Fermilab

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Particle Physics Division

Engineering and Technical Teams

Mechanical Support Engineering Note

Number: MD-ENG-02/009 Date: May 2, 2002

Project: Minos Project Internal Reference:

Title: Minos Veto Shield Structural Calculations

Author(s): J. Kilmer

Reviewer(s): 5-3-02

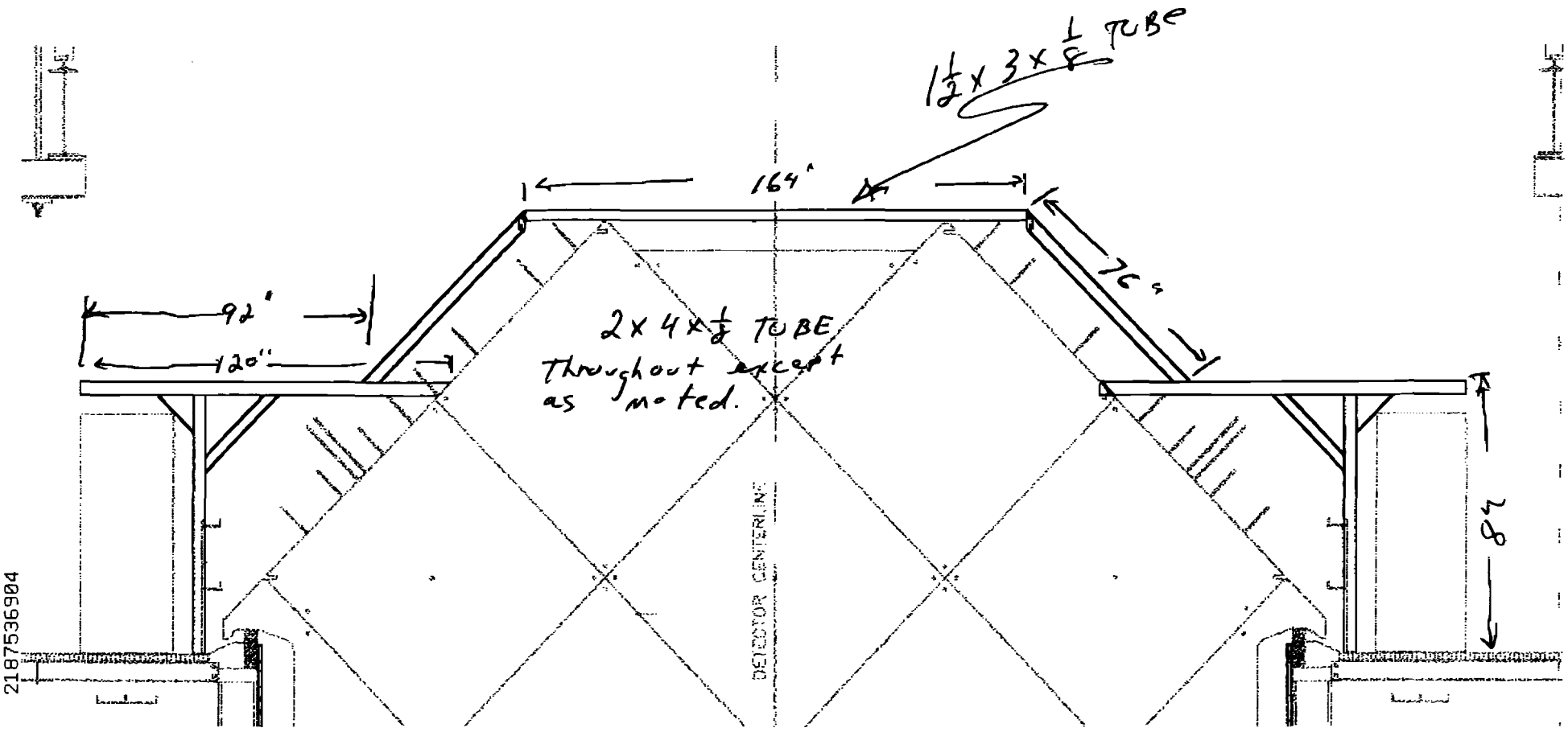
Key Words:

Abstract/Summary:

This note calculates the loads and stresses on the structure proposed for installing a Veto Shield on the Minos Far detector. The structure is capable of supporting a veto shield of two layers even if those layers are composed of the heavier panels of the Soudan 2 veto system. The stresses on the steel planes from the extra weight are not excessively increased. The system meets normal Fermilab standards for structural integrity.

