Spring 2016

The Pneumatic Leg Extension

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By

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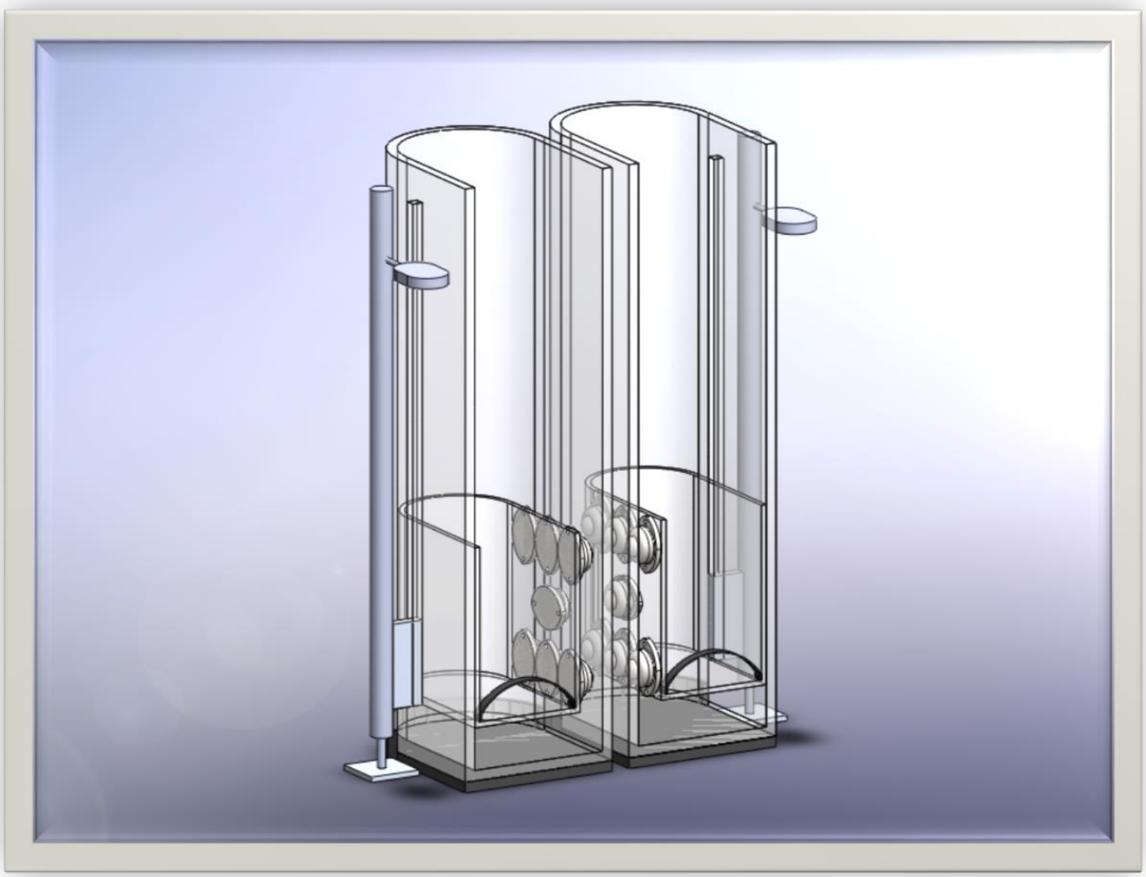

Abstract

In recent years, reaching altitudes that are higher than your normal-height has evolved from pure amusement to an “in-demand” necessity out in the field. Means of achieving greater than normal height range from wooden poles to aluminum stilts. The era of ladders and other extension methods are slowly fading away. There are many designs in the market that focus on different factors to make a stilt. As other designs focus on one or two enhancements, the pneumatic leg extension’s objective is to improve all aspects of the stilt. This radical new design differs greatly from traditional stilt designs. The pneumatic leg extension focused on achieving the following advantages: simple operation, light weight, cost-efficient, sustain high weight capacity up to 280 lbs., 18 inches extension above the operator’s height, stability, Grip/shock absorption under slippery conditions and most importantly; safety. The pneumatic leg extension is mostly constructed with acrylic plastic, general rubber and aluminum. Overall, the pneumatic leg extension extended up to the proposed height and sustained an operator’s weight of 165 lbs. Further testing will reveal the device’s true potential. This device is designed to meet employers' standards and the operators' needs.

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INTRODUCTION

Motivation:

A Pneumatic lifting system is needed to enhance a problem for the classic stilt design. Stilts have substituted for the traditional ladder. Some designs do have extension capabilities, but fall under certain limitations. These limitations include semi-automatic extension, weight tolerance, and oscillating motion. A solution to this problem is to enhance the design by equipping and improving these limitations. While, market designs focus on one-two factors, the pneumatic leg extension focuses on the following factors: Light weight, complexity, cost, weight capacity, extension, stability, Grip/shock absorption and most importantly; safety.

Function:

A device is needed that will lift and lower a person vertically; also improving traditional stilt operational struggle. As mentioned before the pneumatic leg extension will improve on all current factors.

Requirements:

The following requirements will enhance the original stilt design.

- Extension:19.5 in
- Operation sustainability of 280 lbs.
- Elevator unit with max compression strength of 280 lb_f
- Weight tolerance recommended of 280 lbs.
- Each stilt must weigh no more than 45 lbs.
- Stilt mounting duration-less than original stilt
- Reasonably cheaper than the stilts sold in the market with same capabilities (money's worth)
- Stable-operational on uneven floor
- Grip under wet conditions
- Safe to operate

Engineering Merit:

The new design will involve torque, compression, and shear stress equations. The torque equation will convey the moment levels and help decide how many bearing balls should be placed for successful shifting of the elevator unit shown in appendix image A-6. The compression equation will determine how much stress the elevator unit, and the lockable gas spring can encounter before failure shown in appendix image A-4. The shear stress equation will determine the support plate dimensions and what screw radius is required to hold the weight needed when the components are assembled together.

Scope of this effort:

Actuators, air cylinders and foot pumps were initially considered as a solution for the new model, but finally, the idea was eliminated because they would become over-operationally complex, limit range availability, max-out weight requirement and increase costs. Instead, a lockable gas spring will be placed to replace manual pin extension. Sketches of device development is presented in appendix image A-1, through image A-3.

Success Criteria:

The new designed stilt will extend semi-automatically, increase desirable height availability, provide comfort while operation, reduce cost and weight, in order to be considered as an overall accomplishment.

Success Scenario:

The design will be rated numerically and by its performance. The numerical progression will be recorded as a percentile; all depending on how many requirements and additional developments are achieved. The performance of the device will be video recorded, demonstrating the fulfillments and over-achievements. All of the numerical and performance success will reflect off of the calculations. The lockable gas spring will be used to help lift the person vertically (muscle component) at a quicker time duration than normal. Stability will be taken in consideration, which is why the frame will not fail, due to its designed features. The elevator unit will hold the proposed weight, avoiding any failure or safety issues. Each stilt will weigh light enough for comfort/efficient use. Best case scenario is if the device becomes efficient and popular enough to mass produce.

DESIGN & ANALYSIS

Proposed Solution:

The traditional stilt sold at the market will be redesigned from sketch. The new modifications will require a particular design in order for this project to function. There will be a pneumatic cylinder on each leg, which will extend the person to a potential height of 18 inches when a lever is engaged. This new modification will eliminate tedious manual pin operation. The proper strut was chosen based off of calculations shown in appendix A, image A-4 and image A-5. The struts' dimensions, along with the frames' parameters were critical because anything above 23.1 inches would cause the frame walls to interfere with the operator's groin, while mounting the pneumatic leg extension. Once the work assignment has been completed, again, a lever will be engaged to descend to initial position. The persons' body mass and gravity play a big role.

There is an inevitable moment that is caused by the person while operating the pneumatic leg extension. Roller ball bearings will be placed between the outside of the elevator unit and the inside of the frame to absorb axial forces and avoid failure caused by moments. Calculations provided in appendix A, image A-7 demonstrates that if a maximum of 280 lbs. is presented, then 10 roller ball bearings will be required to prevent failure. Image A-8 shows that if there are 6 roller ball bearings placed on each leg extension, then the designer engineer will be able to be lifted without a problem.

Rubber padding will be placed on the bottom of the frame structure to prevent vibration fracture issues, provide grip and shock absorption, while the person is operating the device. This less-rigid frame design structure will be built out of acrylic plastic. This material will reduce average stilt weight, reduce costs, and most importantly, eliminate operational struggle (providing comfort ability). There will be rubber straps placed on the elevator unit to secure the person while in motion.

Design Description

Image A-3 which is found in appendix A, is a representation of the pneumatic semi-automatic leg extension. The rough sketch demonstrates an image of the left/right leg's front, top and side view of the design. The image includes the following:

1. Frame LL & RL
2. Elevator unit LL & RL
3. Gas spring (strut)
4. Support plate LL & RL
5. Rubber padding
6. Roller (bearing balls)
7. Rubber Strap
8. Gas spring base plate

The three views also specify a few basic dimensions. These dimensions include retracted gas spring, leg frame thickness, leg frame length (28.0 in), leg frame width, and the slot profile. The front view demonstrates the height of the device (28.50 in), the thickness of the frame (0.35 in), the width of the frame (7.70 in) and the height of the lockable gas spring (27.56 in). The top view has the leg extensions' width (10.84 in) and depth (10.25 in) dimensions; giving the reader an idea of how big each stilt will be. The left view provides length dimension of the slot profile (23.69 inches x 0.5 inches).

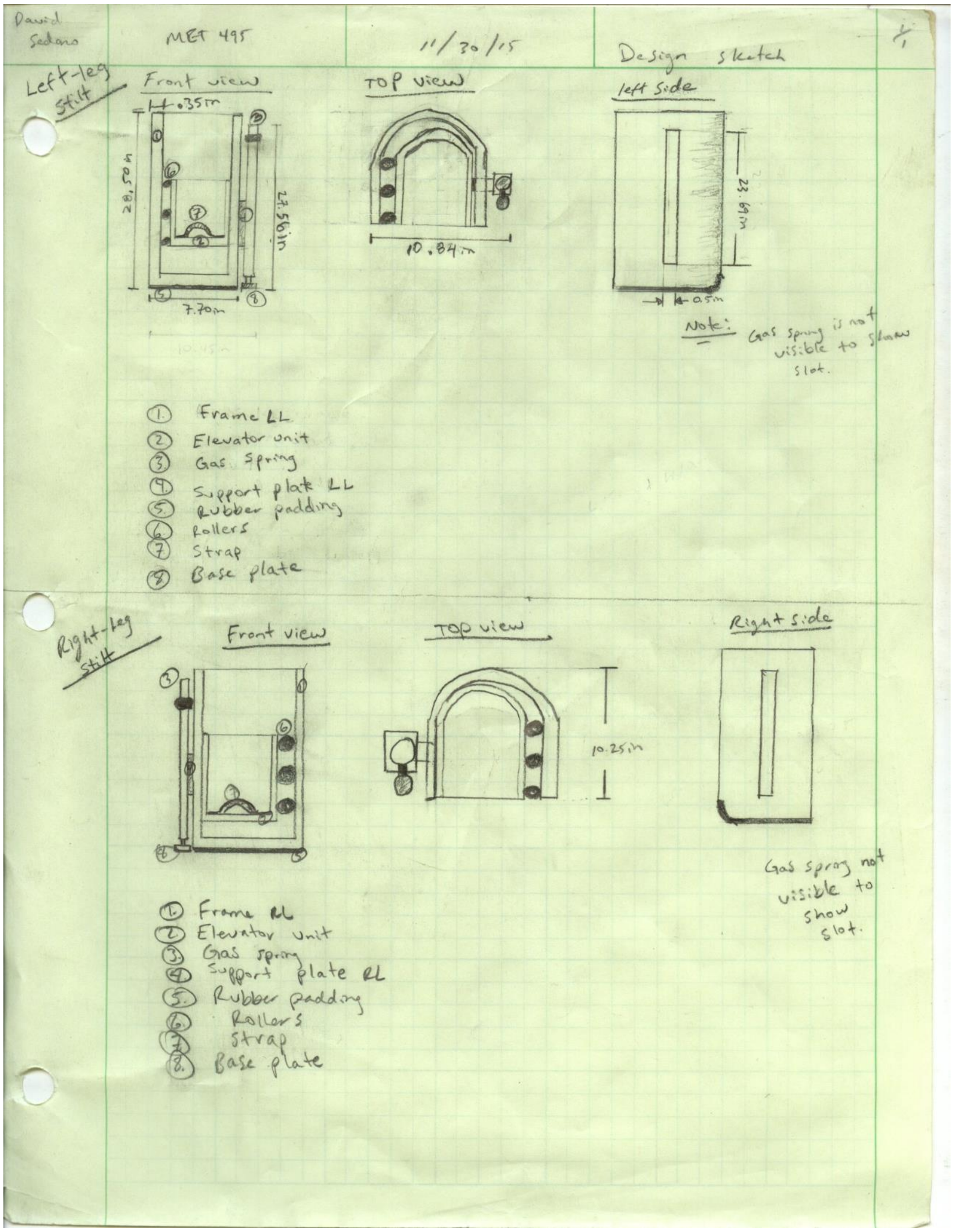


Image A-3: Final draft-stilt design

Benchmark:

The traditional stilt was made out of wood, making it sturdy, but hard to move around (forward/backward and up/down). The newest stilt designs in the market provides manual pinning's to extend or shorten lengths (length limitation and time consuming), making it convoluted and hazardous. The pneumatic semi-automatic leg extension will provide semi-automatic extension/compression, better stability, easier motion availability, yet light enough for better comfort use. Overall, this new design will substantially become more efficient, not only for the user, but also for the employer.

The following images are stilt models that are sold in the market, which compare, but do not outrank the pneumatic leg extension.

Image J-1: Bon Tool 14-644-B5 Dura-Stilt

The Bon Tool 14-644-B5 Dura Stilt is found in *toolfetch.com* and is worth $314.72. This device does not have any extension abilities, with a fixed height of 14 inches. This may bring falling hazards when initially standing up. It has an ability to hold 225 lbs. The designs' main focus is weight efficiency and moving feasibility. Although the company notes that the stilt is built out of aluminum alloy, they do not specify the actual weight of their design. This raises doubts whether in fact the stilt is comfortably light enough.

In comparison to the Bon Tool, the pneumatic leg extension is able to extend up to 19 inches. This ability avoids struggling and experiencing falling hazards because the person initially starts from a low position and extends to desired position. The pneumatic leg extension has an ability to withstand 280 lbs. with a safety factor of 1.18 as shown in appendix A, image A-12. This design has a great light weight efficiency. Most of the device is made out of acrylic plastic, aluminum and rubbers; weighing 17.5 lbs. per leg stilt. Superior

Image J-2: GypTool Adjustable Height Professional Drywall

The GypTool adjustable height professional drywall is found in *rakuten.com* and is worth $164.59. This device has extension abilities of 48 inches, 52 inches, 56 inches, 60 inches, and 64 inches. Although, this design enables the operator to extend by using wing nuts (pin-manual), it is required to sit back down to extend to desirable length. This tedious repetition becomes uncomfortable for the operator and it becomes a falling hazardous because there is not a lot of cross-sectional area on the stilt to support the weight or movement. The stilt is constructed out of aluminum, making it light. Even though the manufacturer specified that the stilt was constructed of light material, they do not indicate what weight capacity it can sustain. This raises doubts whether the stilt is durable and how much weight it can actually hold. By looking at the design, the stilt does not look like it has large enough diameters to encounter much weight. The designs' main focus is weight and cost efficiency. The stilt weighs 28.6 lbs., making it heavier than the pneumatic leg extension.

In comparison to the GypTool, the pneumatic leg extension enables the operator to rise or descend without getting off the stilt. Although the pneumatic leg extension has less extension ability than the GypTool, it provides good stability. The design of the pneumatic leg extension provides a frame that prevents the person from tipping over. Initially, the pneumatic leg extension was going to have longer extension abilities, but there was no need because a standard floor is 8-10 feet. The pneumatic leg extension enables an average height person to almost reach the ceiling. This design has a great light weight efficiency. Most of the device is made out of acrylic plastic and rubbers; weighing 25 lbs. per leg stilt. The pneumatic stilt is lighter than the GypTool. The GypTool may be slightly cheaper, but it does not outrank the pneumatic leg extension because in the long run, safety and operator comfort is what pays off. The following image demonstrates how unstable, risky and painful a market stilt could be.

Image J-3: Market stilt risks-unstable, risky and painful

Overall, the pneumatic leg extension is modified to surpass other stilt expectations and rather than focusing only in one or two perks, it excels in all probable factors.

Performance Predictions:

The most important component in this device is the lockable gas spring because it serves as the power source and the cause of elevating the person. The gas spring will have a force of up to 330 lb_f and the ability to lift the person to the final height of 19 inches in less than 10 seconds. The gas spring has an extending stroke of 19.5 inches and the ability to lift a person with a max weight of 280lb_f. The gas spring parameters and abilities are shown in appendix A, image A-5. There is an 80% possibility that this design will allow and exceed that weight limit. It has been concluded that each stilt will weigh roughly 25 lbs. as shown in appendix A, image A-11. This weight still remains as an estimate because some parts of the pneumatic leg extension were constructed in SolidWorks; only as representations (lockable gas spring, strap, rubber padding and roller baring balls). This project should cost around $250-$300, which includes purchasing of the parts, but excludes labor costs. Labor costs would rise the cost up to $300-$500, which includes only the manufacturing side of the project. The project's cost and scheduling analysis is found in appendix D and appendix E, images D-1 and E-1.

