Fermilab

Particle Physics Division
Engineering and Technical Teams

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Mechanical Support Engineering Note

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Project: Minerva Project Internal Reference:

Title: Minerva Welding fixture Engineering Note

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Key Words:

Abstract/Summary:
This note is the engineering note for the structural calculations for the Minerva welding fixture. The purpose of this fixture is to allow the frames for the Minerva experiment to be welded together on both sides at once in order to minimize distortion on the frame pieces.

Applicable Codes:
American Institute of Steel Construction, Inc, Manual of Steel Construction, Ninth Edition.

Minerva Frame Welding Fixture
October 24, 2006

This fixture is used to weld together the wedges on a strongback in a manner which minimizes the distortion that results from local heating of the steel. See drawing numbers 3938.330-ME-444100 and 444104 for the assembly and weldment for this fixture. The wedges are positioned on the strongback correctly and secured to the strongback with bolted Unistrut holder straps. After the wedges are tacked together to maintain their orientation the strongback is lifted to vertical and hung on the welding fixture vertically. This allows the welder to access both sides of the frame and equalize the heating on both sides of the welds to keep those welds from pulling in some direction as they cool. Hence the welding fixture must support the entire weight of the strongback and the heaviest frames in the experiment. First calculate the maximum weight to be supported. The strongback weldment drawing shows the strongback weight at 3700 pounds. Add 500 pounds for the extras including Hilman rollers and lifting ring connection on the strongback for a total weight of 4200 pounds. Now find the maximum weight of any frame. Using the table attached that frame would weigh about 5200 pounds using a heavy target frame and 1.375" thick OD frame wedges.

$$P := 4200 \cdot lb + 5200 \cdot lb$$

$$P = 9.4 \times 10^{3}\ lb$$

The welding fixture is designed to hold the strongback in exactly the same manner that the strongback is supported on the Minos transport cart.

Columns

The columns are made from 8" by 6" by 0.25" wall structural tubing with Fy=46 ksi. The longest unsupported column length is 80". From page 3-48 of the American Institute of Steel Constructors, Manual of Steel Construction, Ninth Edition, for a 7 foot unsupported colum the allowable concentric load is 162 kips. The load is not concentric.

The load on the column becomes a couple of an upward force from the column and the downward force on the strongback at a distance of 13.9" from the center of the column, both vertical forces equal to 9,400 lbs. The couple therefore supplies a moment to the top of the column of

$$Fy := 46000 \cdot \frac{lb}{in^2}$$ Yield stress of structural tubing

$$M := 9400 \cdot lb \cdot 13.9 \cdot in$$

$$M = 1.307 \times 10^{5}\ lb \cdot in$$

We also need to note that the 9400 lbs is shared by two columns.

First calculate the compressive stress on the columns.

$A := 6.59 \cdot in^2$ Cross sectional area of the column

$$fa := \frac{\frac{P}{2}}{A}$$ Load shared equally on both columns.

$$fa = 713.202 \frac{lb}{in^2}$$

Because of the gussets supporting the columns in both directions assume that the bottom is translation fixed and rotationally fixed as in case d of Table C-C2.1 on page 5-135 giving a K=2.0. Then

$K := 2.0$ $l := 151.79 \cdot in$ $rx := 3.02$

$$K \cdot \frac{l}{rx} = 100.523 \text{ in}$$

From Table C-50 on page 3-17 for structural tubing with Fy = 46Ksi find the allowable stress.

$$Fa := 14000 \cdot \frac{lb}{in^2}$$

Now look at bending from the moment M.

$Ix := 60.1 \cdot in^4$ moment of Inertia of column about bending (x) axis

$c := 4 \cdot in$ distance of stressed fiber to neutral axis

$$fb := \frac{M \cdot c}{Ix}$$

$$fb = 8.696 \times 10^3 \frac{lb}{in^2}$$

$$Fb := 0.66 \cdot Fy$$

$$Fb = 3.036 \times 10^4 \frac{lb}{in^2}$$

Now find the combined stress fraction.

$\frac{fa}{Fa} + \frac{fb}{Fb} = 0.337$ Because this is less than 1.0 the combined stress is OK.

