
			MEDIA: GLASS BEAD
			PRESSURE: 80 PSI
		MPI	MAGNETIC PARTICLE INSPECTION
			PER ASTM E1444-94A
			WET,FLUORESCENT
			P/N 2563-244-ME-339775-4
			AMPS CIRC: 500 AMPS LONG: 3000
			P/N 2563-244-ME-339775-5
			AMPS CIRC: 500 AMPS LONG: 3750
			2563-244-339775-8
			AMPS CIRC: 300 AMPS LONG: 4500
			P/N 2563-244-ME-339775-12
			AMPS CIRC: 300 AMPS LONG: 3000
			RESULTS: 29 PCS ACCEPTED
			1 PC REJECTED FOR SEAMS
		RDG	RADIOGRAPHY/X-RAY INSPECT
			PER ASTM E94/93 & ASTM E142/92
			NO INTERNAL DEFECTS
			LOG# L001 VIEWS: 2
			RESULTS: 29 PCS ACCEPTED
		MSS	MISC SERVICES - CHEM SERVICE
			BLACK OXIDE PER PO
			2563-244-ME-339775-4 QTY:2
			2563-244-ME-339775-5 QTY:4
			2563-244-ME-339775-8 QTY:16
			2563-244-ME-339775-12 QTY:8
			THIS IS TO CERTIFY THAT THE

(4)

CONTINUED ON NEXT PAGE

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NONDESTRUCTIVE TESTING • PRECISION WELDING • METAL FINISHING

JOB NUMBER
102677

CUSTOMER NUMBER	SOLD TO	SHIP TO
40418	DILL BROTHERS, INC. 3401 - 20TH STREET ZION IL 60099-1492	DILL BROTHERS, INC. 3401 - 20TH STREET ZION IL 60099-1492

CUSTOMER P.O. NUMBER	DATE RECEIVED		DATE SHIPPED	SHIP VIA	PPD	COLL	SLSM
1684	10/30/98		11/4/98				

NO. CTNS.	PART NUMBER OR DESCRIPTION
001	MULTI

PIECES	WEIGHT	PROCESS	DESCRIPTION
* * * * * *	* * * * * *	* * *	DOCUMENT OF CERTIFICATION * * * * * * * * * * PAGE 2 OF 2 ITEMS WERE PROCESSED UNDER THE AFOREMENTIONED P.O. AND THAT THE PROCESS CONFORMS TO THE APPLICABLE SPECIFICATIONS. RECORDS ARE ON FILE IN THE CERTIFICATION DEPARTMENT.

TECHNICIAN (S) SIGNATURE (S) D CHIOVARIE J LOSARIA R BACHNER D CHIC

MIL-STD-410/SNT-TC-1A LVL II EXP DATE N/A 4/6/2001 7/1/2001 N

(5)

ORIGINAL

(6)

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NONDESTRUCTIVE TESTING • PRECISION WELDING • METAL FINISHING

CASTING CERTIFICATION/REPORT

DATE: 11/4/98

CUSTOMER: DILL BROTHERS
P.O. NO.: 1684
SPECIFICATION: ASTM E94/93 & ASTM E142/92, NO INTERNAL DEFECTS

PART NO.: 2563-244-ME-339775-4-5-8-12
CLASSIFICATION:
JOB NO.: 102677
FILM USED: NO 5 SIZE 8X10 NO ____ SIZE ____ NO ____ SIZE ____ NO ____ SIZE ____