It has also been concluded that after purchasing parts, construction, and testing, the design will take up to 71 hours. This prediction was tabulated and filed in appendix E, image E-1. These hours exclude the time spent on typing the proposal along with the devices' designing stage. This stilt might seem costly and time consuming, but it should be considered that this is the first design prototype, making it a long process. After the prototype has been designed and constructed, the cost of an average pneumatic leg extension should come down to $230-$280 and a 35 hour time term. These 35 hours include 30 hour maximum wait for parts to arrive, and a maximum of 5 hours to assemble and analyze for errors. These costs and time periods will vary according to mass production.

Description of Analyses

The frame was the primary component that was designed, therefore, the rest of the components parameters and functions referenced off of the frames' dimensions. In this design, the frame came down to a limit. The frames' max height had to be no greater than 28 inches to sit comfortably within the users groin; anything higher than that would get in the way. The lockable gas springs' stroke was finalized accordingly to the frames parameters because if the stroke was greater than 19.5 inches, then the elevator unit would not provide enough stability or material strength for the user (dangerous). In appendix A, image A-Z demonstrates the max height of the gas spring stroke. If the stroke height exceeds this limit then there will be safety hazard.

The elevator units' dimensions were decided accordingly with the frames' parameters because the elevator will be sliding within the frame. The height of the elevator unit was critical and was decided according to the support plate and the weight presented on the elevator unit. Depending on the weight, there would be a torque presented. The support plates' height would need to be long to provide enough material in order to place multiple screws. The number of screws would depend on how much weight is applied in the elevator unit to avoid shear failure. There is a screw calculation displayed in appendix A, image A-13.

The rubber padding was chosen to provide substantial grip in a work area where there might be fluid spills. The dimensions were selected based off of the frames base surface area. There is an additional 1 inch up-vertical extrusion to screw the rubber padding with the frame. The rubber padding will also provide some shock absorption while the user is walking. There is a calculation of how much absorption the designed rubber padding will prevent in appendix A, image A-10. In a worst case scenario, if the user is exhausting the weight limit, shock may cause additional stress and promote failure within the gas spring. In other words, these additional stresses will vary the factor of safety.

The carbon steel bearing rollers were chosen because they would absorb the axial force and prevent the elevator unit from fail under torque. Another reason why this component was chosen was because each roller cost only $2.09 versus the previous nylon roller of $12.60. The 1 inch carbon ball was preferred because if the 1.5 inch nylon roller was used instead, then the width of the frame would have to increase to avoid buckling. Not only would the nylon roller bearings cost more, but it would require more space between each stilt (more material equals more material expense).

Scope of Testing and Evaluation

The following components will be tested and measured by using equipment from our University's labs: Frame, elevator unit, pneumatic gas spring and screws. The compression machine, the tensile strength machine, weights, a ruler, and a stop watch will be used to test and evaluate our predictions.

Analyses

The most important calculations that will be performed will be the max compression stress on the elevator unit, max shear stress on the screws, diameter and material choice for screws, compression resistance on the gas spring, torque created within the device and the number of carbon steel bearing balls required to prevent failure under torque. The calculations are presented in appendix A. Further details of calculations and or component decision making was elaborated in the *description of analysis* section. The calculations is what determined the pneumatic leg extension. One important guide any engineer has to go by, as this project did, is the factor of safety. It is a rule that the safety factor of must be anything greater than 1 to be considered safe. The strut is the most important component in the device because without it, there is no extension (no purpose). Image A-14, from appendix A demonstrates that the factor of safety for the lockable gas spring is 1.18; indicating that it is safe to operate.

Device: Parts, Shapes, and Configuration

The leg frame has a semi-circle shape. This shape was chosen because it best fits the comfort shape of the persons' leg support. Considering a different shape would require more material, therefore, more expensive. The shape is designed to support the back of the persons' leg and provide stability. The semicircles' curve decreases the chances of falling backwards. Another reason for this particular shape is to provide axial support, while the elevator shifts up and down. The carbon steel roller bearing balls will push off of the inner wall of the frame. In other words, the frame aids the bearing balls to encounter the moment that is caused by the persons' presented weight.

Device Assembly and Attachments

The frame is an important component because every other component links to this important piece. The frames' parameters were decided according to a persons' standing position.

The frame would have to fit between a person's legs without making contact with the groin. The frame can be looked as a long boot.

The elevator unit's measurements were then based off of the frames' geometry. The elevator unit needed to fit within the frame because this component will help secure and raise the operator to the desired position. The lockable gas spring was then chosen by the height of the frame and considering a standard room height. A standard room height is between 8-10 feet and the frame is 28.5 inches high. In appendix A, image A-4 and A-5 demonstrate the calculations behind the decision made for choosing the lockable gas spring. It became clear that option B was the best choice (stroke length of 7.8-19.5 inches). Anything less than that would be too low to even require a stilt and anything greater than that stroke length would be too much in a standard room. If a greater stroke length extension was chosen, then there were be no use of most of the leg extension because the frame is only 28.5 inches high, in order to fit within a persons' legs. As the lockable gas spring extended, there would be no possible way to extend past the 28.5 inches.

The frame will have a slot on the outer side of the leg, which will enable the support plate to attach the lockable gas spring to the elevator. The aluminum support plate will be the component between the elevator unit and the strut. As the strut extends, the support plate will slide up and down the slot, lifting or lowering the elevator unit at the same time. Even though there would be high moment and shear forces on the support plate, aluminum was chosen because not only would it sustain the weight required, but it would also help the device be weight efficient. The parameters for the support plate were chosen to fit through the 0.5 inch slot and maintain the lockable gas strut's base plate from getting in the way as the operator walks.

The rubber pad placed on the bottom of each frame provides grip and shock absorption. The rubber pad has obviously the same shape as the frame because it needs to mold (fit) onto the frame. There is an upward extrusion on the back side of the foot, in order to screw it to the frame. In appendix A, image A-10 demonstrates how much shock absorption the rubber pad provides.

The carbon steel ball bearings were added to the device because the persons' weight will create a moment that would enable the stilt to function. The carbon steel ball bearings prevent shear failure on the screws that will be connecting the elevator unit and the support plate. Image A-9, in appendix A, demonstrates the calculation that specifies the flat screw diameter that is required. The carbon bearing balls also prevent shear or bending failure along the support plate. The bearing balls will help the elevator unit lift and descend, parallel to the frames' inner wall.

The rubber strap will be placed on the elevator units' inner bottom. This components' function is to secure the person. It also allows the person and the elevator unit to lift as one. In other words, as the person engages the struts' lever, the operator lifts their leg to descend and in the same time, this enables the strut to extend in place.

Aluminum plates will be placed on the bottom of each strut. Each strut has a skinny rod towards the bottom of the strut that does not provide enough stability. There is an ANSI drawing of this component found in appendix B, Image B-11 with dimensions specified. Lastly but not least, screws will be used to assemble the support plate to the elevator unit, the roller bearing balls to the elevator unit, the rubber strap to the elevator units' inner bottom walls, and the silicon pad to the bottom of the acrylic frame.

Ergonomics

The lockable gas strut is a component that will be manually engaged by the operator. The life span of the lockable gas strut depends on the weight that it is being presented. Image A-12 in appendix A, demonstrates a calculation of the factor of safety that is recommended. Weight that is heavier than the recommended 280 lbs. will drop the safety factor. The safety factor with the recommended 280 lbs. is 1.2 when moving and 2.3 while standing. If the strut is presented with heavier weight, then operator is at risk of falling. The excessive weight presented on the strut will quicken the life span of it.

Technical Risk Analysis, Failure Mode Analyses, Safety Factors, Operation Limits:

There are always risks and consequences to everything; this models' major risk is falling from high elevations. The frame has the half circle geometry for stability, the rubber pad will provide grip and shock absorption, the lockable gas strut will enable the model to move as one whole unit and it will also provide controlled vertical levitation.

The strut components is listed under failure factors. The lockable gas strut will also fail under compression if there is excessive weight applied upon it. As mentioned on the previous section, the recommended safety factor has been calculated and provided in appendix A, image A-12.

Methods and Construction

Construction

The idea was to make the design economically reasonable as possible. There were a lot of ways to promote this; one was to self-manufacture as many components as possible. It was more cost efficient by purchasing the acrylic sheet and bending it around a jig, instead of purchasing the manufactured piece. Having to buy a component that was either casted or machined made the project excessively expensive and pointless. Every component of the pneumatic leg extension was manufactured or modified; all components except the lockable gas springs and the rollers. The remaining components were manufactured or modified here at Central Washington's work shop. The following list demonstrates each component and the work behind it.

0. Skeleton: This jig is not a part of the pneumatic leg extension, but it was constructed to help form the frames and the elevator units. This tool was built from 2 metal base plates that were around 3/16 in thick. The metal plates had the frames' semi-circle shape. Seven rods that were 1 in. in diameter were welded onto the base plates with a potential height of 30 in. The height of the jig needed to be larger than the frame height, in order to get better results. A 1/8 gauge sheet metal was then bent around the 1 in. rods, taking the semi-circle shape. The sheet metal was tack welded with the MIG welder. The dimensions of the jig were based off of the frame itself. In other words, the jig's outer radius took the inner radius of the frame because the acrylic sheet was bent over the jig. After the frames were shaped, the jig was dismantled and re-modified to the elevator units' dimensions. The shape was intentionally different and definitely smaller than the first-made jig. The modified (smaller) jig was scaled down to form the elevator units.
1. Frame LL & RL: These frames were initially sheets of acrylic that were table-sawed down to dimension. The frames were longer than any oven dimensions around campus, so a second alternative was sought. A drape molder was used to preheat the acrylic. The acrylic

needed to be heated up to 380 degrees Fahrenheit before it started to deform. Once, the acrylic started to deform, it was pulled out of the machine and was molded around the jig and clamped in place with boards supporting the sides for it to bend more consistently. Once the acrylic cooled down a little, the formed-frame was removed from the jig and the sides were opened, again by using boards (for consistency) to avoid inward-warping.
The vertical mill was used to mill a 0.358 in. slot on the outer side of the frame. Once, the slot was created, three ½ in. bearing grooves were milled on the inside of the frame (the opposite wall where the slot was milled). The horizontal mill was used to create the ½ in. bearing grooves. The grooves were ¼ in. deep; they were deep enough to prevent any bearing shifting.

2. Elevator unit LL & RL: The elevator units were formed by the scaled-down jig and heated by the construction management oven. The same molding process that was used to mold the frames was followed for the elevator units. Once the elevator units were formed, they were used to trace an acrylic base, which was glued (acrylic glue).
3. Lockable gas springs: This component was purchased from online from an office chair-parts distributer. This component is basically the cylinder piece of an office chair.
4. Support Plate LL & RL: This component was made of a 3/8 in. x 2 ½ in. x 3 in. aluminum plate. The component was milled to dimension. Two holes were drilled and tapped on one end face. The holes were tapped for two 10-24 in. x 1 in. aluminum machine screws, which assembled the support plates to the elevator units. The support plates were later spray painted red to hide the raw aluminum color.
5. Collet: This component was an aluminum pipe, which was mig-welded to the support plate and epoxy glued to the cylinder. A boring tool was used to tight-fit the collet to the cylinder (ID machined). The collet was spray painted red to hide the raw aluminum color.
6. Rubber padding: General Purpose Rubber (GPR) was cut to dimension and epoxy glued to the base of the frame. The frame was used to trace the GPR shape desired. Oil was placed on a cutting knife to smoothen the cut and reduce the required force when cutting the GPR.
7. Roller (bearing balls): The carbon steel bearing balls were purchased from an online website. No modifications were made to this component.
8. Secure Strap: The polypropylene and plastic latch materials were purchased in ACE hardware store because of the low cost. A needle and stitching string was used to stitch both pieces together to form a secure strap.
9. Cylinder base padding: This component was constructed by using the extra GPR, which was used to make the rubber padding of the device. The cylinder was used to trace the GPR shape desired and a door knob cutting tool was used to cut the extrusion for the cylinder to rest in. The GPR is 0.5 in. thick so, a 0.25 in extrusion was machined. A cutting knife was used to cut the OD of the GPR. After all of the cuts were made, epoxy glue was used to assemble the base padding to the bottom of both cylinders.
10. L-Brackets: 1/8 gauge aluminum sheet was used to manufacture the L-brackets. There were 8 strips cut to 1 ½ in. x 4 in. and were bent 90 degree to form the L-shape. A hole was drilled on each end to hold in place 10-24 x ½ in. aluminum machine screws. The L-brackets were painted black to hide the raw aluminum color.

11: L-safe lock: The L-safe lock was purchased as an L-beam. The aluminum component was cut to length, using the vertical band saw. A ½ in slot was milled to reduce excessive weight. The slot was made on the side that was screwed onto the frame to reduce probable deformation will the device is operated. Two holes were made to assemble this component to the frame. The holes were large enough to tight fit an 8-23 x 3/8 in. aluminum post screw. A red spray coating was sprayed on the L-safe lock to neglect the raw aluminum color.

12. Screws: Aluminum screws were purchase at the local ranch & home hardware store. There were 16, 10-24 x ½ in. aluminum machine screws purchased to assemble the L-bracket to the elevator unit and hold it in place. There were 4, 10-24 x 1 in. aluminum machine screws purchase to assemble the support plate to the elevator unit. All screws were sanded down to flesh with the elevator unit and the support plate.

13. Post screws: There were 4, 8-32 x 3/8 in. aluminum post screws purchased and used to assemble the secure strap to the elevator unit wall. No modifications were made.

14. Spray paint: Black and red spray paint was used to spray paint the support plates, L-blocks, and L-safe locks. These spray cans were found lying around the house garage.

15. Epoxy glue: This product was purchased at the ranch & home hardware store. This item was used to assemble the bottom acrylic base to the elevator unit walls and the collet to the cylinder. The epoxy was also used to glue the GPR to the cylinders and the frames. There were no modifications to this product.

There were other collaborative tasks such as assembling the components, extrude cutting the slot on the leg frame and mandatory testing for additional manufacturing purposes.

The vertical CNC will be used to make the slot on the frame. The support plate will be welded onto the struts' housing. Welding the plate on the hollow cylinder might become complex task. If this is the case, a clamp will be designed to clamp the cylinder, while the other end is welded onto the support plate. The elevator unit will be acrylic based material. For more information over the pneumatic leg extensions' construction, refer to the *device assembly and attachments* section.

Description

The following image demostrates the final rough sketch of the pneumatic leg extension. It is numbered to ease configuration of each component. The drawings have not changed; only the constrtuction method has changed, but all of the ANSI drawings will remain the same.

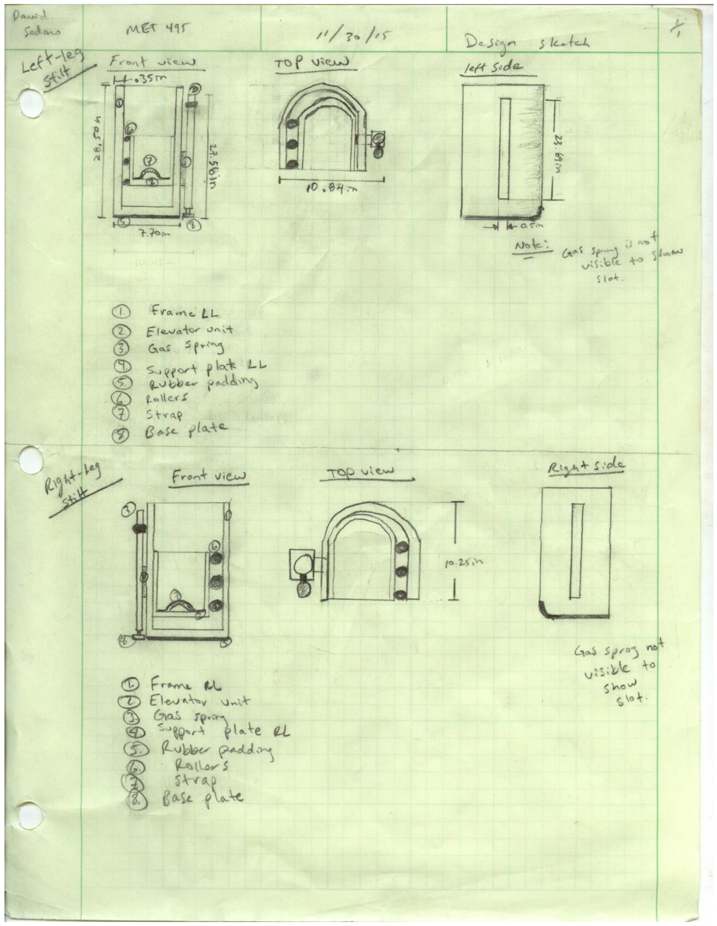
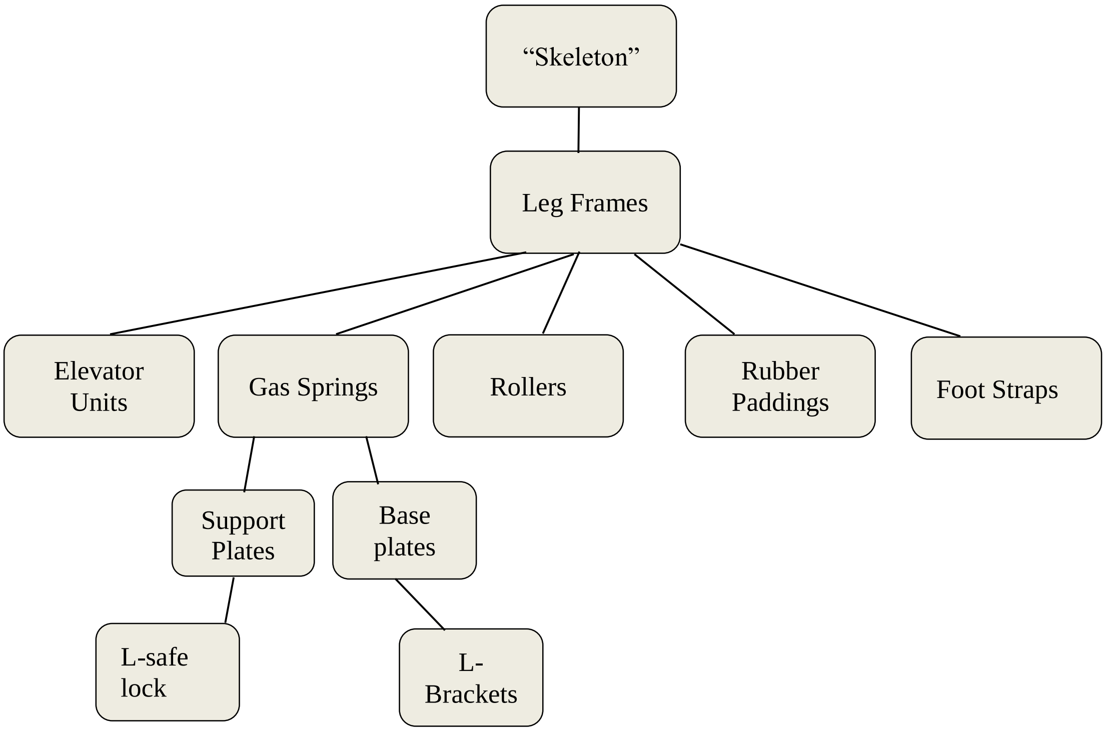