Applicable Codes:

AISC Code


1½ x 3 x ⅛ TUBE
164"
76"
92"
120"
2 x 4 x ⅛ TUBE
Throughout except
as noted.
DETECTOR CENTERLINE
84

FERMILAB ENGINEERING NOTE	SECTION	PROJECT	SERIAL-CATEGORY	PAGE
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SUBJECT	NAME	
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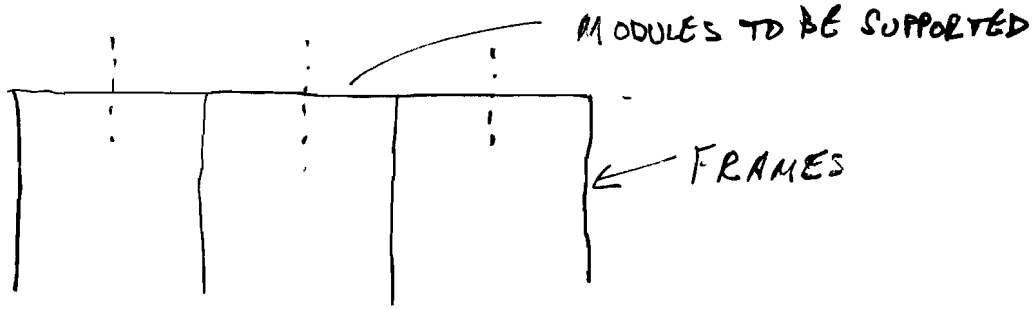
CALCULATE LOAD ON THE FRAME AS A FUNCTION OF AREA

A 20 WIDE MODULE IS 8m x .8m AND WEIGHS 200 lbs

$$\Rightarrow \frac{200\,lbs}{8m \times .8m} = 31.25\ lb/m^2$$

FRAMES ARE 6' APART. CALL IT 2M
THEN EACH FRAME HAS TO SUPPORT A WIDTH OF 2M, EXCEPT THE TWO OUTSIDE FRAMES WHICH ONLY SUPPORT 1/2 THAT.

ie



WEIGH TO SUPPORT ON BEAM / METER IS THEN

FOR MODULES $2m \times 31.25\ lb/m^2 = 62.5\ lb/m = 19\ lb/ft.$

SOUDAN MUON TUBES $2m \times 90\ lb/m^2 = 180\ lb/m = 54.54\ lb/ft$

IF A LAYER OF EACH WAS USED (DOUBLE LAYER) THEN $= 75\ lb/ft$

$\Rightarrow$ USE 100 lb/ft FOR BELTS AND SUSPENDERS

FERMILAB
ENGINEERING NOTE

SECTION	PROJECT	SERIAL-CATEGORY	PAGE
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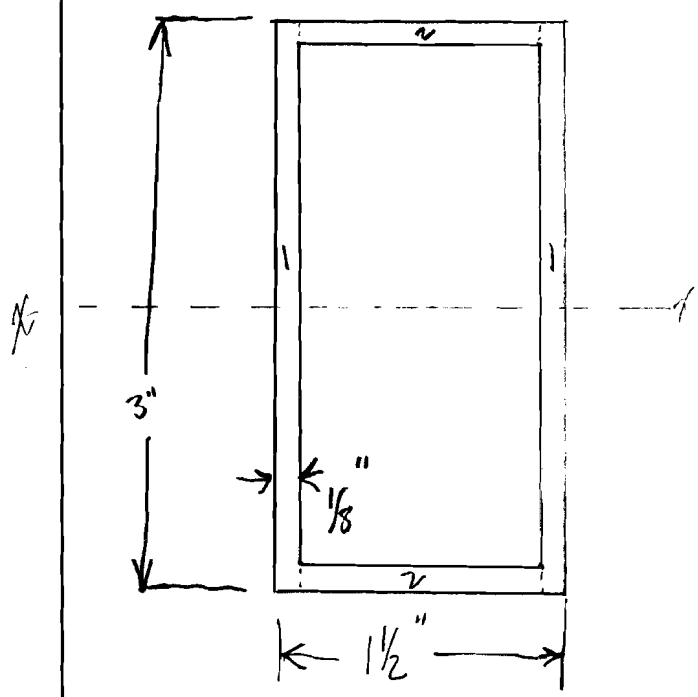
SUBJECT: STRUCTURAL CALCULATIONS AN SHIELD SUPPORT