PART NAME: BOLTS
MATERIAL TYPE: STL
LOG NO.: L001

NO. OF PARTS RECEIVED: 29
NO. OF PARTS X-RAYED: 29
NO. OF PARTS ACCEPTED: 29
NO. OF PARTS REJECTED: 0

VIEWS: 2

SERIAL NUMBER	ACCEPT	REJECT	SHRINKAGE SPONGE	SHRINKAGE FEATHERY	SHRINKAGE CAVITY	SHRINKAGE DENDRITIC	SHRINKAGE FIHAMENTARY	GAS HOLES	GAS POROSITY	SEGREGATION	FOREIGN MAT'L LESS DENSE	FOREIGN MAT'L MORE DENSE	CRACK	COLD SHUT	HOT TEAR	MISRUN	CORE SHIFT	COLUMNAR	MOTTLED	SURFACE	REMARKS
-4 #1	X																				
-5 #1	X																				
2	X																				
3	X																				
4	X																				
-8 1	X																				
2	X																				
3	X																				
4	X																				
5	X																				
6	X																				
7	X																				
8	X																				
9	X																				
10	X																				
11	X																				
12	X																				
13	X																				
14	X																				
15	X																				
16	X																				
-12 1	X																				

INTERPRETER: [signature]
STAMP
ASNT-TC-1A LEVEL II/III:
EXPIRATION DATE:

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CASTING CERTIFICATION/REPORT

PAGE 2 OF 2

DATE: 11/4/98

CUSTOMER: DILL BROTHERS	P.O. NO.: 1684	SPECIFICATION: ASTM E94/93 & ASTM E142/92, NO INTERNAL DEFECTS
PART NO.: 2563-244-ME-339775-4-5-8-12	CLASSIFICATION:	JOB NO.: 102677
PART NAME: BOLTS	MATERIAL TYPE: STL	LOG NO.: L001

FILM USED: NO 5 SIZE 8X10 NO ___ SIZE ___ / NO ___ SIZE ___ NO ___ SIZE ___

NO. OF PARTS RECEIVED:	NO. OF PARTS X-RAYED:	NO. OF PARTS ACCEPTED:	NO. OF PARTS REJECTED:
29	29	29	0

VIEWS: 2

SERIAL NUMBER:	ACCEPT	REJECT	SHRINKAGE SPONGE	SHRINKAGE FEATHERY	SHRINKAGE CAVITY	SHRINKAGE DENDRITIC	SHRINKAGE FIHAMENTARY	GAS HOLES	GAS POROSITY	SEGREGATION	FOREIGN MAT'L LESS DENSE	FOREIGN MAT'L MORE DENSE	CRACK	COLD SHUT	HOT TEAR	MISRUN	CORE SHIFT	COLUMNAR	MOTTLED	SURFACE	REMARKS
-12 2	X																				
3	X																				
4	X																				
5	X																				
6	X																				
7	X																				
8	X																				

INTERPRETER: | STAMP | ASNT-TC-1A LEVEL II/III: | EXPIRATION DATE:

DOCUMENT OF CERTIFICATION

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NONDESTRUCTIVE TESTING • PRECISION WELDING • METAL FINISHING

JOB NUMBER
102614

CUSTOMER NUMBER	SOLD TO	SHIP TO
40418	DILL BROTHERS, INC. 3401 - 20TH STREET ZION IL 60099-1492	DILL BROTHERS, INC. 3401 - 20TH STREET ZION IL 60099-1492

CUSTOMER P.O. NUMBER	DATE RECEIVED		DATE SHIPPED	SHIP VIA	PPD	COLL	SLSM
1682	10/29/98		10/30/98				

NO. CTNS.	PART NUMBER OR DESCRIPTION
001	2563-244-MC-339290 END PLATE MOUNTING SUPPORT

PIECES	WEIGHT	PROCESS	DESCRIPTION
* * * * * *	* * * * * *	* * *	DOCUMENT OF CERTIFICATION * * * * * * * * * *
4			
		PNT	FLUORESCENT PENETRANT INSPECT PER MIL-STD-6866, ACCEPT PER MIL-STD-1907, TABLE I, GRADE A PENETRANT: ZL60D TIME: 30 MIN DEVELOPER: ZP4B TIME: 10 MIN RESULTS: ALL PCS ACCEPTED
		RDG	RADIOGRAPHY/X-RAY INSPECT PER MIL-STD-453C LOG#: K034 VIEWS: 2EDI FILM: 8 (7X17) RESULTS: ALL PCS ACCEPTED
			THIS IS TO CERTIFY THAT THE ITEMS WERE PROCESSED UNDER THE AFOREMENTIONED P.O. AND THAT THE PROCESS CONFORMS TO THE APPLICABLE SPECIFICATIONS. RECORDS ARE ON FILE IN THE CERTIFICATION DEPARTMENT. TECHNICIAN (S) SIGNATURE (S) J FLENTGE R BACHNER MIL-STD-410/SNT-TC-1A LVL II EXP DATE 9/9/99 4/1/2001

