# Table of Contents

1. Important Safety Instructions ........................................................................................................... 4  
2. Parts and Accessories .......................................................................................................................... 5  
  2.1. Gas Springs .................................................................................................................................... 5  
     Figure 1: Gas Spring ......................................................................................................................... 5  
  2.2. Tabletop ........................................................................................................................................ 5  
     Figure 2: Tabletop ............................................................................................................................. 6  
  2.3. Base ............................................................................................................................................... 6  
     Figure 3: 1” by 3” Extrusion ............................................................................................................. 6  
  2.4. Upper Framing and Legs .................................................................................................................. 6  
     Figure 4: 1” by 1” Extrusion ............................................................................................................. 6  
  2.5. Linear Bearings .............................................................................................................................. 7  
     Figure 5: Linear Bearing .................................................................................................................... 7  
  2.6. Brakes .......................................................................................................................................... 7  
     Figure 6: Brake ................................................................................................................................. 8  
  2.7. Gussets ......................................................................................................................................... 8  
     Figure 7: Corner Brackets ................................................................................................................. 8  
  2.8. Hydraulic Release .......................................................................................................................... 8  
     Figure 8: Release Button of Hydraulic Release ................................................................................ 9  
     Figure 9: Cap of Hydraulic Release .................................................................................................. 9  
3. Features ............................................................................................................................................. 10  
  3.1. Gas Springs ................................................................................................................................... 10  
  3.2. Hydraulic Release .......................................................................................................................... 10  
  3.3. Extensions on Base ......................................................................................................................... 10  
  3.4. Locking Legs ................................................................................................................................. 10  
  3.5. Tabletop ...................................................................................................................................... 10  
4. Introduction ....................................................................................................................................... 11  
  4.1.1. Overview ................................................................................................................................. 11  
  4.1.2. Steps for Adjustment ............................................................................................................... 11  
     Figure 10: Brake System ................................................................................................................... 11  
     Figure 11: Brake Setup ...................................................................................................................... 12  
     Figure 12: How to Raise Table ......................................................................................................... 13  
     Figure 13: Picture of Release Button ............................................................................................... 14  
     Figure 14: Positioning of Users for Lowering Table ........................................................................ 15  
5. Maintenance ...................................................................................................................................... 15  
     Figure 15: Where to apply grease on unibearing leg .................................................................... 16  
     Figure 16: Example of a windex cleaning solution ........................................................................ 17  
     Figure 17: Debris inside unibearing leg and base ......................................................................... 18  
     Figure 18: Screw coming loose between base and sliding leg connection .................................... 19  
     Figure 19: Screw coming loose underneath tabletop ..................................................................... 20  
6. Technical Description ......................................................................................................................... 21  
     Figure 20: Dimensions of tabletop ............................................................................................... 22  
     Figure 21: Steel support bars underneath tabletop ......................................................................... 23  
     Figure 22: Dimensions required to cut 1x1” 80/20 extrusion ......................................................... 24
Figure 23: Dimensions and orientation of upper framing
Figure 24: Dimensions of new manufactured corner brackets
Figure 25: Orientation of corner brackets and upper framing underneath tabletop
Figure 26: Dimensions and orientation of sliding unibearing leg
Figure 27: Gusset bracket reinforcing upper framing and leg connection
Figure 28: AutoCAD design of the Unibearing and Brakes Connecting to the 1010 Extrusions
Figure 29: View of Gas Spring Representation and Linear Motion Mechanism
Figure 30: Unibearing Setup with L-Handle Brakes
Figure 31: Stopper for Vertical 1010 Extrusion
Figure 32: Mounts for Unibearing Stoppers
Figure 33: Placement of the unibearing legs and gas springs
Figure 34: Torque encountered when raising the table
Figure 35: Diagram of Linear Motion Problem
Figure 36: Screw Connecting the Two Extrusions on Unibearing
Figure 37: Bracket below the upper sliding leg
Figure 38: The set of sliding legs with just the screw held in by a single hole bracket
Figure 39: Proper Brake System Operation on actual Unibearing
Figure 40: Try to avoid having the two handles interfere
Figure 41: Instead, tighten one so that it is out of the way, then tighten the other
Figure 42: Gas Spring Setup
Figure 43: Free Body Diagram of Third Setup
Figure 44: Optimal Setup
Figure 45: Free Body Diagram of Center
Figure 46: Mount for base connection of gas spring
Figure 47: Mount Positioning on Base
Figure 48: Diagram of Top Gas Spring Attachment
Figure 49: Hydraulic Release
Figure 50: Mounting for Hydraulic Release Button
Figure 51: Engaged Button
Figure 52: Disengaged Button
Figure 53: Top of Gas Spring
Figure 54: Dimensions of base
Figure 55: Testing procedure of base
Figure 56: Base with added extrusion on ends
Figure 57: Dimensions of flat mount
Figure 58: Places to Apply Force
Figure 59: Where to apply grease on unibearing leg
Figure 59: Where to apply grease on unibearing leg
Figure 60: Where to Apply Force Prior to Locking
Problem 5: Gas springs continue to rise after button is released. ........................................ 60

Figure 61: Top of Gas Spring .................................................................................................. 61

Problem 6: Gas springs do not extend when the button is pressed .................................. 61

Problem 7: The table stops raising before maximum height of 42” .................................. 62

9. Letter to the Client ........................................................................................................ 63
1. Important Safety Instructions

- Always have the brakes locked when using the table, this will ensure that the table will stay steady during use and that accidental activation of the gas springs will not allow the table to adjust.

- Never adjust the table with someone underneath. This is to ensure the safety of the user.