The actual weight of the strongback is carried by the 6" by 3" by 0.187" rectangular structural tubing that is welded to the heavy frame. Look at the small tubes, part number 4 on drawing 444104. Each tube must carry half of the weight of the strongback and frame. Each tube is welded to the heavy frame by four 0.3125" welds six inches long. First compression on the tubes.

$Atube := 3.14 \cdot in^2$

$\sigma tube := \frac{P}{Atube}$ $\quad \sigma tube = 2.994 \times 10^3 \frac{lb}{in^2}$

This very low compressive stress is fine for these tubes. Now check on the weld stress in shear.

eight welds six inches long by 5/16" $\quad Aw := 8 \cdot 6 \cdot in \cdot .3125 \cdot \frac{in}{1.414}$

$Aw = 10.608\, in^2$

$\sigma weldshear := \frac{P}{Aw}$

$\sigma weldshear = 886.107 \frac{lb}{in^2}$

The welds will take this load in shear. All welds on the welding fixture are in E70XX rod with a yeild strength of 70KSI. In shear these welds would have a maximum shear stress allowed of 70 KSI/3 or 23 KSI. Notice however that in addition to these welds part number 12 supports each of the vertical tubes.

Part 12 can be modelled as a cantilevered beam with a uniform load as in Case 19 page 2-302 of the AISC code. This assumes that all of the load is carried by the cantilever and none is carried by the welds in shear as calculated just above. Because part 4 is welded completely on the end to part 12 case 20 might be more appropriate, but use case 19 because it yields a higher moment and stress.

$l := 6 \cdot in$ length of cantilever

$w := \frac{P}{2 \cdot l}$ load per inch

$Mmax := w \cdot \frac{l^2}{2}$

$Mmax = 1.41 \times 10^4\, in \cdot lb$

$S_x := 7.03 \cdot in^3$ Section modulus for 6" by 3" by 5/16" wall tubing

$$\sigma bend := \frac{Mmax}{S_x}$$

$$\sigma bend = 2.006 \times 10^3 \frac{lb}{in^2}$$

In bending structural tubing Fb=Fy*0.66 or Fb=30.3 KSI which is much greater than 2000 psi. Hence part 12 in this cantilever is OK.

In order to resist the moment trying to pull the strongback off the welding fixture two threaded fasteners are provided. The welding fixture has two holes drilled through the columns that match threaded holes in the back of the strongback. First calculate the stress the bolts might see. The total moment is the same as calculated above for bending on the columns. The distance the force is supplied at for the moment resistance is from the bottom of the strongback where the rail hits the columns to the holes where the threaded rods are.

$lm := 129.5 \cdot in$ Distance from bottom of strongback to threaded hole

$$Fbolt := \frac{M}{2 \cdot lm}$$ Each bolt supports half the moment

$Fbolt = 504.479\ lb$

$pi := 3.4145$

$$Abolt := \frac{pi}{4} \cdot (.75 \cdot in)^2$$

$Abolt = 0.48\ in^2$

$$\sigma bolt := \frac{Fbolt}{Abolt}$$

$$\sigma bolt = 1.051 \times 10^3 \frac{lb}{in^2}$$

These bolts are 3/4"-10 and any grade will easily support a tensile load of 504 pounds force with a tensile stress of 1051 psi..

Another calculation required is to look at how the frame deals with horizontal forces. Typically a horizontal force of 10% of the vertical load is chosen. In this case that load is then 940 pounds. In both directions Gussets provided stiffening for horizontal loads. The top of these gussets is approximately 98" from the floor and at an angle of 70 degrees. Assume the force of 940 pounds is supplied at the top of the frame. By the first section of this note this force can not overstress the bending of the columns in the strong axis so we need to check the weak axis next. Of course the vertical load on the column is the same 9400 pounds.

$K := 2.0$ $l := 151.79 \cdot in$ $ry := 2.42$

$$\frac{K \cdot l}{ry} = 125.446\ in$$

Again from Table C-50 on page 3-17 for structural tubing with Fy = 46KSI find the allowable stress.

