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

Author(s): C. M. Lei

Reviewer(s):

Key Words: strut, Design

Abstract/Summary:

Two layers of muon tagger panels are planned to install 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 table-top manifold of this framing structure, with a set of panels on top, was firstly attempted to be lifted by two 7-inch C-channels but it appeared the deflection was too much then stopped immediately. FEA are run to verify this lifting condition, and confirm it will be much better if it is lifted with the C-channels bending in the strong axis.

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 all other miscellaneous parts including those double channels B22A, as indicated in Figure 2, is about 1,000 lbs, but the weight of the table-top manifold is about 740 lbs. This design is based on the panel handling experiences in which 1 cm is allowed to be deflected within 1 m span.

2. Allowable Load

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.

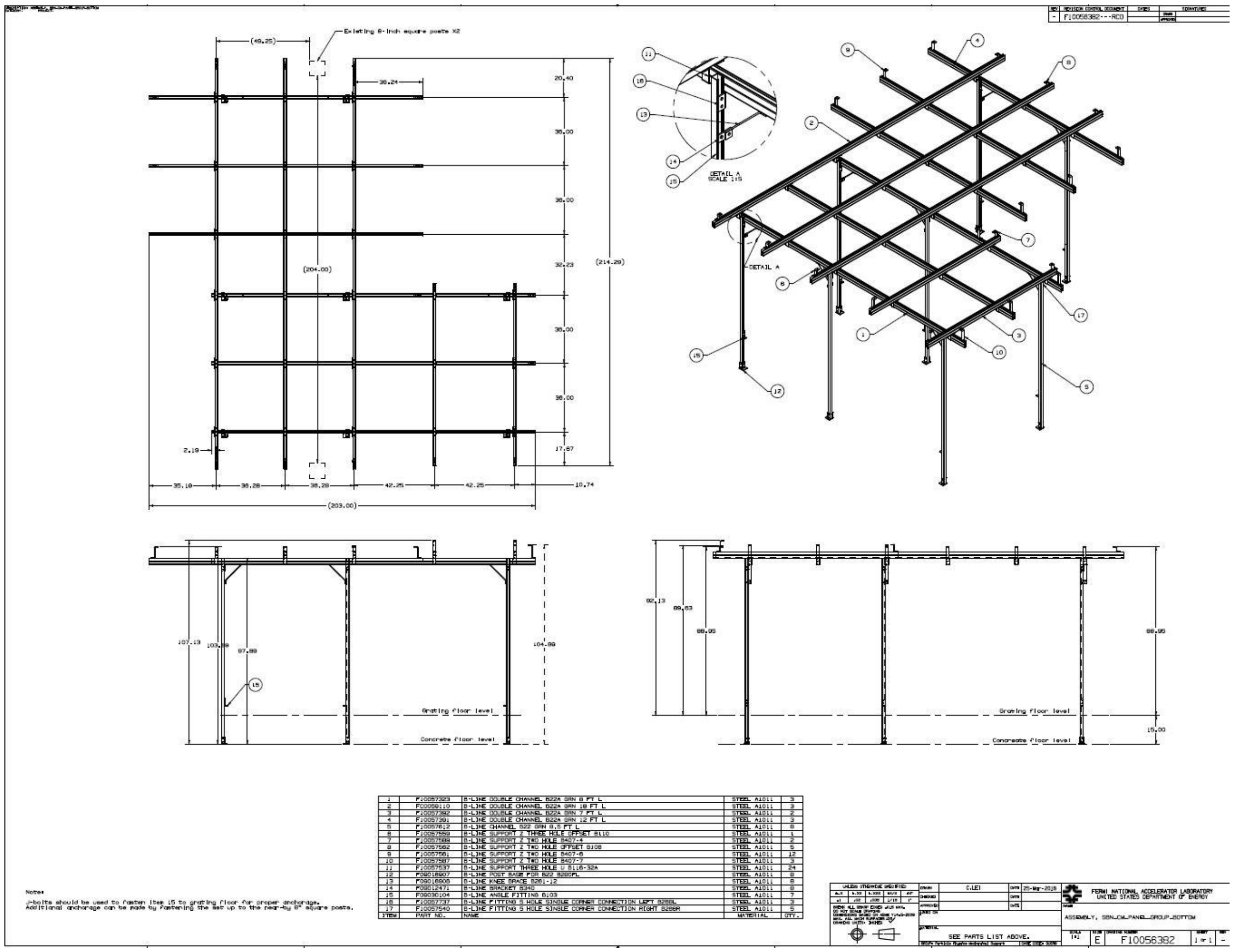


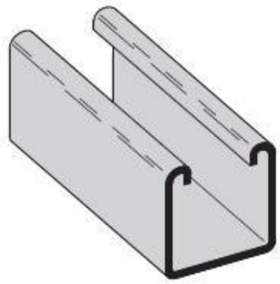
Figure 1. Support Assembly for Underside Panels

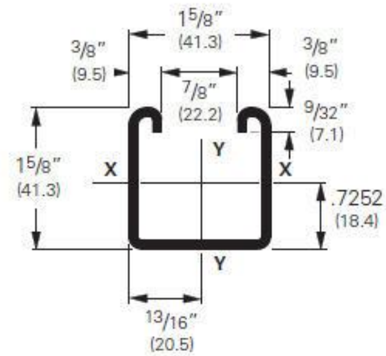
B22 Channel

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)

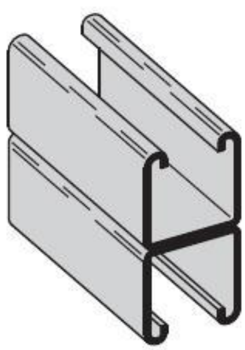
Note:
Aluminum loading, for B22 & B22A, can be determined by multiplying load data times a factor of 0.38





Section Properties			X - X Axis			Y - Y Axis		
Channel	Weight lbs./ft. (kg/m)	Areas of Section sq. in. (cm²)	Momentof Inertia (I) in.⁴ (cm⁴)	Section Modulus (S) in.³ (cm³)	Radius of Gyration (r) in. (cm)	Moment of Inertia (I) in.⁴ (cm⁴)	Section Modulus (S) in.³ (cm³)	Radius of Gyration (r) 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)

