HEAT EXCHANGER SUPPORT BRACKET

DESIGN CALCULATIONS

D-ZERO ENGINEERING NOTE # 3823.115- EN-417

January 12, 1995

Russ Rucinski
RD/DØ Mech.

Approved:

Revision 5/6/96: Added Independent review questions & answers
Added finite element analysis
Added HX top plate analysis
This engineering note documents the design of the heat exchanger support brackets. The heat exchanger is roughly 40 feet long, 22 inches in diameter and weighs 6750 pounds. It will be mounted on two identical support brackets that are anchored to a concrete wall.

The design calculations were done for one bracket supporting the full weight of the heat exchanger, rounded up to 6800 pounds. The design follows the American Institute of Steel Construction (AISC) Manual of steel construction, Eighth edition. All calculated stresses and loads on welds were below allowables. See the Summary table on the next page.

5/16/96 Revision:
The hand done analysis was independently reviewed by Bob Wands of RD/MSD and a memo with his questions and my answers are in Appendix B. As FEA exercise, I ran a element finite element analysis using beam elements. The information from this analysis is included as appendix C. All stresses found in the FEA were below allowables. Additional hand calculations (See Appendix D) for the top attachment plate were done after Bob Wands' review. At the time of fabrication the top plate thickness was increased from 1/4" to 3/8". The stresses for the 3/8" thick top plate were acceptable.
<table>
<thead>
<tr>
<th>DESIGN ITEM</th>
<th>MAX. CALCULATED STRESS OR LOAD</th>
<th>ALLOWABLE STRESS OR LOAD</th>
<th>COMBINED fa/Fa + fb/Fb &lt; 1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper horiz. member</td>
<td>1.1 ksi, tensile</td>
<td>27 ksi, tensile</td>
<td>0.357</td>
</tr>
<tr>
<td>{4&quot; x 8&quot; x 1/4&quot; wall rect. tubing}</td>
<td>2.2 ksi, shear</td>
<td>18.4 ksi, shear</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9.6 ksi, bending</td>
<td>30.4 ksi, bending</td>
<td></td>
</tr>
<tr>
<td>Vertical member, CASE II</td>
<td>1.2 ksi, compressive</td>
<td>27 ksi, tensile</td>
<td>0.155</td>
</tr>
<tr>
<td>{4&quot; x 8&quot; x 1/4&quot; wall rect. tubing}</td>
<td>2.0 ksi, shear</td>
<td>18.4 ksi, shear</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.4 ksi, bending</td>
<td>30.4 ksi, bending</td>
<td></td>
</tr>
<tr>
<td>Vertical member, CASE I</td>
<td>2.0 ksi, shear</td>
<td>18.4 ksi, shear</td>
<td>not applicable</td>
</tr>
<tr>
<td>{4&quot; x 8&quot; x 1/4&quot; wall rect. tubing}</td>
<td>8.7 ksi, bending</td>
<td>30.4 ksi, bending</td>
<td></td>
</tr>
<tr>
<td>Lower horiz. member</td>
<td>1.1 ksi, compressive</td>
<td>27 ksi, compressive</td>
<td>0.357</td>
</tr>
<tr>
<td>{4&quot; x 8&quot; x 1/4&quot; wall rect. tubing}</td>
<td>2.2 ksi, shear</td>
<td>18.4 ksi, shear</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9.6 ksi, bending</td>
<td>30.4 ksi, bending</td>
<td></td>
</tr>
<tr>
<td>Wedge anchors, 1/2&quot; dia.</td>
<td>1820 lbs, tensile load</td>
<td>2400 lbs, tensile load</td>
<td>ft/Ft^2 + fv/Fv^2 &lt; 1.0</td>
</tr>
<tr>
<td>{Hilti Kwik bolt II}</td>
<td>850 lbs, shear load</td>
<td>1960 lbs, shear load</td>
<td></td>
</tr>
<tr>
<td>Fillet weld, top anchor plate</td>
<td>993 lbs/linear inch</td>
<td>1909 lbs/linear inch</td>
<td>not applicable</td>
</tr>
<tr>
<td>{1/8&quot; intermittent fillet weld}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weld, upper horiz. to vert member</td>
<td>4146 lbs/linear inch</td>
<td>3818 lbs/inch - 2 short sides</td>
<td>not applicable</td>
</tr>
<tr>
<td>1/4&quot; fillet, 1/4&quot; groove</td>
<td></td>
<td>5250 lbs/inch - 2 long sides</td>
<td></td>
</tr>
<tr>
<td>Weld, vert. to lower horiz. member</td>
<td>2.4 ksi, compressive</td>
<td>27 ksi, compressive</td>
<td>0.676</td>
</tr>
<tr>
<td>{1/8&quot; groove weld}</td>
<td>10.8 ksi, bending</td>
<td>18.4 ksi, shear</td>
<td></td>
</tr>
<tr>
<td>Fillet weld, bottom anchor plate</td>
<td>993 lbs/linear inch</td>
<td>1909 lbs/linear inch</td>
<td>not applicable</td>
</tr>
<tr>
<td>{1/8&quot; intermittent fillet weld}</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The heat exchanger is to be mounted on the wall beneath the South walkway. The heat exchanger weighs 6750 lbs. The heat exchanger will be mounted on two support brackets.

Based on preliminary design calculations, the support bracket will be as shown in figure 1.

For this formal design analysis I will assume that one support carries the full load, rounded to 6800 lbs.

Using this load I will calculate the factors of safety for all aspects of the design.

Aspects of the design:
A. Upper horizontal member
B. Vertical member
C. Lower horizontal member
D. Wedge anchors
E. Weld to top plate
F. Weld to vertical member
G. Weld at 45° miter
H. Weld at bottom plate
HEAT EXCHANGER SUPPORT

**Figure 1**
HEAT EXCHANGER SUPPORT BRACKET
DESIGN ANALYSIS

FREE BODY DIAGRAM

ASSUME NO MOMENT REACTION
AT MOUNTING PADS. GEOMETRY
ENSURES CONTACT OF BOTH
PADS TO WALL.