Then $Fa := 9560 \cdot \frac{lb}{in^2}$ Allowable compressive stress

Look at the bending also provided by the horizontal load

$Iy := 38.6 \cdot in^4$ $c := 3 \cdot in$ $Mhor := 940 \cdot lb \cdot (151.79 \cdot in - 98 \cdot in)$

$fb := \frac{Mhor \cdot c}{Iy}$ $fb = 3.93 \times 10^3 \frac{lb}{in^2}$

$\frac{fa}{Fa} + \frac{fb}{Fb} = 0.204$ Since this is less than 1.0 the combined stress on the weak axis with horizontal load is still OK.

Check the gussets (part number 2) for horizontal load. Note that because the gussets are not at the top of the frame the horizontal force at the gusset is larger to support the same moment on the frame.

$$Phor := 940lb \cdot \frac{151.79 \cdot in}{98 \cdot in}$$

$Phor = 1.456 \times 10^3\ lb$

Compressive (or tensile) force along a gusset is given by the following

$\frac{3.1415 \cdot 70}{180} = 1.222$ Change 70 degrees to 1.222 radians

$\frac{Phor}{\cos(1.222)} = 4.26 \times 10^3\ lb$

Then for tensile stress:

$\sigma gtensile := \frac{4.26 \cdot 10^3 \cdot lb}{A}$

$\sigma gtensile = 646.434 \frac{lb}{in^2}$ Tensile/compressive stress on a gusset from horizontal force

Find an allowable compressive stress for the gussets.

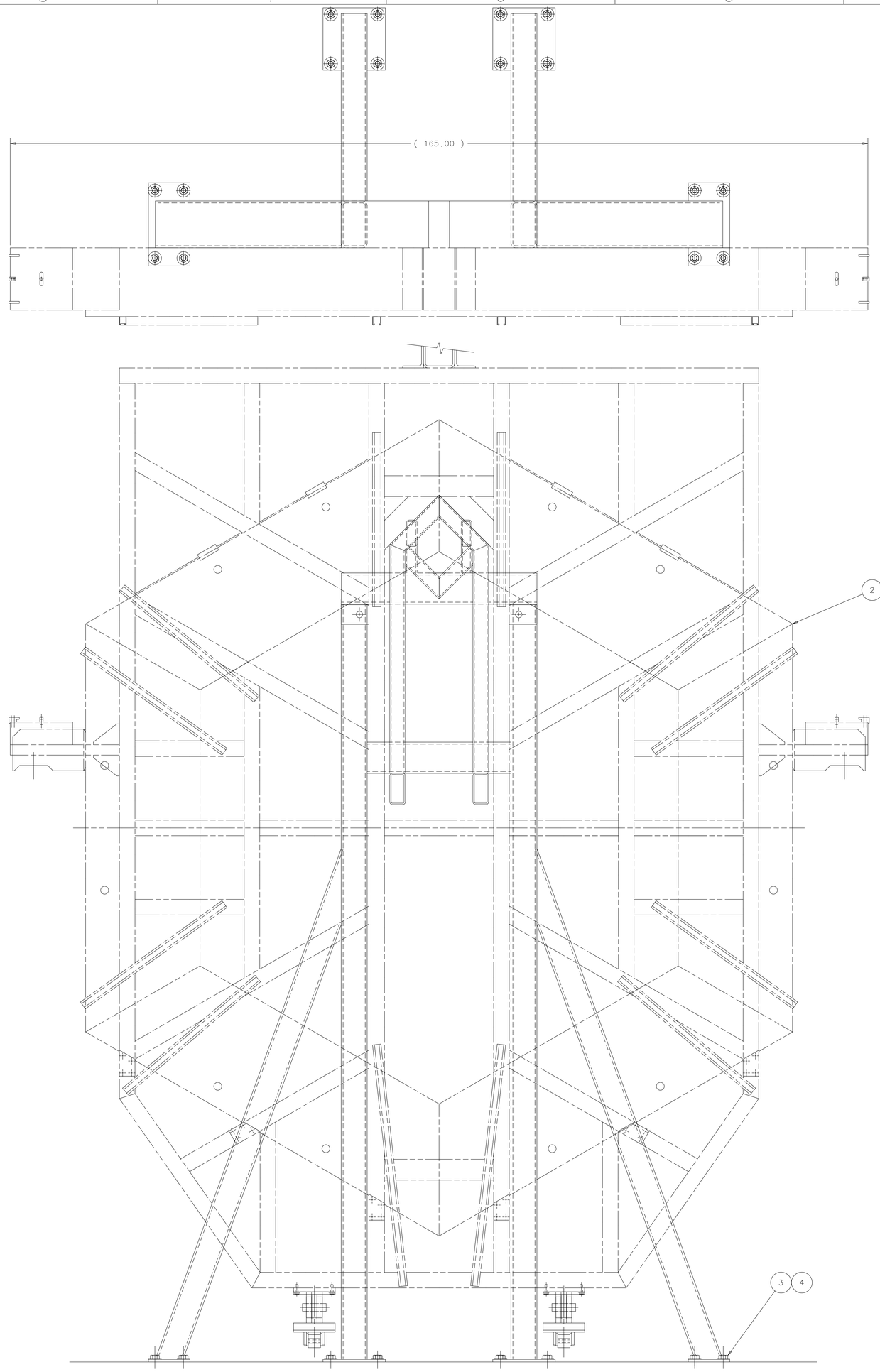
$K := 2$ $l := 98 \cdot in$ $ry := 2.42$ Use the smaller of rx or ry to maximize the equivalent length