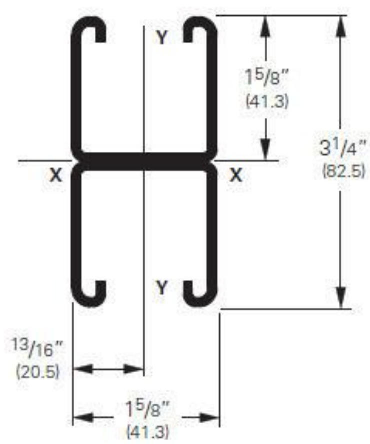
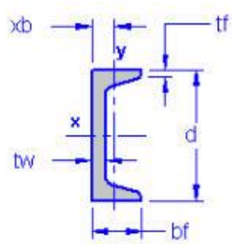


Figure 2. Properties of Channel B22 and Double Channel B22A

3. Installation of the Underside panels

Two steel 7-inch C-channels (C7x12.25) with properties as shown in the last row in Figure 3 were used for the installation. Each channel weighs about 230 lbs, and the ratio of moment of inertia about the strong axis against the weak axis is about 20.7 times. The table-top manifold framing was set on these two C-channels at site first then the scintillating panels were added on top. 12 contacts were thus made among the C-channels and the table-top manifold channels during lifting. The total weight being lifted is about 3,700 lbs and four hoists with 1,000 lbs capacity were attached to the ends of the C-channels. A set of Z brackets which were planned to capture the panels properly without shifting in case of tilting during the lifting process was eventually not used because it was believed that the panels could be raised slowly and carefully with the aid of some level gauges sitting on the panels.



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

Figure 3. Properties of Steel Channels

Attempt was made to lift the Underside panels first with the steel C-channels setting in the weak axis. However, the process was stopped right away as soon as an excessive deflection of the C-channels was observed. A FEA was done to look at the deformation and stresses in this lifting condition. Since the panels were never completely lifted and hence the stress values would have been lower for the real case, this FEA thus represents the worst case analysis of this installation.