NAME:

DATE:

REVISION DATE:



$$I_{xx} = 2I_1 + 2I_2$$

AREA	b	h	A	d	$I_o = \frac{1}{12} b h^3$	$A d^2$	$I = I_o + A d^2$
1	1/8"	3"	.375 in²	0	.281 in⁴	0	.281 in⁴
2	1 1/4"	1/8"	.156 in²	1.4375	2×10^{-4} in⁴	.322	.322 in⁴

$$I_{xx} = 2(.281 \text{ in}^4) + 2(.322 \text{ in}^4)$$

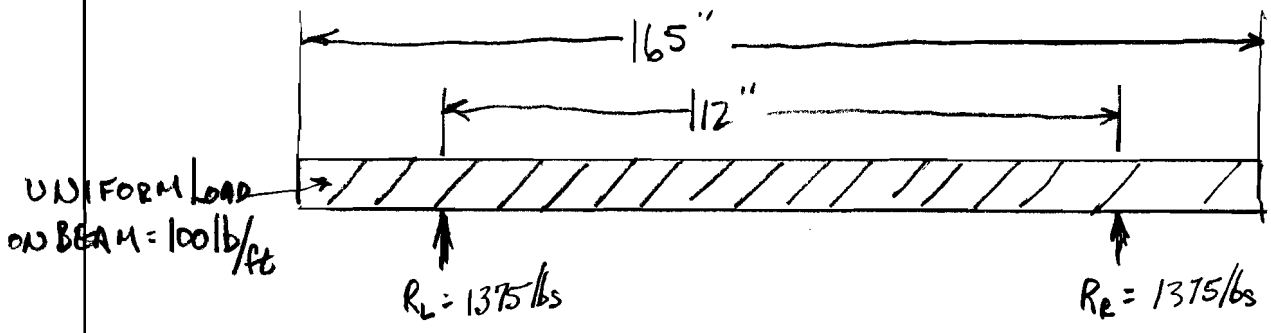
$$= 1.21 \text{ in}^4 \Rightarrow$$ FOR 3 x 1 1/2 x 1/8 WALL TUBING

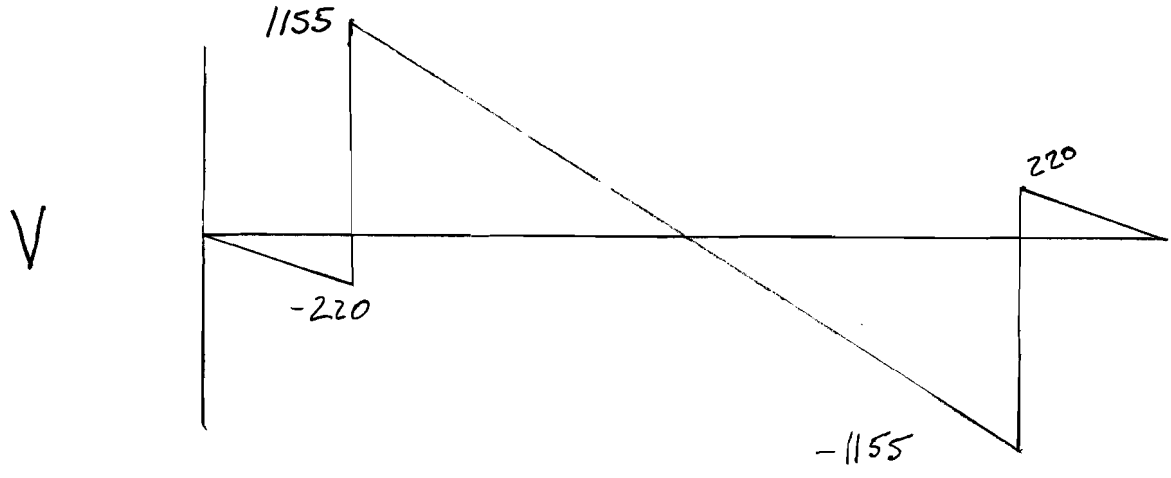
$$S = \frac{I_{xx}}{h/2} = \frac{1.21 \text{ in}^4}{1.5 \text{ in}} = .807 \text{ in}^3$$