$\Sigma F_x = 0 \quad R_{Ax} = R_{Bx}$
$\Sigma F_y = 0 \quad R_{Ay} + R_{By} = P$
$\Sigma M_A = 0 \quad R_{Bx} (39.75) = P (30)$

$R_{Bx} = 6158.5$ lbs
$R_{Ax} = 6158.5$ lbs

SINCE IT IS AN INDETERMINATE STRUCTURE I WILL ANALYZE TWO
CASES. CASE I: $R_{Ay} = P$, $R_{By} = 0$ CASE II: $R_{Ay} = 0$, $R_{By} = P$

CASE I

REACTIONS:

$R_{Ax} = 6158.5$ lbs
$R_{Bx} = 6158.5$ lbs
$R_{Ay} = 6800$ lbs
$R_{By} = 0$

F.B.D. OF UPPER HORIZONTAL
MEMBER FOR USE IN SIZING
WELD TO VERTICAL MEMBER.

$\Sigma F_x = 0 \quad R_{Cx} = 6158.5$ lbs.
$\Sigma F_y = 0 \quad R_{Cy} = 0$; $R_{Ay} = 6800$ lbs
$\Sigma M_0 = 0 \quad -P(16) - R_{Ay} (20) + R_{Cy} (4) + M_c = 0$
$M_c = 220,166 \text{ in.-lbf}$

CASE II

$R_{Ax} = 6158.5$ lbs
$R_{Bx} = 6158.5$ lbs
$R_{Ay} = 0$
$R_{By} = 6800$ lbs

$\Sigma F_x = 0 \quad R_{Cx} = 6158.5$ lbs.
$\Sigma F_y = 0 \quad R_{Cy} = P = 6800$ lbs; $R_{Ay} = 0$
$\Sigma M_0 = 0 \quad -P(16) + R_{Cx} (4) + M_c = 0$
$M_c = 84,166 \text{ in.-lbf}$
The upper horizontal member needs to be analyzed at sections A-A and B-B as shown in Figure 2.

**Figure 4:** F.B.D. of left & right sections of upper horizontal member

<table>
<thead>
<tr>
<th>CASE I</th>
<th>CASE II</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_{ay} = P \quad M_a = P \cdot (12\text{ in}) )</td>
<td>( R_{ay} = P \quad M_a = P \cdot (12\text{ in}) )</td>
</tr>
<tr>
<td>( R_{ay} = 6800 \text{ lbs} \quad M_a = 81,600 \text{ in-lbs} )</td>
<td>( R_{ay} = 6800 \text{ lbs} \quad M_a = 81,600 \text{ in-lbs} )</td>
</tr>
</tbody>
</table>
| Section A-A: \( R_{ax} = R_{ax} \quad R_{by} = R_{ay} \quad M_b = R_{by} \cdot (16\text{ in}) \) | Section A-A: \( R_{ax} = 6158.5 \text{ lbs} \)
| \( R_{by} = 6800 \text{ lbs} \)                                        | \( R_{by} = 0 \)                                                       |
| \( M_b = 108,800 \text{ in-lbs} \)                                     | \( M_b = 0 \)                                                          |

The highest stress location for the upper horizontal member is for Case I at section B-B.

The upper horizontal member is structural tubing 8" x 4" x \( \frac{1}{4} " \). (This is excess stock at D-Zero assembly block.)

AISC Manual of Steel Construction, Eighth Edition is used for this analysis.

\[
A = 5.59 \text{ in}^2 \quad S_x = 11.3 \text{ in}^3 \quad I_x = 45.1 \text{ in}^4 \quad \text{(Per AISC Tables)}
\]

Material is ASTM A500 Gr. B Steel.

\[
F_u = 58,000 \text{ psi} \quad F_y = 46,000 \text{ psi} \quad \text{(Ref. EYERSIN STOCK LIST)}
\]

Allowables:

Axial Tension: \( F_e = 0.60F_y = 27,600 \text{ psi} \) \( \text{\{AISC Par. 1.5.1.1\}} \)

Shear: \( F_s = 0.40F_y = 18,400 \text{ psi} \) \( \text{\{AISC Par. 1.5.2.1\}} \)
HEAT EXCHANGER SUPPORT BRACKET
DESIGN ANALYSIS

BENDING: $F_b = 0.66F_y = 30,360$ psi

CALCULATED HIGHEST STRESSES IN UPPER HORIZONTAL MEMBER

TENSION: $F_a = \frac{R_{ax}}{A} = \frac{6158.5 \text{ lbs}}{5.59 \text{ in}^2} = 1101.7$ psi

SHEAR: Shear varies from 0 at top & bottom to a maximum at the center. The magnitude of shear is small and can be neglected since the higher stress is due to bending. For proof, I will calculate $\gamma_{\text{max}}$ at the center.

\[
\gamma_{\text{max}} = \frac{\nu Q}{I_b} = \frac{\int y dA}{I_b} = \frac{7.3906 \text{ in}^3}{7.3906 \text{ in}^3} = 1
\]

\[
\gamma_{\text{max}} = \frac{(6800 \text{ lbs})(7.3906 \text{ in}^3)}{(45.1 \text{ in}^4)(.50 \text{ in}^2)} = 2229 \text{ psi}
\]

BENDING STRESS: $F_b = \frac{M}{S} = \frac{108,800 \text{ in} \cdot \text{lbs}}{11.3 \text{ in}^3} = 9,628$ psi

COMBINED STRESS: Axial Tension & Bending [AISC Par. 1.6.2]

\[
f_a/0.60F_y + \frac{F_{ax}}{F_{dx}} + \frac{F_{by}}{F_{by}} \leq 1.0 \quad \text{[AISC Eq. 1.6-1b]}\
\]

\[
1101.7/27,600 + 9,628/30,360 + 0 \leq 1.0
\]

\[
0.357 \leq 1.0
\]