(8)

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(9)

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CASTING CERTIFICATION/REPORT

PAGE 1 OF 1

DATE: 10/30/98

CUSTOMER: DILL BROTHERS	P.O. NO.: 1682	SPECIFICATION: MIL-STD-453, REV C
PART NO.: 2563-244-MC-339290	CLASSIFICATION:	JOB NO.: 102614
PART NAME: END PLATE	MATERIAL TYPE: 6061-T6	LOG NO.: K034

FILM USED: NO 8 SIZE 7X17 NO ___ SIZE ___ ; NO ___ SIZE ___ NO ___ SIZE ___

NO. OF PARTS RECEIVED:	NO. OF PARTS X-RAYED:	NO. OF PARTS ACCEPTED:	NO. OF PARTS REJECTED:
4	4	4	0

VIEWS: 2

SERIAL NUMBER:	ACCEPT	REJECT	SHRINKAGE SPONGE	SHRINKAGE FEATHERY	SHRINKAGE CAVITY	SHRINKAGE DENDRITIC	SHRINKAGE FIHAMENTARY	GAS HOLES	GAS POROSITY	SEGREGATION	FOREIGN MAT'L LESS DENSE	FOREIGN MAT'L MORE DENSE	CRACK	COLD SHUT	HOT TEAR	MISRUN	CORE SHIFT	COLUMNAR	MOTTLED	SURFACE	REMARKS
1	X																				NO INDICATIONS ALLOWED
2	X																				
3	X																				
4	X																				

INTERPRETER:	STAMP	ASNT-TC-1A LEVEL II/III:	EXPIRATION DATE:
R Bachner (signature) R BACHNER	RT-3	II	4/1/2001

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JOB NUMBER
102613

CUSTOMER NUMBER	SOLD TO	SHIP TO
40418	DILL BROTHERS, INC. 3401 - 20TH STREET ZION IL 60099-1492	DILL BROTHERS, INC. 3401 - 20TH STREET ZION IL 60099 1492

CUSTOMER P.O. NUMBER	DATE RECEIVED		DATE SHIPPED	SHIP VIA	PPD	COLL	SLS
1682	10/29/98		10/30/98				

NO. CTNS.	PART NUMBER OR DESCRIPTION
001	2563-244-MB-339297 LIFTING PIN

PIECES	WEIGHT	PROCESS	DESCRIPTION
* * * * * *	* * * * * *	* * *	DOCUMENT OF CERTIFICATION * * * * * * * * * *
1			
		MPI	MAGNETIC PARTICLE INSPECTION PER ASTM E1444-94A WET, FLUORESCENT AMPS CIRC: 900 AMPS LONG: 2000 RESULTS: ACCEPTED
		RDG	RADIOGRAPHY/X-RAY INSPECT PER ASTM E94/93 & ASTM E142/92 LOG#: K033 VIEWS: 4 FILM: 5 (8X10) RESULTS: ACCEPTED
			THIS IS TO CERTIFY THAT THE ITEMS WERE PROCESSED UNDER THE AFOREMENTIONED P.O. AND THAT THE PROCESS CONFORMS TO THE APPLICABLE SPECIFICATIONS. RECORDS ARE ON FILE IN THE CERTIFICATION DEPARTMENT. TECHNICIAN (S) SIGNATURE (S) D Solano R Bachner D SOLANO R BACHNER MIL-STD-410/SNT-TC-1A LVL II EXP DATE 5/31/99 4/1/2001

(10)

ORIGINAL

(1)

