Fermilab

Particle Physics Division

Mechanical Department Engineering Note

Number: MD-ENG-550 Date: 07/12/2016

Project: MicroBooNE

Project Internal Reference:

Title: MicroBooNE Underside Tagger Panels Installation

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Reviewer(s): M. Geynisman *Michael Geynisman* 07-15-2016

Key Words: Strut, Design

Abstract/Summary:

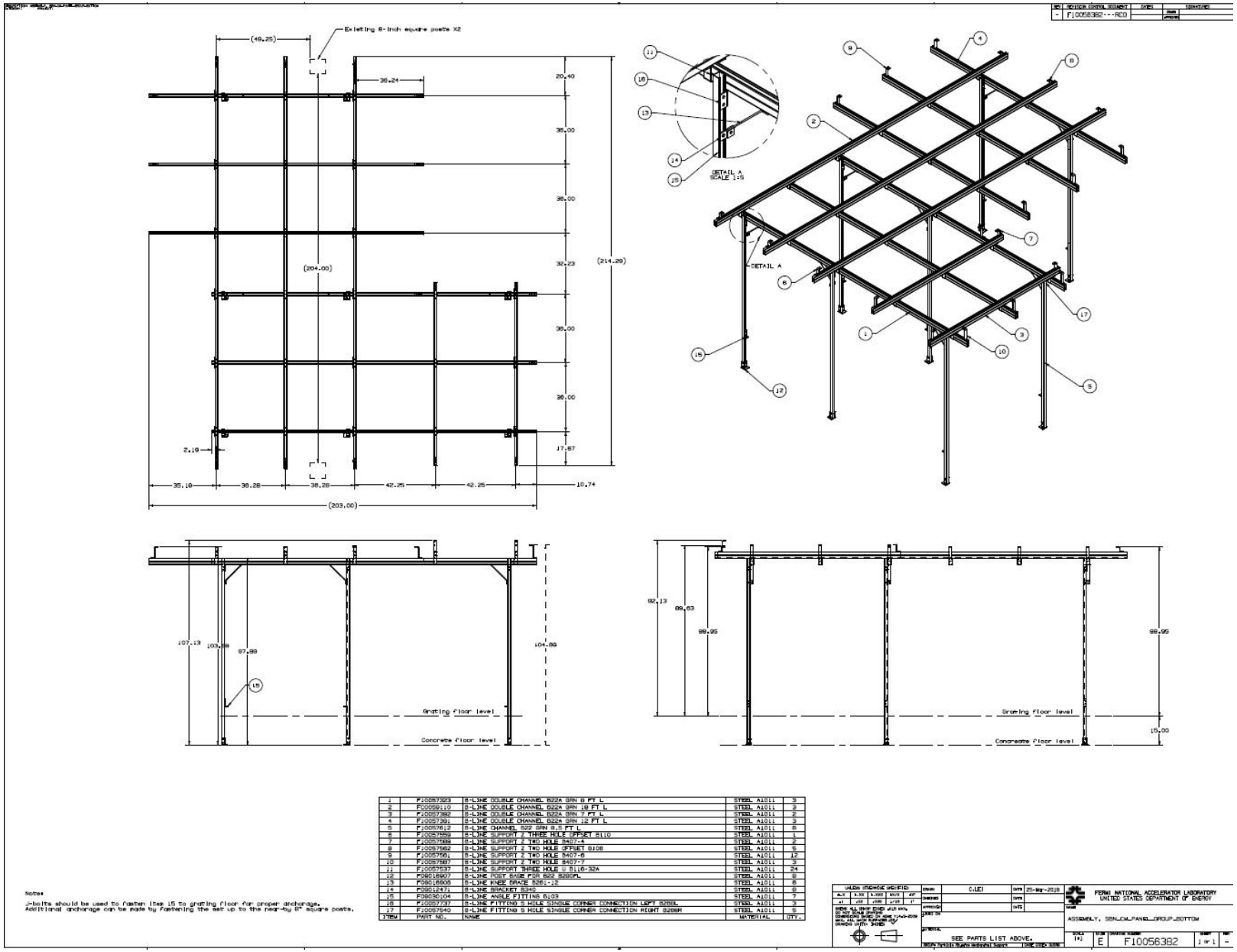
Two layers of muon tagger panels are planned to be installed on the bottom side of the Liquid Argon Time Projection Chamber (LArTPC) within the Liquid Argon Test Facility (LArTF). These panels are supported by a framing structure consisting of the commercial strut products made by B-line. The top grid of this framing structure is made of back-to-back double strut, and it will have 8 supporting legs made of single strut. The scintillator panels sets on top of the top grid of the frame. This note shows the structure is designed to handle the 2500 lb weight of the panels as well as its own weight.

1. Design of the Underside panels support

The support assembly is shown in Figure 1. It is made of a set of commercial parts of struts provided by B-line and contains no custom-made items. It consists of 8 pieces of B22 steel strut channels as the columns, and a set of double channels B22A for the table top manifold. This support assembly then supports a set of scintillating panels with a total weight about 2,500 lbs on top. The total weight of the top grid of the frame of double channels B22A is 565 lb. Figure 2 shows info on the strut from the B-line catalog. This design is based on the panel handling experiences in which 1 cm is allowed to be deflected within 1 m span, therefore the collaborators have asked that the panels be supported at a 1 meter spacing.

2. Allowable Stress

Referring to the channel information provided by B-line (http://www.cooperindustries.com/content/dam/public/bline/Resources/Library/catalogs/bolted_framing/strut_systems/Channel.pdf), the design loads given for strut beam loads are based on a simple beam condition using an allowable stress of 25,000 psi. This allowable stress results in a safety factor of 1.68.



ITEM	PART NO.	NAME	MATERIAL	QTY.
1	F10057323	8-LINE DOUBLE CHANNEL B22A BRN 8 FT L	STEEL A1011	3
2	F10059110	8-LINE DOUBLE CHANNEL B22A BRN 18 FT L	STEEL A1011	3
3	F10057362	8-LINE DOUBLE CHANNEL B22A BRN 7 FT L	STEEL A1011	2
4	F10057391	8-LINE DOUBLE CHANNEL B22A BRN 12 FT L	STEEL A1011	3
5	F10057612	8-LINE CHANNEL B22 BRN 9.5 FT L	STEEL A1011	8
6	F10057589	8-LINE SUPPORT 2 THREE HOLE UPPER B110	STEEL A1011	1
7	F10057588	8-LINE SUPPORT 2 TWO HOLE B407-4	STEEL A1011	2
8	F10057582	8-LINE SUPPORT 2 TWO HOLE UPPER B108	STEEL A1011	5
9	F10057581	8-LINE SUPPORT 2 TWO HOLE B407-6	STEEL A1011	12
10	F10057587	8-LINE SUPPORT 2 TWO HOLE B407-7	STEEL A1011	3
11	F10057537	8-LINE SUPPORT THREE HOLE U B116-32A	STEEL A1011	24
12	F09016807	8-LINE POST BASE FOR B22 B280PL	STEEL A1011	8
13	F09016806	8-LINE KNEE BRACE B261-12	STEEL A1011	8
14	F09012471	8-LINE BRACKET B340	STEEL A1011	8
15	F09030104	8-LINE ANGLE FITTING B103	STEEL A1011	7
16	F10057737	8-LINE FITTING 5 HOLE SINGLE CORNER CONNECTION LEFT B288L	STEEL A1011	3
17	F10057540	8-LINE FITTING 5 HOLE SINGLE CORNER CONNECTION RIGHT B288R	STEEL A1011	5

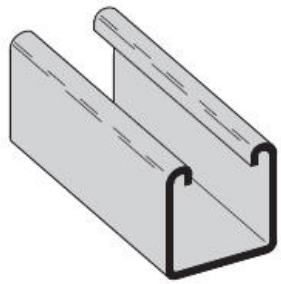
Figure 1. Support Assembly for Underside Panels

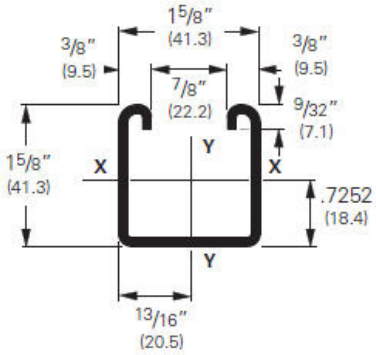
B22 Channel

B22

- Thickness: 12 Gauge (2.6 mm)
- Standard lengths: 10′ (3.05 m) & 20′ (6.09 m)
- Standard finishes: Plain, DURA GREEN™, Pre-Galvanized, Hot-Dipped Galvanized, Stainless Steel Type 304 or 316, Aluminum
- Weight: 1.90 Lbs./Ft. (2.83 kg/m)

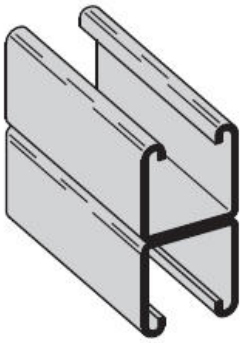
Note:
Aluminum loading, for B22 & B22A, can be determined by multiplying load data times a factor of 0.38





Section Properties					X - X Axis					Y - Y Axis				
Channel	Weight		Areas of Section		Momentof Inertia (I)		Section Modulus (S)		Radius of Gyration (r)	Moment of Inertia (I)		Section Modulus (S)		Radius of Gyration (r)
	lbs./ft.	kg/m	sq. in.	cm^2	$in.^4$	cm^4	$in.^3$	cm^3	in. cm	$in.^4$	cm^4	$in.^3$	cm^3	in. cm
B22	1.910	(2.84)	.562	(3.62)	.1912	(7.96)	.2125	(3.48)	.583 (1.48)	.2399	(9.99)	.2953	(4.84)	.653 (1.66)
B22A	3.820	(5.69)	1.124	(7.25)	.9732	(40.51)	.5989	(9.81)	.931 (2.36)	.4798	(19.97)	.5905	(9.68)	.653 (1.66)
B22X	6.649	(9.89)	1.956	(12.62)	4.1484	(172.67)	1.7019	(27.89)	1.456 (3.70)	1.1023	(45.88)	1.2027	(19.71)	.751 (1.91)

Calculations of section properties are based on metal thicknesses as determined by the AISI Cold-Formed Steel Design Manual.



B22A
Wt. 3.80 Lbs./Ft. (5.65 kg/m)

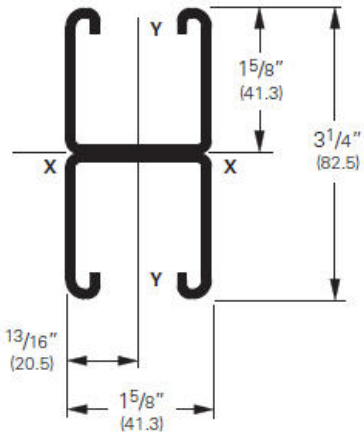
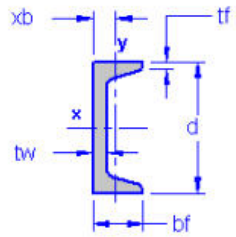


Figure 2. Properties of Channel B22 and Double Channel B22A

3. Installation of the Underside panels

Two steel 7-inch C-channels (C7x14.75) with properties as shown in figure 3 will be used for the installation, and raising of the structure into place. Once in place the 8 legs will be installed, and the lifting fixture removed. For more information on the lifting fixture, reference PPD – Doc #2181.



in x lb/ft	Area (in^2)	d (in)	bf (in)	tf (in)	tw (in)	Ixx (in^4)	Iyy (in^4)	xb (in)
C15x50	14.7	15	3.716	0.65	0.716	404	11	0.798
C15x40	11.8	15	3.52	0.65	0.52	349	9.23	0.777
C15x33.9	9.96	15	3.4	0.65	0.4	315	8.13	0.787
C12x30	8.82	12	3.17	0.501	0.51	162	5.14	0.674
C12x25	7.35	12	3.047	0.501	0.387	144	4.47	0.674
C12x20.7	6.09	12	2.942	0.501	0.282	129	3.88	0.698
C10x30	8.82	10	3.033	0.436	0.673	103	3.94	0.649
C10x25	7.35	10	2.886	0.436	0.526	91.2	3.36	0.617
C10x20	5.88	10	2.739	0.436	0.379	78.9	2.81	0.606
C10x15.3	4.49	10	2.6	0.436	0.24	67.4	2.28	0.634
C9x20	5.88	9	2.648	0.413	0.448	60.9	2.42	0.583
C9x15	4.41	9	2.485	0.413	0.285	51	1.93	0.586
C9x13.4	3.94	9	2.433	0.413	0.233	47.9	1.76	0.601
C8x13.75	4.04	8	2.343	0.39	0.303	36.1	1.53	0.553
C8x11.5	3.38	8	2.26	0.39	0.22	32.6	1.32	0.571
C7x14.75	4.33	7	2.299	0.366	0.419	27.2	1.38	0.532
C7x12.25	3.6	7	2.194	0.366	0.314	24.2	1.17	0.525

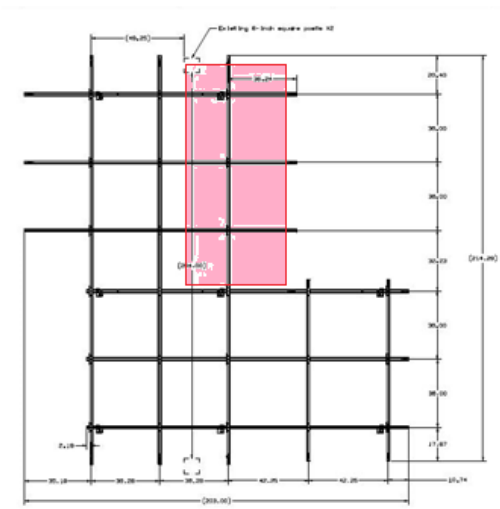
4. Stress Calculations of the Frame

These Calculations show the frame is more than adequate to support the load, all stress values are below allowable limits, and the structure is resistant to buckling.

Stress Calcs of Top Grid Frame:

For stress calcs, we look at the longest span between legs supports, and the representative load on this span, as shown below.

$Area_{Panels} := 32329in^2$ $\quad weight_{panels} := 2500lbf$ $\quad \rho_{Panels} := \frac{weight_{panels}}{Area_{Panels}} = 11.136\frac{lbf}{ft^2}$



$\rho_{B22A} := 3.8\frac{lbf}{ft}$

$width_{section} := 36.24in + 36.28\frac{in}{2} = 4.532ft$

$span := 36in + 36in + 32.23in = 8.686ft$

$area_{panelSection} := span \cdot width_{section} = 3.657m^2$

$weight_{PanelSection} := area_{panelSection} \cdot \rho_{Panels} = 438.308lbf$

$weight_{strut} := width_{section} \cdot 3 \cdot \rho_{B22A} + span \cdot \rho_{B22A} = 84.667lbf$

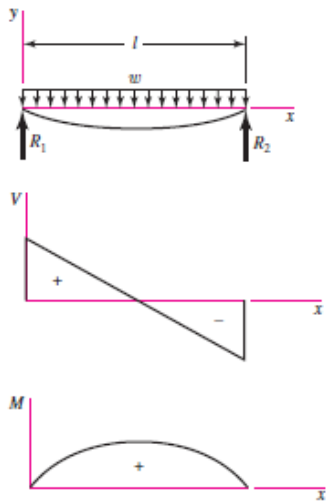
$Total_{Load} := weight_{PanelSection} + weight_{strut} = 522.975lbf$

We assume a distributed load on this strut piece and show calculations for stress of the strut piece underneath.

$I_{B22A} := 0.9732in^4$ $\quad distributed_{weight} := \frac{Total_{Load}}{span} = 60.21\frac{lbf}{ft}$ $\quad E_{steel} := 200GPa$

Calculations for Stress and Deformation - Uniform Distributed Load

7 Simple supports—uniform load



$$R_1 = R_2 = \frac{wl}{2} \qquad V = \frac{wl}{2} - wx$$

$$M = \frac{wx}{2}(l - x)$$

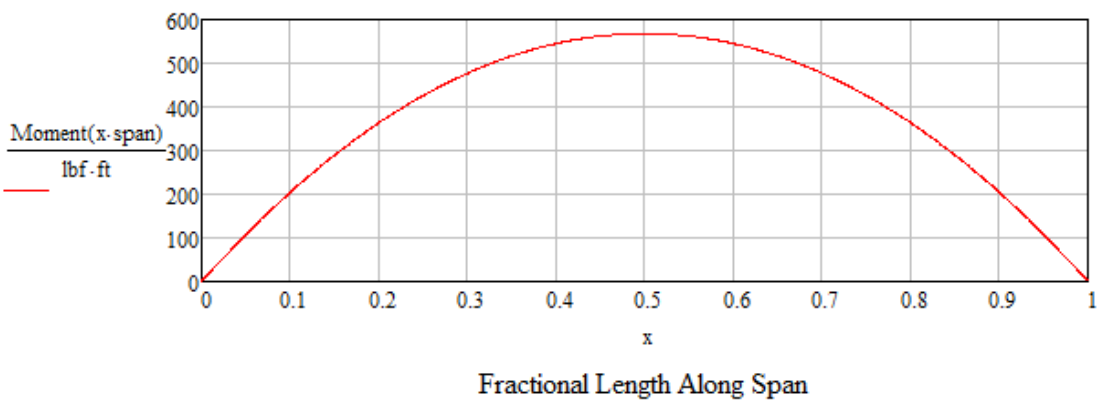
$$y = \frac{wx}{24EI}(2lx^2 - x^3 - l^3)$$

$$y_{max} = -\frac{5wl^4}{384EI}$$

$$R_1 := \text{distributed}_{\text{weight}} \cdot \frac{\text{span}}{2} = 261.488 \cdot \text{lbf}$$

$$\text{Moment}(x) := \frac{\text{distributed}_{\text{weight}} \cdot x}{2} \cdot (\text{span} - x)$$

$$\text{Max}_{\text{Moment}} := \text{Moment}\left(\frac{\text{span}}{2}\right) = 567.81\,\text{lbf} \cdot \text{ft}$$

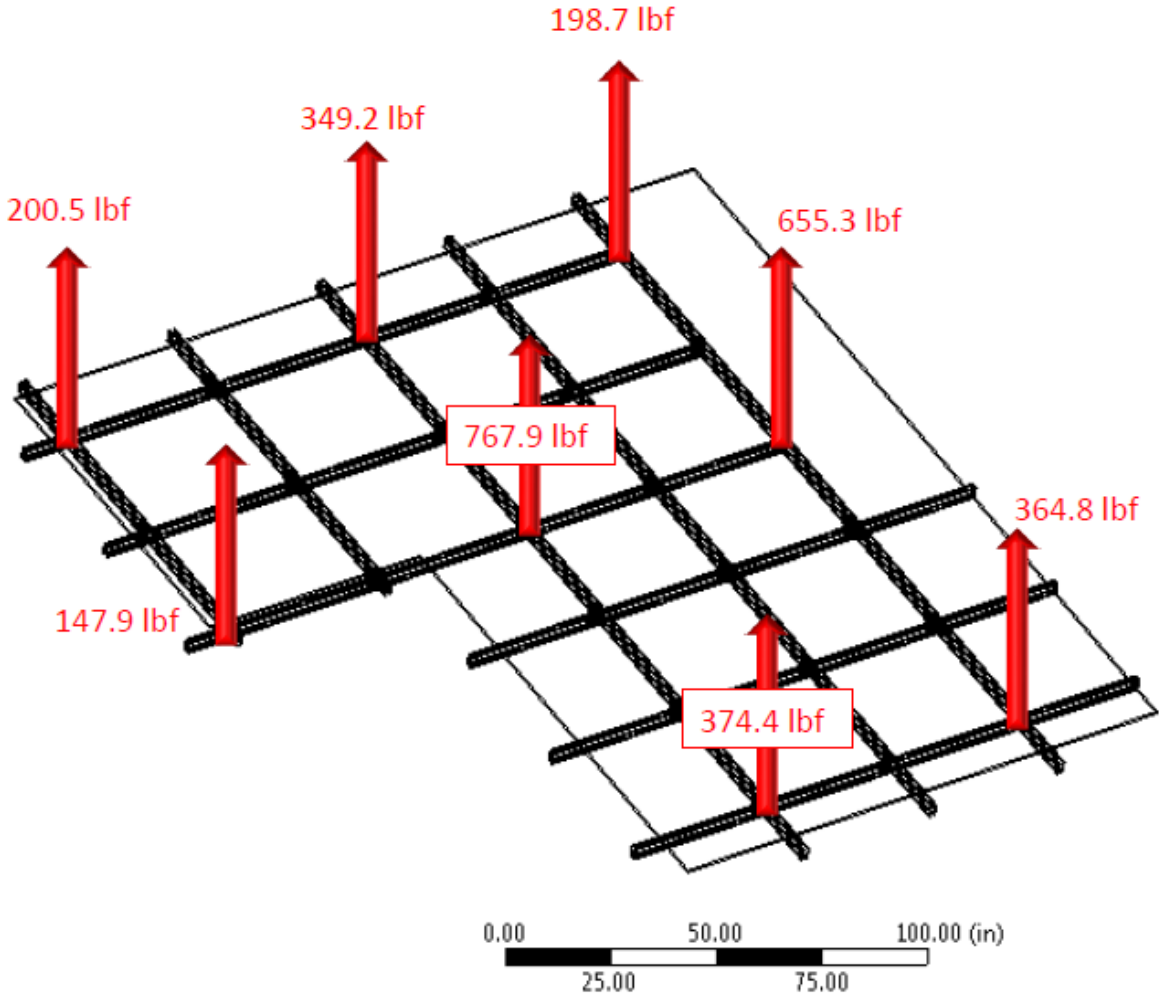


$$\sigma_{\text{bending}} := \frac{\text{Max}_{\text{Moment}} \cdot 1.625\text{in}}{I_{B22A}} = 11.377\,\text{ksi}$$

This is below the allowable of 25 ksi according to the manufacturer of the B-Line strut.

Stress Calcs of 8 Legs:

Results of an FEA of the top grid and panels, performed by Kathrine Cipriano, shows the reaction forces at the 8 legs. We analyze the central leg, which has the highest load.



$max_{LegLoad} := 768lbf$ $\quad area_{B22} := 0.562in^2$ $\quad I_{B22} := 0.1912in^4$ $\quad Length_{Leg} := 103in$

$$\sigma_{compressive} := \frac{max_{LegLoad}}{area_{B22}} = 1.367\,ksi$$

Far below the 25 ksi allowable

Buckling Resistance *We say the two ends are pinned, but in reality, they will not be free to rotate, and would be more like fixed supports. We have a 6.7x safety factor against buckling.*

$K_{end} := 1$

$$Buckling_{Force} := \frac{\pi^2 \cdot E_{steel} \cdot I_{B22}}{(K_{end} \cdot Length_{Leg})^2} = 5159.697\,lbf \qquad SF_{Buckling} := \frac{Buckling_{Force}}{max_{LegLoad}} = 6.718$$

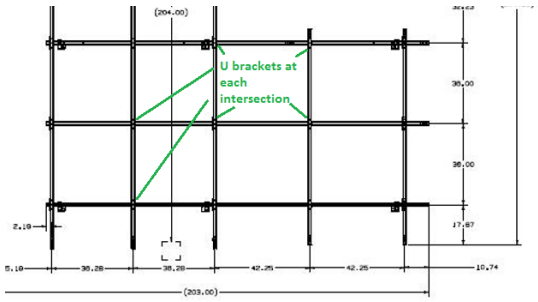
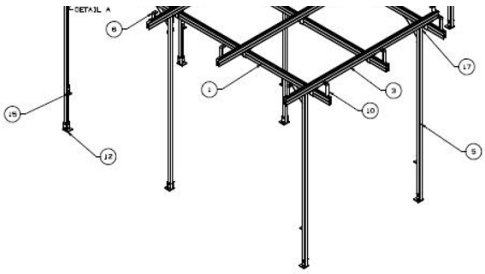
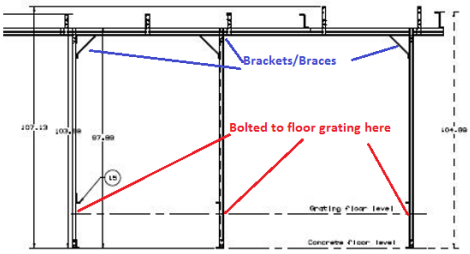
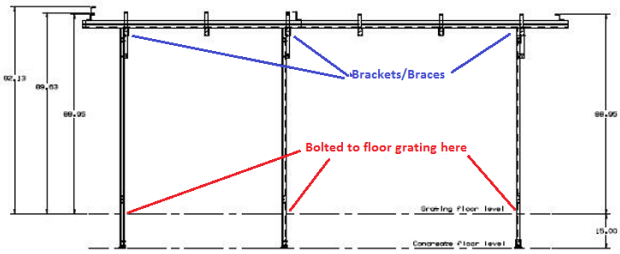
Email exchange between M Geynisman and E Voirin

-----Original Message-----
From: Michael G Geynisman
Sent: Friday, July 15, 2016 7:46 AM
To: Erik A Voirin <evoirin@fnal.gov>
Subject: Eng note

Erik,

How the frame is assembled together? If welded, are any stress concentrations or reducing safety factors that need to be accounted for?

Michael Geynisman

The assembly uses B-line fasteners and is bolted together with angle brackets support angles. U brackets hold the grid to one another.
The largest stress concentrations are at the contact points of the two grids where they intersect, but they are not high enough to be concerning.

As far as tipping over, the legs ore connected to the top grid firmly, and with braces. The bottom of the legs are resting on the floor, and are inserted into grating (2 ft deep) thus bracing against the grating at the floor level.