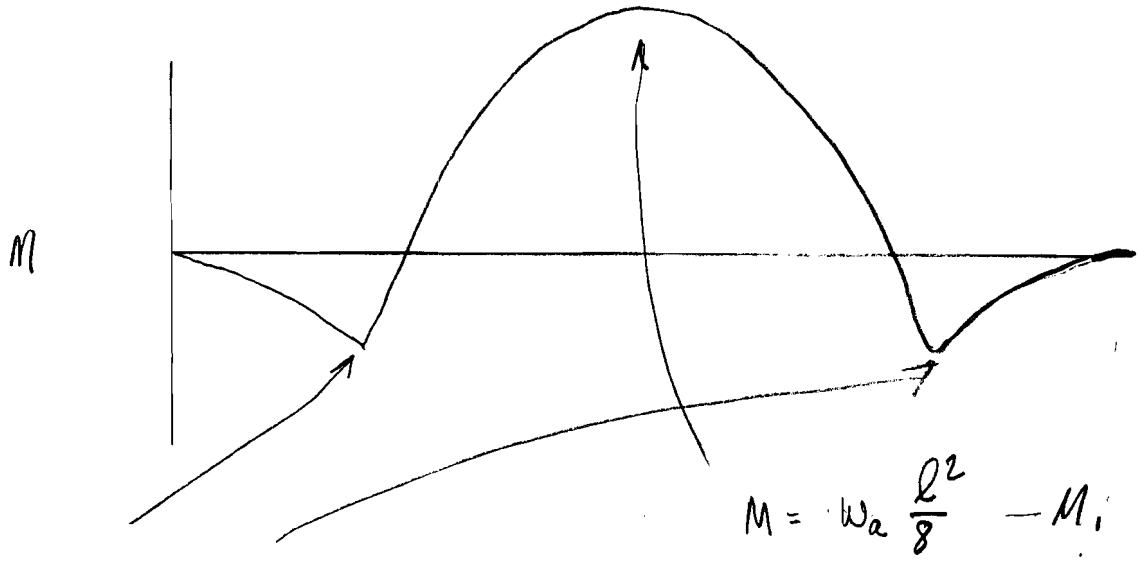
FOR 4" X 2" x 1/8" RECTANGULAR TUBING

$$I_{xx} = 2.82 \text{ in}^4$$

$$S = 1.41 \text{ in}^3$$







$$M_1 = wx \times \frac{x}{2}$$

$$= (100\,\text{lb/ft})(2.2\,\text{ft})\left(\frac{2.2\,\text{ft}}{2}\right)$$

$$= 242\,\text{lb ft} = 2904\,\text{lb-in}$$

$$M = w_a \frac{l^2}{8} - M_1$$

$$= (8.33\,\text{lb/in})\left(\frac{112\,\text{in}^2}{8}\right) - 2904$$

$$= 13067\,\text{lb in} - 2904\,\text{lb in}$$

$$= 10162\,\text{lb-in}$$

FIND STRESS IN BEAM

$$\sigma = M/S = \frac{10162 \text{ lb in}}{.807 \text{ in}^3} = 12{,}702$$

STANDARD STRUCTURAL TUBING IS MADE TO A 500 STANDARDS $\Rightarrow F_y = 46{,}000$ PSI

EVEN ASSUMING ONLY A-36 STEEL ($F_y = 36{,}000$ PSI)

THIS IMPLIES A SAFETY FACTOR OF 3

NOTE THAT THERE IS NO PERSONNEL SAFETY REQUIREMENT — NO ONE IS EVER SUPPORTED BY THIS.

ALSO NOTE THAT THERE IS AS DESIGNED A POCKET CUT INTO THE BEAM AT THE SUPPORTS FOR THE STEEL EARS.

