Engineering Note
for
E906 Detector Assembly

PROJECT: E906

TITLE: Installation of Station 1 Wire Chamber

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ABSTRACT: This document describes the framework used to install a wire chamber into the E906 beamline.

DESIGN:

The Station 1 wire chamber was designed and built by the University of Colorado. The weight of this chamber is conservatively estimated to be 2000 pounds. There are two lifting fixtures attached to the front and back surfaces faces of this chamber. These lifting fixtures are connected to a turnbuckle and I-beam assembly shown in Figure 1. The entire package will be inserted into the beamline by resting the ends of the bottom surface of this I-beam (type S8 x 6.35) onto the top surface of a pair of cantilevered steel I-beams that are part of an existing structure in the experimental hall.

ANALYSIS:

When the chamber is vertical the lifting assemblies will be mounted to the upstream and downstream faces. The crane in NM4 will be used to hold the I-beam and turnbuckles in place and the turnbuckles will be attached to the lifting assemblies. Note that these parts are not to be used for rotating the chamber from horizontal to vertical. Once fully assembled, the chamber will be inserted into the beamline using the crane in NM4. The chamber, lifting assemblies, turnbuckles, I-beam, and all the fasteners must be strong enough to hang vertically for the duration of the experiment. Each of these components is analyzed separately as follows:

LIFTING FIXTURE:

The fixture used to connect the chamber to the turnbuckles is shown in Figure 2. There are two of these fixtures with face plates attached directly to the front and back faces of the detector using twelve (12) 3/8-16 bolts per fixture. The load on each fixture is 1000-lbs. Therefore the load on each of the 3/8-16 bolt is 83.33-lbs. These bolts are always in shear. With a minor diameter of 0.2970" and an area of 0.069-in^2, the resulting shear stress in each 3/8-16 bolt is roughly 1207.7psi. Grade 5 (alloy A325) bolts are readily available. The allowable shear for these bolts, per the Manual of Steel Construction 9th edition, is 17ksi which is far in excess of these expected actual values.

When the detector is hanging in the beamline each Face Plate will be subject to a load of 500 pounds. This creates tension in the vertical Face Plate segments. The cross section area of each Face Plate is 4.5in^2 and the resulting tension is equal to 111.11psi. This is acceptable for Type 6061 aluminum.

For each Lifting Fixture, the Face Plates are connected to the Chamber/Turnbuckle Mount using eight (8) 3/8x16 bolts. With a load on each fixture of 1000-lbs, the load on each the 3/8-16 bolts is 125-lbs. These bolts are always in tension. With a tensile stress area of 0.0774-in^2 each of these bolts experience a tensile stress of 1615psi. The allowable tension for these bolts, per the Manual of Steel Construction 9th edition, is 44ksi which is far in excess of these expected actual values. There is also a stress on the internal threads of the Face Plates. The length of engagement of the 3/8-16 bolts is greater than 0.75" in all cases. For internal 3/8-16 threads this length of engagement provides a thread shear area of 0.6742in^2 and the resulting shear stress of the internal threads is roughly 185psi, which is acceptable for this alloy.

Each Lifting Fixture is connected to the I-Beam turnbuckle at the Chamber/Turnbuckle Mount, shown in Figure 3. The mount has a 0.38" diameter hole at the top to connect to the turnbuckle. This hole is subjected to a tear out stress. From Figure 3, the load on this hole is 1000 pounds and the tear out stress is 1613psi. The yield shear strength of this alloy is 20ksi and the tear out stress of 1613psi is acceptable. The other end of this block is welded to the endplate, all around, with a fillet weld. The weld has a leg size of $^{3}/_{16}$-inch which corresponds to a throat of 0.133". The effective throat area of this weld is $0.632in^2$ and the 1000 pound load results in a shear of 1582.28psi. The filler material is ER4043 and the allowable shear for this type of weld (Aluminum Design Manual, Part VI, 2010) is 5.9ksi which is well in excess of the expected actual value.

TURNBUCKLE ASSEMBLY:

The turnbuckles connect the Lifting Fixture to the I-beam/Turnbuckle Mount. They are purchased from McMaster Carr (part number 3022T54) and have a certified work load limit of 2,200 pounds. The actual load on each turnbuckle is only 1000 pounds and is well below this limit.