ALL COMPUTED STRESSES AND COMBINED STRESSES FOR THE UPPER HORIZONTAL MEMBER ARE MUCH LOWER THAN AISC ALLOWABLES.
FERMILAB SECTION
ENGINEERING NOTE

SUBJECT
HEAT EXCHANGERS SUPPORT BRACKET

NAME
RUSS RUCINSKI

DATE
12-21-94

PROJECT
HEAT EXCHANGER

SERIAL-CATEGORY
3823.115

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THE VERTICAL MEMBER HAS HIGHEST STRESS AT IT'S MID-POINT.

\[ \Sigma F_x = 0 \quad R_{Cx} = 88x \]

\[ \Sigma F_y = 0 \quad R_{Cy} = 88y \]

\[ \Sigma M_c = 0 \quad -M_c = R_{by}(20^\circ) + R_{by}(15.875^\circ) \]

\[ M_c = R_{by}(20^\circ) - R_{by}(15.875^\circ) \]

CASE II

\[ R_{Cx} = 6158.5 \text{ lbs} \]
\[ R_{Cy} = 6800 \text{ lbs} \]

\[ M_c = 6800 \times (20^\circ) - (6158.5 \times 15.875^\circ) \cdot 38,234 \text{ in-lbs} \]

**Axial Compressive Stress:**

\[ F_a = \frac{R_{Cy}}{A} = 1216 \text{ psi} \]

**Shear:**

\[ T_{max} \text{ CENTER, 0@ SIDES.} \]

**Bending Stress**

\[ \sigma_b = \frac{M_c}{S} = \frac{38,234 \text{ in-lbs}}{11.3 \text{ in}^2} = 3384 \text{ psi} \]

CASE I

\[ R_{Cy} = 6158.5 \text{ lbs} \]
\[ R_{Cy} = 0 \]

\[ M_c = -97,766 \text{ in-lbs} \]

**Ratio Result:**

\[ \gamma_{max} = 2019 \text{ psi} \]

\[ F_b = \frac{M_c}{S} = \frac{-97,766 \text{ in-lbs}}{11.3 \text{ in}^2} = 8652 \text{ psi} \]

For Case II, \( \frac{\sigma_b}{F_a} = \frac{3384}{1216} = 0.44 < 0.15 \) for Combine Stress Requirement using Formula 1.6-2

\[ \frac{\sigma_a}{F_a} + \frac{\sigma_b}{F_b} + \frac{\tau_{by}}{F_{by}} \leq 1.0 \]

\[ 0.44 + 3.384/30360 + 0 = 0.155 \leq 1.0 \]

**All Computed Stresses and Combined Stresses for the Vertical Member are Much Lower Than AISC Allowables.**

**Lower Horizontal Member:**

Since the reactions at the right end of this member are the same as the upper member (except for sign) the stresses are the same as at 6-10 of the upper member. It is O.K.
WEDGE ANCHORS

I will select Hilti brand since this is what D-Zero techs are familiar with and because they are known to be good quality.

From Hilti application chart, heavy duty type HFA adhesive anchor or medium duty kwik bolt 11 stud anchor are suitable.

The concrete they will be mounted in is 4000 psi concrete per building plans. (Note from plans in Appendix)

Analyze as a bearing type connection (vs. friction type)

Shear load per bolt = \( \frac{6800}{8} = 850 \) lbs.

Tensile load per bolt will vary with distance from "neutral axis"

\[ M = (6800 \text{ lbs}) \times (36 \text{ in}) = 244,800 \text{ in-lbs} \quad \text{(see sec 10.21)} \]

\[ f_t = \frac{M y}{2A_y^2} \]

\[ y = 19.875 + 5\frac{1}{4} = 25.125 \text{ in.} \]

\[ \leq A_y^2 = 4 \cdot A_b \left[ (14.625)^2 + (25.125)^2 \right] = A_b \left( 3380.625 \text{ in}^2 \right) \]

\[ T_i = f_t \cdot A_b = \frac{M y}{(3380.625 \text{ in}^2)} = 244,800 \text{ in-lbs} (25.125 \text{ in}) = 1819 \text{ lbs} \]
HEAT EXCHANGER SUPPORT BRACKET
DESIGN ANALYSIS

From Hilti Selection Chart, ½" Anchor is adequate. In appendix.

Specify: Hilti KB11 12-412, Item # 000453688

Allowable Working Load: 20% with 2½" Embedment.

\[ F_v = (1960 \text{ lbs shear}) \text{ reduced by 20% since shear?} \]
\[ F_t = 2400 \text{ lbs tension} \]

Using an Interaction Equation:
\[ \left( \frac{F_v}{F_v} \right)^2 + \left( \frac{F_t}{F_t} \right)^2 \leq 1.0 \]
\[ \left( \frac{850}{1960} \right)^2 + \left( \frac{1819}{2400} \right)^2 = 0.763 \leq 1.0 \quad \checkmark \quad O.K. \]

Check the ¼" A36 Plate:

Nominal Stress \( G = \frac{P}{A} = \frac{(850 \text{ lbs})(2 \text{ bolts})}{(12.5 \text{ in}^{-2})(9\frac{1}{2} \text{ in} - 2(5\frac{1}{8} \text{ in}))} \]
\[ = 824 \text{ psi} \quad \text{negligible} \]

Check structural concrete details where anchors will be installed. Approximate building elevation is 740' for top leg, 736' for bottom leg.

From building plans, Sheet SC-19, Org. # 6-3-3,

Section SC-1 shows this wall items of interest

Show there is a construction joint @ El. 736'-6".

Also #4 Rebar @ 12" spacing running vertically.

Also #5 Rebar @ 12" running horizontally.

The Rebar is 1" below the surface.