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NONDESTRUCTIVE TESTING • PRECISION WELDING • METAL FINISHING

CASTING CERTIFICATION/REPORT

PAGE 1 OF 1

DATE: 10/30/98

CUSTOMER: DILL BROTHERS, INC	P.O. NO.: 1682	SPECIFICATION: NO INDICATIONS ALLOWED
PART NO.: 2563-244-MB-339297	CLASSIFICATION:	JOB NO.: 102613
PART NAME:	MATERIAL TYPE: STL	LOG NO.: K033

FILM USED: NO 5 SIZE 8X10 NO ___ SIZE ___ / NO ___ SIZE ___ NO ___ SIZE ___

NO. OF PARTS RECEIVED:	NO. OF PARTS X-RAYED:	NO. OF PARTS ACCEPTED:	NO. OF PARTS REJECTED:
1	1	1	

VIEWS: 4

SERIAL NUMBER:	ACCEPT	REJECT	SHRINKAGE SPONGE	SHRINKAGE FEATHERY	SHRINKAGE CAVITY	SHRINKAGE DENDRITIC	SHRINKAGE FILAMENTARY	GAS HOLES	GAS POROSITY	SEGREGATION	FOREIGN MAT'L LESS DENSE	FOREIGN MAT'L MORE DENSE	CRACK	COLD SHUT	HOT TEAR	MISRUN	CORE SHIFT	COLUMNAR	MOTTLED	SURFACE	REMARKS
1	X																				

INTERPRETER:	STAMP	ASNT-TC-1A LEVEL II/III:	EXPIRATION DATE:
R Backnes (signature)	RT-3	II	4/1/2001

DOCUMENT OF CERTIFICATION

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NONDESTRUCTIVE TESTING • PRECISION WELDING • METAL FINISHING

JOB NUMBER
102950

CUSTOMER NUMBER	SOLD TO	SHIP TO
40418	DILL BROTHERS, INC. 3401 - 20TH STREET ZION IL 60099-1492	DILL BROTHERS, INC. 3401 - 20TH STREET ZION IL 60099-1492

CUSTOMER P.O. NUMBER	DATE RECEIVED		DATE SHIPPED	SHIP VIA	PPD	COLL	SLS
1690	11/05/98		11/10/98				

NO. CTNS.	PART NUMBER OR DESCRIPTION
	2563.244ME-33975-4
001	HEX BOLT

PIECES	WEIGHT	PROCESS	DESCRIPTION
* * * * * *	* * * * * *	* *	DOCUMENT OF CERTIFICATION * * * * * * * * *
2			PAGE 1 OF 2
		BGB	BLAST-GLASS BEAD MEDIA TYPE: GLASS BEAD TIME: 10 MIN PRESSURE: 80 PSI
		MPI	MAGNETIC PARTICLE INSPECTION PER ASTM E1444-94A WET,FLUORESCENTVENT INDICATION AMPS CIRC: 600 AMPS LONG: 4500 RESULTS: 1 PC ACCEPTED AND 1 PC REJECTED FOR CRACK
		RDG	RADIOGRAPHY/X-RAY INSPECT PER ASTM E94/93 & ASTM E142/92 LOG#: L007 VIEWS: 2 FILM: 1 (4.5 X 10) 1 PC INSPECTED RESULTS: 1 PC ACCEPTED
		MSS	MISC SERVICES - CHEM SERVICE BLACK OXIDE PER PO (1 PC ONLY)
			THIS IS TO CERTIFY THAT THE ITEMS WERE PROCESSED UNDER THE AFOREMENTIONED P.O. AND THAT THE PROCESS CONFORMS TO THE APPLICABLE SPECIFICATIONS. RECORDS ARE ON FILE IN THE

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NONDESTRUCTIVE TESTING • PRECISION WELDING • METAL FINISHING

JOB NUMBER
102953

CUSTOMER NUMBER
40418

SOLD TO
DILL BROTHERS, INC.
3401 - 20TH STREET
ZION IL 60099-1492

SHIP TO
DILL BROTHERS, INC.
3401 - 20TH STREET
ZION IL 60099-14

CUSTOMER P.O. NUMBER	DATE RECEIVED		DATE SHIPPED	SHIP VIA	PPD	COLL	SL
1690	11/05/98		11/10/98				

NO. CTNS.	PART NUMBER OR DESCRIPTION
	2563.244ME-33975-4
001	HEX BOLT

PIECES	WEIGHT	PROCESS	DESCRIPTION
* * * * * *	* * * * * * * *		DOCUMENT OF CERTIFICATION * * * * * * * * * * PAGE 2 OF 2 CERTIFICATION DEPARTMENT.