Image A-3

Frame (1): This is the "root component" where everything else is assembled onto. The frame has a slot on the outer side of the leg. The purpose of the slot is to enable the support plate to freely slide up and down, while the gas spring is extending, therefore, lifting the elevator unit.
Elevator unit (2): The elevator unit can be thought simply as an elevator. This component will hold and lift the person as the strut extracts.
Lockable gas spring (3): This will be the "muscle" of the device. The strut will extend and lift the person vertically.
Support plate (4): This component will link the gas spring to the elevator unit. The support plate will be sliding up or down between the frame's slot.
Rubber pad (5): The thin layer rubber pad will be placed on the bottom of the frame. The rubber will provide grip when walking and absorb shock when user is in motion.
Roller (6): There will be a rollers that will be linked to the elevator unit and touching the inner frames' wall. The purpose of this component is to impose torque created from the weight presented and as the gas spring extracts. The rollers will help the elevator unit lift and descend with ease by rolling on the frames wall.
Foot strap (7): The foot strap will be mounted on the elevator unit. The strap will enable the user to secure their foot onto the device.
Base Plate (8): This component will provide stability for the gas spring. The extracting piston will be fixed on the base plate versus extending freely (causes more stresses).

Drawing Tree and Drawing ID's

The following drawing tree illustrates the order that the pneumatic leg extension was designed in solidworks; starting with the leg frames down to the support and base plates.



The skeleton component is a jig that was make to bend the acrylic based components. This jig was constructed by outlining the frame and adding the height of the frame. The skeleton was made of 7 steel rods, two semi-circle base plates, and a sheet metal. The following image is a representation of the skeleton.

Image B-0: Skeleton

The leg frame was designed first because this is considered the “root component”, where the rest of the components link to. In other words, the parameters of the other components are dependent to the dimensions of the frame. The third row components are smaller pieces of those of the second row.

Parts list and labels

The following excel spreadsheet is the most current list and cost analysis. The screws and rivets will be purchased from the McMaster-Carr website; but the rest will be bought from other locations. Most will come directly from the factory. A few will be scraps, provided by Central Washington University. The costs of the pneumatic leg extension is most likely going to change (cheaper).

Label	Part Name	Quantity	Cost of Components	Location	Readiness	Material
0	Skeleton	1	$37.00	Western Metals	Arrived	1/8 gauge sheet metal & 0.5 in. dia. rods
1	Frame RL	1	$50.00	e-voniks	Arrived	Acrylic extruded sheet
2	Elevator Unit	2	$30.00	e-voniks	Arrived	Acrylic extruded sheet
3	Frame LL	1	$50.00	e-voniks	Arrived	Acrylic extruded sheet
4	Lockable Gas Spring	2	$71.96	Chairpartsonline	7 days	Steel
5	Support plate RL	1	$0.00	CWU scraps	Here	Alumium
6	Support plate LL	1	$0.00	CWU scraps	Here	Alumium
7	Rubber padding	2	$41.58	Rubber Sheet Roll (RSR)	7-10 days	General purpose rubber
8	Rollers	6	$12.54	Globalindustrial.com	Arrived	Carbon steel
9	Secure strap	2	$2.10	ACE Hardware	Here	polypropylene
10	Base support for gas springs	2	$0.00	RSR-remaining scraps	Here	General purpose rubber
11	Epoxy Glue	1	$6.00	Ranch and Home	Here	Glue
12	Collet	2	$0.00	CWU scraps	Here	Aluminum pipe
13	screws	28	$14.00	Ranch and Home	Here	Aluminum 10-24 x 1/2
14	Post screws	4	$3.00	Ranch and Home	Here	Aluminum 8-32 x 3/8
15	L-brackets	8	$0.00	Home Scraps	Here	Aluminum sheet metal
16	L-safe lock	2	$15.00	Ranch and Home	Here	Aluminum-1/8 gauge
17	Spray paint	1	$0.00	Home resource	Here	Paint
		Actual Total	**$333.18**			

Image D-1: List and Costs

Manufacturing Issues

There are welding, assembling and product modification issues in the device. The aluminum support plate will need to be welded to the gas spring or welded to a clamp-like component. This clamp-like piece will clamp to the strut. This may become complicated because too deep of a weld will spoil the air cylinder. The acrylic sheets have become a manufacturing issue because of the lack of equipment. The university does not have a large enough oven or heat ability to help bend the acrylic to shape. Heat guns have been used with little success, but not enough. The art department will be contacted and see if they have a kiln that may be used.

Assembly, Sub-assembly, Parts, Drawings

The rubber pad will be glued the bottom of the frames' base to save money and weight. The support plate will be screwed to the elevator unit and the other end will be welded to the air cylinder or as mentioned before, the clamp method will be taken in consideration. The support plate will slide vertically, within the slot made on the frames' outer side. The press-fit roller will be screwed to the outer elevator unit wall and leaning against the inner frame wall. A groove will be CNC on the inner wall of the frame. This groove will enable the rollers to roll within a path groove. A rubber strap will be riveted to the bottom base of each elevator unit. This strap will secure the operator. The following listing represents the order on how the device is constructed.

Label	Part Name	Quantity
0	Skeleton	1
1	Frame RL	1
2	Elevator Unit	2
3	Frame LL	1
4	Lockable Gas Spring	2
5	Support plate RL	1
6	Support plate LL	1
7	Rubber padding	2
8	Rollers	6
9	Secure strap	2
10	Base support for gas springs	2
11	Epoxy Glue	1
12	Collet	2
13	screws	28
14	Post screws	4
15	L-brackets	8
16	L-safe lock	2
17	Spray paint	1

Image C-3: Construction Order

Testing Method

Introduction Testing Method

The primary testing will be based off the device requirements. After testing, the measurement data, that will determine whether modifications may be taken in consideration to improve the device. The gas spring will be measured by applying weight, to determine if the component is able to withstand the predicted weight. Additional weight will be added until the gas spring fails to compare what the manufacturers' assured (the max weight cability). A timer will be needed to record how long the mounting duration is to raise the person to the devices' potential height. The support plates' shear max will be calculated and measured. This will determine if the support plate can be made lighter by removing material area. Finally, once the assembly has been assembled, the weight of the device will be recorded. The assembly must meet the max weight requirement. If the max weight requirement if not met, there will be modifications on the device to try and meet that requirement. Again, the testing measurements will help improve the device.

Approach/ Method

The following list are tools that will be needed to stress predictions and elicit the devices' performance:

- Video camera
- Weights
- Stop watch
- Calipers
- Metric ruler
- Weighing scale
- Tensile tester

The video camera will be used to record the devices performance. The weights will be needed to test the gas springs' compression reliability. Stilt mounting is known for being a hassle and sometimes risky. The stop watch will confirm the time it takes to mount the stilt and reach its potential height. The calipers and the metric ruler will be used to measure the gas springs' compressive failure after it has exceeded its weight capacity. They will also be used to measure the initial x-axis position of the elevator unit and once it has been compressed by the support plate. There is a torque created by the gas spring when it is extracted. This torque will create an axial load from the support plate to the elevator unit' outer wall, causing it to compress. Again, this x-axis distance will be measured. The weighing scale will be used to measure the stilts' weight, in order to determine if the requirement was achieved. The tensile tester will help provide feedback on tensile stresses that must be avoided.

Deliverables

The following Excel spreadsheet demonstrates a testing format. This spreadsheet demonstrates what was tested and the results. The excel spreadsheet can be found in appendix G.

Task	Testing comments:	Test method	Results
1:Stability	a). Firm-does not rock b). Tipped over at angle but operational	a). Visual b). Protractor	a). Good b). 25 degrees
2: Stilt mounting duration	This design avoids complexity while mounting. This considers the time to mount and secure oneself and extend to potential height	Stop watch	10 sec, 9 sec, 11 sec
3: Light weight (each stilt)	Scale is calibrated and the device is placed on the weighing scale. These values are values before making the device lighter. Can drill holes on frame to make lighter.	weighing scale. Camera.	17.5 lbs., 17.5 lbs., 17.5 lbs.
X 4: Extension feasibility	Unsuccessful because the elevator unit rubbed on the L-safety lock. Extension height potential is 18 in.	Operator on device. Public tested.	N/A
5: Weight capacity	The operator mounted the device and additional weight was added to max out at 280 lbs. 160 lbs. + 120 lbs. =280 lbs.	Operator, backpack and weights.	Max 280 lbs.
6: Oprreration sustainability (each leg)	Test #5 on each leg. While the operator walks, all the weight shifts on each leg. Weight was applied on each stilt.	Operator, backpack and weights.	Max 280 lbs.
7: Lockable gas spring encounter force 44-330 lbs.	As tests #5 & #6 were performed, test #7 was analyzed and tested. The 280 lbs. did not create any height displacement, meaning there is excessive encounter force: A weaker cylinder is required.	Operator, backpack, weights, and ruler.	Max 280 lbs.
8: Grip/shock absorption	Water was poured on the floor and the device was set on wet floor and dragged to see the friction between both surfaces. Grooves can be made on the rubber to increase traction.	Visual method. peumatic Leg Extension and operator	Good traction
x 9: Cost efficient	There was a lists/cost and a device comparison excel spreadsheet that indicated that the device cost more than the devices compared.	Excel spreadsheet	Costs more
X 10: Safe to operate	The device was not able to operate because test #4 failed. The elevator unit rubbed on the L-safe lock, disabling it to operate. Due to this, the device is not considered safe until fixed.	Visual method. Data from other tests.	Needs fix

Image G-1: Testing Spreadsheet

The Light weight test was recorded at home using a weighing scale and a camera. The weighing scale was first calibrated by stepping on the scale and recalibrating it. The weight for each device was 17.5 lbs. (before reducing weight). This test was a success (below 45 lbs.)The Light weight test was recorded at home using a weighing scale and a camera. The weighing scale was first calibrated by setting the scale to zero. The operator stepped onto the weighing scale to make sure the weighing scale was not broken. The device was placed onto the weighing scale and recorded the weight for each device. The weight for each device was 17.5 lbs. This weight is without any weight reduction. The requirement was to have designed and constructed a device under 45 lbs. This test was a success because the weight for each device was way below 45 lbs.

The excel spreadsheet below demonstrates the pneumatics leg extensions' construction and costs list. The pneumatic leg extension became to be slightly pricey because of manufacturing issues. Overall, the device was around the price range, but was successful for what it was worth.

The testing process was a long, but meaningful process. The tests relied on numerous tools such as a ruler, camera, backpack with weights, weighing scale, protractor, stop watch, excel, and the operator. There were many modifications along the testing phase, but for the most part, these issues were solved. The following table illustrates the task, testing comments, test methods, and the results.

Each task represents each requirement for the pneumatic leg extension. The testing comments column explains the purpose of the task and how the device may be improved, after analyzing each test. The test method column illustrates what tools or testing method was approached. Finally, the last column demonstrates the results for each testing. Some tests were visual tests, which produced qualitative results, while the rest produced quantitative results. Even though the device did not achieve its purpose, the tests illustrate success for the most part of the project. There were manufacturing issues that lead to struggles through the testing process. Some of these struggles were overcome, others were not as simple. For example, the device can be weight-reduced, but the cost of the device cannot be changed, unless there is a design change. Overall, the tests well highlighted the devices' qualities and things that need to be redesigned to improve the prototype.

Label	Part Name	Quantity	Cost of Components	Location	Readiness	Material
0	Skeleton	1	$37.00	Western Metals	Arrived	1/8 gauge sheet metal & 0.5 in. dia. rods
1	Frame RL	1	$50.00	e-voniks	Arrived	Acrylic extruded sheet
2	Elevator Unit	2	$30.00	e-voniks	Arrived	Acrylic extruded sheet
3	Frame LL	1	$50.00	e-voniks	Arrived	Acrylic extruded sheet
4	Lockable Gas Spring	2	$71.96	Chairpartsonline	7 days	Steel
5	Support plate RL	1	$0.00	CWU scraps	Here	Alumium
6	Support plate LL	1	$0.00	CWU scraps	Here	Alumium
7	Rubber padding	2	$41.58	Rubber Sheet Roll (RSR)	7-10 days	General purpose rubber
8	Rollers	6	$12.54	Globalindustrial.com	Arrived	Carbon steel
9	Secure strap	2	$2.10	ACE Hardware	Here	polypropylene
10	Base support for gas springs	2	$0.00	RSR-remaining scraps	Here	General purpose rubber
11	Epoxy Glue	1	$6.00	Ranch and Home	Here	Glue
12	Collet	2	$0.00	CWU scraps	Here	Aluminum pipe
13	screws	28	$14.00	Ranch and Home	Here	Aluminum 10-24 x 1/2
14	Post screws	4	$3.00	Ranch and Home	Here	Aluminum 8-32 x 3/8
15	L-brackets	8	$0.00	Home Scraps	Here	Aluminum sheet metal
16	L-safe lock	2	$15.00	Ranch and Home	Here	Aluminum- 1/8 gauge
17	Spray paint	1	$0.00	Home resource	Here	Paint
		Actual Total	**$333.18**			

Image D-1: Expected Budget

Discussion

Design Evolution

Initially, the frame was designed squared with a wider profile, but then it was redesigned to a semi-circular shape. This geometry was finalized because it would reduce material costs, provide more comfort while walking, and prevent the user from tipping backwards. The power source choices varied for a while. First, an actuator was considered, but was replaced by a foot pump and an air cylinder. The actuator was not only expensive and heavy, but it was also range limiting because it would need to be connected to an electricity supply. Finally, the foot pump and the air cylinder were replaced by a simple gas spring (strut). The foot pump and the air cylinder would work, but a lot of factors came into play. One of those factors was that the air cylinder would work as a spring (like walking in the moon). Sure, the foot pump would produce air for the air cylinder to extend, but very slowly. Not only that, but if the design was made to function, then pins would need to be engaged, once the person reached to the final position. This would not only eliminate the purpose of avoiding manual operation, but it would also limit range. This means that the person would either be at initial positon or the final extended position. In order to solve this issue, multiple pin holes would need to be made, making the frame weaker (risking failure). This power supply design was more expensive, heavier, and a lot more complicated than a simple lockable gas spring.

The lockable gas spring is basically the same mechanism of an office chair. The gas spring extends by engaging a lever with no pressure on it. The user will now have to simply step into the frame, secure strap his/her foot on the elevator unit, lift the foot and engage the lever for the extension. Once the users' assignment is done, the lever is engaged and the gas spring is retracted by the users' mass plus earth's gravity. This will enable the user to extend to desired positon without any descending restrictions. At the end, the design remains being a manual operational device, but this projects efforts have made it most efficient. These improvements include: device reduced cost, weight, extension desirability, stability safety, operational comfort and complexity.

Project Risks

There are always tradeoffs in every project. There are two considerations to this device that could become a risk if precautions are not taken seriously. These factors are the devices' material and weight. The market stilt is made of stainless steel and or aluminum, making it heavier. The pneumatic leg extension is mostly made of acrylic plastic, making it lighter. Obviously, metals are in most cases, stronger than most plastics; but the requirements to this device permits additional considerations. Using acrylic for this device enables it to become lighter, cheaper, and more comfortable, while still keeping the user safe. Although this will change, if precautions are not taken in consideration and the devices abilities are exceeded.

As earlier discussed, the device presents forces that came as a probable concern. Bearings became a solution and a number of bearings were placed to meet the requirement weight. Again, weight and the material can become as risk factors. As presented in the calculations found in appendix A, the solution to the issue was the number of carbon steel bearing balls. The requirements are presented as capabilities; anything exceeding those requirements might result as safety risks.