Installers should avoid both.
WELD TO TOP PLATE

THE WORST CASE LOADING FOR
THIS WELD IS FOR \( R_{ax} = 6800 \text{ Lbs} \)
\( R_{ay} = 6158.5 \text{ Lbs} \)

THE ALLOWABLE LOAD, \( f \) FOR THE WELD IS PER AISC TABLE 1.5.3, FILLET WELDS

\[
f = 0.30 \times \text{NOMINAL TENSILE STRENGTH OF WELD METAL, BUT NOT TO \( 0.40 \times \text{YIELD STRENGTH OF BASE METAL} \)}
\]

\[
F_{\text{tensile}} = \text{SAME AS BASE METAL} = F_k = 0.6F_y = 0.6(36,000) = 21,600 \text{ psi}
\]

USE E70XX ELECTRODE; 70 ksi TENSILE STRENGTH. (AWS TOL) \( ^2 \)

\[
F_{\text{shear}} = 0.3(70) = 21 \text{ ksi} \quad \text{but not} \quad > 0.4(36 \text{ ksi}) = 14.4 \text{ ksi}
\]

\[
F_{\text{tensile}} = 21.6 \text{ ksi}
\]

CALCULATE RESULTANT FORCE.

\[
W = \sqrt{R_{ax}^2 + \left[R_{ay} \cdot \left( \frac{21.6}{14.4} \right) \right]^2} = 11,915 \text{ Lbs}
\]

MINIMUM FILLET WELD SIZE IS \( \frac{1}{8} \)" (PER AISC TABLE 1.17.2A)

ASSUME THE MINIMUM WELD SIZE, CALCULATE REQ'D LENGTH.

\[
f, \text{ ALLOWABLE LOAD PER LINEAR INCH OF WELD} = F_{\text{tensile}} \times 0.707 \times (0.125 \text{ in})
\]

\[
f = 1,909 \text{ Lbs PER in}.
\]

\[
L = \frac{11915 \text{ Lbs}}{1909 \text{ Lbs/IN}} = 6.24 \text{ in.}
\]

USE INTERMITTENT FILLET WELDS.

MINIMUM LENGTH = \( 1\frac{1}{2} \)" PER AISC.
Possible patterns for intermittent welds are:

1/8" fillet size

12 in. of weld length

I prefer this pattern

F Weld to Vertical Member

Joint designation BTC-P10-GF

Loads on weld (from bottom of page 3) (CASE I is WORST)

\[ R_{cx} = 6158.5 \text{ lbs} \]
\[ R_{cy} = 0 \text{ lbs} \]
\[ M_c = 220,166 \text{ in-lbs} \]

Weld outline

4"

Analysis like fillet all around.

\[ S_w = bd + \frac{d^2}{3} \]

where \( b = 4" \), \( d = 8" \)

\[ S_w = 53.33 \text{ in}^2 \]

\[ W_0 = \frac{M}{S_w} = \frac{220,166 \text{ in-lbs}}{53.33 \text{ in}^2} = 4128.10 \text{ lbs/in} \]

\[ W_{shear} = \frac{R_{cx}}{L} = \frac{6158.5 \text{ lbs}}{24 \text{ in}} = 256.6 \text{ lbs/in} \]

Resultant loading (must increase shear load due to lower allowable)

\[ W = \sqrt{(4128.10 \text{ lbs})^2 + (256.6 \text{ lbs/in})(21.4)}^2 = 4146 \text{ lbs/in} \]
HEAT EXCHANGER SUPPORT BRACKET

DESIGN ANALYSIS

CHECKED: Todd M. Zuidt 1-12-95

SIZE WELDS: Allowable load per inch of weld = \( \frac{F_{\text{tensile}} \times 0.707}{t_{\text{weld}}} \)

\[ t_{\text{weld}} = \frac{4146 \text{ lb/lin}}{21600 \text{ lb/sq in} \times 0.707} = 0.27'' \]

Allowable 1/2 fillet = \( (21,600 \times 0.707 \times 0.25) \)

Long sides allowable = 20 (Electrode tensile strength

\[ = 3813 \text{ lbs per lin in} \]

The welds on the rounded corner length will be greater in size than a 0.27" fillet due to geometry. Also the case I, case II scenario is conservative. Therefore call out 1/4" fillet on 2 sides, non-grounded butt weld 2 other sizes.

\( \theta \) WELD @ 45° MITER.

Worst case is case II

\[ R_{Dx} = R_{By} = 6158.5 \text{ lbs} \]

\[ R_{Dy} = R_{By} = 6800 \text{ lbs} \]

\[ M_0 = R_{By} (20 \text{ in}) = 136,000 \text{ in-lbs} \]

WELD LENGTH: 2 sides x (4 in) + 2 sides x (8 in x \sqrt{2}) = 30.63 in.

DESIGNATE WELD JOINT B-P16 per Fig 2.5 of AWS D1.1-90

PARTIAL JOINT PENETRATION GROOVE WELD

\[ \frac{1}{8} \text{ in} \] to \( 1/32 \text{ in} \)

\[ 1/8 \text{ in} \]

\[ E70xx \text{ in } E60xx \]

Cross sectional area of weld, \( A_{\text{w}} = (0.125 \text{ in})(30.63 \text{ in}) = 3.829 \text{ in}^2 \)

The electrode will "match" the base material so allowables for the weld are the same as for the tube it joins.

