The Stable Cable Table

Designer/Fabricator: [redacted]

June 2022

Contents

1 Introduction

This paper describes the design and fabrication of a decorative steel end table built as the final project for an associate's degree in Welding & Fabrication Technology at [redacted] College. The table uses steel cables held in tension to create the appearance of an "impossible" floating object.

2 Design Principles

It is possible to design stable structures where cables held in tension fully support and constrain rigid pieces which do not otherwise connect. This principle is known as *tensegrity* (a portmanteau of *tension* and *integrity*) , named by architect and artist Buckminster Fuller in the 1960s and used extensively by sculptor Kenneth Snelson.

One application of tensegrity principles is to create a table which appears to be floating without obvious support, but is in fact perfectly stable and rigid.

2.1 Table Design

The design intent for this end table is to securely support at least 50 pounds of added weight while also minimizing build cost, assembled dead weight, and visual bulkiness.

The two table arms need to withstand substantial vertical force, but relatively small lateral forces. I designed each arm to be made from two parallel pieces of vertically oriented 1/8" sheet steel. This orientation aligns the load along the comparatively strong and stiff axis of the part without requiring heavier materials. Buckling and out-of-plane bending of each arm is resisted by a series of small support dowels which tie the planar parts together. The end result is a lightweight but incredibly robust structure.

DIY tensegrity builds often use rope or chain. However, I elected to use stainless steel aircraft cable, which has the advantage of enormous tensile strength and low elasticity. All cables for this build were 1/16" stainless steel using 7x7 strand construction rated to a mean break strength of 480 pounds. One end of each cable is fitted with a #10-24 thread, and the other end is a 1/4" plain ball.

To enhance stability, all cables were angled a few degrees from vertical. This slight angle applies mutually opposed horizontal forces to the upper part of the table. These horizontal forces work to keep the upper table fully centered in the equilibrium position, both in response to a disturbance and at rest.

2.2 Load Forces

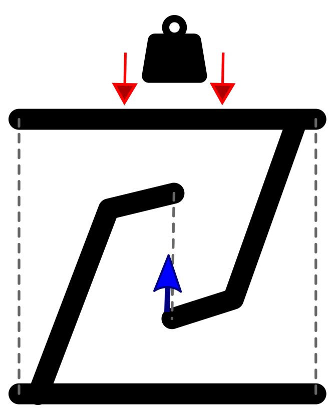


Figure 1: Weight applied at the center of the table.

In the simplest case, the net vertical load on the table is directly above the center cables. All force is applied through the table center with minimal involvement of the side cables.

Since the hanging center is supported by a cable doubled around a pivot point and oriented at some angle (α) off of vertical, the tensile load on the center cable **C1** becomes

$$F_{C1} = \frac{F_{center}}{2 * cos(\alpha)} \tag{1}$$

Solving for the maximum supportable load, we get

$$F_{center} = 2 * F_{C1} * cos(\alpha) \tag{2}$$

Since α is small in this design, its effect on the force applied to the table is almost negligible. However, I think it's important to note the effect that placing cables off of vertical has on their loading, since a different design where cables were more sharply angled may have substantial reductions is supportable load.

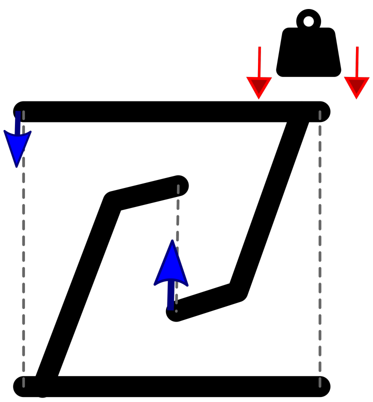


Figure 2: Weight applied near the edge of the table.

If the weight is substantially off-center things become a little bit more complicated. An off-center load applies a torque which must be resisted by tension on the side cables **C2**. In the worst case, the off-center weight is placed at the very corner of the table, so that the tension must be supported by the single cable at the opposite corner. In this worst case of a load at the very edge, the applied load and a single side cable C2 are equidistant from the center point. Since the angle of the side cable is negligible (about 2°), the force becomes

$$F_{C2} = F_{edge} \tag{3}$$

If the top anchor of this cable C2 is held in place, the center must now also endure additional load to fully support the weight applied as a class-3 lever. Since C1 is halfway between C2 and the weight, the force on cable C1 becomes

$$F_{C1} = 2 * \frac{F_{edge}}{2 * cos(\alpha)} \tag{4}$$

Again solving for the maximum supportable load, we get

$$F_{edge} = F_{C1} * cos(\alpha) \tag{5}$$

For my table, the angle α of **C1** is about 5°. and the rated mean break strength of the cable is 480lb. Therefore, by Equation 1, the maximum load which can be applied to the center of the table is 956 pounds. The maximum supportable load at the edge of a table is constrained by both Equation 3 and Equation 5, with Equation 5 having the lesser value due to the angle of cable C1. Using the actual parameters of the built table, this gives a *theoretical* maximum F_{edge} of 478lb.

In practice the actual amount of weight which can be reasonably supported will likely be a lot less than this theoretical maximum. Limiting factors include the dead weight of the upper table assembly and glass tabletop, uncertainty in the true cable breaking strength, pull-out strength of the cable fittings and anchors, elasticity of both the cables and the steel structure, and the substantial pre-loads required for adequate cable tension. Nonetheless, this analysis gives me confidence that this table can more than meet the design target of supporting 50 pounds with a substantial factor of safety.

3 Safety Equipment & Procedures

Figure 3: Personal protective equipment.

- Safety-appropriate clothing worn at all times – UPF-rated long shirt & pants made from non-synthetic fibers, and work boots with composite safety toe. All protective clothing was well-fitted and in good condition.
- ANSI Z87-2+ protective prescription eyewear with side shields worn at all times. Anti-fog lens coating was used to ensure full visibility and comfort.
- Medium-weight, correctly-fitted leather welding gloves were worn throughout fabrication. While using the drill press and disk sander which pose the risk of glove entanglement, frangible nitrile gloves were worn instead.

- Long hair was tied back at all times.
- Auto-shade, auto-darkening welding helmet and cotton weld cap worn during all welding operations.
- Disposable foam earplugs with a NRR of 33dB worn during use of loud tools (grinding, sanding, etc).
- All welding was performed with appropriate work area ventilation.
- All welding was performed with light shields in place.
- A mask or respirator for COVID-19 protection was worn at all times, in accordance with prevailing local and school policy.
- Work was performed in compliance with all other non-enumerated shop safety and tool use policies and best practices.
- Washed hands at the end of every working day.

4 Tools Used

Shop Tools

Cincinnati CL-707 2600W industrial laser cutter
Cincinnati G-Series mechanical plate shear
Clausing Kalamazoo horizontal bandsaw
Drill press
12" disk sander

Power and Air Tools

Makita Corded 4.5" angle grinder
- *cutting disk*
- *80-grit sanding disk*
- *120-grit flapper disk*

Harbor Freight air grinder
- *120-grit sanding disk*

DeWalt 20v cordless drill

Hand Tools

C-clamps, 6"
Locking clamps, 6" and 9"
Vice grip pliers
Angle magnets, 3" and 6"
Ball peen hammer, 12oz
Hand file, flat
Hand taps, #6-32 and #10-24

Marking & Measuring

Markzall permanent markers
Tungsten carbide scribe
Manual centerpunch
Combination square, 12"
Framing square, 12x18"
Spirit level, magnetic, 8"
Tape measure, compact, 12'

4.1 Welding Process & Parameters

Welder:	**Miller Dynasty**
Process:	**GTAW**
Polarity:	**DCEN**
Torch:	**CK 26-Series air cooled**
Gas:	**100% argon @ 15CFM**
Cup:	**#5 alumina with gas lens**
Electrode:	**2% lanthanated, 3/32"**
Current:	**90-100A with foot pedal control**
Filler:	**ER70S-2, 0.045" and 1/16"**

Welding was performed in the 1G and 2F positions whenever possible. Some welding of tube corners was performed vertical uphill.

5 Bill of Materials

5.1 Parts and Materials

All listed costs were at time of purchase and do not include tax or shipping.

5.1.1 Metal

Description	Dimensions	Supplier	Qty.	Price
Square steel tube	1"x1"x14ga, 2ft	MetalsDepot.com	9	$77.67
HRPO mild steel	1/8" thick	[redacted]	2x2'	*donated*
Mild steel rod	3/8" x 2ft	[redacted]	1	*donated*
16ga CR steel sheet	18" x 6"	Home Depot	4	$41.40
				$109.07

5.1.2 Hardware

ID	Description	Vendor	Item #	Qty.	Price
H1	Swivel Leveling Mount	McMaster-Carr	6111K511	4	$28.60
H2	Clevis pin, 3/32" x 2"	McMaster-Carr	92735A196	1	$7.92
H3	Weld Nut #10-24	McMaster-Carr	98001A120	4	$7.42
H4	Spacer, 3/16ID x 3/4"	McMaster-Car	92320A467	2	$6.88
H5	Wire Rope Thimble, C3	Lexco Cable	AN111-C3	1	$3.25
H6	Weld Nut #10-32	McMaster-Carr	98001A120	4	$7.42
H7	Single Wave Washer #10	McMaster-Carr	99842A113	2	$9.21
H8	Sealing Washer #10	McMaster-Carr	94709A113	8	$15.17
					$76.66

5.1.3 Custom Cable Assemblies

ID	Description	Length	Vendor	QTY.	Price
C1	Center Cable	17 1/2”	Lexco Cable	1	$30
C2	Side Cables	26 7/8”	Lexco Cable	4	$120
					$150

Figure 4: Cable assemblies.