Conclusion

One valuable lesson learned is that a prototype will hardly function the way it was designed. There is at least one thing that can be mentioned for the three main components, which could have been a probable cause of malfunction. Plastics sometimes have unpredictable characteristics. For instance, when the acrylic was bent over the jig, the varying temperature over the plastics' surface caused the sheet to pull unevenly. This issue resulted with an uneven frame, causing a ripple-like affect. The uneven frame changed the elevator units' shape and dimensions, the bearing groove affectability, and rubbing (between the support plate and the slot made on the frame wall). The lockable gas spring (cylinder) extended when the button was initiated and retracted when the button was engaged with a potential counter force applied. The function of this component was perfect for this design because it extended and retracted by the push of a button. This would eliminate the need to sit back down (market stilt) and shift pins for extension desirability. One, unexpectedly issue, was the different potential forces and extension lengths of each cylinder. These cylinders were manufactured for a different purpose: office chair operations. When manufacturing the cylinders, different potential forces and extensions within the cylinders are not an issue because only one cylinder is used per chair. The potential force and extension are between a range, thus not a promising exact measurement. The support plate created a large moment force. The support plate was manufactured accordingly, to the designed specifications. It was predicted that that length would be perfect under the moment force circumstances; because the moment would be absorbed by the bearing balls, which were screwed onto the frame wall. Due, to the uneven manufactured frame, additional force was applied onto the bearing balls because of the bearing groove depth variance.

Overall, some issues were modified to find a solution, but others were avoidable. For instance, rubber padding was epoxy glued to the bottom of each cylinder to absorb the unequal stroke lengths, making the lengths equal. On the other hand, the devices' cost was unavoidable. The pneumatic leg extension prototype came across many manufacturing issues, changing the result and the cost. As modifications were made, the cost increased. Even though, the prototype did not execute its purpose, the results webpage demonstrates the devices' achievements. Important aspects were learned to improve the next prototype. The next prototype will be cost efficient and with better results. It seems that stilts sold in the market have been focused on one or two perks, but unlike these designs, the pneumatic leg extension has surpassed and improved all of these perks; all in one design. The ability to look at an existing design and enhance all factors, while others haven't been able to: That is engineering. This pneumatic leg extension does not only put engineering one step ahead, but it also changes the world of stilts completely.

Acknowledgements

Resources

Central Washington University is acknowledged for its resources. The university has presented high qualified staff with a great learning environment; machinery, and a few scrap components that will be used in the device.

Mentors

This section is specifically dedicated for the following mentors: Dr. Craig Johnson, Professor Charles Pringle, Professor Roger Beardsley, Professor Mathew Burvee, Ted Bramble, assistant Nathan Wilhelm, lab technician Jose Bejar and aeronautical engineer Dennis Capovilla. It is thanks to the support and advisement of these mentors that the Pneumatic Leg Extension was able to prosper.

Extra Assistance

Michael Waytuck was another individual that helped the pneumatic leg extension become possible. Michael calculated the torque that the device presented. It was helpful having an extra person review and confirm to a critical calculation.

Resources

MACHINE ELEMENTS IN MECHANICAL DESIGN - FIFTH EDITION

Mott, Robert L. *Machine Elements in Mechanical Design*. Fifth ed. 789. Print.

STATICS & MECHANICS OF MATERIALS – FOURTH EDITION

Hibbeler, R. C. *Statics and Mechanics of Materials*. Fourth ed. 877. Print.

Appendix A

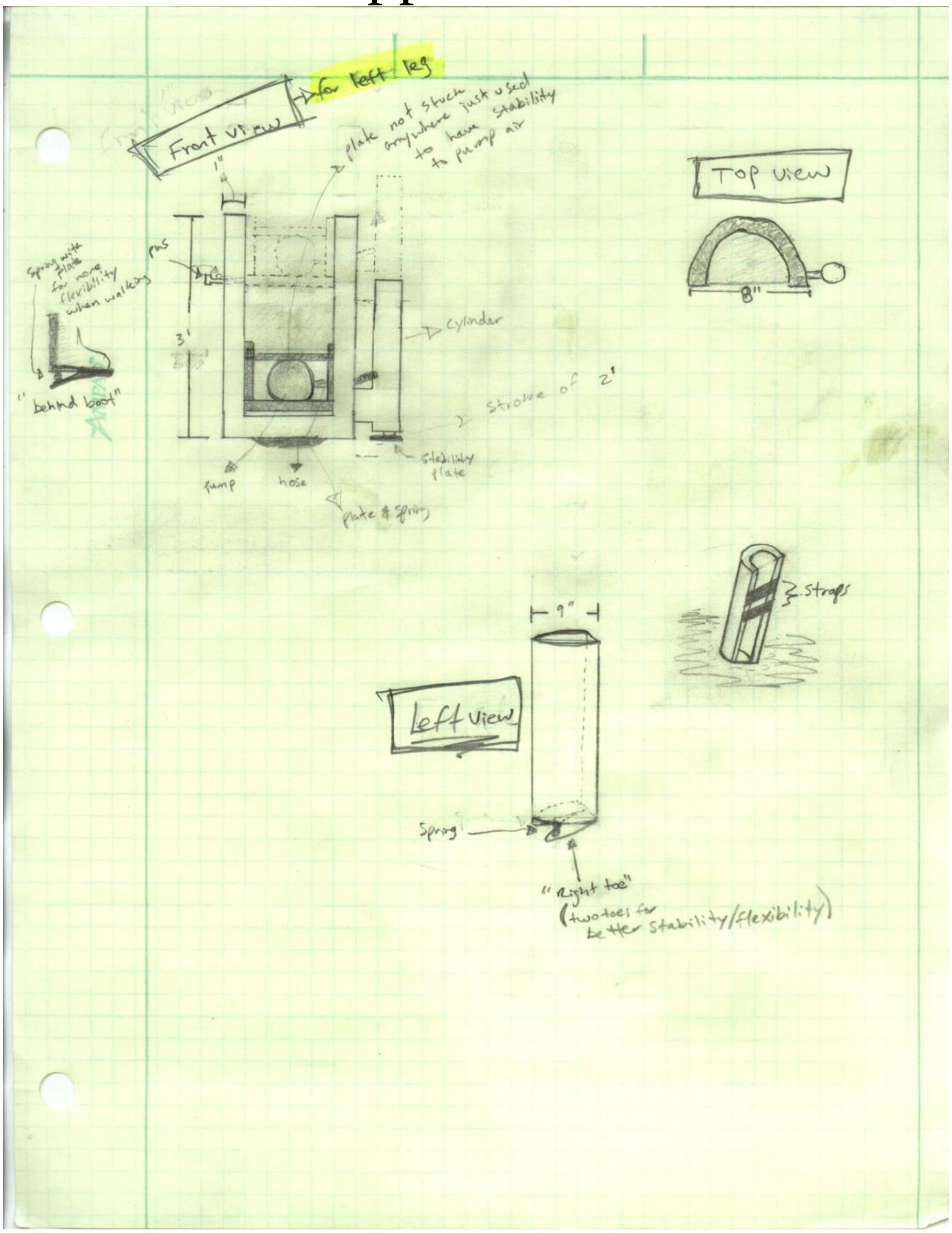


Image A-1: First rough draft-stilt design

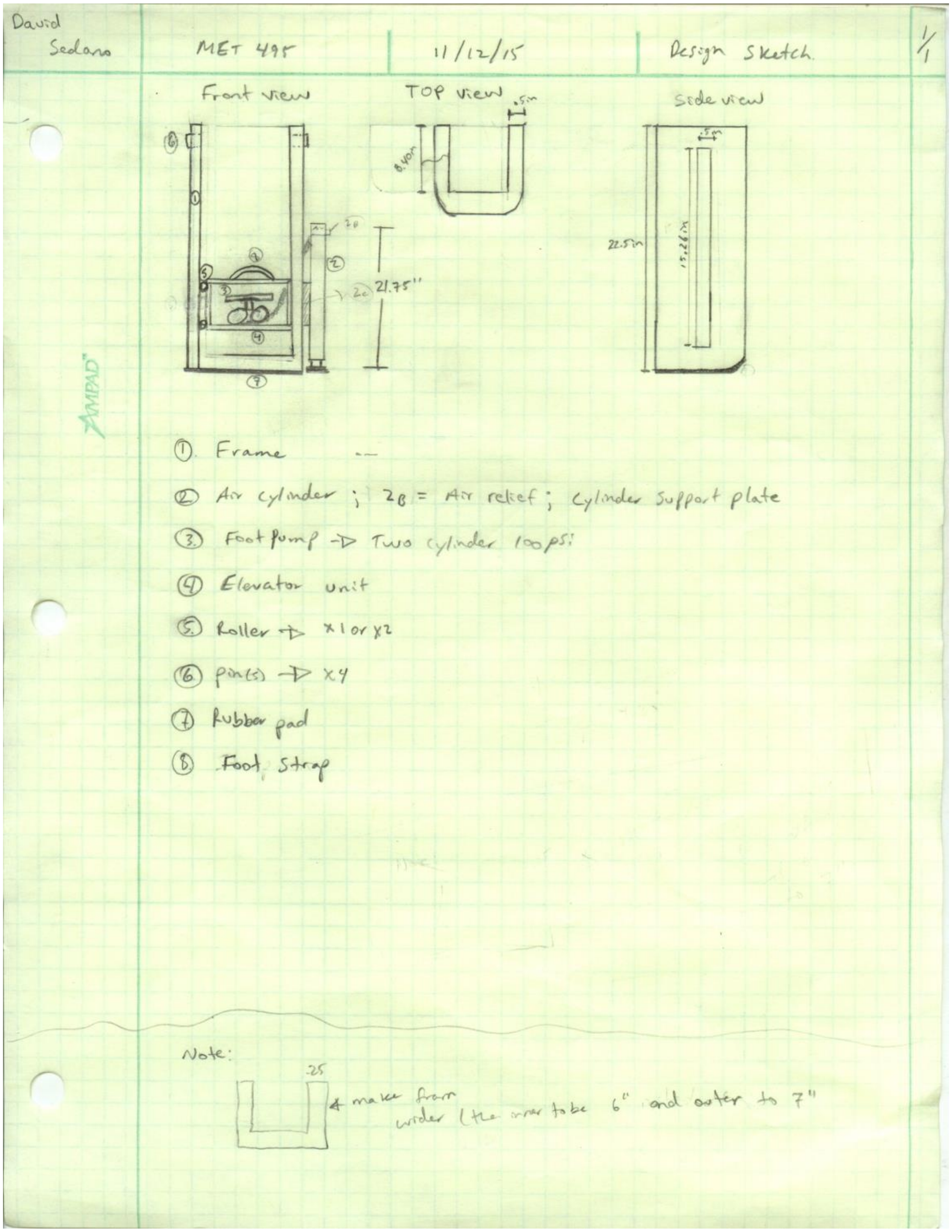


Image A-2: Second rough draft-stilt design

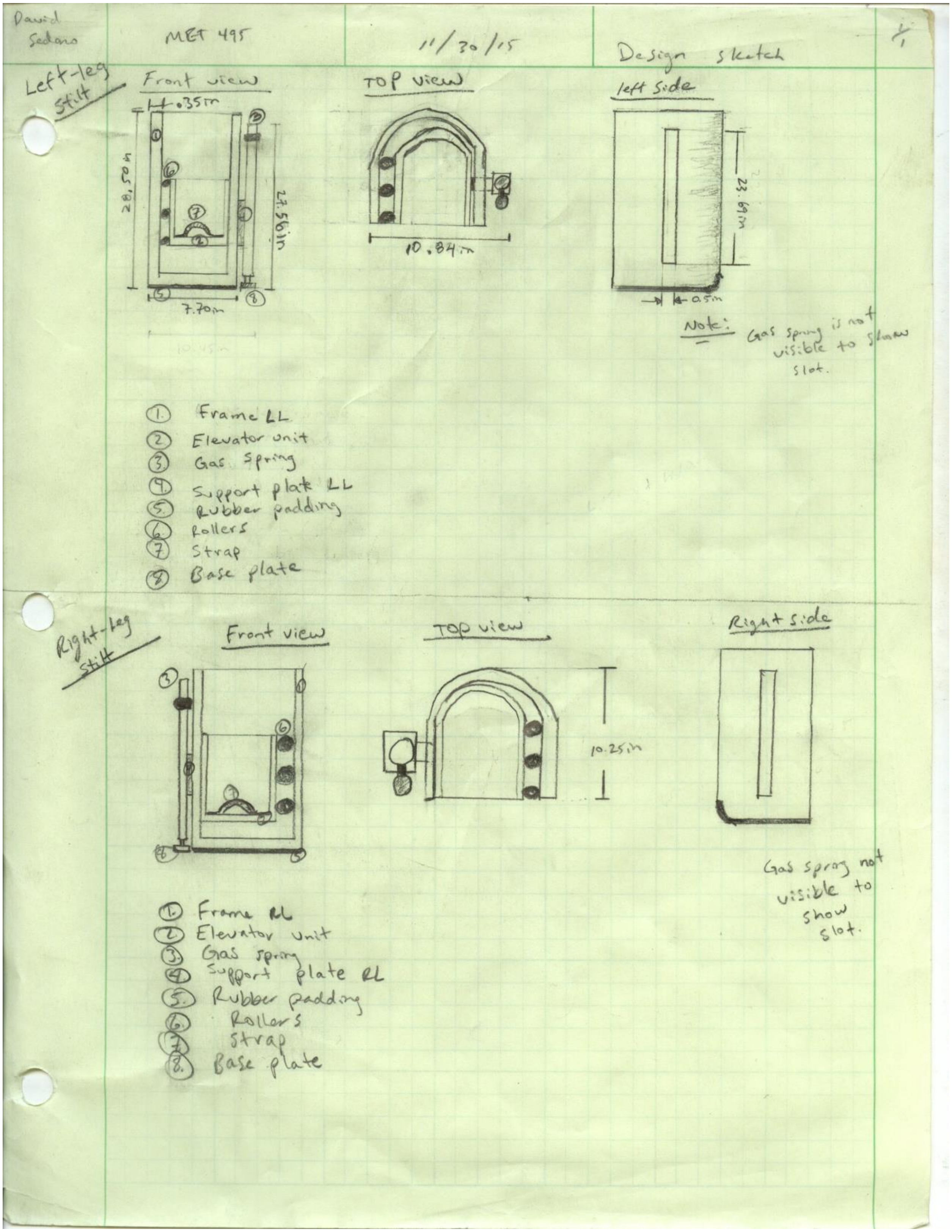
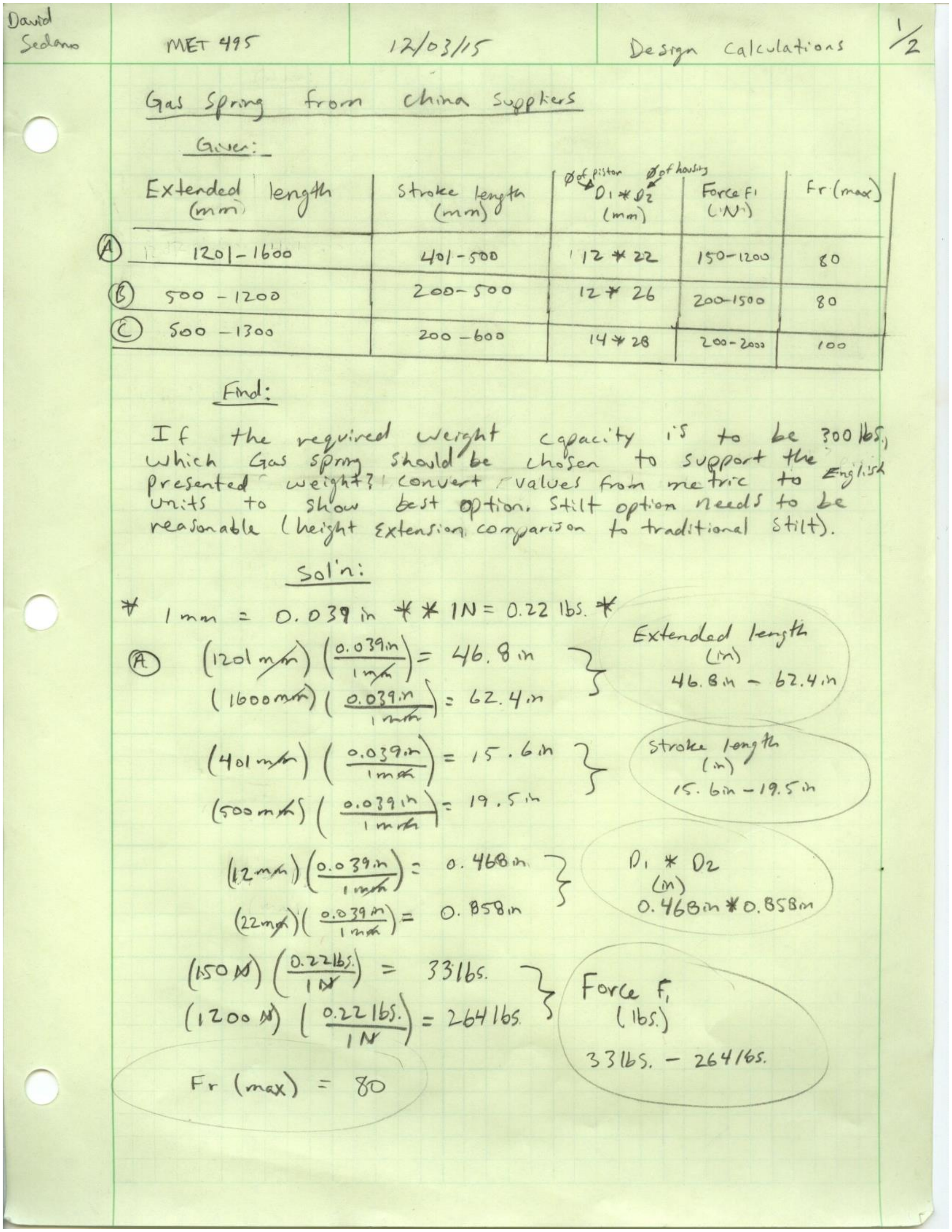


Image A-3: Final design draft



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Gas Spring from china suppliers

Given:

	Extended length (mm)	Stroke length (mm)	Ø of piston, Ø of housing: $D_1 * D_2$ (mm)	Force F_1 (N)	Fr (max)
(A)	1201–1600	401–500	12 * 22	150–1200	80
(B)	500 – 1200	200–500	12 * 26	200–1500	80
(C)	500 – 1300	200 – 600	14 * 28	200 – 2000	100

Find:

If the required weight capacity is to be 300 lbs, which Gas spring should be chosen to support the presented weight? Convert values from metric to English units to show best option. Stilt option needs to be reasonable (height extension comparison to traditional stilt).