SHEAR LOAD

\[ V = (R_{Dx} + R_{Dy}) \cos(45°) = 0 \]

COMPRESSION

\[ C = (R_{Dx} + R_{Dy}) \cos 45° = 9163 \text{ lbs} \]
COMPRESSION STRESS IS NEGLIGIBLE \( \sigma_c \) = \( \frac{9163 \text{ lb}}{3.8 \text{ in}^2} = 2411 \text{ psi} \)

**BENDING**

\[ \frac{I}{L} = \left( \frac{4 \text{ in}}{12} \right) \left( 8 \text{ in} \frac{12}{12} \right)^3 - \left( 3.75 \text{ in} \frac{12}{12} \right)^3 \]

\[ = 482.72 \text{ in}^4 - 411.43 \text{ in}^4 \]

\[ G_0 = \frac{Mc}{I} = \frac{136,000 \text{ inlb} \left( \frac{8 \text{ in}}{12} \right)}{71.29 \text{ in}^4} = 10,792 \text{ psi} \]

**BENDING ALLOWABLE = 30,360 psi**  
\( \sigma_b < \sigma_c \)  
\( \sigma_b < \sigma_c \)  
\( \sigma_b = \frac{M_C}{I} = \frac{136,000 \text{ inlb} \left( \frac{8 \text{ in}}{12} \right)}{71.29 \text{ in}^4} = 10,792 \text{ psi} \)

COMPUTED STRESSES ARE MUCH LESS THAN ALLOWABLES  
Therefore the \( \frac{1}{8} \)" groove weld, which is the minimum size allowed per AWS, is fine.  
\( \frac{f_a}{f_{aw}} + \frac{f_w}{f_{bw}} = \frac{2.411}{27} + \frac{10.8}{18.4} = .676 < 1.0 \)

**WELD AT BOTTOM PLATE**

THE ANALYSIS IS IDENTICAL TO THE ANALYSIS FOR THE WELD AT THE TOP PLATE. SEE PGS. 9 & 10.
3. The soil under the base mat foundation slabs shall have a
  safe bearing value of 7,500 psi for the lower base mat and
  5,000 psi for the upper base mat.

4. The building footings shall be founded on granular embankment
  with a safe bearing value of 4,000 psi. See Specification
  Section 2A, SITE WORK, PARAGRAPH C.13.

5. Denature excavations by appropriate means necessary to provide
  a firm, dry subbase for construction or backfill.

6. All excavations shall be inspected by the Fermilab
  Construction Coordinator before placing forms or reinforcing.

7. No foundation concrete shall be placed in excavations
  containing free water or frozen soil.

8. No backfill shall be placed against structures until concrete
  has cured for 7 days and been approved by the Fermilab
  Construction Coordinator.

9. See Specification Section 2A, SITE WORK, PARAGRAPH C.15, for
  the provisions and special sequencing required for the
  filling and backfilling for structures and bents.

10. See Specification Section 2A, SITE WORK, PARAGRAPH C.16, for
    filling and backfilling for slabs on grade.

REINFORCING STEEL

1. Reinforcing bars shall conform to the requirements of ASTM
   A615, Grade 60.

2. Welded wire fabric shall conform to ASTM A185.


4. All continuous bars shall be lapped 36 diameters for #6 bars
   and smaller, and 48 diameters for #7 bars and larger, where
   splices are required, unless otherwise noted.

5. Support the welded wire fabric on chairs or concrete blocks.

6. Welded splices shall be used where shown on the drawings.

CONCRETE

1. Material and workmanship shall be in accordance with the
   requirements of Building Code for Reinforced Concrete ACI
   Standard 318.

2. Minimum 28 day strength for structural concrete including
   precast slabs shall be 4000 psi.

3. Minimum 28 day strength for the fill over the stair treads
   shall be 3000 psi.

4. Concrete cover shall be as shown on the drawings and as
   required by ACI Standard 318-77.

5. Subcontractor shall coordinate the placement of concrete so as
   to provide proper and adequate cutouts, sleeves, inserts, and
   other built-in devices for electrical and mechanical
   equipment and piping and architectural devices.

6. Construction joints shall be located as shown on the
   drawings. Any joints not shown but necessary for
   construction shall be approved by the Fermilab Engineer. A
   period of 48 hours shall elapse between adjacent concrete
   placements.

10. Connections for details not shown but necessary to develop
    member or joint are subject to Fermilab Approval.

11. After erection, touch-up all abraded spots and spots burned
    by welding with same paint as prime coat.

12. Provide temporary bracing guys or other devices as required
    to provide safety and stability for the erection of
    structural steel. Leave bracing in place until all steel
    work is in final position and approved.

13. Portions of steel to be embedded in concrete shall not be
    primed or shop coated.

PRECAST CONCRETE

1. Furnish the precast roof slabs as specified under
   Specification Section 3E, PRECAST CONCRETE.

METAL DECKING

1. Metal decking shall be in accordance with ASTM A446 with a
   minimum yield of 33000 psi.

2. All decking shall be galvanized in accordance with ASTM A525
   with the coatings as specified under Specification Section
   5C, METAL DECKING.

3. The deck shall be the depth, type and gage shown on the
   plans.

4. Faster deck panels to the structural framework at ends and at
   intermediate supports by welds spaced not more than 12
   inches spaced across the width of the panel. Welding shall be
   by the arc-welding process. Use weld washers on the roof deck.

FERMILAB FURNISHED MATERIALS

1. The materials and services furnished by Fermilab will be as
   outlined in Section 4.0 of Exhibit A, SCHEDULE AND
   SUPPLEMENTARY TERMS AND CONDITIONS.
### Specification Table

