Fermilab

Lifting Device # 145

Particle Physics Division

12-01-01

Mechanical Department Engineering Note

Number: MD-Eng/03-0014 Date: July 24, 2003

Project: NuMI

Project Internal Reference:

Title: Target Hall Green/Blue Block Lifting Fixture

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Key Words: NuMI, Green Block, Blue Block and Target Hall

Abstract/Summary:

The NuMI Target Hall Green/Blue Block Lifting Fixture is designed to lift 60,000 pounds. Height of lifted load should be below the top rail of this fixture. The minimum sling angle off horizontal plane is 60 degree. All slings should be equal length. Lifting should be accomplished in such a manner that prevents unequal loading of the slings.

The design analysis was performed according to both AISC " Allowable Stress Design" code and ANSI B30-20 " Below the Hook Lifting Devices". The results show that all members will safely support Green/Blue Block within the allowable stress and deflection limits.

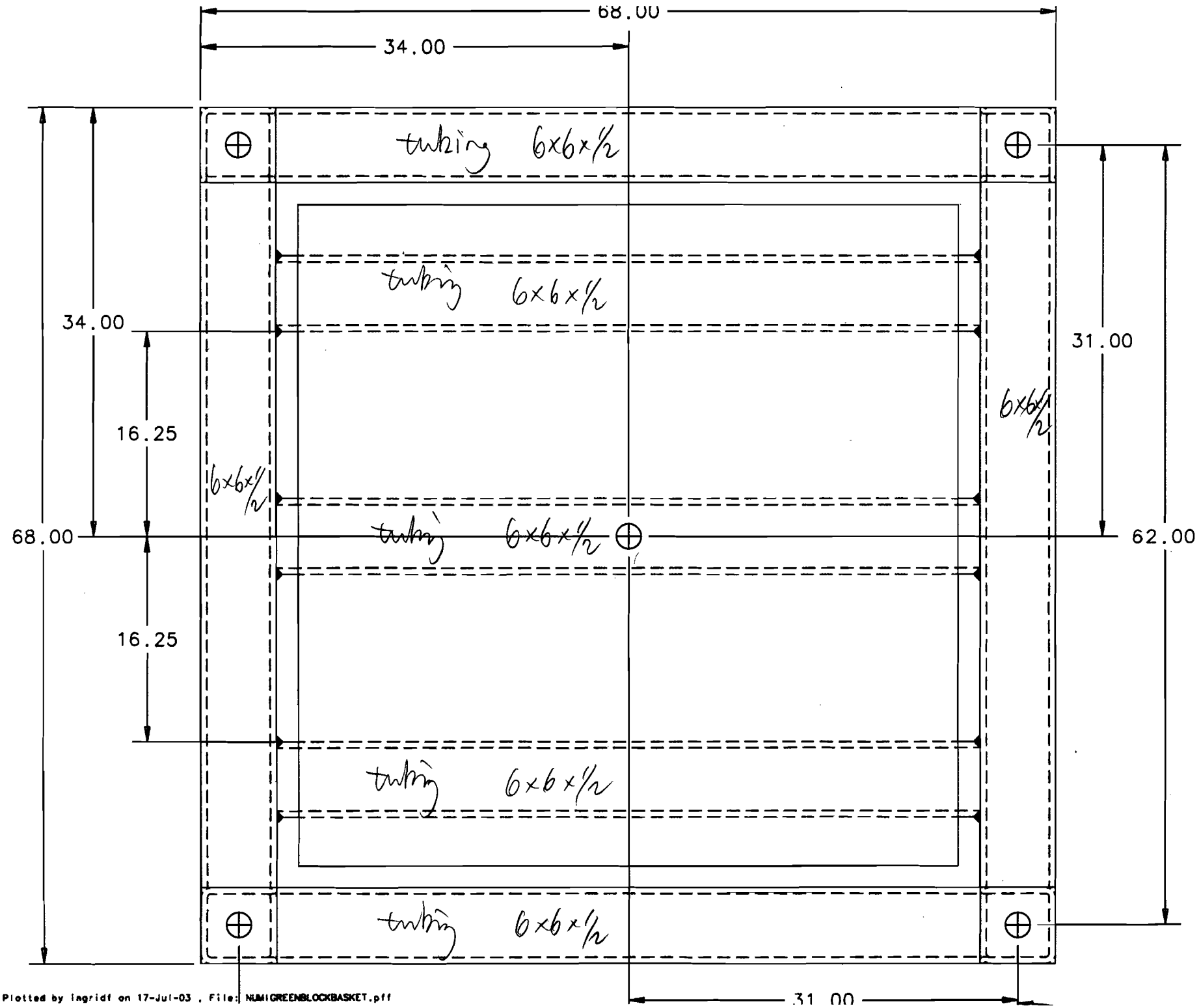
Applicable Codes:

- ***AISC Manual of Steel Construction, Allowable Stress Design, Ninth Edition***
- ***ANSI/ASME B30.20-1993, Below the Hook Lifting Devices***
- ***ANSI/AWS D1.1-98, Structural Welding Code - Steel***