I-BEAM:

The I-Beam is connected to the turnbuckles using the I-Beam/Turnbuckle Mount. See Figure 4. The mount has a 0.38" diameter hole for the turnbuckle. This hole is subjected to a tear out stress. From Figure 4, the load on this hole is 1000 pounds and the tear out stress is 1613psi. The yield shear strength of this alloy is 20ksi and the tear out stress of 1613psi is acceptable. The other end of this block is welded to the endplate, all around, with a fillet weld. The weld has a leg size of $^{3}/_{16}$-inch which corresponds to a throat of 0.133". The effective throat area of this weld is $0.632in^2$ and the 1000 pound load results in a shear of 1582.28psi. The filler material is ER4043 and the allowable shear for this type of weld (Aluminum Design Manual, Part VI, 2010) is 5.9ksi which is well in excess of the expected actual value.

The I-Beam/Turnbuckle Mounts are secured to the long I-beam using four (4) 3/8-16 bolts. The load on each I-Beam/Turnbuckle Mount is 1000-lbs. Therefore the load on each of the 3/8-16 bolts is 250-lbs. These bolts are always in tension. With a tensile stress area of $0.0774\text{-}in^2$ each of these bolts experience a tensile stress of 3229psi. The allowable tension for these bolts, per the Manual of Steel Construction 9^{th} edition, is 44ksi which is far in excess of these expected actual values.

The chamber assembly will be inserted into the beam line by resting the ends of the bottom surface of the aluminum I-beam onto the top surface of a pair of cantilevered steel I-beams that beams that are part of an existing structure in the experimental hall. Once in place this aluminum I-beam will experience stress and deflection from the weight of the drift chamber. If treated as a beam supported on both ends subject to concentrated identical loads equidistant from center then the stress and deflection of the I-beam can be calculated using standard formulas:

Stress at center of constant cross section: $$s = \frac{-Wa}{Z} \qquad \textbf{(1)}$$

Maximum deflection at center: $$y = \frac{Wa}{24EI}(3L^2 - 4a^2) \qquad \textbf{(2)}$$

Where: W is the weight of each load (1000-lb)
L is the length of the beam(141 inches)
a is the distance from the end to the load (31.27 inches)
I is the moment of inertia of S8x6.35 beam (57.6in^4)
Z is the section modulus
E is the modulus of elasticity of 6061 aluminum

Substituting the values into equation (1) yields:

$$s = -\frac{1000lb \times 31.27in}{\left(57.6in^4 / 4in\right)} = -2171.5lb/in^2$$

Likewise, substituting the values into equation (2) yields:

$$y = \frac{1}{24}\left[\frac{1000lb \times (31.27in)}{10e7\,psi \times 57.6in^4}\right]\left[3(141in)^2 - 4(31.27in)^2\right] = 0.126in$$

The bending stress of 2171.5psi and deflection of 0.126-in of the S8x6.35 I-beam are acceptable.

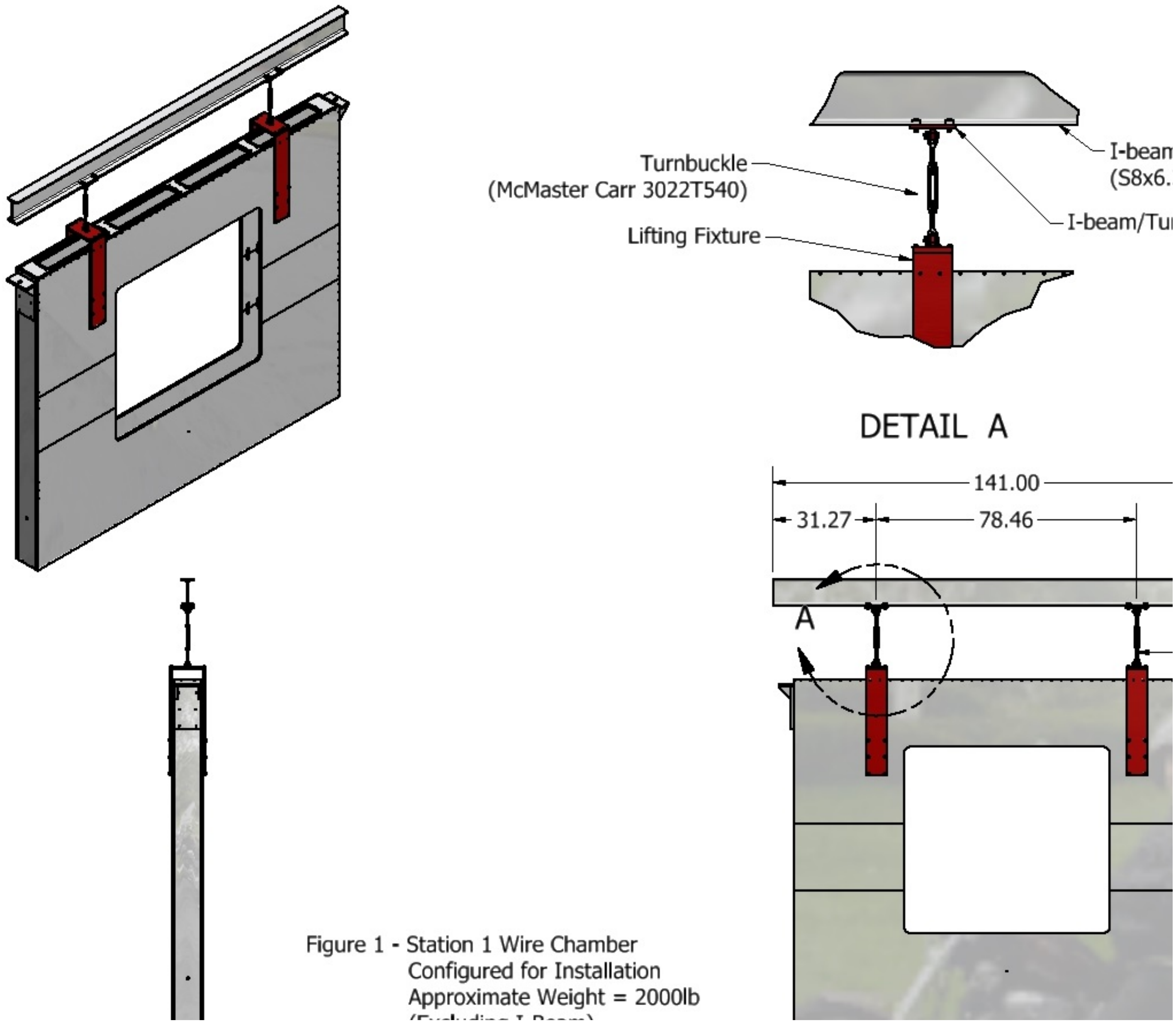


Figure 1 - Station 1 Wire Chamber
Configured for Installation
Approximate Weight = 2000lb

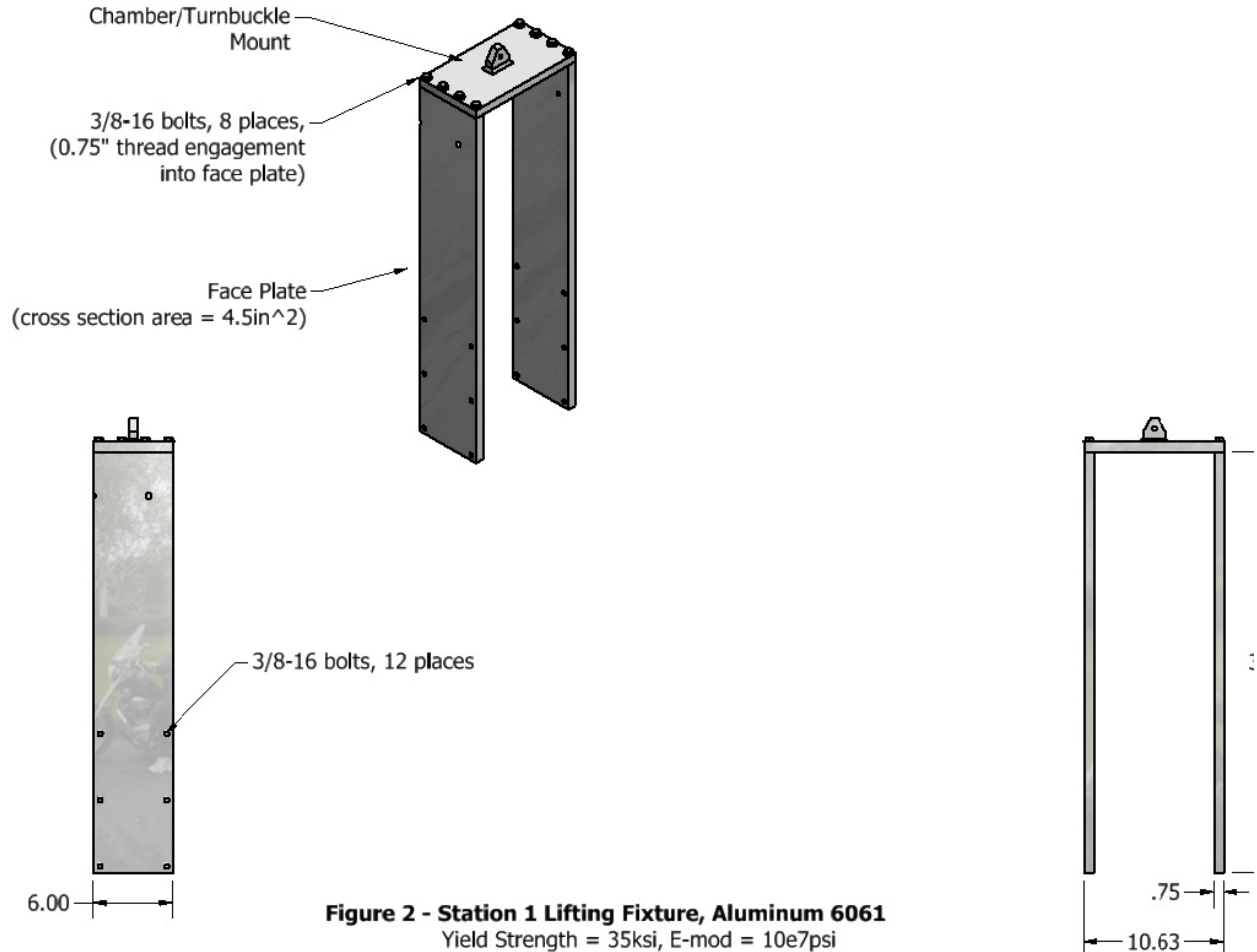
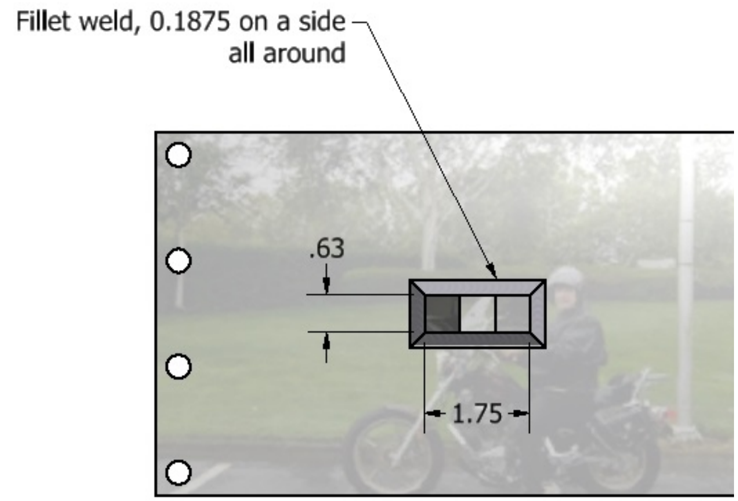


Figure 2 - Station 1 Lifting Fixture, Aluminum 6061
Yield Strength = 35ksi, E-mod = 10e7psi
Yield Shear Strength = 20ksi (per Al. Design Manual,

Weld Analysis:

Weld Leg Size = $\frac{3}{16}$-inch, Throat = 0.133"
Effective Throat Area:
A = 2(1.75+0.625)(0.133)
= 0.632-in^2

Shear on weld = 1000/0.632 = 1582.28psi



Hole Tearout Analysis:

Load on Ø.38 thru hole = 1000 pounds
Effective Cross Sectional Area:
A = 2(0.49)(0.63)
= 0.62-in^2

Shear on hole = 1000/0.62 = 1612.90psi

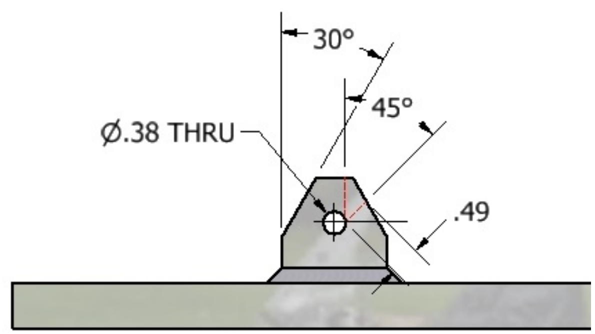


Figure 3 - Chamber/Turnbuckle Mount
Yield Strength = 35ksi, E-mod = 10e7psi

Weld Analysis:

Weld Leg Size = $\frac{3}{16}$-inch, Throat = 0.133"
Effective Throat Area:
A = 2(1.75+0.625)(0.133)
= 0.632-in^2

Shear on weld = 1000/0.632 = 1582.28psi

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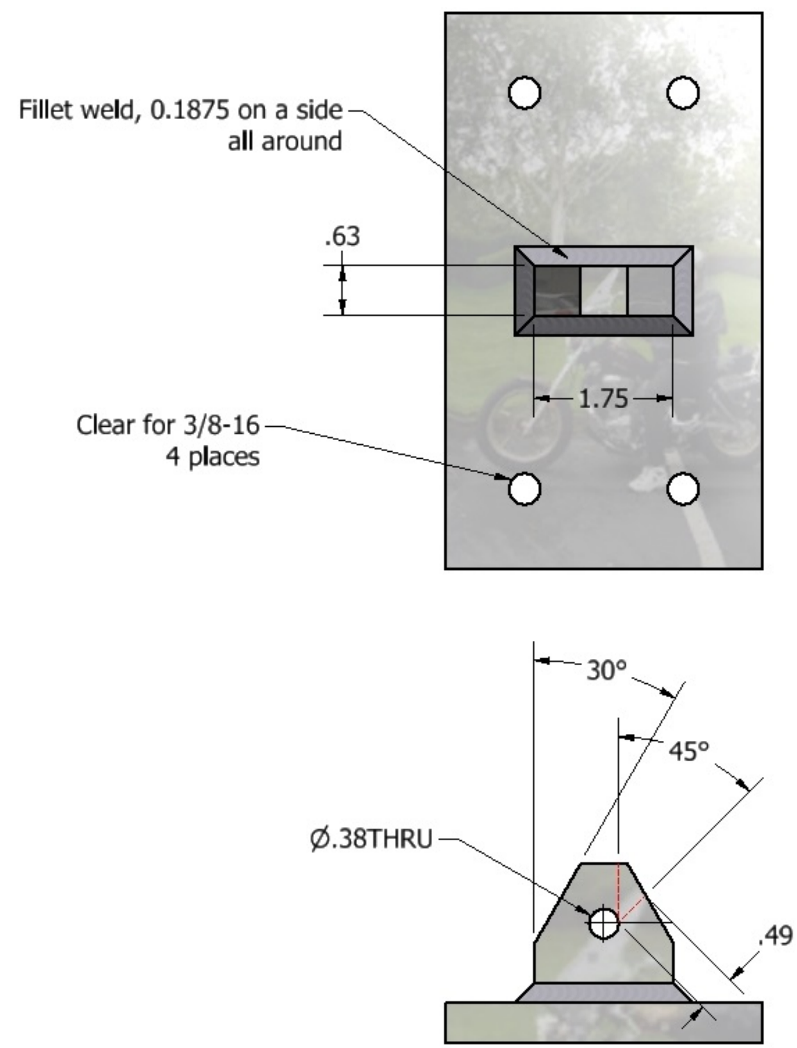

Figure 4 - I-Beam/Turnbuckle Mount
Yield Strength = 35ksi, E-mod = 10e7psi
Yield Shear Strength = 20ksi (per Al. Design Manual.