$$\frac{K \cdot l}{ry} = 80.992\,in$$

From Table C-50 for this the Fa is18.81 Ksi. Therefore the gussets are OK for compressive or tensile forces

The horizontal force on the gussets must also be supported by shearing of the anchor bolts. Those bolts are 3/4" - 10 UNC bolts into Hilti Drop-in anchors. Those anchors are rated for 3830 lbs each in tension and 5580lbs each in shear in 4000 psi concrete. Each gusset or column leg has four bolts for a total tensile rating of 15,320 lbs or a total shear rating of 22,320 lbs.

REV	DESCRIPTION	DRAWN	DATE
		APPROVED	DATE
A	UPDATED	G SMITH	19-JAN-2007
		J KILMER	19-JAN-2007



ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
6	COML	HEX NUT 1"-8 UNC-2B STEEL GRADE 8	4
5	COML	1"-8 UNC-2A THREADED ROD X 13.50 LG.-STEEL GRADE 8	2
4	COML	FLAT WASHER - 1" BOLT SIZE STEEL GRADE 8	28
3	COML	1"-8 UNC-2A HEX BOLT X 1 1/2 LG.-STEEL	24
2	ME-444081	STRONGBACK LAYOUT ASSEMBLY	1
1	ME-444104	STRONGBACK FLOOR SUPPORT WELD	1

PARTS LIST

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	J.KILMER	20-SEP-2006
.XX	.XXX	ANGLES	DRAWN	G.SMITH	20-SEP-2006
± ---	± ---	± ---	CHECKED	D.FRIEND	19-OCT-2006
			APPROVED	J.KILMER	19-OCT-2006

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES
5. DRAWING UNITS: U.S. INCH