TECHNICIAN (S) SIGNATURE (S) D Chiovarie V Vizjon R Bachner D Chiovarie

	D CHIOVARIE	V VIZJON	R BACHNER	D CHIOVARIE
MIL-STD-410/SNT-TC-1A LVL II EXP DATE	N/A	7/2/2001	4/1/2001	N/A

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NONDESTRUCTIVE TESTING • PRECISION WELDING • METAL FINISHING

CASTING CERTIFICATION/REPORT

DATE: 1/10/98

CUSTOMER: DILL BROTHERS	P.O. NO.: 1690	SPECIFICATION: ASTM E94-93 AND ASTM E142-92
PART NO.: 2563-244ME-33975-4	CLASSIFICATION:	JOB NO.: 102953
PART NAME: HEX BOLT	MATERIAL TYPE: STL	LOG NO.: L007

FILM USED: NO 1 SIZE 4.5X10 NO ___ SIZE ___ ; NO ___ SIZE ___ NO ___ SIZE ___

NO. OF PARTS RECEIVED:	NO. OF PARTS X-RAYED:	NO. OF PARTS ACCEPTED:	NO. OF PARTS REJECTED:
1	1	1	0

VIEWS: 2

SERIAL NUMBER:	ACCEPT	REJECT	SHRINKAGE SPONGE	SHRINKAGE FEATHERY	SHRINKAGE CAVITY	SHRINKAGE DENDRITIC	SHRINKAGE FIHAMENTARY	GAS HOLES	GAS POROSITY	SEGREGATION	FOREIGN MAT'L LESS DENSE	FOREIGN MAT'L MORE DENSE	CRACK	COLD SHUT	HOT TEAR	MISRUN	CORE SHIFT	COLUMNAR	MOTTLED	SURFACE	REMARKS
1	X																				

INTERPRETER:	STAMP	ASNT-TC-1A LEVEL II/III:	EXPIRATION DATE:
R Brachnek (signature)	RT-3	II	4/1/2001

DILL BROTHERS, INC.
3401 - 20TH STREET
ZION, IL 60099
(847) 746-8323
FAX (847) 746-0163

SHIPPER
~~INVOICE~~

SALESPERSON	DATE OF INVOICE
	11/10/98
SHIP TO	

FERMI NATIONAL ACCELERATOR LAB
RECEIVING WAREHOUSE 2
KIRK RD. & WILSON STREET
BATAVIA, IL. 60510

ACCOUNT	DATE SHIPPED	SHIPPED VIA	COL	PP	F O B POINT	TERMS	YOUR ORDER NUMBER
	11/10	UPS-NEXT DAY					514958

QUANTITY	DESCRIPTION	UNIT PRICE	AMOUNT
1	2563-244-ME-339775-4 -		
	1"-8 UNC-2A X 2.50 LG.		
	BLACK FINISH HEAVY HEX BOLT ASTM A325		
		TOTAL	

From: FNALD::RAFAEL "J. Rafael Silva - (630)840-8311" 4-NOV-1998 15:07:◆
To: @CDF_SF
CC: @CDF_FYI,RAFAEL
Subj: Presentation of the CDF/COT Flipping Fixture EN to Safety Review

Hi,

Based on the availability of the four members of the CDF mechanical safety committee, I was able to reserve the

Hornet Nest meeting room,located at WH11NW,
^^^^^^

for my presentation of the CDF / COT Flipping Fixture Engineering Note to the Safety Committee, for

tomorrow, Thursday, 11/05/98, from 2:30pm to 4:30pm.
^^^^^^

Thanks,

Rafael

From: FNALD::RAFAEL "J. Rafael Silva - (630)840-8311" 5-NOV-1998 17:47:◆
To: @CDF_SF
CC: RAFAEL
Subj: Spreader Bar Tubing Checking

