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.

Summary of Support bracket design analysis

DESIGN ITEM	MAX. CALCULATED STRESS OR LOAD	ALLOWABLE STRESS OR LOAD	COMBINED fa/Fa + fb/Fb < 1.0
Upper horiz. member	1.1 ksi, tensile	27 ksi, tensile	0.357
{4" x 8" x 1/4" wall rect. tubing}	2.2 ksi, shear	18.4 ksi, shear	
	9.6 ksi, bending	30.4 ksi, bending	
Vertical member, CASE II	1.2 ksi, compressive	27 ksi, tensile	0.155
{4" x 8" x 1/4" wall rect. tubing}	2.0 ksi, shear	18.4 ksi, shear	
	3.4 ksi, bending	30.4 ksi, bending	
Vertical member, CASE I	2.0 ksi, shear	18.4 ksi, shear	not applicable
{4" x 8" x 1/4" wall rect. tubing}	8.7 ksi, bending	30.4 ksi, bending	
Lower horiz. member	1.1 ksi, compressive	27 ksi, compressive	0.357
{4" x 8" x 1/4" wall rect. tubing}	2.2 ksi, shear	18.4 ksi, shear	
	9.6 ksi, bending	30.4 ksi, bending	
Wedge anchors, 1/2" dia.	1820 lbs, tensile load	2400 lbs, tensile load	ft/Ft^2 + fv/Fv^2 < 1.0
{Hilti Kwik bolt II}	850 lbs, shear load	1960 lbs, shear load	0.763
Fillet weld, top anchor plate	993 lbs/linear inch	1909 lbs/linear inch	not applicable
{1/8" intermittent fillet weld}			
Weld, upper horiz. to vert.member	4146 lbs/linear inch	3818 lbs/inch - 2 short sides	not applicable
1/4" fillet, 1/4" groove		5250 lbs/inch - 2 long sides	
Weld, vert. to lower horiz. member	2.4 ksi, compressive	27 ksi, compressive	0.676
{1/8" groove weld}	10.8 ksi, bending	18.4 ksi, shear	
Fillet weld, bottom anchor plate	993 lbs/linear inch	1909 lbs/linear inch	not applicable
{1/8" intermittent fillet weld}			

Russ Rucinski, RD/D0 Mechanical

FERMILAB ENGINEERING NOTE	SECTION RD/DØ	PROJECT HEAT EXCHANGER	SERIAL-CATEGORY 3823.115	PAGE 1

SUBJECT: HEAT EXCHANGER SUPPORT BRACKET DESIGN ANALYSIS

NAME: RUSS RUCINSKI

DATE: 12-20-94

REVISION DATE:

CHECKED: Todd M. Leicht 1-12-95

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.

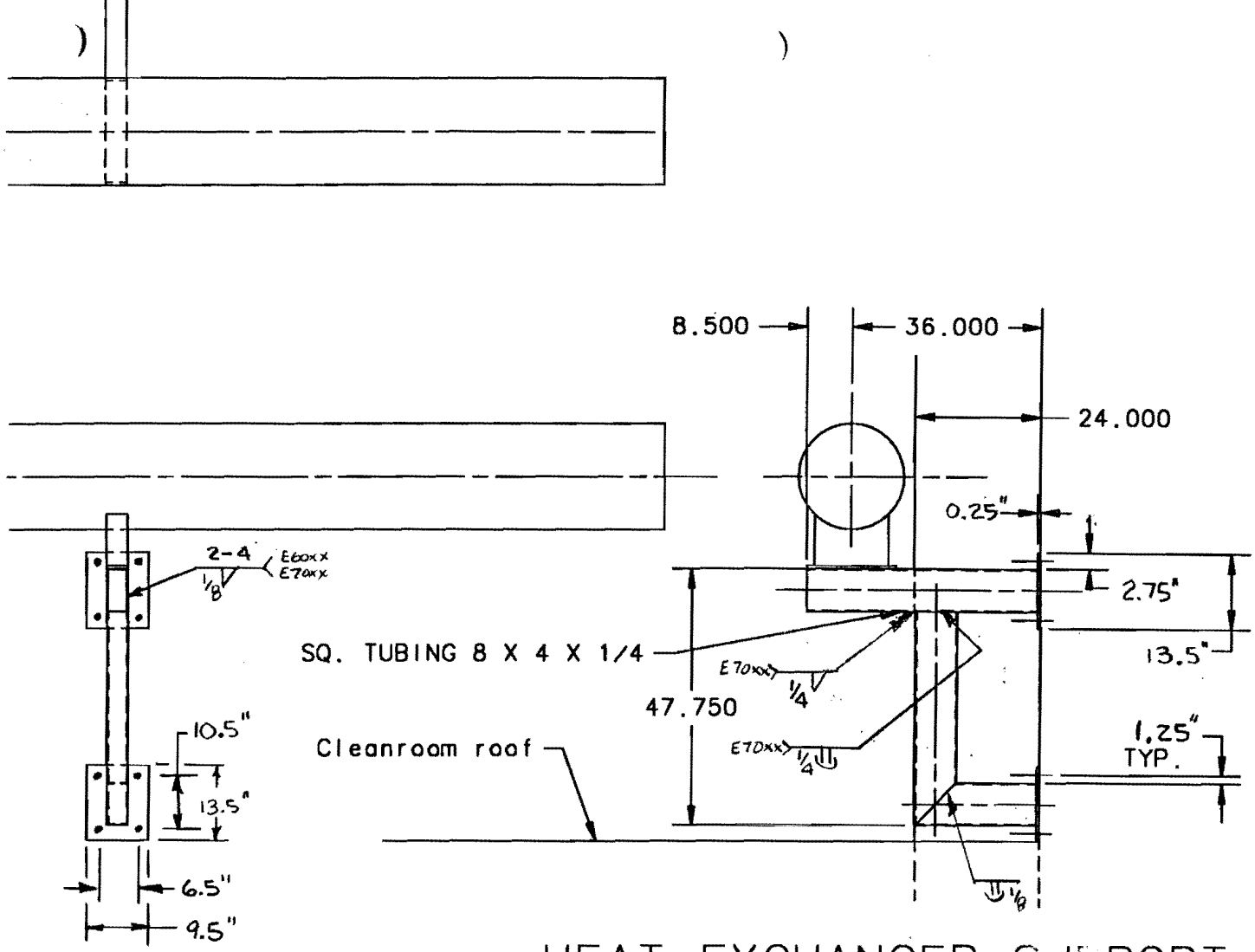
BASED ON PRELIMINARY DESIGN CALCULATIONS THE SUPPORT BRACKET WILL BE AS SHOWN IN FIGURE 1.

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

Plotted Tue Dec 20 09:42:18 CST 1994 by rucinski

FIGURE 1

SUBJECT: HEAT EXCHANGER SUPPORT BRACKET DESIGN ANALYSIS

NAME: RUSS RUCINSKI

DATE: 12-20-94 | REVISION DATE:

CHECKED: Todd M. Leicht 1-12-9

FREE BODY DIAGRAM

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

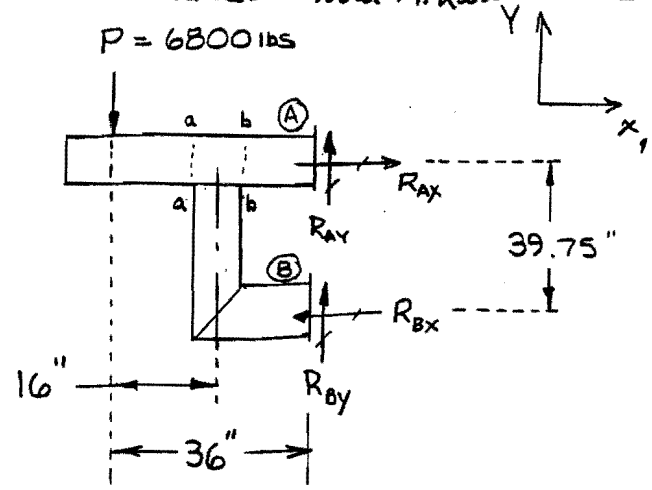


FIGURE 2

$\Sigma F_x = 0 \qquad R_{AX} = R_{BX}$

$\Sigma F_y = 0 \qquad R_{AY} + R_{BY} = P$

$\Sigma M_A = 0 \quad \circlearrowleft^{+} \quad R_{BX} \cdot (39.75) = P(36)$

$R_{BX} = 6158.5$ 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.