USED ON

MATERIAL
SEE PARTS LIST ABOVE

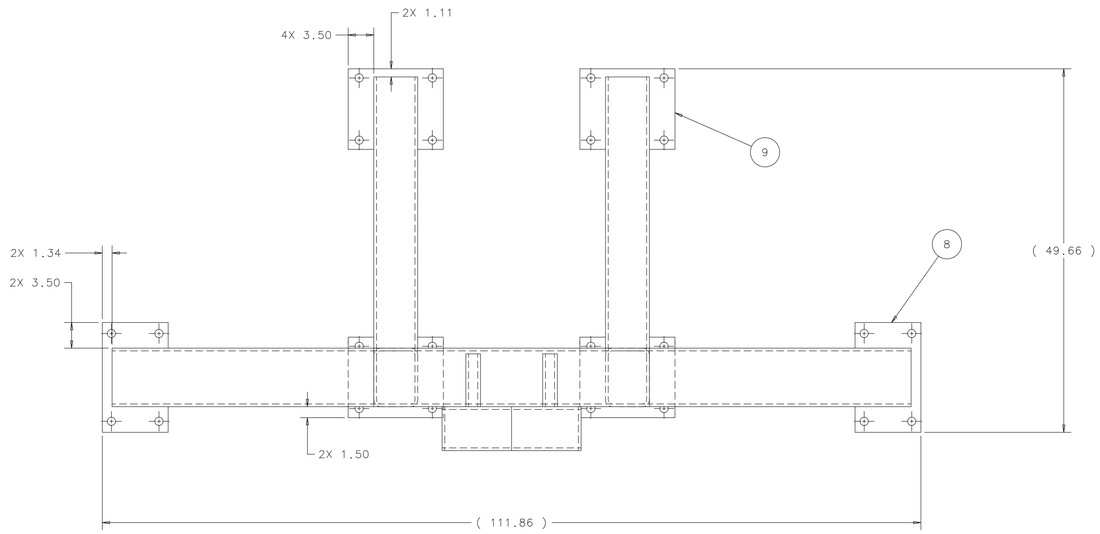
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