Hi,

For the 6x4x1/2 tubing of the spreader bar, considering:

K =	1	
Fy =	46	ksi
E =	29000	ksi
l =	115.00	in
r =	1.48	in
Sx =	11.8	in3
P =	2750	lb
A =	8.36	in2
J =	42.1	in4
tf =	0.5	in
tw =	0.5	in
Ix =	35.3	in4

From AISC / ASD:

For Compression:	Eq. E2-1,	Fa = 18.5 ksi
For Bending :	(b/t = 5 < 28 & d/tw = 12 < 37) Eq. F3-1,	Fb = 30.4 ksi
For Shear :	(h/tw = 12 < 56) Eq. F4-1,	Fs = 18.4 ksi

And from hand calculations:

For a beam simply supported with a concentrated load (2750 lb) at center:
Maximum Bending Stresses : 6.7 ksi
Maximum Shear Stresses : 0.3 ksi

For a beam fixed at the ends with a torsional moment (8335 in-lb) at center:
Maximum Tosional Shear Stresses: 0.4 ksi

The Von Mises Stress from FEA was 7.5 ksi (SF = 6.1 - i.r.t. Fy)

It seems to be far away from the limits.

Rafael

Item: c

File: E2_c.mcd

Allowable Stresses - Compression

AISC / ASD, 9th ed., p.5-42, sect. E2., allowable stresses:

COT Flipping Fixture - Spreader bar tubing
Note: Material is Bronze instead of structural steel
K: Table C-C2.1, p.5-135:

$K := 1$ (conservative)

Mechanical properties of material (ksi):

$Fy := 46 \qquad E := 29000$

Unbraced length of column - conservative (in):

$l := 115.00$

Governing radius of gyration (in):

$r := 1.48$

Allowable stresses (ksi):

$$Cc := \sqrt{\frac{2\cdot\pi^2\cdot E}{Fy}} \qquad Cc = 111.6 \qquad \frac{K\cdot l}{r} = 77.7$$

$$Fa1 := \frac{\left[1 - \left[\frac{\left(\frac{K\cdot l}{r}\right)^2}{2\cdot Cc^2}\right]\right]\cdot Fy}{\frac{5}{3} + \frac{3\cdot\left(\frac{K\cdot l}{r}\right)}{8\cdot Cc} - \frac{\left(\frac{K\cdot l}{r}\right)^3}{8\cdot Cc^3}} \qquad Fa1 = 18.5 \qquad \text{(E2-1)}$$

$$Fa2 := \frac{12\cdot\pi^2\cdot E}{23\cdot\left(\frac{K\cdot l}{r}\right)^2} \qquad Fa2 = 24.7 \qquad \text{(E2-2)}$$

$$Fa := \text{if}\left[\left[\left(\frac{K\cdot l}{r}\right) > Cc\right], Fa2, Fa1\right]$$

This means that if (K.l/r) > Cc, Fa = Fa2, otherwise Fa =Fa1.

Hence: $Fa = 18.5$

==================== VARIABLE SHEET ==

St	Input----	Name---	Output---	Unit-----	Comment------------------------------
					Table 20 Roark & Young (6 ed)
					Formulas for Torsional Deformation
					and Stress; Page 348-359
		matl#			Material Number from Properties Table
		matl			Material
	8335.25	torque		lb-in	Twisting Moment (Torque), T
		t20th	.0021	rad	Angle of Twist, theta
	115	length		in	Length of Section, L
	1.12E7	G		psi	Modulus of Rigidity, G
		K	41.1736	in^4	Torsional Stiffness Constant, K
					Average Shear Stress:
		tau1	433	psi	Near Midlength of Long Sides
		tau	433	psi	Near Midlength of Short Sides
					Sect 16: Hollow Rectangle - Thin Wall
		DIAGRAM	'y		Generate section diagram? ('n = no)
	6	t20a		in	Long Side, a
	.5	t20t1		in	Thickness of Long Side, t1
	4	t20b		in	Short Side, b
	.5	t20t		in	Thickness of Short Side, t
		Q1	19.25	in^3	Shear Stress Constant - Long Side, Q1
		Q	19.25	in^3	Shear Stress Constant - Short Side, Q

