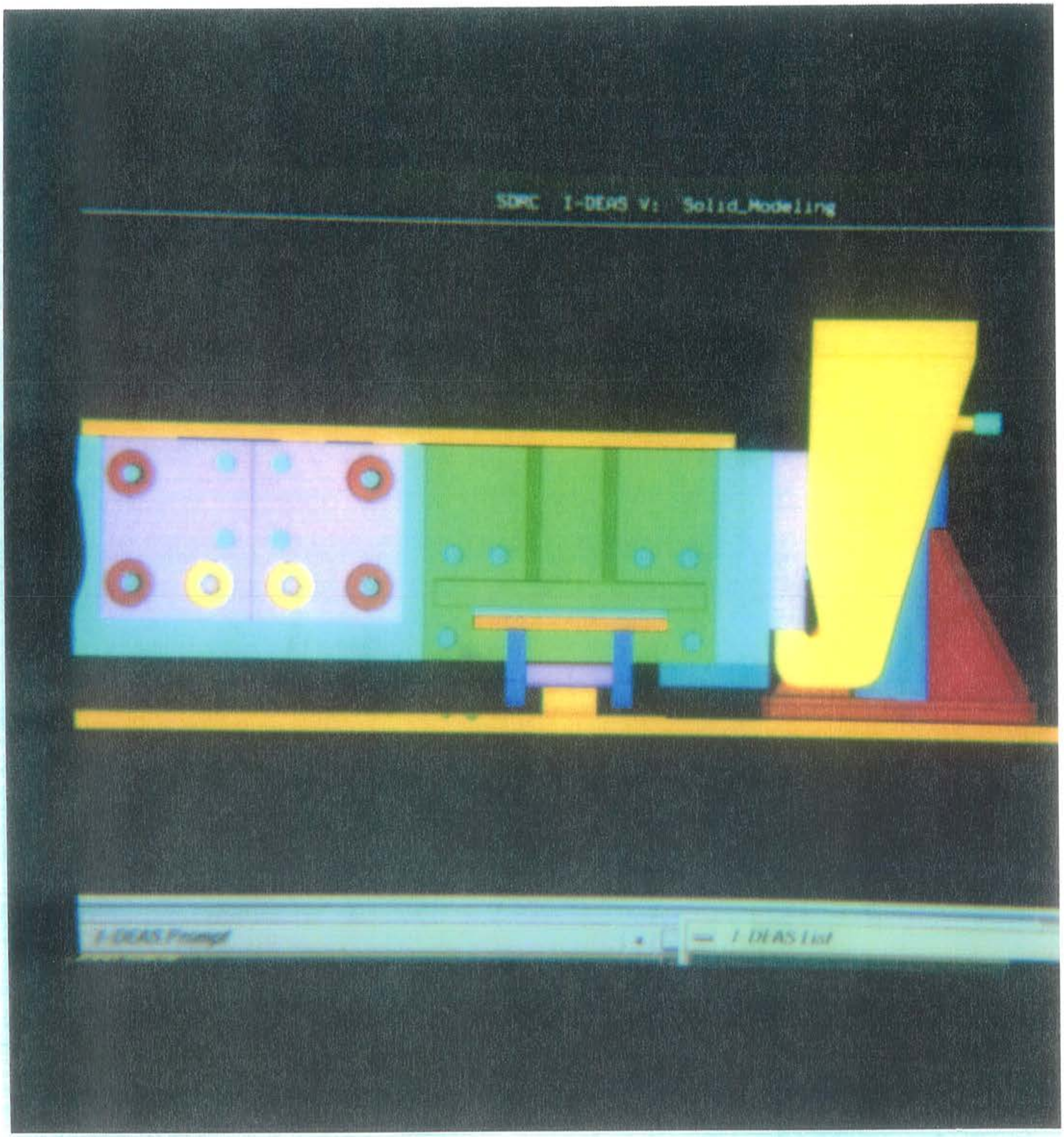
CDF
CMEX
UPGRADE

STRUCTURAL
AND
MECHANICAL
DESIGN

CMEX
Transport
Table

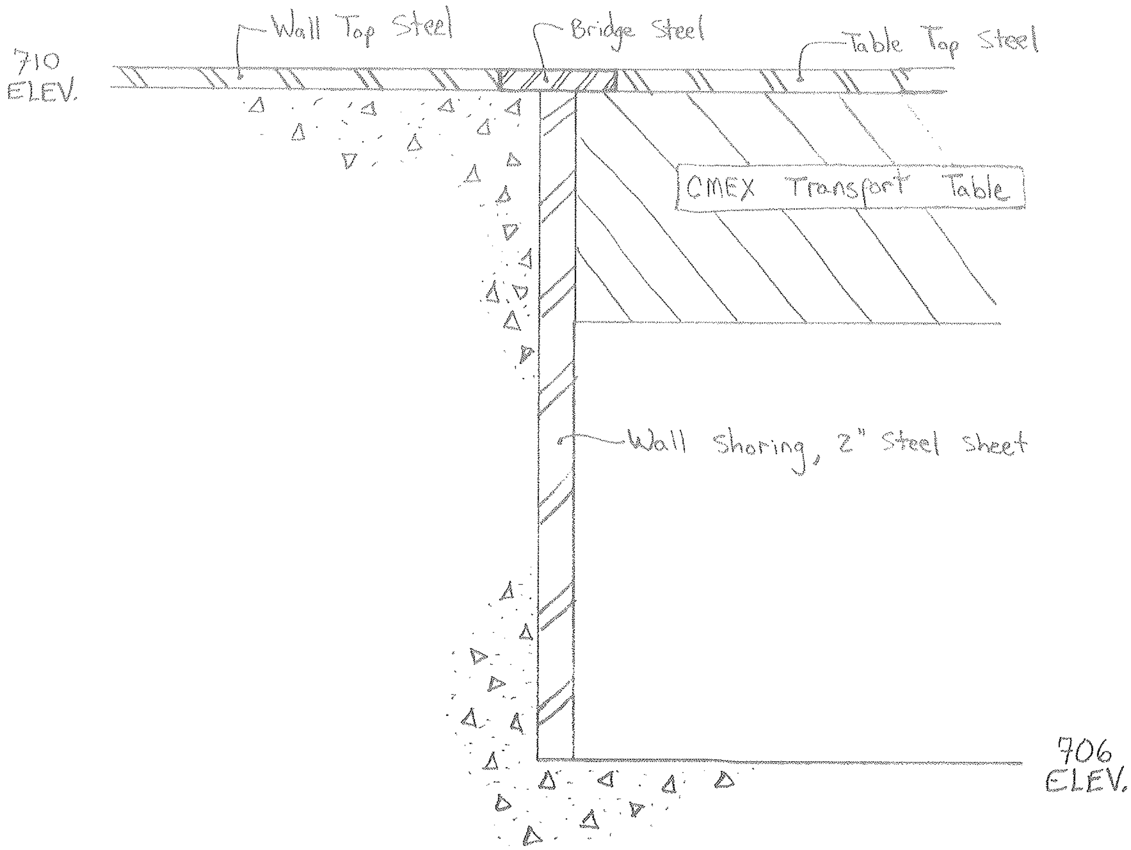

SDRC I-DEAS V: Solid_Modeling
I-DEAS Prompt
I-DEAS List

The CMEX Transport Table will be used to raise and lower, and roll a 30 ton CMEX frame from the CDF Assembly Hall into the CDF Collision hall. The raising and lowering of the frame between the 706 and the 710 elevations at CDF is necessary so that the top of the frame clears the hallway ceiling and cable beams.

Four, 50 ton hydraulic jacks will be used as part of a unified lifting system to raise and lower the 22 Ton table. The hydraulic jacks have a vertical stroke of 12". Because the table must be raised and lowered approximately 38", cribbing will be used for safety and to support the table between intermediate lifts.

Once the table has been raised to the 710 elevation, the entire table will be bolted to the existing wall for added stabillity.

The top of the table has been covered with 1" thick steel sheets to provide a smooth surface for rolling the CMEX Frame. A 2" space has been left around the table top edge. a 2" space also exists on the top edge of the existing 4 foot tall walls in the pit at CDF. When the table is aligned with the wall, a 6" space on the top surface will be filled with a 6" wide, 1" thick piece of steel. This steel will act as a "bridge" or transition between the wall and the table.



For added stability, the hydraulic jacks will be bolted into a jackstand. The jackstand has a 1/2" deep, 5 1/4" ϕ countersunk hole for the jack to be placed. There are also three gussets to further stabilize the jack. The base of the jackstand is 15" x 15".

The hydraulic jack pushes vertically against a 230# steel lifting hook. (Design calculations are attached) The lifting hook firmly seats under a lifting plate. (again, calculations are attached)

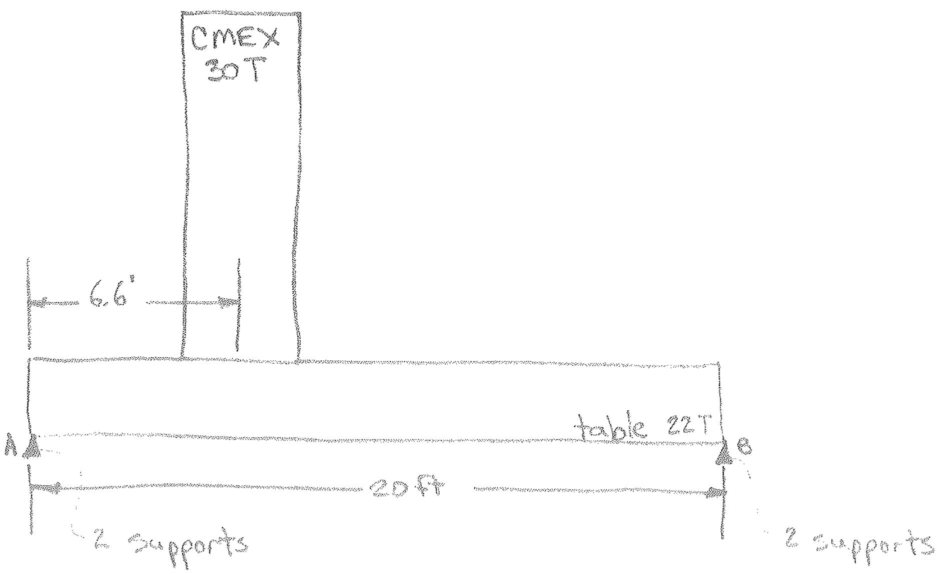
Once the table is lowered to the floor, it is placed on top of 4 Hilman rollers. Each Hilman roller is designed to handle 37.5 Tons. Each Hilman Roller will actually only be loaded to less than 16 Tons. A fiberboard, wood, or rubber spacer will be placed between the roller and the roller support. These rollers can be mounted in two positions; both 90° apart.

Photographs of Finite element analyses are included. The color scale on the right of each picture represents the stress in "psi." Keep in mind that some of the high stress areas are only extreme surface stresses that will distribute across the material once minor deformations take place.

A movement procedure will be distributed shortly for your review.

In order to move a CMEX Frame into the collision hall a change in elevation is required. This will be achieved by utilizing a steel transport table.

The Hilman rollers (4) and lifting hooks (4) will be loaded by the combined weight of the transport table (~22 tons) and by a CMEX frame (~30 tons). It is possible that the CMEX frame will be positioned off center of the table. It will be assumed that the maximum load on any support will be the sum of the table weight divided by 4 supports, plus the additional load of a CMEX frame positioned at ⅓ the total length of the table. Those loads are as follows:



$$\Sigma M_A = (-6.6)(60{,}000) + 20\,F_B = 0$$

$$20\,F_B = 396000$$

$$F_B = 19{,}800 \text{ lbs}$$

$$F_A + F_B = 60000 \text{ lbs}$$

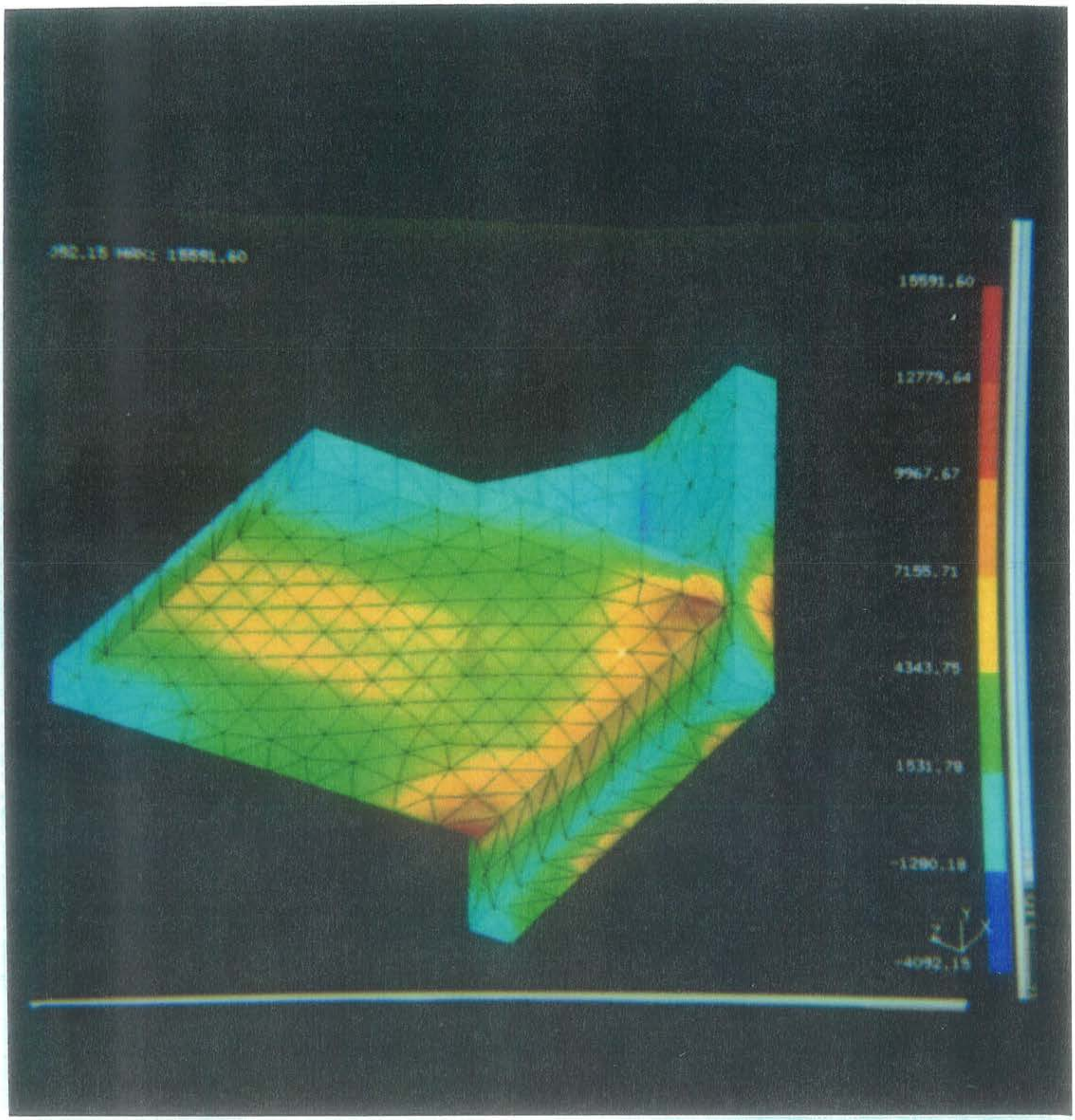
$$F_A = 40{,}200 \text{ lbs}$$ ← divide by 2 supports

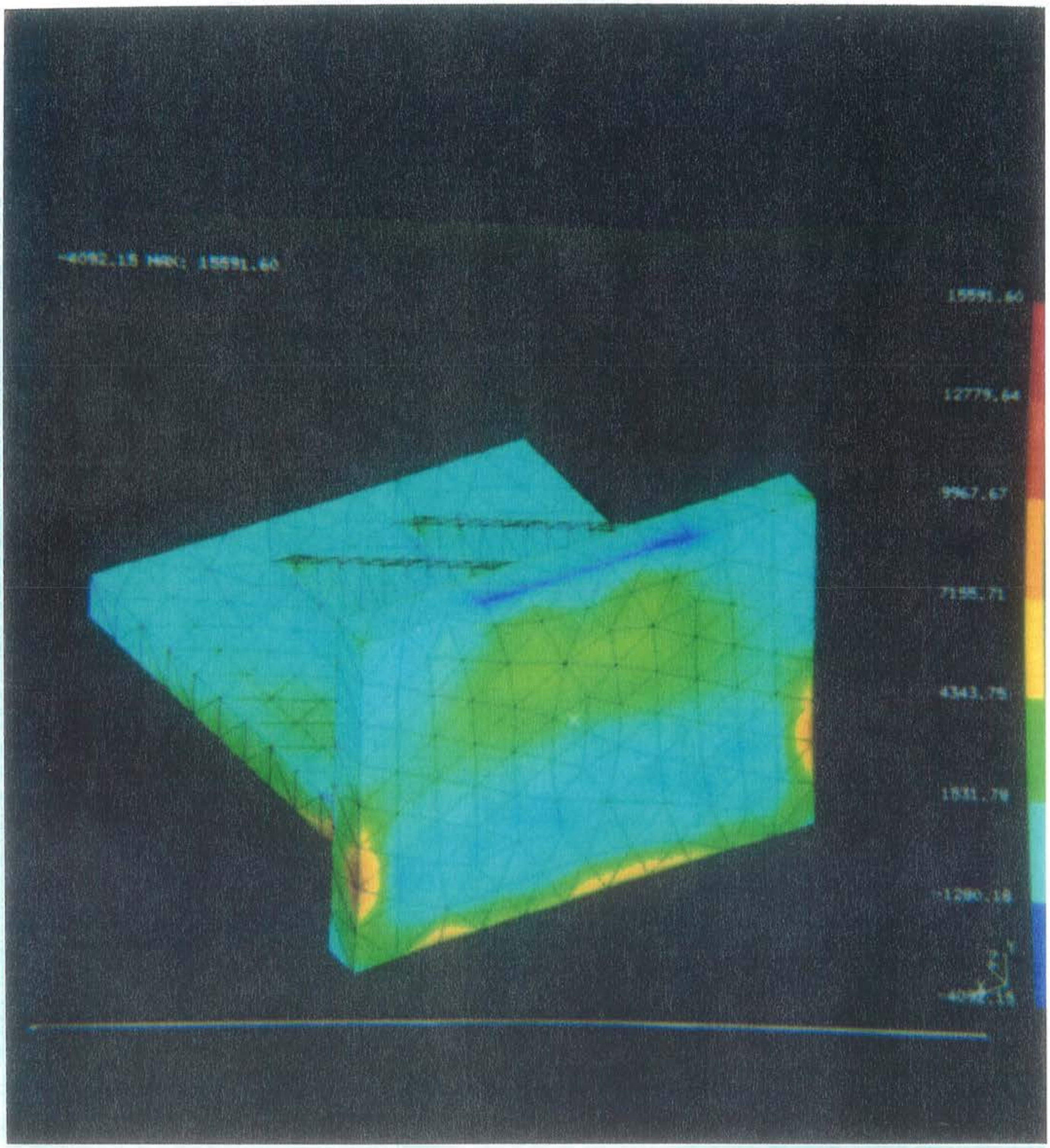
22 Ton table divided by 4 supports = 11,000 lbs

<u>Maximum weight on one support:</u>

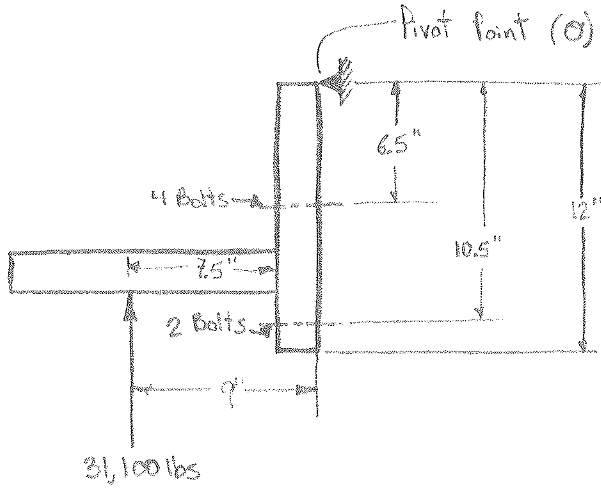
$$\begin{array}{r} 20{,}100 \text{ lbs} \\ +\ 11{,}000 \text{ lbs} \\ \hline 31{,}100 \text{ lbs} \end{array}$$

max. weight on support: 31,100 lbs


15591.60
12779.64
9967.67
7155.71
4343.75
1531.79
-1280.18
-4092.15
Y
Z
X



-4092.15 MAX: 15591.60
15591.60
12779.64
9967.67
7155.71
4343.75
1531.78
-1280.18
-4092.15



Find tension on 4 Bolts ONLY

$$\Sigma M_O = (-9)(31{,}100) + (4 \text{ bolts})(6.5")(F_{Bolt}) = 0$$

$$F_{Bolt} = \frac{(9")(31{,}100 \text{ lbs})}{(4 \text{ bolts})(6.5")} = \underline{\underline{10{,}765 \text{ lbs tension}}} / \text{bolt}$$

Find tension on 2 Bolts ONLY

$$\Sigma M_O = (-9)(31{,}100) + (2)(10.5)(F_{Bolt})$$

$$F_{Bolt} = \frac{(9)(31{,}100)}{(2)(10.5)} = \underline{\underline{13{,}329 \text{ lbs tension}}} / \text{Bolt}$$

Shear load on 6 Bolts

$$V = \frac{31{,}100 \text{ lbs}}{6 \text{ Bolts}} = \underline{\underline{5{,}183 \text{ lbs shear}}} / \text{Bolt}$$

Note: For the rest of the calculations assume that only 4 Bolts are being used. The two lower bolts will be ignored.

Given: tension/Bolt = 10,765 lbs

shear/Bolt = 5,183 lbs

Note: [Calculations will be based on using ASTM A325 1" ⌀ Bolts with yield strength = 92,000 psi = F_u

Stress area on 1" ⌀ Bolt = .606 in²]

From From "Guidelines for Structural Bolting"... AISC 9th ed. (Fermilab TM-1664):

$$F_v = \frac{V}{area} \leq .17 F_u$$

$$F_v = \frac{5183}{.606} = 8,553 \text{ psi}$$

$$.17 F_u = (.17)(92000) = 15,640 \text{ psi}$$

OK

$$F_{v_{nominal}} = \frac{5183 \text{ lbs}}{\pi(.5")^2} = 6,599 \text{ psi}$$

Find the Allowable Tension Stress in a Bearing Type Connection

reference: Table J3.3 AISC ASD 9th. ed p. 5-74

For A325 Bolt w/ threads in shear plane:

$$F_t = \sqrt{(44)^2 - 4.39 F_{v_{nominal}}^2}$$

$$F_t = \sqrt{(44)^2 - 4.39(6599)^2}$$

$$F_t = 41.77 \text{ Ksi} = 41,770 \text{ psi}$$

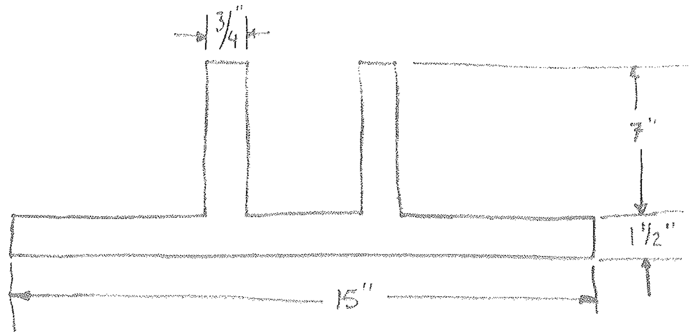
Convert to tensile load:

$$(41,770 \text{ psi})(.7854 \text{ in}^2) = \underline{32,806 \text{ lbs}}$$

$$\text{Safety factor} = \frac{\text{Allowable load}}{\text{actual load}} = \frac{32,806 \text{ lb}}{10,765 \text{ lbs}} = \underline{3.047}$$

Not including the 2 lower bolts.

Because gussets will be used on this support bracket, only shear loads will act on the weld group. The weld group has the following geometry:



The total weld length is : 61 in

A 1/16" weld can handle 928 lbs/in

The shear load on this weld group is 31,100 lbs

Using a 1/16" weld would require a minimum weld length of:

$$\frac{31,100 \text{ lbs}}{928 \text{ lbs/in}} = 33.5 \text{ in}$$

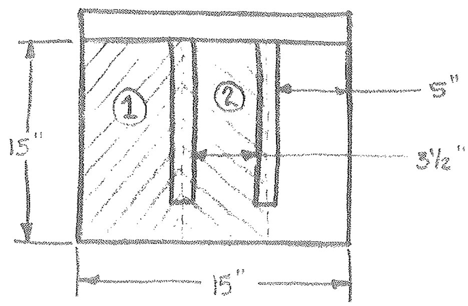
The actual weld length is nearly twice the required length. OK

Note: Table J 2.4 in AISC ASD p. 5-67 9th ed. states that material thickness over 3/4" must use as a minimum, a 5/16" weld.

Therefore, a 5/16" weld will be used.

Using Roark & Young 6th ed.: Flat plate design thickness calculations for the Hilman support base plate were performed.

top view of support



The Hilman Roller is 10" X 15" and applies a load of 31,100 lbs onto the 15" X 15" base support.

The face pressure (q) exerted onto the base plate is:

$$q = \frac{31{,}100 \text{ lbs}}{(15'')(10'')} = 207.3 \text{ psi}$$

With a factor of safety = 3, the allowable stress is:

$$\sigma_a = \frac{36{,}000 \text{ psi}}{3} = 12{,}000 \text{ psi}$$

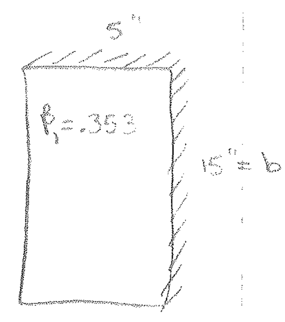
Using Roark & Young, find the maximum stress on the base plate:

(The base plate is broken down into 2 sections)

Section (1)

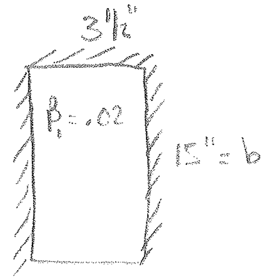
$$\sigma_a = \frac{\beta_1 q b^2}{t^2} \quad \text{where } \beta_1 = .353$$

$$t = \sqrt{\frac{(.353)(207.3)(15)^2}{12{,}000 \text{ psi}}} = \boxed{1.1713 \text{ in thick}}$$



Section ②

$$\sigma_a = \frac{\beta_1 \, q \, b^2}{t^2}$$



$$t = \sqrt{\frac{(.02)(207.3)(15)^2}{12000 \text{ psi}}}$$

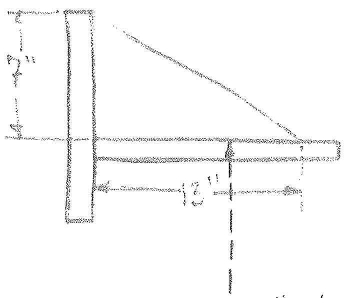
t = .2788 in thick

Use, at a minimum, 1¼" thick plate steel

A 1½" thick plate will be used.

Reference: Steel Structures, Design & Behavior 3rd ed. pp 878-883

Hilman Side View



$31{,}100 \text{ lbs}/2 \text{ Gussets} = 15{,}550 \text{ lbs}/\text{Gusset} = P_u$

Given: $P_u = \phi_c F_y Z b t$ where: $\phi_c = .6$

F_y = yield strength

b = base dimension (13")

t = gusset thickness

P_u = max load on gusset

$$Z = 1.39 - 2.2\left(\frac{b}{a}\right) + 1.27\left(\frac{b}{a}\right)^2 - .25\left(\frac{b}{a}\right)^3$$

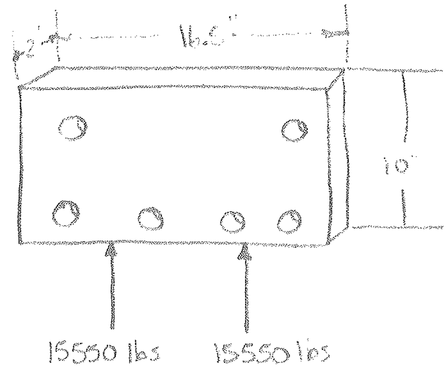
using the above equation yields:

$t = .66577$ in

Use gusset thickness = 3/4"

A 2" Thick lifting plate is bolted onto the transport table with 6, 1"Φ, A325 Bolts.

A lifting hook gets mounted to the lifting plate. The hook applies a vertical load to the plate in two locations. A shear load is applied to each of the six bolts.



The total load is 31,100 lbs

The shear per bolt is $\dfrac{31,100 \text{ lbs}}{6 \text{ bolts}} = 5,183 \text{ lbs}$

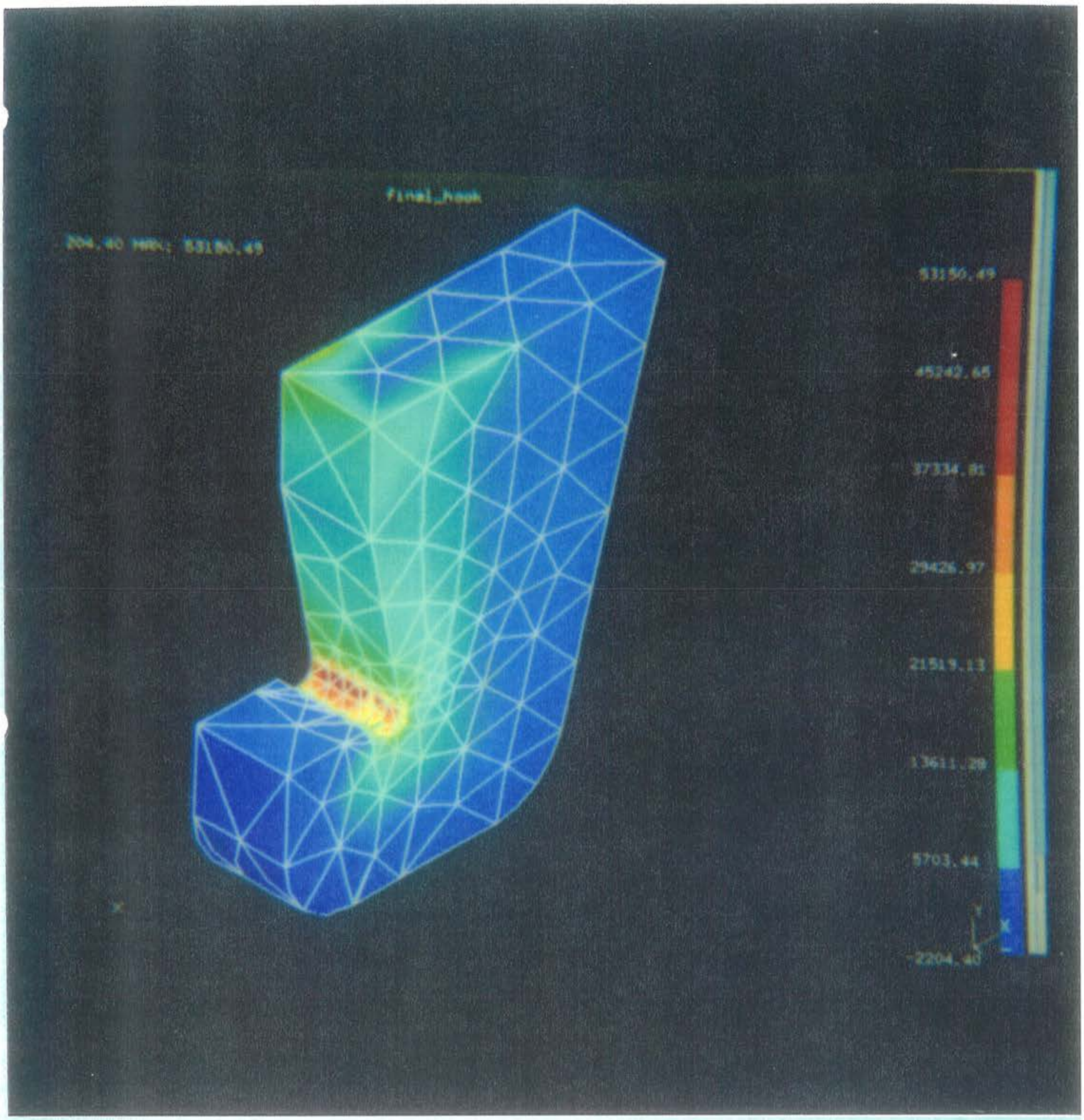
$$F_v = \frac{V}{\text{nominal area}} = \frac{5,183 \text{ lbs}}{(\pi)(.5)^2} = 6599 \text{ psi}$$

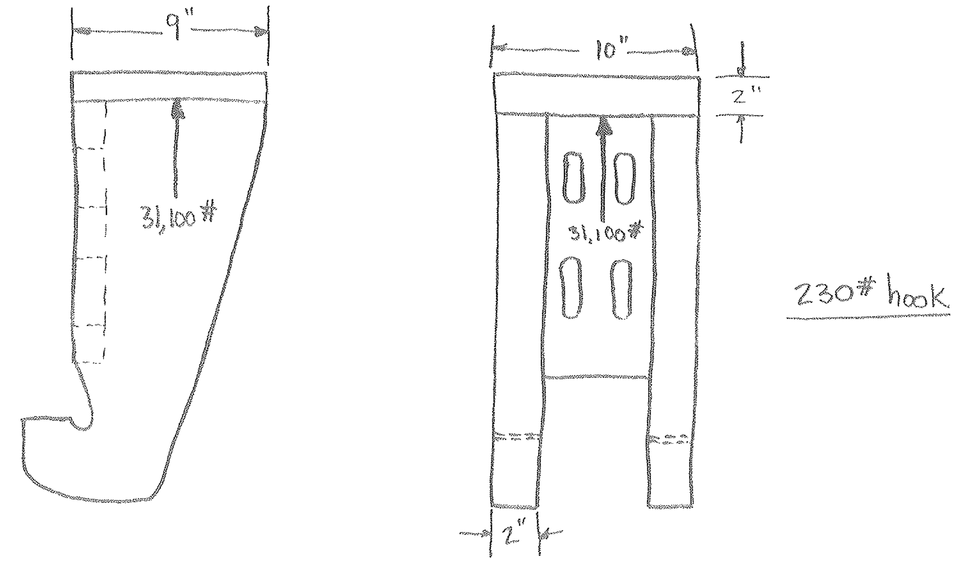
From "Guidelines for Structural Bolting" AISC 9th ed. :

$$F_v \leq .17\, F_u \quad \text{where} \quad F_u = 92,000 \text{ psi}$$

$$.17\, F_u = 15,640 \text{ psi}$$

$$6599 \leq 15640 \quad \text{with safety factor} = 2.37$$

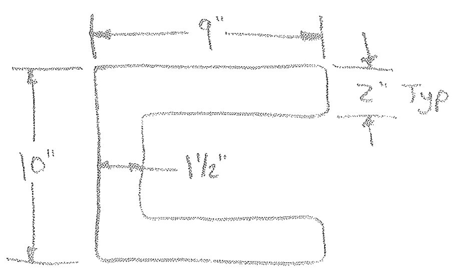

final_hook
53180.49
45242.65
37334.81
29426.97
21519.13
13611.29
5703.44
-2204.40



Weld Calculations:

The top plate has a full penetration weld on the inside and outside. It is loaded with 31,100 lbs.

The weld group looks like:



total weld length: 53"

top view

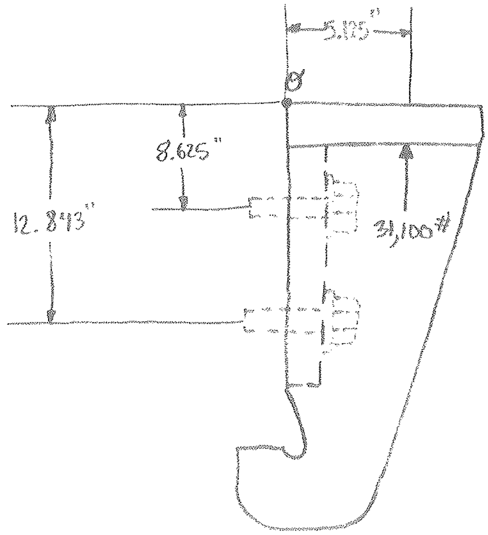
The weld must withstand a shear force of 31,100 lbs

The required weld size is: $\frac{31,100 \text{ lbs}}{53"} = 587 \text{ lbs/in} < 928 \text{ lbs/in}$

The required weld is smaller than a 1/16" weld.

However, Table J 2.4 in AISC ASD p. 5-67 9th ed. states that material thicker than 3/4" requires a 5/16" minimum weld.

There fore, a 5/16" weld will be used.



The bolts are placed in slots so that no shear load is placed on the four bolts. Therefore, the bolts must be designed to withstand a tensile load.

A tensile load is induced when the 31,100# vertical load tries to pivot the hook about pt. "O."

Assume that only the top two bolts take the entire tensile load. Then, by summing the moments about point "O" the tensile load on these two bolts can be calculated:

$$\Sigma M_O = (31{,}100\#)(5.125") - (x\#)(8.625") = 0$$

$$x\# = \frac{(31{,}100)(5.125)}{(8.625)} = 18{,}479.7 \text{ lbs}/2 \text{ Bolts}$$

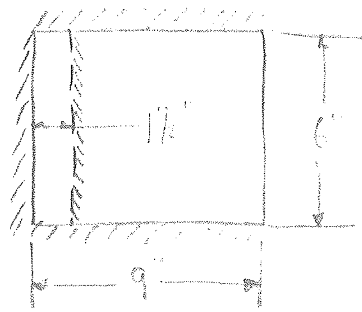
$$= 9{,}240 \text{ lbs/bolt in tension}$$

The allowable load is 34,600 lbs for an A325 1" ø Bolt.

It has been shown that two bolts are adequate.

To insure that the hook does not pivot at all, 2 additional bolts will be added.

top view



$\beta_1 = .1998$

Using Roark & Young, calculate required plate thickness.

$\sigma_a = \sigma_{allowable} = \dfrac{36{,}000 psi}{3} = 12{,}000 psi$ {using safety factor = 3}

from Roark & Young

$\sigma_a = \dfrac{\beta_1 q b^2}{t^2}$ where $q = \dfrac{31{,}100\#}{(7.5)(6)} = 691.111 psi$

$b = 7\frac{1}{2}''$

$\beta_1 = .1998$

$\sigma_a = \dfrac{(.1998)(691)(7.5)^2}{t^2} = 12000 psi$

$t = \sqrt{\dfrac{(.1998)(691)(56.25)}{12000}} = .8044$ in thick

The initial design called for a 2" thick plate
The material has already been cut. Therefore, NO changes
will be made.

FERMILAB
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February 25, 1992

TO: see distribution

FROM: DONALD V. MITCHELL DVM

SUBJECT: CMEX Transport Table Load Test

FINDINGS: After loading the CMEX Transport Table to 76000 lbs (126% of the design load), the table was hydraulically lifted off of the Hilman roller supports to a height of 7". The table and all of its attached parts performed exceptionally well. There were no problems to report.

TEST SETUP:

A load test of the CMEX Transport Table was conducted on Friday, February 21, 1992 at MAB. The test was performed by the Blackhawk construction team. The Blackhawk team leader for the test was Mike Mascione. MAB representative, Dave Erickson was also present to lend assistance to the Blackhawk workers.

TEST SPECIFICS:

A load of 56000 lbs was placed off-center of the table on one side while a 20000 lb load was placed on the opposite side. The 20 ton table and its load were supported by the Hilman roller supports located at each corner of the table. No signs of stress or deformations were observed. The load was then lifted off of the supports utilizing 4 lifting hooks and 4 hydraulic jacks. Again, there were no signs of stress or deformations in any of the parts. The table was then lowered back to the supports and the test was concluded. Photographs were taken and are attached to verify that the test was performed.

Distribution:
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