Sol'n:

* 1 mm = 0.039 in ** 1N = 0.22 lbs. *

(A)

$(1201\,mm)\left(\frac{0.039\,in}{1\,mm}\right) = 46.8\,in$

$(1600\,mm)\left(\frac{0.039\,in}{1\,mm}\right) = 62.4\,in$

Extended length (in): 46.8 in – 62.4 in

$(401\,mm)\left(\frac{0.039\,in}{1\,mm}\right) = 15.6\,in$

$(500\,mm)\left(\frac{0.039\,in}{1\,mm}\right) = 19.5\,in$

Stroke length (in): 15.6 in – 19.5 in

$(12\,mm)\left(\frac{0.039\,in}{1\,mm}\right) = 0.468\,in$

$(22\,mm)\left(\frac{0.039\,in}{1\,mm}\right) = 0.858\,in$

$D_1 * D_2$ (in): 0.468 in * 0.858 in

$(150\,N)\left(\frac{0.22\,lbs.}{1\,N}\right) = 33\,lbs.$

$(1200\,N)\left(\frac{0.22\,lbs.}{1\,N}\right) = 264\,lbs.$

Force F_1 (lbs.): 33 lbs. – 264 lbs.

Fr (max) = 80

Image A-4: Gas spring parameters calculation-finding proper gas spring

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continued...

(B.)

$(500\,mm)\left(\frac{0.039\,in}{1\,mm}\right) = 19.5\,in$

$(1200\,mm)\left(\frac{0.039\,in}{1\,mm}\right) = 46.8\,in$

Extended length (in): 19.5 in − 46.8 in

$(200\,mm)\left(\frac{0.039\,in}{1\,mm}\right) = 7.8\,in$

$(500\,mm)\left(\frac{0.039\,in}{1\,mm}\right) = 19.5\,in$

Stroke length (in): 7.8 in − 19.5 in

$(12\,mm)\left(\frac{0.039\,in}{1\,mm}\right) = 0.468\,in$

$(26\,mm)\left(\frac{0.039\,in}{1\,mm}\right) = 1.014\,in$

$D_1 * D_2$ (in): 0.468 in * 1.014 in

$(200\,N)\left(\frac{0.22\,lbs.}{1\,N}\right) = 44\,lbs.$

$(1500\,N)\left(\frac{0.22\,lbs.}{1\,N}\right) = 330\,lbs.$

Force F_1 (lbs.): 44 lbs − 330 lbs.

Fr (max) = 80

(C.)

$(500\,mm)\left(\frac{0.039\,in}{1\,mm}\right) = 19.5\,in$

$(1300\,mm)\left(\frac{0.039\,in}{1\,mm}\right) = 50.7\,in$

Extended length (in): 19.5 in − 50.7 in

$(200\,mm)\left(\frac{0.039\,in}{1\,mm}\right) = 7.8\,in$

$(600\,mm)\left(\frac{0.039\,in}{1\,mm}\right) = 23.4\,in$

Stroke length (in): 7.8 in − 23.4 in

$(14\,mm)\left(\frac{0.039\,in}{1\,mm}\right) = 0.546\,in$

$(28\,mm)\left(\frac{0.039\,in}{1\,mm}\right) = 1.092\,in$

$D_1 * D_2$ (in): 0.546 in * 1.092 in

$(200\,N)\left(\frac{0.22\,lbs}{1\,N}\right) = 44\,lbs.$

$(2000\,N)\left(\frac{0.22\,lbs}{1\,N}\right) = 440\,lbs$

Force F_1 (lbs): 44 lbs. − 440 lbs.

Fr (max) = 100

Gas spring (B.) is the best option; Force = 330 lbs. Although option (C.) has a weight capacity of 440 lbs., it becomes too long when retracted; meaning that it would become uncomfortable when the person is getting on the stilt.

Image A-5: Continued-Gas spring parameters

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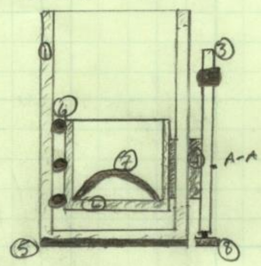
part 1

Given:

	weight	width
① Frame LL	→ 15.4 lbs.	→ 7.7 in
② Elevator unit	→ 2.3 lbs.	→ 5.5 in
③ Gas spring	→ N/A	→ Ø 1.02 in
④ support plate LL	→ 0.3 lbs.	→ 1.56 in
⑤ Rubber padding	→ 1.8 lbs.	→
⑥ Roller	→ 0.3 lbs	→ Do not need
⑦ Strap	→ ≈ 0.01 lbs.	→
⑧ Base plate	→ 0.15 lbs.	→

Front view



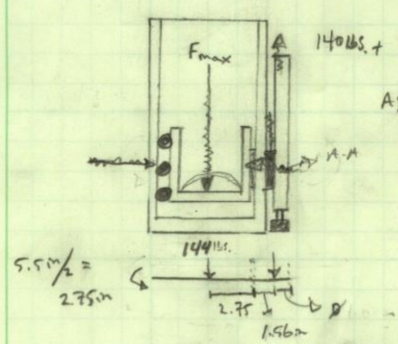
The device is analyzed when the person is standing still (perpendicular to the floor).

Find:

What is the moment of force about point A-A. Units will be lb-in.

Sol'n:

Standing still weight distributed to both legs. → 280 lbs. / 2 = 140 lbs per stilt



2.75 in + 1.56 in + .51 in = 4.82 in

140 lbs. + 2.3 lbs + 0.01 lbs + 0.3 lbs (x) = F_{max}

Assuming x = 5 → F_{max} = 143.81

F_{max} = 144 lbs.

$\circlearrowleft + \sum M_{A\text{-}A} = (144\,lbs)(4.82\,in) + (0.3\,lbs)(1.29\,in)$

= 694.5 lb-in

$M_{A\text{-}A} = 694.5\ lb\text{-}in$

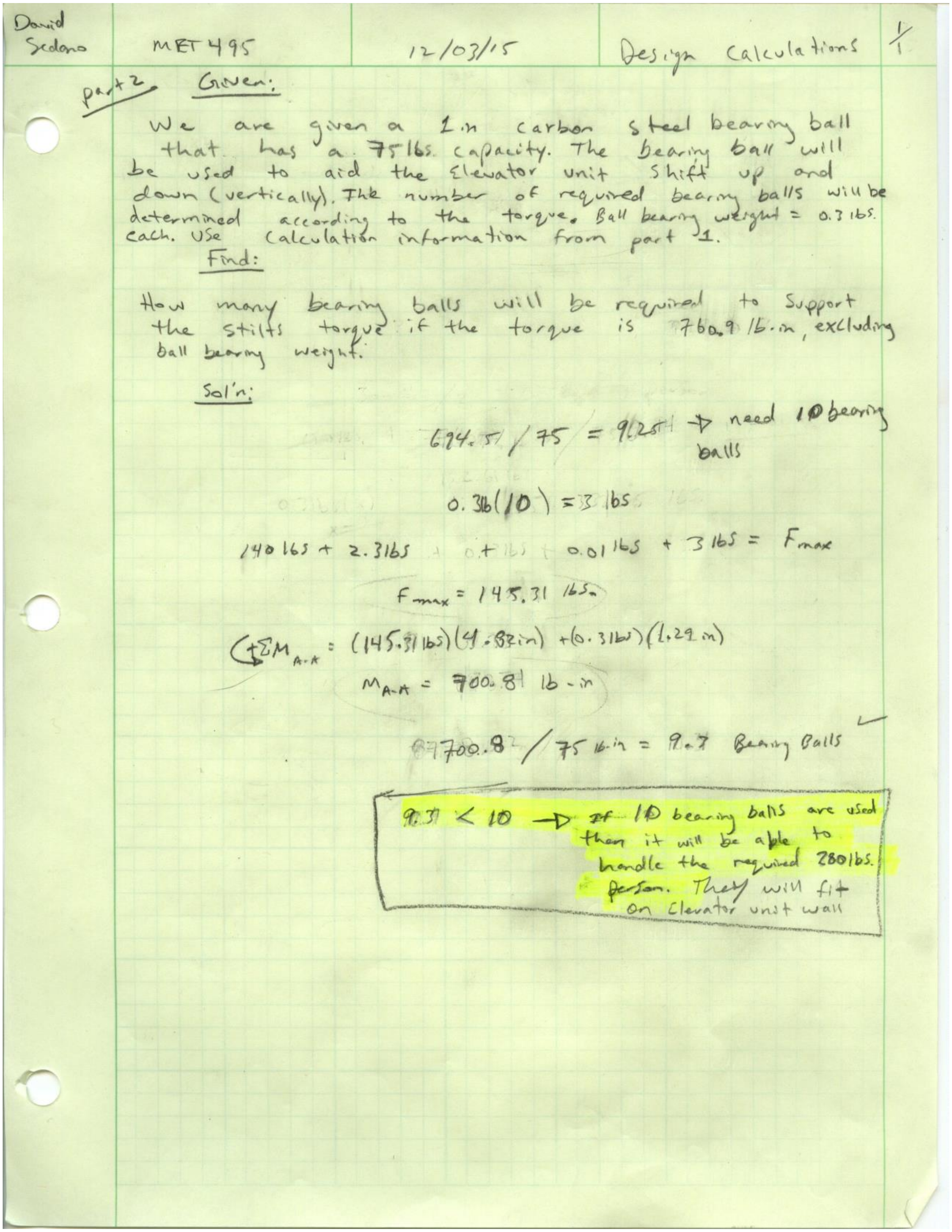
This only applies if the person is actually that heavy → 280 lbs.

&

if 5 bearing balls are used

Note: we will need 10 bearing balls to meet requirements. (x needs to be 10).

Image A-6: Part 1- Max weight moment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part 2

Given:

We are given a 1 in carbon steel bearing ball that has a 75 lbs. capacity. The bearing ball will be used to aid the Elevator unit shift up and down (vertically). The number of required bearing balls will be determined according to the torque. Ball bearing weight = 0.3 lbs. each. Use calculation information from part 1.

Find:

How many bearing balls will be required to support the stilts torque if the torque is 760.9 lb·in, excluding ball bearing weight.

Sol'n:

$694.51 / 75 = 9.251 \rightarrow$ need 10 bearing balls

$0.3 lb(10) = 3$ lbs

140 lbs $+ 2.31$ lbs $+ 0.01$ lbs $+ 3$ lbs $= F_{max}$

$F_{max} = 145.31$ lbs.

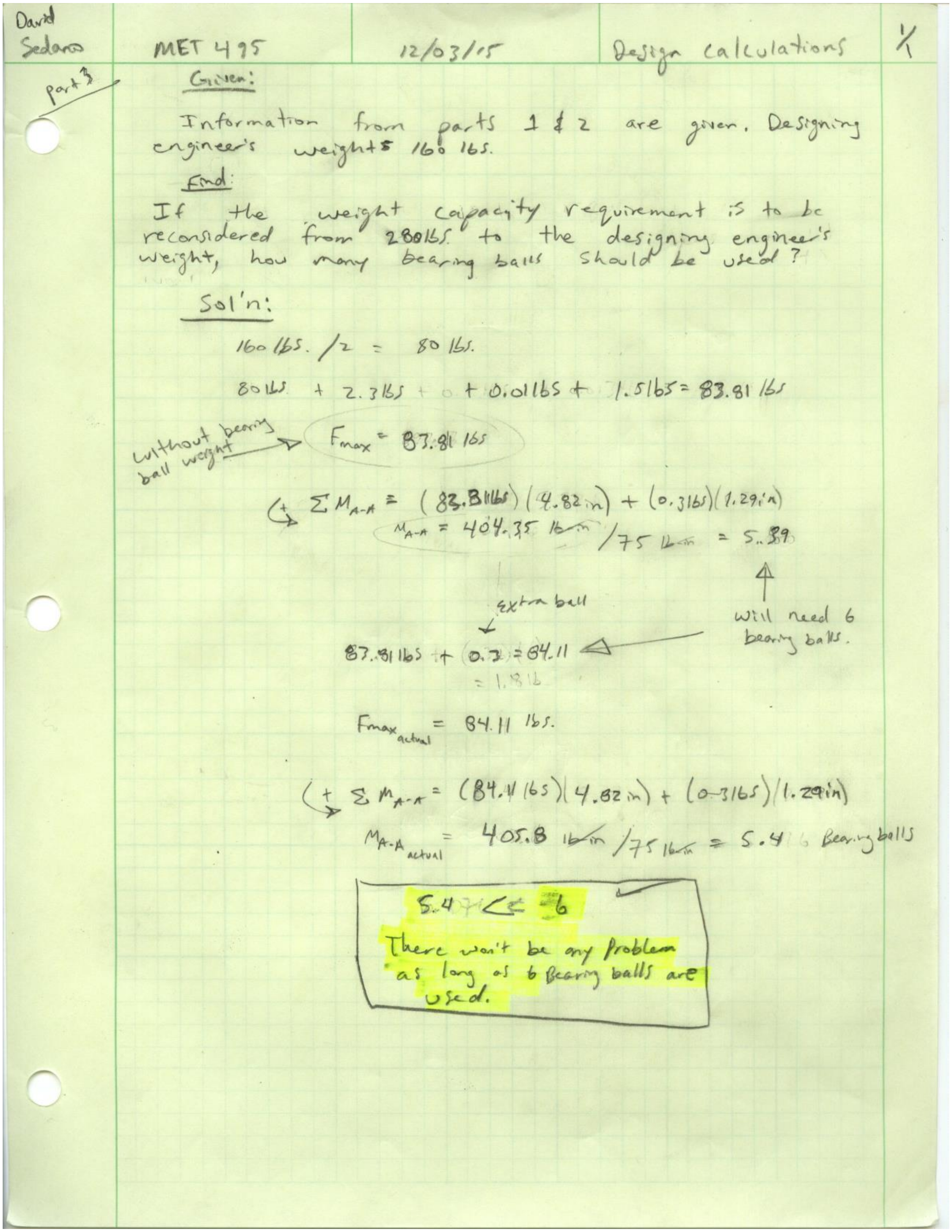
$\circlearrowleft + \Sigma M_{A\text{-}A} = (145.31 \text{ lbs})(4.82 \text{ in}) + (0.31 \text{ lbs})(1.29 \text{ in})$

$M_{A\text{-}A} = 700.81$ lb·in

$700.82 / 75$ lb·in $= 9.3$ Bearing Balls

$9.37 < 10 \rightarrow$ If 10 bearing balls are used then it will be able to handle the required 280 lbs. person. They will fit on Elevator unit wall

Image A-7: Part 2- Determining number of required bearing balls



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part 3

Given:

Information from parts 1 & 2 are given. Designing engineer's weight is 160 lbs.

Find:

If the weight capacity requirement is to be reconsidered from 280 lbs. to the designing engineer's weight, how many bearing balls should be used?

Sol'n:

160 lbs. / 2 = 80 lbs.

80 lbs + 2.3 lbs + 0 + 0.01 lbs + 1.5 lbs = 83.81 lbs

without bearing ball weight → F_{max} = 83.81 lbs

ΣM_{A-A} = (83.81 lbs)(4.82 in) + (0.3 lbs)(1.29 in)

M_{A-A} = 404.35 lb-in / 75 lb-in = 5.39

will need 6 bearing balls.

extra ball

83.81 lbs + 0.3 = 84.11

= 1.8 lb

$F_{max_{actual}}$ = 84.11 lbs.

ΣM_{A-A} = (84.11 lbs)(4.82 in) + (0.3 lbs)(1.29 in)

$M_{A-A_{actual}}$ = 405.8 lb-in / 75 lb-in = 5.41 → 6 Bearing balls

5.41 < 6

There won't be any problem as long as 6 Bearing balls are used.

Image A-8: Part 3- Determining required bearing balls according to designing engineer's weight

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Given:

(p9) We are given the material properties of a stainless steel flat head phillips machine screw.

- Yield strength = 24995.65867 lb/in²
- Tensile strength = 74493.26756 lb/in²
- Poisson's ratio = 0.28
- Elastic modulus = 29007547.53 lb/in²

Find:

- Find the required radius of the screw to support the 280 lbs. presented to avoid shearing
- How many screws do you need if you will use 1/4"-20 #3 drive flat screws? → Ø = 0.25 in

sol'n:

$$F_{shear\ yield} = \frac{280\text{ lbs.}}{\pi r^2}$$

$$r = \sqrt{\frac{280\text{ lbs.}}{\pi F_{shear\ yield}}}$$

$$= \sqrt{\frac{280\text{ lbs.}}{\pi (24995.65867\text{ lb/in}^2)}}$$

radius: $r = 0.0597\text{ in}$ ← this would change if clamping forces were considered

x2

diameter: $d = 0.1194\text{ in}$

One 0.25 in diameter screw would do the job but at least two will be placed to hold the elevator unit and support plate together and avoid rotation.