- Although the table legs can hold upwards of 300 pounds, it is advised that no one sits on the table or overloads it. This is especially important for when someone is sitting at the table.

- Never press the gas spring release button unless attempting to adjust the table, doing this while someone is using the table can cause bodily harm.
2. Parts and Accessories

2.1. Gas Springs

Manufacturer: Easylift of America
Part: Rigid Blocking in the Push in Direction Locking Gas Spring
Specifications: Stroke Length - 330 mm
Force – 65 N (14.6 lbs)

![Gas Spring](image)

*Figure 1: Gas Spring*

2.2. Tabletop

Manufacturer: Iceberg
Part: Model 64054
Specifications: Length – 72”
Width – 30”
Depth – 2”
2.3. **Base**
   Manufacturer: Air Inc
   Part: 1030 1” by 3” Extrusion

![Figure 2: Tabletop](image2)

2.4. **Upper Framing and Legs**
   Manufacturer: Air Inc
   Part: 1010 1” by 1” Extrusion

![Figure 3: 1” by 3” Extrusion](image3)

![Figure 4: 1” by 1” Extrusion](image4)
2.5. **Linear Bearings**

Manufacturer: Air Inc  
Part: Single Side Long Unibearing (10 Series)

![Figure 5: Linear Bearing](image)

2.6. **Brakes**

Manufacturer: Air Inc  
Part: L-Handle Linear Brake (10 Series)
2.7. **Gussets**

Manufacturer: Home Depot  
Part: 10” Corner Bracket

![Figure 7: Corner Brackets](image)

2.8. **Hydraulic Release**

Manufacturer: Easylift of America  
Part: 5.2 Parallel Hydraulic Release  
Specifications: Tubing Lengths – 915 mm, 915 mm, and 1065 mm
Figure 8: Release Button of Hydraulic Release

Figure 9: Cap of Hydraulic Release
3. Features

3.1. Gas Springs

These gas springs are necessary for adjusting the table height. They provide a constant amount of force to the bottom of the tabletop when engaged. This force is just enough to slowly raise the table. To lower the table, the force applied to the top of the tabletop must be larger than the force applied by the gas springs.

3.2. Hydraulic Release

This release allows both gas springs to be adjusted simultaneously using one single release button. This allows equal adjustment of the two gas springs and also ensures that only one person is needed to raise the table because there is only one release to push. The release is mounted to one side of the table in a location that is out of the way so that no one can accidentally activate the gas springs.

3.3. Extensions on Base

These extensions prevent the table from rocking side to side. They extend a couple inches in each direction from the edges of the 1” by 3” base pieces.

3.4. Locking Legs

These legs provide support in the corners of the tables not held up by gas springs. These legs have linear bearings separating two pieces of aluminum that allow easy sliding while the gas springs are engaged. Prior to use, it is necessary to lock the brakes on the legs to prevent linear motion during use. This allows the table to be adjusted by only two gas springs while also gaining the stability benefits of having four legs.

3.5. Tabletop

The tabletop is a light plastic surface that is 72” by 30”. This surface is very easily cleaned and provides plenty of space for numerous people to work on. In addition to this, the tabletop weighs approximately 25 pounds, which can easily be lifted by the combination of the two gas springs.
4. Introduction

4.1.1. Overview

This table is a multipurpose adjustable table that can be specifically used for art projects. The table adjusts using two gas springs positioned at opposite corners of the tabletop. These gas springs are charged to provide just enough force to slowly raise the tabletop, while requiring a small amount of force to lower the tabletop. The other two corners have aluminum legs that are made up of two aluminum bars joined by a linear motion bearing. The bearing allows the two legs to slide along each other uninhibited, but the bearing can also be locked to provide stability during use. The table comes completely assembled, so one must only adjust the table to the appropriate height and enjoy. The components of the table are described below.

4.1.2. Steps for Adjustment

_Raising the Table:_

1. Disengage breaks from both sliding legs.

![Figure 10: Brake System](image)
2. Press and hold release button while table rises.
Figure 12: How to Raise Table
3. Pull button towards you to disengage gas springs and stop table when at desired height.

**Figure of disabling button (opposite of above)**

4. Lock breaks of both sliding legs (these legs might need to be lifted slightly to make table level before locking).

**Figure showing lifting corners (same as in trouble shooting section)**

5. Table is ready to be used for numerous activities.
**Lowering the Table:**

1. Ensure artists are out from underneath the table.
2. Disengage breaks from both sliding legs.
3. Position one person at each end of the table. See Figure 2.

**Figure 14: Positioning of Users for Lowering Table**

4. Press and hold release button while applying even force on each end to lower the table to the desired height.
5. Pull button towards you to disengage gas springs.
6. Lock breaks of both sliding legs (these legs might need to be lifted slightly to make table level before locking).
7. Enjoy the table.

**5. Maintenance**

As with every mechanical device out there today, a regular maintenance would assure that it is kept functioning properly. The maintenance with this table is relatively simple. The proper maintenance for this table goes hand in hand with its ease in using it. If maintained properly, the table should last a lifetime.
**Routine Maintenance**

- Apply a thin coating of generic grease or WD-40 to the sliding leg which attaches at the base as often as necessary. Make sure the table is fully extended when this is performed. A diagram of this can be seen in Fig. 6. below.