5.1.4 Damper Module Hardware

ID	Description	Vendor	Item #	QTY.	Price
D4	Connector 1/4 NPSC	McMaster-Carr	46685K262	1	$4.07
D6	Plug 1/4 NPTF	McMaster-Carr	4452K542	1	$1.68
D7	Screw #6-32 x 1/4”	McMaster Carr	91355A159	2	$5.12
-	5W30 Motor Oil	O’Reilly Auto	-	100mL	*on-hand*
					$10.87

5.1.5 Additional Components

Description	Dimensions	Vendor	Price
Tabletop, tempered glass	18”x18”x1/8”	Fab Glass and Mirror	$103.26
Non-stick bump pads for glass	3/4”	Amazon.com	$4.50
Vinyl screw cover	3/16” x 1”	McMaster-Carr	$12.57
		Subtotal	$120.51

6 List of Fabricated Parts & Assemblies

6.1 Assemblies

ID	Name	Sheet
T1	Lower Table	8
T2	Upper Table	11
T3	Damper Retrofit	13

6.2 Sub-Assemblies

ID	Name	Sheet
T1-F	Lower Table Frame	6
T1-A	Lower Table Arm	7
T2-F	Upper Table Frame	9
T2-A	Upper Table Arm	10

6.3 Fabricated Components

ID	Name	Material	QTY.	Sheet
A1	Lower Arms	1/8" steel HRPO	2	2
A2	Hang Plate A	1/8" steel HRPO	1	2
A3	Hang Plate B	1/8" steel HRPO	1	2
A4	Arm Gusset	1/8" steel HRPO	2	2
A5	Arm Brace Dowel	3/8 steel dowel	12	5
A6	Upper Arms	1/8 steel HRPO	2	2
F1	Lower Frame Sides	1" square tube	2	3
F2	Lower Frame Front	1" square tube	1	3
F3	Lower Frame Rear	1" square tube	1	3
F4	Upper Frame Sides	1" square tube	2	4
F5	Upper Frame Front	1" square tube	1	4
F6	Upper Frame Rear	1" square tube	1	4
F7	Side Skirt	16ga CRS	4	5
D1	Damper Tuber	1" square tube	1	13
D2	Damper Closed End	16ga CRS	1	13
D3	Damper Port End	16ga CRS	1	13

7 Cuts

7.1 Laser Cutting

Components **A1**, **A2**, **A3**, **A4**, and **A6** were laser cut from 1/8th mild steel, hot roll pickled & oiled (HRPO). CNC laser cutting was chosen to easily fabricate the complex geometry of the support arms while providing a precise and attractive cut finish.

Figure 5: Setting up the laser cutter.

Cutting was performed on a Cincinnati CL-707 2600W CO_2 laser. I performed the nest file layout, set appropriate cutting parameters, and operated the laser for the setup and duration of the cut.

7.2 Tube and Dowel Cutting

The 1" x 14ga square tube was purchased as 2ft lengths. Eight pieces were cut down to 18" with a 45° angle per the blueprint for **F1** through **F6**. These cuts were performed on a horizontal bandsaw with adjustable cut angle. Since these components are all visually similar, it's recommended to mark the designation ID on each piece.

Pieces of 3/8" steel dowel were cut to slightly less than 2" length to create component **A5**.

After cutting, all pieces were cleaned, deburred, and ground to remove mill scale on surfaces to be welded.

7.3 Side Skirt Cutting

Four pieces of 16ga cold roll steel were cut to 18" x 2.5" using a Cincinnati plate shear, then deburred to create the side skirts **F7**

8 Fabrication & Welding

8.1 Frame sub-assemblies

8.1.1 Lower Frame sub-assembly T1-F

1. Scribe the location of all holes in frame pieces **F1**, **F2** and **F3** per the drawing.
2. Center punch all hole locations.
3. Pilot drill all hole locations. Use appropriate lubricant for all drilling operations throughout fabrication.
4. Drill holes in lower frame sides **F1** to 1/4", first surface only.
5. Drill holes in **F2** and **F3** to 3/16", all the way through.
6. Enlarge the far side of holes drilled through **F2** and **F3** to 3/8". Since these larger holes are just for pass-through clearance, it's okay if they're not perfectly co-axial with the smaller holes.
7. Fit up lower frame pieces **F1**, **F2**, and **F3**, firmly clamped to a weld table. **F1** is positioned with holes facing down. **F2** and **F3** are positioned with the small side of each hole facing up and the large side facing down.
8. Tack frame pieces together, then weld (complete joint penetration). Perform as much welding as possible before clamp removal.
9. Grind groove welds flush.
10. Tack in place weld nuts **H6** at the 1/4" holes in the frame sides, then lap weld all-around.

8.1.2 Upper Frame sub-assembly T2-F

1. Scribe the location of all holes in frame pieces **F5** and **F6**, per the drawing.
2. Center punch all hole locations.
3. Pilot drill all hole locations.
4. Drill holes to 1/4", first surface only.
5. Fit up upper frame pieces **F4**, **F5**, and **F6**, firmly clamped to a weld table. All holes are positioned facing the same direction.
6. Tack and weld the upper frame in the same manner as the lower frame.
7. Grind groove welds flush.
8. Tack in place weld nuts **H2** at the 1/4" holes, then lap weld all-around.

(a) Lap welds around a weld nut.

(b) Lower arm sub-assembly, tacked.

Figure 6: Sub-assembly fabrication.

8.2 Arm sub-assemblies

8.2.1 Lower Arm sub-assembly T1-A

1. Cut several lengths of scrap tube to 1.75" long to use as spacers.
2. Carefully fit up components **A1**, **A2**, **A3**, **A4**, and**A5**. Use spacers cut in the previous step were between the two lower arm pieces **A1** to help ensure correct spacing and parallelness.
3. Lightly tack in place arm dowels **A5** and hang plates **A2** & **A3**.
4. Plug weld to join lower arms **A1** and arm dowels **A5**, filling to higher than the plane of the surrounding material. Do this as a series of short passes in alternating locations to minimize heat buildup.
5. Fillet weld from lower arms **A1** to arm gusset **A4** and to hang plates **A2** & **A3**.
6. Grind plug welds flush.

8.2.2 Upper Arm sub-assembly T2-A

1. Tap the hole in hang plate **A2** to #10-24.
2. Fit up upper arms **A6**, arm gusset **A4**, and arm dowels **A5** in the same manner as for the lower arm sub-assembly **T1-A**.

3. Lightly tack components into place.
4. Plug weld arm dowels in the same manner as the lower arm sub-assembly.
5. Fillet weld arm gusset **A4** to the upper arms.
6. Grind plug welds flush.

Figure 7: Partially completed assemblies.

8.3 Attaching arms to frames

8.3.1 Lower Assembly

1. Clamp the lower frame sub-assembly **T1-F** to a work surface, positioned right-side up (i.e, weld nuts facing downwards).
2. Scribe a short-axis center line across the face of lower frame piece **F3**.
3. Fit up lower arm sub-assembly **T1-A** to lower frame sub-assembly **T1-F**. The engraved centerline on **A4** can be aligned to the centerline on **F3** scribed in the previous step. Use as many fixtures as necessary to ensure that all components are centered and square.
4. Tack the sub-assemblies together.
5. Fillet weld as many joint surfaces as can be reasonably accessed, or per the drawing.

8.3.2 Upper Assembly

1. Clamp upper frame sub-assembly **T2-F** to a work surface, positioned upside-down (i.e, weld nuts facing upwards).

2. Scribe a short-axis center line across the face of upper frame piece **F5**.

3. Fit up the upper arm sub-assembly **T2-A** to the lower frame sub-assembly **T1-F**. The engraved centerline on **A4** can be aligned to the centerline on **F5** scribed in the previous step. Use as many fixtures as necessary to ensure that all components are centered and square.

4. Tack the sub-assemblies together.

5. Fillet weld as many joint surfaces as can be reasonably accessed, analogous to Lower Assembly **T1-A**.

6. Assemble axial components **H2, H3, H4, H5, and H7** to upper arm as shown in *Detail A* of drawing T2. Use the included snap ring to secure the pin in place.

7. Fillet weld spacers **H4** all-around to upper arm **A2**. Welding the spacers with the clevis pin in place ensures that components are coaxial.

8.4 Attaching Side Skirts

Each side skirt piece is positioned 3/16" proud of the upper frame, and is designed to both create a recessed area for a glass table surface to fit into and to shroud the upper end of the cable assemblies.

1. Clamp the upper frame assembly upside-down to a work surface, with 3/16" plate used as a spacer between the assembly and the work surface.

2. Clamp a side skirt piece **F7** to the outside of one of the frame pieces in **T2**, using the spacer plate and work surface to ensure constant 3/16" edge offset.

3. Tack the side skirt piece F7 to the upper frame.

4. Repeat the previous three steps for all four side skirts.

5. Remove clamping.

6. Weld the corner edges of the side skirts together as outside corner joints. Use aluminum backing blocks to prevent the corners from collapsing.

7. Weld skirts **F7** to the frame, using three or four 1-inch fillets per side. Minimize heat.

(a) Welds between the arm and frame sub-assemblies.