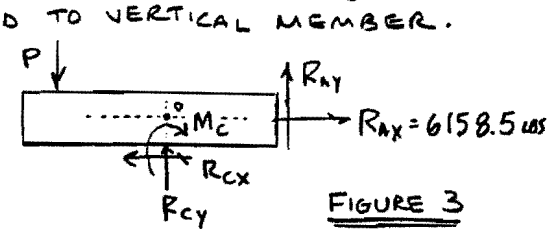


FIGURE 3

$\Sigma F_x = 0 \qquad R_{CX} = 6158.5$ lbs.

$\Sigma F_y = 0 \qquad R_{CY} = 0$; $R_{AY} = 6800$ lbs

$\Sigma M_o = 0 \circlearrowleft^{+} \quad -P(16) - R_{AY}(20) + R_{CX}(4) + M_C = 0$

$M_C = 220{,}166$ IN-lbs

CASE II

$R_{AX} = 6158.5$ LBS

$R_{BX} = 6158.5$ LBS

$R_{AY} = 0$

$R_{BY} = 6800$ LBS.

$\Sigma F_x = 0 \qquad R_{CX} = 6158.5$ LBS.

$\Sigma F_y = 0 \qquad R_{CY} = P = 6800$ lbs ; R_{AY}

$\Sigma M_o = 0 \circlearrowleft^{+} \quad -P(16) + R_{CX}(4) + M_C = 0$

$M_C = 84{,}166$ IN-lbs

SUBJECT: HEAT EXCHANGER SUPPORT BRACKET DESIGN ANALYSIS

NAME: RUSS RUCINSKI

DATE: 12-21-94 | REVISION DATE:

CHECKED: Todd M. Lucht 1-12-95

(A) THE UPPER HORIZONTAL MEMBER NEEDS TO BE ANALYZED AT SECTIONS a-a AND b-b AS SHOWN IN FIGURE 2.

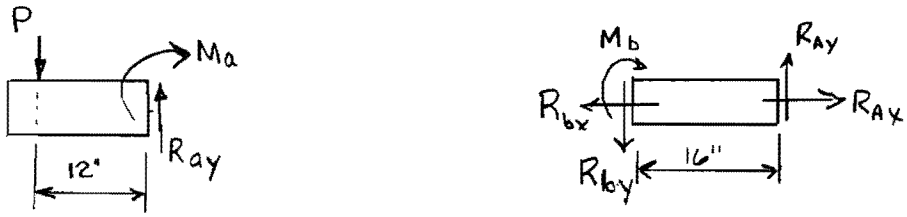


FIGURE 4: F.B.D. OF LEFT & RIGHT SECTIONS OF UPPER HORIZONTAL MEMBER

CASE I	CASE II
SECTION a-a $R_{ay} = P$ $M_a = P\cdot(12\text{ in.})$ $R_{ay} = 6800$ lbs $M_a = 81,600$ in-lbs	$R_{ay} = P$ $M_a = P\cdot(12\text{ in.})$ $R_{ay} = 6800$ lbs $M_a = 81,600$ in-lbs
SECTION b-b $R_{bx} = R_{Ax}$ $R_{by} = R_{Ay}$ $M_b = R_{Ay}\cdot(16\text{ in})$ $R_{bx} = 6158.5$ lbs $R_{by} = 6800$ lbs $M_b = 108,800$ in-lbs	$R_{bx} = 6158.5$ lbs $R_{by} = 0$ $M_b = 0$

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 1/4". (THIS IS EXCESS STOCK AT D-ZERO ASSEMBLY BLDG.)

AISC MANUAL OF STEEL CONSTRUCTION, EIGHTH EDITION IS USED FOR THIS ANALYSIS.

$A = 5.59\text{ in}^2$, $S_x = 11.3\text{ in}^3$, $I_x = 45.1\text{ in}^4$ {PER AISC TABLES}

MATERIAL IS ASTM A500 GR. B STEEL.

$F_u = 58,000$ psi $F_y = 46,000$ psi {REF. RYERSON STOCK LIST & DATA BOOK '87-88}

ALLOWABLES

AXIAL TENSION : $F_t = 0.60 F_y = 27,600$ psi {AISC PAR. 1.5.1.1}

SHEAR : $F_v = 0.40 F_y = 18,400$ psi {AISC PAR. 1.5.2.1}

SUBJECT: HEAT EXCHANGER SUPPORT BRACKET DESIGN ANALYSIS

NAME: RUSS RUCINSKI

DATE: 12-21-94 | REVISION DATE:

CHECKED: Todd M. Leidt 1-12-95

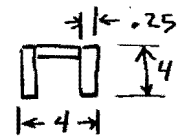
BENDING : $F_b = 0.66F_y = 30,360$ psi {AISC PAR. 1.5.1.4.1}

- CALCULATED HIGHEST STRESSES IN UPPER HORIZONTAL MEMBER

TENSION : $f_a = \frac{R_{ox}}{A} = \frac{6158.5 \text{ lbs}}{5.59 \text{ in}^2} = 1101.7$ 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 τ_{MAX} @ THE CENTER.

$\tau_{MAX} = \frac{VQ}{Ib}$ $\quad Q = \int y\,dA = 7.3906 \text{ in}^3$



$$\tau_{MAX} = \frac{(6800 \text{ lbs})(7.3906 \text{ in}^3)}{(45.1 \text{ in}^4)(.50 \text{ in.})} = 2229 \text{ psi}$$

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

COMBINED STRESS, AXIAL TENSION & BENDING {AISC PAR. 1.6.2}

$$f_a/0.60F_y + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0 \quad \text{\{AISC Eq. 1.6-1b\}}$$

$$1101.7/27,600 + 9628/30,360 + 0 \leq 1.0$$

$$\boxed{0.357 \leq 1.0}$$

→ ALL COMPUTED STRESSES AND COMBINED STRESSES FOR THE UPPER HORIZONTAL MEMBER ARE MUCH LOWER THAN AISC ALLOWABLES.

SUBJECT: HEAT EXCHANGER SUPPORT BRACKET DESIGN ANALYSIS

NAME: RUSS RUCINSKI

DATE: 12-21-94 | REVISION DATE:

CHECKED: Todd M. Leidt 1-12-95

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

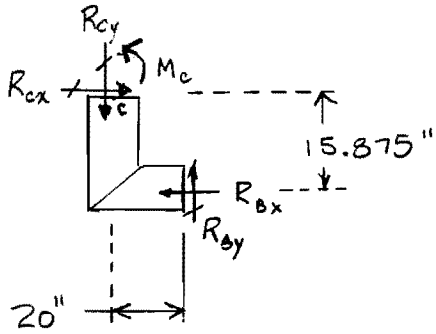


FIGURE 5: F.B.D. OF LOWER PORTION

$\Sigma F_x = 0 \qquad R_{cx} = R_{Bx}$

$\Sigma F_y = 0 \qquad R_{cy} = R_{By}$

$\Sigma M_c = 0 \circlearrowleft + \qquad -M_c - R_{By}(20\text{ in.}) + R_{Bx}(15.875) = 0$

$M_c = R_{By}(20\text{ in.}) - R_{Bx}(15.875)$

CASE II	CASE I
$R_{cx} = 6158.5$ LBS	$R_{cx} = 6158.5$ LBS
$R_{cy} = 6800$ LBS	$R_{cy} = 0$
$M_c = 6800\text{lbs}(20) - (6158.5\text{ lbs})(15.875) = 38{,}234$ in-lbs	$M_c = -97{,}766$ in-lbs.
AXIAL COMPRESSIVE STRESS: $f_a = \frac{R_{cy}}{A} = 1216$ psi	$f_a = 0$
SHEAR: τ_{MAX} @ CENTER, 0 @ SIDES. {RATIO RESULT ON PAGE 5 UPPER MEMBER} $\tau_{MAX} = \frac{6158.5}{6800} \times (2229\text{ psi}) = 2019$ psi	$\tau_{max} = 2019$ psi
BENDING STRESS $f_b = \frac{M_c}{S} = \frac{38{,}234\text{ in-lbs}}{11.3\text{ in}^3} = 3{,}384$ psi	$f_b = \frac{M_c}{S} = \frac{-97{,}766\text{ in-lbs}}{11.3\text{ in}^3} = 8{,}652$ psi

FOR CASE II, $f_a/F_a = 0.044 < 0.15$ ∴ COMBINE STRESS REQUIREMENT USING FORMULA 1.6-2

$$f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$$

$$.044 + 3{,}384/30{,}360 + 0 = .155 \leq 1.0$$

→ ALL COMPUTED STRESSES AND COMBINED STRESSES FOR THE VERTICAL MEMBER ARE MUCH LOWER THAN AISC ALLOWABLES.

