Fermilab

Particle Physics Division
Mechanical Department Engineering Note

Number: MD-ENG-240 Date: 29 March 2010

Project Internal Reference:

Project: DECAM

Title: DECAM Imager Lifting Fixture

Author(s): Mike Zuckerbrot

Reviewer(s): 1 Apr 10

Key Words: DECAM

Applicable Codes: Design of Below the Hook Lifting Fixtures

Abstract Summary: Stresses on the components of the lifting fixture are checked to be in the allowable range with hand calculations, and a FEA analysis done on both the individual components as well as the entire assembly.

5022TA

BELOW-THE-HOOK LIFTING DEVICE

Engineering Note Cover Page

Lifting Device Numbers:

FNAL Site No/ PPD 174 Div. Specific No. _____ Asset No. _____

If applicable — If applicable — If applicable

ASME B30.20 Group: (check one)

- [x] Group I — Structural and Mechanical Lifting Devices
- [ ] Group II — Vacuum Lifting Devices
- [ ] Group III — Magnets, Close Proximity Operated
- [ ] Group IV — Magnets, Remote Operated

Device Name or Description _____

Device was (check all applicable)

- [ ] Purchased from a Commercial Lifting Device Manufacturer. Mfg Name _____
- [x] Designed and Built at Fermilab
- [ ] Designed by Fermilab and Built by a Vendor. Assy drawing number _____
- [ ] Provided by a User or other Laboratory
- [ ] Other: Describe _____

Engineering Note Prepared by M. Zuckerbrot Date 3/29/10

Engineering Note Reviewed by Greg Derylo Date 4/1/10

Lifting Device Data:

Capacity 2500 #

Fixture Weight 5 #

Service: [x] normal [ ] heavy [ ] severe (refer to B30.20 for definitions)

Duty Cycle _____ 8, 16 or 24 hour rating (applicable to groups III, and IV)

Inspections Frequency every time

Rated Load Test by FNAL (if applicable) Date 4-22-10 Load 2500#

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

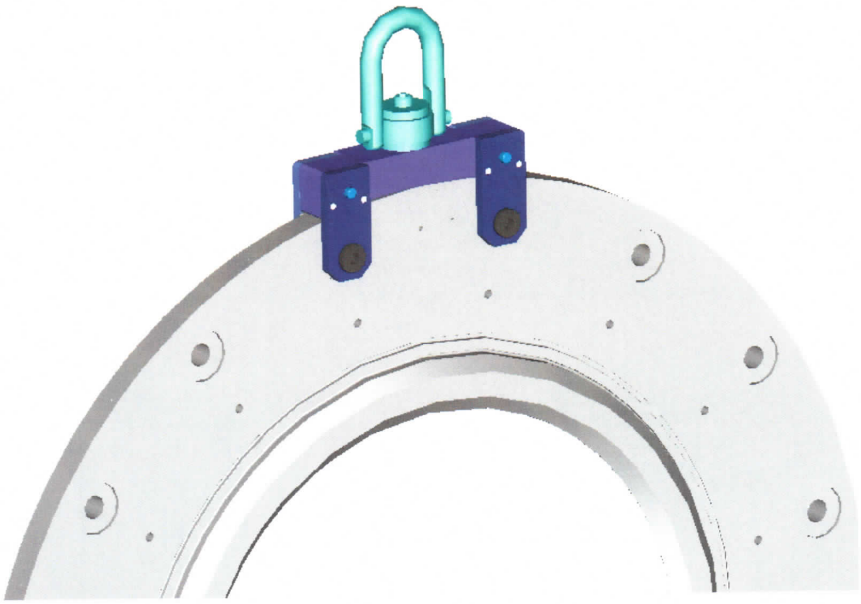
Satisfactory Load Test Witnessed by: Mike Zuckerbrot

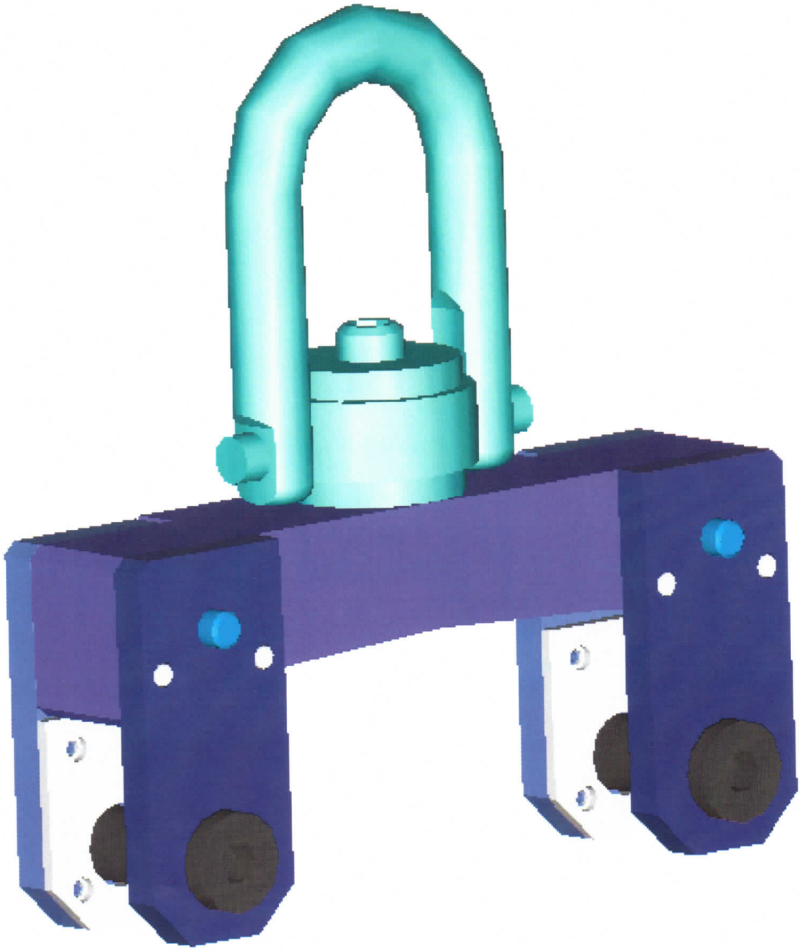
Signature (of Load Test Witness) [signature]

Notes or Special Information:

Chatillon

Drawing 480335





Fermilab

Fermi National Accelerator Laboratory
P.O. Box 500 • Batavia, Illinois • 60510

Discussion

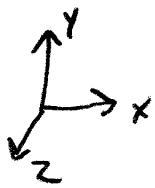
- F_y steel = 36 ksi, F_u = 58 ksi
- The capacity of the lifting ring is 2500# which will be considered as the load P.
- $(b/t)_{bar_{min}} = 8''/1\frac{1}{4}'' = 6.4$

  → Compact limit: $1.12\sqrt{E/F_y} = 1.12\sqrt{3\times10^7/36{,}000} = 32.33$

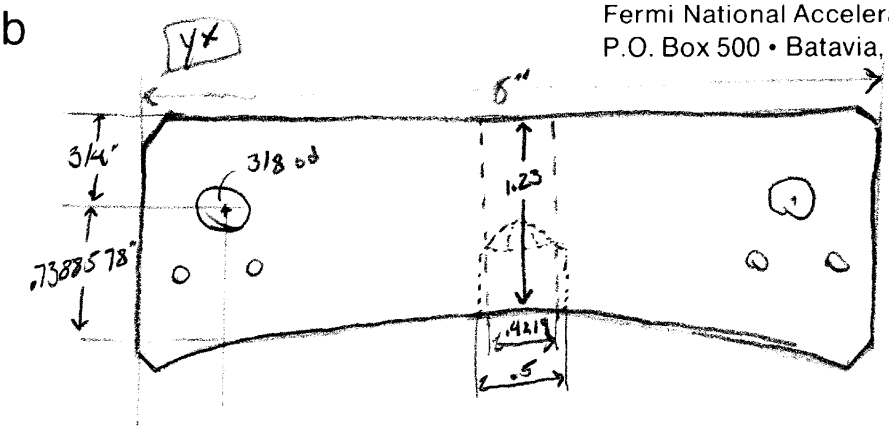
  → b/t < compact $\frac{b}{t}$ limit; Bar is compact
- Design Category A; $N_d = 2$

Fermilab
Fermi National Accelerator Laboratory
P.O. Box 500 • Batavia, Illinois • 60510

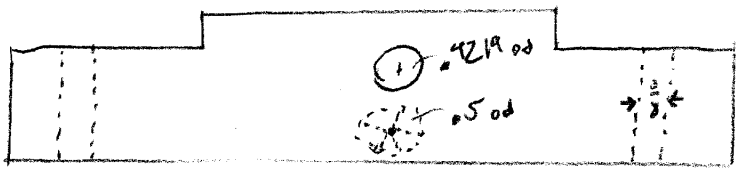
Bar



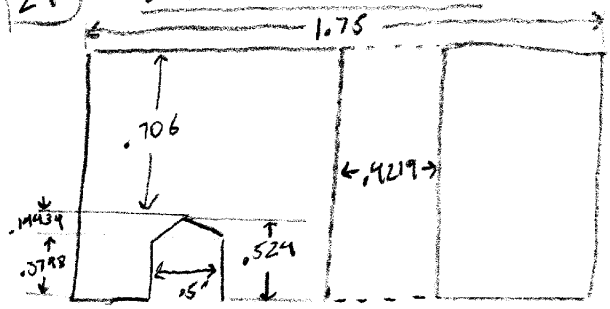
YX



XZ



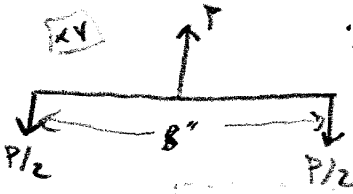
ZY center cross section



→ Bending Stress

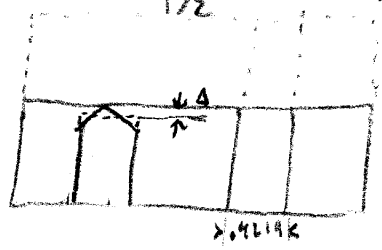
$$\sigma_b = \frac{Mc}{I}$$

XY



$$M_{max} = \frac{Pl}{4} = \frac{2500(8)}{4} = 5000 \text{ in}^{\#}$$

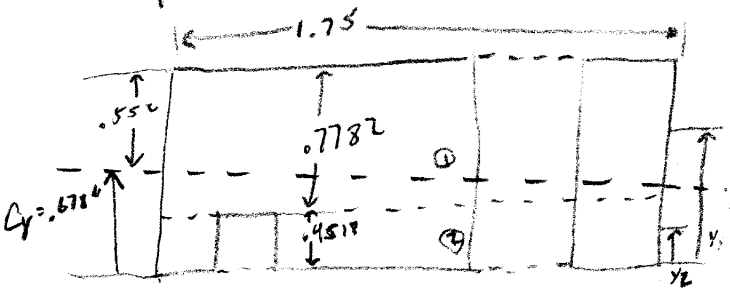
equivlent cross-section → ZY



$$A_{c/triangle} = (.25)(.14434) = .036 \text{ in}^2$$

$$.036 \text{ in}^2 = (.5)h_{eq}$$

$$h_{eq} = .072 \text{ in} \; ; \; \Delta = .0722 \text{ in}$$



$$A_1 = (1.75 \times .7782) - (.4219 \times .7782) = 1.034 \text{ in}^2$$

$$A_2 = (1.75 \times .4518) - (.4219 \times .4518) - (.5 \times .4518) = .374 \text{ in}^2$$

$$C_y = \frac{Y_1 A_1 + Y_2 A_2}{A_1 + A_2} = \frac{\left(.4518 + \frac{.7782}{2}\right)1.034 + \left(\frac{.4518}{2}\right).374}{(1.034 + .374)}$$

$$C_y = .678"$$

$$I_c = \frac{1}{12}(1.75)(1.23)^3 - \frac{1}{12}(.4219)(1.23)^3 - \frac{1}{12}(.5)(.4518)^3 = .202 \text{ in}^4$$

$$F_{b,allowable} = \frac{1.25 F_y}{N_d} = \frac{1.25(36{,}000)}{2} = 22{,}500 \text{ psi}$$

$$\sigma_b = \frac{(5000 \text{ in}^{\#})(.678)"}{.202 \text{ in}^4} = 16{,}782 \text{ psi} < F_b \quad \underline{ok}$$

Fermilab

Fermi National Accelerator Laboratory
P.O. Box 500 • Batavia, Illinois • 60510

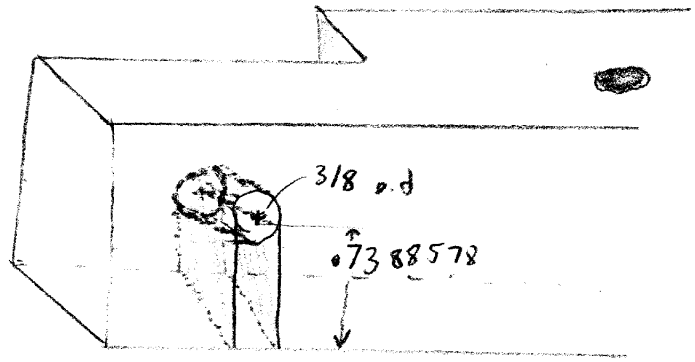
→ Shear Stress

$h/t = \frac{.73}{1.25} = .584$

$2.45\sqrt{E/F_y}$

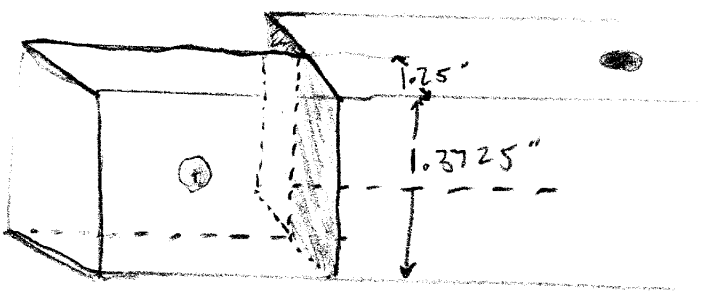
$= 2.45\sqrt{(5\times10^7)(36{,}000)} = 28.8$

$28.8 > h/t$ ✓



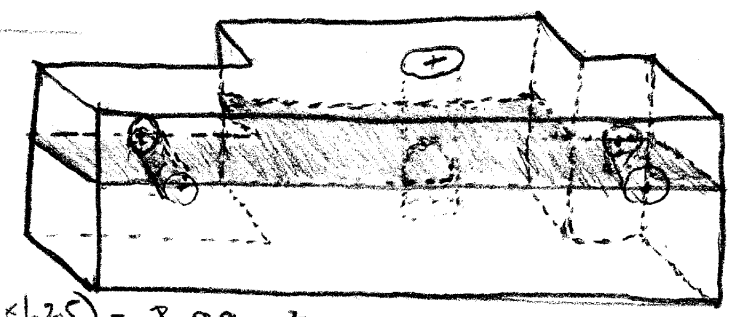
$F_{v,\text{allowable}} = \frac{F_y}{N_s\sqrt{3}} = \frac{36{,}000}{2\sqrt{3}} = 10{,}392$ psi

$\sigma_v = \frac{P/2}{2A_c} = \frac{2500/2}{2(.7388588\times1.25)} = 677$ psi $< F_v$ ok



$\sigma_v = \frac{P/2}{A_c} = \frac{1250}{1.25\times1.3725} = 729$ psi

$< F_v$ ok



→ Tensile Stress

$A_c = (1.77\times1.25) + (4.46\times1.75)$

$A_c = 10.0175 - (\pi(.4219)^2) - (3/8\times1.25) = 8.99$ in^2

$F_{t,\text{allowable}} = \frac{F_y}{N_s} = \frac{36{,}000}{2} = 18{,}000$ psi ; $\sigma_t = \frac{P}{A} = \frac{2500}{8.99} = 278$ psi $< F_t$ ok

→ Combined Normal and Shear Stresses

$F_{cr} = \frac{F_y}{N_s} = 18{,}000$ psi $\quad f_x = 0$

$f_{cr} = (f_x^2 - f_xf_y + f_y^2 + 3f_v^2)^{1/2} = [(278)^2 + 3(729)^2]^{1/2} = 1293$ psi $< F_{cr}$ ok

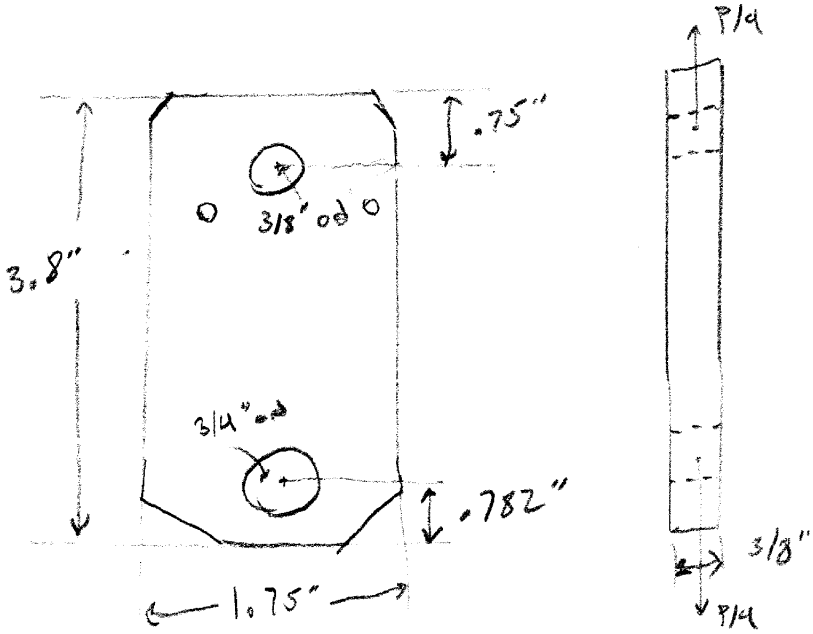
Fermilab

Fermi National Accelerator Laboratory
P.O. Box 500 • Batavia, Illinois • 60510

Combined Axial and Bending Stresses

$$\frac{f_t}{F_t} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \le 1.0 \rightarrow \frac{154}{18{,}000} + \frac{14{,}927}{22{,}500} = .67 \le 1.0 \quad \underline{ok}$$

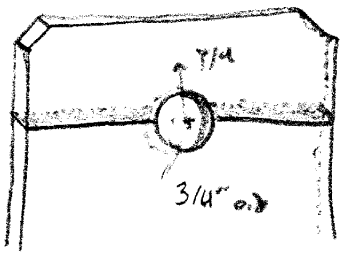
Plate



→ Tensile Stress

$F_{t,allowable} = 18{,}000$ psi

$\sigma_t = \frac{2500/4}{.375 in^2} = 1667$ psi

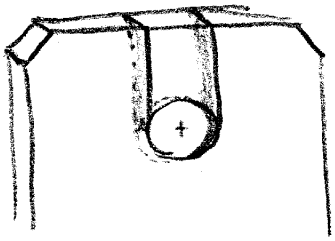


$A_c = (1.75 - 3/4) \times 3/8 = .375 in^2$

$\sigma_t < F_t$ ok

→ Shear Stress

$F_{v_{allowable}} = 10{,}392$ psi



$A_v = (3/4 \times 3/8) \times 2 = .5625 in^2$

$\sigma_v < F_v$ ok

$\sigma_v = \frac{2500/4}{.5625 in^2} = 1{,}111$ psi

→ Combined Normal and shear stresses

$F_{cr} = 18{,}000$ psi $\quad f_{cr} = [1667^2 + 3(1{,}111)^2]^{1/2} = 2546$ psi $< F_{cr}$ ok

Fermilab

Fermi National Accelerator Laboratory
P.O. Box 500 • Batavia, Illinois • 60510

Bolts

→ 3/8" o.d. bolt will be analyzed for the most restrictive cases.

→ Shear Stress

$$F_{v,allowable} = \frac{.62 F_u}{1.2 N_d} = \frac{.62(58{,}000)}{1.2(2)} = 14{,}983 \text{ psi}$$

$$\sigma_v = \frac{V}{2A_c} = \frac{P/2}{2A_c} = \frac{1250\#}{2(\frac{1}{4}\pi(\frac{3}{8})^2)} = 5659 \text{ psi} < F_v \quad \underline{ok}$$

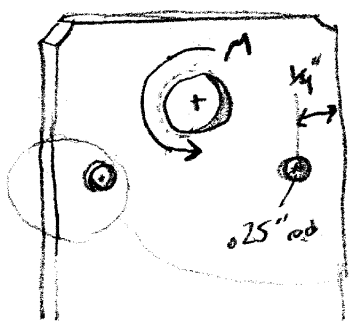
→ Bearing Stress

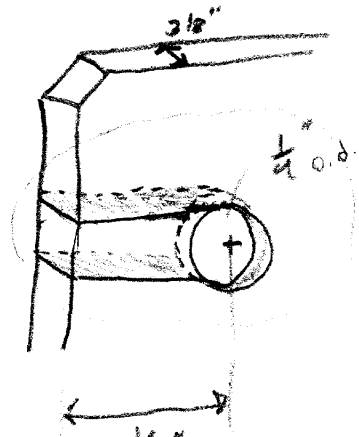
$$F_{p,allowable} = \frac{2.4 F_u}{1.2 N_d} = \frac{2.4(58000)}{1.2(2)} = 58{,}000 \text{ psi}$$

$$\sigma_p = \frac{P/2}{d \times t} = \frac{1250}{3/8 \times (3/8 - .15)} = 14{,}815 \text{ psi} < 58{,}000 \text{ psi} \quad \underline{ok}$$

Pins

→ 8 pins total, no applied load unless there's rotation





→ Shear Stress

$F_v = 10{,}392$ psi

$$\sigma_v = \frac{P/8}{2(\frac{1}{4} \times \frac{3}{8})} = 1{,}666 \text{ psi} < F_v \quad \underline{ok}$$

→ Bearing Stress

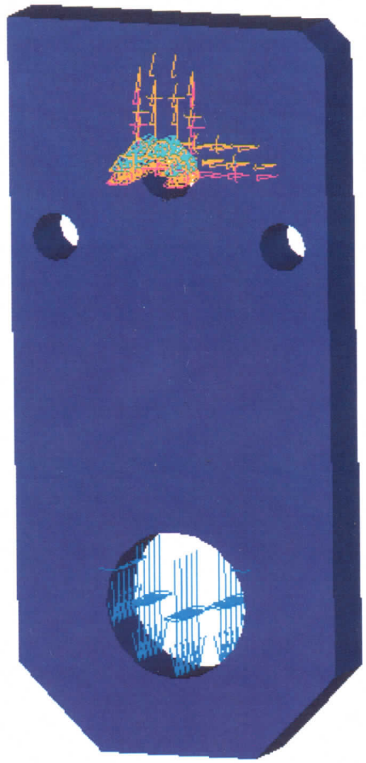
$F_p = 58{,}000$ psi

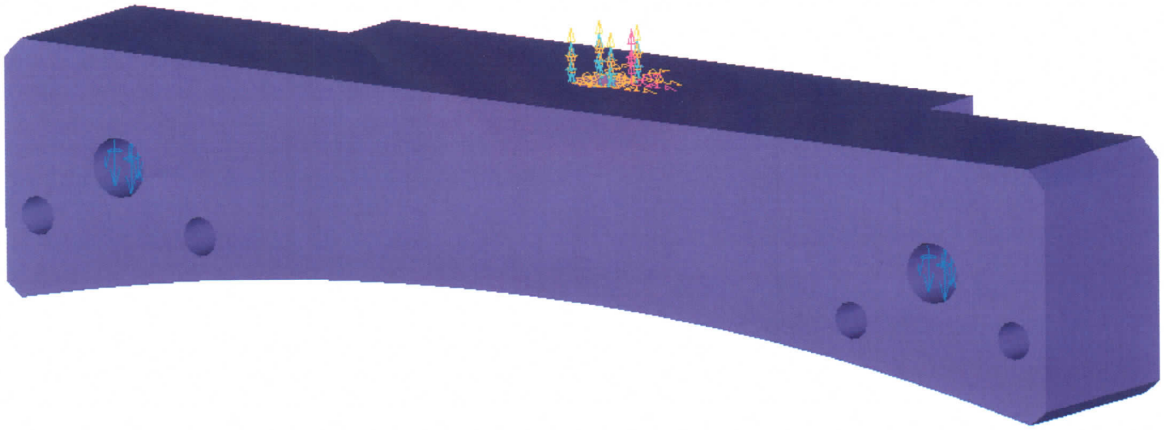
$$\sigma_p = \frac{P/8}{(3/8 \times 1/4)} = 3{,}333 \text{ psi} < F_p \quad \underline{ok}$$

→ Shear Stress on Pin

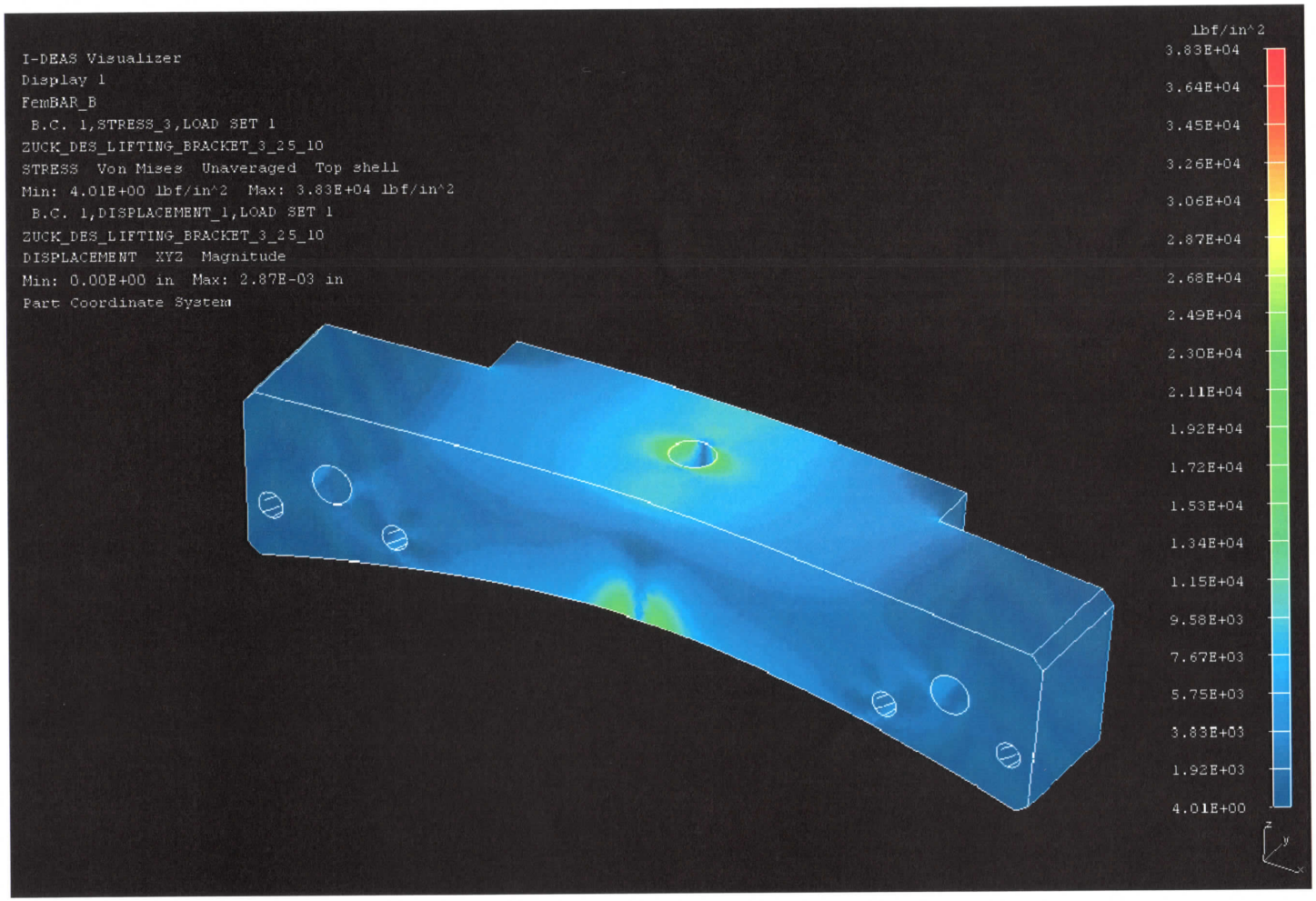
$F_v = 14{,}983$ psi

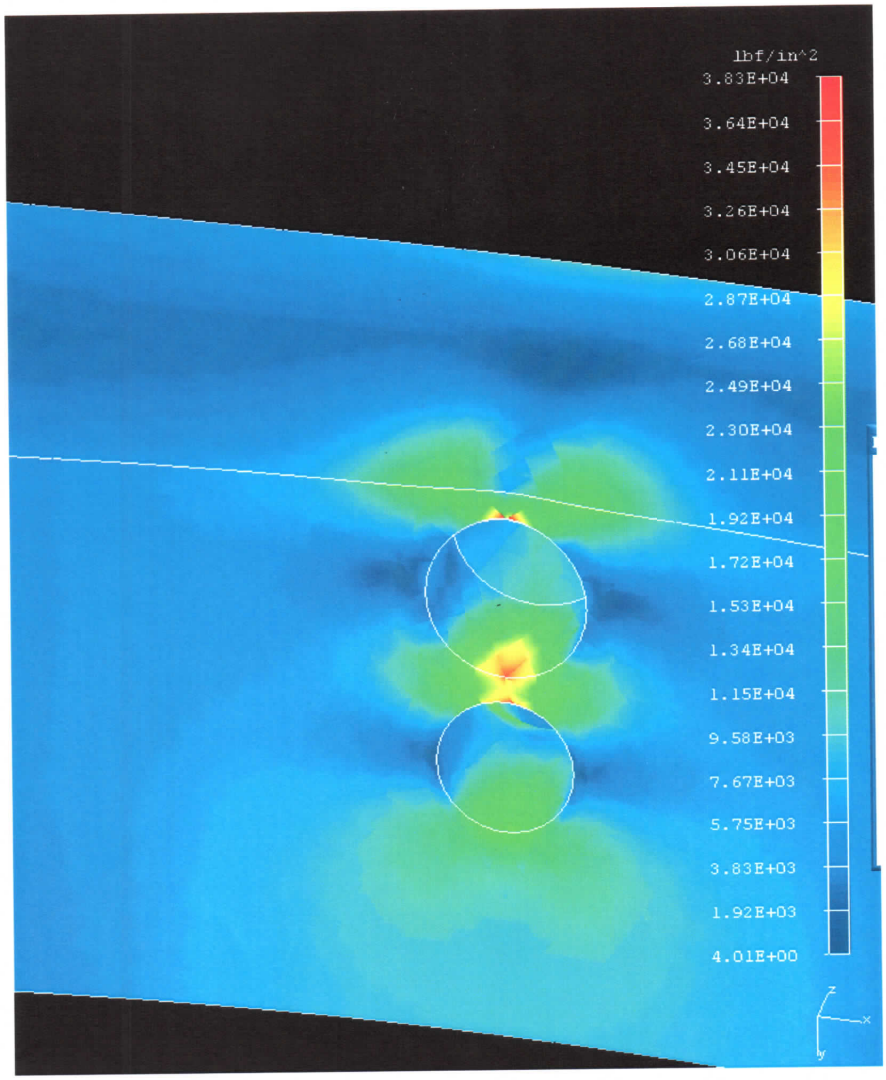
$$\sigma_{v,pin} = \frac{P/8}{\frac{1}{4}\pi(\frac{1}{4})^2} = 6366 \text{ psi} < F_{v,pin} \quad \underline{ok}$$



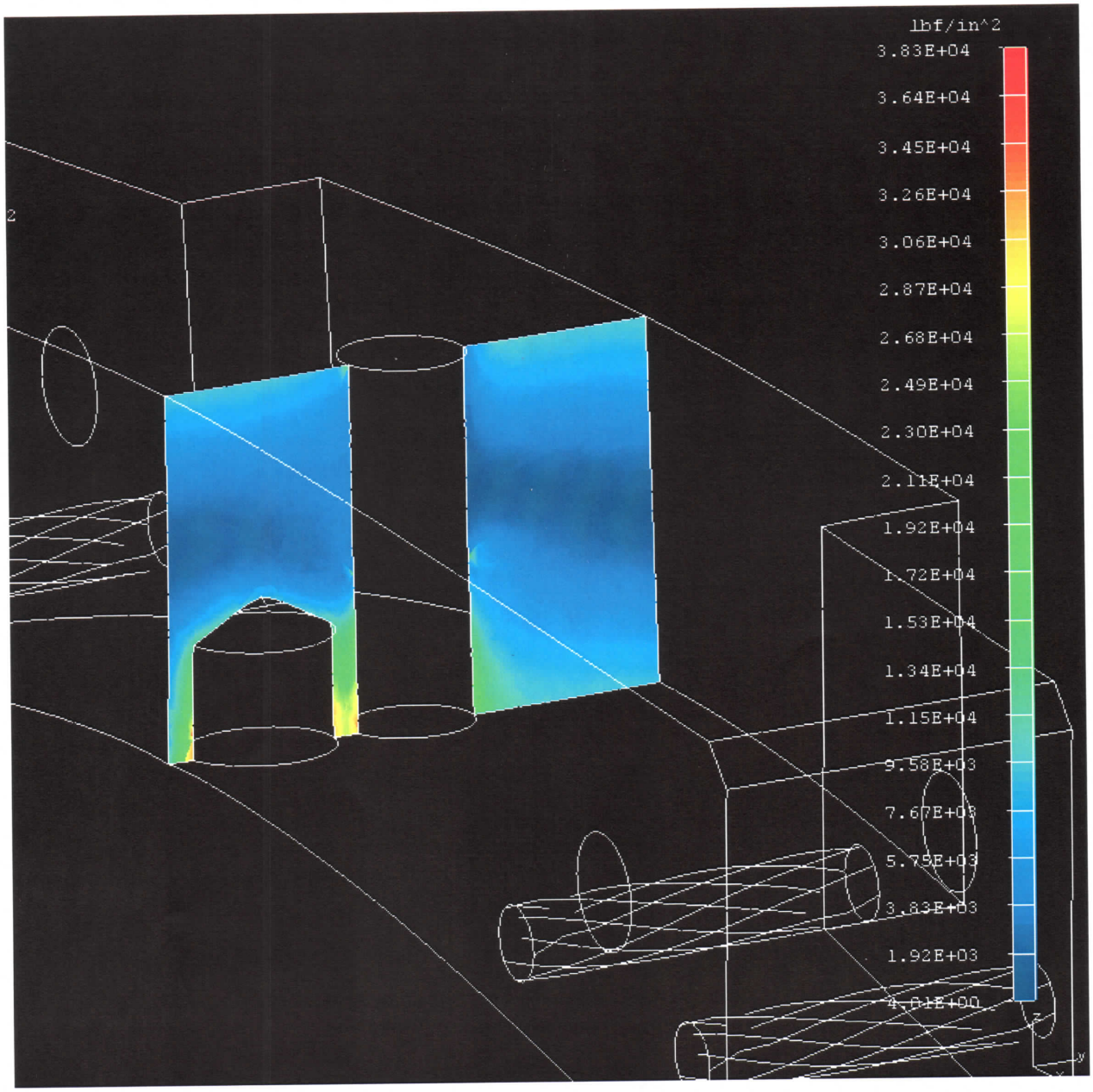


Boundary conditions used for individual part FEA; the center bar (below) is restrained in the center hole down through 0.7'' as the 2500# capacity lifting ring's bolt will be, with a 1250# load on the bottom half of each of the 3/8'' o.d. holes. In the top figure the plate is restrained on the top half of the 3/8'' o.d. hole and a 625# load is applied to the bottom half of the ¾'' o.d. hole.

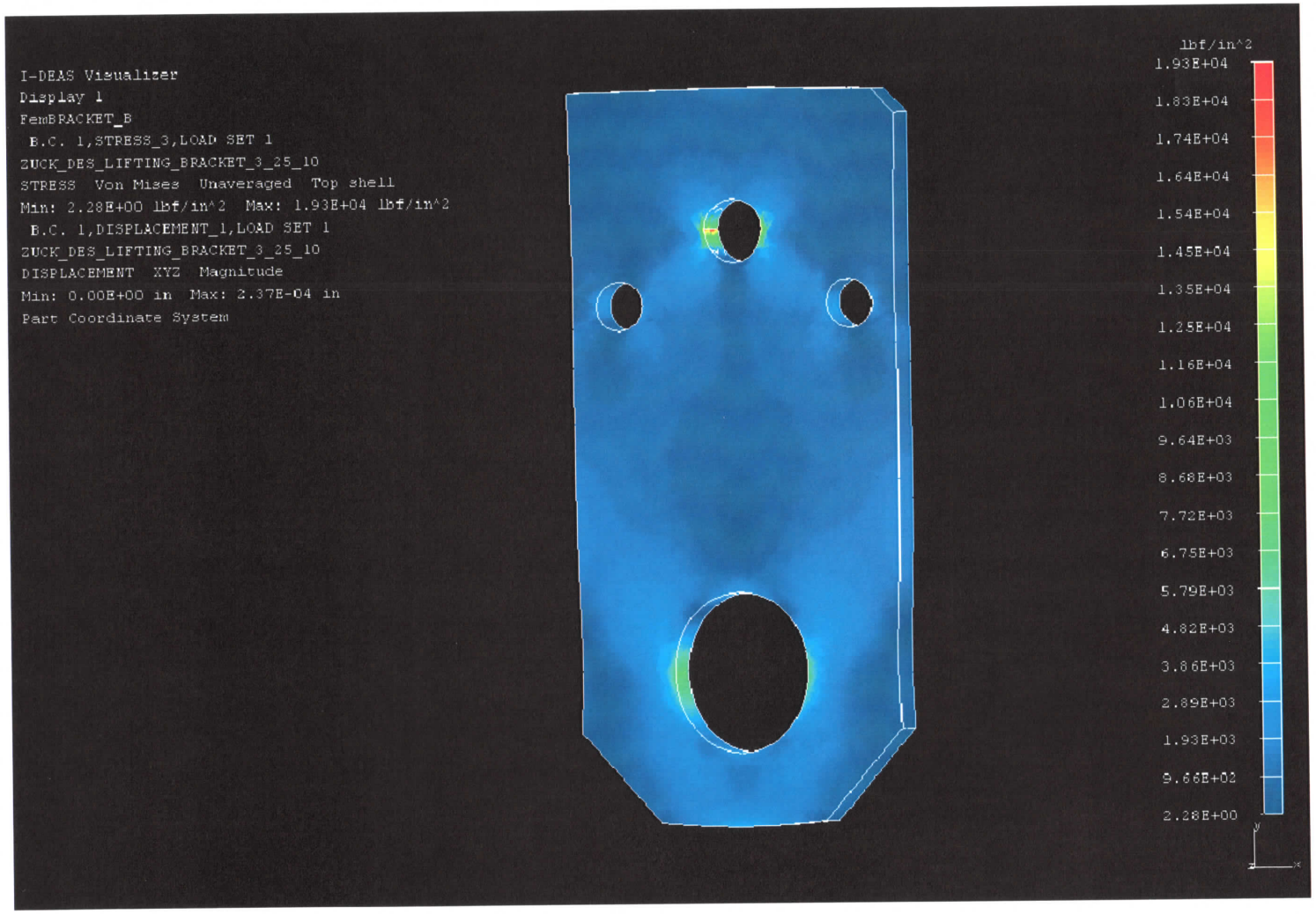

I-DEAS Visualizer
Display 1
FemBAR_B
B.C. 1,STRESS_3,LOAD SET 1
ZUCK_DES_LIFTING_BRACKET_3_25_10
STRESS Von Mises Unaveraged Top shell
Min: 4.01E+00 lbf/in^2 Max: 3.83E+04 lbf/in^2
B.C. 1,DISPLACEMENT_1,LOAD SET 1
ZUCK_DES_LIFTING_BRACKET_3_25_10
DISPLACEMENT XYZ Magnitude
Min: 0.00E+00 in Max: 2.87E-03 in
Part Coordinate System
lbf/in^2
3.83E+04
3.64E+04
3.45E+04
3.26E+04
3.06E+04
2.87E+04
2.68E+04
2.49E+04
2.30E+04
2.11E+04
1.92E+04
1.72E+04
1.53E+04
1.34E+04
1.15E+04
9.58E+03
7.67E+03
5.75E+03
3.83E+03
1.92E+03
4.01E+00
z
y
x

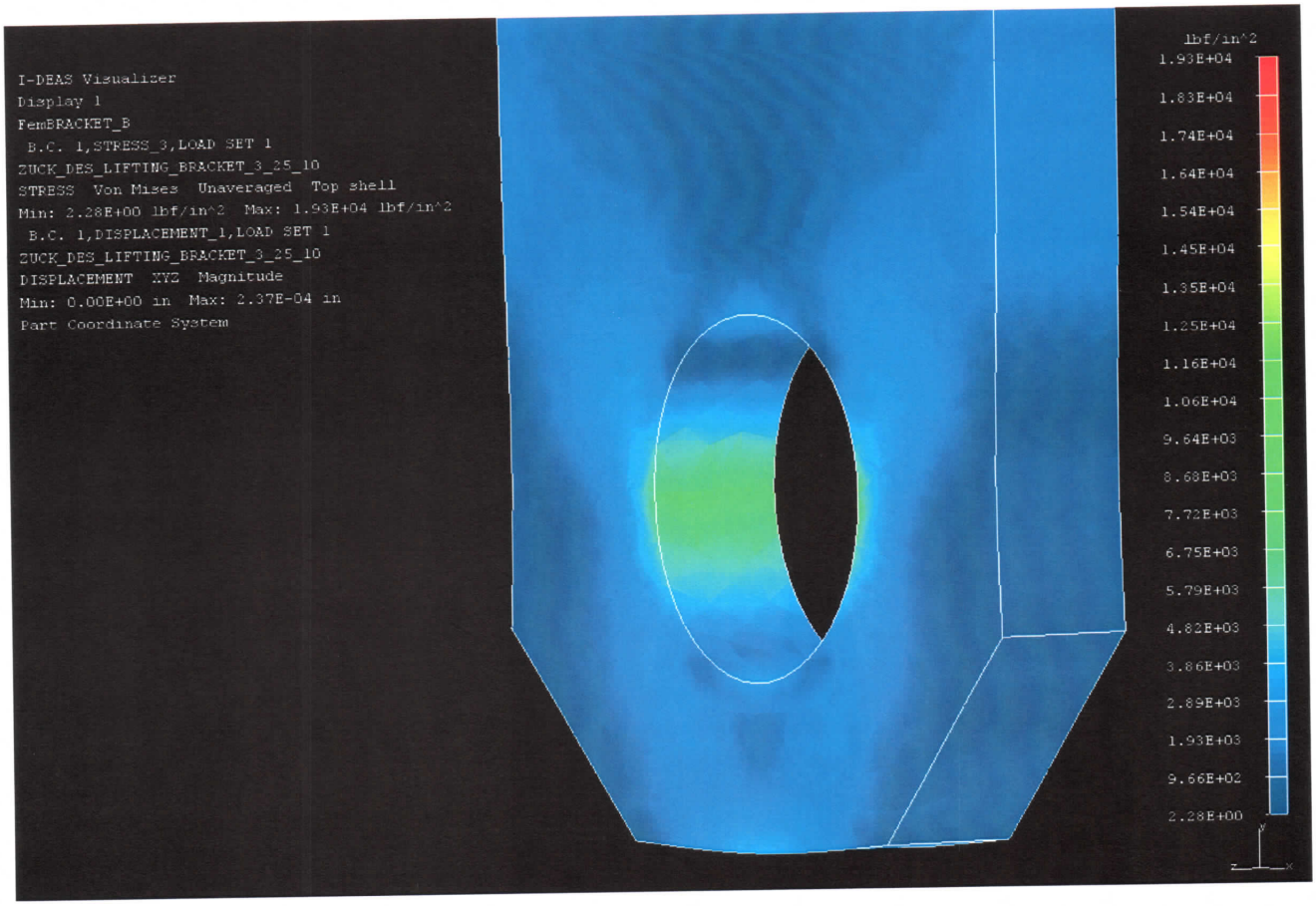


Bottom of the center bar shown, maximum stress is about 19 ksi in the center and on the toop edge except for in localized areas, while most of the area is 11 ksi or less.

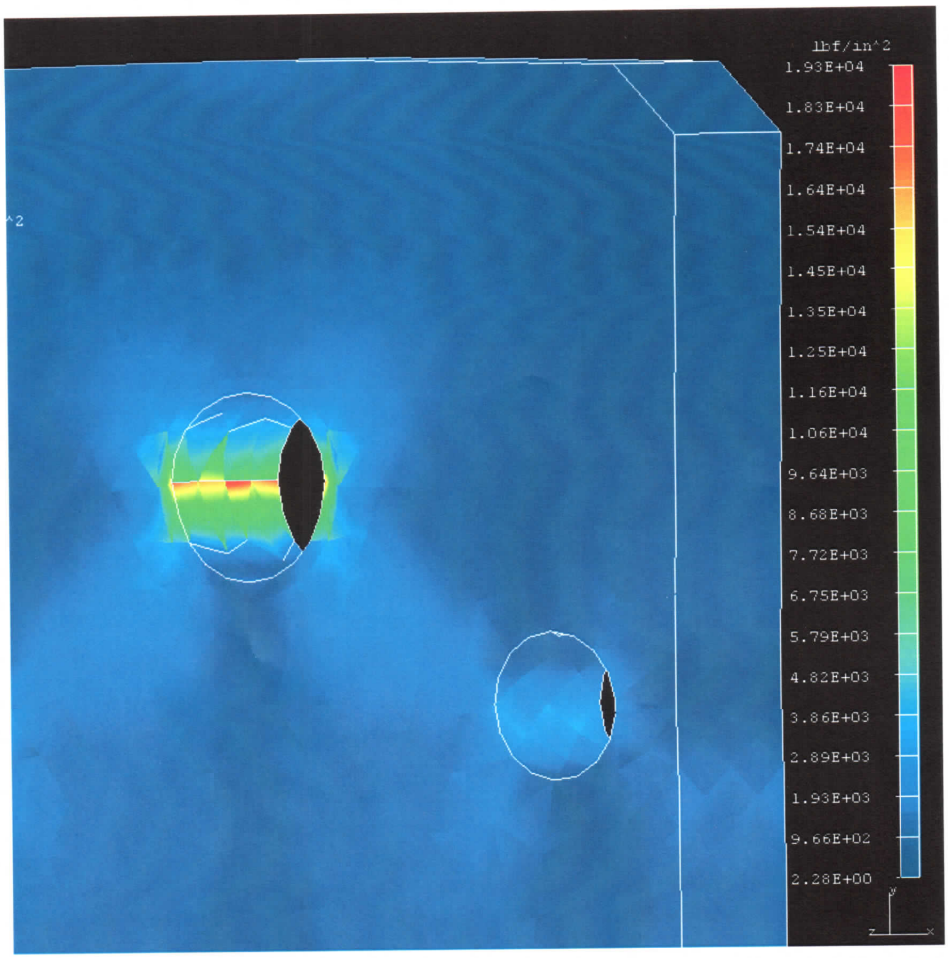
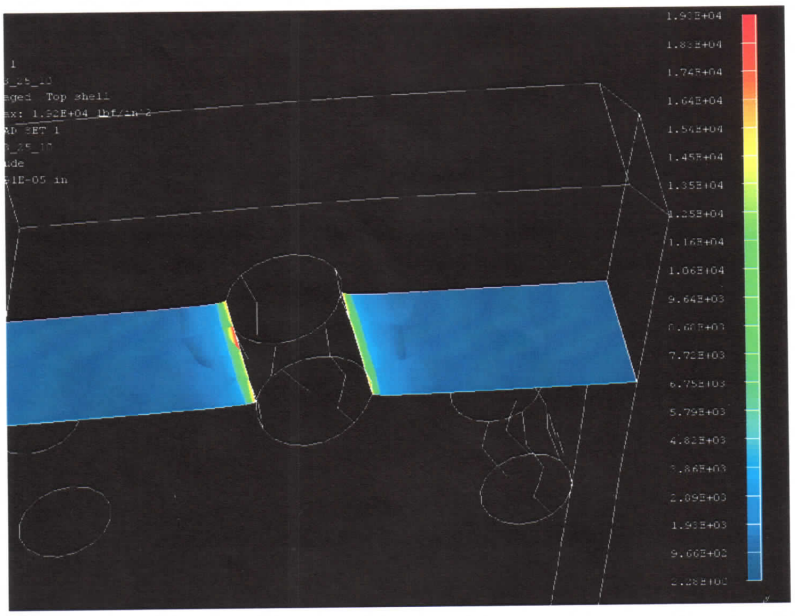


Split surface view of the center plane of the bar where the maximum stress is located, showing most of the bars internal area under low levels of stress.


I-DEAS Visualizer
Display 1
FemBRACKET_B
B.C. 1,STRESS_3,LOAD SET 1
ZUCK_DES_LIFTING_BRACKET_3_25_10
STRESS Von Mises Unaveraged Top shell
Min: 2.28E+00 lbf/in^2 Max: 1.93E+04 lbf/in^2
B.C. 1,DISPLACEMENT_1,LOAD SET 1
ZUCK_DES_LIFTING_BRACKET_3_25_10
DISPLACEMENT XYZ Magnitude
Min: 0.00E+00 in Max: 2.37E-04 in
Part Coordinate System
lbf/in^2
1.93E+04
1.83E+04
1.74E+04
1.64E+04
1.54E+04
1.45E+04
1.35E+04
1.25E+04
1.16E+04
1.06E+04
9.64E+03
8.68E+03
7.72E+03
6.75E+03
5.79E+03
4.82E+03
3.86E+03
2.89E+03
1.93E+03
9.66E+02
2.28E+00



The ¾'' hole of the plate is shown, with the maximum stress acceptable at under 10 ksi.



3/8'' plate support hole where the center bar is connected shown above with local stresses up to 20 ksi, though main stress is 10 ksi or less. Split surface view of the support hole is shown below, with stresses limited mainly to the edge of the hole.