FOR THAT SECTION

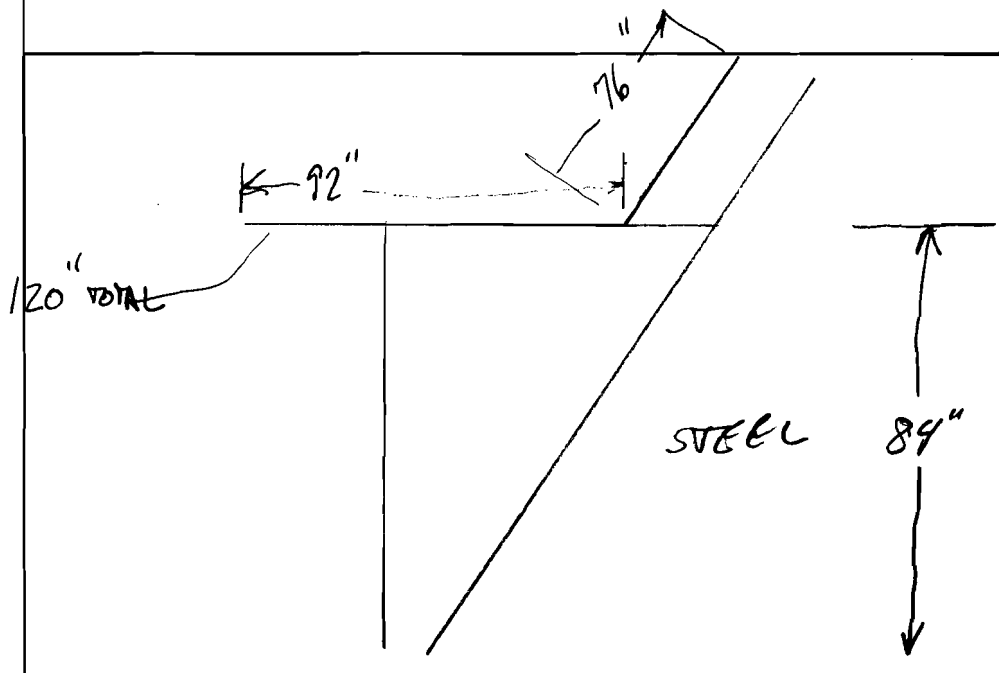
FROM page 1 THE MOMENT OF INERTIA MUST BE LESS AS $I_{xx} = 2 \times (.281 \text{ in}^4) + .322 \text{ in}^4$

$= .884 \text{ in}^4$

MOMENT AT THAT POSITION IS ONLY 2904 lb-in

$$\Rightarrow \sigma = \frac{Mc}{I_{xx}} = \frac{(2904 \text{ lb in})(1.5 \text{ in})}{.884 \text{ in}^4} = 4927 \text{ psi.}$$

THIS IS ALSO OK FOR BENDING STRESS.



ALL OF THIS MATERIAL MADE FROM 4"X2"x 1/8" WALL STRUCTURAL TUBING

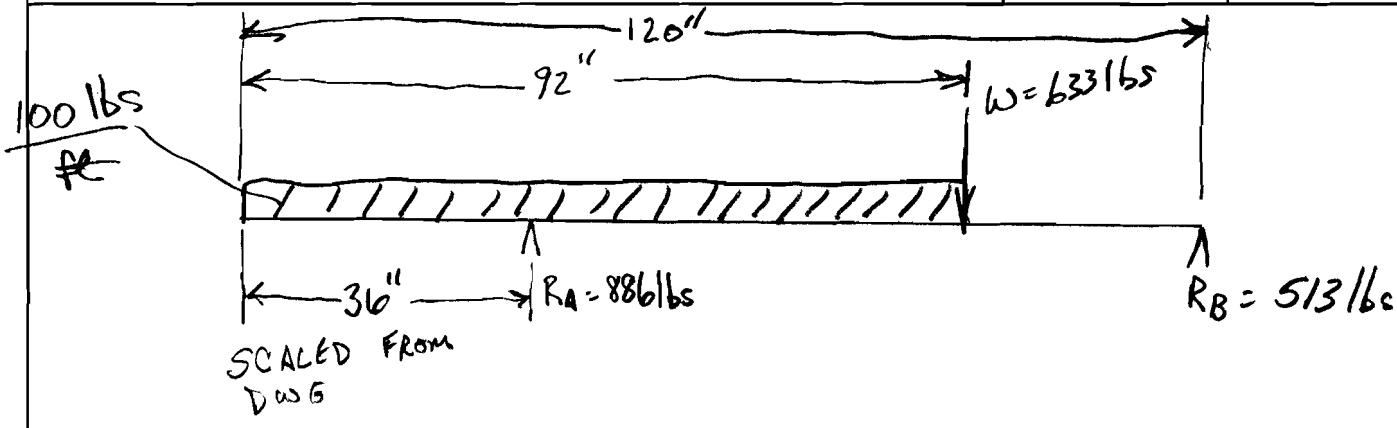
ASSUME 76" PIECE HAS NO CONNECTION AT TOP AND ALL WEIGHT IS TRANSFERED DIRECTLY TO HORIZONTAL BEAM