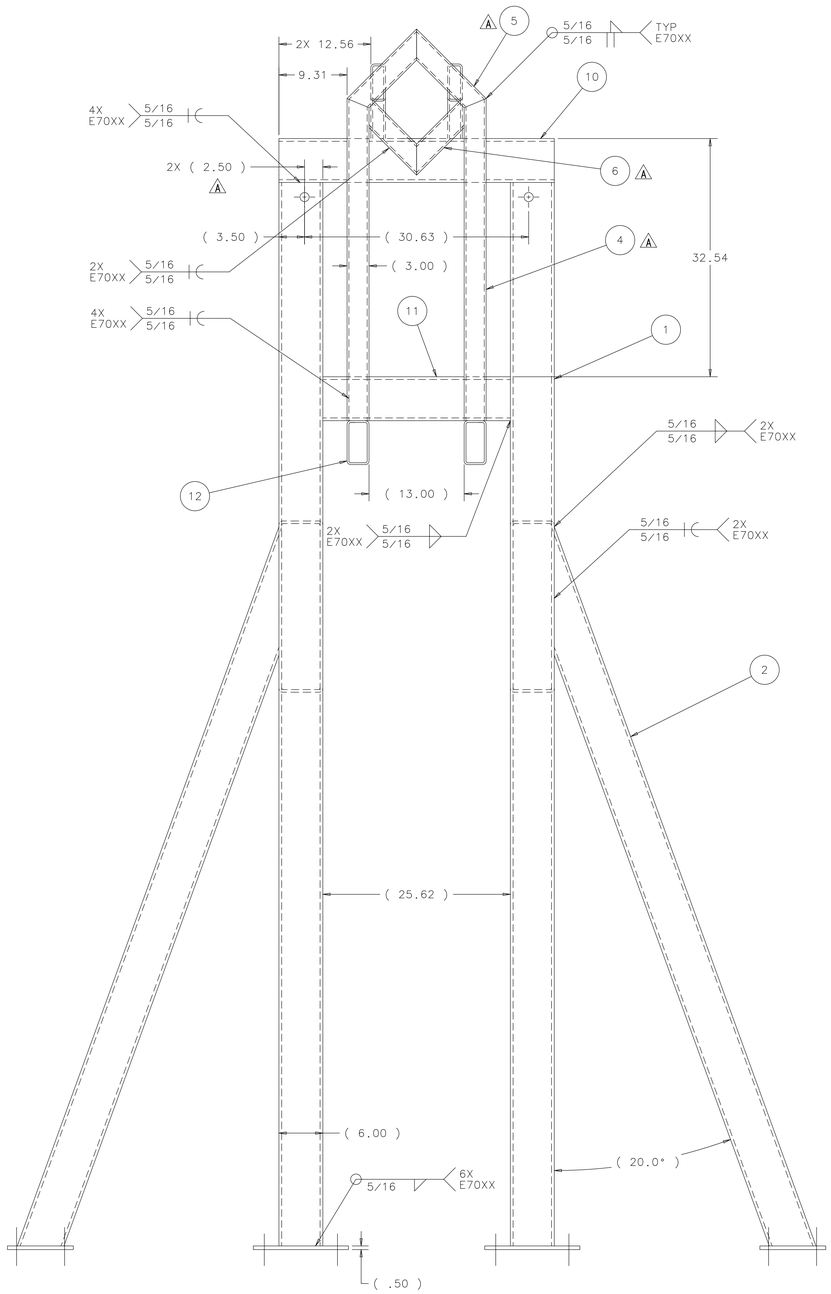
MINERVA - MECHANICAL DETECTORS STRONGBACK FLOOR SUPPORT ASSY

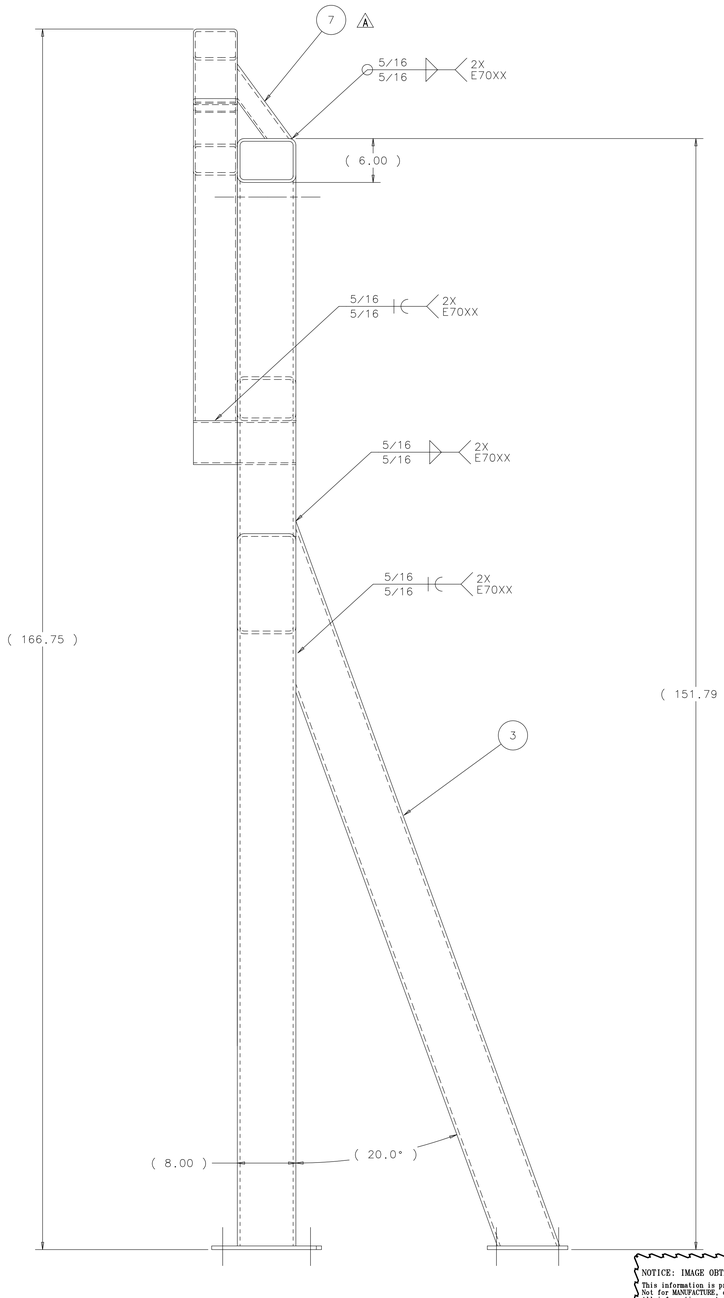
SCALE	DRAWING NUMBER	SHEET	REV
1:8	3938.330-ME-444100	1 OF 1	A

CREATED WITH : Ideas12NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

REV	DESCRIPTION	DRAWN	DATE
		APPROVED	DATE
A	ITEMS 4,5,6 & 7 WERE 6 X 2 X .38 WALL NOW 6 X 3 X .188 WALL. (2.50) DIM. ADDED	G SMITH	19-JAN-2007
		J KILMER	19-JAN-2007







ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
12	COML	RECTANGLAR TUBING, 6 X 3 X .188 WALL X 14.00 LG-CARBON STEEL ASTM A500 GR.B	2
11	COML	RECTANGLAR TUBING, 8 X 6 X .250 WALL X 25.62 LG-CARBON STEEL ASTM A500 GR.B	1
10	COML	RECTANGLAR TUBING, 8 X 6 X .250 WALL X 37.62 LG-CARBON STEEL ASTM A500 GR.B	1
9	MD-444105-09	BACK FOOT	4
8	MD-444105-08	SIDE FOOT	2
7	MD-444105-07	ANGLE BRACE (BACK)	2
6	MD-444105-06	ANGLE BRACE (LOWER)	2
5	MD-444105-05	ANGLE BRACE (UPPER)	2
4	MD-444105-04	VERTICAL BEAM (SHORT)	2
3	MD-444105-03	BACK GUSSET	2
2	MD-444105-02	SIDE GUSSET	2
1	MD-444105-01	VERTICAL BEAM (LONG)	2

PARTS LIST

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	J.KILMER	21-SEP-2006
.XX	.XXX	ANGLES	DRAWN	G.SMITH	21-SEP-2006
± .06	± ---	± ---	CHECKED	D.FRIEND	19-OCT-2006
			APPROVED	J.KILMER	19-OCT-2006

1. BREAK ALL SHARP EDGES .015 MAX
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES
5. DRAWING UNITS: U.S. INCH

USED ON: ME-444100

MATERIAL: SEE PARTS LIST ABOVE

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MINERVA – MECHANICAL DETECTORS STRONGBACK FLOOR SUPPORT WELD

SCALE	DRAWING NUMBER	SHEET	REV
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CREATED WITH : Ideas12NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

REV	DESCRIPTION	DRAWN	DATE
		APPROVED	DATE
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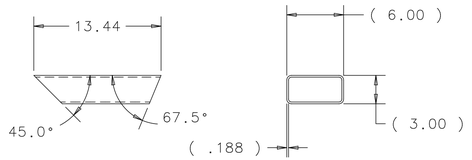
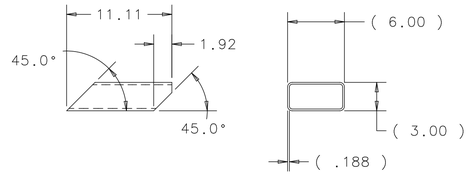
		J JILMER	19-JAN-2007



MD-444105-05 - ANGLE BRACE (UPPER)

A MAT'L.: 6 X 3 X .188 WALL STRUCTURAL TUBING
CARBON STEEL ASTM A500 GR. B



MD-444105-06 - ANGLE BRACE(LOWER)

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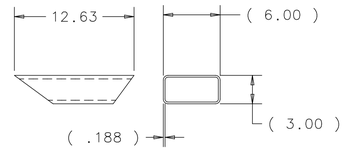
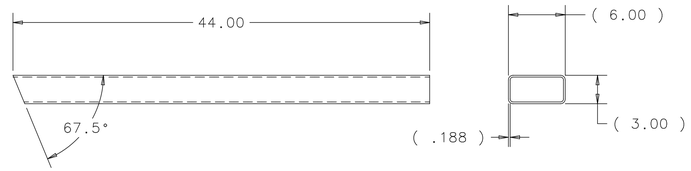
CARBON STEEL ASTM A500 GR. B



MD-444105-07 - ANGLE BRACE (BACK)

A MAT'L.: 6 X 3 X .188 WALL STRUCTURAL TUBING
CARBON STEEL ASTM A500 GR. B



MD-444105-04 - VEERTICAL BEAM SHORT

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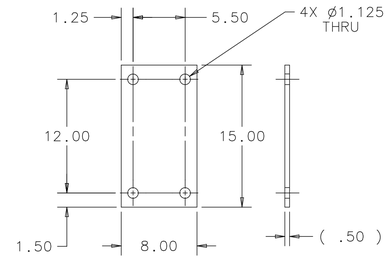
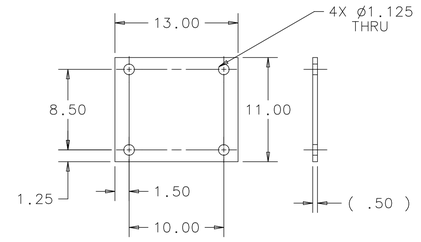
CARBON STEEL ASTM A500 GR. B