(C) 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 b-b OF THE UPPER MEMBER. ∴ IT IS O.K.

(D) 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 II STUD ANCHOR ARE SUITABLE.

THE CONCRETE THEY WILL BE MOUNTED IN IS 4000psi CONCRETE PER BUILDING PLANS. (NOTE FROM PLANS IN APPENDIX)

ANALYZE AS A BEARING TYPE CONNECTION (VS. FRICTION TYPE)

$$\text{SHEAR LOAD PER BOLT} = \frac{6800}{8} = 850 \text{ lbs.}$$

TENSILE LOAD PER BOLT WILL VARY WITH DISTANCE FROM "NEUTRAL AXIS"

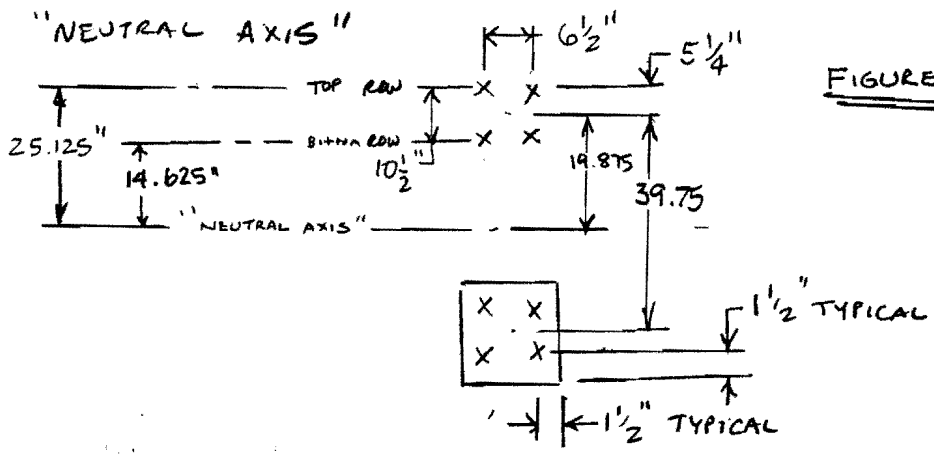


FIGURE 6: ANCHOR BOLT PATTERN

FOLLOW EXAMPLE 4.10.6(b) ("STEEL STRUCTURES, DESIGN & BEHAVIOR, 2nd ED, CHARLES SALMO et al. BEARING CONNECTION

$$M = (6800 \text{ lbs}) \times (36 \text{ in.}) = 244{,}800 \text{ in-lbs}$$ {ALSO SEE FIG. 2}

$$f_t = \frac{My}{\Sigma A y^2}$$ (EQ. 4.10.23)

$$y = 19.875 + 5\tfrac{1}{4} = 25.125 \text{ in.}$$

f_t = AXIAL TENSILE STRESS IN TOP MOST BOLT.

$$\Sigma A y^2 = 4 \cdot A_B \left[(14.625)^2 + (25.125)^2 \right]$$

$$= A_B \cdot (3380.625 \text{ in}^2)$$

$$T_i = F_t \cdot A_B = \frac{My}{(3380.625 \text{ in}^2)} = \frac{244{,}800 \text{ in-lbs}\,(25.125 \text{ in})}{3380.625 \text{ in}^2} = \underline{1819 \text{ lbs}}$$

FERMILAB ENGINEERING NOTE	SECTION	PROJECT	SERIAL-CATEGORY	PAGE
	RD/DØ	HEAT EXCHANGER	3823.115	8

SUBJECT: HEAT EXCHANGER SUPPORT BRACKET DESIGN ANALYSIS

NAME: RUSS RUCINSKI

DATE: 12-27-94 REVISION DATE:

CHECKED: Todd M. Leicht 1-12-95 CHART INCL. IN APPENDIX.

FROM HILTI SELECTION CHART, 1/2" ANCHOR IS ADEQUATE.
SPECIFY: HILTI KB II 12-412, ITEM# 000453688
ALLOWABLE WORKING LOAD, 1/2"Ø WITH 3 1/2" EMBEDMENT.

$(.8)\,F_v = 1960$ lbs SHEAR {REDUCED BY 20% SINCE SHEAR PLANE THRU BOLT THREADS}

$F_T = 2400$ lbs TENSION

USING AN INTERACTION EQUATION: $\left(\frac{f_v}{F_v}\right)^2 + \left(\frac{f_t}{F_t}\right)^2 \leq 1.0$ {REF. EQ. 4.10.2 STEEL STRUCTURES DESIGN & BEH.}

$$\left(\frac{850}{1960}\right)^2 + \left(\frac{1819}{2400}\right)^2 = .763 \leq 1.0 \quad \checkmark \text{ O.K.}$$

CHECK THE 1/4" A36 PLATE:

NOMINAL STRESS $\sigma = P/A_{NET} = \dfrac{(850\text{ lbs})(2\text{ BOLTS})}{(.25\text{ IN THICK})(9\tfrac{1}{2}'' - 2\cdot(5/8''))}$

$= 824$ psi NEGLIGIBLE.

CHECK STRUCTURAL CONCRETE DETAILS WHERE ANCHORS WILL BE INSTALLED. APPROXIMATE BLDG. ELEVATION IS 740' FOR TOP LEG, 736' FOR BOTTOM LEG.

FROM BUILDING PLANS, SHEET SC-19, DRG. # 6-3-3,
SECTION B/SC-1 SHOWS THIS WALL ITEMS OF INTEREST

SHOW THERE IS A CONSTRUCTION JOINT @ EL. 736'-6".
ALSO #4 REBAR @ 12" SPACING RUNNING VERTICALLY.
#5 REBAR @ 12" " " HORIZONTALLY.
THE REBAR IS 1" BELOW THE SURFACE.
INSTALLERS SHOULD AVOID BOTH.

SUBJECT: HEAT EXCHANGER SUPPORT BRACKET DESIGN ANALYSIS

NAME: RUSS RUCINSKI

DATE: 12-22-94 | REVISION DATE:

CHECKED: Todd M. Leicht 1-12-95

(E) WELD TO TOP PLATE

THE WORST CASE LOADING FOR THIS WELD IS FOR $R_{AY} = 6800$ lbs
$R_{AX} = 6158.5$ LBS

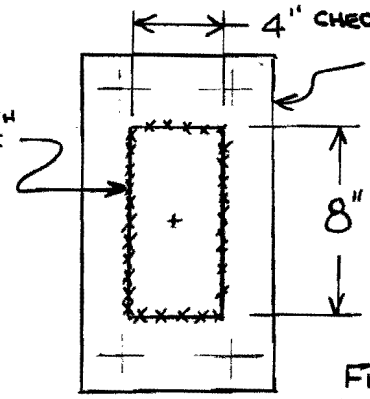


FIGURE 7: WELD OUTLINE TOP MOUNTING PAD

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

$f_{SHEAR} = 0.30 \times$ NOMINAL TENSILE STRENGTH OF WELD METAL, BUT NOT TO EXCEED $0.40 \times$ YEILD STRESS OF BASE METAL

$f_{TENSILE}$ = SAME AS BASE METAL $= F_t = 0.6 F_y = 0.6(36{,}000) = 21{,}600$ psi

USE E70XX ELECTRODE; 70 KSI TENSILE STRENGTH. {AWS TABLE}

$f_{SHEAR} = 0.3(70) = 21$ KSI BUT NOT $> 0.4(36\text{ksi}) = 14.4$ KSI

$\therefore$ $f_{SHEAR} = 14.4$ KSI
$f_{TENSILE} = 21.6$ KSI

CALCULATE RESULTANT FORCE.

$$W = \sqrt{R_{AX}^2 + \left[R_{AY}\left(\frac{21.6}{14.4}\right)\right]^2} = 11{,}915 \text{ LBS.}$$

MINIMUM FILLET WELD SIZE IS 1/8" {PER AISC TABLE 1.17.2A}

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

f, ALLOWABLE LOAD PER LINEAR INCH OF WELD $= f_{TENSILE} \times .707 \times (.125 \text{ in.})$

$f = 1{,}909$ lbs PER IN.

$$L = \frac{11{,}915 \text{ LBS}}{1909 \text{ LBS/IN}} = 6.24 \text{ IN.}$$

USE INTERMITTENT FILLET WELDS.