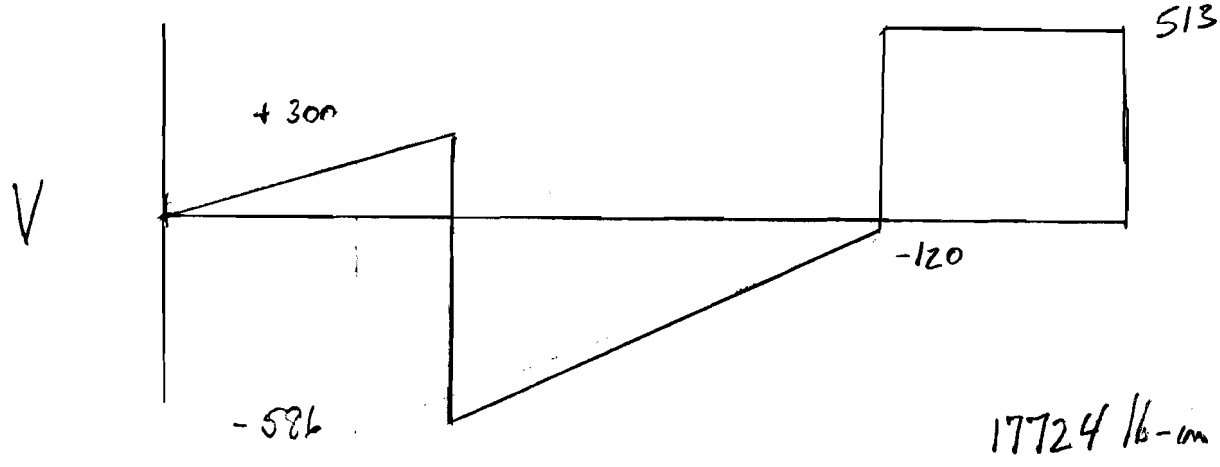
LOOK AT HORIZONTAL BEAM FIRST.

FIND W.

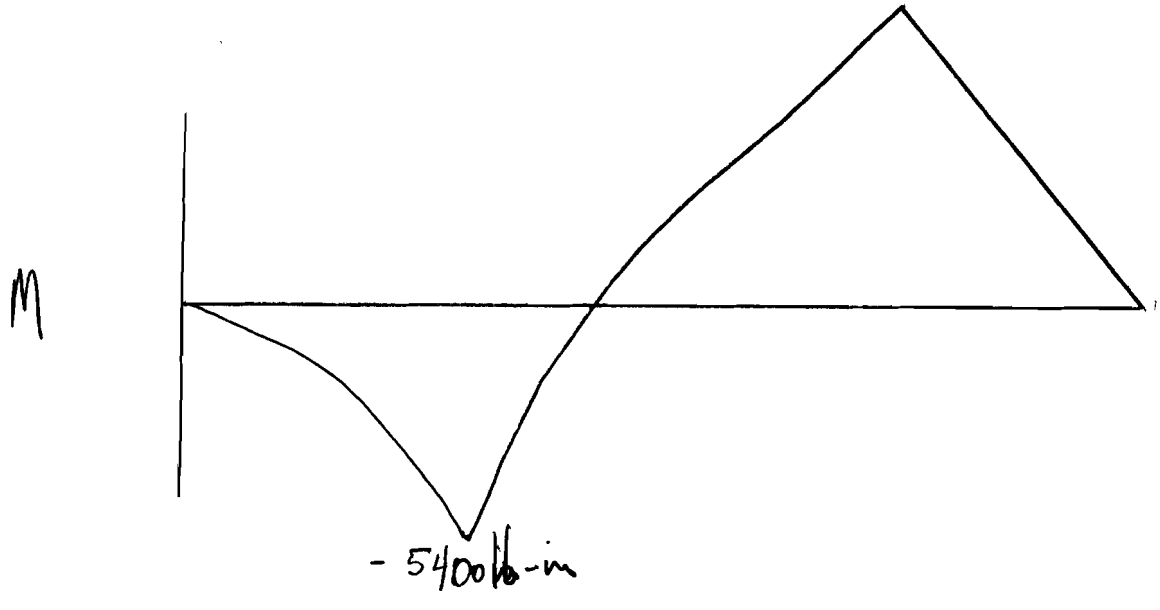
IN THIS AREA 1-20 WIDE AND 1-28 WIDE ARE USED. HOWEVER FOR OVER ESTIMATE USE 100 lb/ft HERE TOO.

