E - 831

WIDE BAND LABORATORY

Design of Steel Beam & Column Support for
Scintillator Support & Rail System
East Side; Between Column Lines 5 & 6

REFERENCE DRAWINGS

Drawing No.:	Description:
1) 9220.687-ME-202540, Sheet 1 of 3, dtd. 5-15-85	Scintillator Support & Rail System.
2) 9220.687-ME-202540, Sheet 2 of 3, dtd. 6-6-85	Scintillator Support & Rail System.
3) 9220.687-ME-202540, Sheet 3 of 3, dtd. 6-13-8	Scintillator Support & Rail System.
4) 9220.687-ME-202541, dtd. 6-10-85	Scintillator Support & Rail System.

Dead Load Inventory: Aluminum Beams & Trolley-Extrusions:

From Table 3; Dwg. 2285-3-MC-209509; Aluminum Association "I" Beams: $\text{Density}_{AL} := 0.098 \frac{lbs}{in^3}$ $\quad (12^3) \cdot \text{Density}_{AL} = 169 \frac{lbs}{ft^3}$

Depth	$d1_{al} := 7.0$	$d2_{al} := 8.0$	$d3_{al} := 8.0$	$d4_{al} := 9.0$
Weight	$Wt1_{al} := 5.80$	$Wt2_{al} := 6.18$	$Wt3_{al} := 7.02$	$Wt4_{al} := 7.51$

Depth	$d5_{al} := 10.0$	$d6_{al} := 10.0$	$d7_{al} := 12.0$	$d8_{al} := 12.0$
Weight	$Wt5_{al} := 8.65$	$Wt6_{al} := 10.29$	$Wt7_{al} := 11.67$	$Wt8_{al} := 14.29$

From Sketch No. : Total Length of Al. Beam & Extrusion Carried by Steel Supports, near Beam Center Line and proposed tubular support. Use 14.29 lbs. per L. Ft. for Aluminum Beam.

Length: $L_{al_bm} := 12.0 \ ft$

Group - of - Three:

Aluminum Support Beams: $3 \cdot (12) \cdot 14.29 = 514$ lbs

Use 9.44 lbs. per foot for D. L. Wt. of Trolley Extrusion.

Area of Trolley-Extrusion: $AREA_{extrusion} := 8.0571$

Trolley-Extrusions: $3 \cdot \left(\frac{8.0571}{144}\right) \cdot 12.0 \cdot 169 = 340$ lbs

Total Dead Load of Aluminum Beam & Trolley Extrusion: $DL_{Bm_Tr} := 23.77$ lbs. per foot.

Total Dead Load; Group - of - Three; $DL_3 := 514 + 340$

$DL_3 = 854$ lbs

Group - of - Four:

Aluminum Support Beams: $4 \cdot (12) \cdot 14.29 = 686$ lbs

Trolley-Extrusions: $4 \cdot \left(\frac{8.0571}{144}\right) \cdot 12.0 \cdot 169 = 454$ lbs

Total Dead Load; Group - of - Four: $DL_4 := 686 + 454$

$DL_4 = 1140$ lbs

Grand Total Dead Load Group 3 & 4: $GT_{D_L} := DL_3 + DL_4$

$GT_{D_L} = 1994$ lbs

This Load is Equally Shared by proposed support beam and μ-Filter-Steel Support near Beam-Line. $\text{Beam}_{load} := \frac{1994}{2}$ $\quad \text{Beam}_{load} = 997$ lbs

Design Weight for Future Scintillator Arrays;
Carried by Beam & 2-Column Support Structure.

Reference Wiss/Rahimi/Cogswell Document; "Mounting the MH1 and MH2 Arrays", dtd. April 21,1995.

Weight of Symmetric Half of:	**X 2 = Total Weight, LBS.:**
MH1X; 427.9	855.8
MH1Y; 422.4	844.8
MH2X; 388.7	777.4
MH2Y; 413.8	827.6

Maximum Design Weight of MH Array: $Wt_{MH} := 1000.$

Design Weight of Future Array: $Wt_{Future} := 1600.0$

Apply AISC Load Factors to Instrumentation Wire only:

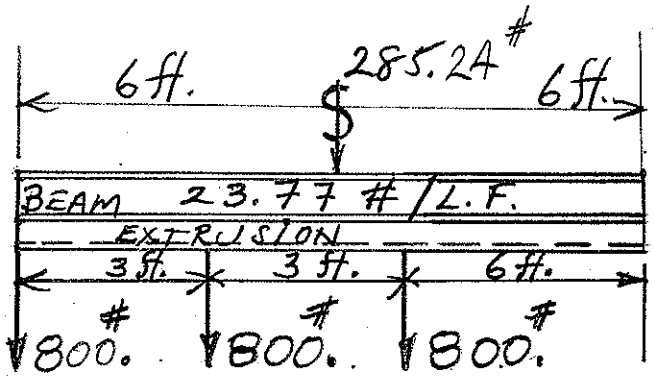
Live Load Assumption for Instrumentation Wire: $Wt_{live} := 1000.0$ lbs

$$1.6 \cdot Wt_{live} = 1600 \quad \text{lbs}$$

For this design we will assume that the heaviest Array - weight is: $Wt_{Future} + \frac{1.6 \cdot Wt_{live}}{2} = 2400$ lbs

Array is supported by three, rod-hangers, and placed as shown in Sketch A on page 4, to produce maximum support reactions and maximum moments.

FERMILAB ENGINEERING NOTE	SECTION B	PROJECT	SERIAL-CATEGORY	PAGE 4
SUBJECT MAX. ARRAY LOAD & BEAM-EXTRUSION DEAD LOAD			NAME PETER DE VERE	
			DATE 08-14-95	REVISION DATE



(@ Cat-Walk) R_{Left} $R_{Rt.}$ (@ μ-filter)

SKETCH A

$\circlearrowleft + \sum @ R_{Rt} = 0$

$+(R_{Left} * 12) - (800*12) - (800*9) - (800*6) - (285.24*6)$

(9600) (7200) (4800) (1711.44)

$(R_{LEFT} * 12) - 23{,}311.44$

$$R_{Left} = \frac{23311.44}{12} = 1942.62^{\#}$$

$\uparrow \sum F_y = 0$

$+1942.62^{\#} - (800*3) - (285.24) + R_{Rt} = 0$

$$R_{Rt} = 742.62^{\#}$$

FERMILAB
ENGINEERING NOTE

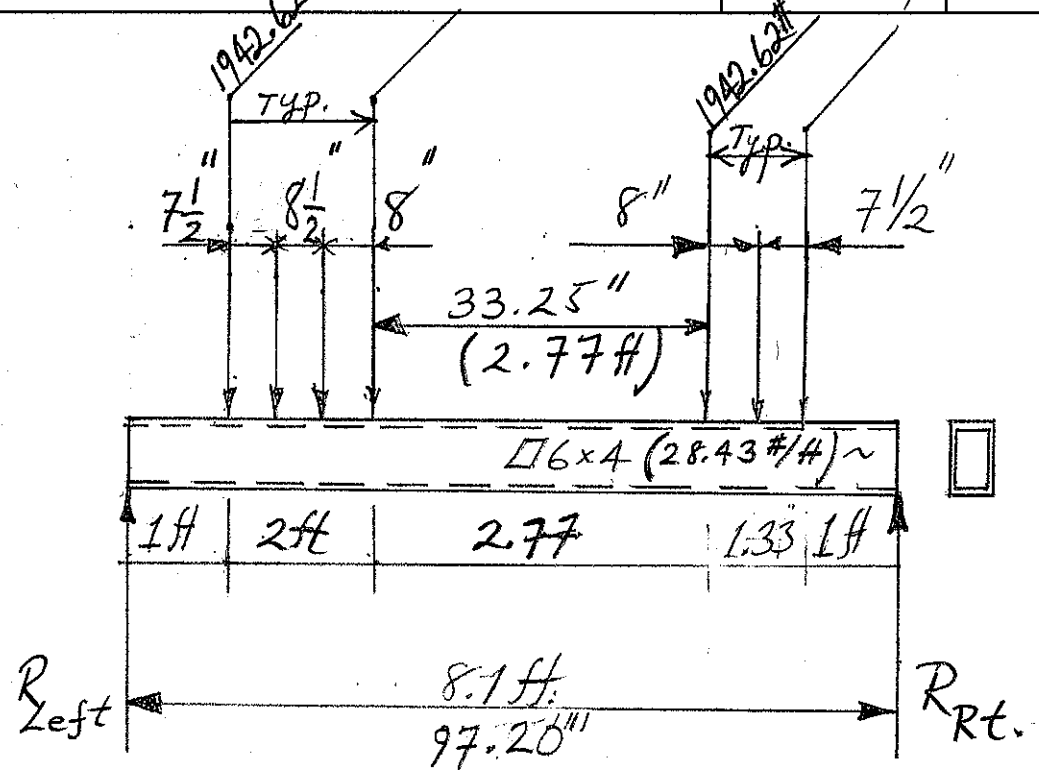
SECTION	PROJECT	SERIAL-CATEGORY	PAGE
B			5

SUBJECT: AL.-BEAM & EXTRUSION LOADS ON □6×4 TUBE-# BEAM

NAME: PETER DE VERE

DATE: 08-14-95

REVISION DATE:



SKETCH B

$\overset{+}{\uparrow}\Sigma M @ R_t = 0$

$$+(R_{LEFT} * 8.1) - (7.1' * 1942.62^{\#}) - (6.39' * 1942.62) - (5.73 * 1942.62)$$
$$- (5.06 * 1942.62) - (2.29 * 1942.62) - (1.62 * 1942.$$
$$- (1. * 1942.62)$$

$$(R_{LEFT} * 8.1) - (56{,}705.08 \text{ ft-lb.}) = 0$$

$$\boxed{R_{LEFT} = \frac{56{,}705.08}{8.1} = 7000.63\ \#}$$

$\overset{+}{\uparrow}\Sigma F_y = 0 \quad +(7000.63) - (7 * 1942.62) + R_{Rt} = 0$

$$\boxed{R_{Rt} = 6597.71\ \#}$$

23

PETE DEVERE
MSD-EN008
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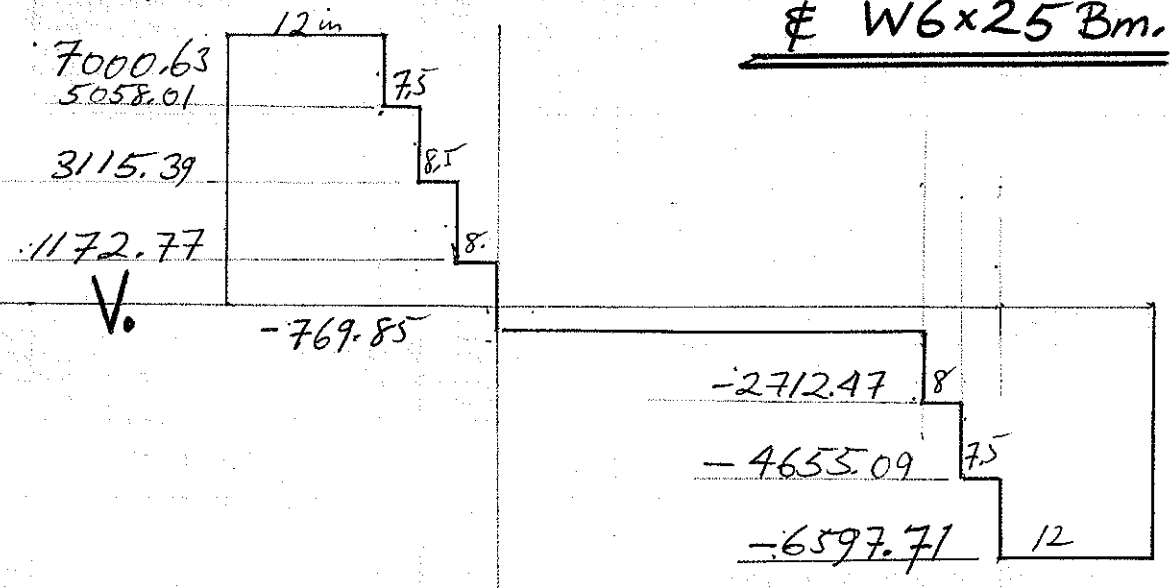
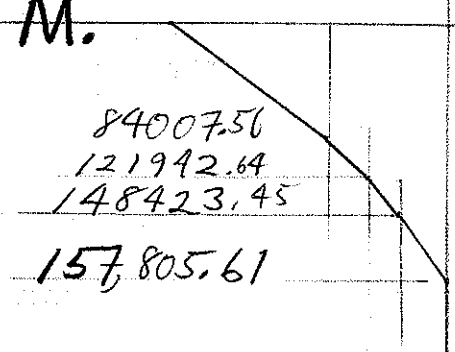
MAX SHEAR & MOMENT ON ▯ 6x4 Bm. & W6x25 Bm.





FOR M_{MAX}: 161382.97 lb.-INCH

79172.32	-3577.36
34913.18	75595.16
21699.76	110508.34
25597.51	132208.0975
161382.97	

AISC, ASD 9th Ed.: Section F3.

Minimum Yield Stress for Structural Tubes & Rectangles;AISC, ASD Table 3, pg. 1-92; $F_y := 33.0$ ksi
Min. Yield Stress:

Allowable Stress: Bending of Rectangular Tubes.

F3.1. Members with compact sections:

a) Bent about strong or weak axis;

b) with compact sections as defined in **Sect. B5;**

c) with flanges continuously connected to the webs;

Allowable Stress : $F_b := (0.66) \cdot F_y$ **(Eq. F3.1)**

Compact Section Requirements Additional to Sect. B5. :

d) Depth < 6 X Width

e) $t_f < 2 \times t_w$

f) Laterally Supported Unbraced Length, $L_b < L_c$ **(Eq. F3.2)**

Actual Unbraced Length: $L_b := 8.1$ ft

End Moments for this set-up are Zero. $M_1 := 0.0$ $M_2 := 0.0$

Lateral Unbraced Length, L_b , must be Less Than:

$$L_c := \left[1950.0 + 1200.0 \cdot \left(\frac{M_1}{M_2} \right) \right] \cdot \left(\frac{b1_f}{F_y} \right) \quad \textbf{(Eq. F3.2)}$$

AISC, ASD 9th Ed.: Section B5.1 Local Buckling; Compact, Noncompact & Slender Element Sections.

Compact Section: Width - Thickness Ratios of its Compression elements
not to Exceed Limiting Values of Table B5.1

For Tubular Sections; Width, b, is defined as: b = (Width of Section) - (3 X Flange (Web) Thickness)

Table B5.1

Flanges of Rectangular Tubes:

Compact

$$b_{t_compact} := \left(\frac{190}{\sqrt{F_y}} \right)$$

$$b_{t_compact} = 33.07$$

NonCompact

$$b_{t_noncom} := \left(\frac{238}{\sqrt{F_y}} \right)$$

$$b_{t_noncom} = 41.43$$

Determine the "Design Strength" for 6 X 4 inch tubular beams:

Minimum Yield Stress for Structural Tubes & Rectangles;AISC, ASD Table 3, pg. 1-92; $F_y := 33.0$ ksi
Min. Yield Stress:

$E := 29000.0$ ksi

For Flanges or Webs of Rectangular Hollow Sections:
b = (Total Section Width) - 3 x $t.f_{or\ w}$

Section Properties; 6 X 4 Structural Tubes:

Wall Thickness:

1) 3/16" $t1_f := 0.1875$ $Wt1 := 11.97$ $A1 := 3.52$ $J1 := 19.5$

$I1_x := 17.4$ $S1_x := 5.81$ $Z1_x := 7.06$ $r1_x := 2.23$

$I1_y := 9.32$ $S1_y := 4.66$ $Z1_y := 5.34$ $r1_y := 1.63$

Flange: $t1_f := 0.1875$ $b1_f := 4.0 - (3 \cdot t1_f)$ $b1_f = 3$ inch

Web: $t1_w := 0.1875$ $b1_w := 6.0 - (3 \cdot t1_w)$ $b1_w = 5$ inch

2) 1/4" $t2_f := 0.2500$ $Wt2 := 15.62$ $A2 := 4.59$ $J2 := 25.0$

$I2_x := 22.1$ $S2_x := 7.36$ $Z2_x := 9.06$ $r2_x := 2.19$

$I2_y := 11.70$ $S2_y := 5.87$ $Z2_y := 6.84$ $r2_y := 1.60$

Flange: $t2_f := 0.2500$ $b2_f := 4.0 - (3 \cdot t2_f)$ $b2_f = 3$ inch

Web: $t2_w := 0.2500$ $b2_w := 6.0 - (3 \cdot t2_w)$ $b2_w = 5$ inch

3) 5/16 $t3_f := 0.3125$ $Wt3 := 19.08$ $A3 := 5.61$ $J3 := 30.1$

$I3_x := 26.20$ $S3_x := 8.70$ $Z3_x := 10.90$ $r3_x := 2.16$

$I3_y := 13.80$ $S3_y := 6.92$ $Z3_y := 8.21$ $r3_y := 1.57$

Flange: $t3_f := 0.3125$ $b3_f := 4.0 - (3 \cdot t3_f)$ $b3_f = 3$ inch

Web: $t3_w := 0.3125$ $b3_w := 6.0 - (3 \cdot t3_w)$ $b3_w = 5$ inch

4) 3/8" $t4_f := 0.3750$ $Wt4 := 22.37$ $A4 := 6.58$ $J4 := 34.60$

$I4_x := 29.7$ $S4_x := 9.70$ $Z4_x := 12.50$ $r4_x := 2.13$

$I4_y := 15.6$ $S4_y := 7.82$ $Z4_y := 9.44$ $r4_y := 1.54$

Flange: $t4_f := 0.3750$ $b4_f := 4.0 - (3 \cdot t4_f)$ $b4_f = 3$ inch

Web: $t4_w := 0.3750$ $b4_w := 6.0 - (3 \cdot t4_w)$ $b4_w = 5$ inch

5) 1/2" $t5_f := 0.5000$ $Wt5 := 28.43$ $A5 := 8.36$ $J5 := 42.1$

$I5_x := 35.30$ $S5_x := 11.8$ $Z5_x := 15.4$ $r5_x := 2.06$

$I5_y := 18.40$ $S5_y := 9.21$ $Z5_y := 11.5$ $r5_y := 1.48$

Flange: $t5_f := 0.5000$ $b5_f := 4.0 - (3 \cdot t5_f)$ $b5_f = 3$ inch

Web: $t5_w := 0.5000$ $b5_w := 6.0 - (3 \cdot t5_w)$ $b5_w = 5$ inch

Width Thickness Ratios:

Laterally-Unbraced-Length of proposed Tube-Beam: $L_b := 8.1$ ft

Flange Local Buckling

flange width - thickness ratio: b_f / t_f :

Compact

$b_{t_compact} := \left(\frac{190}{\sqrt{F_y}}\right)$

$b_{t_compact} = 33.07$

Width Thickness Ratios for 6 X 4 Tubes:

1) 3/16" Flange: $\lambda 1_{flb} := \frac{b1_f}{t1_f}$ $\lambda 1_{flb} = 18.33$

2) 1/4" Flange: $\lambda 2_{flb} := \frac{b2_f}{t2_f}$ $\lambda 2_{flb} = 13$

3) 5/16 Flange: $\lambda 3_{flb} := \frac{b3_f}{t3_f}$ $\lambda 3_{flb} = 9.8$

4) 3/8" Flange: $\lambda 4_{flb} := \frac{b4_f}{t4_f}$ $\lambda 4_{flb} = 7.67$

5) 1/2" Flange: $\lambda 5_{flb} := \frac{b5_f}{t5_f}$ $\lambda 5_{flb} = 5$

Actual Unbraced Length of proposed Tube-Beam: $L_b := (8.1)\cdot 12$

$L_b = 97.2$ in

Allowable Unbraced Length:

$$L1_c := \left[1950.0 + 1200.0\cdot\left(\frac{M_1}{M_2}\right)\right]\cdot\left(\frac{b1_f}{F_y}\right)$$

$L1_c = 203$ inch

$$L2_c := \left[1950.0 + 1200.0\cdot\left(\frac{M_1}{M_2}\right)\right]\cdot\left(\frac{b2_f}{F_y}\right)$$

$L2_c = 192$ inch

$$L3_c := \left[1950.0 + 1200.0\cdot\left(\frac{M_1}{M_2}\right)\right]\cdot\left(\frac{b3_f}{F_y}\right)$$

$L3_c = 181$ inch

$$L4_c := \left[1950.0 + 1200.0\cdot\left(\frac{M_1}{M_2}\right)\right]\cdot\left(\frac{b4_f}{F_y}\right)$$

$L4_c = 170$ inch

$$L5_c := \left[1950.0 + 1200.0\cdot\left(\frac{M_1}{M_2}\right)\right]\cdot\left(\frac{b5_f}{F_y}\right)$$

$L5_c = 148$ inch

Width Thickness Ratios for 6 X 4 Tubes:

$\lambda 1_{flb} = 18.33$ compact flange
$b1_f = 3.44$ inch

$\lambda 2_{flb} = 13$ compact flange
$b2_f = 3.25$ inch

$\lambda 3_{flb} = 9.8$ compact flange
$b3_f = 3.06$ inch

$\lambda 4_{flb} = 7.67$ compact flange
$b4_f = 2.88$ inch

$\lambda 5_{flb} = 5$ compact flange
$b5_f = 2.5$ inch

Actual Unbraced Length of proposed Tube-Beam: $L_b := (8.1)\cdot 12$

$L_b = 97.2$

From page 4, Max. Moment $M_{max} := \frac{(13449.0)\cdot 12}{1000.}$

$M_{max} = 161.39$ K-in.

AISC, ASD Table 3, pg. 1-92; Min. Yield Stress: $F_y := 33.0$ ksi

Max. Allowable Bending Stress: $F_b := 0.66\cdot F_y$

$F_b = 21.78$ ksi

Minimum Allowable Section Modulus: $S_{min} := \frac{M_{max}}{F_b}$

$S_{min} = 7.41$ in^3

Wall Thickness: $S_{min} = 7.41$ in^3

1) 3/16" $S1_x := 5.81$ NG

2) 1/4" $S2_x := 7.36$ NG

3) 5/16 $S3_x := 8.70$ O.K.

4) 3/8" $S4_x := 9.70$ O.K.

5) 1/2" $S5_x := 11.8$ O.K. ∴ 6 X 4 Structural Tubes marked as O. K. are acceptable.

Design Wide Flange Alternate for Tube 6 X 4; Use W6X25

From page 6; Design Moment; $M_{max} := 161382.97$ lbs.-inch

Section Properties; W6X25 $F_y := 36.0$ ksi

$b_f := 6.080$ $t_f := 0.455$ $d := 6.38$ $A_f := \frac{6.38}{2.31}$ $A_f = 2.76$

ASD Ch. F, Sec. F1.1

Lateral unsupported length of compression flange: $L_b := 8.1 \cdot 12\text{inch}$

$L_b = 97$ inch

Conservatively assume that fixture-clamping forces of Aluminum Beams - to Steel cross-member does ***NOT*** provide adequate force to develop lateral braces.

$$L_{c1} := \frac{76 \cdot (b_f)}{\sqrt{F_y}} \qquad L_{c1} = 77 \text{ inch}$$

$$L_{c2} := \frac{20000.0}{\left(\frac{d}{A_f}\right) \cdot F_y} \qquad L_{c2} = 241 \text{ inch}$$

ASD, Table B5.1, pg. 5-36
Limiting Width-Thickness Ratio for Compression Elements of W6X25:

Compact Section Element

$$b_t_{com_allow} := \frac{65}{\sqrt{F_y}} \qquad b_t_{com_allow} = 10.83 \qquad \frac{b_f}{t_f} = 13.36$$

NonCompact Section Element

$$b_t_{non_com} := \frac{95}{\sqrt{F_y}} \qquad b_t_{non_com} = 15.83 \qquad \frac{b_f}{t_f} = 13.36$$

∴ Allowable Bending Stress, Fb, is the larger value of Equations F1-6, -7, -8.

$l := L_b$ $\quad r_T := 1.66\ \text{inch}$ $\quad C_b := 1.75$ $\quad F_y = 36\ \text{ksi}$

WHEN l/rT is

$$\sqrt{\frac{(102\cdot 10^3)\cdot C_b}{F_y}} = 70 \quad < \quad \frac{l}{r_T} = 59 \ \text{inches} \quad < \quad \sqrt{\frac{(510\cdot 10^3)\cdot C_b}{F_y}} = 157$$

THEN

$$F_{b_6} := \left[\left(\frac{2}{3}\right) - \left[\frac{(F_y)\cdot\left(\frac{l}{r_T}\right)^2}{(1530.0\cdot 10^3)\cdot C_b}\right]\right]\cdot F_y \qquad F_{b_6} = 22.34 \ \text{ksi}$$

$M_{design} := 244289\ \text{in_lbs}$ $\qquad f_{b_reqd} := F_{b_6}$

$$S_{reqd} := \left[\frac{\left(\frac{M_{design}}{1000.0}\right)}{(f_{b_reqd})}\right] \qquad S_{reqd} = 10.93 \ \text{in}^3 \qquad S_{W6X25} := 16.7\ \text{in}^3 \ \text{O.K.}$$

Use W6 X 25 as an alternative to Structural Tube 6 X 4;

See Fabrication details in Section C.

Determine the "Design Strength" for each 4 X 4 tubular column listed in AISC; LRFD, 1st. Ed:

Reference AISC, LRFD, Chapter "E."

Use Minimum Yield Strength; AISC, ASD, Table 3, pg. 1-92. $F_y := 33.0$ ksi $E := 29000.0$ ksi

Compressive Residual Stress from Welding in Flange: $F_r := 16.5$ ksi

Section Properties; 4 X 4 Structural Tubes:

Wall Thickness:				
1) 3/16"	$t1_f := 0.1875$	$Wt1 := 9.42$	$A1 := 2.77$	$I1 := 6.59$
	$S1 := 3.30$	$r1 := 1.54$	$J1 := 10.6$	$Z1 := 3.91$
2) 1/4"	$t2_f := 0.2500$	$Wt2 := 12.21$	$A2 := 3.59$	$I2 := 8.22$
	$S2 := 4.11$	$r2 := 1.51$	$J2 := 13.5$	$Z2 := 4.97$
3) 5/16	$t3_f := 0.3125$	$Wt3 := 14.83$	$A3 := 4.36$	$I3 := 9.58$
	$S3 := 4.79$	$r3 := 1.48$	$J3 := 16.1$	$Z3 := 3.91$
4) 3/8"	$t4_f := 0.3750$	$Wt4 := 17.27$	$A4 := 5.08$	$I4 := 10.7$
	$S4 := 5.35$	$r4 := 1.45$	$J4 := 18.4$	$Z4 := 6.72$
5) 1/2"	$t5_f := 0.5000$	$Wt5 := 21.63$	$A5 := 6.36$	$I5 := 12.3$
	$S5 := 6.13$	$r5 := 1.39$	$J5 := 21.8$	$Z5 := 8.02$

LRFD Sec. B5. Pg. 6 - 31, Local Buckling:

Three Classifications of Compression Elements:

Compact : $b/t < \lambda_p$ $\qquad \lambda_p := \frac{190.0}{\sqrt{F_y}}$ $\qquad \lambda_p = 33$

NonCompact: $\lambda_p < b/t < \lambda_r$

Slender Compression Element: $b/t > \lambda_r$ $\qquad \lambda_r := \frac{238}{\sqrt{F_y - F_r}}$ $\qquad \lambda_r = 59$

For Flanges of Rectangular Hollow Sections: b = (Total Section Width) - 3 x t_f

$Width_{section} := 4.0\,inch$

Wall Thickness:				
1) 3/16"	$t1_f := 0.1875$	$b1 := 4.0 - (3 \cdot t1_f)$	$b1 = 3$	inch
2) 1/4"	$t2_f := 0.2500$	$b2 := 4.0 - (3 \cdot t2_f)$	$b2 = 3$	inch
3) 5/16	$t3_f := 0.3125$	$b3 := 4.0 - (3 \cdot t3_f)$	$b3 = 3$	inch
4) 3/8"	$t4_f := 0.3750$	$b4 := 4.0 - (3 \cdot t4_f)$	$b4 = 3$	inch
5) 1/2"	$t5_f := 0.5000$	$b5 := 4.0 - (3 \cdot t5_f)$	$b5 = 3$	inch

Width Thickness Ratios:

$\frac{b1}{t1_f} = 18$ $\qquad \frac{b2}{t2_f} = 13$ $\qquad \frac{b3}{t3_f} = 10$

$\frac{b4}{t4_f} = 8$ $\qquad \frac{b5}{t5_f} = 5$

$\lambda_p = 33$ $\qquad \lambda_r = 59$

$\therefore$ "Elements" of each 4 X 4 Square Tube are " Compact Sections"

Initial Value of Effective Length Factor : $K := 2.0$ (base plate; pin. top; "fixed"; with Side-Sway)

Total Unbraced Length of Proposed Column: $l := 207.5$ inches

$\frac{K \cdot l}{r1} = 269$ $\frac{K \cdot l}{r3} = 280$

$\frac{K \cdot l}{r5} = 299$

$\frac{K \cdot l}{r2} = 275$ $\frac{K \cdot l}{r4} = 286$

AISC ; LRFD Spec.: B7 "preferably" limits the Slenderness Ratio, Kl/r, to a value of 200. However, Service Loads for the Detector Support are small. In the event that the weight of future experiments exceed the limits of the 4 X 4 column; $Kl/r_{x\,\&\,y}$ may be decreased by welding angles or channels to the structural tubes.

Determine Design Strength of each 4 X 4 Tube and compare to proposed service dead & live loads.

AISC, LRFD, 1st. Ed. Ch. E, para. E2:

$b/t_f < \lambda_r$; Design Strength of Column: $\phi_c * P_n$ $\phi := 0.85$

1) 4 X 4 X 0.1875 : $\frac{b1}{t1_f} = 18$ $< \lambda_r = 59$

$\lambda 1_c := \left(\frac{K \cdot l}{r1 \cdot \pi}\right) \cdot \sqrt{\frac{F_y}{E}}$ $\lambda 1_c = 3$

For $\lambda_c > 1.5$ $F1_{cr} := \left(\frac{0.877}{\lambda 1_c^{\,2}}\right) \cdot F_y$ $F1_{cr} = 3$ ksi

$P1_n := A1 \cdot F1_{cr}$ $P1_n = 10$

For $\lambda_c > 1.5$:

Design Strength: $Load_1_{allowable} := \phi \cdot P1_n$

$Load_1_{allowable} = 8$ kips

2) 4 X 4 X 0.2500 :

$\frac{b2}{t2_f} = 13$ < $\lambda_r = 59$

$\lambda 2_c := \left(\frac{K \cdot l}{r2 \cdot \pi}\right) \cdot \sqrt{\frac{F_y}{E}}$ $\lambda 2_c = 3$

For $\lambda_c > 1.5$ $F2_{cr} := \left(\frac{0.877}{\lambda 2_c^2}\right) \cdot F_y$ $F2_{cr} = 3$ ksi

$P2_n := A2 \cdot F2_{cr}$ $P2_n = 12$

Design Strength: $Load_2_{allowable} := \phi \cdot P2_n$

$Load_2_{allowable} = 10$ kips

3) 4 X 4 X 0.3125:

$\frac{b3}{t3_f} = 10$ < $\lambda_r = 59$

$\lambda 3_c := \left(\frac{K \cdot l}{r3 \cdot \pi}\right) \cdot \sqrt{\frac{F_y}{E}}$ $\lambda 3_c = 3$

For $\lambda_c > 1.5$ $F3_{cr} := \left(\frac{0.877}{\lambda 3_c^2}\right) \cdot F_y$ $F3_{cr} = 3$ ksi

$P3_n := A3 \cdot F3_{cr}$ $P3_n = 14$

Design Strength: $Load_3_{allowable} := \phi \cdot P3_n$

$Load_3_{allowable} = 12$ kips

4) 4 X 4 X 0.3750 : $\frac{b4}{t4_f} = 8$ < $\lambda_r = 59$

$\lambda 4_c := \left(\frac{K \cdot l}{r4 \cdot \pi}\right) \cdot \sqrt{\frac{F_y}{E}}$ $\lambda 4_c = 3$

For $\lambda_c > 1.5$ $F4_{cr} := \left(\frac{0.877}{\lambda 4_c^2}\right) \cdot F_y$ $F4_{cr} = 3$ ksi

$P4_n := A4 \cdot F4_{cr}$ $P4_n = 16$

Design Strength: $Load_4_{allowable} := \phi \cdot P4_n$

$Load_4_{allowable} = 13$ kips

5) 4 X 4 X 0.5000 : $\frac{b5}{t5_f} = 5$ < $\lambda_r = 59$

$\lambda 5_c := \left(\frac{K \cdot l}{r5 \cdot \pi}\right) \cdot \sqrt{\frac{F_y}{E}}$ $\lambda 5_c = 3$

For $\lambda_c > 1.5$: $F5_{cr} := \left(\frac{0.877}{\lambda 5_c^2}\right) \cdot F_y$ $F5_{cr} = 3$ ksi

$P5_n := A5 \cdot F5_{cr}$ $P5_n = 18$ kips

Design Strength: $Load_5_{allowable} := \phi \cdot P5_n$

$Load_5_{allowable} = 15$ kips

Reference page 5: Maximum Column Reaction Loads; R_{left} = 7000. lbs. & R_{right} = 6598. lbs.

Each 4 X 4 Structural Tube listed below has the capacity to carry the maximum vertical load, 7000. lbs.

Four wall thicknesses are provided to allow for current market availability at the time of construction or purchase.

Use Structural Tube; 4 X 4 X 1/4: Design Strength: $Load_2_{allowable} := \phi \cdot P2_n$

$Load_2_{allowable} = 10$ kips

Use Structural Tube; 4 X 4 X 5/16: Design Strength: $Load_3_{allowable} := \phi \cdot P3_n$

$Load_3_{allowable} = 12$ kips

Use Structural Tube; 4 X 4 X 3/8: Design Strength: $Load_4_{allowable} := \phi \cdot P4_n$

$Load_4_{allowable} = 13$ kips

Use Structural Tube; 4 X 4 X 1/2: Design Strength: $Load_5_{allowable} := \phi \cdot P5_n$

$Load_5_{allowable} = 15$ kips