MINIMUM WELD LENGTH $= 1\frac{1}{2}$" PER AISC.

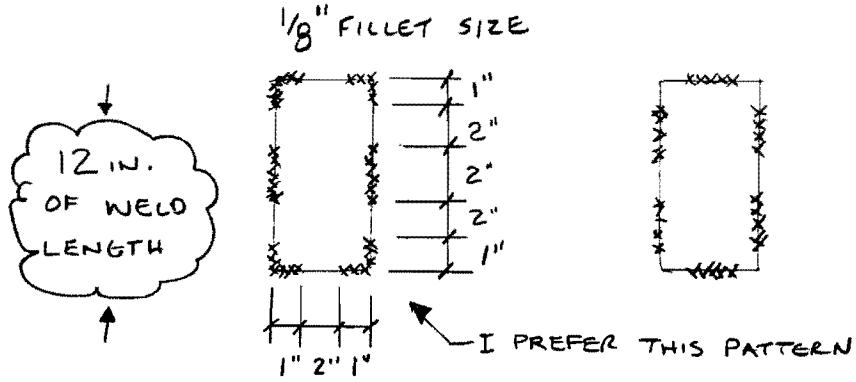
SUBJECT: HEAT EXCHANGER SUPPORT BRACKET DESIGN ANALYSIS

NAME: RUSS RUCINSKI

DATE: 12-22-94 | REVISION DATE:

CHECKED: Todd M. Lucht 1-12-95

POSSIBLE PATTERNS FOR INTERMITTENT WELDS ARE:

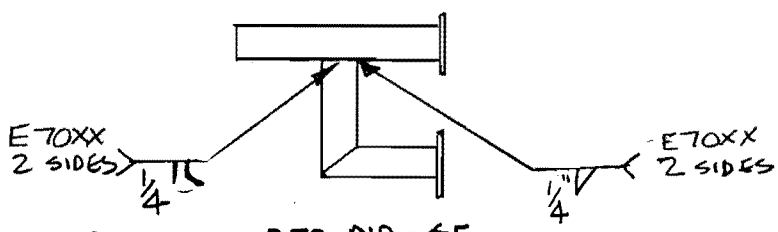


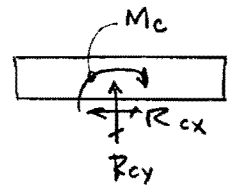
ACTUAL LOAD PER INCH = $\frac{11915 \text{ lbs}}{12 \text{ in.}}$

$= 993 \text{ lbs/in.}$

FIGURE 8: INTERMITTENT WELD PATTERNS

(F) WELD TO VERTICAL MEMBER

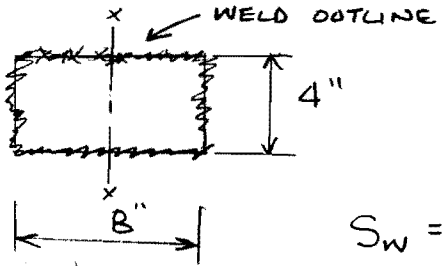




JOINT DESIGNATION BTC-P10-GF

LOADS ON WELD (FROM BOTTOM OF PAGE 3) {CASE I IS WORST}

$R_{cx} = 6158.5$ LBS, $R_{cy} = 0$ lbs, $M_c = 220{,}166$ in-lbs



ANALYZE LIKE FILLET ALL AROUND.

$$S_w = bd + \frac{d^2}{3}$$ ABOUT X-X

WHERE $b = 4''$ $d = 8''$

$S_w = 53.33 \text{ in}^2$

$$W_B = \frac{M}{S_w} = \frac{220{,}166 \text{ in-lbs}}{53.33 \text{ in}^2} = 4{,}128 \text{ lbs/in.}$$

$$W_{SHEAR} = \frac{R_{cx}}{L} = \frac{6158.5 \text{ LBS}}{24 \text{ in}} = 256.6 \text{ lbs/in}$$

RESULTANT LOADING (MUST INCREASE SHEAR LOAD DUE TO LOWER ALLOWABLE & COMPARE TO TENSILE ALLOWABLE)

$$W = \sqrt{(4128 \text{ lb/in})^2 + \left[(256.6 \text{ lbs/in})\left(\frac{21.6}{14.4}\right)\right]^2} = 4146 \text{ lb/in.}$$

SUBJECT: HEAT EXCHANGER SUPPORT BRACKET DESIGN ANALYSIS.

NAME: RUSS RUCINSKI

DATE: 12-29-94 | REVISION DATE:

CHECKED: Todd M. Leicht 1-12-95

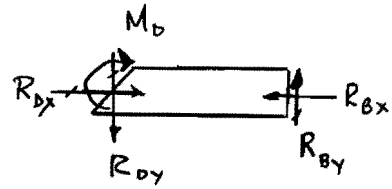
SIZE WELD: ALLOWABLE LOAD PER INCH OF WELD = $f_{TENSILE} \times .707 \times t_{WELD}$

$$t_{WELD\ REQ'D} = \frac{4146\ lb/in}{21{,}600\ lbs/in^2 \times .707} = .27''$$

ALLOWABLE 1/4" FILLET = (21,600)(.707)(.25) = 3818 lbs per lin inc

LONG SIDES ALLOWABLE = .30 (ELECTRODE TENSILE STRENGTH) = .30(70 KSI)(.25 IN.) = 5250 lbs per lin inc

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-GRINDED BUTTWELD 2 OTHER SIZES.



(G) WELD @ 45° MITER.

WORST CASE IS CASE II

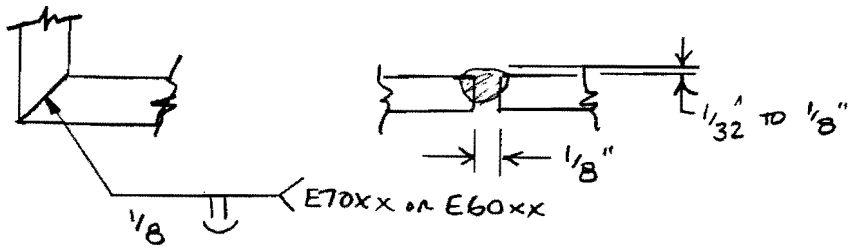
$R_{Dx} = R_{Bx} = 6158.5$ LBS

$R_{DY} = R_{BY} = 6800$ LBS

$M_D = R_{BY}(20\ in.) = 136{,}000$ in-lbs.

WELD LENGTH = 2 SIDES × (4 in.) + 2 SIDES × (8 in. × $\sqrt{2}$) = 30.63 in.

DESIGNATE WELD JOINT B-P1L PER Fig 2.5 OF AWS D1.1-90 PARTIAL JOINT PENETRATION GROOVE WELD



CROSS SECTIONAL AREA OF WELD, $A_W = (.125\ in)(30.63\ in) = 3.829\ in^2$

- THE ELECTRODE WILL "MATCH" THE BASE MATERIAL SO ALLOWABLES FOR THE WELD ARE THE SAME AS FOR THE TUBE IT JOINS.