(b) Welds on the upper frame; side skirt interior.

Figure 8: Weld details.

9 Dampener Module

9.1 Defining the problem

During initial testing of the assembled table, I observed that the upper section was prone to azimuthal oscillations. With the cables sufficiently tensioned the magnitude of movement was pretty small, but any disturbance would result in perceptible twisting oscillations which would persist for up to several minutes.

The upper surface of the table was behaving as a harmonic oscillator. Similarly to a weight suspended from a bouncy spring, an initial displacement resulted in cyclic motion back and forth past the equilibrium position. Increasing the cable tension would reduce the period and magnitude of oscillations, but did little to make the table come to rest any sooner. The only solution would be to add damping; some part of the system which would absorb and dissipate the kinetic/potential energy of the moving mass.

9.2 Principle of Operation

Many engineering domains require the use of damping components to manage movement and oscillation. An engineering application with parallels to the behavior of my table is controlling wind-induced sway in skyscrapers. For this purpose, one solution is to build in large tanks or pipes partially filled with liquid. These devices are known as Tuned Slosh Dampers.

As the structure moves, liquid in the damper vessel sloshes. Movement of waves in the fluid can counteract a structure's swaying motion, similar to a pendulum tuned mass damper. The energy of these waves is dissipated by the liquid's viscosity. Consequently, the damper as a whole functions to reduce swaying and dampen oscillating motion.

Applying this concept to my table, I was able to almost entirely control azimuthal oscillations by simply placing a partially-filled quart jug of motor oil on the table's surface.

Since I only identified the need for damping after the table was partially built, the damping module had to be added on to the table's original design. I decided to add a slosh tank made from the same 1" square tube as the table's frame assemblies. The slosh damper was partially filled with motor oil and bolted directly underneath one of the upper frame pieces, almost entirely concealed.

This size of concealed tank could only be filled with about 100mL of oil while still maintaining the necessary free surface. The relatively small fluid mass meant that damping was only partially successful. The table does return to rest more quickly than without dampening, but the effect is relatively subtle.

9.3 Damper Fabrication

9.4 Cuts

A piece of 1" x 14ga square steel tube was cut to 12" long using the horizontal bandsaw, creating **D1**. After cutting, the piece was then cleaned, deburred, and ground to remove mill scale.

Two pieces of 16ga cold roll steel were cut to 1" square using the plate shear for pieces **D2** and **D3**.

Two pieces of 16ga cold roll steel were cut to 1 1/8" x 1 3/4" using the plate shear for piece **D5**.

9.5 Damper Fabrication

9.6 Adding Mounting Screw Holes to Table

1. Scribe a horizontal centerline on the inner surface of upper frame component **F7**.
2. Scribe marks for two holes at this centerline, 2" from the inner face of each frame side piece (12" hole pitch).
3. Center punch hole locations, then drill and tap for #6-32 screws.

9.7 Component Fabrication

1. To create **D3**, scribe the center point of one of the 16ga x 1" square sheet pieces, center punch, pilot drill, then drill to 3/8".
2. Scribe, center punch, and drill the 1/8" holes in **D5**, per the drawing.

3. Radius the corners of **D5** using a grinder and/or disk sander. Clamp both pieces together while shaping to ensure symmetry. The exact radius of curvature isn't critical, but the radii should be smooth and cosmetically attractive.

4. As shipped, **D4** is a double-ended threaded pipe coupling. Since only one threaded end is required to accommodate the NTP threaded plug, cut the coupling in half using a grinder cutoff wheel or vertical bandsaw. If needed, sand the cut surface smooth with a disc sander, then deburr.

9.8 Damper Welding

1. Tack and then weld the **D2** and **D3** end caps to **D1**. Welds must be watertight.

2. Tack and then all-around fillet weld **D4** to **D3**, centered over the hole. Welds must be watertight.

3. Fit up and tack brackets **D5** to **D1**. The relative position of these components is not symmetric – **D5** overhangs 3/4" on one side to shroud the threaded fill port, but only about 1/8" from the opposite side. The critical dimension is the 12" pitch between the mounting holes on **D5**. To ensure proper positioning, I decided to tack **D1** with **D5** already screwed in place to the upper table assembly.

4. Lap weld brackets **D5** to **D1**.

10 Finishing

Disassemble small axial components in **T2**. Remove any remaining burrs or irregularities. Slightly radius all outside edges using an air grinder & sanding disk. Strip and degrease.

The table was powdered coated using Prismatic Powders PMB-4152 "Lazer Bronze".

11 Final Assembly

11.1 Preparation

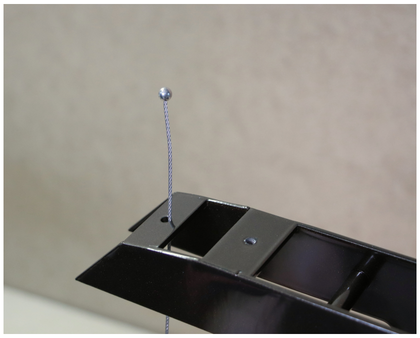
1. Assemble the axial components of the lower arm as shown in *Detail A* of drawing T2.

2. Use a syringe to fill the damper module with about 100mL of 5W-30 motor oil. Screw the threaded plug **D6** tightly in place, using PTFE tape to seal the threads.

(a) Assembly of axial components.

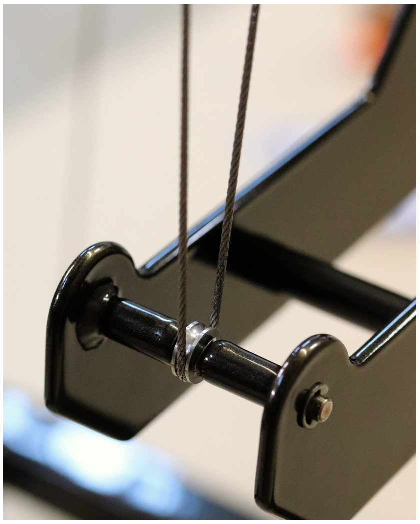
(b) Filling the damper with oil.

(c) Placing the side cables.

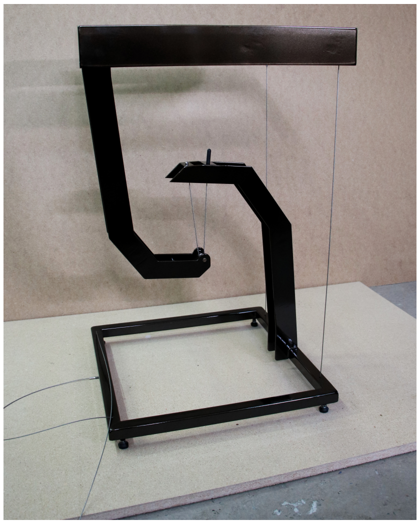


(d) Placing the center cable.

Figure 9: Some assembly steps.



(a) Center cable wrapping around the hang point.



(b) The table midway through hanging.

Figure 10: Hanging the upper table.

3. Mount the damper module in place on the upper table assembly using two #6-32 x 1/4" button cap screws.
4. Thread the swivel feet **H1** into the weld nuts on the lower table assembly. Adjust the feet until the assembly sits level.
5. Thread each of the four **C2** cables upwards through the frame holes in the lower table assembly.
6. Thread the center cable **C1** downwards through the unthreaded hole in hang plate **A2**.

11.2 Hanging the Table

1. Enlist an assistant to hold the upper table assembly in position above the lower table assembly. Loop the threaded plug of center cable **C1** down around the central hang point, then back up to anchor into the tapped hole in hang plate B.
2. Anchor the threaded plugs of the two side cables **C2** into their corresponding weld nuts of the upper table assembly. If you do this with with the two cables opposite the upper arm, the upper table assembly should now be able to hang loosely supported by the center cable.
3. Anchor the remaining side cables **C2** to their corresponding weld nuts on the upper table assembly.

4. Tighten the anchor of center cable **C1** until the upper table assembly sits at the desired height.

5. Tighten the threaded plugs on the side cables such that the upper table surface is level.

6. Continue to tighten the side cables until they are adequately tensioned. Pressing down firmly on a corner can make it easier to increase the tension on that corner's cable.

11.3 Furnishings

1. Place a vinyl screw cover over the exposed thread anchoring center cable **C1**.

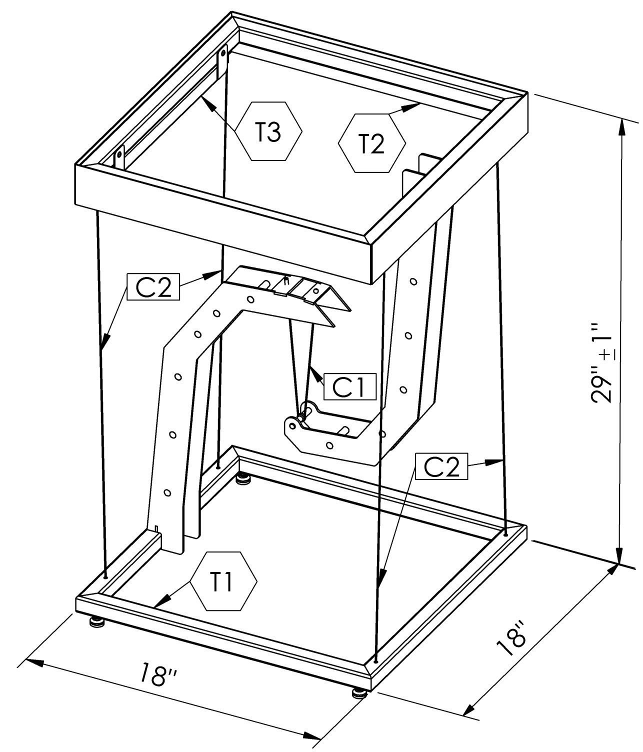
2. Place a small non-stick bumper on each of the four corners where the glass tabletop will rest.