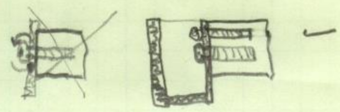
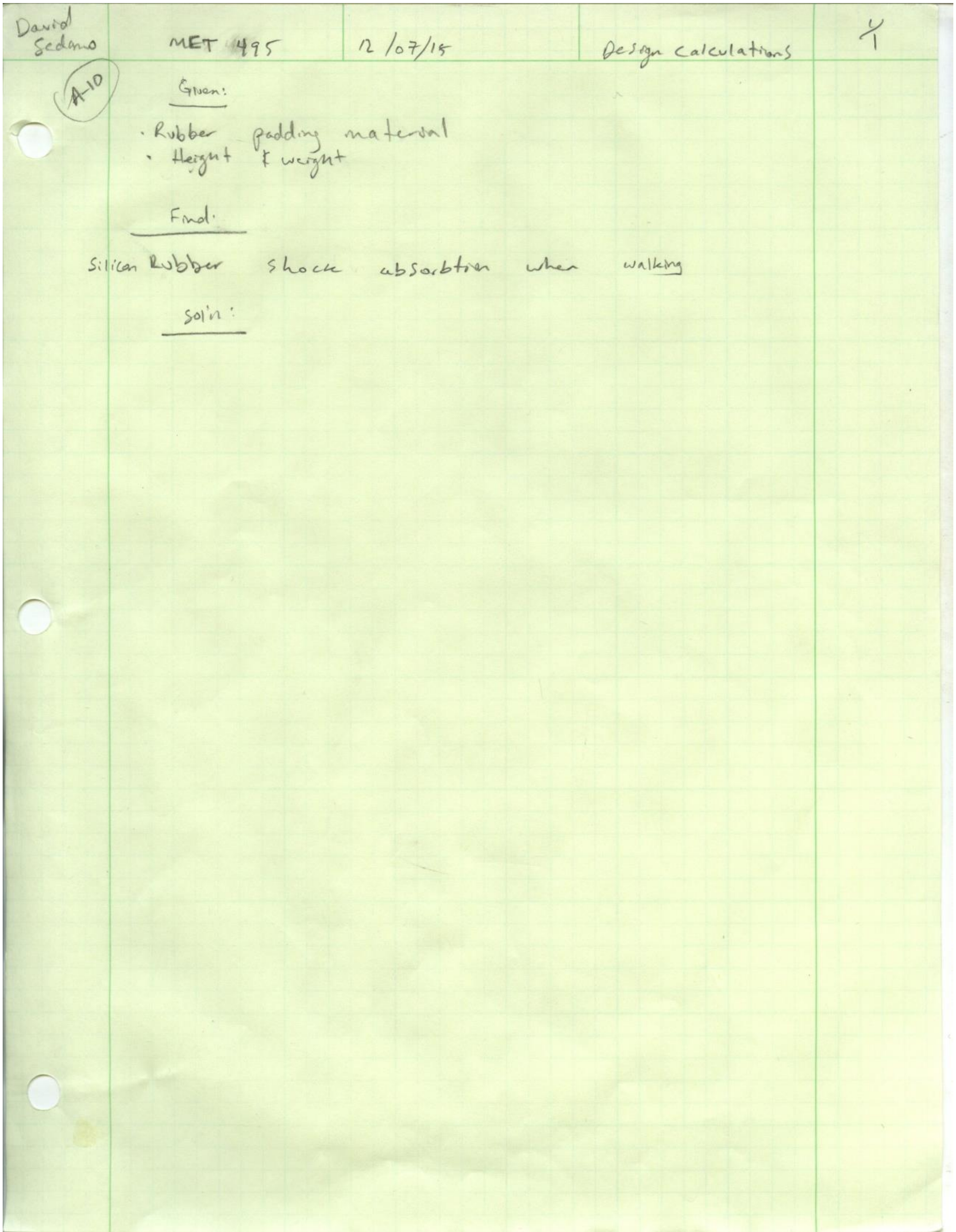


Image A-9: Shear on screws and number of screws



David Sedano | MET 495 | 12/07/15 | Design Calculations | 4/1

(A-10)

Given:

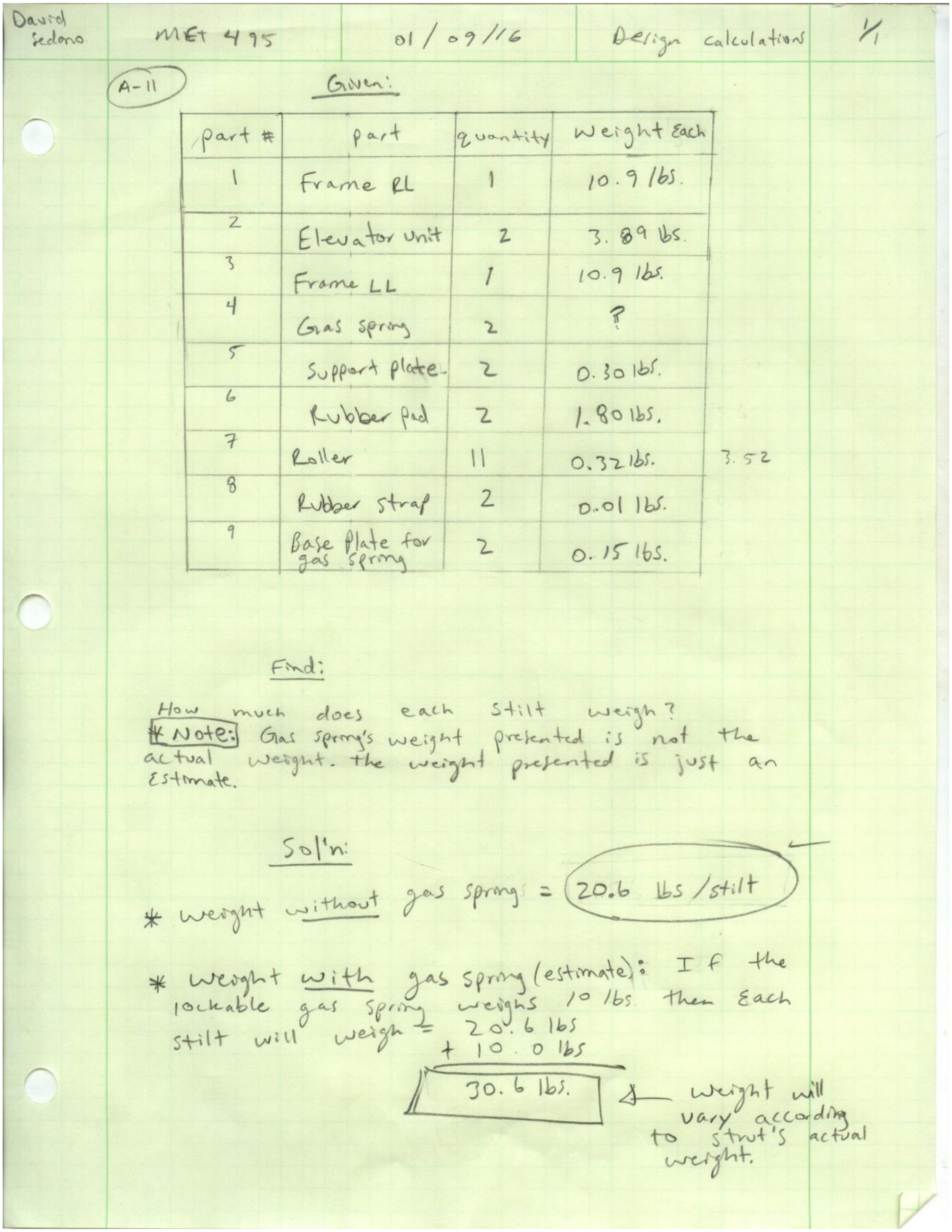
- Rubber padding material
- Height & weight

Find:

Silicon Rubber shock absorbtion when walking

Sol'n:

Image A-10: Shock Absorption-silicon rubber padding



David Sedano | MET 495 | 01/09/16 | Design calculations | 1/1

(A-11)

Given:

part #	part	quantity	weight Each
1	Frame RL	1	10.9 lbs.
2	Elevator unit	2	3.89 lbs.
3	Frame LL	1	10.9 lbs.
4	Gas spring	2	?
5	Support plate	2	0.30 lbs.
6	Rubber pad	2	1.80 lbs.
7	Roller	11	0.32 lbs.
8	Rubber strap	2	0.01 lbs.
9	Base plate for gas spring	2	0.15 lbs.

3.52

Find:

How much does each stilt weigh?

*Note: Gas spring's weight presented is not the actual weight. the weight presented is just an Estimate.

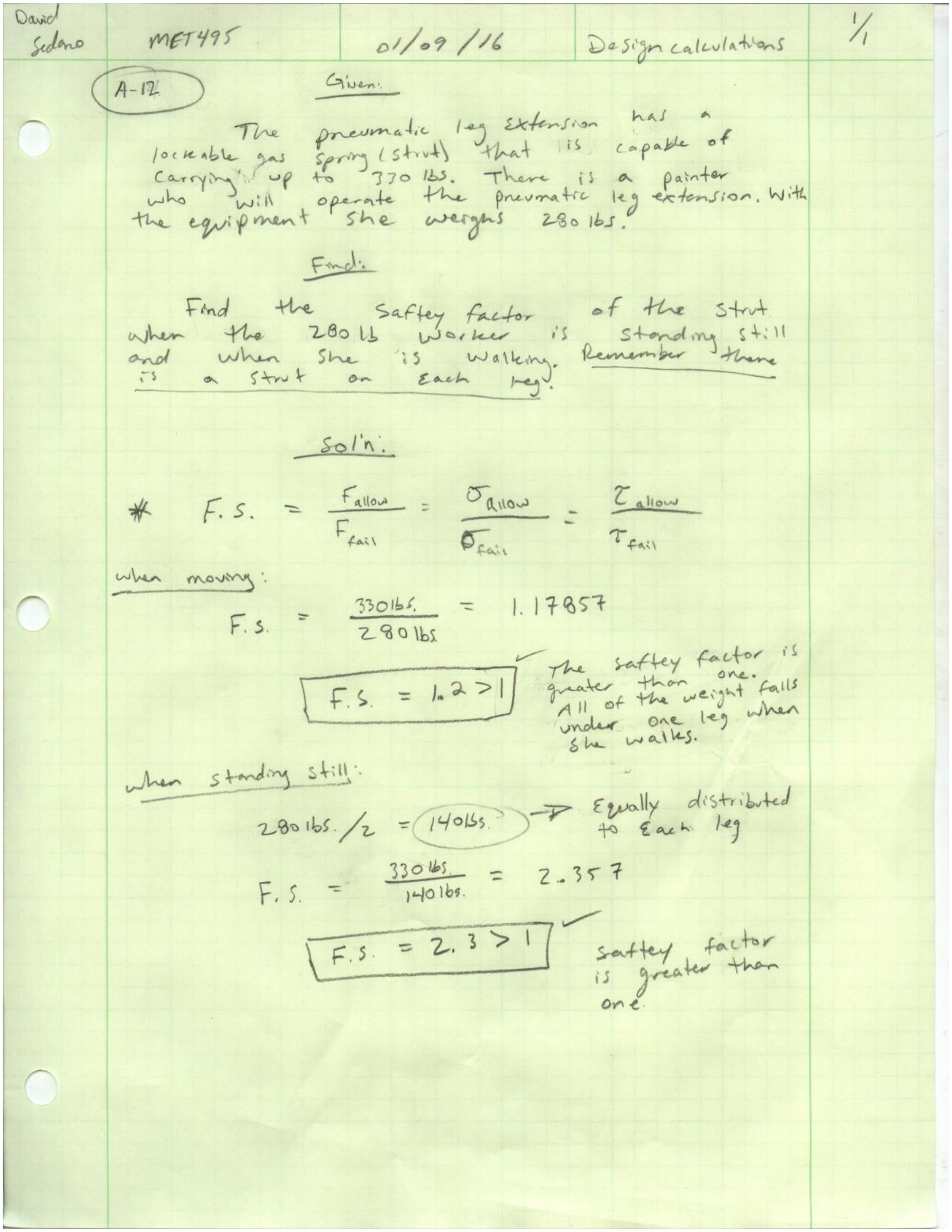
Sol'n:

* weight without gas spring = 20.6 lbs/stilt

* Weight with gas spring (estimate): If the lockable gas spring weighs 10 lbs then Each stilt will weigh = 20.6 lbs + 10.0 lbs

30.6 lbs. ← weight will vary according to strut's actual weight.

Image A-11: Stilt Weight



David Sedano | MET495 | 01/09/16 | Design calculations | 1/1

A-12

Given:

The pneumatic leg extension has a lockable gas spring (strut) that is capable of carrying up to 330 lbs. There is a painter who will operate the pneumatic leg extension. With the equipment she weighs 280 lbs.

Find:

Find the saftey factor of the strut when the 280 lb worker is standing still and when she is walking. Remember there is a strut on each leg.

Sol'n:

$$* \quad F.S. = \frac{F_{allow}}{F_{fail}} = \frac{\sigma_{allow}}{\sigma_{fail}} = \frac{\tau_{allow}}{\tau_{fail}}$$

when moving:

$$F.S. = \frac{330 lbs.}{280 lbs} = 1.17857$$

$$\boxed{F.S. = 1.2 > 1}$$

The saftey factor is greater than one. All of the weight falls under one leg when she walks.

when standing still:

$$280 lbs. / 2 = 140 lbs.$$ → Equally distributed to each leg

$$F.S. = \frac{330 lbs.}{140 lbs.} = 2.357$$

$$\boxed{F.S. = 2.3 > 1}$$

saftey factor is greater than one.

Image A-12: Lockable gas strut factor of safety

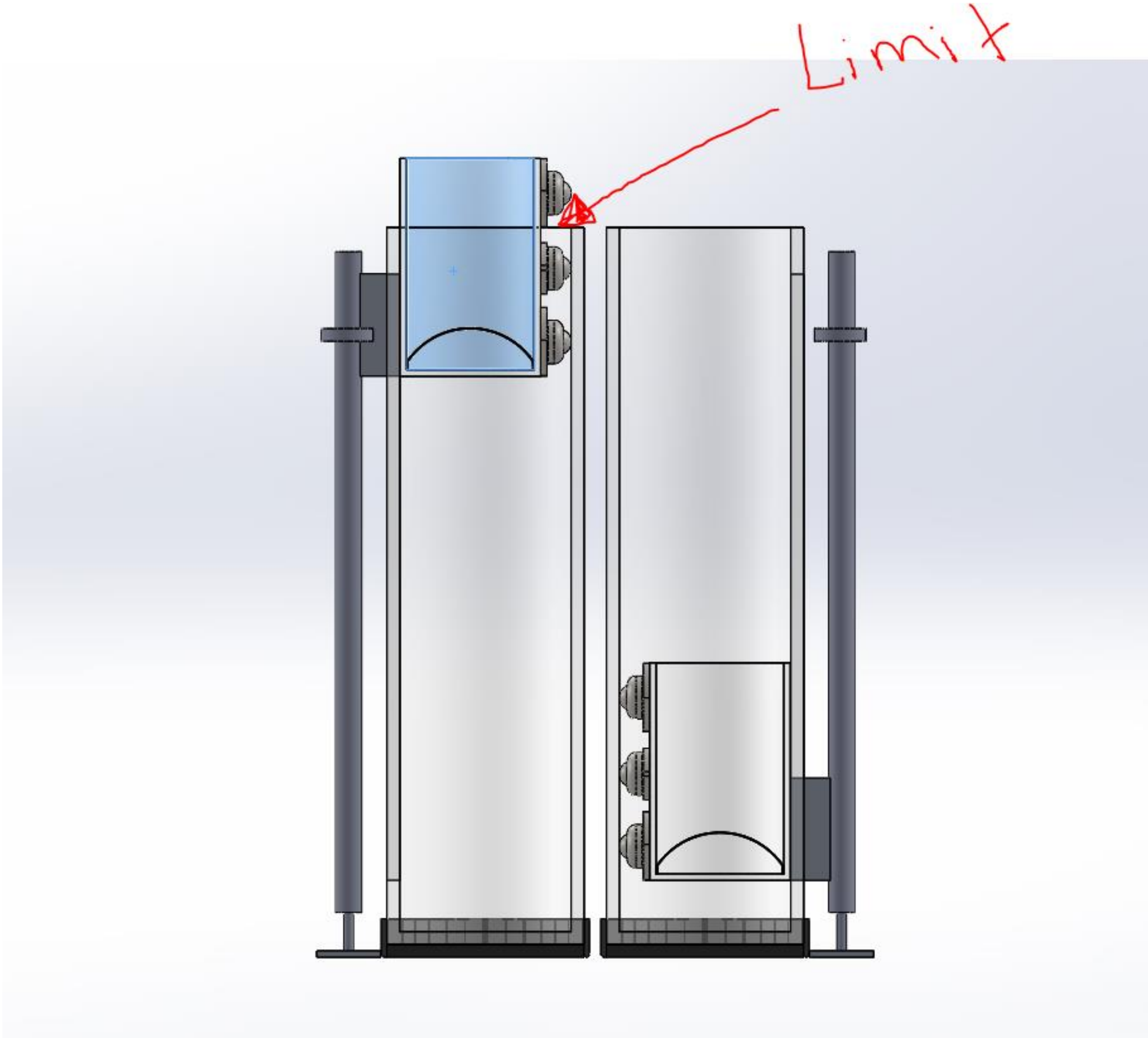
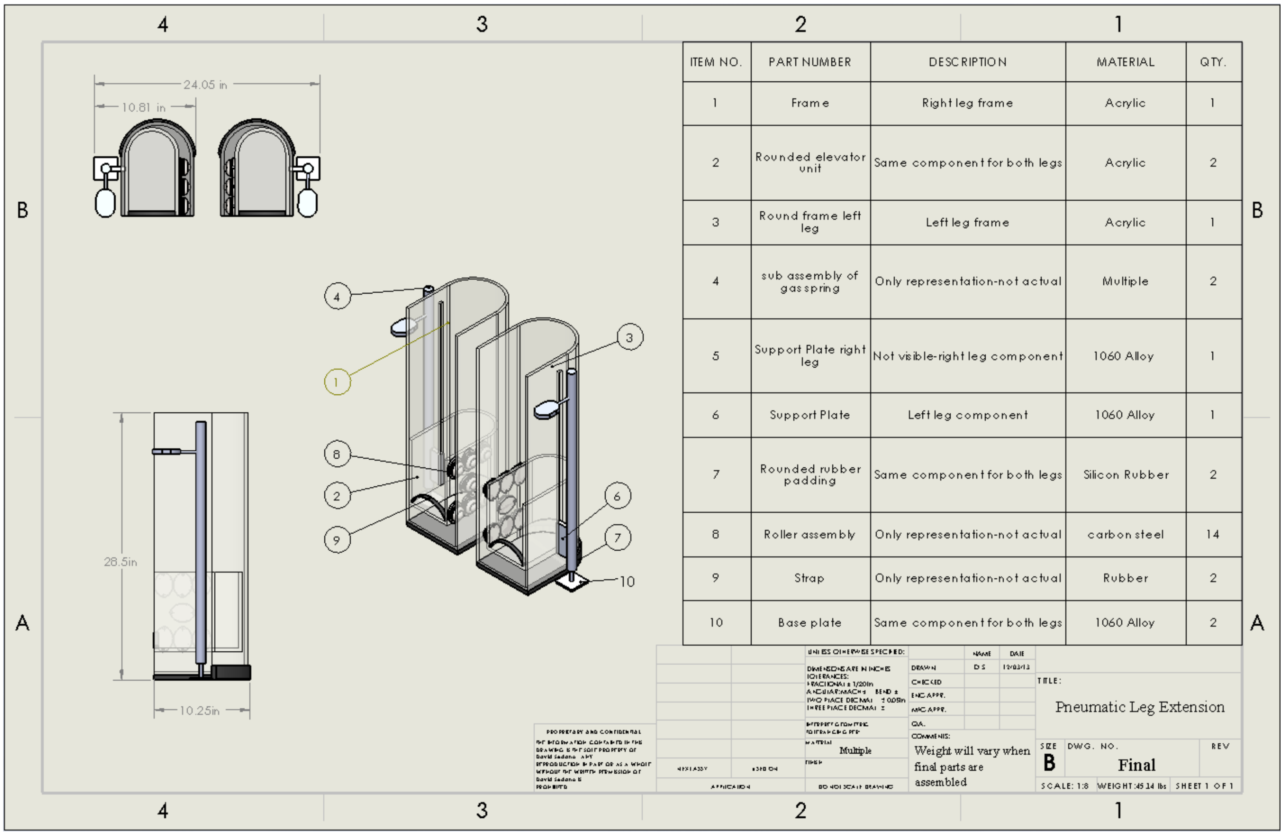