TORSION

$f_v = \tau_{bx} + \tau_{by} + \tau_t$ (4.10) , $\tau_{bx} = 0$

$\tau_{by} = \frac{V}{A_v}$, $\tau_t = \frac{T}{2tA_0}$

$6 \times 4 \times 1/2$, $P = 2{,}750$ lb

$V = \frac{P}{2} = 1.375$ kips $T = 2.75 \times 3.031 = 8.335$ kips-in

$A_v = A/2 = 8.36/2 = 4.18$

FROM JOINT 3 DESIGN: $A_0 = 16.0$ in²

$\tau_{by} = \frac{1.35}{4.18} = .323$

$\tau_t = \frac{8.335}{2 \times (1/2) \times 16} = .521$

$f_v = .323 + .521$

$\Rightarrow f_v = .844$

COMBINED: (4.2la)

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} + \frac{f_v}{F_v} \leq 1.0 \Rightarrow \frac{6.7}{18.5} + \frac{6.7}{30.4} + \frac{0.8}{18.4} \leq 1.0$$

$\Rightarrow .36 + .22 + .04 = .626 \leq 1.0 \Rightarrow$ OK.

```
From:    SMTP%"alee@rdeag1" 16-NOV-1998 10:00:58.02
To:      RAFAEL
CC:
Subj:

Message-Id: <9811161617.AA06226@rdeag1>
To: RAFAEL@fnald.fnal.gov
Subject:
Date: Mon, 16 Nov 98 10:17:36 -0600
From: alee@rdeag1
X-Mts: smtp


------- Forwarded Message

Return-Path: rucinski@fnal.gov
Received: from fnal.fnal.gov by rdeag1; (5.65/1.1.8.2/21Mar96-0305PM)
        id AA10720; Fri, 6 Nov 1998 17:19:00 -0600
Received: from d0-russlp ("port 2825"@d0-russlp.fnal.gov)
 by FNAL.FNAL.GOV (PMDF V5.1-10 #3998)
 with SMTP id <01J3UZWBUK4E0000VQ@FNAL.FNAL.GOV> for ALEE@RDEAG1.FNAL.GOV; Fri,
 6 Nov 1998 17:02:27 -0500 CST
Date: Fri, 06 Nov 1998 17:00:02 +0000
From: Russ Rucinski <rucinski@fnal.gov>
Subject: COT flipping fixture comments
To: lange@admail.fnal.gov
Cc: howell@fnal.gov, alee@fnal.gov
Message-Id: <01J3UZWBV5S00000VQ@FNAL.FNAL.GOV>
Mime-Version: 1.0
X-Mailer: Pegasus Mail for Windows (v2.32)
Content-Type: text/plain; charset=US-ASCII
Content-Transfer-Encoding: 7BIT
Priority: normal
Comments: Authenticated sender is <rucinski@popgtw.fnal.gov>
```

Regarding the COT flipping fixture;

Item a FEA parameters have the incorrect modulus of elasticity. The item is steel, but the modulus is for aluminum. It may just be a typo, and the analysis was done correctly, I'm not sure.

I am curious, what the displacements are for item c. All the FEA plots show stresses with no displacements listed.

Please pass these items along with the other member's comments. If they are resolved to the rest of our committee's satisfaction, then I would endorse approval of the use of the fixture pending the load test and written procedure.

Russ

------- End of Forwarded Message

From: FNALD::RAFAEL "J. Rafael Silva - (630)840-8311" 17-NOV-1998 14:33:◆
To: @CDF_SF
CC: RAFAEL
Subj: Russ' questions

Hi,

Here the answers:

> Regarding the COT flipping fixture;

> Item a FEA parameters have the incorrect modulus of elasticity. The
> item is steel, but the modulus is for aluminum. It may just be a
> typo, and the analysis was done correctly, I'm not sure.