$$W = \left(\frac{100\,lb}{ft}\right)\left(\frac{76\,in}{12\,in/ft}\right) = 633\ lbs.$$


120"
92"
W = 633 lbs
100 lbs/ft
36"
R_A = 886 lbs
R_B = 513 lbs
SCALED FROM DWG


V
+ 300
513
-120
- 586

17724 lb-in


M
- 5400 lb-in

$\Sigma M_A = 0 \quad R_B(84'') - (633\,lbs)(56'') - \left(100\frac{lb}{ft}\right)\left(\frac{92''}{12''/ft}\right)(46''-36'') = 0$

$R_B(84'') = 35448\ in\,lbs + 7666.7\ in\,lbs$

$= 43114\ in\,lbs$

$R_B = 513.3\ \underline{lbs}$

$\Sigma M_B = 0 \quad R_A(84'') - (633\,lbs)(28\,in) - \left(100\frac{lb}{ft}\right)\left(\frac{92''}{12''/ft}\right)(120''-46'') = 0$

$R_A(84'') = 17{,}724\ in\,lbs + 56728$

$R_A(84'') = 74452\ in\,lbs$

$R_A = 886\ lbs$

Check

$R_A + R_B = 633\,lbs + \left(100\,lbs/ft\right)\left(\frac{92''}{12''/ft}\right)$

$1399.26 = 1399.66 \Rightarrow OK$

find M_A $\quad M_a + \left(100\,lb/ft\right)\left(\frac{36\,in}{12\,in/ft}\right)\left(\frac{36\,in}{2}\right) = 0$

$M_a = -5400\ lb\text{-}in$

$$\text{MAX } \sigma = \frac{M_{MAX}}{S} = \frac{17724 \text{ lb in}}{1.41 \text{ in}^3}$$

$$= 12{,}570 \text{ PSI}$$

FOR THIS TUBING $F_y = 46{,}000$ PSI

$$SF = \frac{46{,}000}{12{,}570} = 3.66 \Rightarrow \text{OK.}$$

NOTICE NO ACCOUNT WAS TAKEN OF GUSSETS SHOWN ON THE SKETCH.

NOW CHECK COLUMN

TOTAL LOAD IS THUS R_A = 886 lbs IN COMPRESSION

$$\text{COMPRESSION } \sigma = \frac{F}{A} = \frac{886 \text{ lbs}}{1.40 \text{ in}^2}$$

$$= 632 \text{ PSI}$$

THIS WILL BE FINE.

NOTE THAT FOR A COLUMN 4" X 2" X 3/16" WALL 7 ft TALL AISC ALLOWS 27,000 lb LOAD WHICH WOULD RESULT IN A COMPRESSIVE STRESS

$$\sigma = \frac{F}{A} = \frac{27{,}000 \text{ lbs}}{2.02 \text{ in}^2}$$

$$= 13{,}366 \text{ PSI}$$

WE ARE FAR AWAY FROM THAT

TOTAL LOAD ON A STEEL PLATE IN EXCESS OF NORMAL IS SUM OF ALL REACTION LOADS ON PLATE

$$\text{TOTAL } W = 2 \times (1375 \text{ lbs}) + 2(513 \text{ lbs})$$

$$= 3776 \text{ lbs}$$

PLATE WEIGHS 25,000 lbs

$$\frac{3776 \text{ lbs}}{25000 \text{ lbs}} = 15\%$$

CHECK NOMINAL LOADS AGAINST EXTRA LOADS

AREA OF FAR RAILS

$A = 2'' \times 1'' \times 2$ (2 RAILS WITH 2" WIDTH AND 1" THICK PLATE.)
$= 4 \text{ in}^2$

NOMINAL COMPRESSIVE σ

$$\sigma = \frac{F}{A} = \frac{25000 \text{ lbs}}{4 \text{ in}^2}$$

$$= 6250 \text{ PSI}$$

EXTRA LOAD

$$\sigma = \frac{F}{A} = \frac{25000 \text{ lbs} + 3776 \text{ lbs}}{4 \text{ in}^2}$$

$$= 7194 \text{ PSI}$$

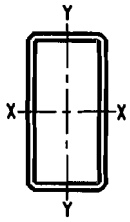
THE STEEL WAS A NOMINAL YIELD VALUE $F_y = 30 \text{ KSI}$

$\therefore$ THE SAFETY FACTOR FOR COMPRESSIVE LOAD IS

$$SF = \frac{30 \text{ KSI}}{6250} = 4.8$$

$$SF = \frac{30 \text{ KSI}}{7194} = 4.17$$

THIS SAFETY FACTOR (4.17) IS ACCEPTABLE FOR THE DETECTOR.



STRUCTURAL TUBING
Rectangular
Dimensions and properties

Dimensions				Properties**									
					X-X Axis				Y-Y Axis				
Nominal* Size	Wall Thickness		Weight per ft	Area	*I*	*S*	*Z*	*r*	*I*	*S*	*Z*	*r*	*J*
in.	in.		lb	in.^{2}	in.^{4}	in.^{3}	in.^{3}	in.	in.^{4}	in.^{3}	in.^{3}	in.	in.^{4}
5×2	0.3125	5/16	12.70	3.73	9.74	3.90	5.31	1.62	2.16	2.16	2.70	0.762	6.24
	0.2500	1/4	10.51	3.09	8.48	3.39	4.51	1.66	1.92	1.92	2.32	0.789	5.43
	0.1875	3/16	8.15	2.39	6.89	2.75	3.59	1.70	1.60	1.60	1.86	0.816	4.40
	0.1250	1/8	5.61	1.65	4.96	1.98	2.53	1.73	1.17	1.17	1.32	0.844	3.15
4×3	0.3125	5/16	12.70	3.73	7.45	3.72	4.75	1.41	4.71	3.14	3.88	1.12	9.89
	0.2500	1/4	10.51	3.09	6.45	3.23	4.03	1.45	4.10	2.74	3.30	1.15	8.41
	0.1875	3/16	8.15	2.39	5.23	2.62	3.20	1.48	3.34	2.23	2.62	1.18	6.67
	0.1250	1/8	5.61	1.65	3.76	1.88	2.25	1.51	2.41	1.61	1.85	1.21	4.68
4×2	0.3750	3/8	12.17	3.58	5.75	2.87	4.00	1.27	1.83	1.83	2.39	0.715	4.97
	0.3125	5/16	10.58	3.11	5.32	2.66	3.60	1.31	1.71	1.71	2.17	0.743	4.58
	0.2500	1/4	8.81	2.59	4.69	2.35	3.09	1.35	1.54	1.54	1.88	0.770	4.01
	0.1875	3/16	6.87	2.02	3.87	1.93	2.48	1.38	1.29	1.29	1.52	0.798	3.26
	0.1250	1/8	4.75	1.40	2.82	1.41	1.77	1.42	0.954	0.954	1.09	0.826	2.34
3×2	0.3125	5/16	8.45	2.48	2.44	1.63	2.20	0.992	1.26	1.26	1.64	0.714	2.97
	0.2500	1/4	7.11	2.09	2.21	1.47	1.92	1.03	1.15	1.15	1.44	0.742	2.63
	0.1875	3/16	5.59	1.64	1.86	1.24	1.57	1.06	0.977	0.977	1.18	0.771	2.16
	0.1250	1/8	3.90	1.15	1.38	0.920	1.13	1.10	0.733	0.733	0.855	0.800	1.57
2½×1½	0.2500	1/4	5.41	1.59	1.05	0.844	1.15	0.815	0.458	0.610	0.793	0.537	1.14
	0.1875	3/16	4.32	1.27	0.920	0.736	0.964	0.852	0.405	0.540	0.669	0.565	0.976

*Outside dimensions across flat sides.
**Properties are based upon a nominal outside corner radius equal to two times the wall thickness.

BARS AND PLA

Product Availabi
Plates are readily
A3.1 of the AISC
A514, and A852.
shows the availab
The Manual us
Structural Steel, f

Classification
Bars and plates ar

Bars: 6 in. or le
Over 6 in
Plates: Over 8 i
Over 48

Bars
Bars are available
practice is to spec
increments.

Plates
Defined according
Sheared plates a
all edges.
Universal (UM)
(sheared or gas cut
Stripped plates a
sheared plates.

Sizes
Plate mills are loca
and the catalogs of i
of UM plates curre
availability togethe
before specifying.

Widths: Vario
the m
Thickness: 1/32-in
1/16-in
1/8-in.
1/4-in.

Ordering
Plate thickness may
edge thickness can
each method.