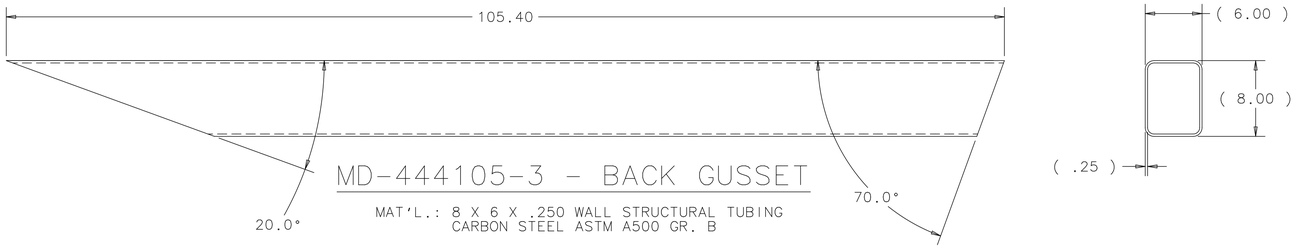
MD-444105-08 - SIDE FOOT

MAT'L.: 1/2" THICK PLATE
CARBON STEEL ASTM A36



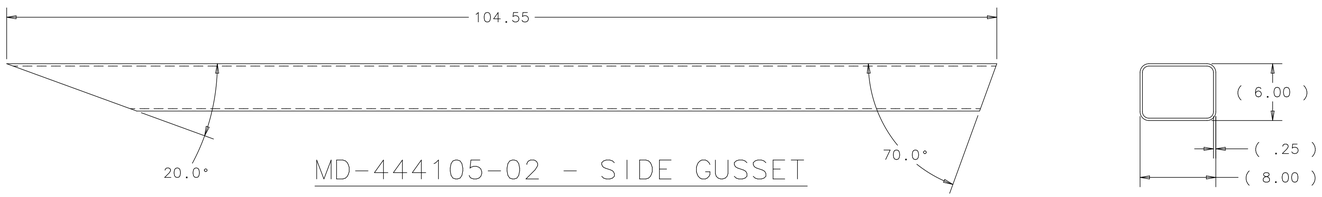
MD-444105-09 - BACK FOOT

MAT'L.: 1/2" THICK PLATE
CARBON STEEL ASTM A36



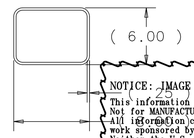
MD-444105-3 - BACK GUSSET

MAT'L.: 8 X 6 X .250 WALL STRUCTURAL TUBING
CARBON STEEL ASTM A500 GR. B



MD-444105-02 - SIDE GUSSET

MAT'L.: 8 X 6 X .250 WALL STRUCTURAL TUBING
CARBON STEEL ASTM A500 GR. B



MD-444105-01 - VERTICAL BEAM (LONG)

MAT'L.: 8 X 6 X .250 WALL STRUCTURAL TUBING
CARBON STEEL ASTM A500 GR. B

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	J.KILMER	21-SEP-2006
.XX	.XXX	ANGLES	DRAWN	G.SMITH	21-SEP-2006
± .03	± ---	±1.0°	CHECKED	D.FRIEND	19-OCT-2006
			APPROVED	J.KILMER	19-OCT-2006

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES 125
5. DRAWING UNITS: U.S.INCH

USED ON: ME-444104

MATERIAL: AS LISTED IN DWG. DETAILS

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

MINERVA - MECHANICAL DETECTORS STRONGBACK FLOOR SUPPORT PARTS

SCALE	DRAWING NUMBER	SHEET	REV
1:8	3938.330-MD-444105	1 OF 1	A

CREATED WITH : Ideas12NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT