THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY
12000 Jefferson Avenue
Newport News, VA 23606

HALL D ANALYSIS NO.:
D00000-05-01-A014 Rev A

TITLE: Hall D DIRC Support Structural Analysis

DATE: 20NOV2016

BY: Tim Whitlatch

APP: Tim Whitlatch

CHK: Wayne Sachleben

REV.	ECO#	DESCRIPTION	BY	CHK.	APP.	APP.	DATE
A		Added analysis of temporary floor tie downs at end	TEW		TEW		12May17
SUMMARY OF CHANGES FROM PREVIOUS REVISION:							

Approved: 5/24/2017; E-Sign ID : 343350; signed by: DCG: T. Fuell; Re. 1: T. Whitlatch; Re. 2: T. Whitlatch

Background

This analysis has been performed to show the support structure for the DIRC detector is adequate for intended use. There is an assumed 3300# crane "bump" loading applied (see figure 3) . This assumes one completely assembled DIRC Bar Box with frame bumps is on the crane and bumps the structure with a 2g force, or an empty Optical Box bumps the structure with 5g force. The other loads are based on fully operating DIRC detector including 600+ liters of water. The structure is definitely overdesigned. This is done on purpose in anticipation of additioal detector loads in the future. The analysis will be modified at the time when this is known.

AISC (American institute of Steel construction release 8) is used for the majority of the analysis as well as Machine Design Theory and Practice (Deutschman).

Appendix A lays out the allowables used based on AISC
Appendix B shows a sample calculation for thread pullout.

Figure 1 shows overall dimensions of the support structure
Figure 2 shows a printout from an online truss analyzer merely showing agreement with the hand calculations
Figure 3 shows the loads applied for the analysis
Figure 4 shows the labelling of the members of the structure

The associated assembly drawing is D00000-05-01-1040

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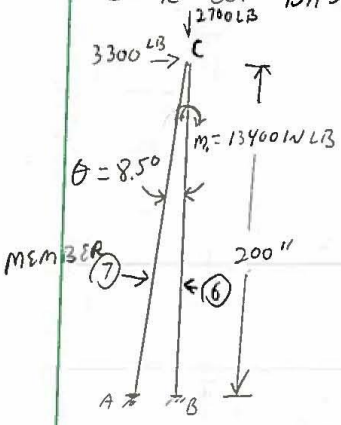
force

DIRC SUPPORT FRAME

MEMBERS 6 & 7

Look at BASE OF UPPER PORTION WITH 3300LB CRANE BUMP.



$\Sigma F_{Cx} = 0 = 3300 + F_{AC} \sin\theta + \frac{M_1}{200}$

$F_{AC} = \frac{-\left(\frac{M_1}{200} + 3300\right)}{\sin\theta} = 22,447$ LBS. TENSION OR COMPRESSION

$\sigma_{AC} = \frac{22447 \text{ LBS}}{11.1 \text{ in}^2} = 2022$ psi < 27.4 KSI → OK

$\Sigma F_{Cy} = 0 = -2700 + F_{AB}\cos\theta + F_{BC}$

$F_{BC} = +2700 - 22,200 = -19,500$ LB compression

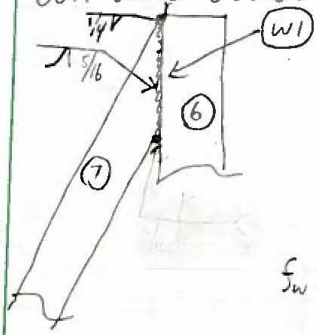
$\sigma_{BC} = 1757$ psi < 27.4 KSI → OK

8x8 TUBE 3/8 WALL
$I = 106 \text{ in}^4$
$A = 11.1 \text{ in}^2$

σ_{ALLOW} = SEE APPENDIX A

WELD @ C - Shear From VERTICAL FORCES

BUTT WELD ONSIDES $\sigma_{ALLOW\text{-}WELD} = 14,500$ psi (.40 S_y)



$F_{VS} = 22,200$ LB ASSUME 8" WELD - 2 sides

HORIZONTAL

$F_{HS} = 3367$ LBS

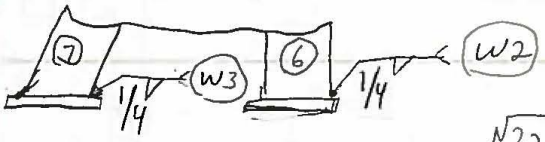
WL = 16" (actual is 46" per side)

$\sqrt{22,200^2 + 3367^2} = 22454$ LBS

$f_w = \frac{22454}{16} = 1403.4$ LB/IN

$W_S = \frac{1403.4}{14,500} = .097"$

USE MIN. WELD of 1/4 Fillet top & 5/16 Flare on sides



W3 $F_S = 3300$ lbs

$F_T = 22,447$

$\sqrt{22,447^2 + 3300^2} = 22688$ LBS

32" OF WELD

$F_w = \frac{22688}{32} = 709$ LB/IN

$W_S = \frac{709}{14,500} = .05$ in

FOR W2 & W3 USE 1/4" FILLET

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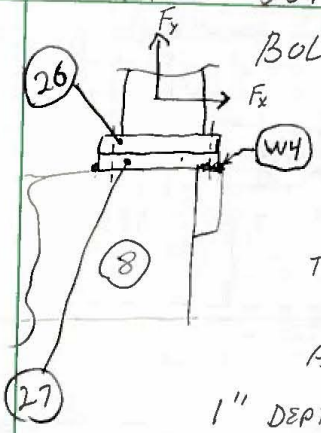
DIRC SUPPORT FRAME MEMBER 6 & 7



BOLT LOADS

4 BOLTS / CONNECTION
THREAD PULL OUT

F_y = 22,200 LBS MAX

TENSION FORCE/BOLT = $P_T = \frac{22,200}{4}$ = 5550 LBS

ALLOWABLE IN PLATE 27 (3/4" holes) F_v = 15,895/in

1" DEPTH OF THREAD (.88 effective Length)

F_v = 15895(.88) = 13988 LBS > 5550 → OK

BOLT LOAD :- 3/4-10 A325 BOLT - TENSION ALLOWABLE = 19,400 L

∴ OK

Shear in Bolt = 3300/4 = 825 LBS

$\sigma_v = \frac{825}{.75^2 \frac{\pi}{4}}$ = 1867 PSI - SMALL

A325 - σ_y = 92 KSI

$\sigma_{T\,ALLOW}$ = 21000 PSI - OK (AISC)

Plate $\sigma_{P_{Brg\,ALLOW}} = 0.3(36) = 14,400$ PSI BEARING TYPE CONNECTION

COMBINED

$f_t = \frac{F_t}{F_v}\sqrt{F_v^2 - f_v^2}$

F_t = Tensile Allowable stress = 44 KSI

with Section 1.6.3 AISC

f_t = 43.8 KSI (Reduction in allowable)

MINIMAL affect ⇒ OK

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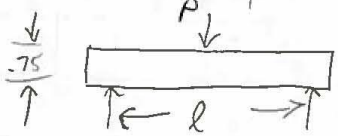
DIRC SUPPORT FRAME PLATE 26

STRESS & DEFLECTION



CONSERVATIVELY ASSUME POINT LOAD IN CENTER & SIMPLY SUPPORTED

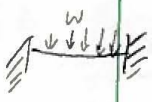
FROM ROARK'S - $M_{max} = \frac{P\ell}{4}$ $\ell = 11''$ $t = 0.75''$

$P = 22{,}200$ LB

$M_{max} = 61{,}050$ in-lbs $\sigma = \frac{Mc}{I}$ $I = \frac{1}{12}10(.75)^3 = .352$

$\sigma = 65039$ PSI - OVER YIELD $c = .5$

$\sigma_{ALL} = 0.6\,\sigma_y = 21{,}600$ PSI $E = 29$ KSI GOOD



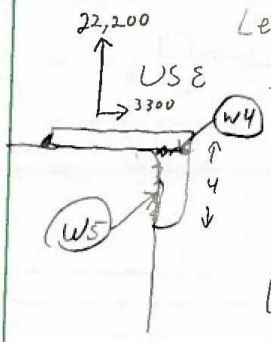
ASSUME BOLTS ARE TORQUED TO create Fixed edges & LOAD IS UNIFORMLY SPREAD

ROARKS $M_{max} = \frac{W\ell^2}{24} = \frac{\frac{22{,}200}{11}(11^2)}{24} = 10{,}175$ in-lbs

$\sigma = \frac{10{,}175(.375)}{.352} = 10{,}839$ PSI $< 21{,}600$ ok

$\delta = \frac{W\ell^4}{384EI} = .0075'' \Rightarrow$ OK.