![Diagram showing where to apply grease on unibearing leg](image)

**Figure 15: Where to apply grease on unibearing leg**

- Wash the tabletop completely with a generic cleaning solution whenever necessary to ensure the integrity of the tabletop does not decrease over time. This will also ensure that the tabletop stays flat and smooth since previously spilt liquids may induce flaws inside the surface over time. An example of what this cleaning solution will look like can be seen in the figure below. Some generic examples of typical cleaning solution include brands of Windex and Sparkle.
Figure 16: Example of a Windex cleaning solution

- Dust and brush away small particles outside the sliding legs as well as the gas springs once a month. This will ensure that no excessive buildup of dust or small particles will occur in between the sliding legs as well as on the gas spring’s sliding pistons. If the debris inside the lubricating fluid of the gas springs is kept to a minimum, the gas springs will always function at an optimal level. A diagram showing where debris may form can be seen on the following page in the figure below.
Figure 17: Debris inside unibearing leg and base

- Check for any loose connections once every couple months. This includes any connection underneath the tabletop as well as between the gas springs and sliding legs with the base. Some examples of where to find these connections can be seen on the following pages in Figs. 9 and 10 on the following pages:
Figure 18: Screw coming loose between base and sliding leg connection
Figure 19: Screw coming loose underneath tabletop
If a connection is loose, you will need either a flat head screw driver or a 5/32” allen wrench. These tools will tighten any loose screws that come about with the table. This checkup will ensure the table’s stability and proper lifting when in use.

**Replacement of Parts**

If failure of the brakes occurs (part # 6850):
Contact

Air Inc 1 800 341 2800 sales@airinc.net

If failure of the single side long unibearing occurs (part # 6762):
Contact

Air Inc 1 800 341 2800 sales@airinc.net

If failure of simple components occurs:
Ex: screws, nuts, brackets
You can obtain similar sized parts at your local hardware stores
Home Depot Lowes

6. Technical Description

This section will provide a complete technical description of the adjustable table from top to bottom. Exact heights and lengths of the major components will be given. All of this information should give the user a very in-depth look into the table and how it functions. After reading through this section, the user should have a full understanding of how the components work the way they do.

6.1. Tabletop

The tabletop used will meet the specifications of the Passion Works artists as well as for anyone who would like to draw on it. The tabletop is going to weigh 25 pounds. This is a lightweight when compared to other tabletops on the market. With having a lighter tabletop, it will be that much easier for the tabletop to be raised and lowered. The edges of the tabletop should be smooth to prevent injury to the user. The surface should also be very smooth, as it will be a surface for drawing on.

The tabletop has dimensions of 72X30”. This longer tabletop is going to allow 2 people to sit comfortably on each side of the table. Each person would also have plenty of drawing space to meet his or her drawing needs. Since people would be sitting on both of the long sides of the table, no bars were able to be placed on the ground connecting the sides. This would impinge upon the artists’ amount of leg room. A diagram showing the tabletop dimensions can be seen in the figure below.
This tabletop is made out of a plastic resin material. This type of material allows for the edges of the tabletop to be extremely smooth. This will prevent any sort of injury that may occur to the user or anyone that accidentally bumps into the table. This plastic material also allows for a smooth and easy to clean tabletop. If juice was spilled on the tabletop, the liquid would not be absorbed into it which could decrease the integrity of the tabletop. Since the tabletop is made of plastic, it is relatively lighter than other conventional tabletops out on the market. This will allow for relatively easier portability of the table.

A downfall to this tabletop is partly in fact to that it is so light. This tabletop will need a strong support between the two sides of it. For example, if someone decided to sit on the table directly in the center, it could possibly start to deform in that particular area if there was no support framing directly underneath. A solution to this problem will be discussed in the framing section. Luckily, the tabletop came equipped with long steel bars that attached underneath the tabletop on each of the long sides. A diagram of this can be seen in Fig. 12. These support beams are very strong and will help prevent the tabletop from trying to torque when it is raised. They will also reinforce the integrity of the tabletop if someone decides to sit anywhere between the two sides.
6.2. Framing

The framing is a very crucial piece in the stability of the table. The framing will affect how the table raises as well as how strong the table will be in certain areas. The frame design would also have to accommodate people sitting on each side of the table. There would also have to be no framing running between the sides along the ground. This would inhibit wheelchair users from using the table in a comfortable manner. The framing has to be distributed evenly along the entire table. It also must be cut exactly to specifications or else the table will not function properly.
All of the framing is fabricated from 80/20 extrusion. The framing consists of three parts made from the following size extrusions:

- **Upper framing**: 1X1” 1010 extrusion
- **Sliding Unibearing legs**: 1X1” 1010 extrusion
- **Base**: 1X3” 1030 extrusion

In order to minimize costs, an order for two 97” extrusions, as well as a 25” extrusion was placed. When the extrusions arrived, they had to be cut into their proper lengths in the machine shop. A diagram of how these extrusions were cut can be seen in Fig. 13 below. Each piece of extrusion will then be placed into its proper orientation to complete the frame setup.

![Diagram of 80/20 extrusion dimensions](image)

*Figure 22: Dimensions required to cut 1x1” 80/20 extrusion*
6.3. Upper Framing

The upper framing of the table is designed to completely attach underneath the tabletop. This secures that the tabletop will remain in place at all times. A schematic of the upper framing can be seen in Fig. 15 below. The sides underneath the tabletop will be fully supported by the 1010 extrusion. Another piece of 1010 extrusion will run straight down the middle connecting the two sides. This setup will be bolted flush underneath the tabletop. This will allow the maximum leg room possible for the user while still remaining strong and stable at the same time.