SHEAR LOAD

$$V = (R_{Dx} + R_{DY})\cos(45°) \approx 0$$

COMPRESSION

$$C = (R_{Dx} + R_{DY})\cos 45° = 9163\ \text{LBS.}$$

SUBJECT: HEAT EXCHANGER SUPPORT BRACKET DESIGN ANALYSIS

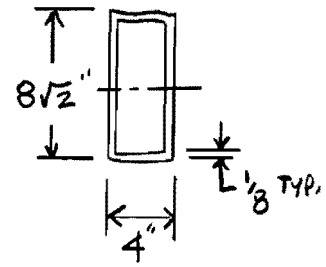
NAME: RUSS RUCINSKI

DATE: 12-29-94 | REVISION DATE:

CHECKED: Todd M. Leicht 1-12-95

COMPRESSIVE STRESS IS NEGLIGIBLE $\approx \frac{9163 \text{ lbs}}{3.8 \text{ in}^2} = 2411$ psi

BENDING



$$I = \frac{b_o h_o^3}{12} - \frac{b_i h_i^3}{12} =$$

$$= \frac{(4 \text{ in.})(8 \text{ in.} \sqrt{2})^3}{12} - \frac{(3.75 \text{ in.})[(7.75)\sqrt{2}]^3}{12}$$

$$= 482.72 \text{ in}^4 - 411.43 \text{ in}^4$$

$$= 71.29 \text{ in}^4$$

$$\sigma_b = \frac{Mc}{I} = \frac{136{,}000 \text{ in-lbs} \left(\frac{8\sqrt{2}}{2}\right)}{71.29 \text{ in}^4} = 10{,}792 \text{ psi}$$

BENDING ALLOWABLE = 30,360 psi {SEE PAGE 5}

COMPUTED STRESSES ARE MUCH LESS THAN ALLOWABLES THEREFORE THE 1/8" GROOVE WELD [WHICH IS THE MINIMUM SIZE ALLOWED PER AWS] IS FINE.

$f_a/F_a + f_b/F_b = 2.411/27 + 10.8/18.4 = .676 < 1.0$

(H) WELD AT BOTTOM PLATE

THE ANALYSIS IS IDENTICAL TO THE ANALYSIS FOR THE WELD AT THE TOP PLATE. SEE PGS. 9 & 10.

AND SHALL BE SUBJECT TO FERMILAB OR TESTING LABORATORY APPROVAL. WHERE REQUIRED, SHEETING AND BRACING SHALL BE UTILIZED.

3. THE SOIL UNDER THE BASE MAT FOUNDATION SLABS SHALL HAVE A SAFE BEARING VALUE OF 7,500 PSF FOR THE LOWER BASE MAT AND 5,000 PSF FOR THE UPPER BASE MAT.

4. THE BUILDING FOOTINGS SHALL BE FOUNDED ON GRANULAR EMBANKMENT WITH A SAFE BEARING VALUE OF 4,000 PSF. SEE SPECIFICATION SECTION 2A, SITE WORK, PARAGRAPH C.13.

5. DEWATER 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 BERMS.

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.

3. REINFORCING DETAILS SHALL CONFORM TO ACI STANDARD 315-80.

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 PLACING 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.

9. WELDS NOT OTHERWISE SHOWN TO BE 1/4" FILLET WELDS CONTINUOUS.

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. FASTEN DECK PANELS TO THE STRUCTURAL FRAMEWORK AT ENDS AND AT INTERMEDIATE SUPPORTS BY WELDS SPACED NOT MORE THAN 12" 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.

AILS

REV.	DATE	DESCRIPTIONS
		REVISIONS

DESIGNED	J. LA FAUCE	6/7/
DRAWN	J. LA FAUCE	6/7/
CHECKED	E. L. Major	6/7/
APPROVED	Wayne R. Nastala	6/7/
SUBMITTED	R. E. Young	6/7/

FERMI NATIONAL ACCELERATOR LABORATOR

UNITED STATES DEPARTMENT OF ENERGY

D-O EXPERIMENTAL AREA

GENERAL NOTES AND TYPICAL WATERPROOFING DETAILS

DRAWING NO. 6-3-3 G-

APPENDIX PAGE A2

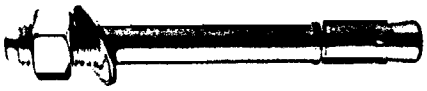
Specification Table

Setting Details				Anchor Size					
				HKB ¼"	HKB ⅜"	HKB ½"	HKB ⅝"	HKB ¾"	HKB 1"
BD = D drill bit size = anchor diameter				¼"	⅜"	½"	⅝"	¾"	1"
E	depth of embedment (minimum/standard)			1⅛"/2"	1⅝"/2½"	2¼"/3½"	2¾"/4"	3¼"/4¾"	4½"/6"
HD	hole depth (E + 1 *D) min./std.			1⅜" / 2¼"	2" / 2⅞"	2¾" / 4"	3⅜" / 4⅝"	4" / 5½"	5½" / 7"
DC	wedge clearance hole			5/16"	7/16"	9/16"	11/16"	13/16"	1⅛"
L	anchor length min./max.			1¾" 4½"	2¼" 7"	2¾" 7"	3¾" 10"	4¾" 12"	6" 12"
TL	thread length std./ extra thread length			¾" 3"	⅞"/1⅛" 4"	1¼" 4"	1½" 3½"/4½"	1½" 3½"/4½"	2¼" 4½"
M	Installation torque (ft. lb.) guide values	Stainless Steel	min. E	4	20	40	85	150	235
			std. E	7	30	75	110	200	450
		Carbon Steel	min. E	4	20	40	85	150	250
			std. E	7	25	65	110	235	450
BMT	Min. Base Material Thickness (inches)			3" or 1.3E whichever number is greater					

Listings

Conforms to the description in Federal Specification FF-S-325, Group II, Type 4, Class 1 for concrete expansion anchors.
UL listed, "Pipe Hangers" (⅜" - ¾" diameters). International Conference of Buildings Officials, ICBO Evaluation Report #4627.
Factory Mutual listed "Pipe Hangers" ⅜ 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



Item Number	Description	Hole Dia. (In.)	Anchor Length (In.)	Min. Embed. Depth (In.)	Thread Length	Hilti Drill Bit	Qty. Per Box/Ctn.	Std. Emb. (In.)	Allowable Working Loads 4000 psi Concrete Tension (lbs.)	Shear (lbs.)
000453597	KB II 14-134	¼	1¾	1⅛	¾"	TE-C+ ¼-6	100/900	2"	630	530*
000453605	KB II 14-214	¼	2¼				100/900			
000453613	KB II 14-314	¼	3¼				100/400			
000453621	KB II 38-214	⅜	2¼	1⅝	⅞"	TE-C+ ⅜-6	100/500	1⅝"	750	1470*
000453639	KB II 38-3	⅜	3	1⅝	1⅛"	TE-C+ ⅜-6	100/400	2½"	1370	1470*
000453647	KB II 38-334	⅜	3¾				100/400			
000453654	KB II 38-5	⅜	5				50/200			
000453662	KB II 12-234	½	2¾	2¼	1¼"	TE-C+½-6	50/200	3½"	2400	2450*
000453670	KB II 12-334	½	3¾				50/200			
000453688	KB II 12-412	½	4½			TE-C+ ½-12	50/200			
000453696	KB II 12-512	½	5½				25/125			
000453704	KB II 58-334	⅝	3¾	2¾	1½"	TE-C+⅝-6	25/100	4"	3290	3840**
000453712	KB II 58-434	⅝	4¾				25/75			
000453720	KB II 58-6	⅝	6			TE-C+ ⅝-12	25/75			
000453738	KB II 58-7	⅝	7				25/75			
000453746	KB II 34-434	¾	4¾	3¼	1½"	TE-C+¾-8	20/80	4¾"	4800	5120**
000453753	KB II 34-512	¾	5½				20/80			
000453761	KB II 34-7	¾	7			TE-C+ ¾-12	10/40			
000453779	KB II 34-8	¾	8				10/40			
000454124	KB II 1-6	1	6	4½	2¼"	TE-FY1-13	5/25	6"	7070	9200
000454132	KB II 1-9	1	9				5/20			

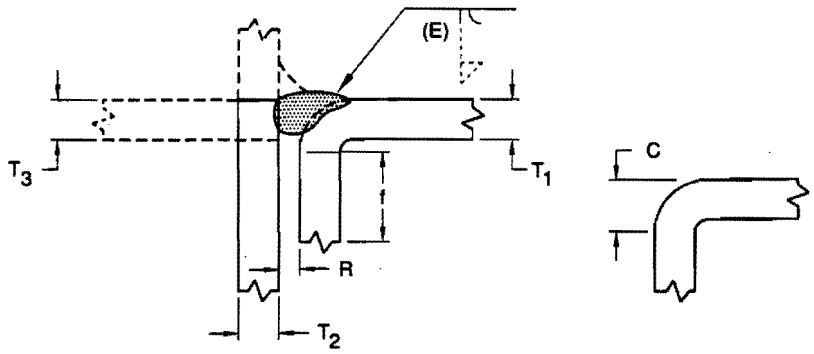
*Values shown are for shear plane acting through the anchor bolt shank. When the shear plane is acting through the anchor bolt threads, reduce shear values by 20%

**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 valves shown are for shear plane acting through either body or threads.

APPENDIX PAGE A3

Flare-bevel-groove weld (10)
Butt joint (B)
T-joint (T)
Corner joint (C)



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)			Groove preparation			Permitted Welding Positions	Weld Size (E)	Notes
					Root Opening Root Face Bend Radius*	Tolerances				
		T_1	T_2	T_3		As Detailed (see 2.10.2)	As Fit Up (see 3.3)			
SMAW	BTC-P10	3/16 min	U	T_1min	R=0 f=3/16 min C=$\frac{3T_1}{2}$ min	+1/16,-0 +U,-0 -0,+Not-Limited	+1/8,-1/16 +U,-1/16 -0,+Not-Limited	All	5/8T_1	J2, Q2, Z
GMAW FCAW	BTC-P10-GF	3/16 min	U	T_1min	R=0 f=3/16 min C=$\frac{3T_1}{2}$ min	+1/16,-0 +U,-0 -0,+Not-Limited	+1/8,-1/16 +U,-1/16 -0,+Not-Limited	All	5/8T_1	A J2, Q2, Z
SAW	T-P10-S	1/2 min	1/2 min	N/A	R=0 f=1/2 min C=$\frac{3T_1}{2}$ min	±0 +U,-0 -0,+Not-Limited	+1/16,-0 +U,-1/16 -0,+Not-Limited	F	5/8T_1	J2, Q2, Z

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 T_1, but need not exceed 3/8 in.

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

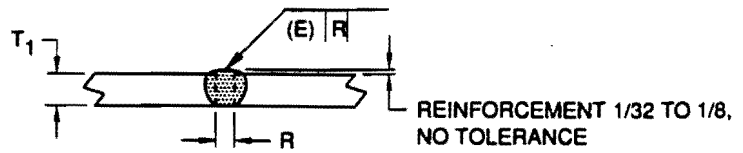
Note Z: Weld size (E) is based on joints welded flush.

*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)

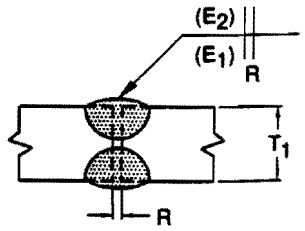
APPENDIX PAGE A4

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



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove preparation			Permitted Welding Positions	Weld Size (E)	Notes
					Tolerances				
		T_1	T_2	Root Opening	As Detailed (see 2.10.2)	As Fit Up (see 3.3)			
SMAW	B-P1a	1/8 max	—	R=0 to 1/16	+1/16,-0	±1/16	All	T_1-1/32	B
	B-P1c	1/4 max	—	R= $\frac{T_1}{2}$ min	+1/16,-0	±1/16	All	$\frac{T_1}{2}$	B

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

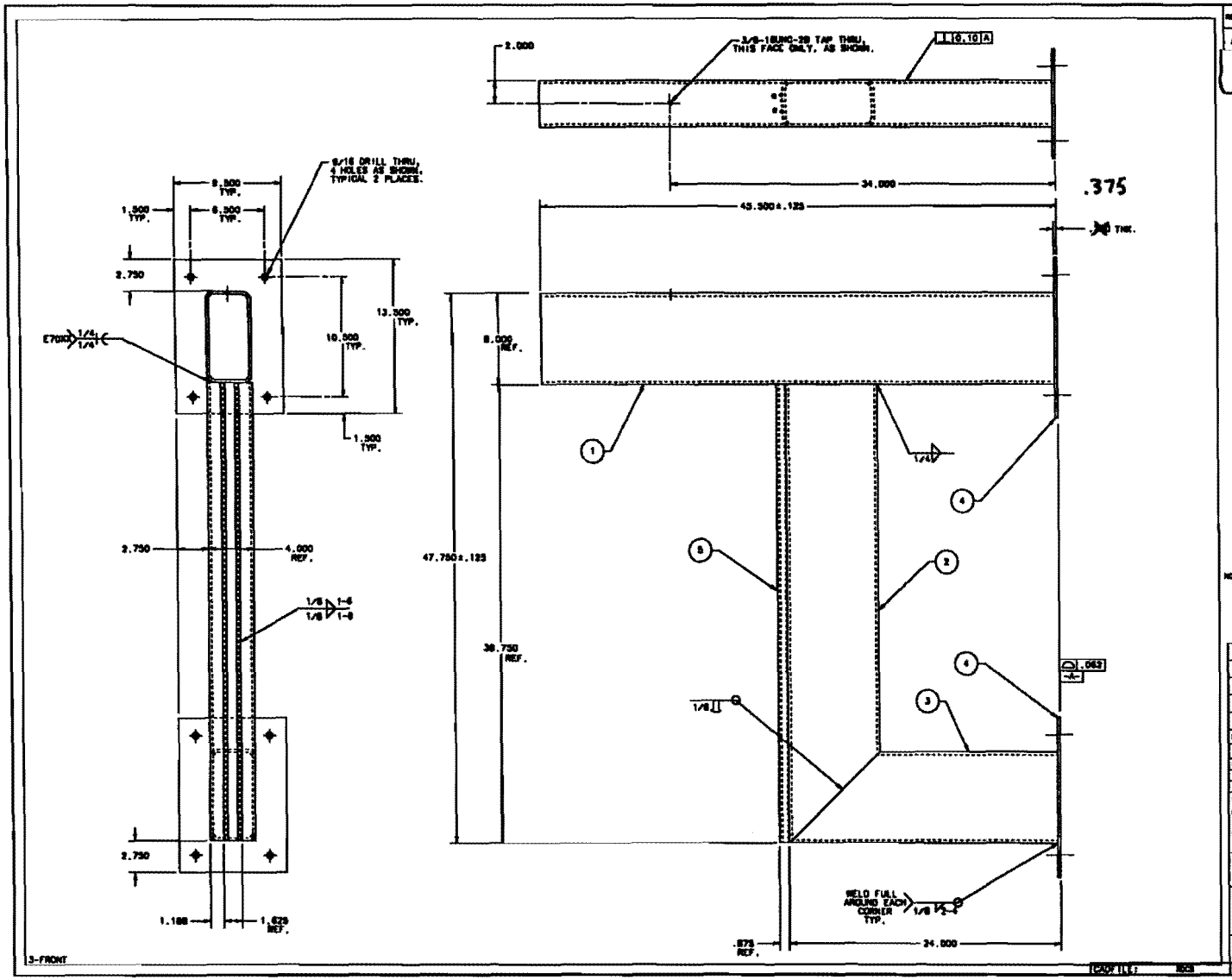


E_1+E_2 MUST NOT EXCEED $\frac{3T_1}{4}$

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove preparation			Permitted Welding Positions	Weld Size (E)	Notes
					Tolerances				
		T_1	T_2	Root Opening	As Detailed (see 2.10.2)	As Fit Up (see 3.3)			
SMAW	B-P1b	1/4 max	—	R= $\frac{T_1}{2}$	+1/16,-0	±1/16	All	$\frac{3T_1}{4}$	

Note B: Joint is welded from one side only.

Figure 2.5 — Prequalified Partial Joint Penetration Groove Welded Joints (see 2.10.1)



REV.	DESCRIPTION	DRAWN	DATE
A	ADDED ITEM 6	WATERKI	2/1/95
B	INCREASED ITEM 4 TO 3/8" THICK		

NOTE: ALL WELD ELECTRODES SHALL BE E70XX UNLESS OTHERWISE NOTED.

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
5	1341-1000	P-3300 UNISTRUT X 20.750" LG. OR EQUIVALENT	1
4	1534-1016	PLATE, 6.500" X 13.500" X 3/8" THK. (LOW CARBON HOT ROLLED STEEL)	8
3		[illegible]	1
2		[illegible]	1
1		[illegible]	1

PARTS LIST

DRAWN	WATERKI	1/13/95
CHECKED	RUSS RUCINSKI	1/24/95
APPROVED	W. KRESPETZ	1/26/95
MATERIAL	NOTED	

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

D-ZERO DETECTOR
STAR HEAT EXCHANGER
SUPPORT BRACKET

SCALE 1/4 | DRAWING NUMBER 3823.115-MD-317284 | REV. B

CREATED WITH I-DEAS 4.1 | USER NAME: WATERKI

Plotted Tue Feb 7 12:55:14 CST 1995 by ruclnskl

APPENDIX A5
REVISED 5/6/96

APPENDIX B1

November 7, 1995

FERMILAB

RD/MSD/Engineering Analysis Group

To: Russ Rucinski
From: Bob Wands BW
Subject: Review of Heat Exchanger Support Bracket Design Calculations

I have reviewed you 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 question, 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 it's 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.

APPENDIX B3

November 11, 1995

Fermilab

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 can 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 allowable. 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.

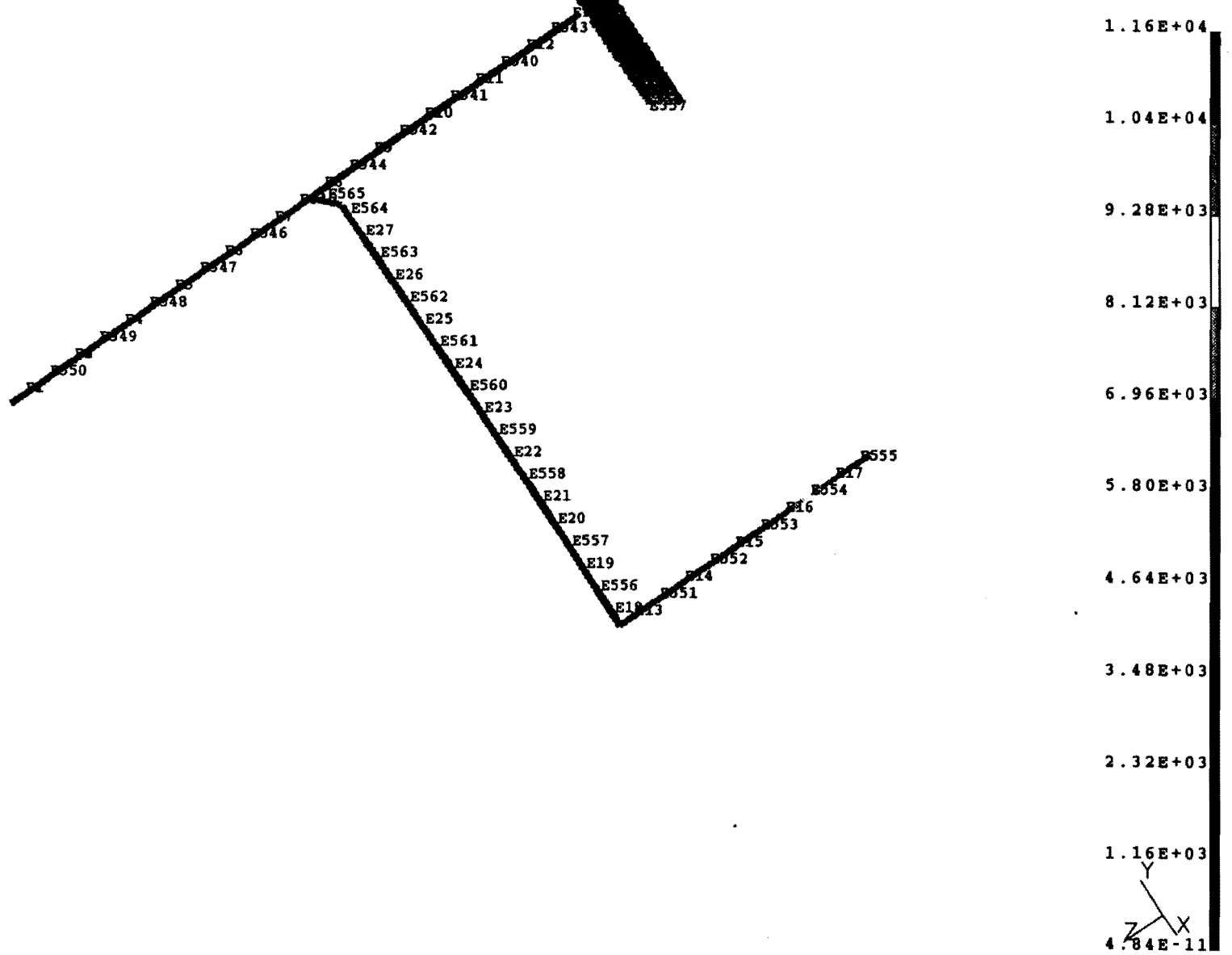
9. Yes, doubling of the design load did give me a margin to take care of any dynamic loading during installation.

/dks4d3s7/ms_rucinski/HX[illegible]cket2.mf1

RESULTS: 6-RESULTS6

STRESS COMPONENT - MAG MIN: 4.84E-11 MAX: 1.16E+04

VALUE OPTION:ACTUAL



APPENDIX C1

APPENDIX C2

I-DEAS Master Series 2.1: Simulation 02-Jan-96 10:44:39
/dks4d3s7/ms_rucinski/HXbracket2.mf1

Gr ID : None
Re t Set : 7 - RESULTS7
Report Type : Contour Units : IN
Result Type : STRESS COMPONENT

Node	Stress
1	4.838E-11
2	4.645E+03
3	7.603E-11
4	1.156E-10
5	2.019E-10
6	3.682E-10
7	3.553E-10
8	1.767E+03
9	3.533E+03
10	3.616E+03
11	4.314E+03
12	5.546E+03
13	6.779E+03
14	5.786E+03
15	2.950E+03
16	2.710E+03
17	2.471E+03
18	2.231E+03
19	1.991E+03
20	1.752E+03
21	1.512E+03
22	1.273E+03
23	1.033E+03
24	8.732E+02
25	4.805E+03
26	4.327E+03
27	3.850E+03
28	3.372E+03
29	2.895E+03
30	2.417E+03
31	2.087E+03
32	2.079E+03
33	2.400E+03
34	2.877E+03
35	3.355E+03
36	3.832E+03
37	4.310E+03
38	4.787E+03
39	5.265E+03
40	5.742E+03
41	6.220E+03
42	6.698E+03
43	6.915E+03
44	4.247E+03
45	4.247E+03
46	4.247E+03
47	4.247E+03
48	4.980E+03

I-DEAS Master Series 2.1: Simulation 02-Jan-96 10:44:39
/dks4d3s7/ms_rucinski/HXbracket2.mfl

APPENDIX C3

Node	Stress
49	6.450E+03
50	7.922E+03
51	9.395E+03
52	1.087E+04
53	1.160E+04
159	8.332E+02

Maximum	1.160E+04	53
Minimum	4.838E-11	1
Average	3.742E+03	

eat Exchanger Bracket Results LIsting

APPENDIX C4

elected 566 entities. Use "Highlight_Selection" to see all
umber of data items : 0
umber of data items : 0
ata component: VON MISES STRESS

Maximum Von Mises Stress

Beam	Location	Point	Loadset	Stress
555	1.0	7	1	11602.9
17	1.0	7	1	10130.7
554	1.0	7	1	8658.4863
545	1.0	5	1	7395.2891
16	1.0	7	1	7186.2974
564	1.0	8	1	6936.2935
565	0.0	8	1	6893.2378
27	1.0	8	1	6458.7412
7	1.0	5	1	6162.7417
563	1.0	8	1	5981.1885
553	1.0	7	1	5714.1079
26	1.0	8	1	5503.6357
18	0.0	6	1	5043.6450
562	1.0	8	1	5026.0825
546	1.0	5	1	4930.1924
556	0.0	6	1	4566.0928
25	1.0	8	1	4548.5283
13	0.0	6	1	4246.6167
14	0.0	6	1	4246.6152
15	0.0	6	1	4246.6152

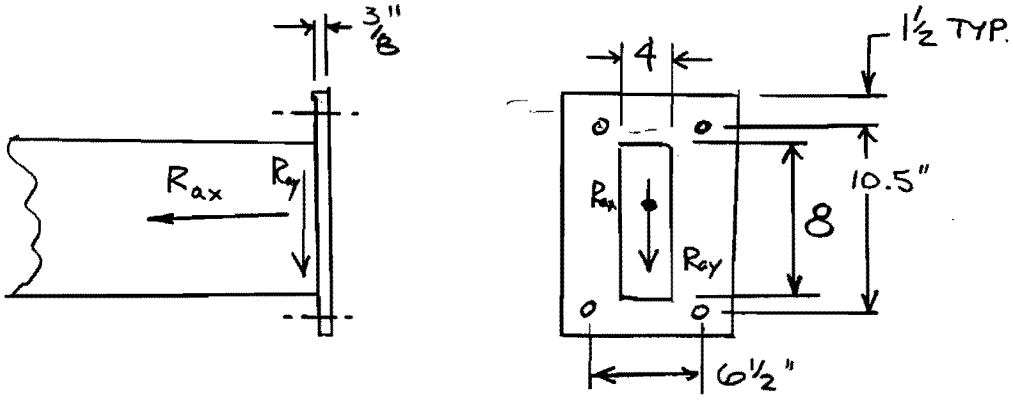
hese beams stored in in the processed group

orces 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
que = 0.007400619
bending moment = -0.06526328
Z bending moment = -122825.2

orces 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

APPENDIX D1

HX TOP PLATE ANALYSIS



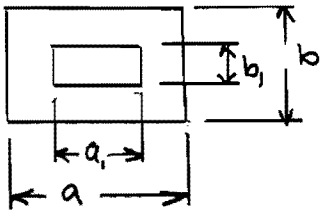
WORST CASE FROM 3823.115-EN-417, SEE PG. 9 ON WELD ANALYSIS.

$R_{ax} = 6158.5$ LBS

$R_{ay} = 6800$ lbs

DEFLECTION & STRESS DUE TO R_{ax}

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



$$\text{Max } \sigma = \sigma_b = \frac{\beta W}{t^2}$$

$W = q a_1 b_1 = 6158.5$ LBS

$t = .375$ INCHES

$a = 10.5$ INCHES $\quad a_1 = 8$ INCHES

$b = 6.5$ INCHES $\quad b_1 = 4$ INCHES

$\frac{a}{b} = 1.615 \qquad b_1/b = 0.615 \qquad a_1/b = 1.23$

INTERPOLATE; FOR $a = 1.4b \quad \beta = .515$

$a = 1.7b$, $\beta = .5775$

FOR $a = 2b \quad \beta = .64$

INTERPOLATE

FOR $a = 1.615b \quad \beta = .562$

$$\sigma = \frac{(.562)(6158.5 \text{ lbs})}{} = 24{,}612 \text{ psi}$$

FIRST PASS LOOKS BAD.

H.R. STEEL, A36 PLATE USED WITH MIN. YIELD = 36 KSI

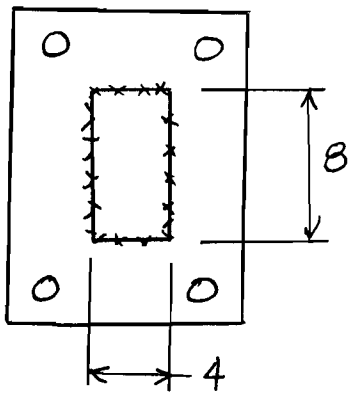
$$F_b = 0.66 F_y = 0.66(36\ \text{ksi}) = 23.76\ \text{ksi}$$

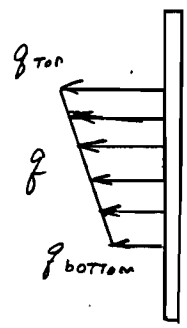
REAL LOADING IS HALF OF DESIGN:

$$\therefore\ \sigma_{b_{REAL}} = \frac{1}{2}(24.6\ \text{ksi}) = 12.3\ \text{ksi}$$

$$\frac{\sigma_{b_{REAL}}}{F_b} = \frac{12.3}{23.76} = \underline{0.52}$$

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





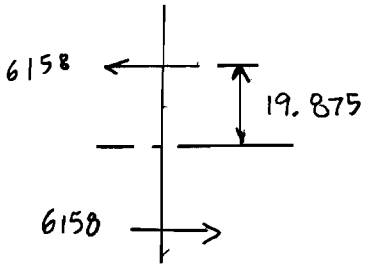
WHERE q = LOAD/INCH

q_{AVG} @ CENTER

$$q_{TOP} \cdot 4\ \text{INCHES} + q_{BOTTOM}\ 4\ \text{INCHES} + \left[\frac{q_{BOTTOM} + q_{TOP}}{\cancel{2}}\right] \times \cancel{2} \times 8\ \text{INCHES} = 6158.5$$

$$12\, q_{BOTTOM} + 12\, q_{TOP} = 6158.5$$

$$q_{BOTTOM} + q_{TOP} = \frac{6158.5}{12\ \text{INCHES}} = 513.2\ \frac{\text{lbs}}{\text{IN.}}$$



$$\text{LOAD TOP} = \frac{19.875 + 4}{19.875}\left(P_{MEAN}\right)$$

$$\text{LOAD BOTTOM} = \frac{19.875 - 4}{19.875}\left(P_{MEAN}\right)$$

$$\frac{q_{TOP}}{q_{BOTTOM}} = \frac{(19.875 + 4)}{(19.875 - 4)} = 1.504$$

APPENDIX D3

SOLVING THE TWO EQUATIONS;

$$q_{BOTTOM} + 1.504\, q_{BOTTOM} = 513.2 \frac{lbs}{IN}$$

$$q_{BOTTOM} = 205 \ lbs/IN.$$

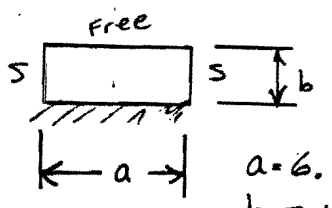
$$q_{TOP} = 308 \ lbs/IN.$$

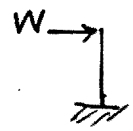
LOOK AT WELD STRESS, 1/8" FILLET TOP WORST CASE

$$\sigma_{TENSILE} = \frac{308 \ lbs/IN}{(.707)(.125 \ IN)} = 3488 \ psi \quad O.K.$$

CHECK A CANTILEVER PLATE, SUPERPOSITION

CASE 7f TABLE 26





DISTRIBUTED LINE LOAD ω, lb/IN @ FREE EDGE

$a = 6.5''$
$b = 1.25'$ $\quad t = 3/8$ INCH

SMEAR SIDE LOAD ALONG FREE EDGE ALSO

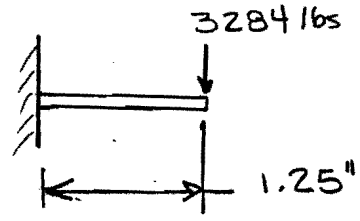
ie. $q_{TOP} = 308 \ lbs/IN. \times 4$ INCHES

$$q_{1/2 \ SIDES} = q_{AVG} = 256.5 \ lbs/IN \times 2 \ SIDES \times (\underbrace{4 \ INCHES}_{1/2 \ OF \ PLATE})$$

$$\omega_{total} = \frac{3,284 \ lbs}{a} = \frac{3284 \ lbs.}{6.5 \ IN.} = 505 \frac{lbs}{IN.}$$

$a/b = 5.2$ BIGGEST TABLE GOES IS 3.0.

TRY CANTILEVER BEAM



$$M = (3284 \ lbs)(1.25 \ IN)$$
$$= 4,105 \ IN\text{-}lbs$$

$$I = \frac{bh^3}{12} = \frac{(6.5 \ IN.)(3/8 \ IN)^3}{12} = .028564 \ IN^4$$

$$\sigma_b = \frac{Mc}{I} = \frac{(4,105 \ IN\text{-}lbs)(3/16 \ IN.)}{(.028564 \ IN^4)} = 26,946 \ psi$$