3. Set the glass tabletop surface on top of the table, snug into the recess created by the side skirts **F7**.

4. The table is now complete.

12 Appendix: Drawings

Figure 11: The completed table, in-situ.



ASSEMBLY	NAME
T1	Table Lower
T2	Table Upper
C1	Center Cable
C2	Side Cable
T3	Damper Module

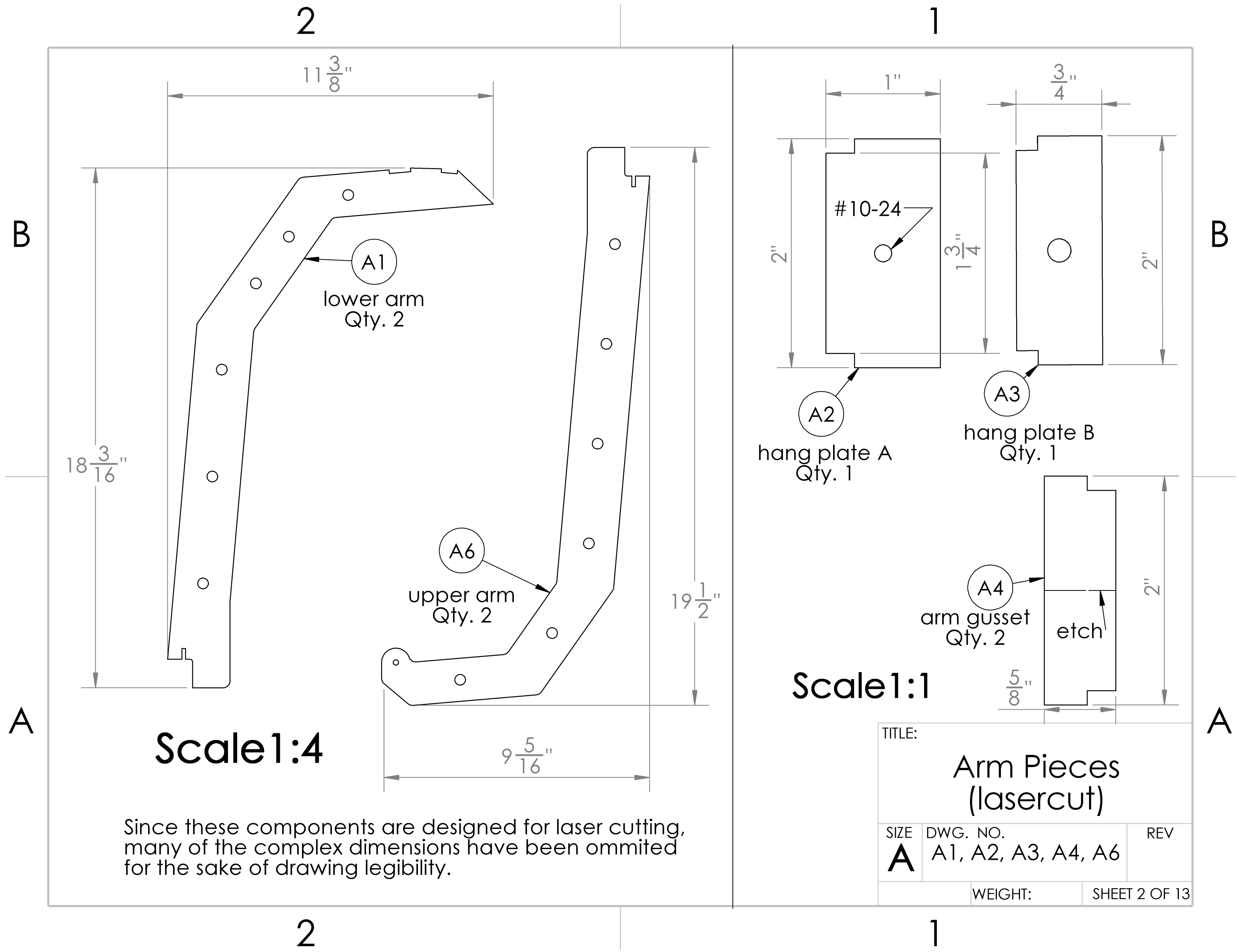
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES STD. TOLERANCES: ±1/16	LAST MODIFIED	[redacted]	6/25/2022
Weld GTAW	COMMENTS: Final Project Welding Fabrication [redacted] Community College Instructor [redacted]		
MATERIAL Steel			
FINISH Painted surface welds ground flush			

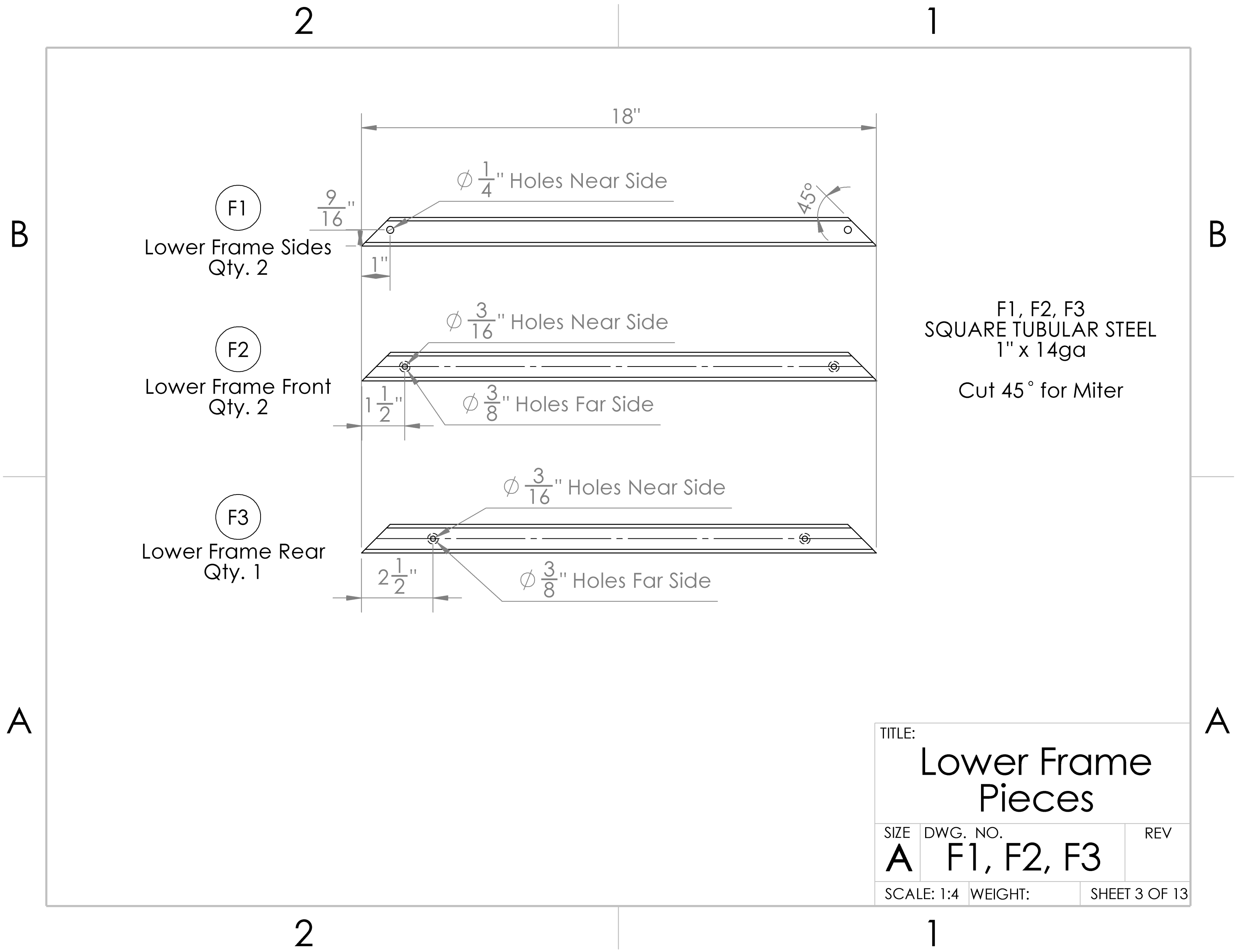
[redacted]