![Figure 23: Dimensions and orientation of upper framing](image)
In order to successfully attach the tabletop to the upper framing, 90 degree corner brackets were required. These brackets would be bolted in between the 1010 extrusion and the tabletop itself. Bolting the upper framing to the tabletop required many corner brackets to make the connection fully secure. Instead of purchasing more of these brackets, they were going to be manufactured in the machine shop instead. A schematic of one of these corner brackets can be seen in Fig. 15. These brackets were going to be a bit smaller in thickness when compared to the original corner brackets from 80/20. This required the purchasing of 3/8” screws. The original ½” screws would be too large to be fully tightened into the corner brackets along the 1010 extrusion.

![Figure 24: Dimensions of new manufactured corner brackets](image.png)
Once all of the new brackets were manufactured, the tabletop would be attached to the upper framing. This had to be done very carefully. Holes had to be drilled into the tabletop in the precise areas where the brackets were going to be placed. Large threaded screws were going to be used to screw into the tabletop. These screws were chosen due to the fact that the tabletop was made of a plastic resin composite. This composite is very flexible, and would quickly tighten around the screw as soon as it was screwed in. Once a screw was put into place, it could not be removed. If a screw were removed from its original location inside the tabletop, it would not be nearly as tight if it were screwed in the same place again. Figure 16 shows a diagram of where the brackets would be placed in relation to the upper framing underneath the tabletop.

**Figure 25: Orientation of corner brackets and upper framing underneath tabletop**
6.4. Support Legs

The sliding unibearing legs are another important component of the framing setup. These legs are going to be fabricated out of 1X1” 1010 extrusion. Each leg will consist of two smaller legs which will slide together in parallel via a single side long unibearing which will be discussed in greater detail in the sections to come. The lower sliding leg will be bolted down to the base, while the higher leg will be bolted to the upper framing. A schematic of this can be seen in Fig. 17.

*Figure 26: Dimensions and orientation of sliding unibearing leg*
The connection between the upper unibearing leg and upper framing had to be extremely secure in all directions. If it was not secure in all directions, it could cause the whole table to be off balance and lose its stability. The whole table was briefly put together and tested for stability. It turned out that the framing was extremely wobbly and unstable due to the connection between the upper framing and unibearing leg. In order to fix this problem, a much stronger bracket was needed which would provide enough reinforcement to the connection so that it would not pivot about its axis. The solution for this problem can be seen in Fig. 18.

Figure 27: Gusset bracket reinforcing upper framing and leg connection

It is easily seen that the gusset bracket is bolted flush against the sliding leg, upper framing, and the tabletop. A second gusset bracket identical to the one above will be placed in the same orientation for the connection between the upper framing and the unibearing leg on the opposite side of the table. This extra reinforcing bracket will take away any swaying that would occur around the connection between the upper framing and sliding unibearing leg. This was the case upon further testing of the table when it was constructed for the second time.
6.5. Unibearings

The unibearing is the mechanism which allows a part of the table to adjust in height. A unibearing consists of two extrusions which run parallel and adjacent to each other with a unit, known as the unibearing itself, and two brakes. All of the parts work in conjunction to allow the extrusion to move when it is desired to move, and to stay put when the brakes are locked. The unibearing works using friction; the extrusion is held so tightly that it does not move. When the brakes are loosened, the extrusion is free to slide along a plastic piece which provides a smooth surface for gliding. Therefore the amount that the unibearing can hold depends on how tightly the user makes the brake. Although this relies on the user significantly, there is no way to have this system automatic.

![Figure 28: AutoCAD design of the Unibearing and Brakes Connecting to the 1010 Extrusions](image)

This AutoCAD drawing shows how the unibearing looks through the extrusion. The two handles are two the left and it is these that essentially hold the extrusion to the unibearing when the handles are tightened. The plastic sliders that were mentioned previously are on the right and consist of the two sets of four rectangular shapes. The drawing depicts how the two extrusions...
run parallel to each other, vertically, and the unibearing connects the two together. In general, this whole apparatus serves as two of the four legs on the table. So for these unibearings to be of any use, it is necessary that one of the extrusions connects to the frame of the tabletop above and with the base on the bottom. The extrusions are connected in the regular fashion with inside corner brackets, on both the top and the bottom. Exactly how the unibearings fit in between the two extrusions is depicted in Fig. 20 below:

Figure 29: View of Gas Spring Representation and Linear Motion Mechanism

Assembling the unibearing unit required minimal installation. There were only screws that used an Allen wrench. The rest of the unibearing was installed so that it slides into the tracks of the extrusions. The brakes are put onto the unibearing by turning them on screws that come out of the unibearing. These could be particular because if the brake itself is disassembled into its parts,
such as the plastic handle and the inner nut then the brake will not function properly. Instead one would have to push in on the brake handle in order to loosen it. This is clearly not what the user desires, so the inner nut will have to be taken out and put into the handle properly.

One of the L-handle brakes was defective because the spring was assembled on the wrong side, so that had to be fixed before the remainder of the table could be put together. A picture of one of the unibearing devices, as it appears completed, can be seen in Fig. 21 below.

![Figure 30: Unibearing Setup with L-Handle Brakes](image)

A problem that was encountered with the unibearing was that when the L-handle brakes are fully disengaged, then one 1010 extrusion can slide all the way through the bearing. This could be a problem when the user tries to raise the table too high. If this is the case, additional pressure could be put on the mounts of the gas springs, or the gas springs themselves. The team devised a stopper that could be used in order to prevent the extrusion from traveling completely through the unibearing. A drawing of the stopper appears in Figure 22 below.

![Figure 31: Stopper for Vertical 1010 Extrusion](image)
The stopper consists of a screw, a fastener, and a manufactured piece of scrap metal. The metal is there to give the screw enough tension on the fastener that is inside the 1010 extrusion, as denoted by the black piece around the screw in the above figure. With this stopper, the table will not be adjusted to heights out of the desired range. Of course, a stopper is not necessary for the top of the extrusion because this range of motion is physically impossible with the presence of the tabletop.