The deflection of C-Channel is shown in Figure 4. The C-Channel deformation is found high enough that the table-top manifold was only supported at the two end pieces, with none of the central strut pieces touching the C-channel as circled in Figure 5. The maximum deflection is found to be about 2.7" while the deflection of the near-by support, which is about 40 inches apart, is 1.8". The relative deflection is thus about 0.9" and thus it appears the deflection along this section may have exceeded the allowable deflection of 0.4" for the panels. However, this region is assigned to support two small panels on top. In fact, several pieces of 2x6 wood spacers are placed there in between the small panels and the double channels. In view of the lifting process was actually never completed and the wood spacers and small panels were sitting there freely, the small panels might not get damaged.

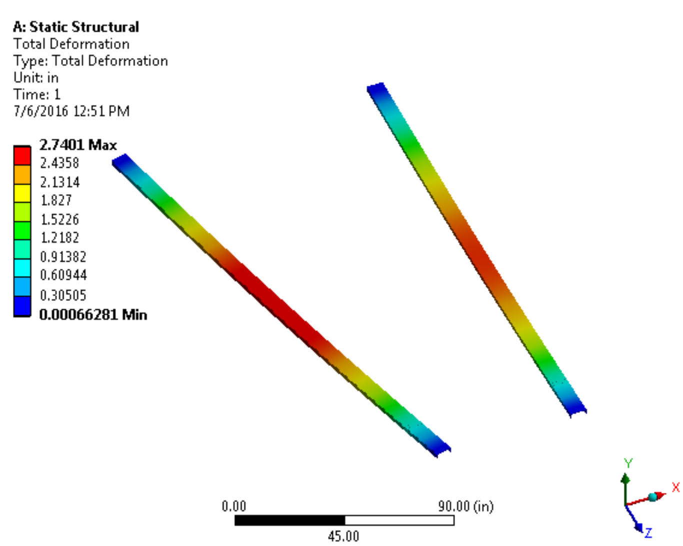


Figure 4. Deflection of C-Channels when Lifting in Weak Axis

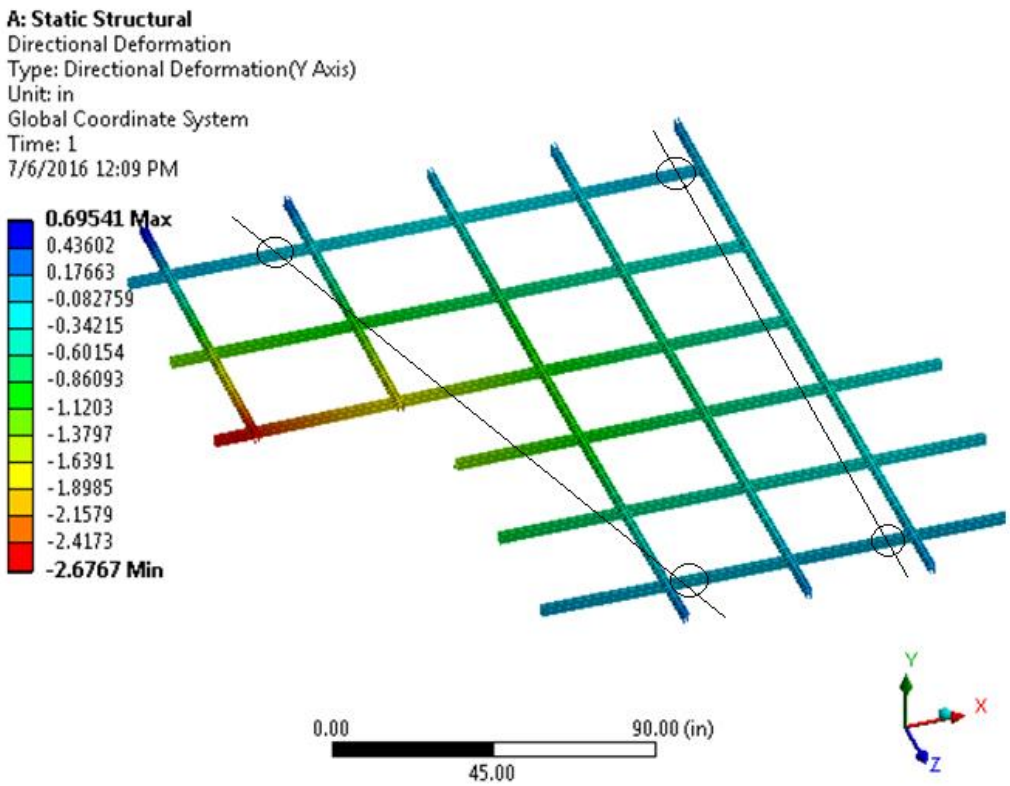


Figure 5. The Deflection of the Table-Top Manifold when Lifting in Weak Axis

The bending moments acting on the double channels are shown in Figure 6 in which it shows the maximum on the double channel is 11420 in*lbf. As the allowable bending moment is 14360 in*lbs as provided by the vendor, the double channel was in the elastic region, and did not sustain any permanent deformation. The corresponding bending stress due to this maximum bending moment can be calculated and it is equal to 19 ksi, which is also less than the allowable stress of 25 ksi as suggested by the vendor.

The resultant stresses from FEA is as shown in Figure 7. The maximum value over there is due to the FEA singularity, (the intersection of two infinitely sharp corners at one node.), and thus it is only numerical and should be ignored. Referring to the color scale, central piece (3 of 5) has the highest bending stress around 19 ksi which agrees with the bending moment results.