WELD W4 SIZING



Length of Weld $= 7 + 4(1) = 15''$

USE 5/16 fillet weld

$P = \sqrt{22{,}200^2 + 3300^2} = 22{,}444$ LBS

$f_v = \frac{22444}{15} = 1496$ LBS/IN

$W_s = \frac{1496}{14500} = 0.103''$ 3/16 Fillet OK

Use 5/16" for 1" Plate

W5 $\ell = 4(4) = 16''$

$f_v = \frac{22{,}200}{16} = 1388$ LB/IN

$W_s = \frac{1388}{14{,}500} = .096''$ Use 3/16 Fillet

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DIRC SUPPORT FRAME PLATE 26

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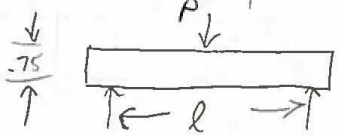

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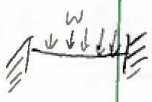

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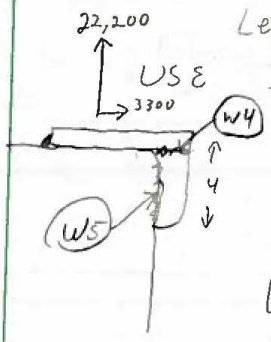
WELD W4 SIZING



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MEMBER 6 has Combined Bending, TENSION & Compressio

AISC Section 1.6

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \leq 1$$

$$\frac{3300/10.4}{20,270} + \frac{21,735}{25,700} = 0.86 \Rightarrow OK$$

COMPRESSION IN MEMBER 14 (BUCKLING)

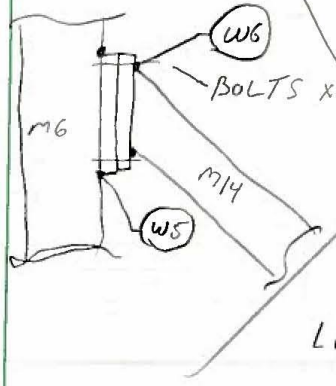
FOR 6x6 x 1/4" TUBE, $I = 28.6$ in^4 $n = 1$ (conservative)

$$P_{crit} = \frac{n\pi^2 EI}{L^2} = 3.2 \times 10^6 \text{ LBS} - \underline{OK} \qquad L = 50 \text{ in}$$

$F_{oc} = 16593$ LBS $< P_{cr} \Rightarrow OK$

WELDS 5 & 6

N/A



$L_{W6} = 6 \times 4 = 24"$

$f_v = \frac{16593}{24} = 691$ LBS/IN

SEE NEXT Page

$W_5 = \frac{691}{14,500} = .05"$

USE 3/16" FILLET

$L_{W5} > L_{W6} \Rightarrow OK$

USE 3/16" Fillet

Deflection of MEMBER 6

IGNORE MEMBER 5 & 14 @ TOP

3300 LBS →

$$\delta = \frac{Pl^3}{3EI} = \frac{3300(164)^3}{3(29\times10^6)\,99.6} = 1.68" \text{ (ROARKS)}$$

THIS IS A LARGE DEFLECTION!

PARTS MAY Get Damaged From a 3300 LB BUMP.

SEE NEXT PAGE

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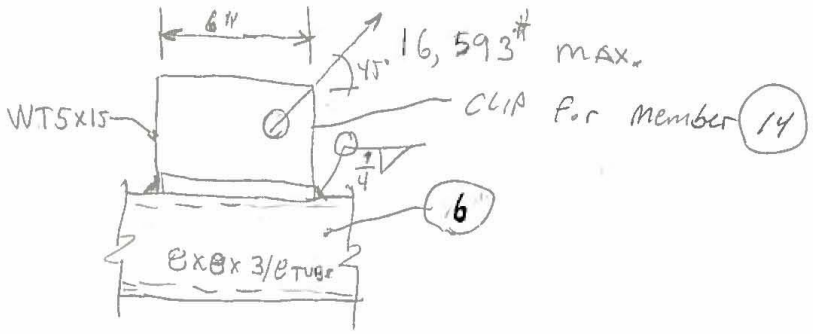
DIAGONAL BRACE TEE WELD

(5)



$l_w = 5.75(2) + 6(2) = 23.5"$

$P = 16,593\ \#$

$f_v = \frac{16,593}{23.5} = 706\ \#/"$

$W_s = \frac{706}{12,726} = .055$, Use 1/4" WELD

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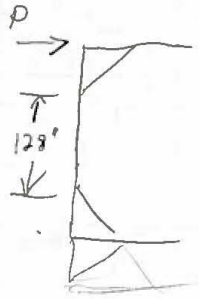
DIRC SUPPORT MEMBER 6 DEFLECTION

ADD IN STIFNESS FROM CONNETION TO FAR SIDE & MEMBER 7 BOTH SIDES



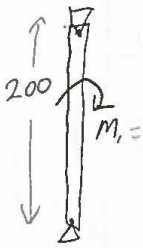
$I = 4(99.6)$

$\delta = \frac{3300(128)^3}{3E(4)I} = 0.2" \Rightarrow$ OK

Plus a little more.

DIRC BAR FRAME ADDS ADDITIONAL STIFFNESS

MEMBER 22 - RAIL SUPPORT - 6061-T6 6x6x1/2 WALL TUBE



ASSUME PINNED JOINT ⇒ CONSERVATIVE

ROARKES $\delta_{max} = .0642\frac{ML^2}{EI} = .07"$ OK

$I = 48.2 IN^4$

$E = 10 \times 10^6$ (ALUMINUM)

$\sigma = \frac{MC}{I} = \frac{13,400(3)}{48.2} = 834$ PSI.

$\sigma_y = 40$ KSI $\quad FOS = \frac{40000}{834} > 40$ OK

Conservatively assumes Thompson Rail adds no STIFFNESS,

BOLTS ON MEMBER 14/6 N/A

SHEAR LOAD ON BOLTS = 4 3/4 #10 A325 BOLTS

$P_V = 16,593 \sin 45 = 11,731$ LBS

PER BOLT $\frac{11,731}{4} = 2933$ LBS/BOLT SHear.

$F_V = 17,500$ PSI $\quad A_{Bolt} = \pi \cdot .75^2 = 0.441^2$

$P_V = 17500(.44) = 7700$ LBS ⇒ OK

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DIRC SUPPORT | BOLTS Connecting Member 4/6 | 7

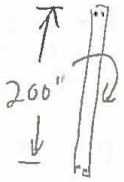
BEARING ON PLATE $t = 3/4''$ BOLT HOLES

$F_p = 32.4$ KSI $\quad A = .75(.75) = .5625$

$F_p = \frac{2933}{.5625} = 5214$ PSI < 32.4 KSI OK

MEMBER 22 BOLT LOAD

$P_{Bolts} = \frac{13,400}{200} = 67.0$ LBS

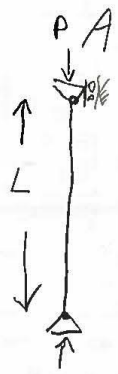


M = 13,400 IN LBS

3/8-16 screws used. X4

17 LBS EA.

$\sigma_t = \frac{17 \text{ LBS}}{.078 \text{ in}^2} = 218$ PSI < 44 KSI OK



ACME THREADED ROD

CONSERVATIVELY ASSUME PINNED JOINTS

LOOK @ CRITICAL BUCKLING LOAD (EULER LOAD)

$P_{CR} = \frac{n \pi^2 EI}{L^2}$ Machine Design - Deutchman eq 5-50

$E = 29 \times 10^6$ PSI

$I = .049 D^4 \quad D = 1.066''$

$L = 78''$

$n = 1$ (Pinned slider)

$P_{CR} = 2983$ LBS.