The stoppers were manufactured and are show below in Fig. 23. This would keep the extrusion from coming off of the track. These mounts were simply pieces of metal with a hole drilled in them. The stock metal used was the same metal used for the brackets. This meant that both the stoppers and the brackets were 1/8” thick, which required a different size 80/20 screw than we already had. These screws also fit the corner brackets that were previously machined. There are two stoppers needed—one for each unibearing, which is why two appear in the Fig. 23 below.

Figure 32: Mounts for Unibearing Stoppers

The unibearings were put in the proper place, one on each side of the table, diagonally from each other. The following diagram in Fig. 24 on the following page shows the table as seen from above, where the gas springs are diagonal, and the unibearings are also diagonal.
The unibearings were put on diagonals in order for the table to raise without twisting. When the table is being raised, the gas springs push up on the bottom of the table. Since the gas springs are on diagonal corners, the table will raise level. The unibearings worked fine without any of the rest of the table interfering, but when the unibearings were installed on the table, many more problems were encountered.

**Problems Encountered After Installation**

It should be stated that the unibearings that were originally intended to smoothen the height adjustment process actually caused most of the problems. It was discovered that the table did not adjust smoothly because of the linear motion bearings. The legs do not adjust smoothly unless they are kept in the correct alignment. When the gas springs raise the table, the tabletop twists because the gas spring is pushing up so far away from the unibearings. This can be seen in Fig. 25 below.
As a result of the torque in the previous diagram, the extrusions that are connected by the unibearing want to twist out of place. The bottom of the upper extrusion rubs extrusion that connects to the base, so the adjustment is no longer smooth. An unacceptable amount of friction is put on the two extrusions which can be seen in Fig. 26 below.

*Figure 34: Torque encountered when raising the table.*
Since the unibearing was able to slide along the wide base (1030 extrusion), it was slid closer to the gas spring. This meant loosening, with the Allen wrench, the screws that hold the four hole and two hole corner brackets to the extrusions onto the base. The location of the unibearing actually made a significant difference in the performance. The closer the unibearing was to the gas spring, the less torque there was, and so the easier it was to raise the table.

Instead, an alternate setup was used to tweak the unibearing problem. It involved placing a screw between both of the unibearing legs. Eventually, it became difficult to continually tweak the unibearing because of this screw. This screw that was preventing the two extrusions from becoming out of line was also connecting the two together so that they can not be adjusted easily. In order for the unibearing to be moved, or for the extrusion to be taken off the tabletop, the screw had to be taken out of the extrusion, which was a significant task considering it screwed into a regular nut and a t-nut. Since the table was standing up, the t-nut tends to fall to the bottom of the extrusion. Additionally the nut was becoming abrasive with the extrusion upon lowering the table. The metal was gouging into the extrusion, and shavings of metal were coming off upon lowering the table. The team experimented with using automobile grease in order to lower the
amount of friction, but this proved to be only temporarily successful. A photogram of the screw that connects the two extrusions appears in Fig. 27 below.

![Figure 36: Screw Connecting the Two Extrusions on Unibearing](image)

It was finally decided upon that it would be best to take out the screw in one of the sliding legs and attaching a corner bracket underneath the upper sliding leg. This setup can be seen in Fig. 28 on the following page. This bracket served as a stopper and also aided in the movement of the two extrusions.
For the other unibearing leg, the screw was left in place, but the nut which was in between the two sliding legs was taken out. This nut was causing a great amount of friction when the table was being raised up. In order to keep the screw in place, a single square bracket was put on the outside of the upper extrusion which ended up covering almost half of the screw head. The other end of the screw was screwed flush with a t-nut inside the lower sliding leg. This setup can be seen in Fig. 29 below. This setup enabled the two sliding legs to constantly stay apart during the whole lifting process without a nut in between them.
7. Proper Use

7.1. Unibearings

This unibearing set is the most important piece to the proper function of the table. In order for any height adjustments to occur properly, the breaks must be disengaged properly. The breaks on both legs must be disengaged before any height adjustments are made; this is to allow for proper adjustments and to maintain the integrity of the table. It is also essential to have the brakes locked during use to ensure the safety of the user and the stability of the table. When locked, the brakes have the ability to hold at least 300 lbs per leg. This locking power ensures that no accidental adjustments can occur to the extent that harm could be inflicted on the user. To ensure that the brakes are completely released before adjusting, turn each brake handle counterclockwise one or two turns until the brake feels loose. To lock, turn each handle clockwise until rotation can no longer occur. It is necessary to get a feel for how much the handles can be turned, because sometimes they can be tightened to the point where it is extremely difficult to loosen. A schematic and photograph of how the unibearing is tightened and loosened appears in Figs. 30 and 31 below.
Figure 39: Proper Brake System Operation

Figure 40: Proper Brake System Operation on actual Unibearing
These figures show that both handles must be tightened. Although only one tightened handle will prevent the table from raising, only one is not sufficient to prevent the unibearing from moving. The handles should be tightened enough so that they hold the extrusions in place, but not too tight so that the handles break or they cannot be loosened. Sometimes the handles actually hit each other, such as when the top handle is pointing down, and the bottom handle is pointing up. Therefore, one handle should be tightened at a time so that it is out of the way of the other handle. A schematic demonstrating this is shown in Fig. 32 below.