It is a typo. The modulus used was 30,000,000 psi.

> I am curious, what the displacements are for item c. All
> the FEA plots show stresses with no displacements listed.

Maximum Deformation:

X: .89" (top members)
Y: .14" (vertical and top members)
Z: .0001"

The load test was done on 11/12/98, with no visually detectable residual deformation. It also preformed very well as far as the flipping function.

We (Bob, Aseet, Ken, Stanek, myself) are writing the procedure for the whole operation, and it should be ready tomorrow, but it needs also to be approved by the division. As we intend to use the fixture this coming Saturday, please let me know if you need to review any aspect of this procedure for your approval.

Thanks,

Rafael

\\ROSE\Mech_Sys.MSD\USERS\RAFAEL\Data\Current\cdf\COT\Flipping

File Edit View Help

Flipping

Name	Size	Type	Modified
B5_g.mcd	4KB	Mathcad 4.0	10/20/98 12:13 PM
B5_i.mcd	4KB	Mathcad 4.0	10/20/98 4:38 PM
C15_i.mcd	5KB	Mathcad 4.0	10/20/98 6:53 PM
C16_d.mcd	6KB	Mathcad 4.0	11/2/98 6:09 PM
C26_g.mcd	5KB	Mathcad 4.0	11/2/98 8:05 PM
Comp_i.mcd	4KB	Mathcad 4.0	10/20/98 7:04 PM
E2_i.mcd	5KB	Mathcad 4.0	10/20/98 6:55 PM
Ecc_Sh_Ult_Str.mcd	4KB	Mathcad 4.0	10/26/98 11:58 PM
EP_h.mcd	8KB	Mathcad 4.0	10/28/98 6:29 PM
F2.1_d.mcd	4KB	Mathcad 4.0	10/16/98 11:30 AM
F3.1_g.mcd	4KB	Mathcad 4.0	10/20/98 12:37 PM
F3.1_i.mcd	4KB	Mathcad 4.0	10/20/98 5:11 PM
H1_i.mcd	5KB	Mathcad 4.0	10/20/98 6:59 PM
Joint1.mcd	6KB	Mathcad 4.0	11/2/98 7:51 PM
Joint2.mcd	6KB	Mathcad 4.0	11/2/98 6:22 PM
Joint3.mcd	7KB	Mathcad 4.0	11/2/98 6:29 PM
Joint4.mcd	7KB	Mathcad 4.0	11/2/98 6:33 PM
Joint5.mcd	8KB	Mathcad 4.0	11/2/98 6:48 PM
Joint6.mcd	6KB	Mathcad 4.0	11/2/98 6:51 PM
JointA.mcd	4KB	Mathcad 4.0	10/29/98 10:16 AM
JointB.mcd	4KB	Mathcad 4.0	10/29/98 10:14 AM
JointC.mcd	6KB	Mathcad 4.0	10/28/98 10:34 PM
JointD.mcd	4KB	Mathcad 4.0	10/29/98 10:13 AM
T_C.mcd	8KB	Mathcad 4.0	10/28/98 11:53 PM
Th_C.mcd	7KB	Mathcad 4.0	10/27/98 1:08 PM
FEA_a_cases.xls	17KB	Microsoft Excel Worksheet	10/16/98 3:41 PM
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Flipping_members.xls	23KB	Microsoft Excel Worksheet	11/2/98 8:07 PM
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Welds.xls	17KB	Microsoft Excel Worksheet	11/2/98 2:50 PM
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FEA_b.doc	14KB	Microsoft Word Document	10/16/98 1:43 PM
FEA_c.doc	30KB	Microsoft Word Document	10/16/98 3:41 PM
FEA_e.doc	14KB	Microsoft Word Document	10/28/98 1:20 AM
Flipping_EN.doc	101KB	Microsoft Word Document	11/3/98 11:22 AM
req_flipping.doc	99KB	Microsoft Word Document	8/12/98 1:37 PM
TS_REQ_Flipping_structure.doc	17KB	Microsoft Word Document	9/2/98 3:24 PM

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