TITLE: Tensegrity Table

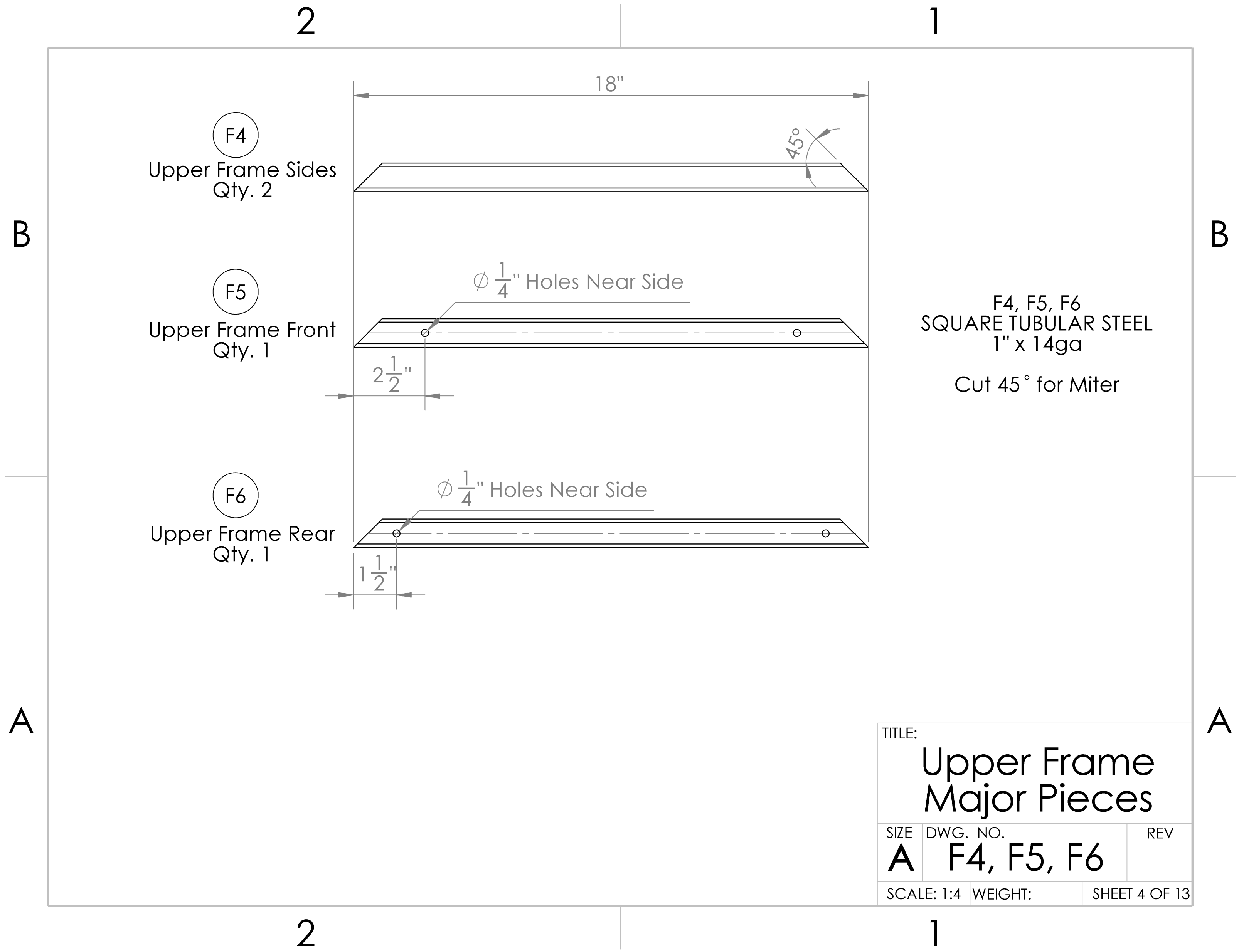
SIZE A | DWG. NO. Overview | REV

SCALE: 1:8 | WEIGHT: 22lb | SHEET 1 OF 13

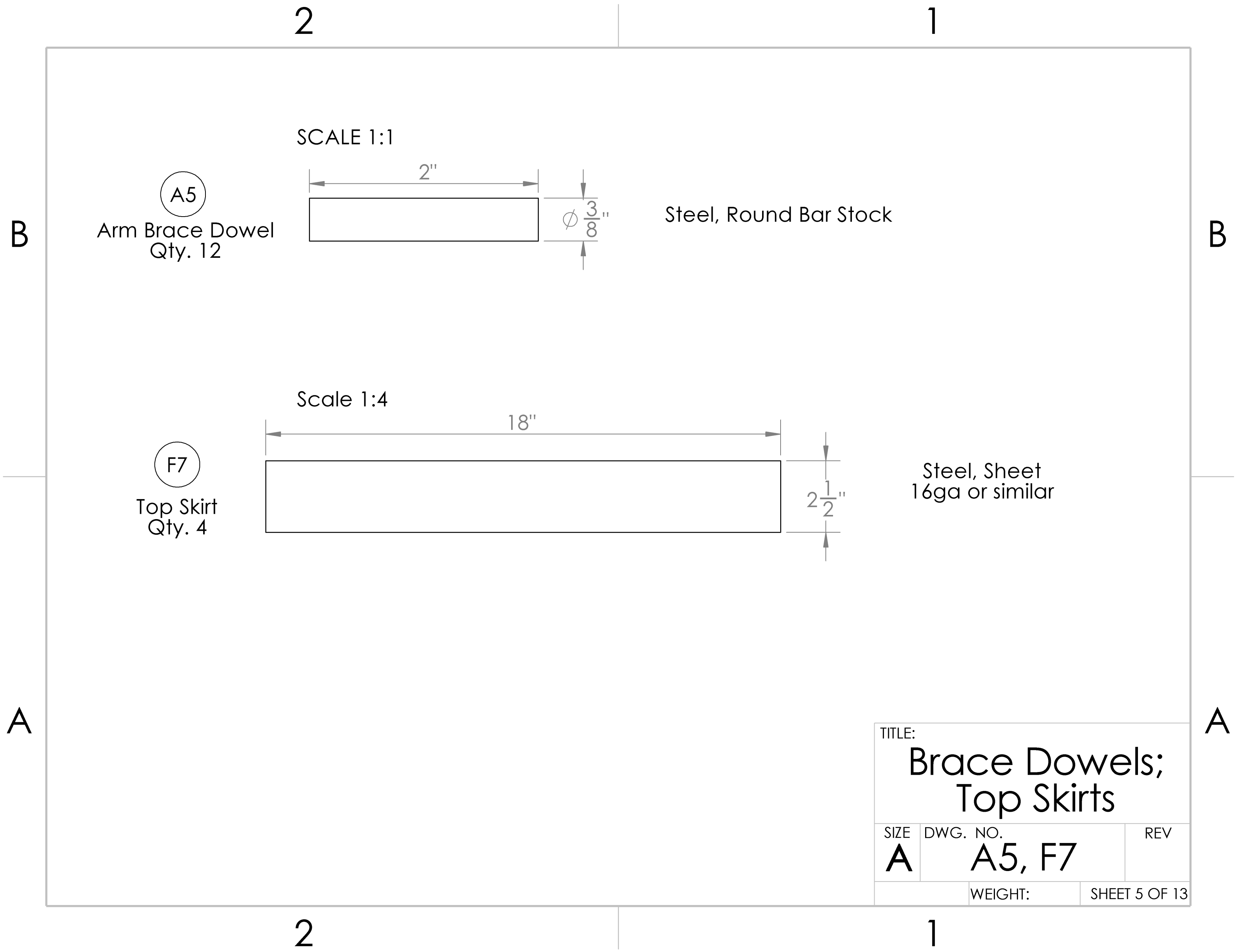

2
1
B
A
11 3/8"
18 3/16"
A1
lower arm
Qty. 2
A6
upper arm
Qty. 2
19 1/2"
9 5/16"
Scale1:4
Since these components are designed for laser cutting, many of the complex dimensions have been ommited for the sake of drawing legibility.
1"
3/4"
2"
#10-24
1 3/4"
A2
hang plate A
Qty. 1
A3
hang plate B
Qty. 1
A4
arm gusset
Qty. 2
etch
5/8"
Scale1:1
TITLE:
Arm Pieces
(lasercut)
SIZE
A
DWG. NO.
A1, A2, A3, A4, A6
REV
WEIGHT:
SHEET 2 OF 13