![Figure 41: Try to avoid having the two handles interfere](image)

If the two handles interfere with one another, then it will be difficult to tighten them to their full potential. Instead, one should take an approach where one handle is tightened so that it is in a position out of the way. Then the second handle should be tightened so that it can rotate freely.
In the previous figure, the upper handle was tightened by turning it in the clockwise direction. This handle was tightened to a point that it was out of the swinging space of the lower handle. The lower handle can now be tightened with no problems.

7.2. Gas Springs

Gas springs utilize pressurized gas to supply the necessary force to extend a piston. The gas springs used in this table consist of a 22 mm diameter cylinder filled with nitrogen gas that applies constant force on a 10 mm diameter piston rod. The gas is filled in the cylinder so that it applies 14 pounds of force on the base of the piston rod. The base of the piston rod is slightly smaller than the 22 mm diameter cylinder, close enough so that no gas can escape but also small enough so that the piston can slide up and down unobstructed. When the forces applied onto the gas spring, such as the weight of the tabletop or external forces applied by a user, exceed the force applied by the pressurize gas the piston will be forced into the cylinder and the table will lower. When the forces are less than the force of the pressurized gas the piston extends out of the cylinder and the table rises. The piston is long enough so that it can move a distance of 13 inches out of the cylinder. This distance is the stroke length, which corresponds to the amount of adjustment that is possible. A diagram of this can be seen in Fig. 34 on the following page.
Figure 43: Gas Spring Setup

The force applied by the compressed gas is directly related to the pressure the gas is kept at. The force applied by an amount of gas can be related to the pressure based on the area of the surface the gas is pressing against.

\[
\text{Force} = \text{area} \times \text{pressure}
\]

The gas springs were specified to produce 14 pounds of force, so the nitrogen gas has to be kept at a pressure of 20.6 pounds per square inch (psi) to produce the 14 pounds of force. The weight of the tabletop and framing is approximately 25 pounds, so there is enough force from the two gas springs combined to raise the table, and there is also not too much force to make lowering the table extremely difficult. As the piston is pushed further out of the cylinder, the volume of the gas increases and the pressure decreases slightly. This causes the force produced by the gas spring to decrease slightly at the end of the piston stroke. So, when raising the table it is sometimes necessary to aid the gas springs over the final inches. The small decrease in pressure can make the force generated less than the force necessary to overcome gravity, friction, and the weight of the table. Therefore, in these situations the tabletop will not rise under its own accord. Very little force is required from the user in these occasions, just enough to help overcome these external forces.
The most important feature of these gas springs is the locking feature. Most gas springs are not locking springs, so they are continually forcing the piston out of the cylinder unless the external forces are greater than the force produced by the compressed gas. These gas springs are often used in applications such as lifting aides in heavy doors or lids. The gas spring only stops in the fully extended position, which would not be suitable for an adjustable table that needs to be able to stop at any height between its maximum and minimum. The locking gas spring utilizes a release lever in the cylinder that only allows motion when it is disengaged. There are two types of locking gas springs, rigid blocking and elastic blocking gas springs. Elastic blocking springs are filled only with nitrogen gas, and when locked will give a bit when external forces are applied. This creates a bounce effect on the spring such as in computer chairs, where a person is cushioned as they sit down. The rigid blocking springs resist all movement once locked, which is achieved by including a compartment of oil in the cylinder in addition to the nitrogen gas. The oil is not as easily compressed as the nitrogen gas, so when the external forces are applied the spring remains securely in place.

The specific gas springs used in this table are the rigid blocking in the push in direction from Easylift of America. These gas springs utilize a “floating piston” in between the gas and the oil layers. The piston presses on to the oil when the gas spring is locked and under compression. In the elastic blocking gas springs, the piston presses onto the nitrogen gas. Nitrogen gas is easier to compress than the oil, this is why the bouncing effect occurs when forces are applied to the elastic blocking springs.

The locking force of the table is very strong when in the locked position. The springs are specified to be able to hold approximately 2500 pounds without slipping. This is much more than can ever be expected to be loaded onto the table. The largest load on the table that can be expected to be experienced is the weight of a person sitting on the table.

The positioning of the gas springs is very important when examining the stability and functionality of the table. As stated earlier, the optimal placement of the gas springs would be one on the upper left side, and one on the lower right side of the table. This is seen in Fig. 24 in the pages above. This setup is the best configuration because it allows for the most even distribution of force. The force at the two opposite corners keeps the torque from getting too large and also assures that the table will rise evenly. This can be seen in Fig. 35 below. There is also analysis done on this setup through a series of equations which can also be seen corresponding to Fig. 35.
The moment found in these equations causes rotation over the side edge of the tabletop. This is much lower than the moment founding other test setups attempted. Also, since the two forces applied by the gas springs equal, the moments will be equal and will cancel each other out. The moment of one side of the table will actually help to hold up the opposite end.

This is obviously the best setup because the gas springs are put under less stress. Also, less force is required from the gas springs to raise the table so the table will rise faster and smoother.

Again, the setup should keep the tabletop even as it is adjusted, but if any problems occur one would simply have to raise the corner over the locking aluminum legs before locking them. This is much less additional work than would be required from the other setups.
The final setup adjustment that can be seen from the equations is that as the gas springs are situated more towards the center, causing more of a balance of torque at the joints of the gas spring mounts as well as at the joints of the upper framing. So, the gas springs are pushed closer to the center than the actual corner of the tabletop. This setup can be seen in the figure below.