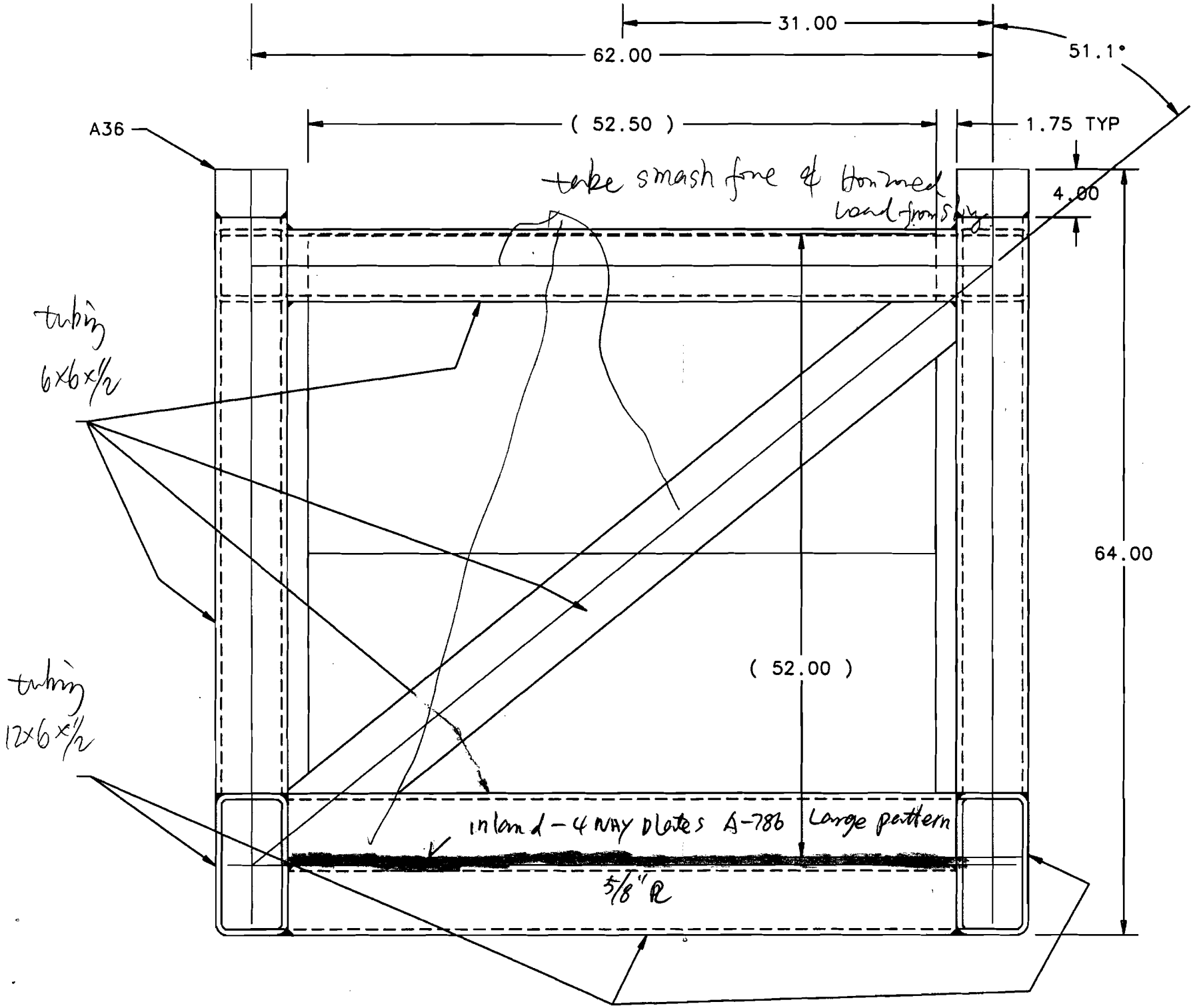
This lifting fixture is designed to lift 60,000 pounds. Height of lifted load should be below the top rail of this fixture. The minimum sling angle off horizontal plane is 60°. All slings should be of equal length. Lifting should be accomplished in such a manner that prevents unequal loading of the slings.

The design analysis was performed according to both AISC "Allowable Stress Design" Code and ANSI B30_20 "Below the Hook Lifting Devices". The results show that all members will safely support Green Block within the allowable stress and deflection limits.

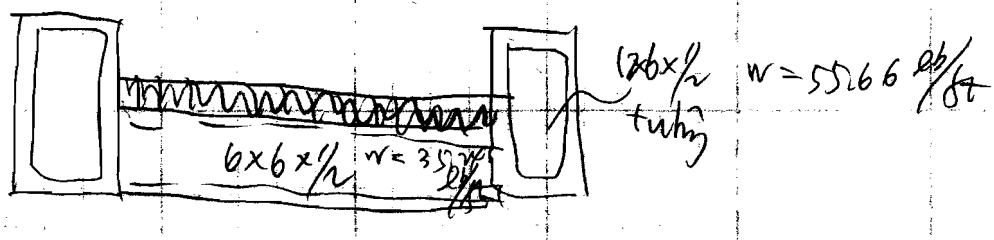
The sketch of this lifting fixture is shown below:

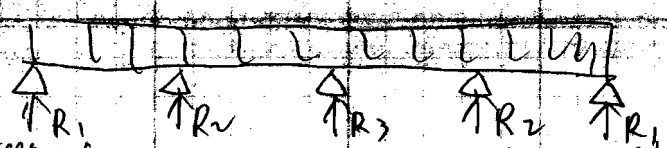


Plotted by ingridf on 17-Jul-03 , File: NUMIGREENBLOCKBASKET.pff


31.00
62.00
51.1°
A36
(52.50)
1.75 TYP
4.00
take smash force & Horizontal load from sling
tubing 6x6x1/2
64.00
(52.00)
tubing 12x6x1/2
inland - 4 WAY plates A-786 Large pattern
5/8" R

1. Design the floor plate





Green Block $W = 30\,\text{ton} \times 2000 = 60000\,\text{lb}$

$$\text{Area} = (68-12)^2 = 3136\ \text{in}^2$$

$$\frac{W}{\text{Area}} = \frac{60000}{3136} = 19.13\ \text{lb/in}^2$$

Assume 3/16" plate $W = 31.68\ \text{lb/ft}^2$

Live load $= 100\ \text{lb/ft}^2$

$$\Sigma W = 31.68 + 100 = 131.68\ \text{lb/ft}^2 = 0.914\ \text{lb/in}^2$$

$$\text{Design load} = \text{Green Block} + \Sigma W$$
$$= 19.13 + 0.914 = 20.04\ \text{lb/in}$$

From Ansys, knowing

$R_1 = 35.4\ \text{lb/in}$

$R_2 = 321\ \text{lb/in}$

$R_3 = 412\ \text{lb/in}$

$M_{max} = 667.65 \times 1.05^{*} = 701\ \text{lb-in}$ (at center)

*: Additional factor due to the weight of the floor plate.

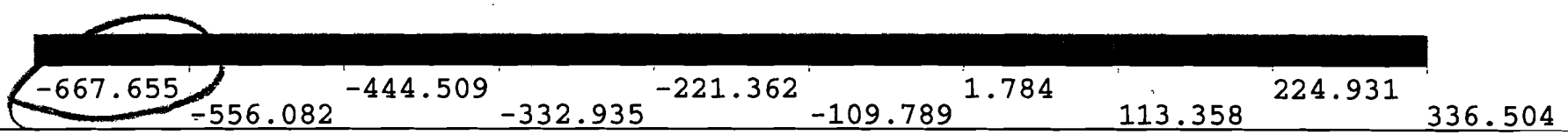
1
LINE STRESS

STEP=1
SUB =1
TIME=1
MON1 MON2
MIN =-667.655
ELEM=1
MAX =336.504
ELEM=12

U

ANSYS

JUL 7 2003
14:34:31



Check Bending on the plate.

$f_b = \frac{M}{S}$ where $f_b = \frac{1}{3}F_y = \frac{1}{3} \times 46 = 15.3$ ksi

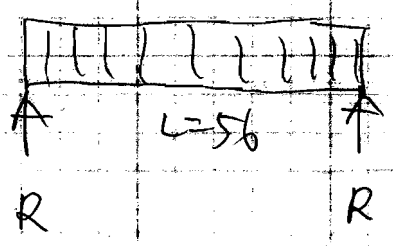
$M = 701$ lb-in

$S = \frac{bh^2}{6} = \frac{1 \times h^2}{6}$

$15300 \times \frac{h^2}{6} = 701$ $h = 0.52$ in

use 5/8" PL.

2. Design the tubings under the floor plate



$W_{max} = 412$ lb/in

$W_{tubing} = 35.24$ lb/ft $= 2.94$ lb/in

$\Sigma W = 412 + 2.94 = 415$ lb/in

$M_{max} = \frac{wl^2}{8} = \frac{415 \times 56^2}{8} = 162680$ lb-in

$S = 16.8$ in^3

$f_b = \frac{M_{max}}{S} = \frac{162680}{16.8} = 9.683$ ksi

$R = \frac{1}{2}(415 \times 56) = 11620$ lbs

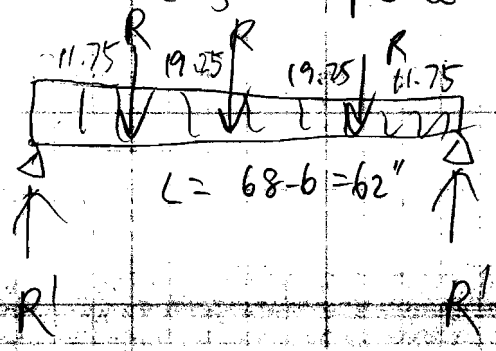
Compression, due to smash force (crane runway [illegible] Force)

$20\% W = 20\% \times 60000 = 12000$ lbs

$f_a = \frac{F}{A} = \frac{12000}{10.4} = 1.153$ ksi

$\frac{f_a}{F_a} + \frac{f_b}{F_b} \le 1$ $\frac{1.153}{\frac{1}{3}F_y} + \frac{9.683}{\frac{1}{3}F_y} = \frac{10.836}{\frac{1}{3} \times 46} = 0.7 < 1$ OK

3. Design the 12x6x½ tubing which connects to the tubings under the floor plate



$W = 55.66\ lb/ft = 4.64\ lb/in$

$R = 11620\ lbs$

$M_{1\,max} = \frac{1}{4}PL = \frac{11620}{4} \times 62 = 180110\ lb\text{-}in$

$M_{2\,max} = Pa = 11620 \times 11.75 = 136535\ lb\text{-}in$

$M_{3\,max} = \frac{WL^2}{8} = \frac{4.64 \times 62^2}{8} = 2229.52\ lb\text{-}in$

$\Sigma M_{max} = 180110 + 136535 + 2229.52$

$= 318874.52\ lb\text{-}in$

$S = 47.8\ in^3$

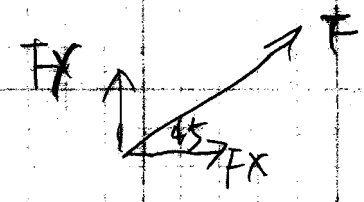
$f_b = \frac{M}{S} = \frac{318874.52}{47.8} = 6.671\ ksi < \frac{1}{3}F_y = 15.3\ ksi$

OK

$R' = (3 \times 11620 + 4.64 \times 62)/2 = 17573.8\ lb$

4. Design the column 6x6x½

Assume the sling angle off horizontal plane is 45°



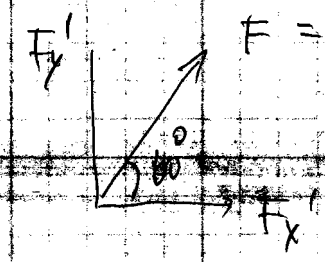
The Hoise Ring for 1½"–6' is rated to lift 24000 lb.

Thus $F = 24000\ lbs$

$F_x = F_y = \frac{F}{\sqrt{2}} = \frac{24000}{\sqrt{2}} = 16973.\ lb$

Since $R = 17573.8\ lb > F_y$ N.G.

— Assume the sling angle is 60°



$F_x' = \frac{1}{2}F = \frac{1}{2} \times 24000 = 12000\ lb$ — governs

$> 10\%\ W = 6000\ lbs$

$F_y' = \sqrt{F^2 - F_x'^2}$

$= \sqrt{24000^2 - 12000^2} = 20784.6\ lb$ (governs)

Since $R = 17573.8\ lb < F_y'$ OK

— check for sliding force

$f = \mu N$ where $\mu = 0.78$ (steel to steel)

$= 0.78 \times 60000$ $N = 60{,}000\ lb$

$= 46800\ lb$

↳ Sliding would never happen

— Assume the horizontal load F_x' will be taken by the Diagonal tubing $6 \times 6 \times \frac{1}{2}$

$tg\alpha = \frac{54}{62} = \frac{F_y''}{F_x''}$ where $F_x'' = F_x' +$ smash Force

$= F_x' + 20\%\ W$

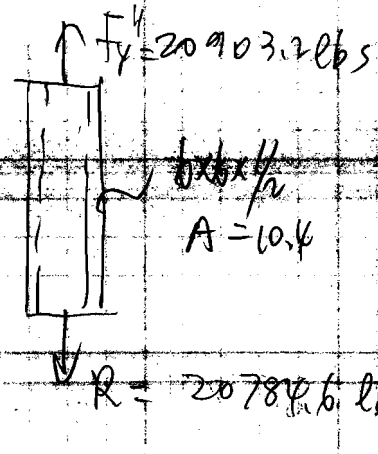
$= 12000 + 20\% \times 60000$

$= 24000\ lbs$

$F_y'' = 20903.2$ lbs

$$T = \sqrt{F_x''^2 + F_y''^2} = \sqrt{(20903)^2 + (24000)^2} = 31826.6 \text{ lbs}$$

check tension in column

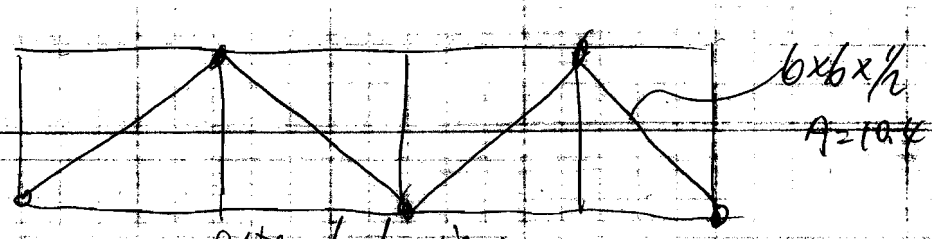


$$3F_t = R + F_y''$$
$$= 20784.6 + 20903.2$$
$$= 41687.8 \text{ lbs}$$

$$f_t = \frac{F}{A} = \frac{41687.8}{10.4} = 4.008 \text{ ksi} < F_t \quad \text{ok}$$

$$F_t = \frac{1}{3}F_y = \frac{1}{3} \times 46 = 15.3 \text{ ksi}$$

5. Design the diagonal member.



extended view

~~For tension or compression,~~

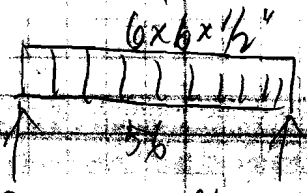
$$f = \frac{F}{A} = \frac{31826.6}{10.4} = 3.060 \text{ ksi} < F_a \text{ or } F_t \quad \text{ok}$$

$$F_a / F_t = \frac{1}{3}F_y = \frac{1}{3} \times 46 = 15.3 \text{ ksi}$$

6. Design the member connecting to the dignal on the top and on the Bottom.

Since the top member is 6x6x1/2 and Bottom member is 12x6x1/2.
use 6x6x1/2 only for the calculation

Bending:



$R_1 = 35.4$ lb/in

$W_t = 2.94$ lb/in

$R = 1073.5$ lb R

$\Sigma W = R_1 + W_t$
$= 35.4 + 2.94 = 38.34$ lb/in

$M_{max} = \frac{WL^2}{8} = \frac{38.34 \times 56^2}{8} = 15.029$ kip-in

$f_b = \frac{M}{S} = \frac{15029}{16.8} = 0.894$ ksi

Compression: $F_x'' = 24000$ lb

$f_a = \frac{F}{A} = \frac{24000}{10.4} = 2.307$ ksi

Combined stress $\frac{f_a}{F_a} + \frac{f_b}{F_b} \leq 1.0$

$\frac{2.307}{\frac{1}{3}F_y} + \frac{0.894}{\frac{1}{3}F_y} = \frac{3201.69}{15.3} = 0.209 < 1$

OK

7. Design the Hook Block

Cold draw square 6x6x4
1018

Shear: $f_v = \frac{F}{A} = \frac{F_x''}{A} = \frac{24000}{6 \times 6} = 666.6$ psi < 12000 psi

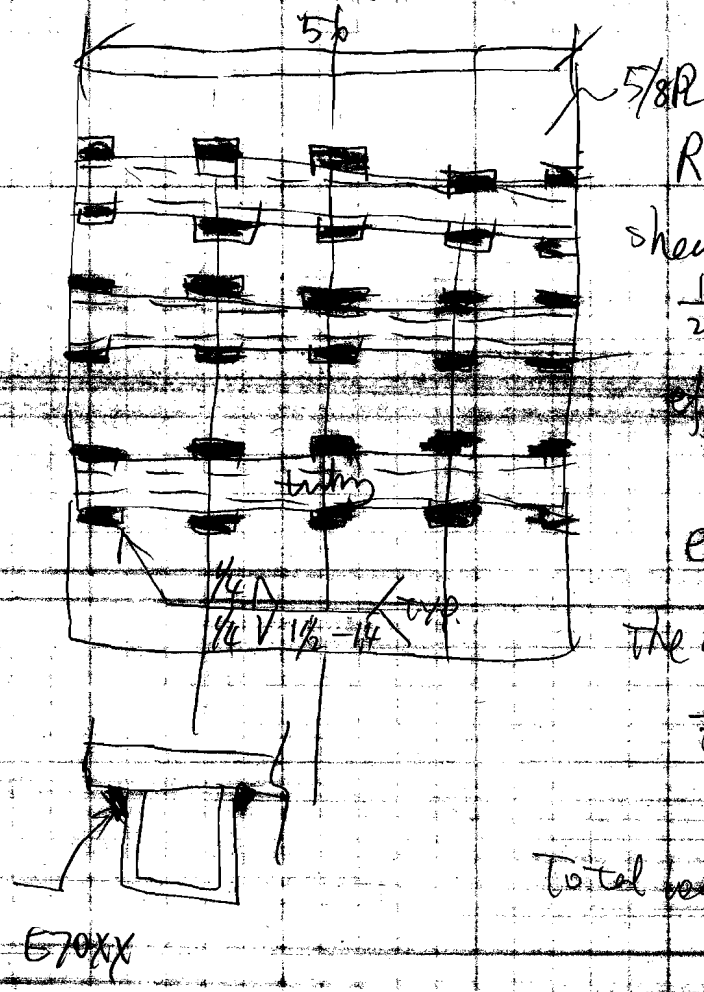
OK

$F_v = \frac{1}{3}F_y = \frac{1}{3} \times 36 = 12$ ksi

tension: $f_t = \frac{F}{A} = \frac{41687.8}{6 \times 6} = 1.157$ ksi < 12 ksi

OK

8. Design welds for the member under the plate



$R_3 = 412$ lb/in

shear load on each side

$\frac{1}{2}R_3 = \frac{1}{2} \times 412 = 206$ lb/in

effective throat for fillet weld

1/4"

$e = 1/4 \times 0.707 = 0.18''$

The allowable load on welds

$\frac{1}{3}F_y \times e = 12 \times 0.18$

$= 2.16$ kips/in

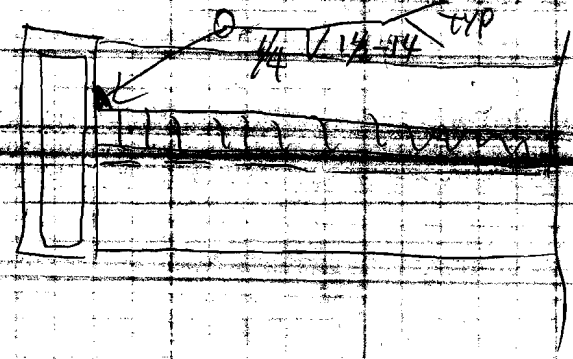
Total load $= 206 \times 5b$

$= 1153b$ lb

$= 11.5$ kips

$\frac{11.5}{2.16} = 5.3$ in use 6 1/4 inch weld

9. Design welds for the floor plate

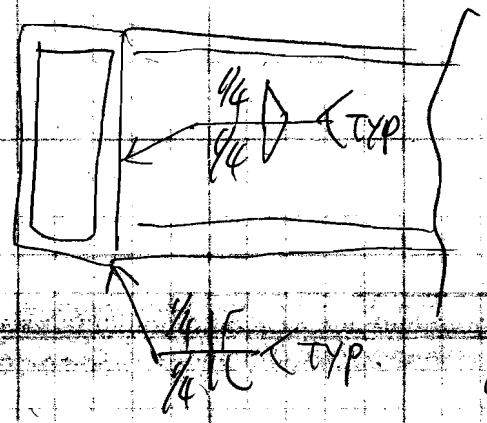


$R_1 = 35.4$ lb/in $< R_3$

use the same welds

design as outlined above.

10. Design welds between two tubing 12x6x1/2.



Tension = smash force + Horizontal sliding force

= 24000 lbs

$$f_t = \frac{F}{A} = \frac{24000}{(12+6)\times 2} = 666.6 \text{ lb/in}$$

Shear = R = 1073.5 lbs

$$f_v = \frac{F}{A} = \frac{1073.5}{(6+6)} = 89.45 \text{ lb/in}$$

The resultant force

$$f = \sqrt{f_t^2 + f_v^2}$$

$$= \sqrt{666.6^2 + 89.45^2} = 672.57 \text{ lb/in}$$

the effective throat for fillet weld 1/4" is

$e_1 = 0.707 \times 1/4 = 0.18"$ — governs

the effective throat for flare bevel groove

$e_2 = 5/8 \times T_1 = 5/8 \times 1/2 = 0.3125"$

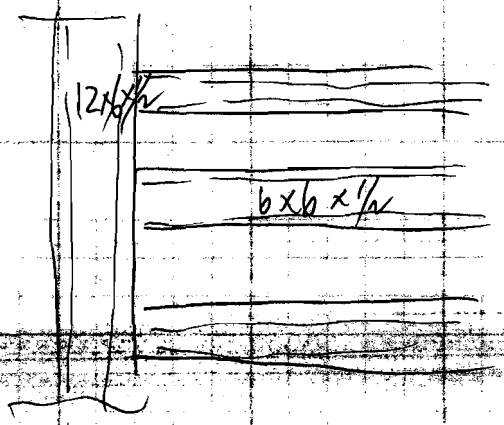
the allowable load on weld is

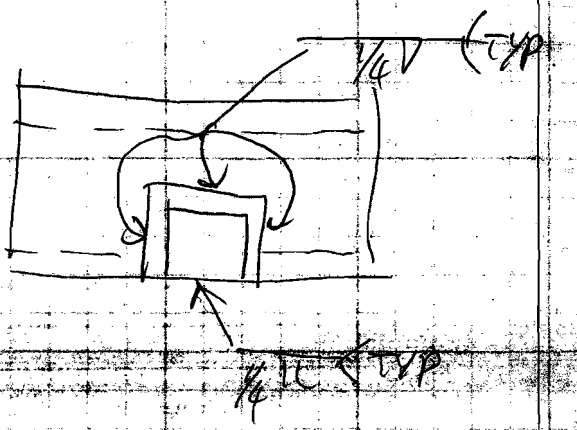
$$\frac{1}{3} F_y \times e_1 = \frac{1}{3} \times 46 \times 0.18 = 2.76 \text{ kip/in}$$

the safety factor on weld is

$$SF = \frac{2.76}{0.672} = 4.10$$

11. Design connection between the 12x6x1/2 & 6x6x1/2





shear: $F_v = R = 11620$ lb.

$$f_v = \frac{F}{A} = \frac{11620}{6+6} = 968.33 \text{ lb/in}$$

the effective throat for fillet weld 1/4" is

$e_1 = 0.707 \times 1/4 = 0.18"$ — governs

the effective throat for flare bevel groove

$e_2 = \frac{5}{8} T_1 = 5/8 \times 1/2 = 0.3125"$

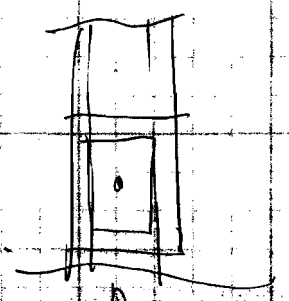
the allowable load on weld is

$$\frac{1}{3} F_y \times e_1 = \frac{1}{3} \times 46 \times 0.18 = 2.76 \text{ kips/in}$$

The safety factor on weld is

$$SF = \frac{2.76}{0.968} = 2.85$$

12. Design connection between the column and 12x6x1/2 tubing

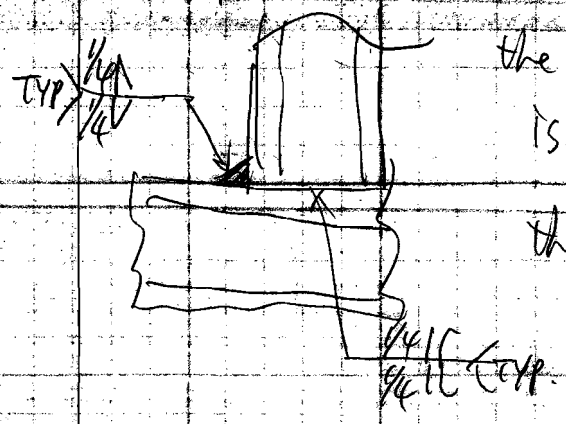


Tension $= \Sigma F_x = 41687.8$ lb

$f_t = \frac{F}{A} = \frac{41687.8}{6 \times 4} = 1.736$ kips/in

the effective throat for fillet weld 1/4" is

~~$e_1 = 0.707 \times 1/4 = 0.18$" governs~~



the effective throat for flare bevel weld 1/4 is $e_2 = \frac{5}{8} t_1 = \frac{5}{8} \times 1/2 = 0.3125$"

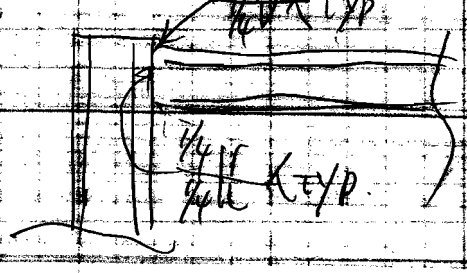
the allowable load on weld is

$\frac{1}{3} F_y \times e_1 = \frac{1}{3} \times 46 \times 0.18 = 2.76$ kips/in

The safety factor on welds is

$SF = \frac{2.76}{1.736} = 1.58$

13. Design connection between the column and top/bottom rail.



Tension = Smash load + Nominal sling load

$= 24000$ lbs

$f_t = \frac{F}{A} = \frac{24000}{(6+6) \times 2} = 1000$ lb/in

Shear $= R = 1073.5$ lb

$f_v = \frac{F}{A} = \frac{1073.5}{(6+6)} = 89.45$ lb/in

The resultant force $f = \sqrt{f_t^2 + f_v^2}$

$= \sqrt{1000^2 + 89.45^2} = 1.003$ kips/in

the effective throat for fillet weld 1/4" is

$e_1 = 0.707 \times 1/4 = 0.18''$ (governs)

the effective throat for flare bevel groove $1/4''$ is

$$e_2 = \frac{5}{8} T_1 = \frac{5}{8} \times 1/2 = 0.3125''$$

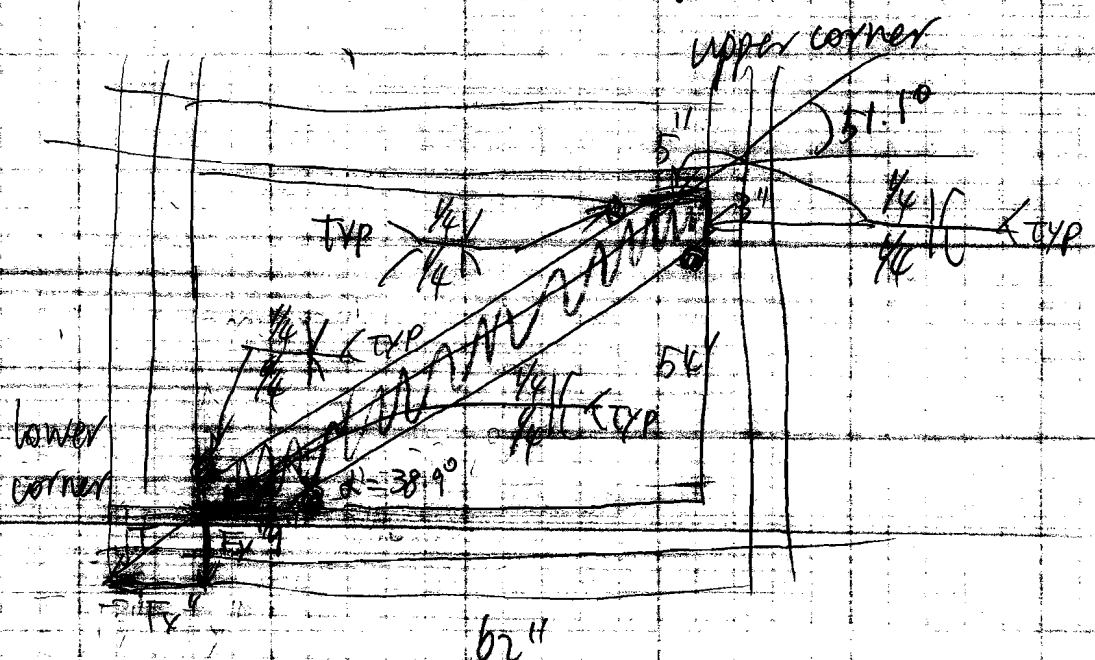
the allowable load on weld is

$$\frac{1}{3} F_y * e_1 = \frac{1}{3} \times 46 \times 0.18 = 2.76 \text{ kips/in}$$

the safety factor on weld is

$$SF = \frac{2.76}{1.003} = 2.75$$

14. Design connection between diagonal and top/bottom rail



$F_x'' = 20000$ lb

$F_y'' = 20903.02$ lb

Lower corner: Tension: $f_x = \frac{F_y''}{(a+b) \times 2} = \frac{20903.02}{30} = 697$ lb/in

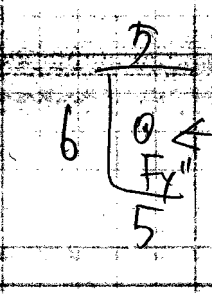
Shear: $f_v = \frac{F_x''}{a+b} = \frac{20000}{18} = 1333.3$ lb/in

The resultant force $f = \sqrt{f_x^2 + f_v^2}$

$= \sqrt{697^2 + 1333.3^2} = 1.504$ kip/in

from the previous study, knowing the allowable load on weld is 2.76 kips/in. Thus, the safety factor on weld is $\frac{2.76}{1.501} = 1.8$ OK

upper corner:

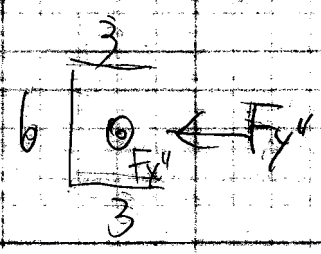


for $F_x'' = 24000$ lbs

$$f = \frac{F}{A} = \frac{24000}{(5+5)+(3+3+6)} = 1091 \text{ lb/in}$$

for $F_y'' = 20903.02$ lbs

$$f = \frac{F}{A} = \frac{20903.02}{(5+5+6)+(3+3)} = 950 \text{ lb/in}$$

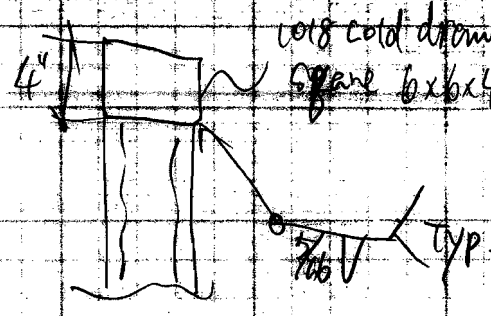


the resultant force is

$$f = \sqrt{1091^2 + 950^2} = 1.446 \text{ kips/in}$$

from the previous study, knowing for 1/4" weld, the allowable load on weld is 2.76 kips/in. Thus, the safety factor on weld is $\frac{2.76}{1.446} = 1.9$ OK

15. Design the connections between the column & Ring Blade



$F_x'' = 24000$ lbs

$2F_y'' = 41687.8$ lbs

Tension: $f_t = \frac{F_t''}{A} = \frac{41687.8}{6 \times 4} = 1.737$ kip/in

Shear: $f_v = \frac{F_x''}{A} = \frac{24000}{6+6} = 2.0$ kips/in

The resultant force on weld is

$$f = \sqrt{f_t^2 + f_v^2} = \sqrt{1.737^2 + 2.0^2} = 2.648 \text{ kips/in}$$

The effective throat for fillet weld 5/16" is

$$e_1 = 0.707 \times 5/16 = 0.22''$$

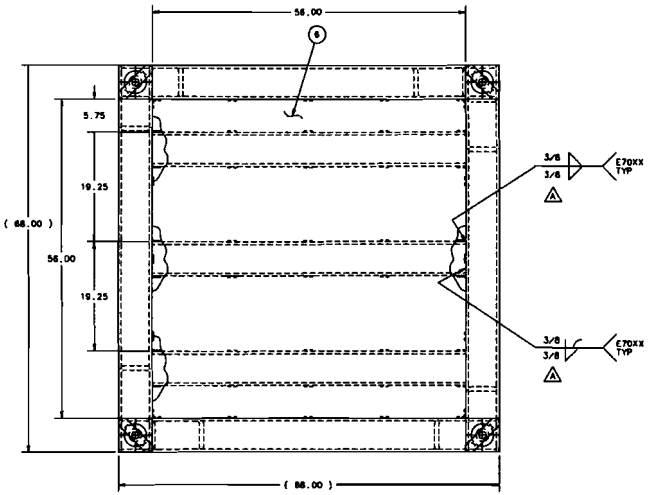
The allowable load on weld is

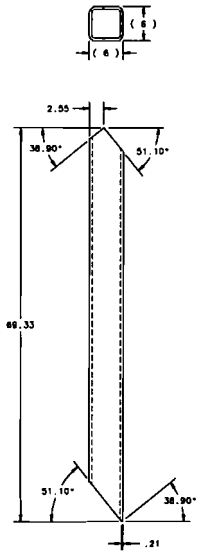
$$\tfrac{1}{3} F_y \times e_1 = \tfrac{1}{3} \times 46 \times 0.22 = 3.38 \text{ kips/in}$$

The safety factor on the weld is

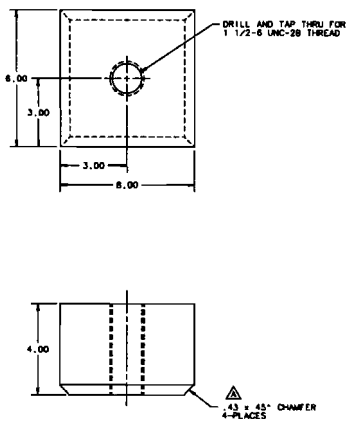
$$SF = \frac{3.38}{2.648} = 1.27$$

REV	DESCRIPTION	DRAWN	DATE
A	REVISED BILL SIZES. ITM 3 WAS 1 TUB & REVISED TO 7 SHEETS. .06 WAS .31.	APPROVED	DATE
		B. CYKO	08-20-03



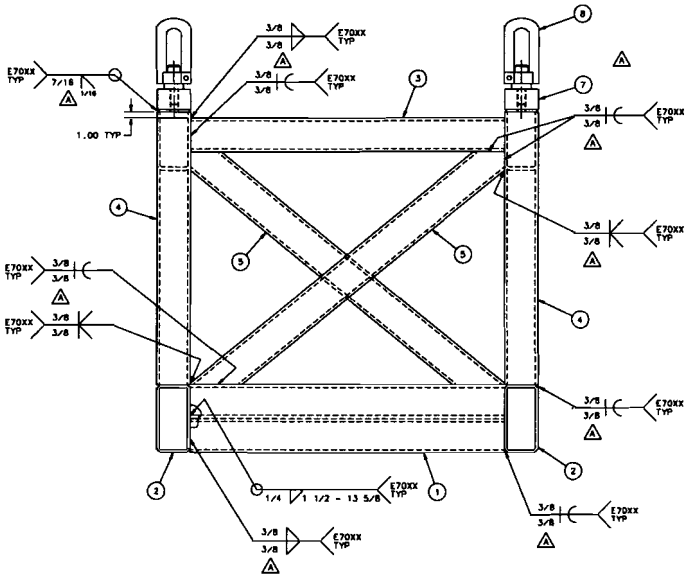


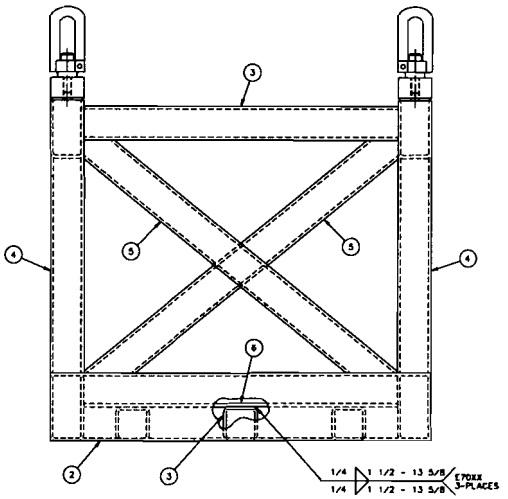
ITEM 5



ITEM 7

SCALE: 1/2





5. ALL SLINGS SHOULD BE OF EQUAL LENGTH. LIFTING SHOULD BE ACCOMPLISHED IN SUCH A MANNER THAT PREVENTS UNEQUAL LOADING OF SLINGS.

4. THE MINIMUM SLING ANGLE OFF HORIZONTAL PLANE IS 60 DEGREES.

3. HEIGHT OF LIFTED LOAD SHOULD BE BELOW THE TOP RAIL OF THIS FIXTURE.

2. THIS LIFTING FIXTURE IS DESIGNED TO LIFT 60,000 POUNDS.

1. TORQUE ITEM 6 TO 800 FT.-LBS.

NOTES:

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
8	COML	HOIST SLING, 1 1/2"-6 BOLT SIZE, 24,000 LB. WORK LOAD LIMIT, BOMASTER-CAMS P/ 3868TP4	4
7	COML	COLD DRAWN SQUARE - 6 x 6 x 4.00 LG., CARBON STEEL 1018 "SEE DETAIL ON DRAWING"	4
6	COML	INLAND 6-WAY PLATE, LARGE PATTERN, 5/8 x 88.88 x 30.38, CARBON STEEL ASTM A-786	1
5	COML	SQUARE TUBING, 6 x 6 x 1/2 x 69.33 LG. CARBON STEEL ASTM A500 GR. B "SEE DETAIL ON DRAWING"	4
4	COML	SQUARE TUBING, 6 x 6 x 1/2 x 46.06 LG. CARBON STEEL ASTM A500 GR. B	4
3	COML	SQUARE TUBING, 6 x 6 x 1/2 x 56.00 LG. CARBON STEEL ASTM A500 GR. B	7
2	COML	RECTANGULAR TUBING, 12 x 6 x 1/2 x 56.00 LG., CARBON STEEL ASTM A500 GR. B	2
1	COML	RECTANGULAR TUBING, 12 x 6 x 1/2 x 56.00 LG., CARBON STEEL ASTM A500 GR. B	2

PARTS LIST

UNLESS OTHERWISE SPECIFIED			ORIGINATOR		18-JUL-2003
.XX	.XXX	ANGLES	DRAWN	W. CYKO	18-JUL-2003
± .03	±	± 1°	CHECKED	G. ARNOLD	23 JUL 2003
			APPROVED	L. FANG	24 JUL 2003

1. BREAK ALL SHARP EDGES 1/16 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS PRIOR TO ASME Y14.5M-1994.
4. ALL TOLERANCE DIM. HOLES
5. BRK. ALL MACH. SURFACES 300

USED ON

MATERIAL SEE ABOVE PARTS LIST

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

PPD/MECHANICAL DEPARTMENT
NUMI TARGET HALL
GREEN/BLUE BLOCK LIFTING FIXTURE

SCALE	DRAWING NUMBER	SHEET	REV
1/2 & AS NOTED	8875.126-ME-431221	1 OF 1	A

CREATED WITH : Ideas8x3 GROUP: PPD/MECHANICAL DEPARTMENT

APPROX. WT. = 4,600 LBS.

Plotted by stefanik on 14-Oct-03 . File: NUMIGRNBLUBLOCKLIFTINGFIXTURE.prf