BELOW-THE-HOOK LIFTING DEVICE
Engineering Note Cover Page of #MD-ENG-066

Lifting Device Numbers:

FNAL Site No/ ________ (If applicable) Div. Specific No. **151** (If applicable) Asset No. ________ (If applicable)

ASME B30.20 Group: (check one)

- [**X**] 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 **Spreader Bar for SM3 Disassembly & VM Assembly**

Device was (check all applicable)

- [ ] Purchased from a Commercial Lifting Device Manufacturer. Mfg Name ________
- [**X**] Designed and Built at Fermilab **See eng. drawing ME – 407814 for details**.
- [ ] Designed by Fermilab and Built by a Vendor. Assy drawing number ________
- [ ] Provided by a User or other Laboratory ________
- [ ] Other: Describe ________

Engineering Note Prepared by **James Kilmer, Edward Chi** Date **Dec. 20, 2004**

Engineering Note Reviewed by **Dave Pushka** Date **Dec. 22, 2004**

Lifting Device Data:

Capacity **16,600 lbs**.

Fixture Weight **1,400 lbs**.

Service: [X] 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 ________

Rated Load Test by FNAL (if applicable) Date ________ Load ________

[ ] Check if Load Test was by Vendor and attach the certificate

Satisfactory Load Test Witnessed by: ________

Signature (of Load Test Witness) ________

Notes or Special Information:

1. **The spreader bar was originally designed for Mino project. It was modified to retrofit the applications of the SM3 disassembly and VM assembly**.
2. **See pages 13, 14 & 15 for load tes**t.

Fermilab

Particle Physics Division
Mechanical Department Engineering Note

Number: MD-ENG- 066 Date: Dec. 20, 2004

Project Internal Reference:

Project: BTeV, SMTF

Title: Spreader Bar for SM3 Disassembly and Vertex Magnet Assembly

Author(s): James Kilmer, Edward Chi

Reviewer(s): Dave Pushka

Key Words: Spreader Bar, Lifting, Allowable stress, Eccentric, Torsional Shear, Primary shear, Bolt, Weld size, torque.

Abstract Summary: The spreader bar was originally designed for the application of the Mino project. It was modified to retrofit the applications for handling the different coils in multiple positions. The working stresses, welding sizes and bolt selections subject the different applications have been presented for discussion per related specifications codes.

Applicable Codes:

ASME B30.20, "Below the Hook Lifting Devices"
(#5022, ES&H manual, FermiLab)
"Allowable Stress Design", AISC, 9th edition
ANSI/AWS D1.1-90, "Structural Welding Code-Steel"

Analysis and Calculations of Spreader Bar for Coil Handling During SM3 disassembly and VM assembly

Background:

Reuse the existing spreader bar of the Mino project to modified it, to retrofit the multiple coil handling applications during SM3 disassembly and VM assembly process. It is not only a design approach, but also it is a budgetary and environmental approach. Figure 1 shows an isometric view of one of the application of the spreader bar.

Reference Drawings and Others:

1. ME – 397459, ME – 397326;
   MD – 397452,
2. "Steel Structure Design and Behavior" by C. Salmon & J. Johnson, 3rd edition.
3. "Fastening & Joining", by Robert Parmley, 2nd edition
4. "Allowable Stress Design", AISC, 9th edition