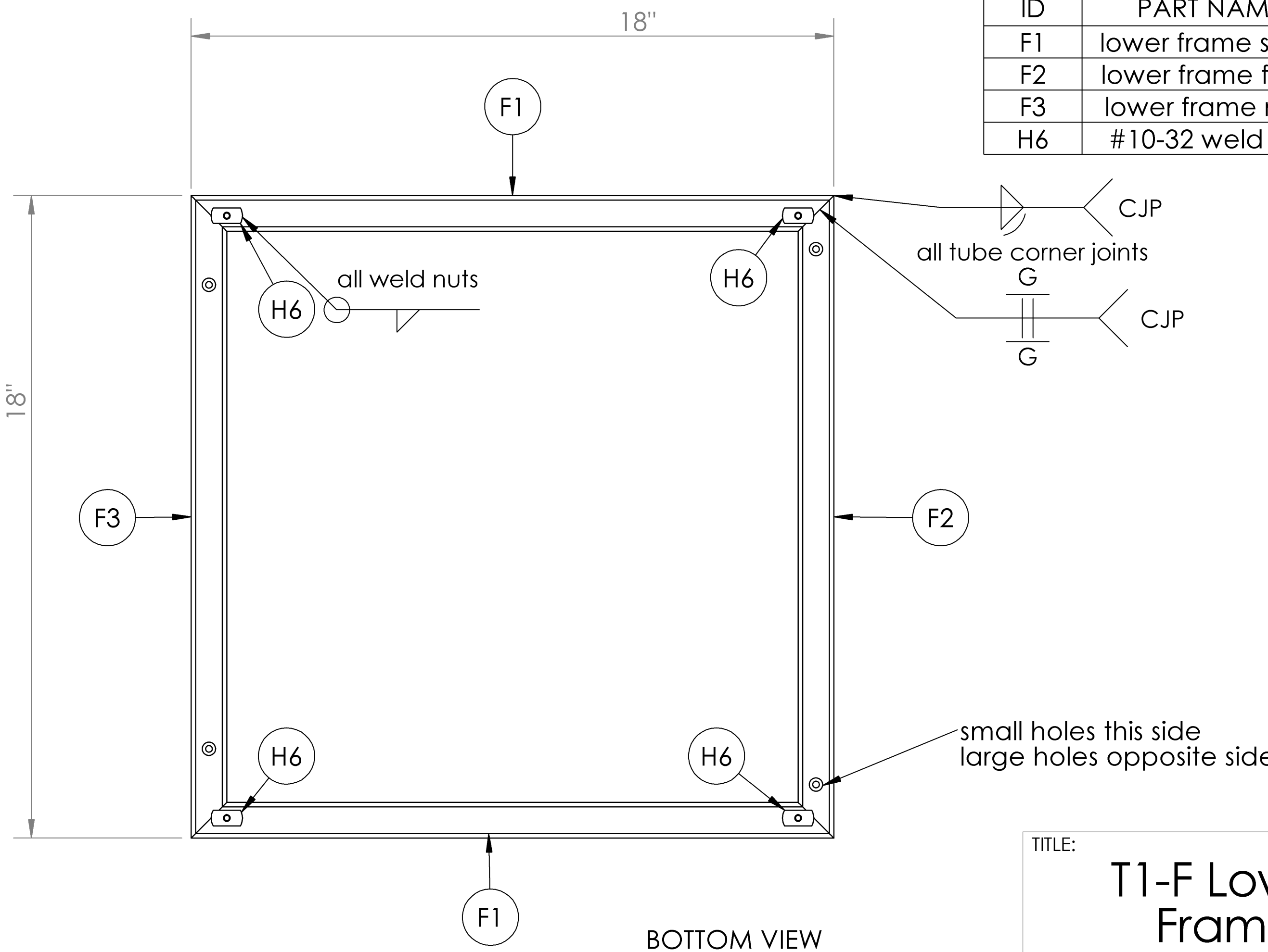
18"
F1
Lower Frame Sides
Qty. 2
9/16"
1"
∅ 1/4" Holes Near Side
45°
F2
Lower Frame Front
Qty. 2
∅ 3/16" Holes Near Side
∅ 3/8" Holes Far Side
1 1/2"
F3
Lower Frame Rear
Qty. 1
∅ 3/16" Holes Near Side
∅ 3/8" Holes Far Side
2 1/2"
F1, F2, F3
SQUARE TUBULAR STEEL
1" x 14ga
Cut 45° for Miter
TITLE:
Lower Frame Pieces
SIZE A
DWG. NO. F1, F2, F3
REV
SCALE: 1:4
WEIGHT:
SHEET 3 OF 13



18"
45°
F4
Upper Frame Sides
Qty. 2
F5
Upper Frame Front
Qty. 1
$\phi \frac{1}{4}$" Holes Near Side
$2\frac{1}{2}$"
F6
Upper Frame Rear
Qty. 1
$\phi \frac{1}{4}$" Holes Near Side
$1\frac{1}{2}$"
F4, F5, F6
SQUARE TUBULAR STEEL
1" x 14ga
Cut 45° for Miter
TITLE:
Upper Frame
Major Pieces
SIZE
A
DWG. NO.
F4, F5, F6
REV
SCALE: 1:4
WEIGHT:
SHEET 4 OF 13


SCALE 1:1
2"
Ø 3/8"
A5
Arm Brace Dowel
Qty. 12
Steel, Round Bar Stock
Scale 1:4
18"
2 1/2"
F7
Top Skirt
Qty. 4
Steel, Sheet
16ga or similar
TITLE:
Brace Dowels; Top Skirts
SIZE A
DWG. NO. A5, F7
REV
WEIGHT:
SHEET 5 OF 13
2
1
B
A

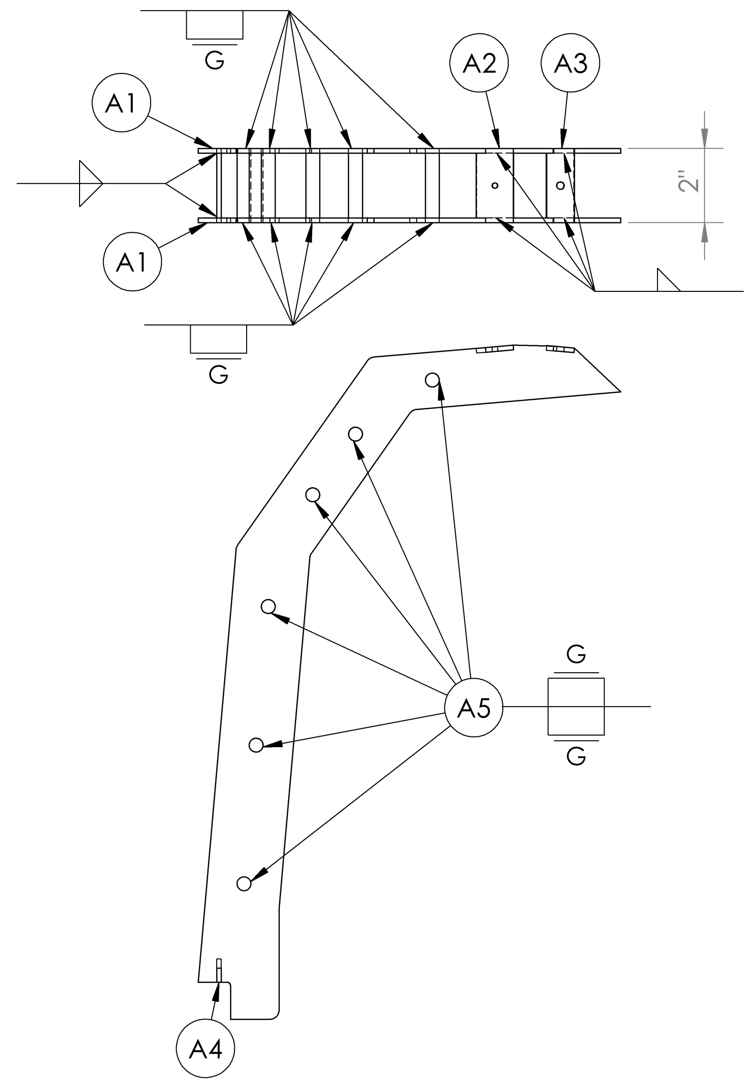
ID	PART NAME	QTY.
F1	lower frame sides	2
F2	lower frame front	1
F3	lower frame rear	1
H6	#10-32 weld nut	4



TITLE: T1-F Lower Frame

SIZE	DWG. NO.	REV
A	T1-F	

SCALE: 1:4 | WEIGHT: | SHEET 6 OF 13

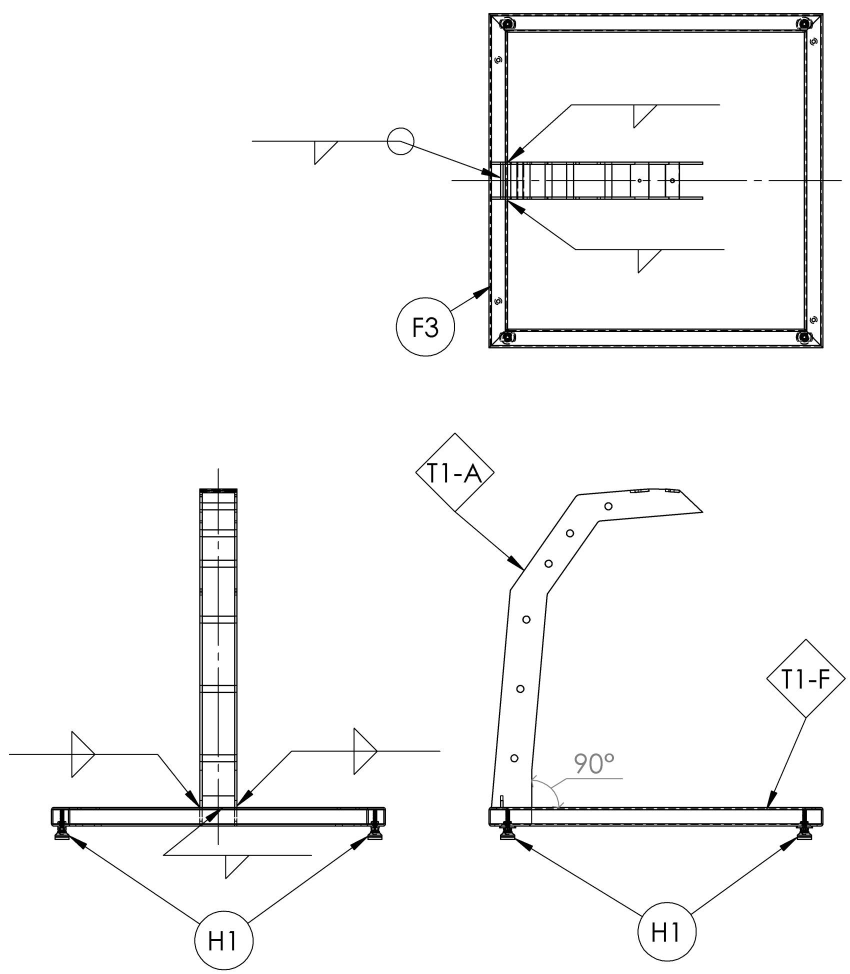


ID	PART NAME	QTY.
A1	lower arm	2
A2	hang plate A	1
A3	hang plate B	1
A4	arm gusset	1
A5	arm brace dowel	6