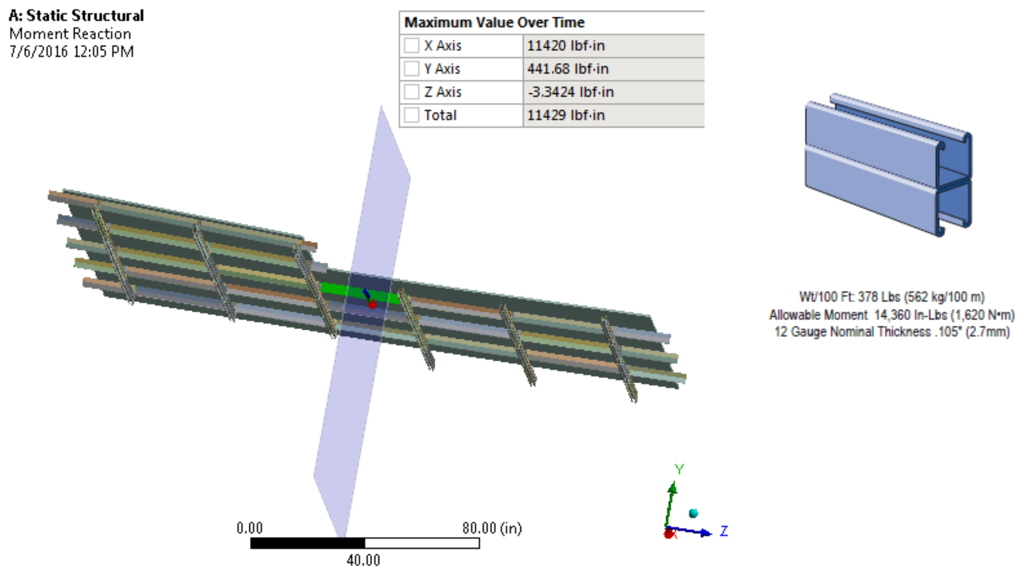


Figure 6. The Bending Moment on the Table-Top Manifold when Lifting in Weak Axis

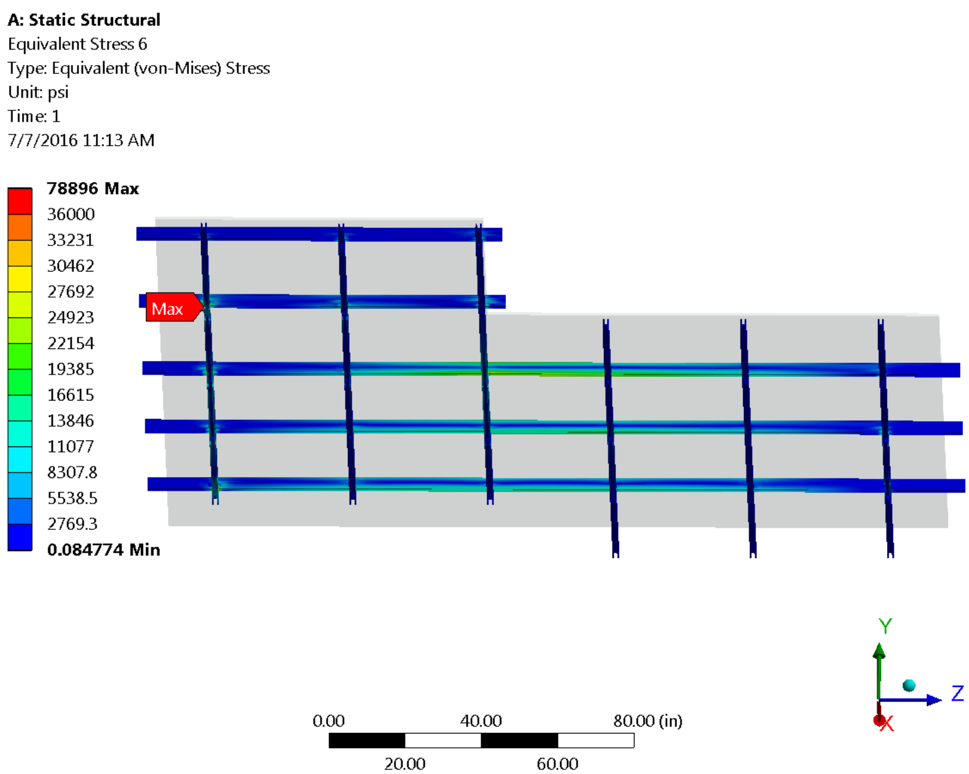


Figure 7. The Stresses of the Table-Top Manifold when Lifting in Weak Axis

Another attempt can be made to lift the Underside panels with the steel C-channels setting in the strong axis. A FEA was also done to look at the deformation and stresses in this lifting condition. The maximum relative deflection, as shown in Figure 8, is found about 0.2" within the neighboring supports. On the other hand, the bending stresses on the C-channels are very low as shown in Figure 9 in which reaction loading to be taken by each hoist is also shown. It should be noted that the reactional loading which is taken by the hoist is close to the hoist capacity. Consideration of changing to a larger capacity hoist should thus be reviewed. This round of FEA confirms that the table-top manifold should be lifted with the steel C-channel setting in the strong axis.