$P = 2700$ LB MAX $< 2983 \Rightarrow$ OK

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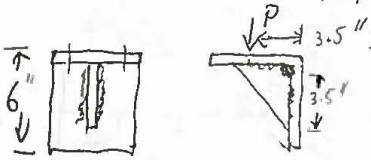
DIRC SUPPORT ACME ROD SUPPORT 8

MEMBERS 34 & 43

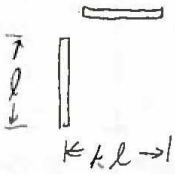


P = 2.7 Kips MAX

t = 0.5" for all

- USE XIX FOR THIS CALC!

AISC TABLE XXV - ECCENTRIC Loads on Weld Groups



$l = 3.5$ in, $A = 3.5$"

$kl = 4$

$k = \frac{4}{3.5} = 1.14$ (use 1.0 conservative)

FROM TABLE XXV, $x = 0.250$, $y = 0.250$

$xl = .25(3.5) = .875$ in

$al = A - xl = 2.625$, $a = 0.75$

interpolate $\Rightarrow k = 1$, $a = .75 \Rightarrow C = .735$

$D = \frac{P}{CC_1 l} = .98 \Rightarrow 1/16$" minimum

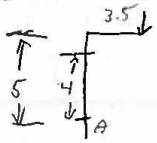
$C_1 = 1$

This conservatively assumes weld one side only

Use $W_s = 3/16$" > .25" Fillet all around. SEE ADDITIONAL CALC TABLE XI.

BOLT LOADING

P_t = Tension in each bolt.



$\Sigma M_A = 3.5(2700) + 4P_t$

$P_t = 2362$ LBS

EACH BOLT CARRIES HALF = 1181 LBS

$F_{tall} = 44$ KSI $= \frac{P_t}{A}$ $A = .027$ in^2

$A = \frac{\pi D^2}{4}$ $D = \sqrt{\frac{4A}{\pi}} = .185$"

USE 1/4 BOLTS AND OR LARGER.

Shear $\frac{2700}{A} > 17500$ PSI $A = .155$" Minimum

1/4" or larger ok

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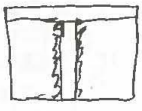
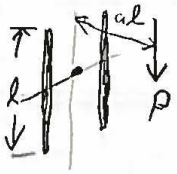
DIRC SUPPORT ACME ROD SUPPORT 8

MEMBERS 34 & 43



1/2" plate WELD STRESS

USE AISC TABLE X1X



USING A 5/16 WELD D = 5

$l = 3.5$

$al = 3.5$ $C_1 = 1$

$a = 1$ $k = 0$

$C = .419$

$P = C C_1 Dl = 7.3$ kips

$P_{actual} = 2.7$ kips $\Rightarrow$ OK.

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DIRC SUPPORT MEMBER 344/3 Bolt Thread PULL OUT

BOLTED INTO 3/8 WALL A500 TUBE

5/8 BOLT

Shear Circumference = $.57\pi = 1.79''$

Shear Length = $.66L = .248$

$F_v = 0.3F_y = .3(39\ KSI) = 11{,}700\ PSI$

PULL OUT STRENGTH/IN = $11{,}700(.66)1.79 = 13{,}822$ LBS/IN

$P_{ALL} = 13{,}822(.248) = 3428$ LBS/BOLT > 1181 LBS => OK

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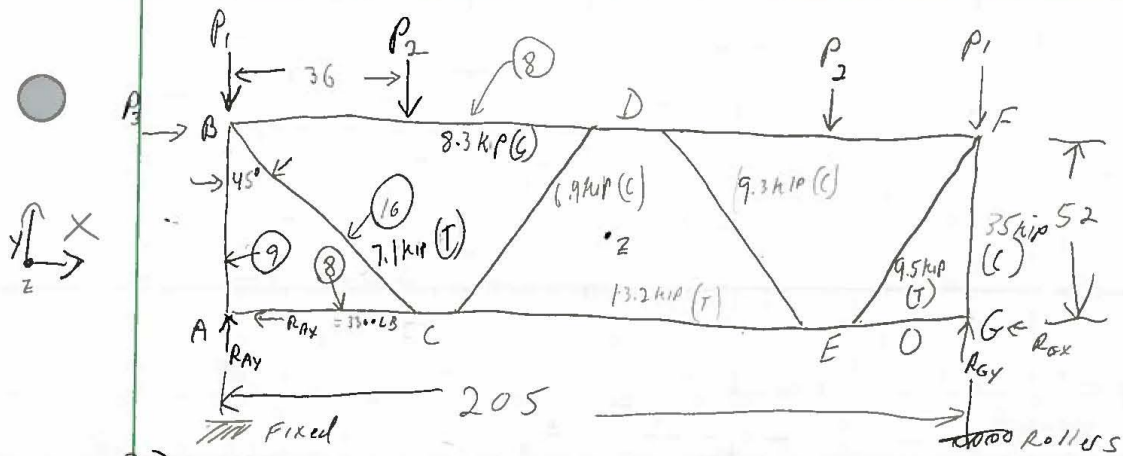
DEBC SUPPORT BASE TRUSS



2D ANALYSIS ASSUMES SIMULTANEOUS LOADS FROM 3300 LB BUMP @ BOTH ENDS (Very Conservative) IN Z PLUS a Lateral 3300 LB Bump.

$P_1 = 22{,}447$ LBS, $P_2 = 16593(\sin\theta) = 11{,}733$ LBS. (From LATERAL Bump)

$P_3 = 3300$ LBS. (From Lateral Bump)

$$\Sigma M_A = 0 = P_3(52) + P_2(36) + P_2(169) + P_1(205) - R_{GY}(205)$$

$$R_{GY} = 35{,}017 \text{ LBS}$$

$$\therefore R_{AY} = 33{,}343 = F_{AB} \text{ (compression)}$$

NODE B

$$\Sigma F_{BX} = 0 = 3300 + F_{BD} + F_{BC}\sin 45$$

$$\Sigma F_{BY} = 0 = P_1 + P_2/2 + F_{AB} + F_{BC}\cos 45$$

$$F_{BC} = -\frac{(P_1 + P_2/2 - F_{AB})}{\cos 45} = 7113 \text{ LBS (Tension)}$$

Substitute F_{BC}

$$F_{BD} = -(3300 + F_{BC}\sin 45) = 8329 \text{ LBS (Compression)}$$

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MAXIMUM LOAD IN 8x8 x 3/8" MEMBER

P_{max} = 35000 LBS

AS SHOWN EARLIER - MAX ALLOWABLE LOAD = 243,380 LBS

OK.

FOR 6x6 x 1/4" TUBE MEMBER

P_{max} = 9300 LBS

MAX ALLOWABLE = 122,616 LBS

OK

BUCKLING

$P_{cr} = \frac{n \pi^2 EI}{L^2}$ $n=1$ (NO FOS.

FOR 8x8x3/8" x 103" LONG

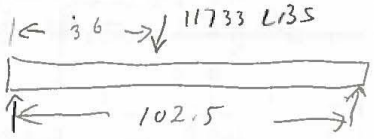
P_{cr} = 272,000 LBS ← AISC ALLOWABLE

FOR 6x6x1/4" x 72" LONG (longest membr)

P_{cr} = 140,000 LBS AISC ALLOWABLE

OK

8x8x3/8"



MEMBER 8 Bending due to Force from Member 14

CONSERVATIVE PIN JOINTS

FROM ROARKS - $M = R_A a$ = 274,037 in-LBS

$R_A = \frac{P(l-a)}{l}$ = 76112 LBS

$\sigma = \frac{Mc}{I}$ = 10,380 PSI < 25,700 PSI OK

$\delta = \frac{-Pa}{3EIl}\left(l^2 - \frac{a^2}{3}\right)^{3/2} \pm 4.76 \times 10^{-7}(170,108)$ = .08" OK

OK

See section 11a

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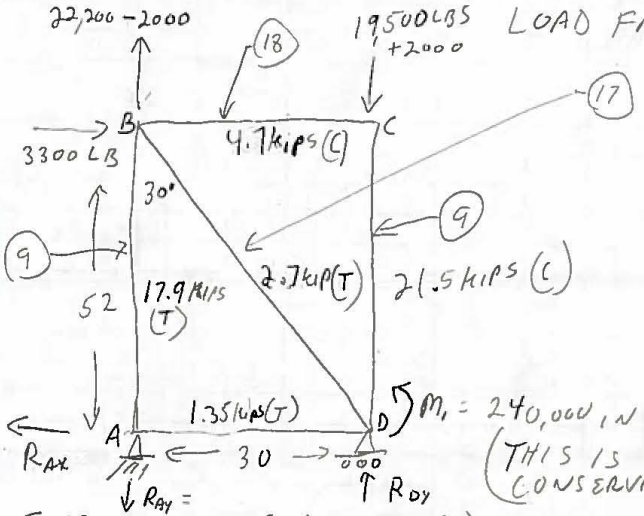
DIRC SUPPORT TRUSS TIE IN (US → DS)



LOAD FROM PREVIOUS CASE PLUS WEIGHT

TOTAL WEIGHT = 8000LBS

2000 LBS per point

$\Sigma M_A = 0 = 3300(52) + 21500(30) - 240,000 + R_{DY}(30)$

$R_{DY} = 19,230$ LBS

$\therefore R_{AY} = 19,230 - 21500 + 20,200 = -17,930$ LBS

UNSTABLE - Point A NEEDS TO BE ATTACHED TO FLOOR.

$\Sigma F_{DX} = 0 = F_{AD} + F_{DB} \sin 30 = 0$

$\therefore F_{AD} = 1.35$ KIPS

$\Sigma F_{BY} = 0 = 20,200 - 17,900 + F_{BD} \cos 30$

$F_{BD} = 2656$ PSI (TENSION)

$\Sigma F_{BX} = 0 = 3300 + F_{BD} \sin\theta + F_{BC}$

$F_{BC} = 4650$ LBS (compression)

$\Sigma F_{CY} = 0 = -21,500 + F_{CD}$

$F_{CD} = 21,500$ (compression)

FROM PREVIOUS MEMBER ANALYSIS, NO MEMBERS ARE OVER stressed OR Subject TO Buckling

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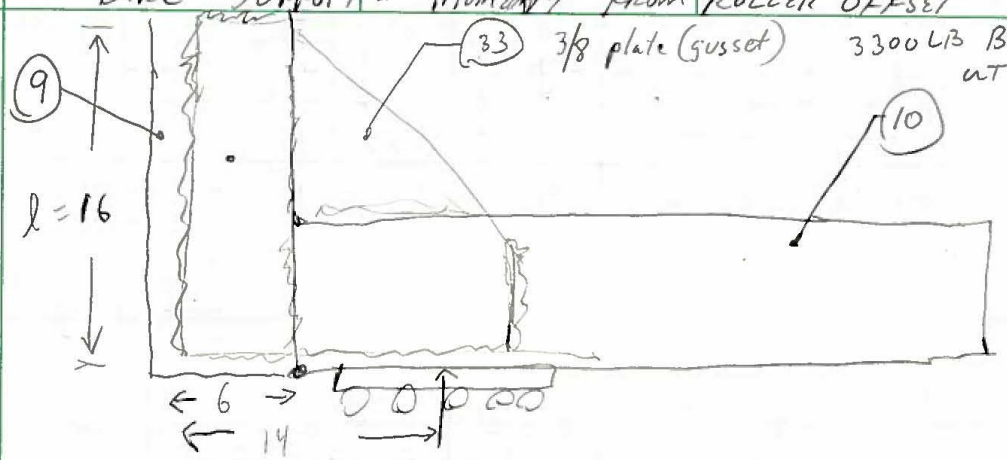
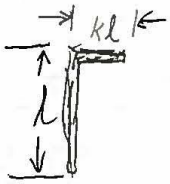
DIRC SUPPORT - MOMENT FROM ROLLER OFFSET



$C_1 = 1$
$l = 16$
$kl = 6$
$k = .375$

How much weld is REQUIRE TO handle 24 kips LOAD ON ROLLER

USE AISC TABLE XXV



USE ONE SIDE WELD (12 kips)

$D = \frac{P}{CC_1 l}$

INTERPOLATE
$x = .051$
$y = .364$
$\Rightarrow a =$

$xl = .051(16) = .816$, $al = (14 - .816) = 13.18$

$\therefore a = .824$

$\therefore C = 0.4$

$D = \frac{12}{1(.4)16} = 1.9 \Rightarrow 1/8"$ use $3/16"$ min.

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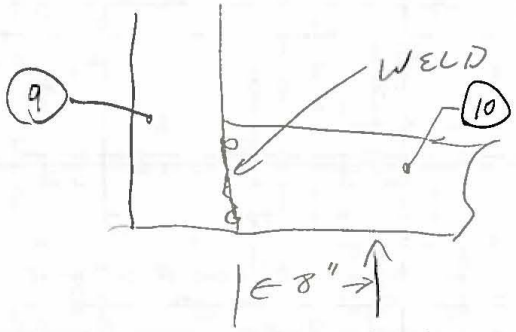
DISC SUPPORT - moment from Rollers offset 14

3300 LB BUMP @ TOP

NO - GUSSET



24 kips = P

M = 192,000 IN LBS.

$I = 99.6\ in^4$ $C = 4$

$\sigma = \frac{Mc}{I}$ = 7710 psi - OK on TUBE

I weld Required

From Machine Design - Deutschman
SECTION 17-3

Shear stress from ECCentric LOAD
Based on ASSUMED 1" Throat $A = 8 \times 4 = 32\ in^2$

$$\tau' = \left[\left(\frac{P}{L}\right)^2 + \left(\frac{Mc}{I_x}\right)^2\right]^{1/2}$$

~~$I = \frac{1}{12}(8 \times 8^3 = 7.25(7.25)$~~

$I_{Tube} = 99.6\ in^4$

$I' = \left(562500 + 5.946 \times 10^7\right)^{1/2}$ = 7747 psi

Weld leg $h = \frac{7747}{.707(14,400} = .76"$ - TOO MUCH

NEEDS MEMBER 33 GUSSET ! (previous page)

THIS IS VERY CONSERVATIVE

see section 14a

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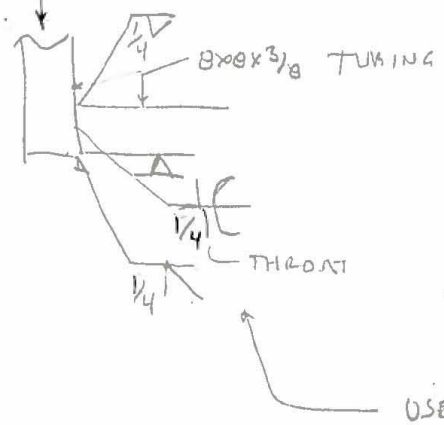
14a

3300# HIT ⇒ $\frac{3300(257)}{205} = 4057 \approx 4000$

P = 14000# (weight of current loaded system + future 10,000 detector)



$l_w = 4(8) = 32"$, P = 14,000#

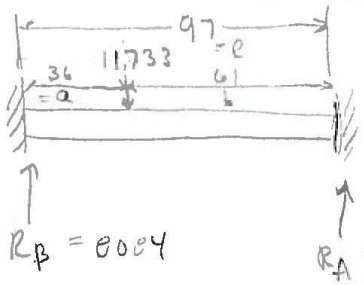
$f_v = \frac{14000}{32} = 313$ #/"

$w = \frac{438}{12,726} = .035"$

USE welds as shown

P = 4000 + 5000 + 5000 = 14,000#
crane hit DIRECT future detector

11a member 8



$R_A = \frac{Pa^2}{\ell^3}(a+3b)$

$= \frac{11733(36^2)}{97^3}(36+3(61))$

$= 1616\ (219) = 3649$

$R_B = \frac{Pb^2}{\ell^3}(3a+b)$

$= \frac{11733(61)^2}{97^3}(108+61)$

$= 8084$

$M = \frac{Pab^2}{\ell^2} = \frac{11733(36)(61)^2}{97^2}$

$= 167,043$ "#

$f_b = \frac{M}{S} = \frac{167043}{26.4} = 6,846$ OK

Your analysis was conservative and adequate @ 10,380 psi

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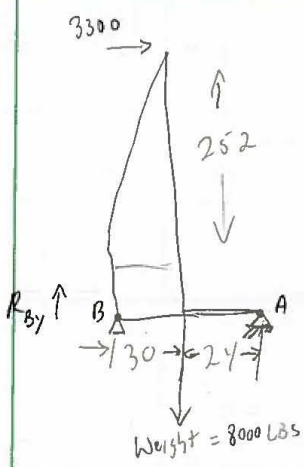
DIRC SUPPORT - OVER TURNING MOMENT DURING CRANE BUMP



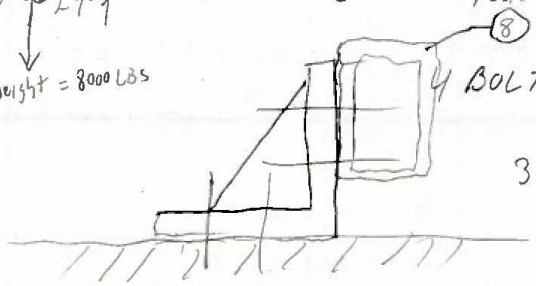
$\Sigma M_A = 0 = 3300(252) - 8000(24) + R_{By}(54)$

$R_{By} = 11,844$ LBS

NEED TO ATTACH TO GROUND TO PREVENT OVERTURN IN A BUMP EVENT

ADD 2 SUPPORTS TO GROUND

ASSUME EACH ONE Take FULL Load (CORNER BUMP)



4 BOLTS EACH SUPPORT

3000 #/BOLT

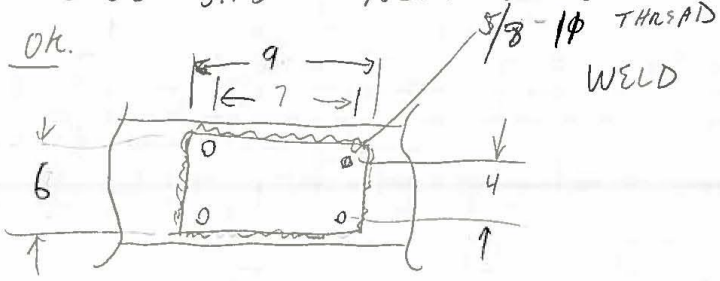
LOOK AT HILTI TO ATTACH TO GROUND

USE 3/4" DROP IN ANCHORS (HDI)

4000 PSI Concrete

4065 LB PULL OUT ALLOWABLE
5000 LB SHEAR ALLOWABLE

OK.



$F_V = 12\,000$ LB $w\ell = 9(2) + 6(2) = 30$ IN

$F_W = \frac{12000}{30} = 400$ LB/IN

$W_S = \frac{400}{14,400} = .03$ ⇒ USE 3/16" minimum.

1" plate use 5/16" weld

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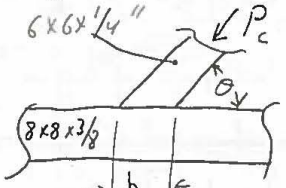
DIRC SUPPORT - "CRUSHING" OF 8 x 8 x 3/8" TUBE FROM 6 x 6 x 1/4" TUBE

CHORD FACE LOADING CAPACITY
(USE WAYNE S. CALC FROM FCAL PLATFORM)



P_c = Axial load of connecting member
P_y = LOAD CAPACITY base member
F_{y_0} = yield stress = 39 KSI
t_0 = wall thickness of chord (.375")
b_0 = outside width of chord (8")

$$P_y \sin\theta = \frac{F_{y_0} t_0^2}{1-\beta'}\left[\frac{2h_1'}{b_0'} + 4\sqrt{1-\beta'}\sqrt{1-n^2}\right]$$

b_0' = effective width of chord
$= b_0 - 2w = 8 - .5 = 7.5$
w = weld leg size = .25"

h_1' = effective connection length
$= (h_1/\sin\theta) + 2w = \frac{b_1}{\cos(90-\theta)\sin\theta} + 2w$

b_1 = outside width of conn. member
$= 6"$

b_1' = effective width of conn. member
$= b_1 + 2w = 6 + .5 = 6.5$

$\beta' = b_1'/b_0' = \frac{6+.5}{8-.5} = .867$

n = Chord member preload ratio
$= F_0/F_{y_0}$

F_0 = Chord axial stress
$= 0$ for worst case

$h_1 = \frac{b_1}{\cos\theta}$

$$P_y \sin\theta = \frac{39000(.375)^2}{1-.867}\left[\frac{2}{7.5}\left(\frac{6}{\cos(90-\theta)\sin\theta} + .5\right) + \left(4\sqrt{1-.867}\right)\sqrt{1-0}\right]$$

$$P_y \sin\theta = 41236\left[.267\left(\frac{6}{\cos(90-\theta)\sin\theta} + .5\right) + 1.459\right]$$

@ $\theta = 45^\circ$

$P_y (.7071) = 137,625$

$P_y = 194,633$ LBS.

MAXIMUM BRANCH LOAD

$P_c = 9500$ LB $< 194,633$ LB $\Rightarrow$ OK

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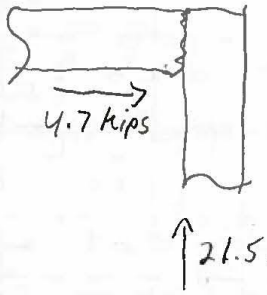
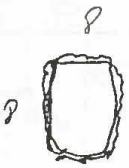
DISC SUPPORT - MAX WELD STRESS ON 8X8 x 3/8" BOX TUBE

MEMBER 9 TO 18





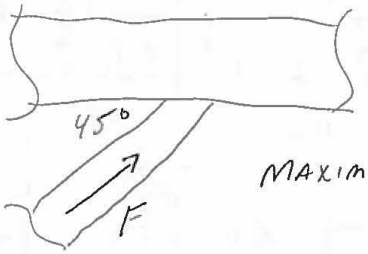
$W_L = 4(8) = 32''$

$F_v = \sqrt{21.5^2 + 4.7^2} = 22 \text{ kips}$

$f_w = \frac{22000}{32} = 688 \text{ LB/IN}$

$W_s = \frac{688}{14.500} = .05''$ $\Rightarrow$ use 5/16" Bevel/Fillet

6x6 x 1/4" Box Tube



MAXIMUM F = 9.5 kips

$W_L = 4(6) = 24$

$f_w = \frac{9500}{24} = 396 \text{ LB/IN}$

$W_s = .03''$ $\Rightarrow$ use 3/16" Bevel/Fillet

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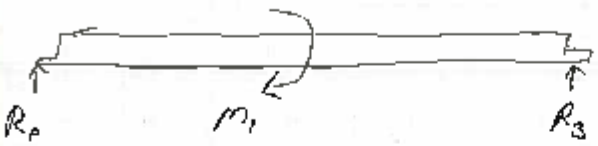
DIAC RAIL SUPPORT

MEMBER 22

TOTAL MOMENT = 6700 x 2 = 13400 in-LBS

ASSUME SIMPLY SUPPORTED



$\Sigma M_A = 0 = M_1 - R_B \ell$

ℓ = 200 inches

$\therefore R_B = \frac{13400}{200} = 67$ LBS

$R_A = -R_B = -67$ LB

ASSUME SIMPLY SUPPORTED.

TUBE - 6x6 structural Aluminum Tube 3/8 wall

$M_{max} = M_1$

$I = \frac{1}{12} bh^3 = 39.4\ in^4$

$C = 3$ in

$E = 10 \times 10^6$ PSI

$\sigma = \frac{M_1}{I} = 1043$ PSI

$\delta = \frac{.0642 M \ell^2}{EI} = .087''$

ASSUME 6061 T6 since there is welding

$\sigma_{Allowable} = \frac{\sigma_y}{FOS}$

CONSERVATIVE since actual moment in 2 places not at mid span.

ALSO, IGUS RAIL STIFFENS BEAM

$FOS = \frac{8000\ PSI}{1043\ PSI}$

FOS $\geq 8 \Rightarrow$ OK

LOOK @ WELD

We have 13" weld.

$F_{vs} = 0.4(8000) = 3200$ PSI

$F_w = \frac{67}{13} = 5.2$ LB/in

$w_s = \frac{5.2}{3200} = .002$ in

1/4" weld is fine.

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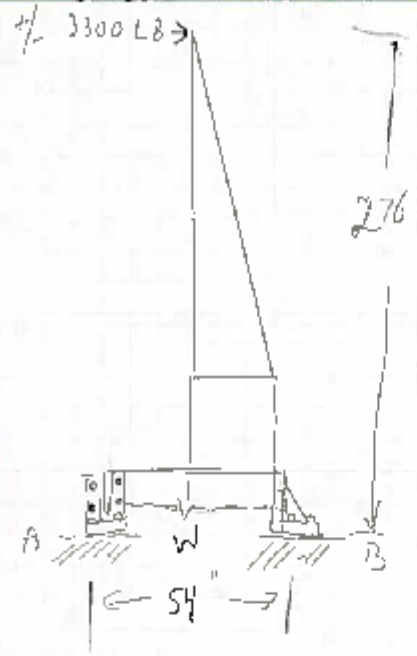
DIRC STRUCTURE FLOOR TIE DOWNS (1)

5/11/2017 T. Whitlatch



$W = 11{,}500$ LBS

$\sum M_A = 0 = 3300(276) + 11500(28) - R_B(54)$

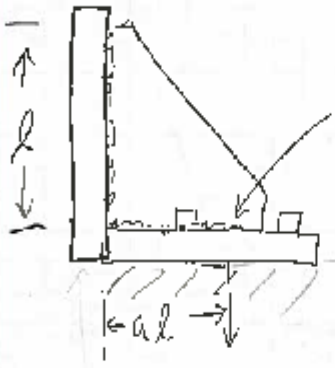
$\therefore R_{By} = \dfrac{910800 + 322{,}000}{54}$

$R_{By} = 23$ KIPS

$\sum F_y = 0 = R_{By} - W + R_{Ay}$

$R_{Ay} = -11.5$ KIPS

D00000-05-01-2104 FLOOR ANCHOR SUPPORT



ASSUME ONLY 1 WELD Lastres Load

Required weld AREA

$\dfrac{11{,}500 \text{ LBS}}{14{,}4000 \text{ LBS/in}^2 \text{ Allowable}} = 0.8 \text{ in}^2$

3/8" weld => 11.4" of weld needed

11.5 KIPS (VERY CONSERVATIVE SINCE SHARED OVER 2 PIECES)

(1963 Version)

USING AISC TABLE XV SPECIAL CASE

1" plate

3/8" weld. 6/16 : D = 6

$l = 11$ $al = 5$ $\therefore a = 0.45$ in

$C_1 = 1$ (FOR E 70XX electrode)

$C = 0.421$

$D = CDl = 27.8$ kips >> ACTUAL

USE K=0 since weld

OK

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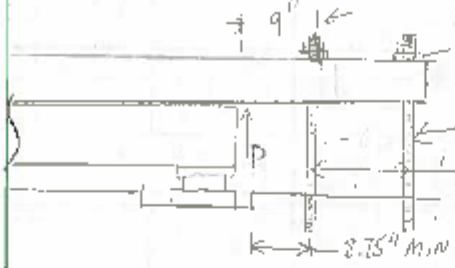
NEW DIRC TIE DOWN CONCEPT 5/15/2017

D/S END

USE 2 - 3/4" DROP IN HILTI HDI

P = 11,500/2 = 5750 LBS



BENDING IN 6 x 6 x 1/4 WALL TUBE (STEEL)

$I = 28.6 in^4$

$\sigma = \frac{Mc}{I} = \frac{5750(9)(3)}{28.6} = 5428 PSI < 35700 PSI$

BUCKLING

Assume 1/10 OF LENGTH

BUCKLING $P_{CR} = \frac{\pi^2 EI}{L^2}$

$E = 29 \times 10^6 PSI$

$L = 5.5$

$I = \frac{1}{12}(.25)^3(4) = .0052083 in^4$

$P_{CR} = 49280 LBS$

$FOS = \frac{49280}{5428/2} = 18$ OK

THREADED ROD

3/4" $A = 0.344 in^2$

USE GRADE 5 -- 92 KSI YIELD STRENGTH

92 KSI $(.344 in^2) = 31650$ LBS

USE FOS = 2

∴ ALLOWABLE LOAD = 15,000 LB

EACH BOLT HAS 5750/2 LBS = 2875 LB

∴ NEED 6 1/2 SPACING FOR 3/4" HILTI & 9" EDGE DISTANCE

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NEW DIRC TIE DOWN CONCEPT (2)

3/4" HILTI HAS 4065# P_{ult} DROP IN - HDI DROP IN ANCHOR

FOR DS 6x6" BOX BEAM TIE DOWN

P_{Anc} = 2375 LB

TABLE 7 ON HILTI DOCUMENTATION SHOWS Factors for minimal Spacing

IN ORDER TO Get 2375 LB ALLOWABLE.

FOR a 3/4" HILTI, a Factor OF

$\frac{2375}{4065} = .707$ Needed

FROM HILTI TABLE

EDGE DISTANCE NEAR TRACK Needs to be 8.5" & Distance between anchors needs to be 6.5"

FOR US END

USE 4 - 5/8 HDI DROP IN ANCHORS 2920 LBS pullout

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DIRC SUPPORT FRAME APPENDIX A

AISC ALLOWABLES

TENSION - $F_t = 0.6\ F_y$ (yield)

SHEAR - $F_v = 0.40\ F_y$

COMPRESSION - $F_a = 0.6\ F_y$ (NON-slender)

BENDING - $F_b = 0.66\ F_y$

BEARING - $F_p = 0.90\ F_y$

MATERIALS

		PLATE A36 (F_y = 36 KSI)	TUBING A500 (F_y = 39 KSI)
BOLTS - A325 →			
TENSION	F_t = 44 KSI	21.6 KSI	23.4 KSI
SHEAR	F_v = 17.5 KSI (STD Holes THREADS)	14.4 KSI	15.6 KSI
COMPRESSION	F_a ~	21.6 KSI	23.4 KSI
BENDING	F_b ~	23.7 KSI	25.7 KSI
BEARING	F_p ~	32.4 KSI	35.1 KSI

FOR TUBING A500 8 x 8 x 3/8" THICK WALL

$P_A = P_t = 23.4\ (10.4) = 243{,}360$ LBS (ALLOWABLE LOAD)

$P_v = 15.6\ (10.4) = 162{,}240$ LBS (ALLOWABLE SHEAR FORCE)

FOR TUBING A500 6 x 6 x 1/4" WALL

$P_A = P_t = 23.4\ (5.24) = 122{,}616$ LBS

$P_v = 15.6\ (5.24) = 81{,}744$ LBS

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APPENDIX B

FROM AISC EDITION 8
BOLTED CONNECTIONS- HEAVILY LOADED

PULL OUT STRENGTH, A-36 STEEL FEMALE THREADS

1-8 UNC

SHEAR CIRCUMFERENCE = .95π = 2.98"
SHEAR LENGTH = .66 L
$F_v = .3 F_y = .3(36{,}000) = 10{,}800$ psi

PULL OUT STRENGTH/IN. (P_c)
$= 2.98(.66)10800 = 21{,}241$ #/"