![Figure 45: Optimal Setup](image)

![Figure 46: Free Body Diagram of Center](image)
If the distance moved in is 8 inches, the forces $F_A$ and $F_B$ are both 14 pounds as specified by the gas springs, and the weight of the tabletop, $W$, is 25 pounds the change in moments between the third setup and this setup can be examined. For the setup with the legs at the corners, the moments $M_{A1}$ and $M_{B1}$ are the same as those for the setup with the legs moved more to the center. This moment becomes -108 inch-pounds. The negative sign means that the moment actually is in the opposite direction. This makes sense because it is forcing the unsupported side of the table down. For the moments $M_{A2}$ and $M_{B2}$, the moment is a value of -21 inch-pounds compared to the -45 inch-pounds in the original setup. This decreases the moment around the joint by a factor of $\frac{1}{2}$.

7.3. Mounts Used

The bottom of the gas spring is a threaded piece that is 13 mm long and has a 10x1.5 mm thread. The threaded bottom made it possible to machine a mount to attach to the base. The mount was a simple piece of aluminum with a raised center portion with very thin sections as the sides. The side sections were thin enough for our standard 3/8” screws to work with it, so two 9/32” screw holes were drilled into each side. The center of the mount was .7” thick, which was thick enough to screw the entire gas spring into it. A hole was drilled into the center of the mount and threaded to fit the gas spring. A diagram of this mount can be seen in the figure below.
The screw holes were screwed into the outer two slots of the 1x3” extrusion in the base. The mount is attached in the same way the rest of the extrusions are connected, using t-nuts in the slots. A diagram of this setup can be seen the figure below.

Figure 46: Mount for base connection of gas spring

Figure 47: Mount Positioning on Base
The top of the gas spring is not threaded, which posed a problem for mounting. The top of the gas spring is covered by the hydraulic release, so something needed to be done to attach the hydraulic release to the upper framing at these points. The cap of the hydraulic release is made out of aluminum and consists of a loop. In order to mount this, a hole was drilled down through the upper framing and into the cap. The cap was threaded and attached to the upper framing using a long screw. This can be seen in the figure below.

![Diagram of Top Gas Spring Attachment](image)

*Figure 48: Diagram of Top Gas Spring Attachment*

This was a simple attachment that allowed the gas spring to be attached without destroying the cap or making it necessary to device a complicated mount to interact with the loop.

### 7.4. Hydraulic Release

The gas springs are controlled using a parallel hydraulic release. This release consists of tubing filled with water. A plunger or button is pressed that causes the water to force in a lever at each gas spring. The lever then disengages the locking mechanism and the gas springs can adjust. The parallel hydraulic release is useful in our table because it allows for both gas springs to be adjusted at the same time using one control button. The tubing had to be long enough to stretch between the sides of the table, there also needed to be enough tubing to then run the release button to one side. A diagram of the release system can be seen in the figure below.
The T connector needs to be situated equidistant from the two gas springs. This means that it must be mounted underneath the center of the tabletop. The tubing then extends to each side of the table where the gas springs are mounted and the third tubing is brought to one side as well. This is so that the release button is out of the way of someone sitting at the table. Also, this allows the user to press the button and adjust one of the sides at the same time. The mounting of the tubing is handled by running it in the grooves of the extrusion used for the upper framing of the table. Slot covers are then placed over the tubing to firmly keep it in the slots. The release handle is attached onto the table framing using two simple mounting plates with a hole to screw into the framing and a hole to run the button through. This is attached far enough from the edge of the table so that it can not be accidentally pushed by someone walking by the table. Also, there are nuts on each side of one of the mounts to keep the button in place. The covering of the button and plunger is threaded, so this keeps the button securely in place. A diagram of this can be seen in the figure below.

**Figure 49: Hydraulic Release**
Figure 50: Mounting for Hydraulic Release Button

The release system screws onto the top of the gas springs and depresses a button on the gas spring when the release button is pushed.

Figure 51: Engaged Button.
Based on the degree in which the release is screwed onto the gas spring the gas spring will adjust at different speeds. If the release is screwed on too far the gas spring will stay engaged at all times, which will make it impossible to lock or stop the gas springs at a desired height. If the release is not screwed on enough the gas springs will never disengage when the release button is pressed. They will stay in a constantly locked state that makes adjustments impossible. To find the perfect positioning of the release on the gas springs it is necessary to screw the release on in different positions and find the optimal one. This position is then marked by placing a nut at that point so that it can be screwed to the exact position in the future. This can be seen in the figure below.
7.5. Base

The table base will be a determining factor in the overall stability when the table is on a flat surface. Ideally, it would be easiest to create a base that could run across the ground from one side to the other. This would ensure that the base was totally in line with the orientation of the tabletop. Unfortunately, this base connection could not be made due to the fact that it would impinge upon the leg room of the user. The next best setup was to create two separate bases which would each be the width of the tabletop. The extrusion used for the base is also three times as thick as the extrusion used in the rest of the framing. This extra thickness will greatly help in the stability of the table as a whole. The thicker the base, the harder it will be to twist it off the ground. The dimensions of the 1030 extrusion used for the base can be seen in the figure below.