TITLE:
T1-A Lower Arm

SIZE: A | DWG. NO.: T1-A | REV

SCALE: 1:4 | WEIGHT: | SHEET 7 OF 13

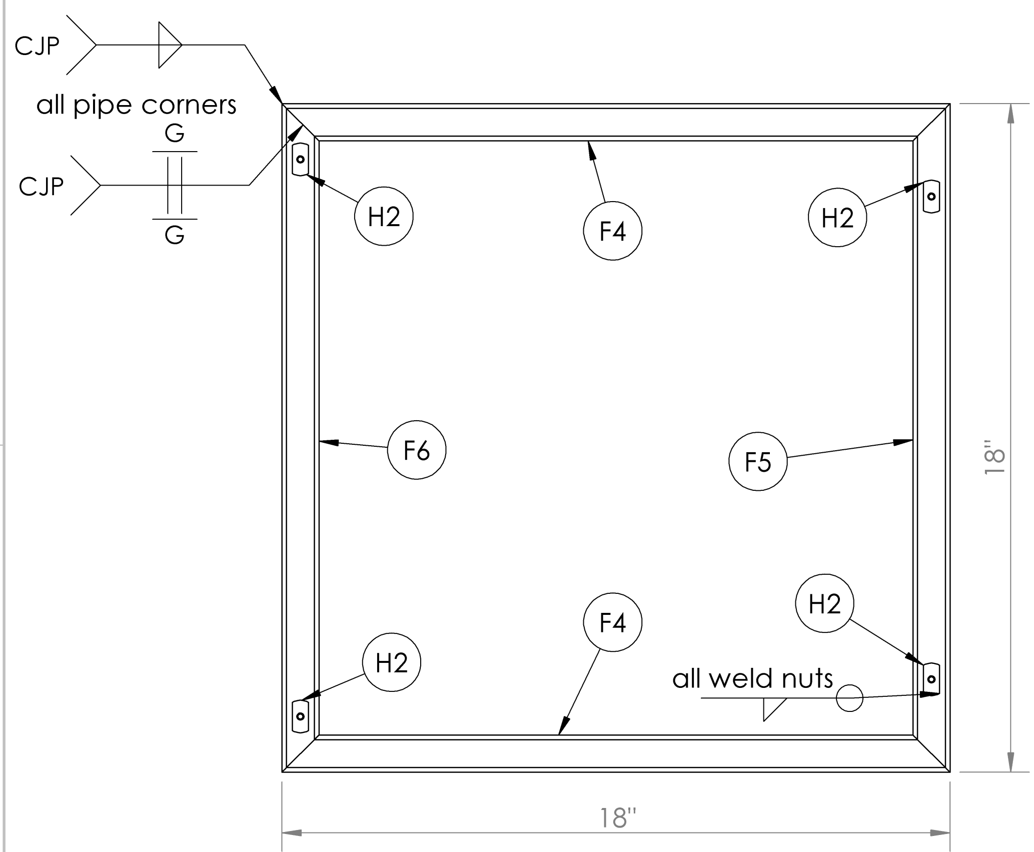


ID	PART NAME	QTY.
T1-A	lower arm s.assembly	1
T1-F	lower frame s.assembly	1
H1	leveling foot	4

Carefully note relative positions of F2 and F3 frame holes. T1-A must be welded to component F3.

TITLE: T1 Lower Table Assembly			
SIZE A	DWG. NO. T1		REV
SCALE: 1:8	WEIGHT:		SHEET 8 OF 13

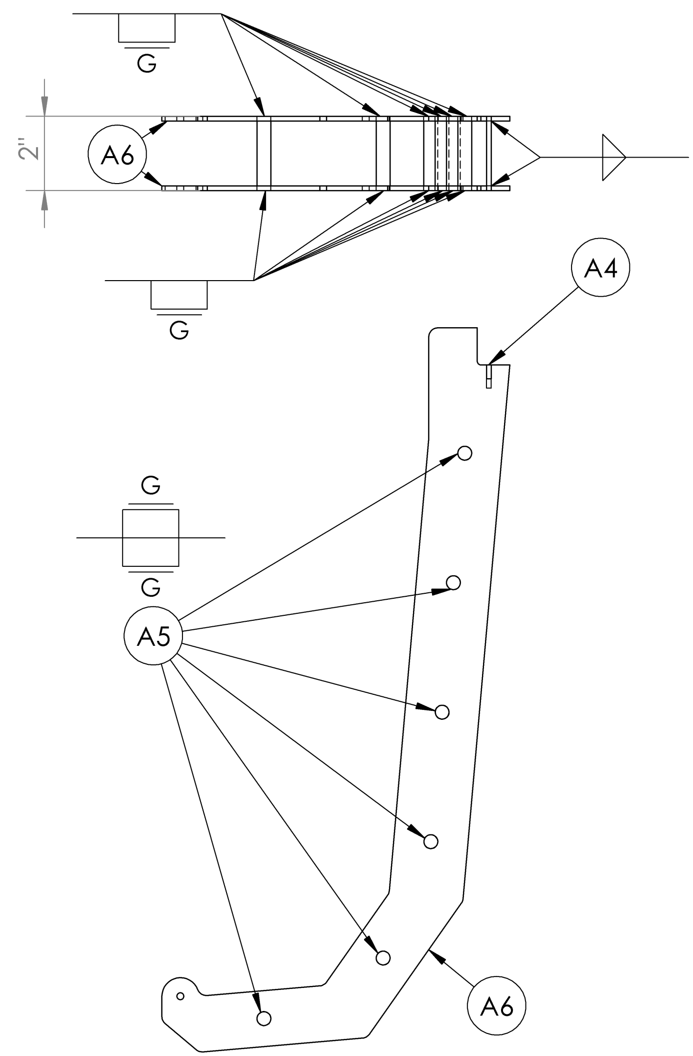
ID	PART NAME	QTY.
F4	frame upper side	2
F5	frame upper front	1
F6	frame upper rear	1
H2	#10-24 weld nut	4