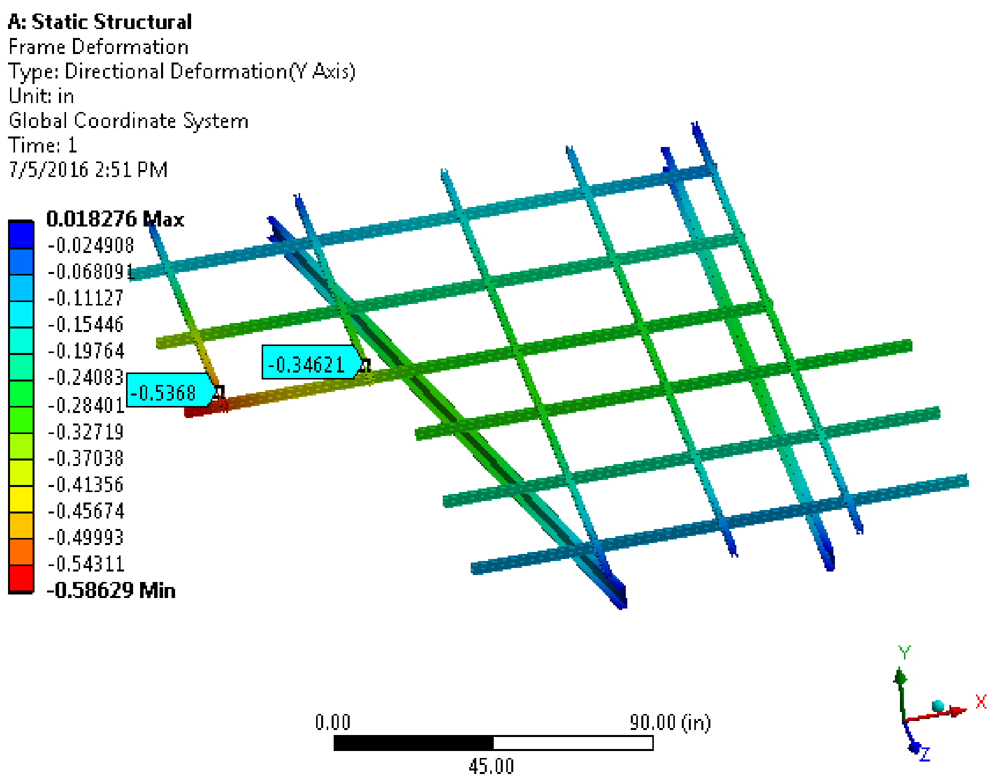


Figure 8. The Stresses of the Table-Top Manifold when Lifting in Strong Axis

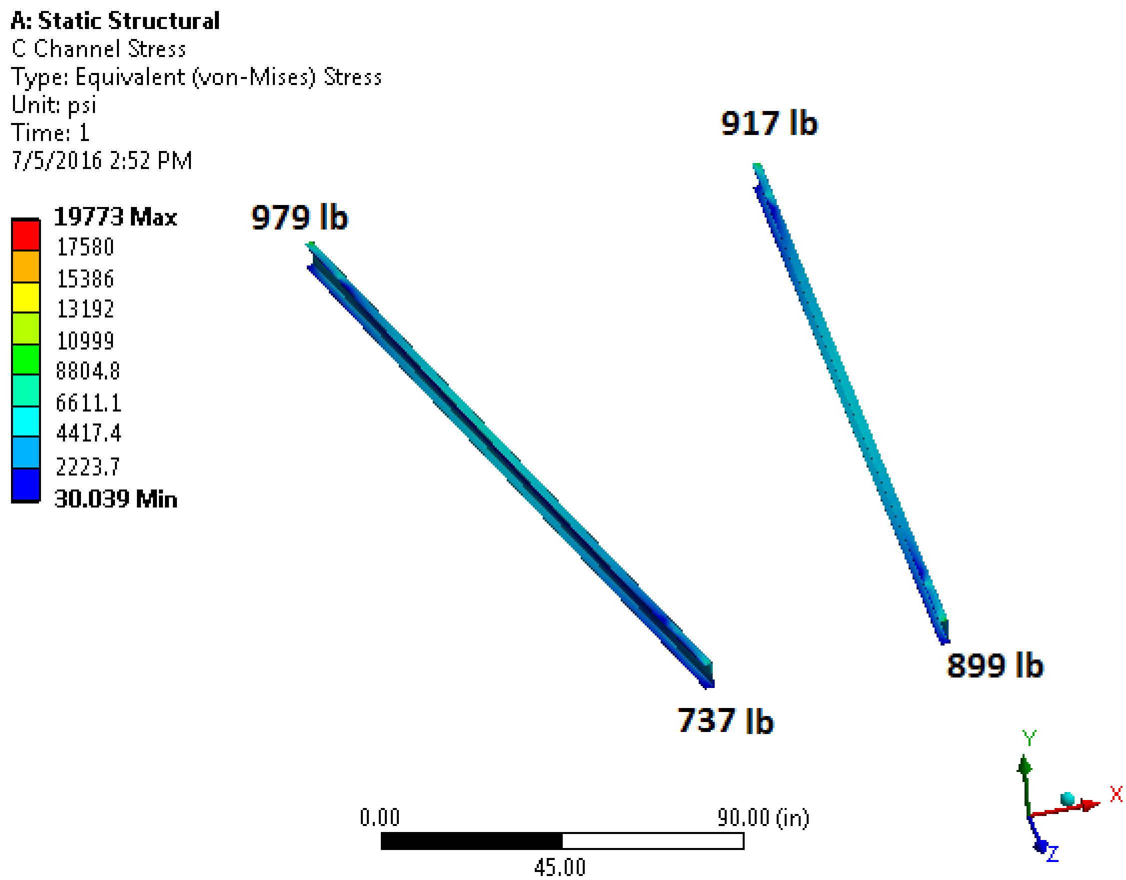


Figure 9. The Stresses of the C-Channels when Lifting in Strong Axis

Summary

While the table-top manifold appears not exceeding the allowable stress in the FEA when it was lifted with the C-channel in the weak axis, the deflection in the corner region might be too excessive. However, it should be noted that this region is to support two small panels on top and thus this deflection may not damage anything. The table-top is much better to be lifted with the C-channel arranged in the strong axis.