<table>
<thead>
<tr>
<th>Setting Details</th>
<th>HKB 1/4&quot;</th>
<th>HKB 3/8&quot;</th>
<th>HKB 1/2&quot;</th>
<th>HKB 5/8&quot;</th>
<th>HKB 3/4&quot;</th>
<th>HKB 1&quot;</th>
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<tbody>
<tr>
<td>BD = D drill bit size = anchor diameter</td>
<td>1/4&quot;</td>
<td>3/8&quot;</td>
<td>1/2&quot;</td>
<td>5/8&quot;</td>
<td>3/4&quot;</td>
<td>1&quot;</td>
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<td>E depth of embedment (minimum/standard)</td>
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<td>1 1/4&quot;/2 1/2&quot;</td>
<td>2 1/4&quot;/3 1/2&quot;</td>
<td>2 1/4&quot;/4&quot;</td>
<td>3 1/4&quot;/4 1/2&quot;</td>
<td>4 1/4&quot;/6 1/2&quot;</td>
</tr>
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<td>HD hole depth (E + 1 &quot;D) min./std.</td>
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<td>2&quot;</td>
<td>2 1/4&quot;</td>
<td>3 1/4&quot;</td>
<td>4&quot;</td>
<td>5 1/4&quot;</td>
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<tr>
<td>DC wedge clearance hole</td>
<td>9/16&quot;</td>
<td>7/16&quot;</td>
<td>9/16&quot;</td>
<td>11/16&quot;</td>
<td>13/16&quot;</td>
<td>1 1/8&quot;</td>
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<td>L anchor length min./max.</td>
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<td>4 1/2&quot;</td>
<td>7&quot;</td>
<td>10&quot;</td>
<td>12&quot;</td>
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<td>TL thread length std./extra thread length</td>
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<td>7/16&quot;/1 1/16&quot;</td>
<td>1 1/4&quot;</td>
<td>1 1/4&quot;</td>
<td>1 1/2&quot;</td>
<td>1 1/2&quot;</td>
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<td>M Installation torque (ft. lb.) guide values</td>
<td>Stainless Steel</td>
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<td>20</td>
<td>40</td>
<td>85</td>
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<td>Carbon Steel</td>
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<td>4</td>
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<td>BMT Min. Base Material Thickness (inches)</td>
<td>3&quot; or 1.3E whichever number is greater</td>
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### Listings

Conforms to the description in Federal Specification FF-S-325, Group II, Type 4, Class 1 for concrete expansion anchors.
Factory Mutual listed "Pipe Hangers" 1/8" KB II w/rod coupler.
Southern Building Code Congress International, SBCCI Report #8913
City of Los Angeles Research Report #24946

### Anchor Program

#### Standard Kwik Bolt II Sizes

<table>
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<tr>
<th>Item Number</th>
<th>Description</th>
<th>Hole Dia. (In.)</th>
<th>Anchor Length (In.)</th>
<th>Min. Embed. Depth (In.)</th>
<th>Thread Length</th>
<th>Hilti Drill Bit</th>
<th>Qty. Per Box/CTN.</th>
<th>Std. Emb. (In.)</th>
<th>Allowable Working Loads 4000 psi Concrete</th>
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<td>2&quot;</td>
<td>630 / 530*</td>
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<td>000453605</td>
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<td>1 1/4</td>
<td>3/8&quot;</td>
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<td>750 / 1470*</td>
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<td>3/8&quot;</td>
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<td>1 1/4</td>
<td>3/8&quot;</td>
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<td>20/100</td>
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<td>8000 / 5120**</td>
</tr>
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<td>2 1/2&quot;</td>
<td>TE-C+ 1/4-8</td>
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<td>2 1/2&quot;</td>
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<td>20/100</td>
<td>16&quot;</td>
<td>8000 / 5120**</td>
</tr>
</tbody>
</table>

*Values shown are for shear plane acting through the anchor bolt shank. When the shear plane is acting through the anchor bolt threads, reduce shear values by 20%.

**Values shown are for a shear plane acting through the anchor bolt shank. When the shear plane is acting through the anchor bolt threads, reduce the shear value by 12%.

All other values shown are for shear plane acting through either body or threads.
Flare-bevel-groove weld (10)
Butt joint (B)
T-joint (T)
Corner joint (C)

<table>
<thead>
<tr>
<th>Welding Process</th>
<th>Joint Designation</th>
<th>Base Metal Thickness (U = unlimited)</th>
<th>Groove preparation</th>
<th>Tolerances</th>
<th>Permitted Welding Positions</th>
<th>Weld Size (E)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMAW</td>
<td>BTC-P10</td>
<td>3/16 min U T₁ min</td>
<td>R=0 f=3/16 min C=3T₃/2</td>
<td>+1/16, -0 U₁, -0 -0, +Not-Limited</td>
<td>All</td>
<td>5/6T₁</td>
<td>J2, Q2, Z</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GMAW</td>
<td>BTC-P10-GF</td>
<td>3/16 min U T₁ min</td>
<td>R=0 f=3/16 min C=3T₃/2</td>
<td>+1/16, -0 U₁, -0 -0, +Not-Limited</td>
<td>All</td>
<td>5/6T₁</td>
<td>A, J2, Q2, Z</td>
</tr>
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<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>SAW</td>
<td>T-P10-S</td>
<td>1/2 min N/A</td>
<td>R=0 f=1/2 min C=3T₃/2</td>
<td>±0 U₁, -0 -0, +Not-Limited</td>
<td>F</td>
<td>5/6T₁</td>
<td>J2, Q2, Z</td>
</tr>
</tbody>
</table>

Note A: Not prequalified for gas metal arc welding using short circuiting transfer. Refer to Appendix A.

Note J2: If fillet welds are used in statically loaded structures to reinforce groove welds in corner and T-joints, they shall be equal to 1/4 T₁, but need not exceed 3/8 in.

Note Q2: The member orientation may be changed provided that the groove dimensions are maintained as specified.

Note Z: Weld size (E) is based on joints welded flush.

*For cold formed (A500) rectangular tubes, C dimension is not limited (see commentary).