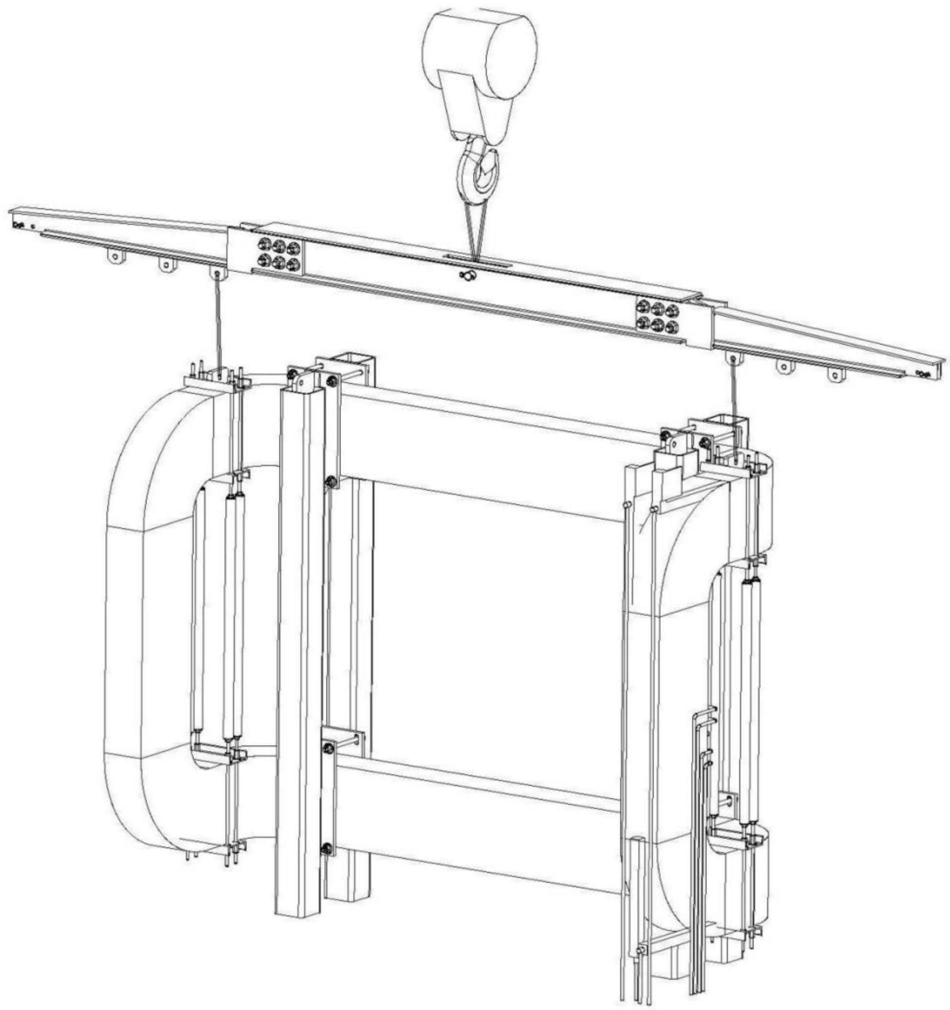

Figure 1, The isometric view of the application of the Spreader bar

Allowable Stresses:

The materials of all Plates, channels are:
ASTM A36, where F_y = 36 ksi, so $F_v = F_b$ = 12 ksi
Welds are E70, where F_u = 70 ksi, F_{wv} = 0.30 x 70 ksi = 21ksi
Bolts for A490, where F_u = 150 ksi, F_t = 54 ksi, F_v = 21 ksi

Applying Load P_a and Others:

Figure 2 showed the force distribution diagram of the spreader bar,

Where $W_{inner\ coil}$ = 13,000 lbs.
$W_{spre.\ bar}$ = 1,360 lbs.
$W_{coil\ turning\ fix.}$ = 3,200 lbs
$W_{coil\ lift.\ Fix}$. = 370 lbs.
$P_{at} = W_{inner\ coil} + W_{spre.\ bar} + W_{coil\ turning\ fix} + W_{coil\ lift.\ Fix}$
= 17,930 lbs.

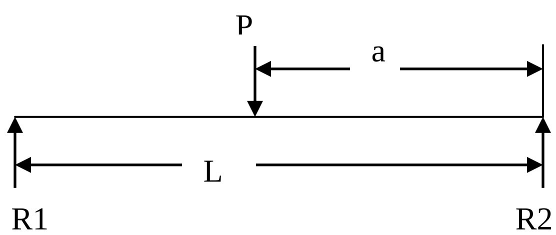

Figure 2. The force distribution diagram of the spreader bar

From figure 2 and drawing ME - 407814, it is found that:

L = 201 inch (the span distance for the largest coil – inner coil)
P = P_{at} =17,930 lbs.
a_c = 0.5 L = 100.50 in (@ the center of the spreader bar)
$R_1 = R_2$ =0.5P = 8,965 lbs.

1. ***Calculate the working stresses at different locations***.

1.1. The working stresses in the center of the spreader bar:

The sectional modulus S_{xc} at the center of the spreader bar of the strong axis x-x Per Figure 3 on page 4, it was conservatively simplified and calculated as:

$I_{xx1} = (78.9 \text{ x } 2) \text{ in}^4 = 157.80 \text{ in}^4$ for 2 channels
$A_1 = 5.88 \text{ in}^2 \text{ x } 2 = 11.76 \text{ in}^2$
$I_{xx2} = ((0.75 \text{ x } 10^3 \text{ x } 2) \div 12) \text{ in}^4 = 125 \text{ in}^4$ for 2 vertical plates
$A_2 = (0.75 \text{ x } 10 \text{ x } 2) \text{ in}^2 = 15 \text{ in}^2$
$I_{xx3} = ((8.50 - 2.50) \text{ x } (11^3 - 10^3) \div 12) \text{ in}^4 = 165.5 \text{ in}^4$
for 2 horizontal plates which assumed that both have 2.50 central cut out.
$A_3 = ((8.50 - 2.50) \text{ x } 0.50 \text{ x } 2) \text{ in}^2 = 6 \text{ in}^2$
$I_{total} = I_{xx1} + I_{xx2} + I_{xx3}$
$= 448.30 \text{ in}^4$
$A_{total} = A_1 + A_2 + A_3 = 32.76 \text{ in}^2$
$S_{xc} = I_{total} \div 5.50 \text{ in} = 81.5 \text{ in}^3$