3/4-10 UNC

SHEAR CIRCUMFERENCE = .71π = 2.23"
SHEAR LENGTH .66 L
$F_v = .3 F_y = 10{,}800$ psi

PULL OUT STRENGTH/IN. (P_c)
$= 2.23(.66)(10{,}800) = 15{,}895$ #/"

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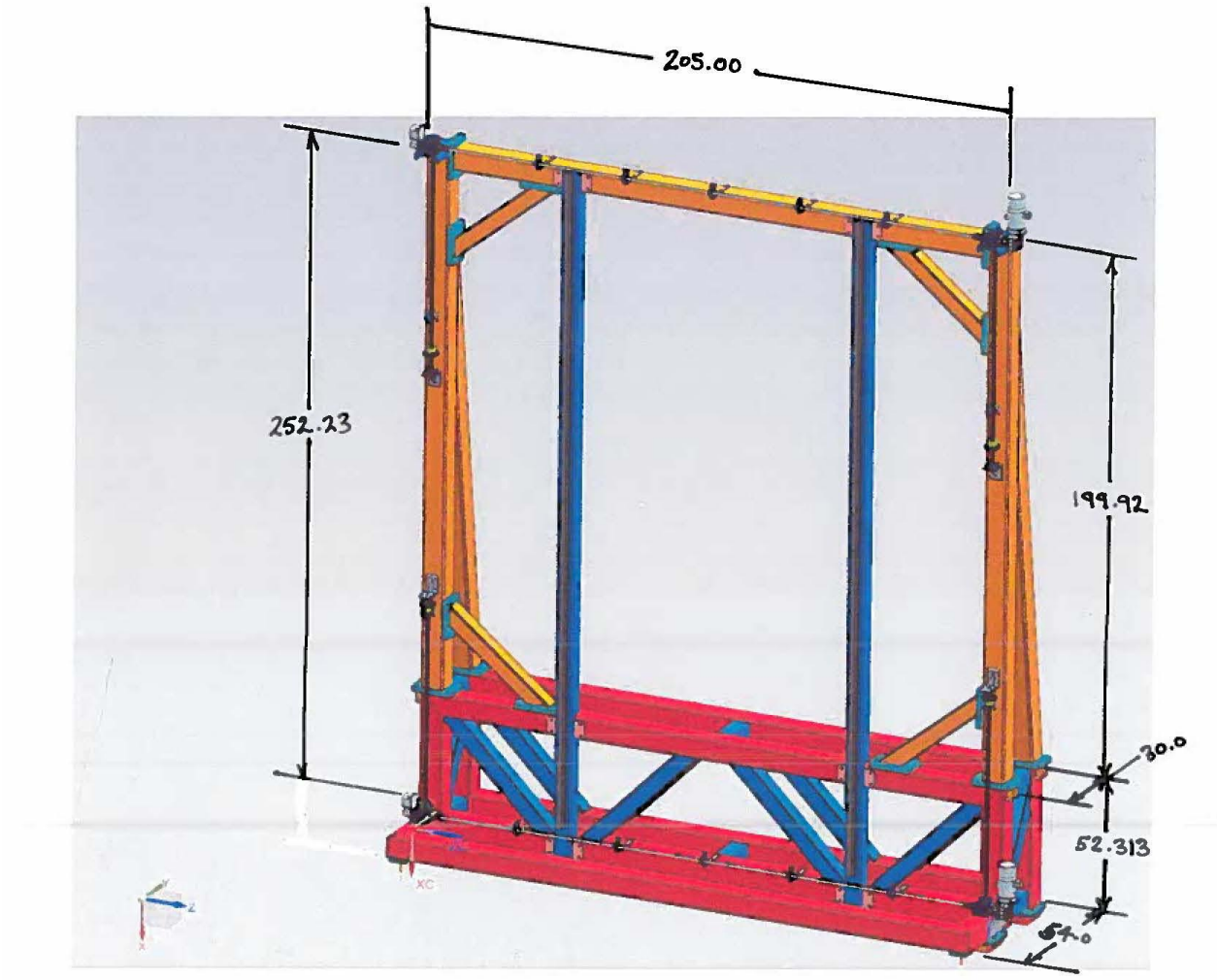

Figure 1 Overall dimensions

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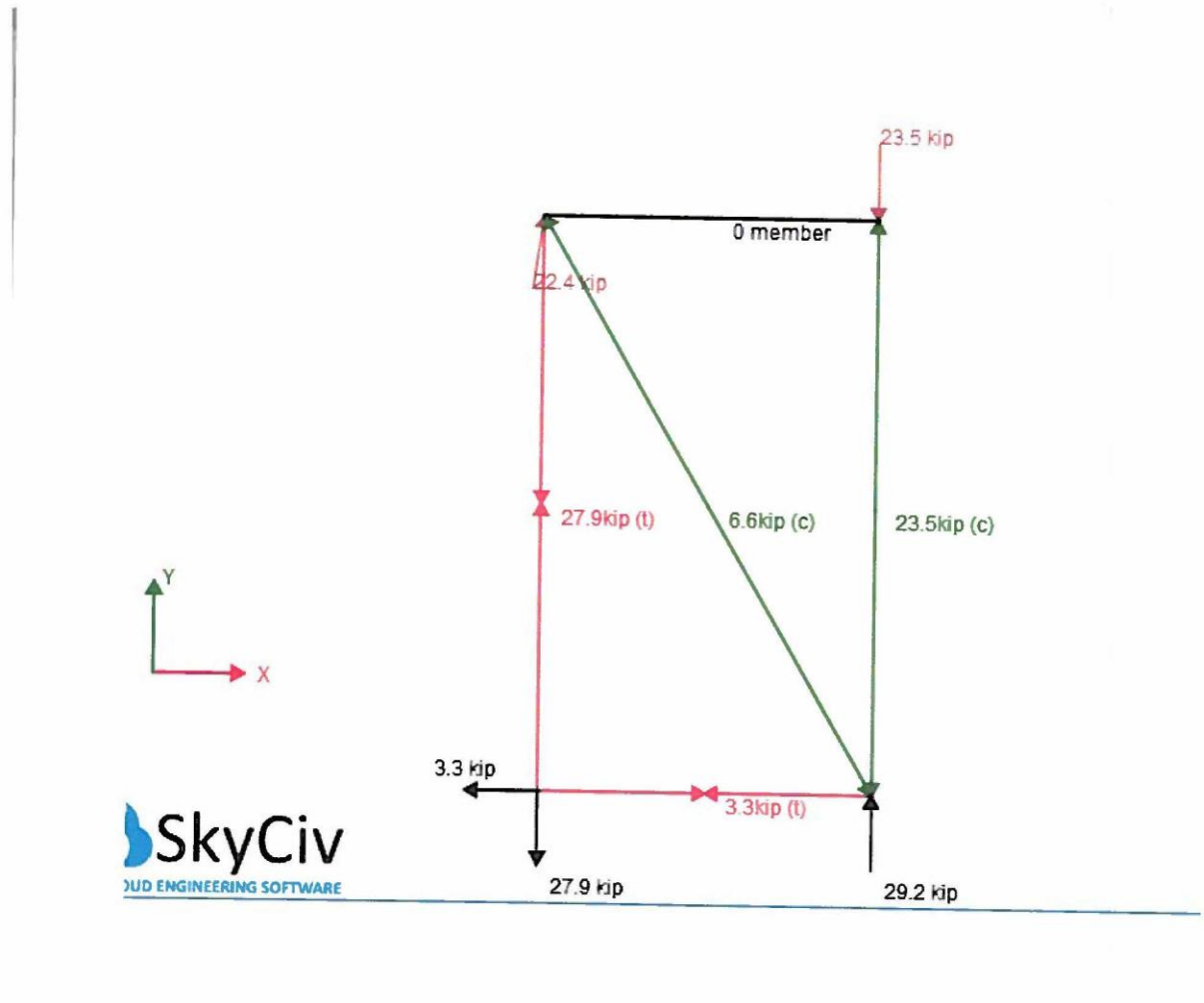