Figure 2.5 (continued) — Prequalified Partial Joint Penetration Groove Welded Joints (see 2.10.1)
**Square-groove weld (1)**
Butt joint (B)

<table>
<thead>
<tr>
<th>Welding Process</th>
<th>Joint Designation</th>
<th>Base Metal Thickness (U = unlimited)</th>
<th>Groove preparation</th>
<th>Tolerances</th>
<th>Permitted Welding Positions</th>
<th>Weld Size (E)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMAW</td>
<td>B-P1a</td>
<td>1/8 max</td>
<td>R=0 to 1/16</td>
<td>+1/16,-0</td>
<td>±1/16</td>
<td>All</td>
<td>T₁-1/32</td>
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<tr>
<td></td>
<td>B-P1c</td>
<td>1/4 max</td>
<td>R= ( \frac{T_1}{2} ) min</td>
<td>+1/16,-0</td>
<td>±1/16</td>
<td>All</td>
<td>( \frac{T_1}{2} )</td>
</tr>
</tbody>
</table>

**Square-groove weld (1)**
Butt joint (B)

<table>
<thead>
<tr>
<th>Welding Process</th>
<th>Joint Designation</th>
<th>Base Metal Thickness (U = unlimited)</th>
<th>Groove preparation</th>
<th>Tolerances</th>
<th>Permitted Welding Positions</th>
<th>Weld Size (E)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMAW</td>
<td>B-P1b</td>
<td>1/4 max</td>
<td>R= ( \frac{T_1}{2} )</td>
<td>+1/16,-0</td>
<td>±1/16</td>
<td>All</td>
<td>( \frac{3T_1}{4} )</td>
</tr>
</tbody>
</table>

Note B: Joint is welded from one side only.

**Figure 2.5** — Prequalified Partial Joint Penetration Groove Welded Joints (see 2.10.1)
I have reviewed your design calculations and believe that the basic frame design is sound. In theory design safety factors will exceed three on the yield of the frame material, due to the criteria of a single support carrying the entire heat exchanger weight, and the application of AISC safety factors.

The following questions, however, do arise:

1. What was the source of information on the heat exchanger weight?

2. Is there the possibility of a horizontal load parallel to the long axis of the heat exchanger, and how large can such a load be?

3. Is there the possibility of incidental vertical loads (personnel or equipment)?

4. No estimation of the effects of prying action were presented, and given the relatively thin plate through which the Hiltis anchor the bracket to the wall, this effect could be significant.

5. The bracket is of unusual shape; a simple truss would be more efficient. Was this shape driven by the need to avoid certain volumes due to cable trays, etc?

6. The calculation of vertical force on the vertical member assumes that force can be a maximum of the heat exchanger weight. However, one simplified analysis can show that, if the upper bracket is assumed to be pinned to the wall (simply supported) and the upper horizontal member is loaded, there is a mechanical advantage that tends to multiply the vertical load on the vertical member. For consistency this load should be examined as the highest load the member will see.

7. No calculation is presented for stability of the vertical member. As this design will transfer most of its shear to the bottom bracket via this member, (see 6 above) some check of stability should be made.

8. Are there any plans to load test the platform to some reasonable margin over its true
operational load?

9. No factor was included for dynamic loading during installation. Did you intend the doubling of design load to accommodate this effect?

Overall the note was very complete, well written, and easy to follow. I doubt that answering any of the questions above will result in a modification to the design, and as soon as I receive your reply and we get these issues resolved the note will be approved.
TO: Bob Wands
FROM: Russ Rucinski
SUBJECT: Reply to comments on review of Heat Exchanger Support Bracket Design Calcs.

Thank you for your review of the calculations. I will address your questions and comments in this memo. To document the information, a copy of your memo and this memo will be appended to D-Zero engineering note 3823.115-EN417 as a revision.

ANSWERS:

1. The heat exchanger weight of 6700 lbs was obtained by weighing the heat exchanger with a below the hook scale when the heat exchanger was initially moved into the D-Zero assembly building. The heat exchanger was recently weighed at 7100 lbs. The weight change was due to piping modification work. The center of gravity of the heat exchanger is approximately 24" towards the bayonet can end. So in the final installation the support closest to the bayonet will see a static load of 3960 lbs. and the other will see 3140 lbs.

2. The possibility of a horizontal load parallel to the axis is only present during installation. A calculation was done in which I estimated that each support could safely withstand a load of 1835 lbs in this direction, acting at a point 34" away from the wall mounting connection. Even though the expected horizontal load is an order of magnitude less than this, a temporary member is attached to one of the brackets to strengthen it in this direction during installation. Due to the nature of the installation, the other bracket does not have a possibility of horizontal loading.

3. Some additional vertical loading will be applied to the bracket furthest from the bayonet can end from piping being supported off of the vertical member. It is estimated that the additional weight will be less than 500 lbs. There will probably be very little if any piping supported off of the bracket nearest the bayonet can of the heat exchanger.

4. The plate through which the Hilti anchors act was increased to 3/8" thickness at the time of fabrication. In addition, the weld attaching this plate to the rectangular tubing was made continuous rather than intermittent. Since these changes only increased the strength of the design, I never revised the calculations. In hindsight, I agree that an analysis of the attachment plate should have been made. The effects of prying are not easily analyzed, and simple conservative models do indicate that it may have been a concern if the plate thickness was not increased.

5. The shape of the bracket was chosen by the installation location. The outermost surface of the vertical member matches the surfaces of concrete support columns in D-Zero.

6. The simplified analysis that you propose models the connection of the vertical member to the upper horizontal member as pinned. I think that model is interesting and conservative. I chose to consider that connection to be rather rigid considering the full around welding at the joint. If I consider the mechanical advantage model, the stresses in the member are still below allowables. I prefer not to revise the calculations for a pinned model.
7. The vertical member was not analyzed for buckling because it is a very short, stout member with relatively low stresses.

8. We have no plan to load test the supports.

9. Yes, doubling of the design load did give me a margin to take care of any dynamic loading during installation.
RESULTS: 6-RESULTS6
STRESS COMPONENT - MAG MIN: 4.84E-11 MAX: 1.16E+04

/dks4d3s7/ms_rucinski/HEucket2.mfl

VALUE OPTION: ACTUAL

1.16E+04
1.04E+04
9.28E+03
8.12E+03
6.96E+03
5.80E+03
4.64E+03
3.48E+03
2.32E+03
1.16E+03

APPENDIX C

Y
x
z
4.84E-11
## Node Stress

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### Node Stress

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Maximum: 1.160E+04  
Minimum: 4.838E-11  
Average: 3.742E+03
Heat Exchanger Bracket Results Listing

Elected 566 entities. Use "Highlight_Selection" to see all

Number of data items: 0

Number of data items: 0

Data component: VON MISES STRESS

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These beams stored in in the processed group.