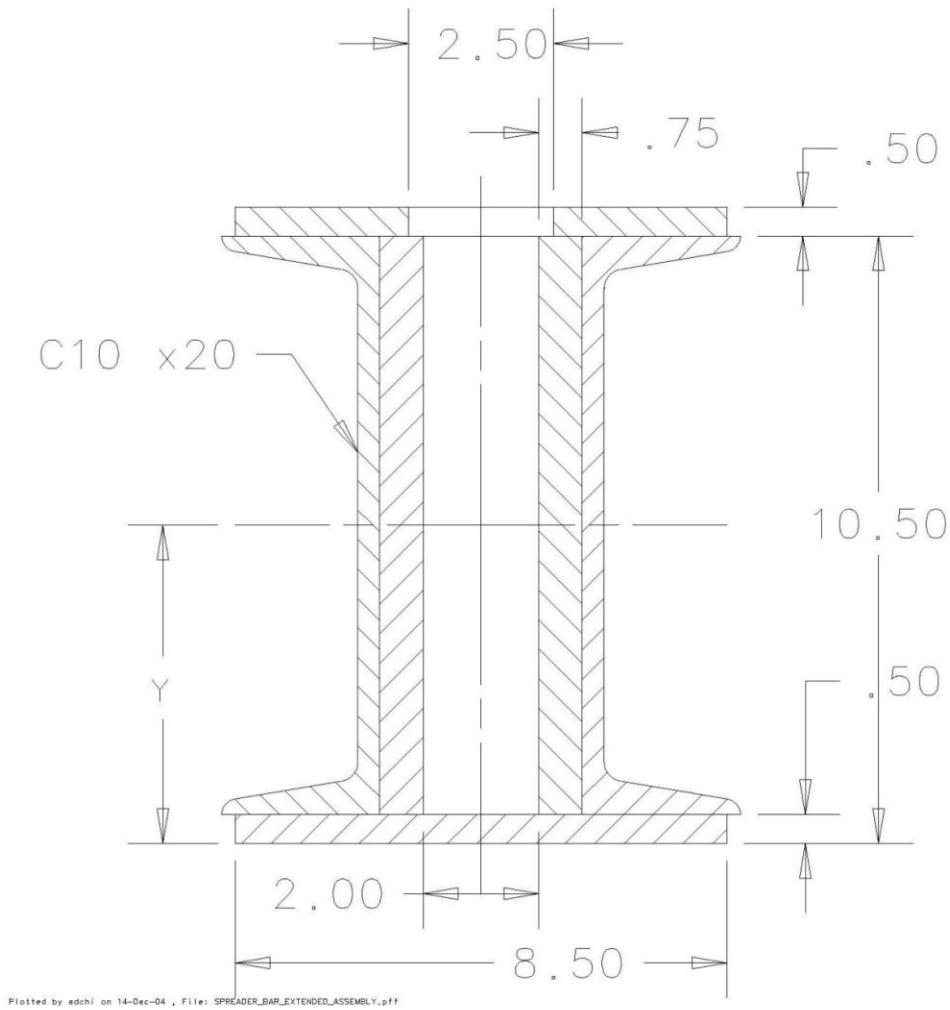

Figure 3. The cross-section view of the spreader bar in the center location

The moment at the center location subject to the force application:

$M_{max} = PL/4$
$= (17{,}930 \text{ lbs.} \times 201 \text{ in}) \div 4$
$= 900{,}983 \text{ lbs-in}$

The max. working bending stress f_b:
$f_b = M_{max} / S_{xc}$
$= 900{,}983 \text{ lbs-in} \div 81.5 \text{ in}^3$
$= 11.06 \text{ ksi} < F_b = 12 \text{ ksi}$,

The working shear stress fv:
$Fv = P_{at} / A_{total} = 548 \text{ psi} < F_v = 12 \text{ ksi}$

The design in this location is satisfactory.

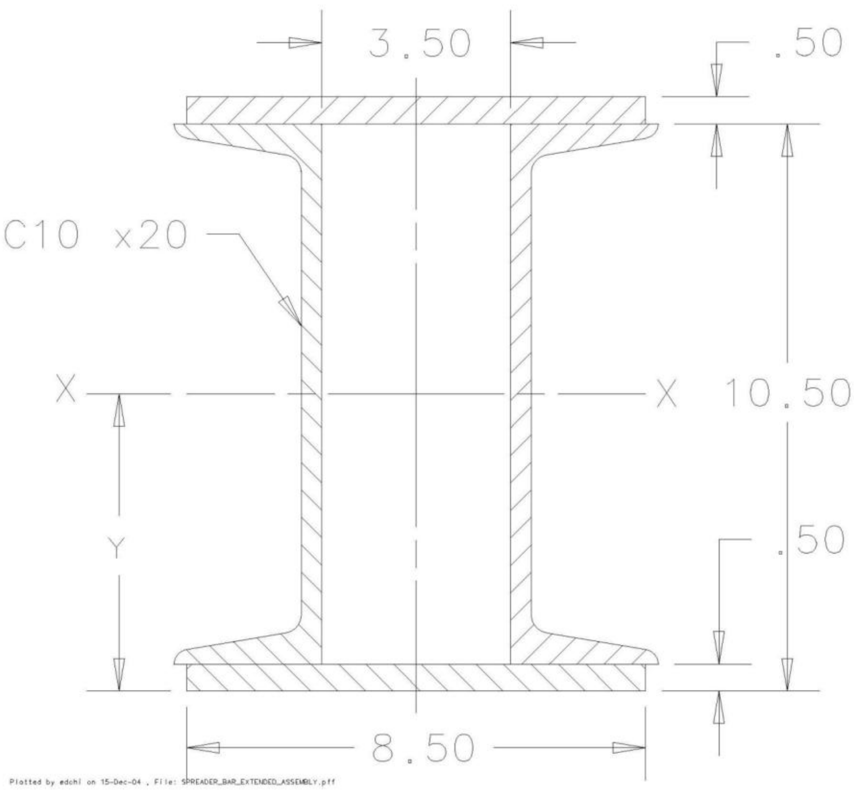

Figure 4, <u>The cross-section view of the spreader bar in the location of 12" away from the center.</u>

1.2. The working stresses in the location 12 inches away from the center of the spreader bar:

Find out the sectional modulus S_{x12} in the location of 12" away from the center of spreader bar about the strong axis x-x:

Per Figure 4 on page 5, it was found that:

I_{xx1} = (78.9 x 2) in^4 = 157.80 in^4 for 2 channels
A_1 = 5.88 in^2 x 2 = 11.76 in^2
I_{xx2} = (8.50 x (11^3- 10^3) ÷ 12) in^4 = 234.45 in^4 for 2 horizontal plates
A_2 = (8.50 x 0.50 x 2) in^2 = 8.50 in^2
$I_{total} = I_{xx1} + I_{xx2}$
= 392.25 in^4
$A_{total} = A_1 + A_2$ = 20.26 in^2
S_{x12} = I_{total} ÷ 5.50 in = 71.31 in^3

The applying moment in this location subject to the force application:

M_{12} = R_2 x (100.5 -12) lbs.-in
= 8,965 lbs. x 88.5 in
= 793,403 lbs-in

The max. work bending stress f_b:
f_b = M_{12} / S_{x12}
= 793,403 lbs-in ÷ 71.31 in^3
= 11.13 ksi < F_b = 12 ksi,

The max. work shear stress fv:
Fv = R_2 / A_{total} = 443 psi < F_v = 12 ksi

The design in this location is satisfactory.

1.3. The working stresses in the location of 60 inches away from the center of the the spreader bar:

Find out the sectional modulus S_{x60} in the location of 60" away from the center of spreader bar about the strong axis x-x:

Per Figure 5 on page 7, it was found that:

I_{xx1} = ((1 x 9.94^3) ÷12)in^4 = 81.84 in^4 for one vertical central plate
A_1 = (1 x 9.94) in^2 = 9.94 in^2
I_{xx2} = (1 x 8.50^3 x 2) ÷ 12) in^4 = 102.35 in^4 for 2 vertical side plates
A_2 = (8.50 x 1.0 x 2) in^2 = 17 in^2
$I_{total} = I_{xx1} + I_{xx2}$
= 184.19 in^4
$A_{total} = A_1 + A_2$ = 26.94 in^2

$S_{x12} = I_{total} \div 4.97$ in = 37.06 in^3

The applying moment in the location subject to the force application:

M_{12} = R_2 x (100.5 -60) lbs.-in
= 8,965 lbs. x 40.5 in
= 363,083 lbs-in

The max. work bending stress f_b:
f_b = M_{12} / S_{x12}
= 363,083 lbs-in ÷ 37.06 in^3
= 9.80 ksi < F_b = 12 ksi,

The max. work shear stress fv:
Fv = R_2 / A_{total} = 333 psi < F_v = 12 ksi

The design in this location is satisfactory

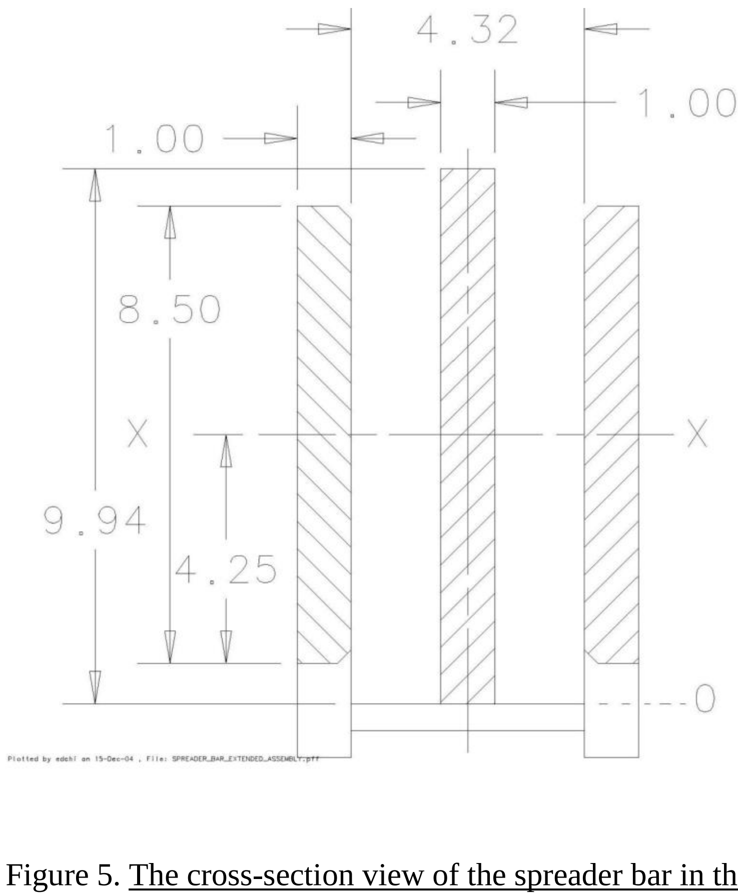

Figure 5. The cross-section view of the spreader bar in the location of 12" away from the center.

2. The Calculation and discussion of the fastener group of the spreader bar:

<u>*Background*</u>:

Try to re-use (or to modify) the existing Mino project spreader bar for the SM3 disassembly project. the capacity of the spreader bar for the SM3 project is:

Overall load P_{at} = 17,930 lbs = 9 tons with max. span distance L_s = 201 in

<u>Assumptions</u>:

Slip critical connection, single shear

2.1 <u>The selection of the fastening group and the others</u>

Figure 6 is showing that when the applying load P is eccentric to the centroid of the bolt group. This physical configuration is represented by the design of the spread bar using for the SM3 project, which is also shown pictorially in figure 1 on page 3.

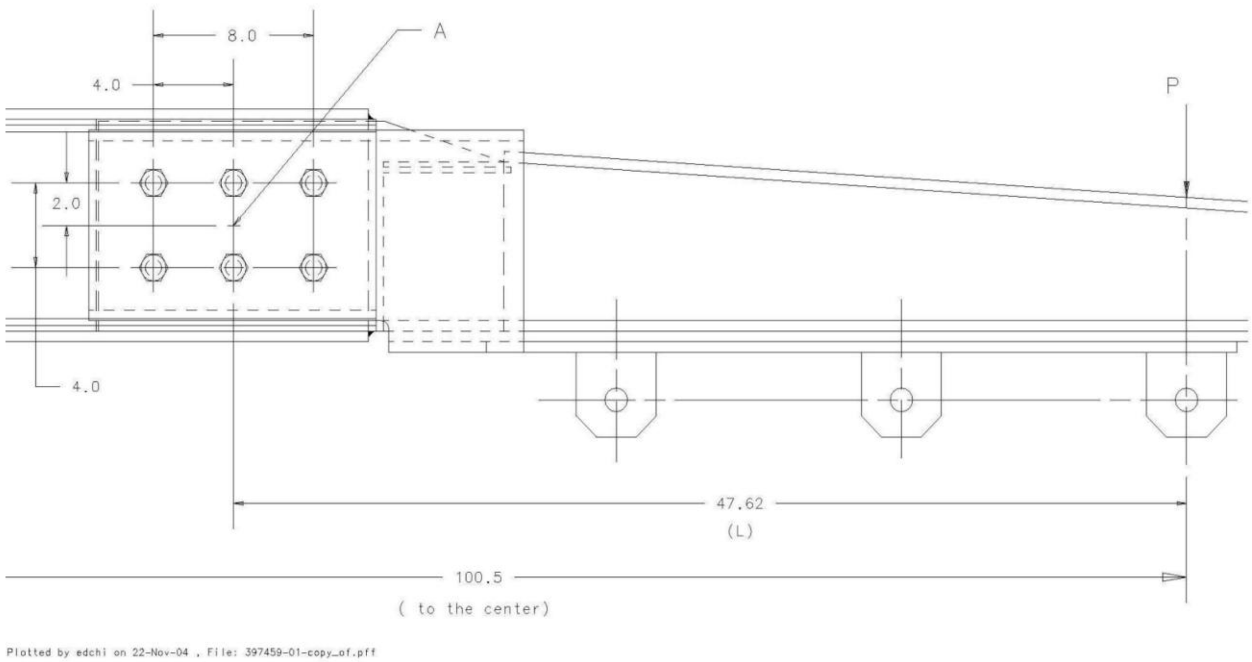

Figure 6. Eccentric load P and the group of bolt (6 bolts) of the spreader bar

Where:

P = R1 = R2 = 8,965 lbs, applying load
L = 47.625 in
Location A is the geometrical centroid of the bolt group, 6 bolts are located as showing in Figure 6. currently, the spec. of bolt is assuming:
A490, 1 1/4 - 7, UNC
n = 6 (number of bolts)

Per Table I –D, part 4 of ASD, it is found that:
R_{av} = 25.8 kip (allowable shear load for the bolt)

Find out the local properties of the fastener group:

$\sum x^2 = 4 (4)^2 = 64 \text{ in}^2$
$\sum y^2 = 6 (2)^2 = 24 \text{ in}^2$
$\sum x^2 + \sum y^2 = 88 \text{ in}^2$

The primary shear load f_{v1} of each bolt subject to the applying load P:

$R_{v1} = P/n = 8{,}965 \text{ lbs} / 6$
$= 1{,}494 \text{ lbs} \downarrow$

The secondary torsional shear load of the bolt is subjected to the moment PL:
Pick the bolt of the most right top one as shown in figure 1,
(which is subjected by the largest 2nd shear force)

Where: $R_{vx} = PLy \div (\sum x^2 + \sum y^2)$
$= (8{,}965 \text{ lbs}) \times (47.625 \text{ in}) \times (2 \text{ in}) \div 88 \text{ in}^2$
$= 9{,}704 \text{ lbs.} \rightarrow$

$R_{vy} = PLx \div (\sum x^2 + \sum y^2)$
$= (8{,}965 \text{ lbs}) \times (47.625 \text{ in}) \times (4 \text{ in}) \div 88 \text{ in}^2$
$= 19{,}407 \text{ lbs} \downarrow$

The resultant force applying to the most right top bolt:

$R = [(R_v + R_y)^2 + R_x^2]^{1/2}$
$= [(1{,}494 + 19{,}407)^2 + (9{,}704)^2]^{1/2} \text{ lbs}$
$= \underline{23.044 \text{ kip}} < R_{av} = 25.8 \text{ kip}$

Using (6) A490 (or grade 8) high strength structural bolts with specification of 1 ¼ - 7, UNC – 2B can be meet the current applications.

2.2**.** The Assembly Torque Value for Two Arms of the Spreader Bar

There are (12) A490 structural bolts for connecting the center piece to the arms (2) of the spreader bar as shown on drawing ME – 407814 and on figure 6.

The suggested tightening torque value T can be calculated as:
F_t = 150 ksi   Min. tensile strength of A490 bolt.
F_p = 120 ksi, proof strength of A490 bolt.
$P_c = 0.75 \text{ As } F_p$ Clamp load, where
$A_s = 0.969 \text{ in}^2$, stress area for 1 ¼ -7, UNC bolt

$P_c = 0.75 \times 0.969 \times 120$ ksi
$= 87{,}210$ lbs
$T = K D_b P_c$ where $K = 0.2$, torque coefficient,
$D_b = 1.25$ in, nominal bolt diameter
$T = 0.2 \times 1.25$ in $\times 87{,}210$ lbs
$= 21{,}803$ lbs–in $= 1{,}817$ lbs-ft
(Per table 4.1.1, page 107 of ref. 2, also table 1-2, Page 1-25 of ref.3)

3. Weld Calculations and Discussions:

Per figure 1 on page 3, design drawings of ME – 407814 and MD – 407915, it is found that the welds on 3 plates (MD-397452, MD-407815) are subjected:
Stress due to direct load P_y
Stress due to torsional moment T

Figure 7 is based on the design weld configuration to treat it as line with unit thickness.

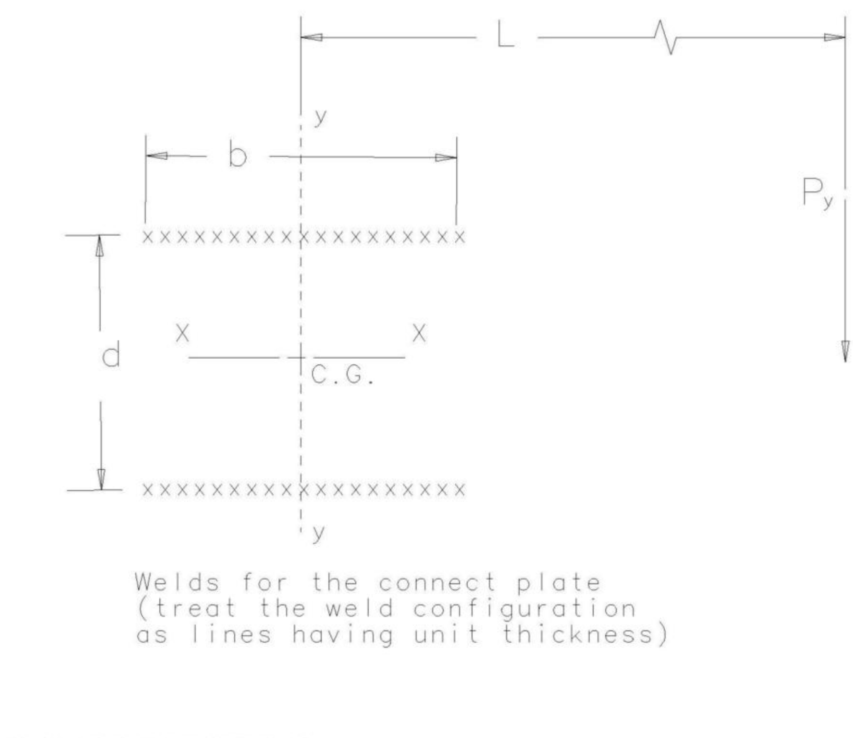

Figure 7. The weld configuration of the connect plate to treat as lines

Find the geometric properties of the welds (treated as lines):

Length $l = 2b = 16.50$ in   where $b = 8.25$ in, $d = 7$ in
$I_p = b(3d^2 + b^2) \div 6$ (Per table 5.18.1, section 5.18 of reference 2)
$= (8.25 \times (3 \times 7^2 + 8.25^2) \div 6)$ in^3

$= 295.7$ in^3 Where I_p is the polar moment of inertia about C.G.

Compute the components of the force on the weld at the maximum area:
Per figure 7, the locations to subject the maximum force are 4 corners .

$T = P_y * L$ Where T is torsional moment,
$P_y = 0.5\ R_1 = 0.5\ R_2 = 4{,}483$ lbs, assuming 2 plates (conservative)
$L = 36.56$ in

$= 4{,}483$ lbs x 36.56 in
$= 163{,}899$ lbs-in

The primary shear R_{v1}:
R_{v1} = Py ÷ weld length
= 4,483 lbs ÷ 16.50 in
= 272 lbs/in ↓

The secondary torsional shear about the centroid of the welds:

$R_{vx} = (T\ y)/ I_p$
= ((163,899 x 3.50) ÷ 295.7) lbs/in
= 1,940 lbs/in →
$R_{vx} = (T\ x)/ I_p$
= ((163,899 x 4.125) ÷ 295.7) lbs/in
= 2,287 lbs/in ↓
The resultant force R_t
$R_t = [(R_{v1} + R_{vy})^2 + R_{vx}^2]^{1/2}$
$= ((272 + 2{,}287)^2 + 1{,}940^2)^{1/2}$ lbs/in
= 3,212 lbs/in

Find the fillet weld size C, assuming all are fillet welds with E70 weld metal:
Allowable stress of the weld metal F_{wv}:

$F_{wv} = 0.30 \times 70$ ksi = 21ksi, for E70 weld metal
$C = R_t / (0.707 \times F_{wv})$ (Per section 5.18, reference 2)
= 3,212 lbs/in ÷ (0.707 x 21,000) lbs/in^2
= 0.217 in

Per drawing MD-407815, it was found that the weld sizes are 0.25", so the design is satisfactory.

Conclusions:

The engineering note was presented by discussing and analyzing several of the most critical structural areas and locations. The calculations have been shown that the modified reused spreader bar has been designed per the related applicable codes.

Rated Load Test Layout and Procedures

Step 1. Review the test setup layout as shown on figure 8.

Step 2. Move B blocks (2) and E blocks (4) to the designated area, lay them out per figure 8 (the center line of E block should be lined up the ctr. line of the B block on top view). The distance of the two B blocks will depend on the distance between AA, BB, CC & DD lifting lugs respectively.