Figure 53: Top of Gas Spring
Figure 54: Dimensions of base

This base setup will give the user the maximum amount of leg room needed when drawing. This setup also provides good stability, but it can be improved upon slightly. This improvement was decided after testing had occurred on the base. Once the table was put together, force was applied horizontally at one side of the tabletop. This force would cause the two base pieces to sway back and forth since they were each bolted into the sliding legs and gas springs. The setup for this testing can be seen on the following page in the figure.
Figure 55: Testing procedure of base

It would be impractical to keep widening the entire length of each base to increase the whole table’s stability. Instead, only the ends of the base can be increased in thickness in order to prevent the entire base from wanting to lift off the ground when the table was pushed from the side. This was achieved by purchasing another 1010 extrusion of 30” length. The final schematic of the base can be seen on the following page in the figure below.
The 30” 1010 extrusion was cut into two sections 7” long, and 2 sections 8” long. These were then placed at each end of the 1030 extrusion. These extra pieces were connected to the base by flat connecting brackets which were manufactured in the machine shop. A schematic of these brackets can be seen below in the figure below.
Figure 57: Dimensions of flat mount
8. Troubleshooting

**Problem 1: Table won’t raise on its own**

This is generally occurs because of either overloading of the tabletop during adjustment (the tabletop must be unloaded or else the force of the weight of the tabletop and the weight of the load will be greater than the force applied by the gas springs) or because there is friction or sticking in the aluminum legs. This can be fixed by first unloading the table if it is weighed down. The second possible way is to gently apply upwards pressure at the corners of the tabletop. This will help to overcome any friction forces and any small loads that are on the tabletop. A diagram of this can be seen in the following figure.

![Diagram of places to apply force](image)

**Figure 58: Places to Apply Force**

**Problem 2: Table legs stick or catch when raising**

This is often caused by misalignment of the aluminum legs. This may require adjustment from the user to realign the legs, but it is often fixed by slightly tapping or lifting the
corner of the affected leg. This will often provide enough force to overcome any obstacles or friction forces. If the legs do not seem to be out of alignment, but instead are just rubbing against each other, a thin coating of grease is often enough to make the legs adjust smoothly. Simply apply a small amount of WD-40, or another standard grease, between the two parts of the leg.

**Problem 3: Table legs squeak when adjusting**

This is caused by rubbing between the two parts of the aluminum leg. This can be fixed in much of the same way as in Problem 2. Just simply apply grease between the two parts of the leg to allow smoother articulation between them.

![Diagram showing grease application on unibearing leg](image)

*Figure 59: Where to apply grease on unibearing leg*
Problem 4: The table is crooked or uneven after adjustment

If the problem is because the corners over the metal legs are lower than the corners over the gas springs, lift the corners up to make the table level before locking the legs. This problem often occurs because the corners are unsupported during adjustments, and therefore will sag a little below the level of the corners with the gas springs. If the two ends of the table are uneven, then the gas springs raised unevenly. In order to fix this, press the release button and hold one end down while lifting or lowering the other end until the table is level.

Figure 60: Where to Apply Force Prior to Locking

Problem 5: Gas springs continue to rise after button is released.

This occurs because the hydraulic release is screwed too tightly onto the top of the gas spring. This effectively keeps the gas spring in a constantly activated state. This makes it impossible for the gas springs to lock or stop in any position except in the fully extended position when the load is less than the force applied by the gas springs and in the completely compressed position when the load applied is greater than the force applied by the gas springs. To fix this problem it is necessary to recalibrate the gas springs. This is most easily done when the gas springs are fully extended, so press the release button and adjust the tabletop to its highest position. This may require help from the user to reach this height. Once the table is at its maximum height, clamp your right hand on the piston. Your left hand should hold the nut in
place just below the upper mount. Once your hands are in place, turn the piston rod clockwise with your right hand for about one quarter to a half of a turn. Press the button and let the gas springs compress fully. Quickly release the button and check for any slow upward movement of the upper mount. If upward motion is still occurring, the repeat the steps stated above until spring remains locked. If the gas spring no longer extends at all, then the piston rod has been screwed too far into the upper mount. To fix this simply unscrew the piston rod a small amount until the adjustment is perfect.

![Figure 61: Top of Gas Spring](image)

**Problem 6: Gas springs do not extend when the button is pressed**

This is generally caused by jamming of the legs. This can be caused by not unlocking the brakes, or by extreme cases of friction. If this is the case, try the solution presented in Problem 1. If this does not work and it appears to be caused by the gas spring itself, the hydraulic release is to blame as in Problem 5. This time the release cap is not screwed on enough, so the release button is never activating the gas springs. This is done in the opposite way of the previous solution. One must lower the nut approximately one quarter to one half of a turn. Then screw the piston rod counter-clockwise up into the release cap. Press the release button and check to see if the gas spring extends. If the gas spring does extend it is recommended that you lower the table to its minimum position and make sure that there are no slow upward movements.
indicating that the gas spring is not locking as in Problem 5. If it is, then follow the steps for Problem 5.

**Problem 7: The table stops raising before maximum height of 42”**

This is caused by the gas springs loosing some of their ability to raise the table as they extend to their maximum positions. This occurs because as the piston is forced out of the gas spring cylinder it creates a larger volume. This larger volume causes the pressure of the gas to lower and therefore the force generated to decrease. So, as the gas springs go through their final few inches of extension it may be necessary to apply a small amount of force to help makeup for the loss in generated force.
9. Letter to the Client

Dear friends,

Thank you for allowing us to build you this fine table. We are truly proud of the outcome. The table has been a delight to build from the beginning to the end and we think that this will show in the quality of the table itself.

The table is specifically designed for doing art work but as your needs change this table could be an all-purpose utility table. Its large size and smooth surface make it ideal for any application. The highlight feature however is the height adjustment which allows the table to adjust between 29 and 42.5 inches. *Anybody* can raise the table because it only needs one person. Once the table is set to the desired height, just seat yourself nice and close and focus on your artwork with no worries. There is plenty of space for about three people if the artists happen to be using wheelchairs. With no wheelchairs, as many as eight people can use the table. The possibilities are endless!

We hope that this table brings a bright future. The table was built from the finest quality parts with meticulous workmanship. We expect that you should find no problems with the table, but just in case, here’s an operations manual.

Sincerely,

Bruce Bassi                  Kristen Haldeman                  Richard Sierra