Forces on beam 555 at X = 1.999998 for analysis dataset 5

Axial force = -2634.67
Y shear force = 8122.105
Z shear force = 0.0002531347
Torque = 0.0074000619
Bending moment = -0.06526328
Z bending moment = -122825.2

Forces on beam 566 at X = 1.5 for analysis dataset 5

Axial force = 2634.833
Y shear force = -1322.106
Z shear force = -0.0002531347
Torque = 0.0261942
Y bending moment = 0.4854327
Z bending moment = -246.9303
HX TOP PLATE ANALYSIS

WORST CASE FROM 3B23.115-EN-417, SEE PG. 9 ON WELD ANALYSIS.

\[ R_{ax} = 6158.5 \text{ lbs} \]
\[ R_{ay} = 6800 \text{ lbs} \]

DEFLECTION & STRESS DUE TO \( R_{ax} \)

Case 1c, TABLE 26, ROARK & YOUNG, 6TH ED.
EDGES SIMPLY SUPPORTED

\[ \text{Max } \sigma = G_b = \frac{BW}{t^2} \]
\[ W = qa, b_1 = 6158.5 \text{ lbs} \]
\[ t = 0.375 \text{ inches} \]

\[ a = 10.5 \text{ inches} \]
\[ a_1 = 8 \text{ inches} \]
\[ b = 6.5 \text{ inches} \]
\[ b_1 = 4 \text{ inches} \]

\[ \frac{a}{b} = 1.615 \]
\[ \frac{b_1}{b} = 0.615 \]
\[ a_1/b_1 = 1.23 \]

INTERPOLATE: FOR \( a = 1.4b \) \( B = 0.515 \)
\[ \Rightarrow a = 1.7b, B = 0.5775 \]

FOR \( a = 2b \) \( B = 0.64 \)

INTERPOLATE: FOR \( a = 1.615b \) \( B = 0.562 \)
\[ \sigma = \left( 0.562 \right) \left( 6158.5 \text{ lbs} \right) = 24612 \text{ psi} \]
FIRST PASS LOOKS BAD.

H.R. STEEL, ABG PLATE USED WITH MIN. YIELD = 36 ksi:

\[ F_b = 0.66 F_y = 0.66 (36 \text{ ksi}) = 23.76 \text{ ksi} \]

REAL LOADING IS HALF OF DESIGN:

\[ \sigma_{rem} = \frac{1}{2} (24.6 \text{ ksi}) = 12.3 \text{ ksi} \]

\[ \frac{\sigma_{rem}}{F_b} = \frac{12.3}{23.76} = 0.52 \]

LOOK AT ACTUAL LOADING: MECHANISM [USING DESIGN LOAD = 6800 lbs]

\[ q_{top} \cdot 4 \text{ inches} + q_{bottom} \cdot 4 \text{ inches} + \left( \frac{q_{bottom} + q_{top}}{2} \right) \cdot 2 \cdot 8 \text{ inches} = 6198.5 \]

\[ 12 q_{bottom} + 12 q_{top} = 6158.5 \]

\[ \frac{q_{bottom} + q_{top}}{12 \text{ inch}} = 513.2 \frac{\text{ lbs}}{\text{ in}}. \]

\[ 6198 \leftarrow 19.875 \]

\[ \frac{19.875 + 4}{19.875} \quad (P \text{ mean}) \]

\[ 6158 \rightarrow \]

\[ \frac{19.875 - 4}{19.875} \quad (P \text{ mean}) \]

\[ \frac{q_{top}}{q_{bottom}} = \frac{(19.875 + 4)}{(19.875 - 4)} = 1.504 \]
SOLVING THE TWO EQUATIONS:

\[ q_{\text{bottom}} + 1.504 q_{\text{bottom}} = 513.2 \text{ lbs/in} \]
\[ q_{\text{bottom}} = 205 \text{ lbs/in} \]
\[ q_{\text{top}} = 308 \text{ lbs/in} \]

LOOK AT WELD STRESS, \( \frac{1}{8}'' \) FILLET TOP WORST CASE

\[ \sigma_{\text{tensile}} = \frac{308 \text{ lbs/in}}{0.125 \text{ in}} = 3488 \text{ psi} \text{ O.K.} \]

CHECK A CANTILEVER PLATE, SUPERPOSITION

CASE 7a, TABLE 26

SHEAR SIDE LOAD ALONG FREE EDGE ALSO

\[ q_{\text{top}} = 308 \text{ lbs/in} \times 4 \text{ in} \]
\[ q_{\text{sides}} = q_{\text{avg}} = 256.5 \text{ lbs/in} \times 2 \text{ sides} \times (4 \text{ in}) \]
\[ W_{\text{total}} = \frac{3,284 \text{ lbs}}{a} = \frac{3284 \text{ lbs}}{6.5 \text{ in}} = 505 \text{ lbs/in} \]

\( a/b = 5.2 \) BIGGEST TABLE GOES IS 3.0.

TRY CANTILEVER BEAM

\[ M = (3284 \text{ lbs})(1.25 \text{ in}) \]
\[ = 4105 \text{ in-lbs} \]
\[ I = \frac{bh^3}{12} = \frac{(6.5 \text{ in})(3.8 \text{ in})^3}{12} = 0.028564 \text{ in}^4 \]
\[ \sigma_{b} = \frac{Mc}{I} = \frac{(4105 \text{ in-lbs})(3.16 \text{ in})}{(0.028564 \text{ in}^4)} = 26,946 \text{ psi} \]