Step 3. Select designated rated slings, anchor shackles (1" dia. alloy/carbon steel) and scale, install them per figure 8.

Step 4. Gradually, slowly apply load through crane until the scale reading reaches 22,150 lbs, sustain the load up to 10 minutes, take pictures if it is possible.

Step 5. Release the loads and relocate the bottom 2 slings and anchor shackles to the next 2 lifting lugs.

Step 6. Repeat steps 4 & 5 until all lifting lugs (AA, BB, CC & DD) are been tested.

Step 7. Fill out and sign form 5022.1TA (page 1) as Load Test Witness.

Step 8. Mark the spreader bar as:

Number 151
Lifting Capacity: 16,600 lbs.
Fixture Weight: 1,400 lbs.

Step 9. Remove every item back in order. Thanks for finish the project safely and Successfully!

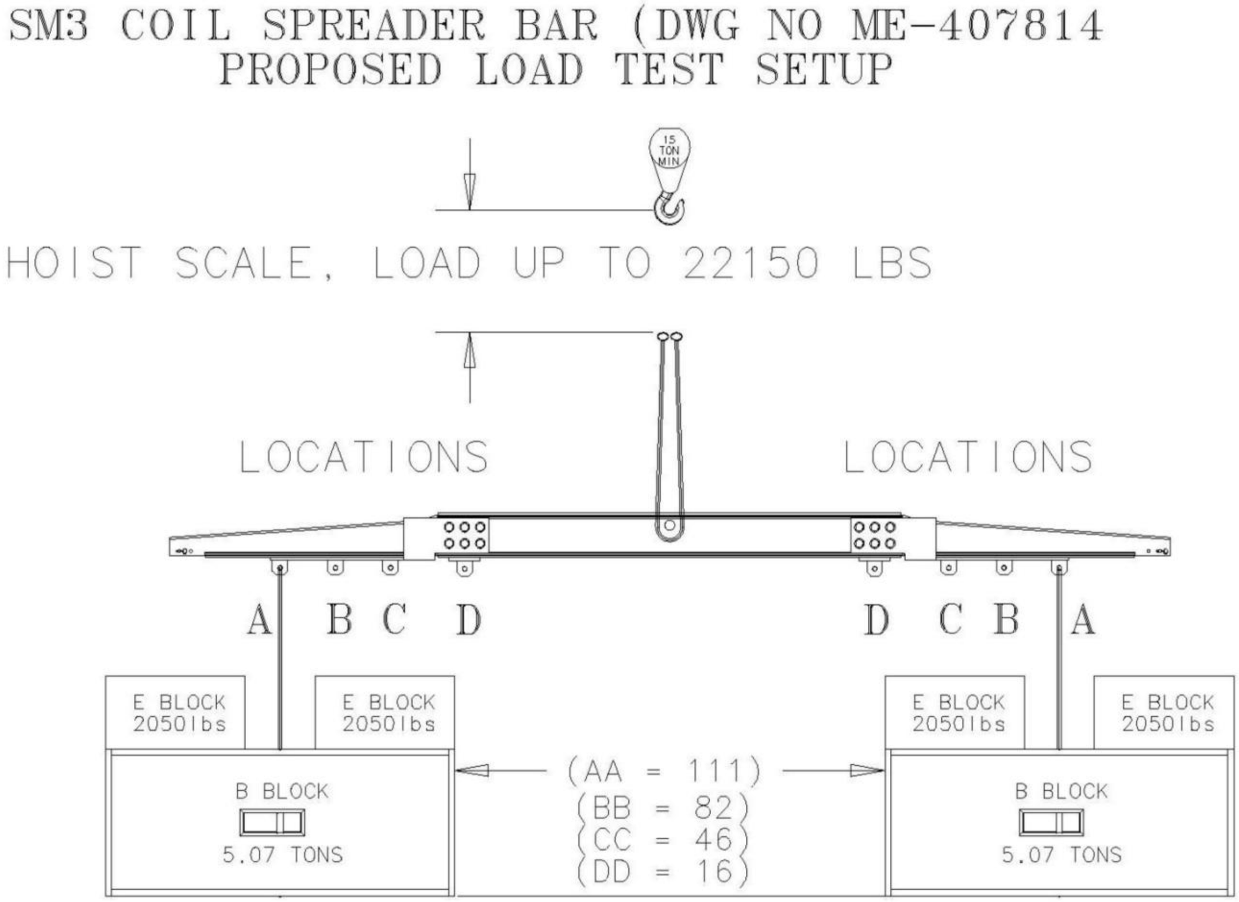

Figure 8. <u>SM3 Coil Spreader Bar Load Test Setup</u>


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Figure 9. The Load Test for SM3 Coil Spreader @ MAB Building