Figure 2 – End Member Loading (From internet program to verify hand calcs)

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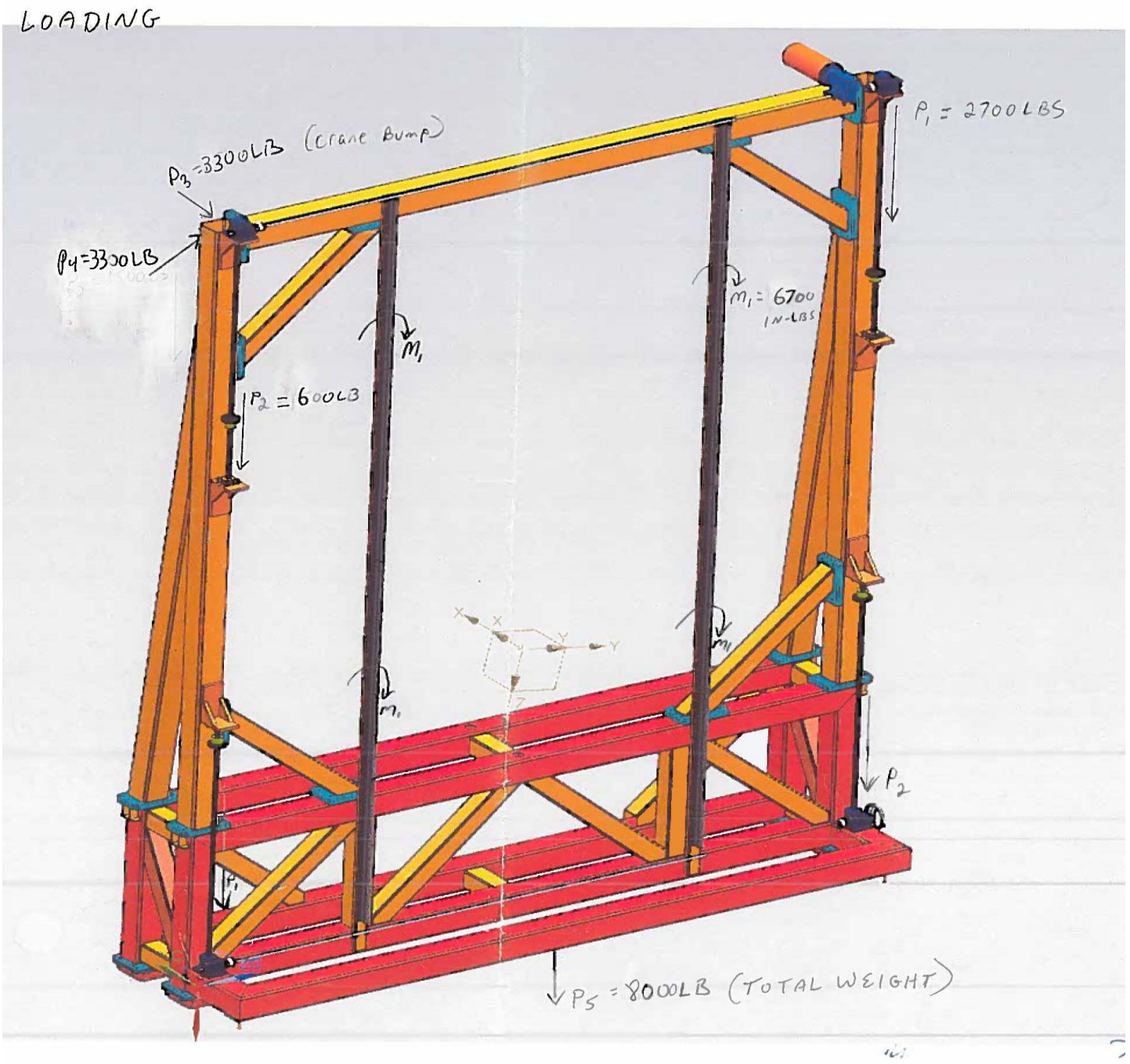

Figure 3 – Overall Loading from DIRC Detector and crane bump (3300#)

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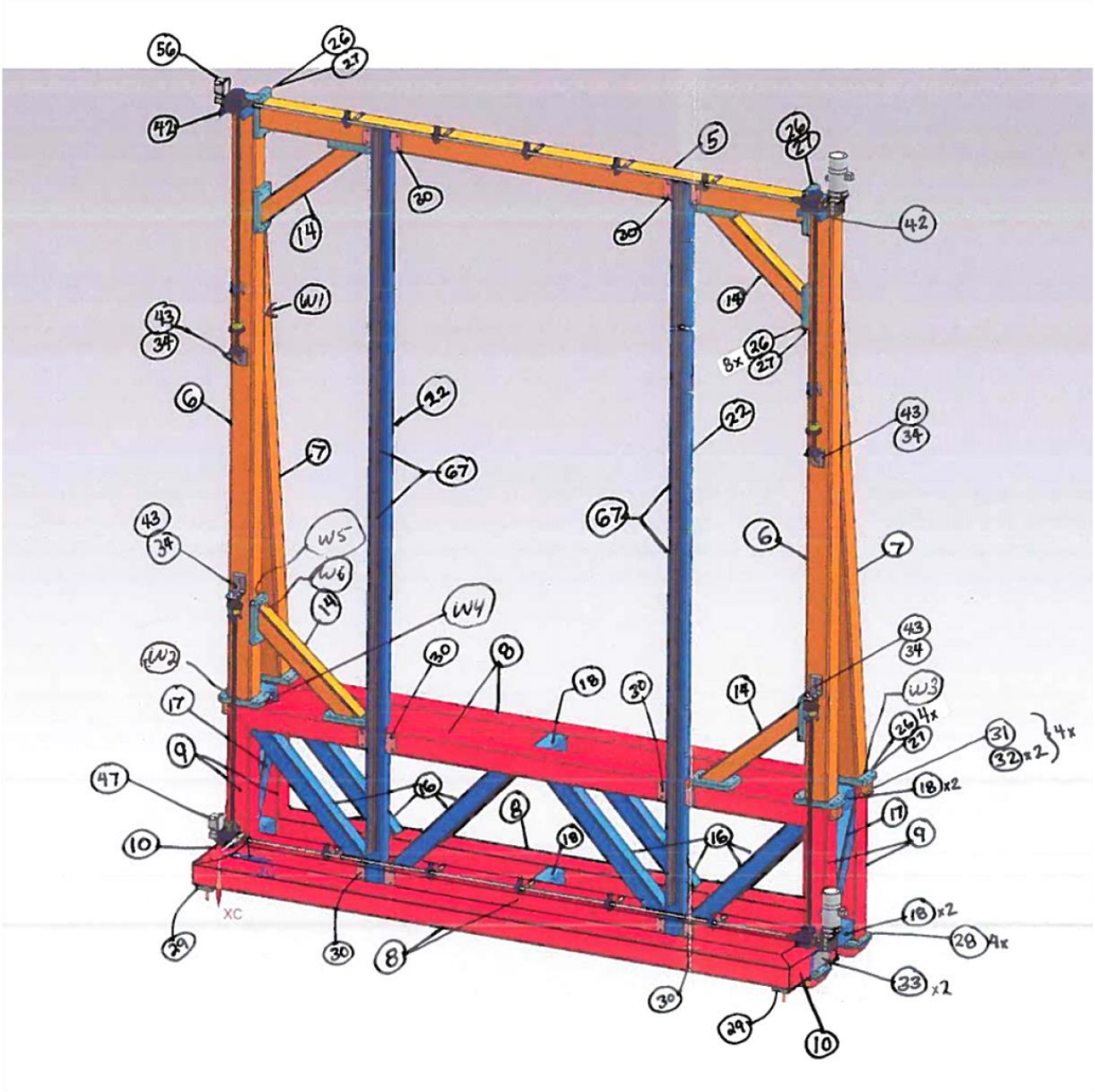

Figure 4 – Labelling of members for this analysis

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