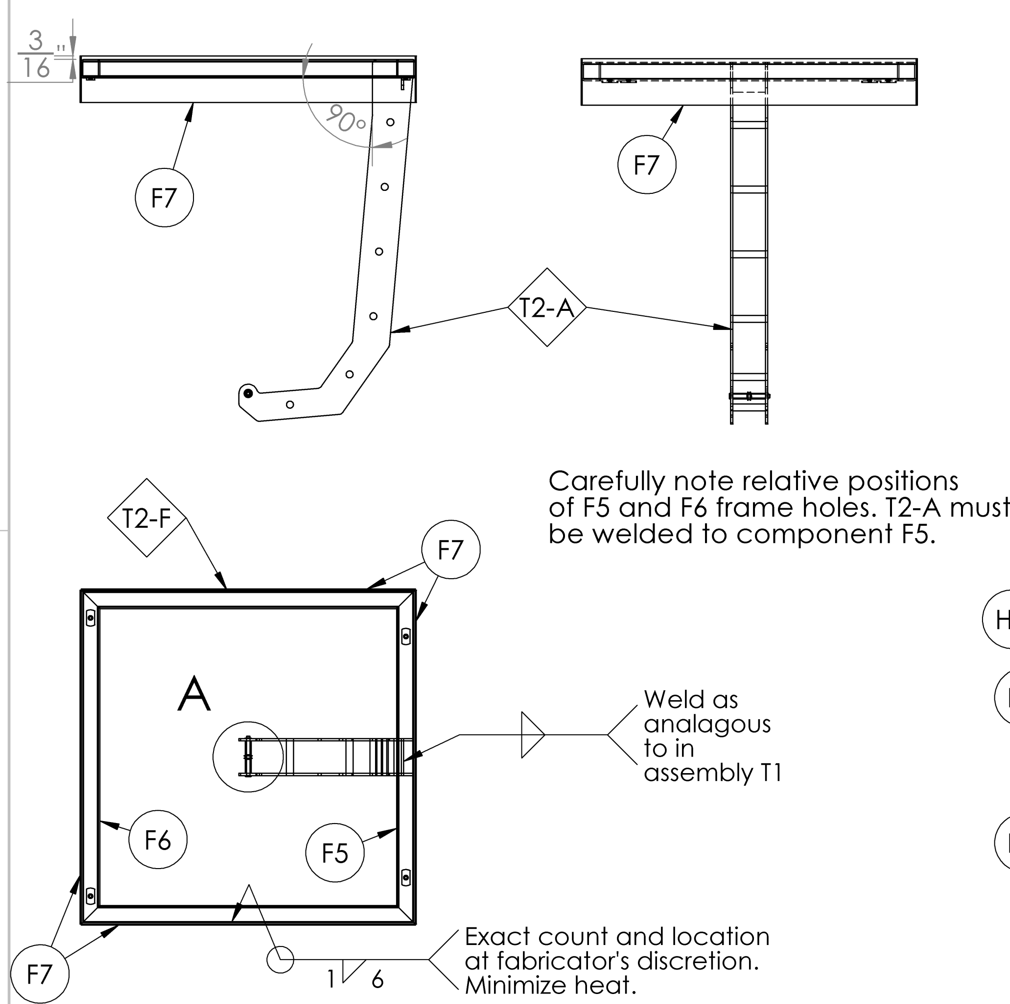
BOTTOM VIEW

TITLE: T2-F Upper Frame			
SIZE A	DWG. NO. T2-F		REV
SCALE: 1:4	WEIGHT:		SHEET 9 OF 13

ID	PART NAME	QTY.
A4	arm gusset	1
A5	arm brace dowel	6
A6	upper arm	2

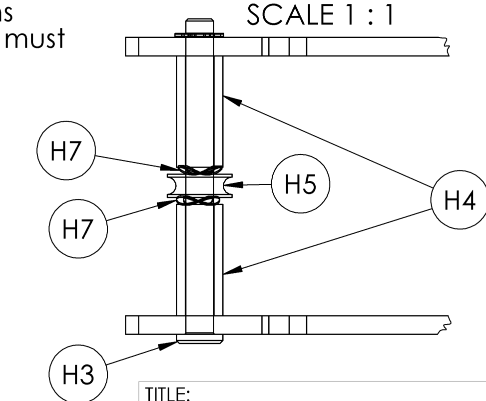


TITLE: T2-A Upper Arm		
SIZE A	DWG. NO. T2-A	REV
SCALE: 1:4	WEIGHT:	SHEET 10 OF 13



ID	PART NAME	QTY.
T2-A	Upper Frame s.assembly	1
T2-F	Upper Arm s.assembly	1
F7	top skirt	4
H2	weld nut	4
H3	clevis pin	1
H4	unthreaded spacer	2
H5	wire rope thimble	1
H7	single wave washer	2

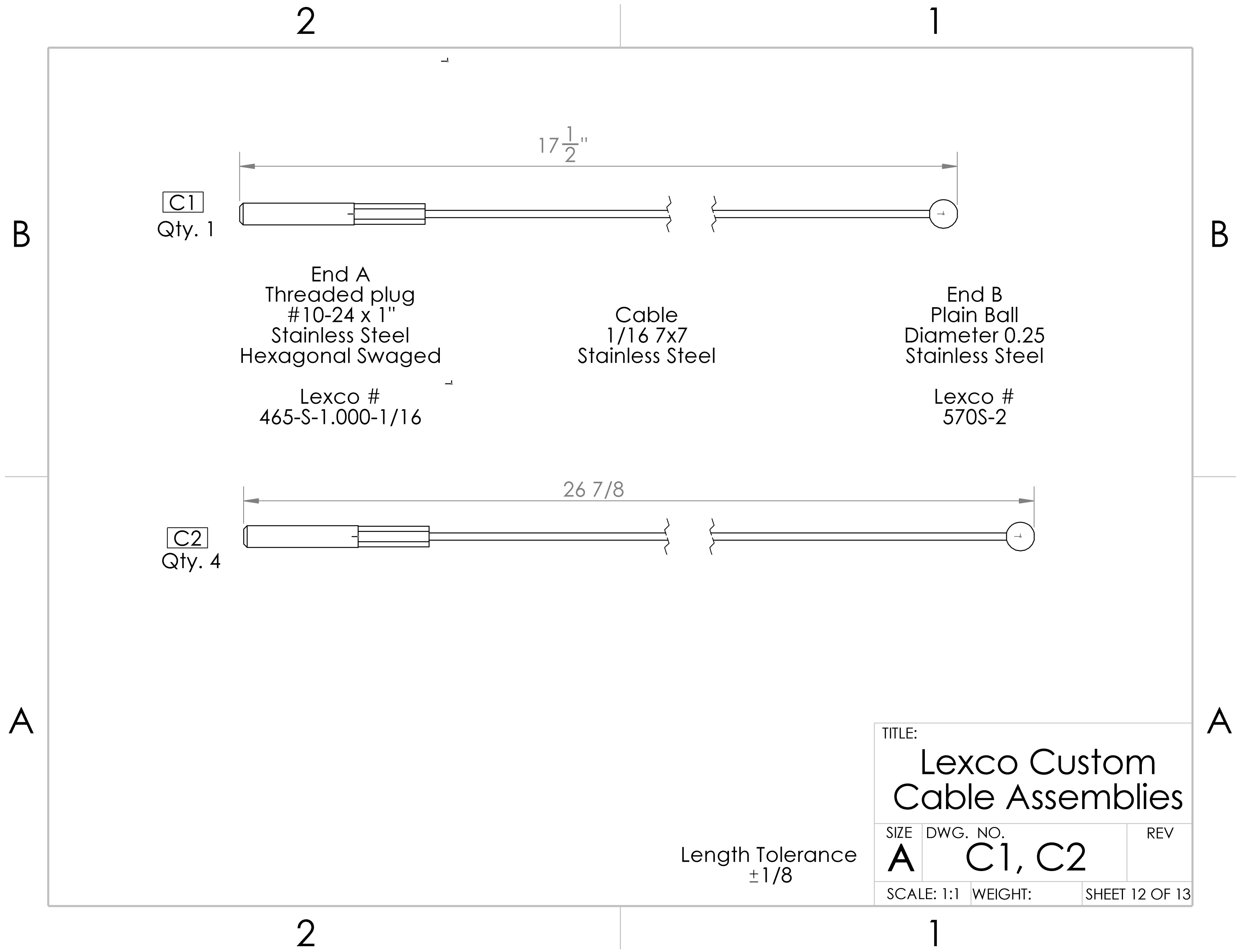
DETAIL A
SCALE 1 : 1



TITLE: Upper Table Assembly

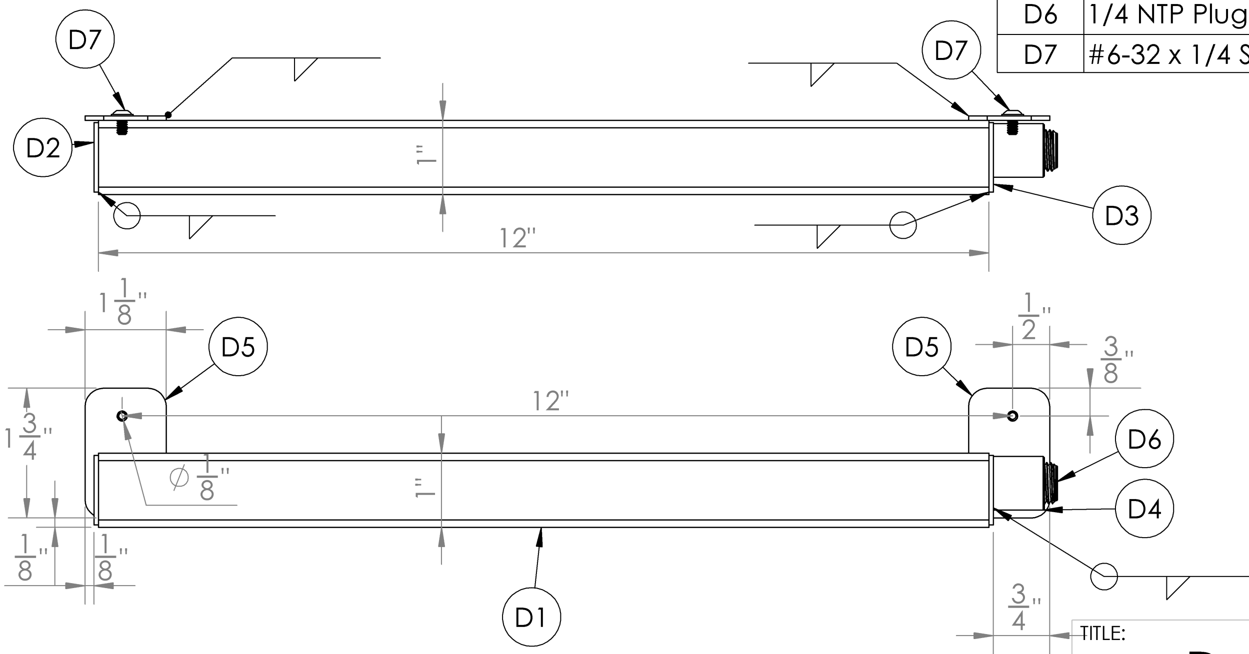
SIZE: A | DWG. NO.: T2 | REV

SCALE: 1:8 | WEIGHT: | SHEET 11 OF 13



C1
Qty. 1
17 1/2"
C2
Qty. 4
26 7/8
End A
Threaded plug
#10-24 x 1"
Stainless Steel
Hexagonal Swaged
Lexco #
465-S-1.000-1/16
Cable
1/16 7x7
Stainless Steel
End B
Plain Ball
Diameter 0.25
Stainless Steel
Lexco #
570S-2
Length Tolerance
±1/8
TITLE:
Lexco Custom
Cable Assemblies
SIZE
A
DWG. NO.
C1, C2
REV
SCALE: 1:1
WEIGHT:
SHEET 12 OF 13

ID	PART NAME	QTY.
D1	Damper Tube	1
D2	Damper Closed End	1
D3	Damper Port End	1
D4	1/4 NTP Connector	1
D5	Damper Bracket	2
D6	1/4 NTP Plug	1
D7	#6-32 x 1/4 Screw	2



Welds must be water-tight

Fill damper unit with approx. 100mL 5W-30 motor oil

TITLE: Damper Module

SIZE	DWG. NO.	REV
A	T3	
SCALE: 1:2	WEIGHT:	SHEET 13 OF 13