

BELOW-THE-HOOK LIFTING DEVICE
Engineering Note Cover Page

Lifting Device Numbers: 127

FNAL Site No.: _____ Div. Specific No.: _____ Asset No. _____
if applicable if applicable if applicable

ASME B30.20 Group: Group I Structural and Mechanical Lifting Devices
(check one) Group II Vacuum Lifting Devices
 Group III Magnets, Close Proximity Operated
 Group IV Magnets, Remote Operated

Device Name or Description: TPC DETECTOR LIFTING FIXTURE

Device was: Purchased from a Commercial Lifting Device Manufacturer
 mfg. name: _____

(check all applicable) 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: DESIGNED BY CONTRACTOR AND BUILT AT FERMI LAB

Engineering Note Prepared by: NORM BOSEK Date: 02/22/01Engineering Note Reviewed by: RAFAEL SILVA Date: 02/23/01

Lifting Device Data:

Capacity: 1980 lbFixture Weight: 170 lb (1,980 + 170 = 2,150)Service: 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: _____

Rated Load Test by FNAL (if applicable): Date: 02/22/01 Load: 2,800 lb Check if Load Test was by Vendor and attach the certificate.Satisfactory Load Test Witnessed by: RAFAEL SILVASignature (of Load Test Witness): [Signature]

Notes or Special Information:



LIFTING FIXTURE
for
MOVING TPC DETECTOR

DATE: 1-25-2001

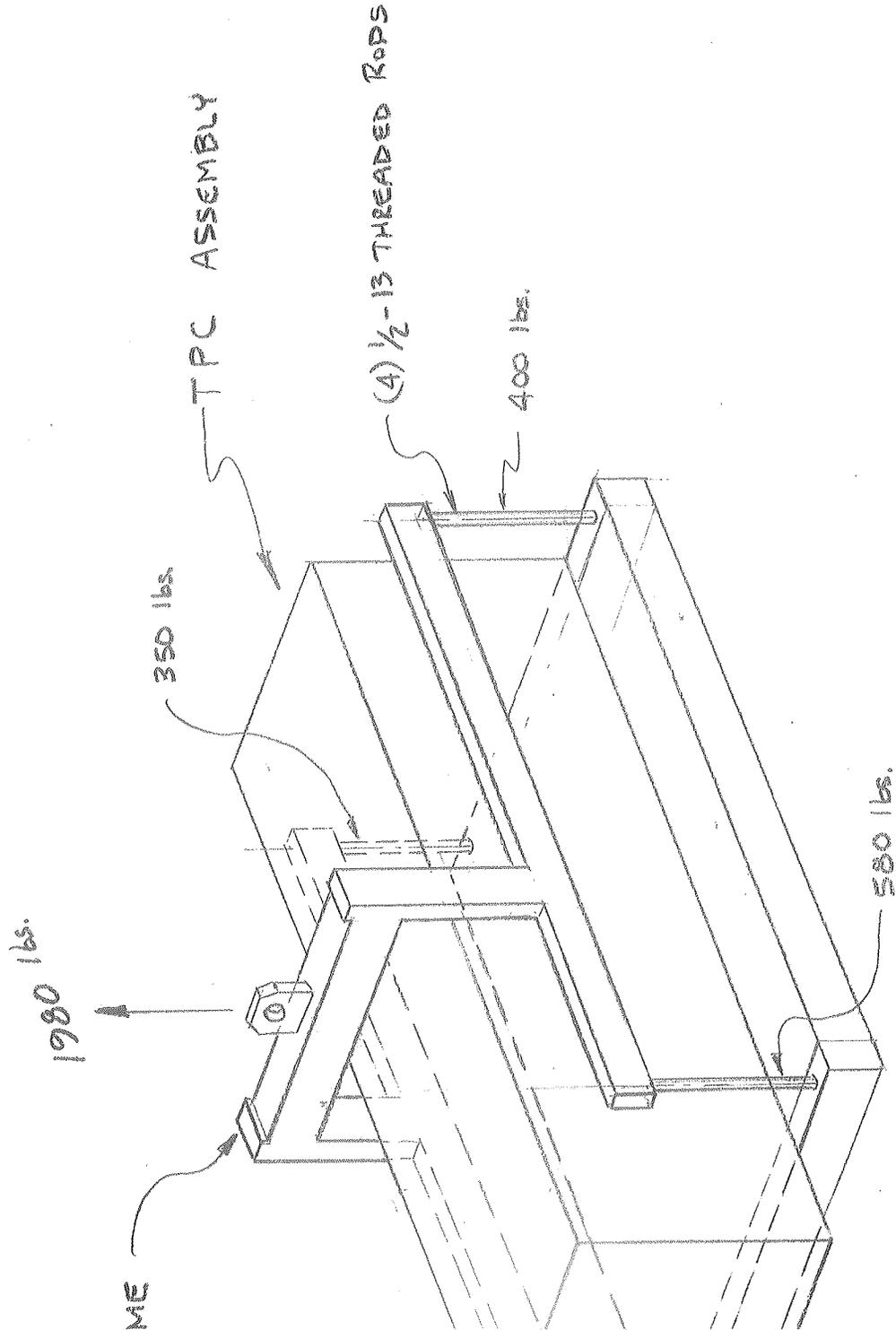
DRAWN BY: NORM BOSEK
205 BRUCE RD.
LOCKPORT, IL 60441
(815) 838-0352

PAGES 1 THRU 8 CONTAIN:

STRESS, LOADING & WELD

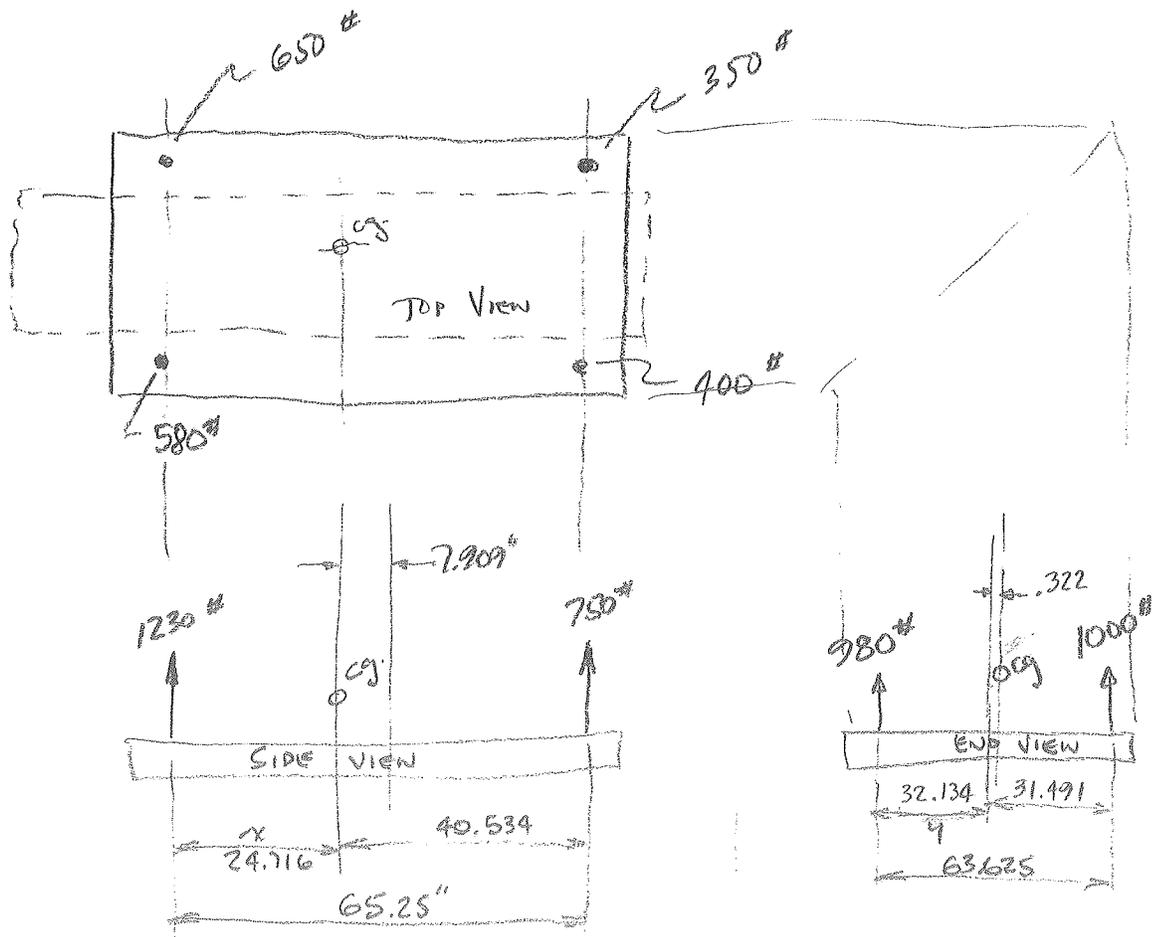
CALCULATIONS FOR THIS

FIXTURE



LIFTING FRAME for
MOVING the "TPC" ASSEMBLY

DWN BY: N. BOSEK 2-16-01



$$1230 x = 750 (65.25 - x)$$

$$1230 x = 48937.5 - 750 x$$

$$1980 x = 48937.5$$

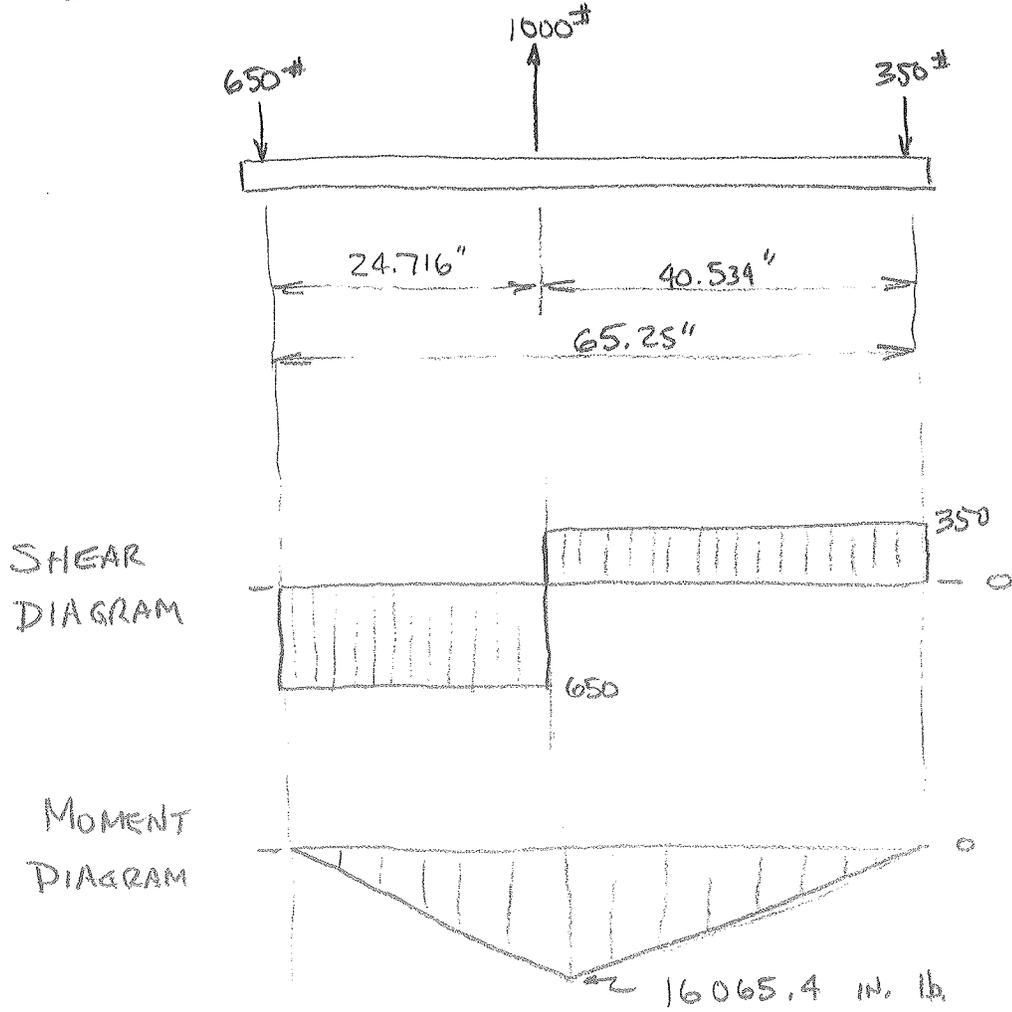
$$x = 24.716$$

$$980 y = 1000 (63.625 - y)$$

$$980 y = 63625$$

$$y = 32.134$$

SIDE BEAM STRESS :



SIDE BEAM STRESS :

TRY 3" x 2" TUBE x 1/4 WALL STEEL

FROM TABLE IN AISC HDBK

$$I_x = 2.26 \text{ IN}^4$$

$$S_x = 1.47 \text{ IN}^3$$

$$r_x = 1.03 \text{ IN.} \quad r_y = .792 \text{ IN.}$$

$$F_b = \frac{M}{S} = \frac{16065.4}{1.47} = 10929 \text{ psi.}$$

$$F_b \text{ ALLOWABLE} \leq .66 F_y = 24,000 \text{ psi}$$

(AISC CODE 1.5.1.4.1)

(OR)

$$F_b \text{ ALLOWABLE} \leq \frac{12,000,000 C_b}{Q_d / A_g} = \frac{12 \times 10^6}{\frac{65.25 \times 3}{.25 \times 2}} = 30651 \text{ ps}$$

(AISC CODE 1.5.1.4.6a)

(OR)

$$F_b \text{ ALLOWABLE} \leq .33 F_y = 12,000 \text{ psi}$$

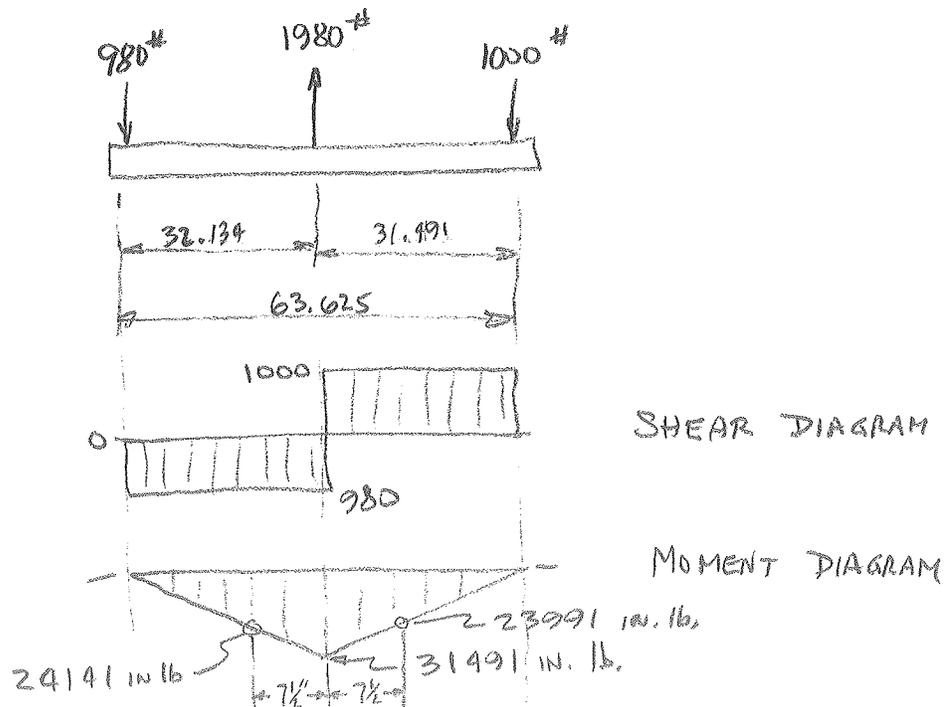
(BELOW HOOK LIFTING DEVICES 20-1.2.2)

USE SMALLEST VALUE = 12,000 psi

$$\text{So } 10929 \text{ psi} < 12,000 \text{ psi}$$

∴ BEAM SECTION IS ADEQUATE

CENTER BEAM STRESS:



USING THE SAME $3" \times 2" \times \frac{1}{4}"$ WALL TUBE

$$F_b = \frac{M}{S} = \frac{31491}{1.47} = 21,423 \text{ psi.}$$

F_b ALLOWABLE SAME AS PAGE 4

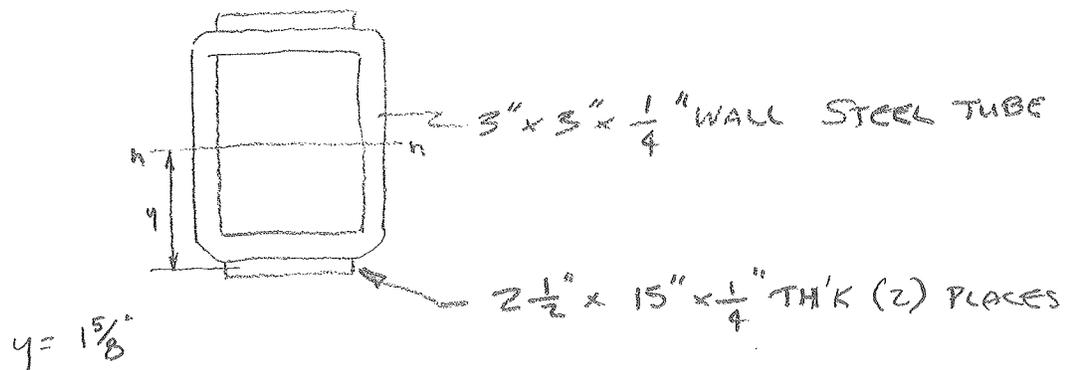
$$\text{SO } 21,423 \text{ psi} < 12,000 \text{ psi.}$$

BEAM SECTION IS NOT ADAQUATE

TRY $3" \times 3" \times \frac{1}{4}"$ WALL TUBE $S = 2.10 \text{ in}^3$

$$F_b = \frac{31491}{2.1} = 14,996 \text{ psi}$$

INCREASE MOMENT OF INERTIA OF TUBE BY WELDING ON (2) PLATES



$$\begin{aligned}
 I_{\text{TOTAL}} &= I_{\text{TUBE}} + \left[I_{\text{PLATE}} + (y^2 A) \right] 2 \\
 &= 3.16 \text{ in}^4 + 2 \left[\frac{bh^3}{12} + 1.625^2 \times .25 \times 2.5 \right] \\
 &= 3.16 + 2 \left(\frac{2.5 \times .25^3}{12} + 1.65 \right) \\
 &= 3.16 + 2 (.003 + 1.65) \\
 &= 3.16 + 3.306
 \end{aligned}$$

$$I_{\text{TOTAL}} = 6.467 \text{ in}^4 \quad C = 1.75$$

$$\text{SECTION MODULUS "S"} = \frac{I}{C} = \frac{6.467}{1.75} = 3.695$$

$$\begin{aligned}
 \text{BENDING STRESS} & F_b = \frac{M}{S} = \frac{31491}{3.695} = 8522 \text{ psi} \\
 \text{AT CENTER} & \\
 \text{LIFTING EYE} &
 \end{aligned}$$

F_b ALLOWABLE FOR 3" x 3" TUBE WITH 1/4" PLATES TOP & BOTTOM

$$F_b = .66 F_y = 24,000 \text{ psi. (AISC CODE 1.5.1.4.1)}$$

(OR)

$$F_b = \frac{12 \times 10^6 C_b}{L d / A_f} = \frac{12 \times 10^6 \times 1}{61.5 \times 3 / .25 \times 3} = 48780 \text{ psi. (AISC CODE 1.5.1.4.6a)}$$

(OR)

$$F_b = .33 F_y = 12,000 \text{ psi.}$$

(BELOW HOOK LIFTING DEVICES 20-1.2.2)

USE SMALLEST VALUE = 12,000 psi

So $8522 \text{ psi} < 12,000 \text{ psi}$

∴ BEAM SECTION IS ADEQUATE

BENDING STRESS
AT 7 1/2" OUT FROM
CENTER LIFTING EYE

$$F_b = \frac{M C}{I} = \frac{24141 \times 1.5 \text{ in.}}{3.16 \text{ in}^4}$$

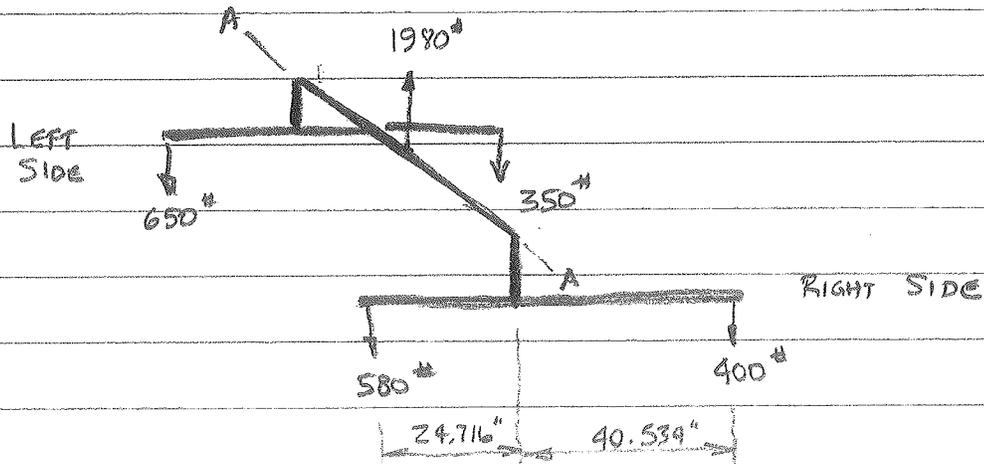
↖ 3" x 3" TUBE ONLY

$$F_b = 11493 \text{ psi.}$$

$$11493 \text{ psi} < 12,000 \text{ psi}$$

BEAM SECTION IS ADEQUATE AT THIS POINT
& FURTHER OUT FROM LIFT EYE AT CENTER

TORSION IN CENTER BEAM:



SUM MOMENTS ABOUT "AA"

$$\begin{aligned} \text{LEFT SIDE: } 650(24.716) - 350(40.534) &= \\ 16065.4 - 14186.9 &= \\ = 1878.5 \text{ COUNTER CLOCKWISE} \end{aligned}$$

$$\begin{aligned} \text{RIGHT SIDE: } 580(24.716) - 400(40.534) &= \\ 14335.3 - 16213.6 &= \\ = 1878.3 \text{ CLOCKWISE} \end{aligned}$$

∴ TORSION IN CENTER BEAM ≈ 1878.4 IN. LB.

MOMENTS ABOUT A-A OF LEFT SIDE

BALANCE MOMENT OF RIGHT SIDE

TORSIONAL SHEAR STRESS OF CENTER BEAM :

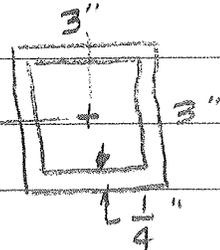
$$F_s = \frac{Tc}{J}$$

Use

THIS

TUBE

STOCK



$$J = I_x + I_y$$

C = MAX. RADIS FROM CENTER

$$= \sqrt{1.5^2 + 1.5^2}$$

$$I_x = I_y = 3.16 \text{ in}^4$$

$$C = 2.121"$$

$$J = 6.32 \text{ in}^4$$

$$T = 1878.4 \text{ in lb.}$$

$$F_s = \frac{Tc}{J} = \frac{1878.4 \times 2.121}{6.32} = 630.4 \text{ psi}$$

COMBINED STRESS OF CENTER BEAM :

$$\text{TORSIONAL SHEAR} = 630.4 \text{ psi}$$

$$\text{BENDING} = 8522 \text{ psi}$$

$$\begin{aligned} \text{COMBINED SHEAR} &= \pm \frac{1}{2} \sqrt{S_x^2 + 4S_{xy}^2} \\ &= \pm \frac{1}{2} \sqrt{8522^2 + 4(630.4)^2} \end{aligned}$$

$$F_{s \text{ comb}} = 4307.4 \text{ psi}$$

$$\begin{aligned} \text{COMBINED BENDING} &= \frac{S_x}{2} \pm F_{s \text{ comb}} \\ &= \frac{8522}{2} \pm 4307.4 \end{aligned}$$

$$F_{b \text{ comb}} = 8568.4 \text{ psi}$$

$$F_{b \text{ comb}} = 8568.4 \text{ psi} < 12,000 \text{ psi} = F_{b \text{ ALLOWABLE}}$$

∴ BEAM SECTION IS WITHIN SPEC.
AT CENTER OF SPAN.

COMBINED STRESS OF CENTER BEAM
AT $7\frac{1}{2}$ " EITHER SIDE OF CENTER
PICK POINT.

$$\text{TORSIONAL SHEAR} = 630.4 \text{ psi}$$

$$\text{BENDING} = 11493 \text{ psi.}$$

$$\text{COMBINED SHEAR} = \pm \frac{1}{2} \sqrt{11493^2 + 4(630.4)^2}$$

$$F_{s \text{ comb}} = 5781 \text{ psi}$$

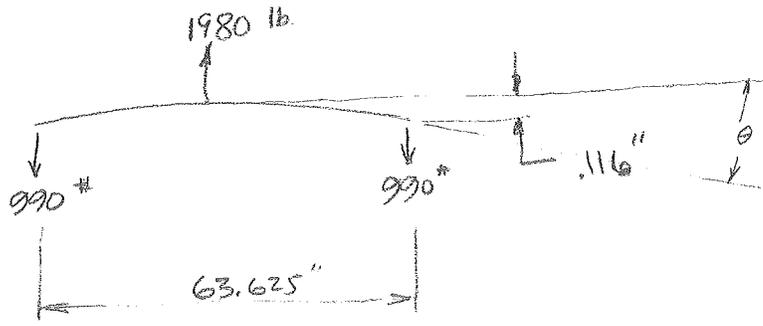
$$\text{COMBINED BENDING} = \frac{11493}{2} \pm 5781$$

$$F_{b \text{ comb}} = 11527 \text{ psi.}$$

$$F_{b \text{ comb}} = 11527 \text{ psi} < 12,000 \text{ psi.} = F_{b \text{ allow}}$$

∴ BEAM SECTION IS WITHIN SPEC.
AT $7\frac{1}{2}$ " EITHER SIDE OF CENTER
OF SPAN.

DEFLECTION of CENTER BEAM :



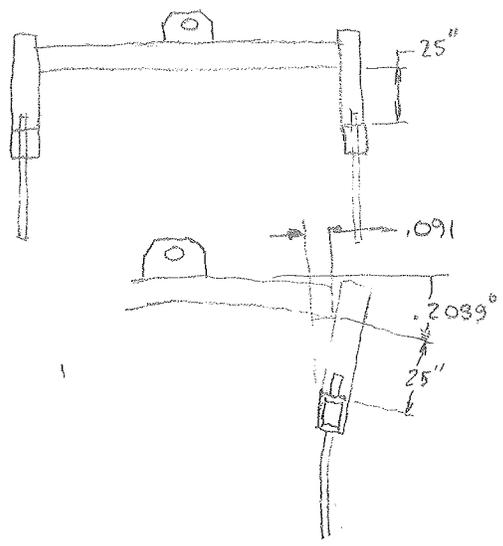
$$\delta_{\text{MAX AT CENTER}} = \frac{Pl^3}{48EI}$$

- $P = 1980 \text{ lb.}$
- $l = 63.625''$
- $E = 29 \times 10^6 \text{ psi.}$
- $I = 3.16 \times 10^4$
- $\angle 3'' \times 3'' \text{ TUBE}$

$$\delta = \frac{1980 \times 63.625^3}{48 \times 29 \times 10^6 \times 3.16}$$

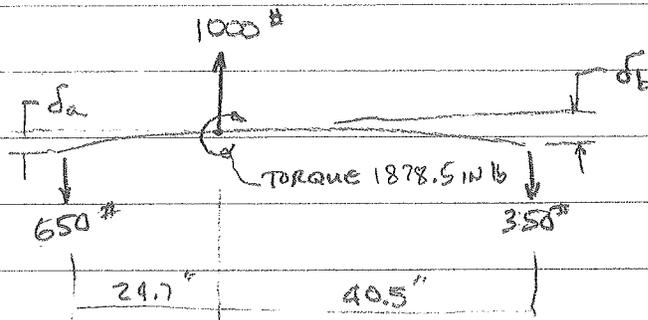
$$\delta = .116''$$

$$\text{APPROX. ANGLE } \theta = \text{ARCTAN } \frac{.116}{63.625/2} = .2089^\circ$$



SHIFT OF THREADED ROD DUE TO DEFLECTION = $25'' \sin .2089$
 = $.091''$

DEFLECTION OF SIDE BEAMS



deflection $\delta_a = \frac{Pl^3}{3EI}$

$$P = 650 \text{ lb}$$

$$l = 24.7''$$

$$E = 29 \times 10^6 \text{ psi}$$

$$I = 1.47 \text{ in}^4$$

CANTILEVER BEAM LOAD

AT END

3" x 2" TUBE

$$\delta_a = \frac{650 \times 24.7^3}{3 \times 29 \times 10^6 \times 1.47}$$

$$\delta_a = .077''$$

$$\delta_b = \frac{Pl^3}{3EI}$$

$$P = 350 \text{ lb}$$

$$l = 40.5''$$

$E \ \& \ I = \text{SAME AS ABOVE}$

$$\delta_b = \frac{350 \times 40.5^3}{3 \times 29 \times 10^6 \times 1.47}$$

$$\delta_b = .182''$$

THREADED ROD STRESS :

MAX. LOAD 650 lb.

 $\frac{1}{2}$ -13 ROD GRADE 2

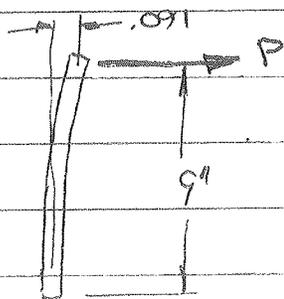
MAX ALLOWABLE LOAD = 5840 lb

PER: MACHINE DESIGN NOV. 1978

TABLE 2 PAGE 85

 $650 \# < 5840 \# \therefore$ THREAD ROD IS
PLENTY STRONG.

BENDING IN THREADED ROD DUE TO SHIFT IN X

 $\frac{1}{4}$ y OF .091 $\frac{1}{4}$.182


ANALYSIS AS CANTILEVER BEAM

CONCENTRATE LOAD AT END

$$\delta = \frac{Pl^3}{3EI}$$

$$l = 9''$$

$$E = 29 \times 10^6 \text{ psi.}$$

$$I = \frac{\pi}{4} r^4 = .001257$$

$$\text{TOTAL } \delta = \sqrt{.091^2 + .182^2}$$

$$\delta = .203$$

$$r = \frac{d}{2} = .20$$

$$\delta = .203 = \frac{P \times 9^3}{3 \times 29 \times 10^6 \times .001257}$$

$$d = .400$$

Root DIA. of $\frac{1}{2}$ -13 THREAD

$$P = \frac{.203 \times 3 \times 29 \times 10^6 \times .001257}{9^3}$$

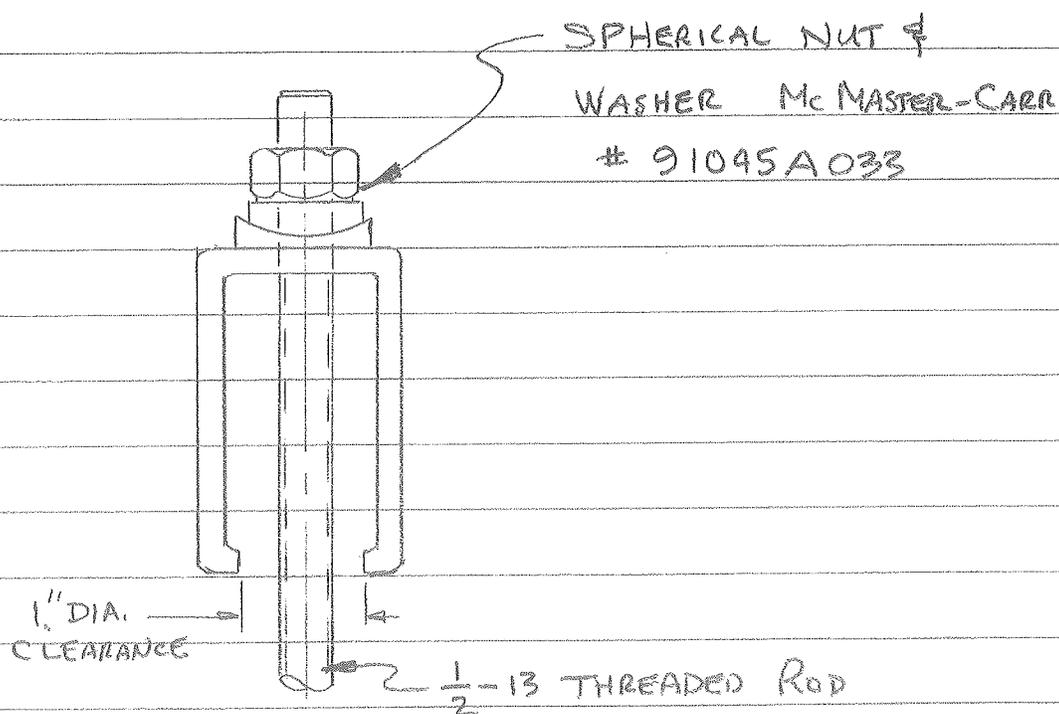
$$P = 30.45 \text{ lb.}$$

BENDING STRESS due to DEFLECTION :

$$M_{\text{MAX}} = Pl = 30.45 \times 9 = 274.07 \text{ IN. LB.}$$

$$F_b = \frac{Mc}{I} = \frac{274.07 \times .2}{.001257} = 43607 \text{ psi}$$

SINCE BENDING STRESS IN THREADED ROD IS SO HIGH, ELIMINATE THIS STRESS BY USING SPHERICAL WASHER UNDER TOP NUT AND A LARGE CLEARANCE HOLE IN BOTTOM OF SIDE BEAMS.



FILLET WELD DESIGN :

ALL WALL THICKNESS ARE $\frac{1}{4}$ "

\therefore USE $.75t = \frac{3}{16}$ " FILLETS ALL PLACES

ANS CODE

CAPACITY OF $\frac{3}{16}$ " FILLET = 1250 lb/in.

WELD AT LIFTING EYE :

$\frac{3}{16}$ ALL AROUND = $(4" + 4") 1250 = 10,000$ lb CAPACITY

SAFETY FACTOR = $\frac{10,000 \text{ lb}}{1980 \text{ lb}} \approx 5 \text{ TO } 1$

WELD AT TOP HORIZONTAL BEAM TO SIDE VERTICAL BEAMS

$\frac{3}{16}$ ALL AROUND = $(3" \times 3" \times 3" \times 3") 1250 = 15,000$ lb.

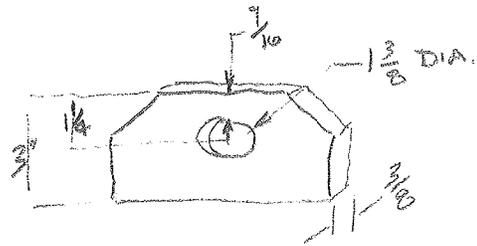
SAFETY FACTOR = $\frac{15,000 \text{ lb}}{1000 \text{ lb}} = 15 \text{ TO } 1$

WELD AT VERTICAL BEAM TO LOWER SIDE HORIZONTAL BEAM

$\frac{3}{16}$ FILLET ALL AROUND = $(3" + 2" + 3" + 2") 1250 = 12,500$ lb

SAFETY FACTOR = $\frac{12,500 \text{ lb}}{1000 \text{ lb}} = 12.5 \text{ TO } 1$

LIFTING EYE PLATE :



TOTAL LOAD = 1980 lb,

$$\text{BEARING STRESS} = \frac{P}{A} = \frac{1980}{1.375 \times 1.375} = 3840 \text{ psi.}$$

$$\text{BEARING ALLOWABLE} = .9 F_y = 33,000 \text{ psi.}$$

AISC CODE 1.5.1.5.1

OR

$$\text{SO } 3840 \text{ psi} < 33,000 \text{ psi.}$$

$$\text{SHEAR STRESS} = \frac{P}{A} = \frac{1980}{1.25 \times 1.375 \times 2} = 2112 \text{ psi}$$

$$\text{SHEAR ALLOWABLE} = .4 F_y = 14500 \text{ psi.}$$

(AISC CODE 1.5.1.3)

$$\text{SO } 2112 \text{ psi} < 14500 \text{ psi.}$$

∴ SHEAR IS IN CODE

Complementary FEA analysis

ASTM A 500 gr B (ksi): $\sigma_y := 46$

ANSI B30.20: $\sigma_a := \frac{\sigma_y}{3}$ $\sigma_a = 15.3$

FEA (Von Mises): $\sigma_{\max} := 12.8$

For members, as σ_{\max} (12.8 ksi) is smaller than σ_a (15.3 ksi), members are OK.

For welds:

Allowable (Salmon, p.247): $R_w = 2.38$ kips/in

Relevant loads (1,000 lb or 1,00lb-in):

3x2 with 3x2

(9.5 in², $I_b = 1.37$ in³; $I_p = 21.6$ in³)

Axial: 1.0 ; Bending: 1.0

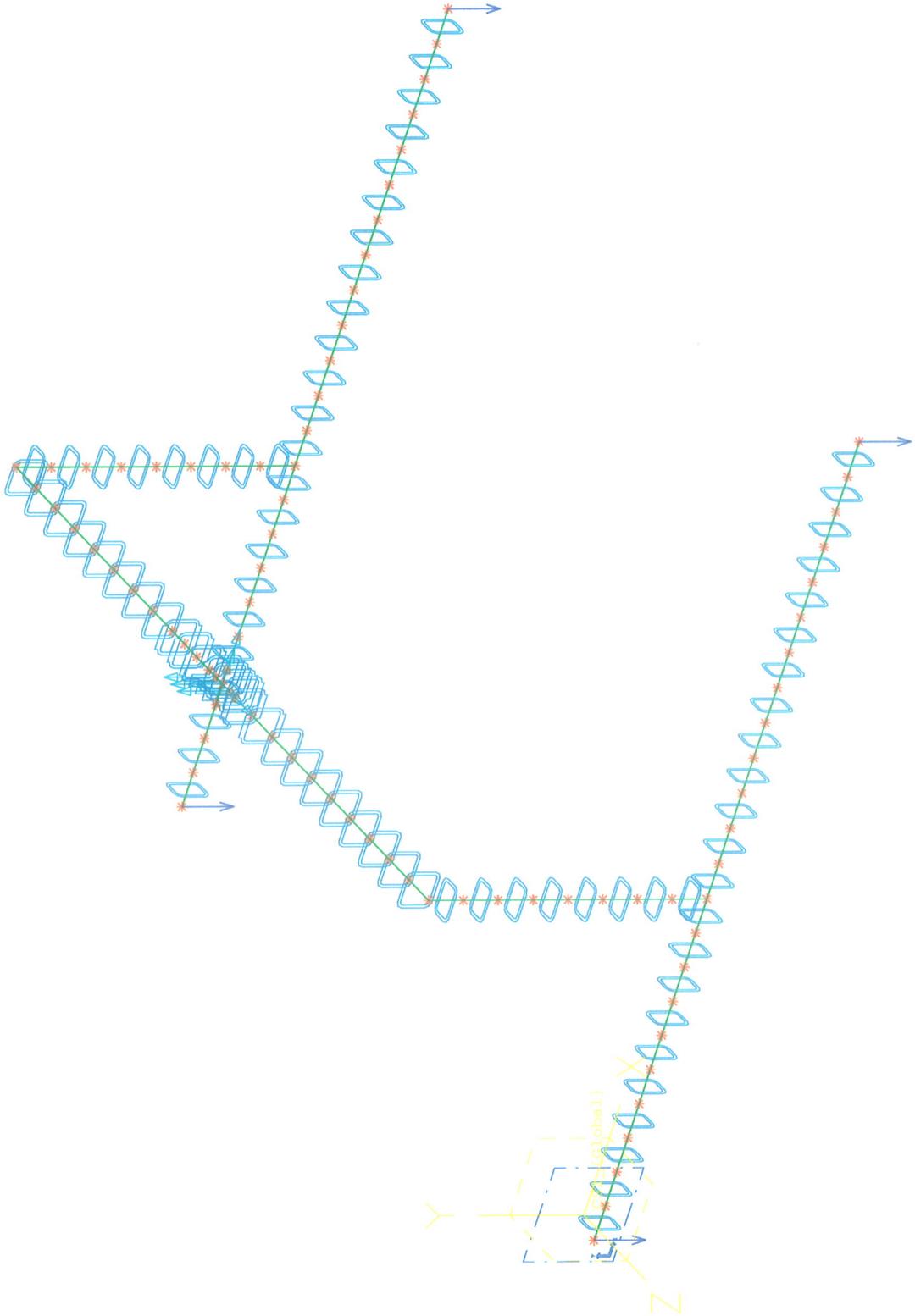
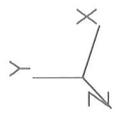
3x3 with 3x2:

Shear: 1.0 ; Torque: 1.0

Worse than worst:
$$R := \sqrt{\left(\frac{1.0}{1.37}\right)^2 + \left(\frac{1.0}{21.6}\right)^2 + \left(\frac{\sqrt{1.0^2 + 1.0^2}}{9.5}\right)^2}$$
 $R = 0.75$

For welds, as R (.75 kips/in) is smaller than R_w (2.38 kips/in), welds are OK.

ASTM A36 plates and their welds are also OK.



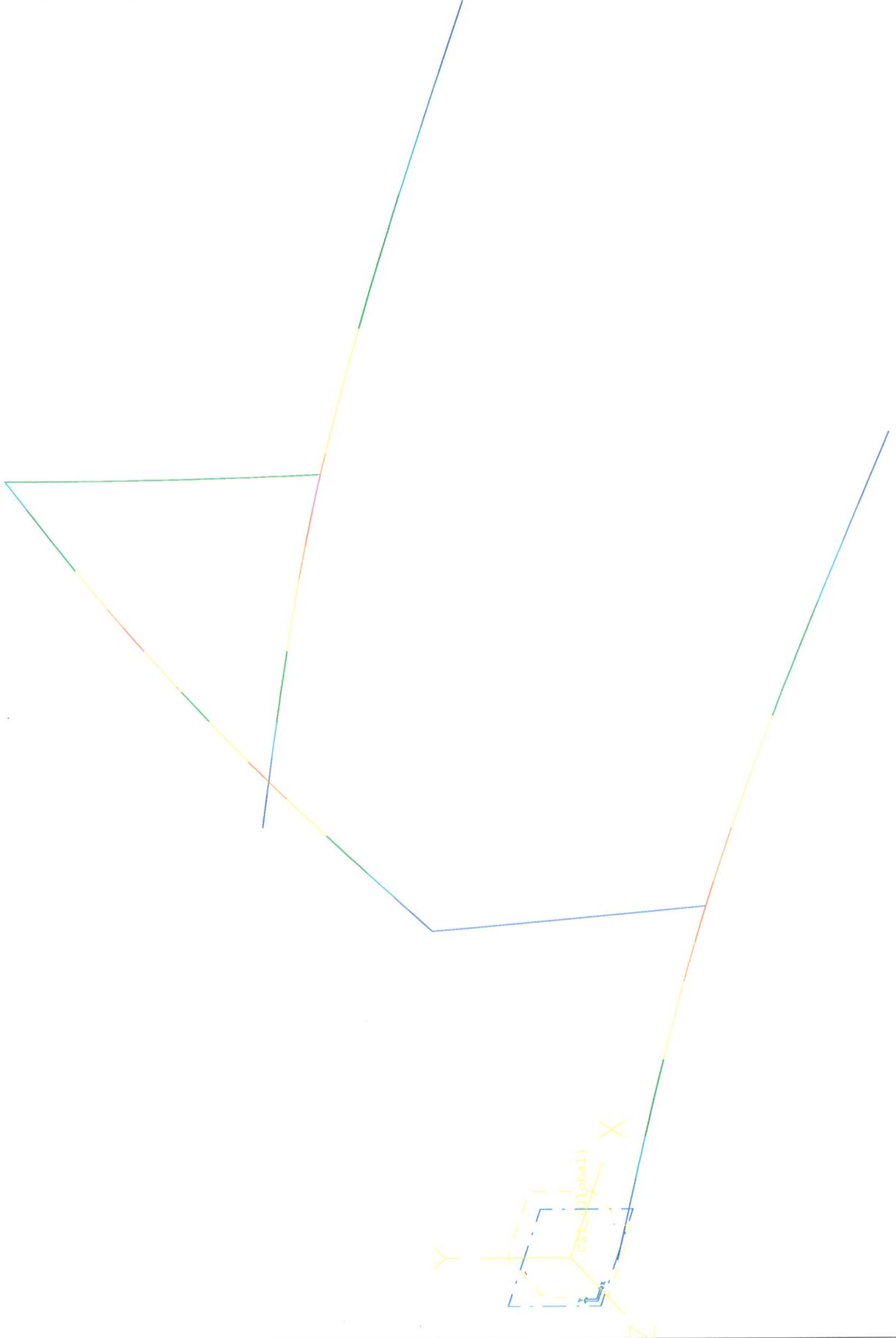
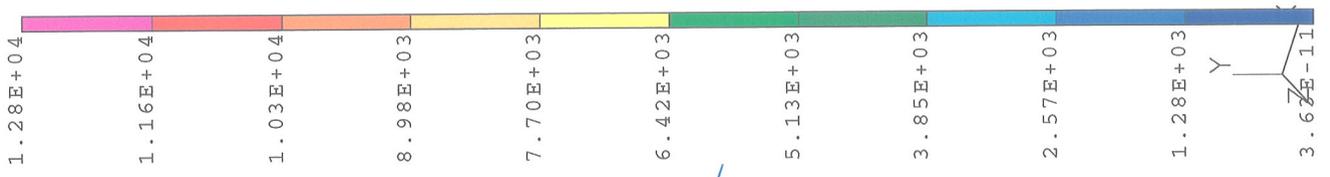
/cadwhs/server02/..._rafael/bosek_lf

RESULTS: 3- B.C. 1, STRESS_3, LOAD SET 1

MAGNITUDE - MIN: 3.63E-11 MAX: 1.28E+04

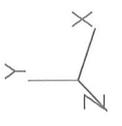
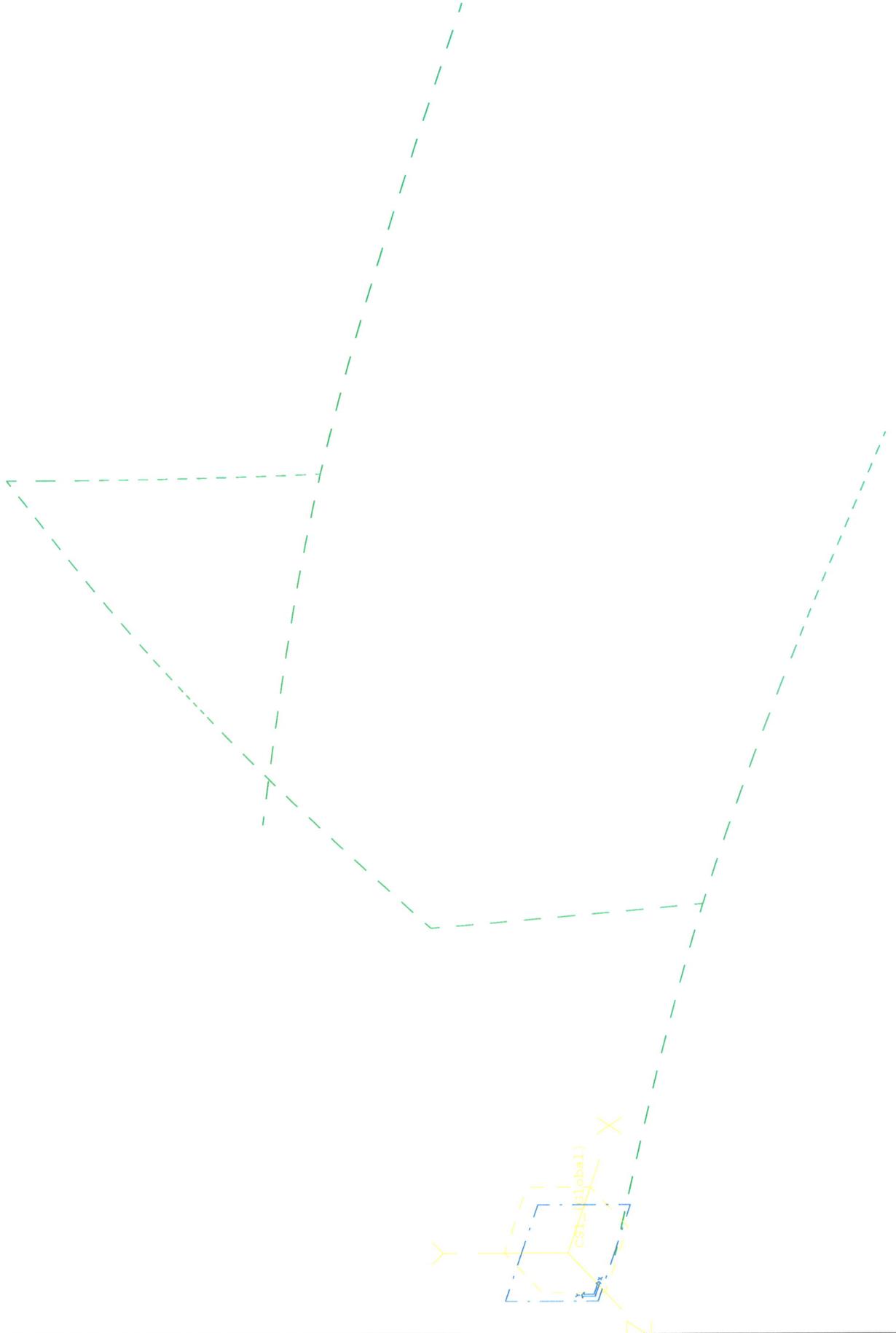
Data component: VON MISES STRESS at maximum point

VALUE OPTION: ACTUAL



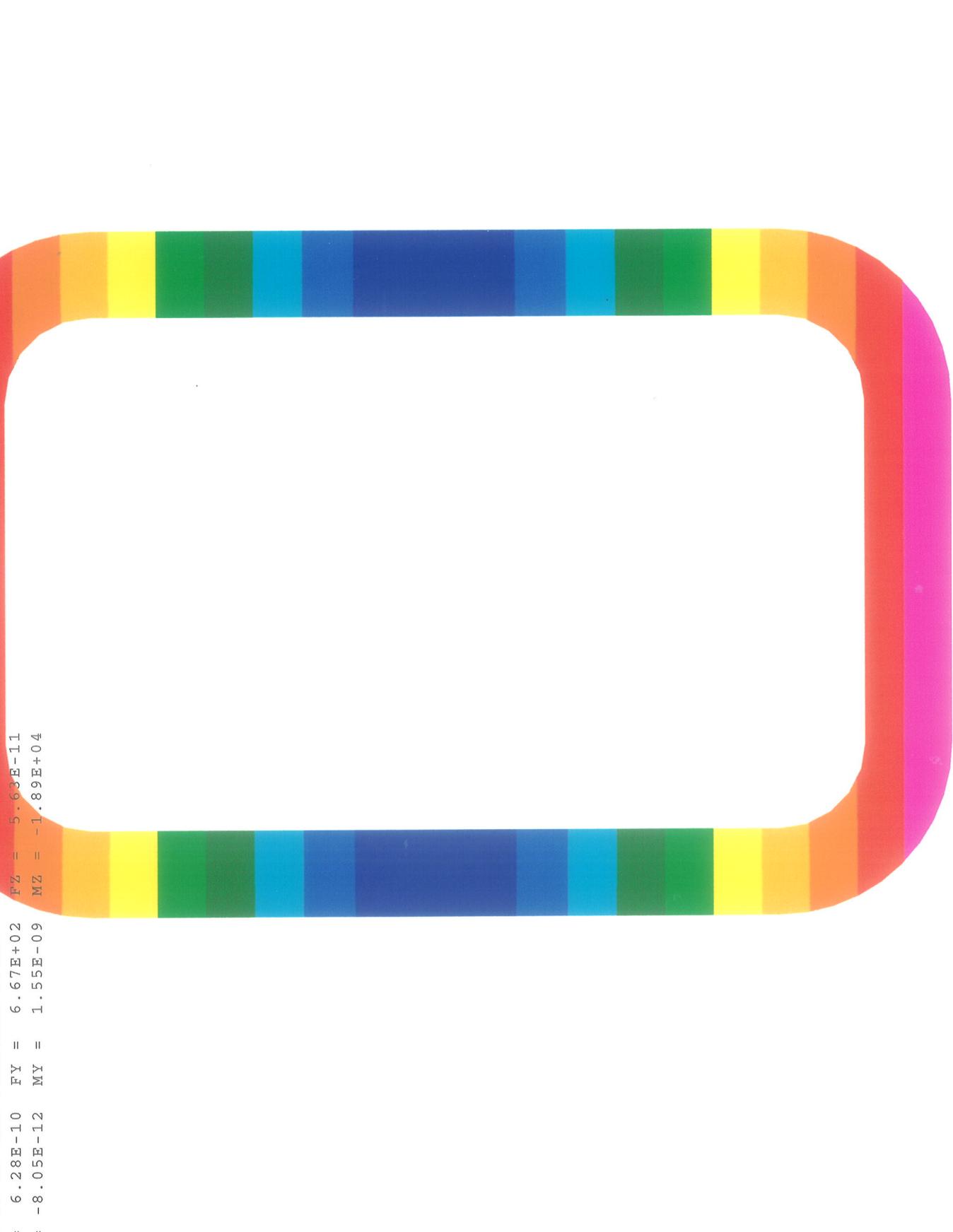
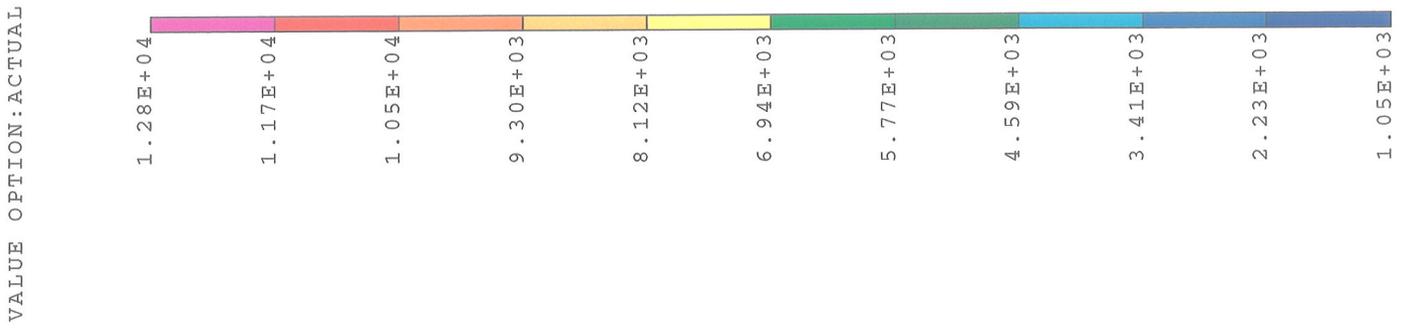
/cadwhs/server02/..._rafael/bosek_lf

DEFORMATION: 1- B.C. 1, DISPLACEMENT_1, LOAD SET 1
DISPLACEMENT - MAG MIN: 0.00E+00 MAX: 2.99E-01
FRAME OF REF: PART



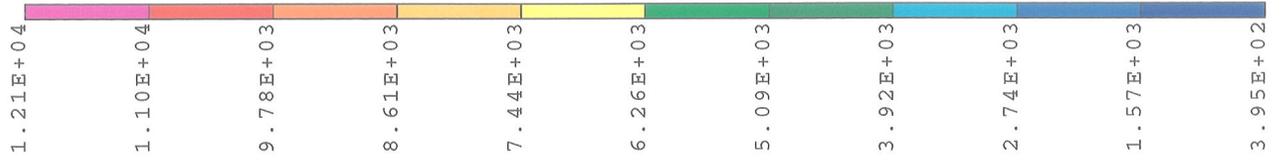
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RESULTS: 4- B.C. 1,ELEMENT FORCE_4,LOAD SET 1
BEAM X-SECTION - VON MISES STRESS MIN: 1.05E+03 MAX: 1.28E+04
BEAM 98 AT MAX POSITION STRESS
FX = 6.28E-10 FY = 6.67E+02 FZ = 5.63E-11
MX = -8.05E-12 MY = 1.55E-09 MZ = -1.89E+04



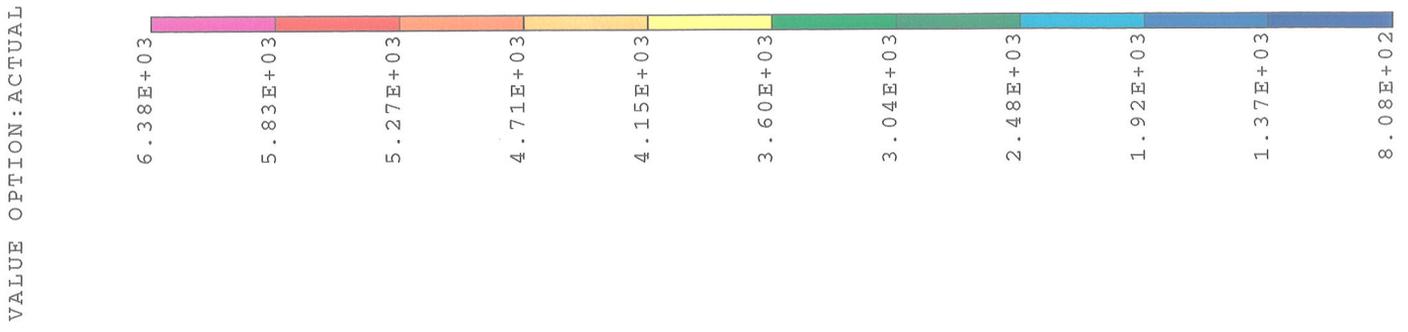
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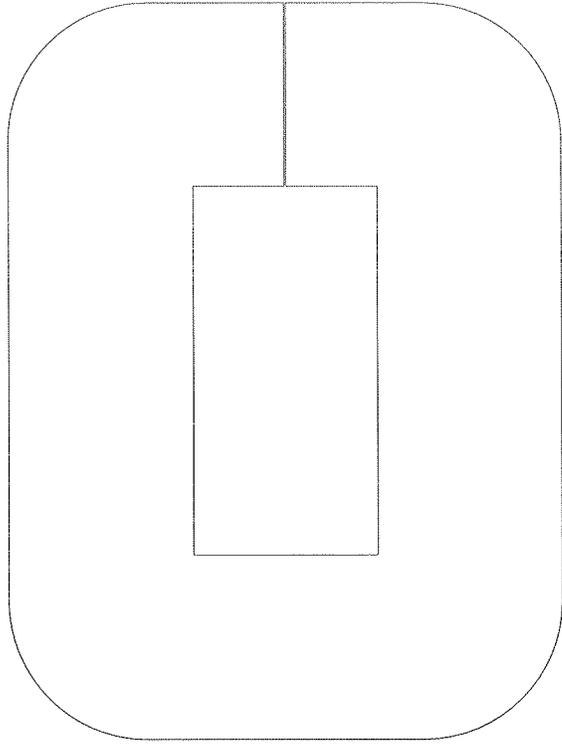
RESULTS: 4- B.C. 1, ELEMENT FORCE_4, LOAD SET 1
BEAM X-SECTION - VON MISES STRESS MIN: 3.95E+02 MAX: 1.21E+04
BEAM 71 AT MAX POSITION STRESS
FX = 9.58E-11 FY = -1.07E+03 FZ = -6.65E-10
MX = -4.99E+03 MY = 1.80E-08 MZ = -2.46E+04



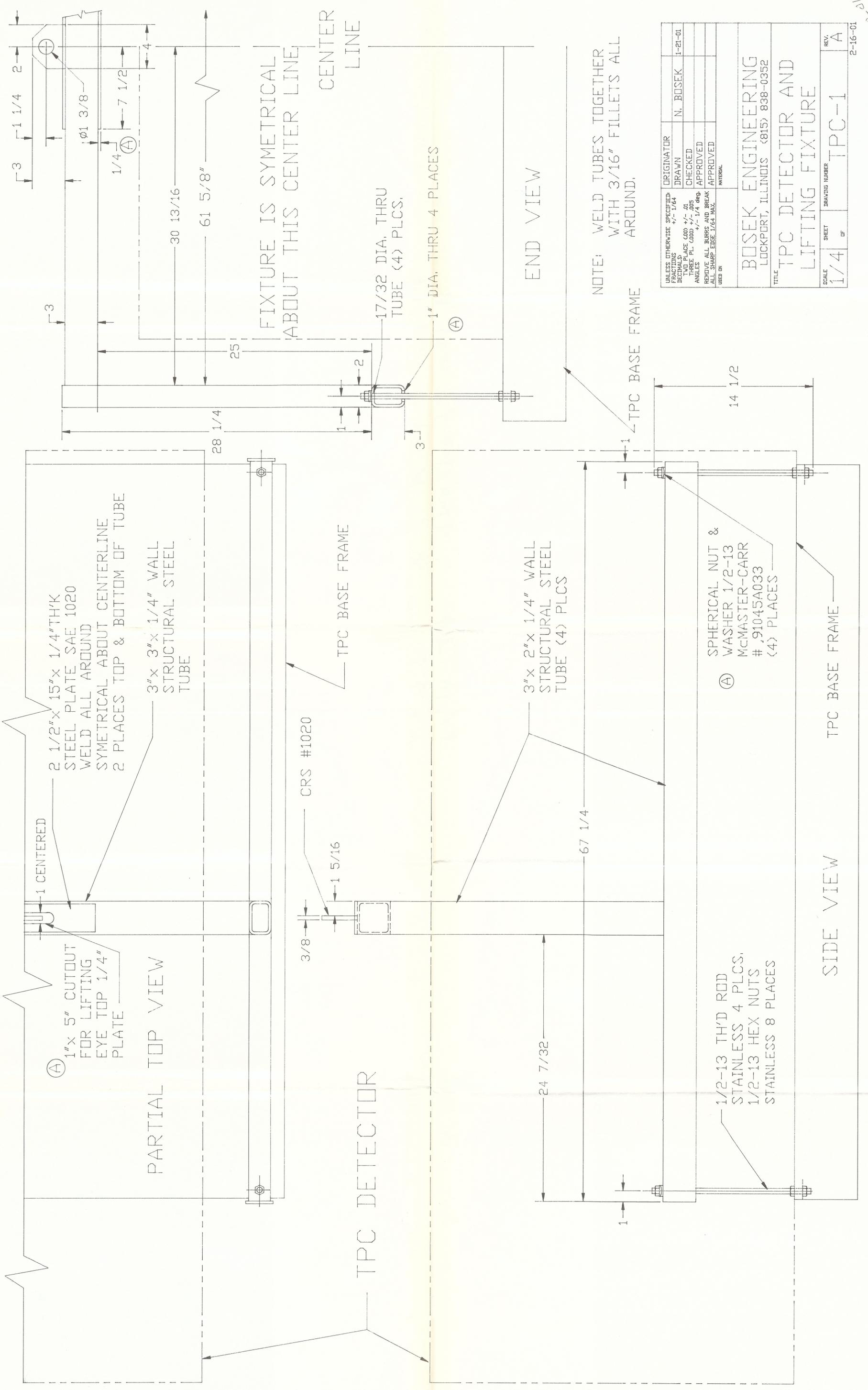
/cadwhs/server02/rafael/bosek_lf

RESULTS: 4- B.C. 1, ELEMENT FORCE_4, LOAD SET 1
BEAM X-SECTION - VON MISES STRESS MIN: 8.08E+02 MAX: 6.38E+03
BEAM 87 AT MAX POSITION STRESS
FX = 9.58E-11 FY = 9.58E+02 FZ = -6.65E-10
MX = -4.99E+03 MY = 2.23E-08 MZ = -3.16E+04





Area=9.50715e+00
Xcg=3.25693e+00
Ycg=4.41818e+00
Ixcg=7.96648e+00
Iycg=1.36790e+01
Ixcg=0.00000e+00
Ixor=1.93549e+02
Iyor=1.14527e+02
Ixyor=1.36805e+02
Kxcg=9.15394e-01
Kycg=1.19951e+00
Kxor=4.51202e+00
Kyor=3.47079e+00
Ixpri=7.96648e+00
Iypri=1.36790e+01
Angle=0.00000e+00
Ipol=2.16455e+01



UNLESS OTHERWISE SPECIFIED	ORIGINATOR	
FRACTIONS	DRAWN	N. BOSEK
DENOMINATOR	CHECKED	
± 1/64	APPROVED	
± 1/32	APPROVED	
± 1/16	APPROVED	
± 1/8	APPROVED	
± 1/4	APPROVED	
± 1/2	APPROVED	
± 3/4	APPROVED	
± 1	APPROVED	
± 1 1/4	APPROVED	
± 1 1/2	APPROVED	
± 2	APPROVED	
± 3	APPROVED	
± 4	APPROVED	
± 6	APPROVED	
± 12	APPROVED	
± 24	APPROVED	
± 48	APPROVED	
± 96	APPROVED	
± 192	APPROVED	
± 384	APPROVED	
± 768	APPROVED	
± 1536	APPROVED	
± 3072	APPROVED	
± 6144	APPROVED	
± 12288	APPROVED	
± 24576	APPROVED	
± 49152	APPROVED	
± 98304	APPROVED	
± 196608	APPROVED	
± 393216	APPROVED	
± 786432	APPROVED	
± 1572864	APPROVED	
± 3145728	APPROVED	
± 6291456	APPROVED	
± 12582912	APPROVED	
± 25165824	APPROVED	
± 50331648	APPROVED	
± 100663296	APPROVED	
± 201326592	APPROVED	
± 402653184	APPROVED	
± 805306368	APPROVED	
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