Image A-Z: Max height for gas spring stroke

Appendix B

Image B-0: Skeleton



ITEM NO.	PART NUMBER	DESCRIPTION	MATERIAL	QTY.
1	Frame	Right leg frame	Acrylic	1
2	Rounded elevator unit	Same component for both legs	Acrylic	2
3	Round frame left leg	Left leg frame	Acrylic	1
4	sub assembly of gas spring	Only representation-not actual	Multiple	2
5	Support Plate right leg	Not visible-right leg component	1060 Alloy	1
6	Support Plate	Left leg component	1060 Alloy	1
7	Rounded rubber padding	Same component for both legs	Silicon Rubber	2
8	Roller assembly	Only representation-not actual	carbon steel	14
9	Strap	Only representation-not actual	Rubber	2
10	Base plate	Same component for both legs	1060 Alloy	2

Image B-1: Leg Extension Assembly Drawing

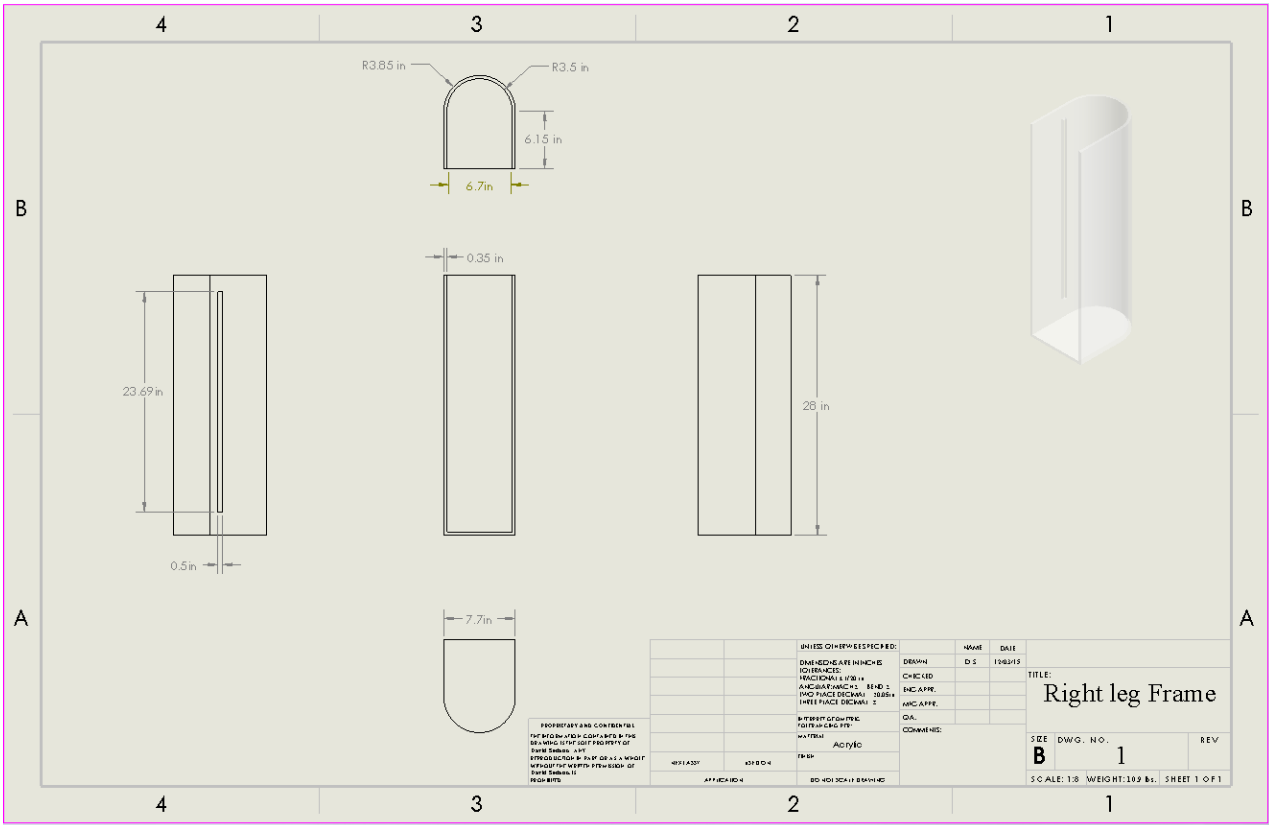


Image B-2: Right Leg Frame

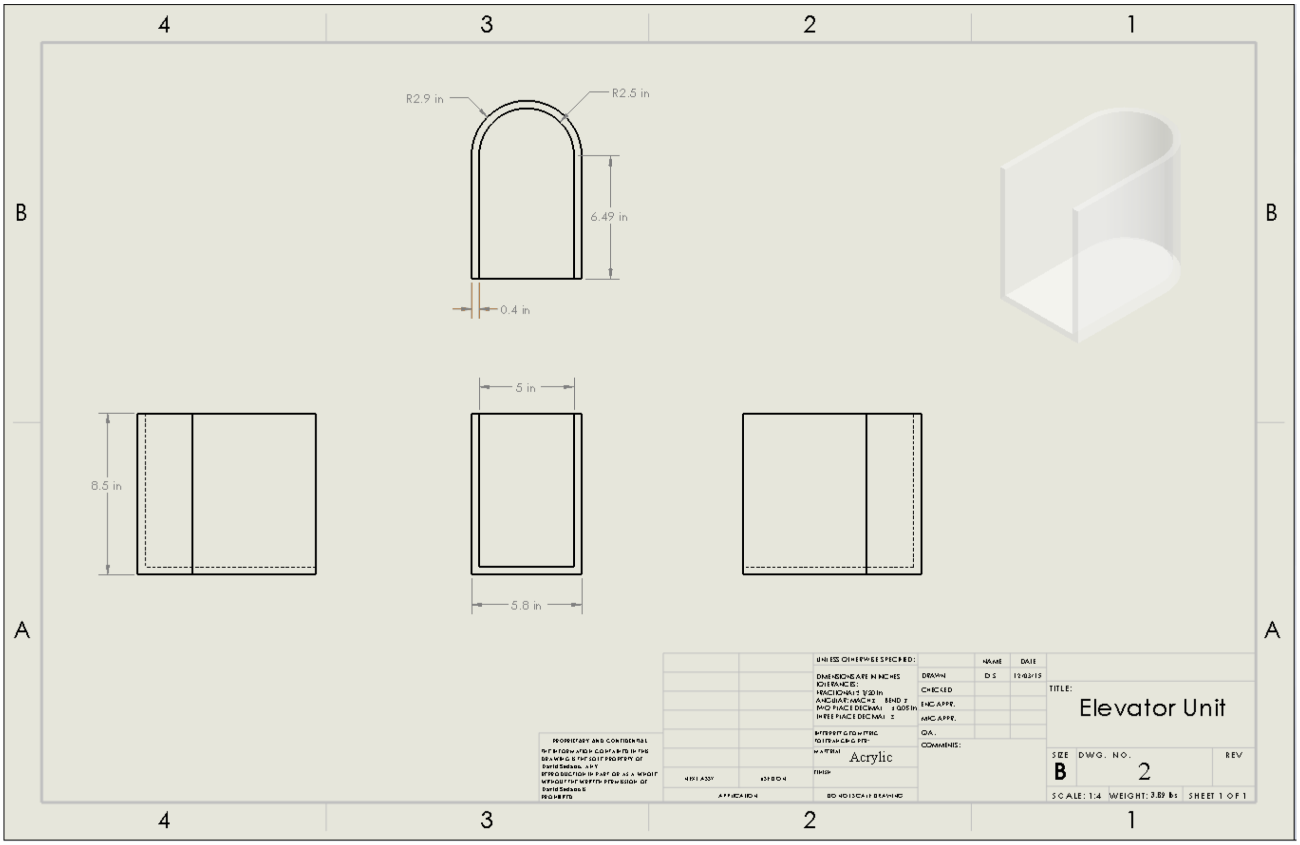


Image B-3: Elevator Unit

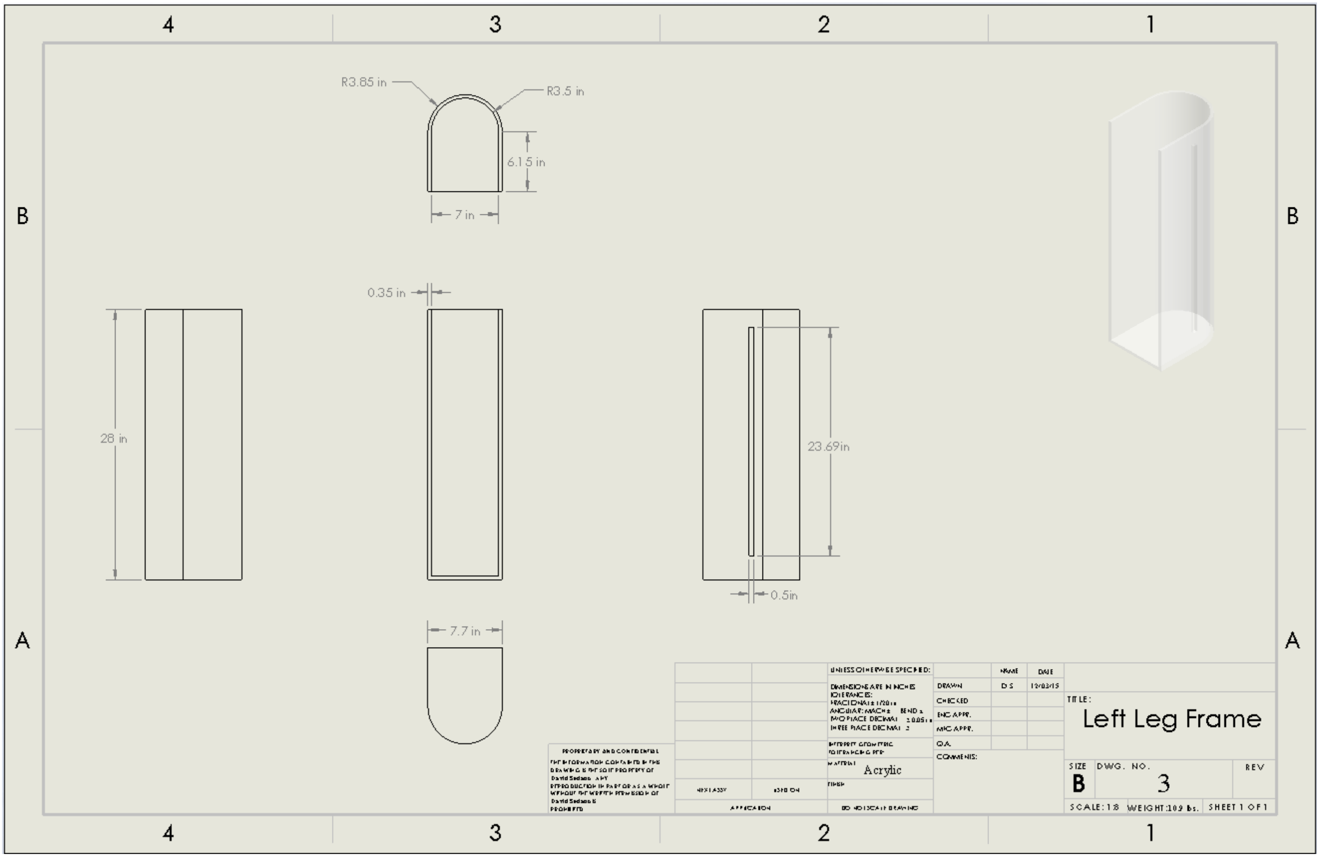


Image B-4: Left Leg Frame

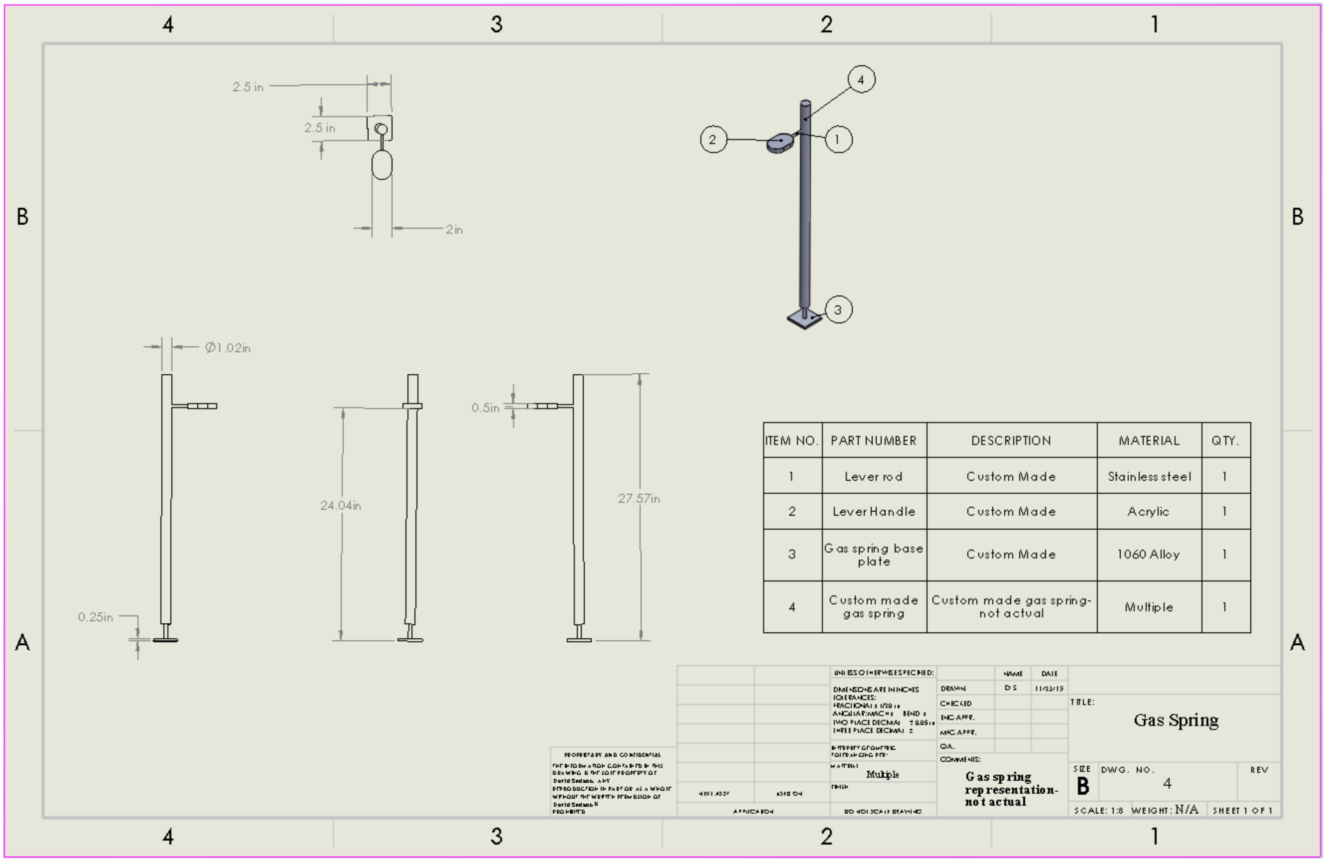


Image B-5: Representation of Gas assembly

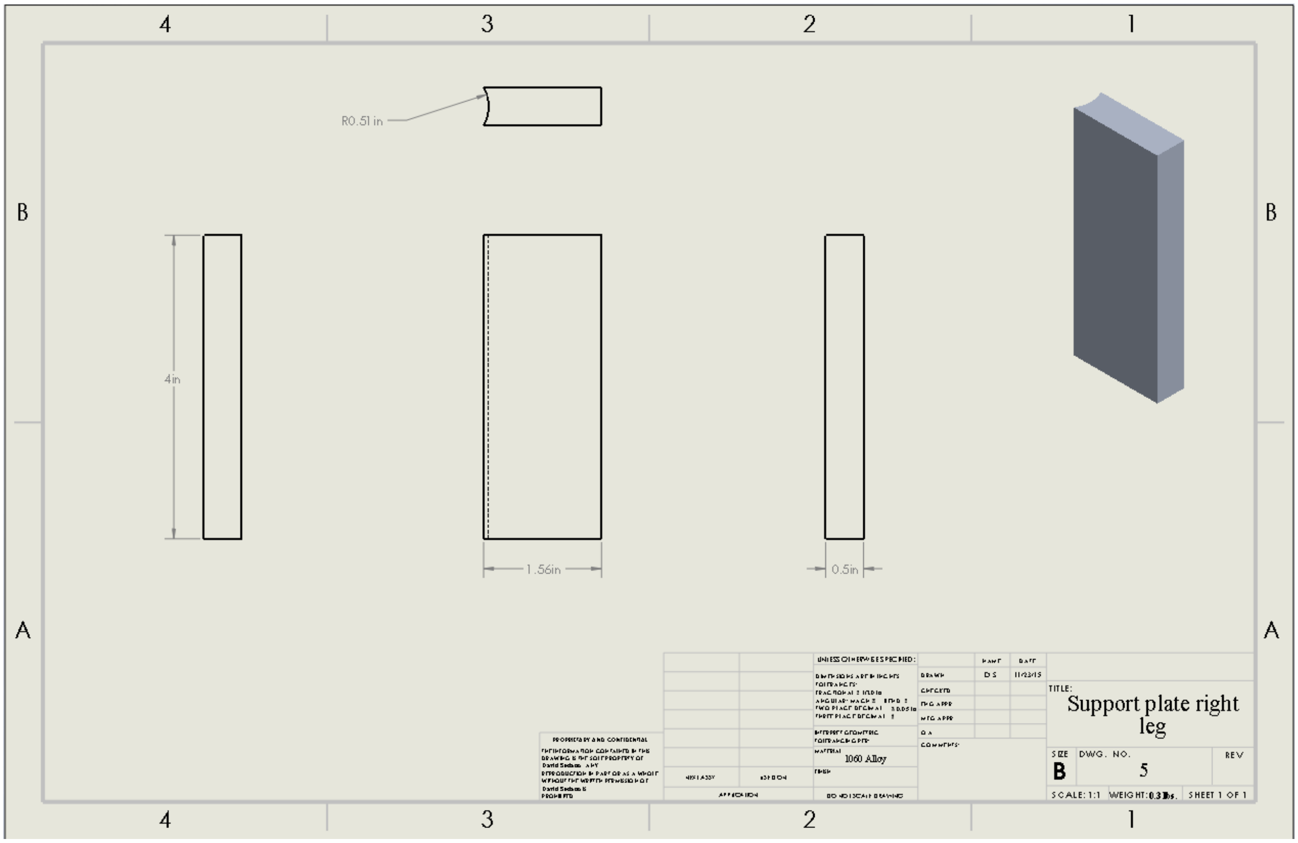


Image B-6: Support plate RL

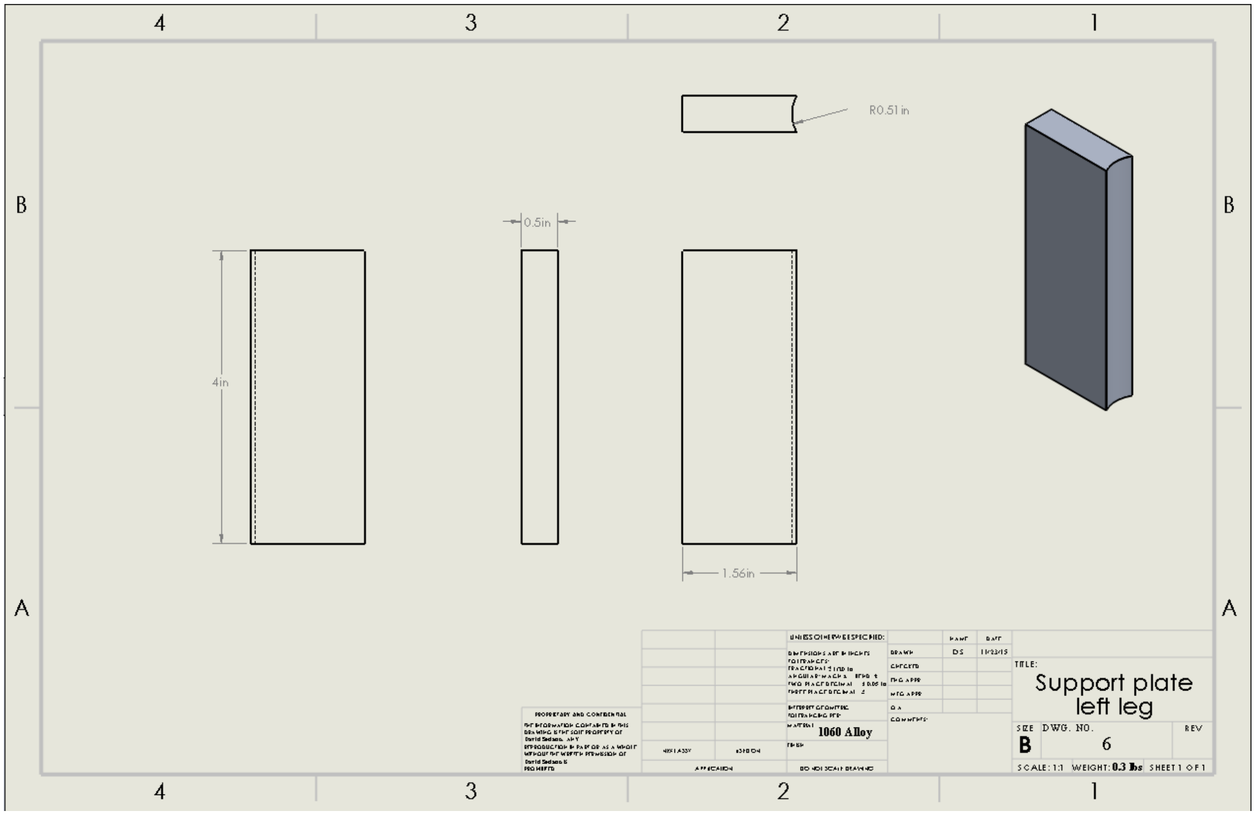


Image B-7: Support plate LL

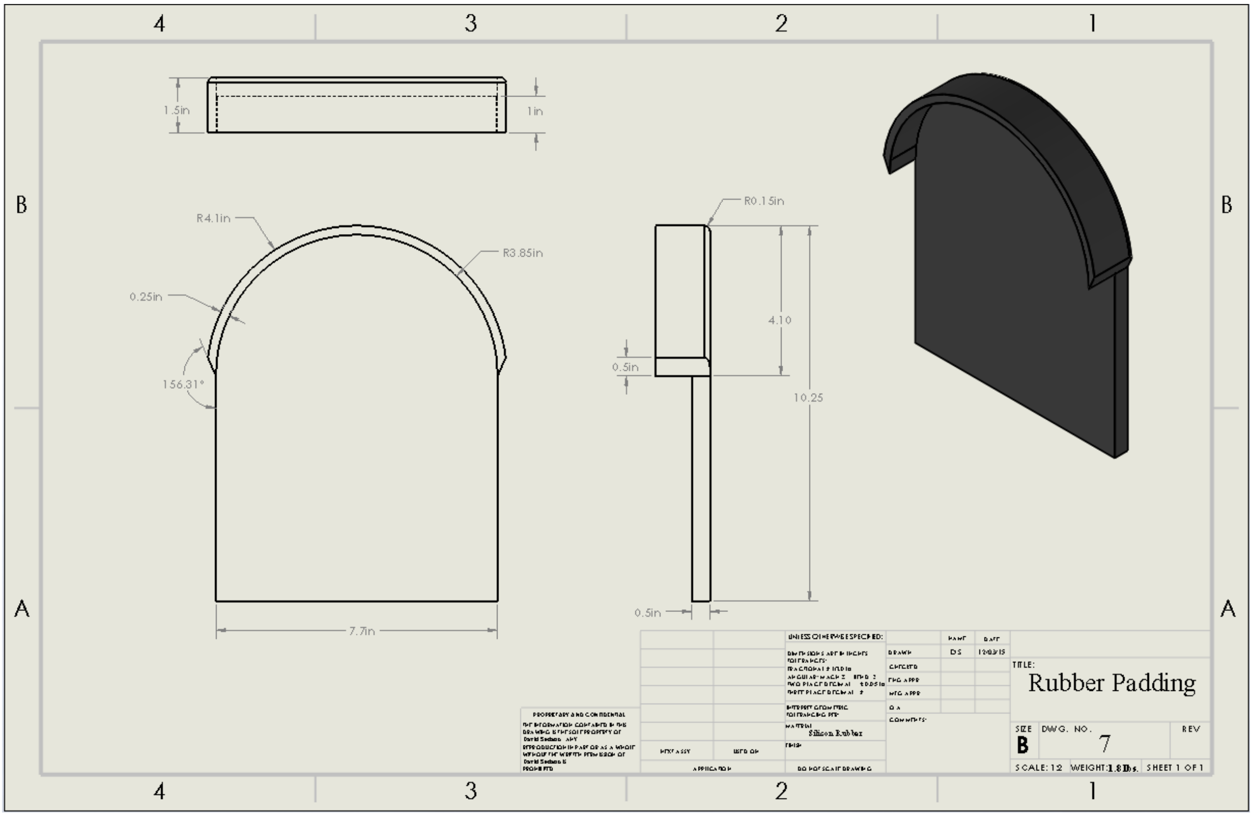


Image B-8: Rubber Padding

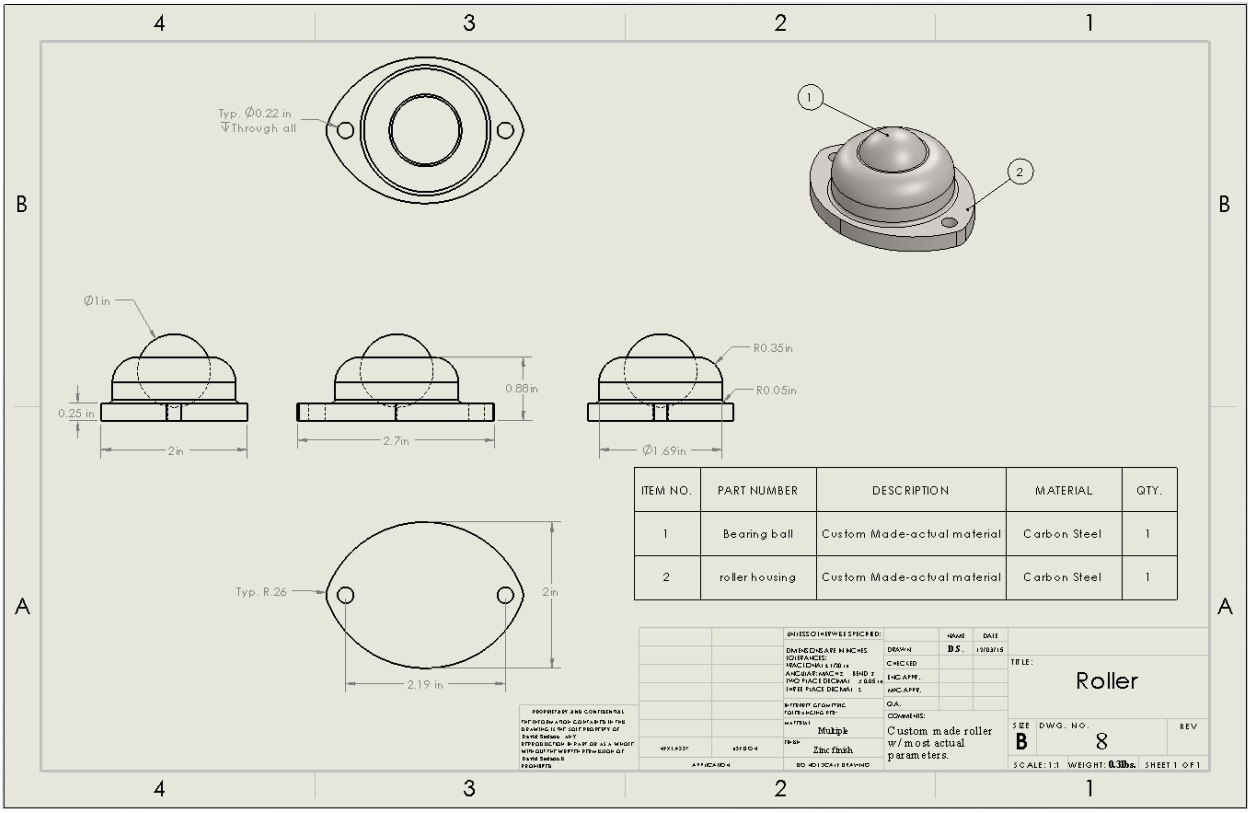


Image B-9: Roller

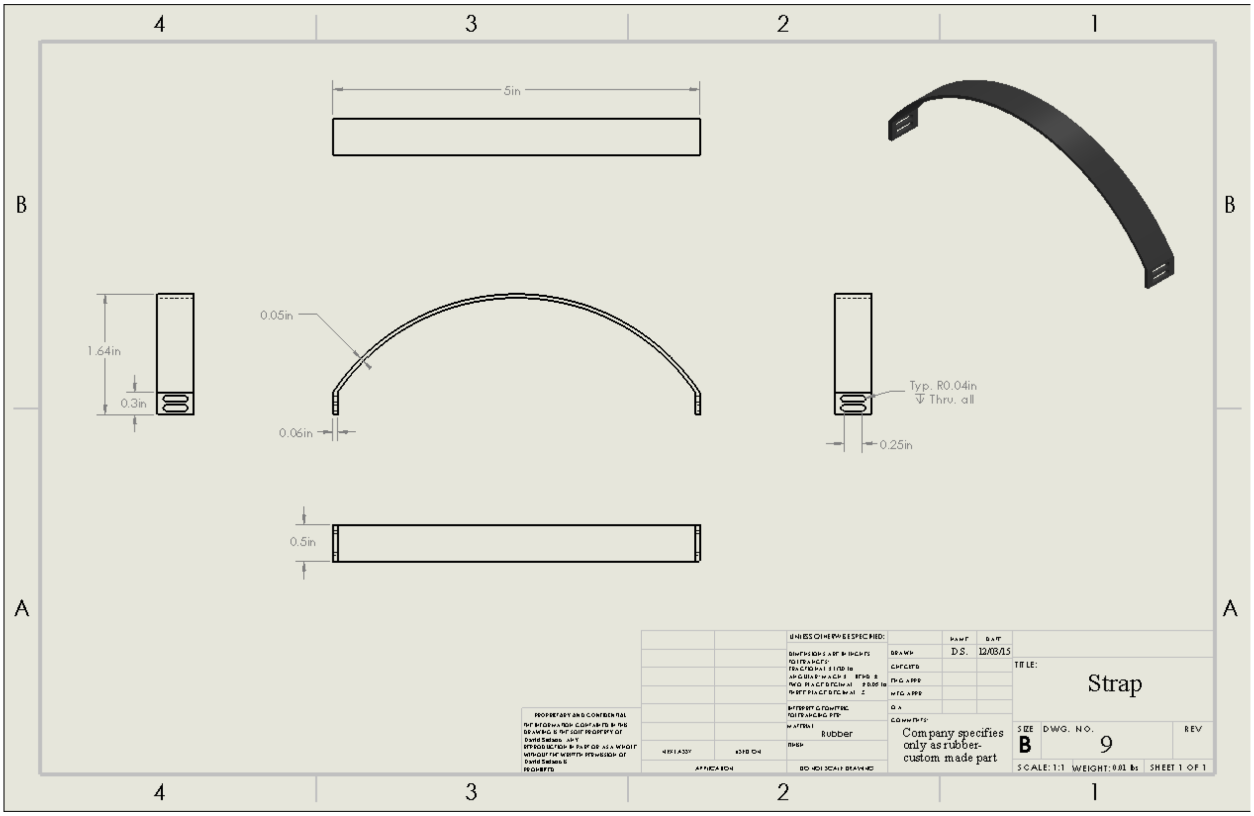


Image B-10: Strap

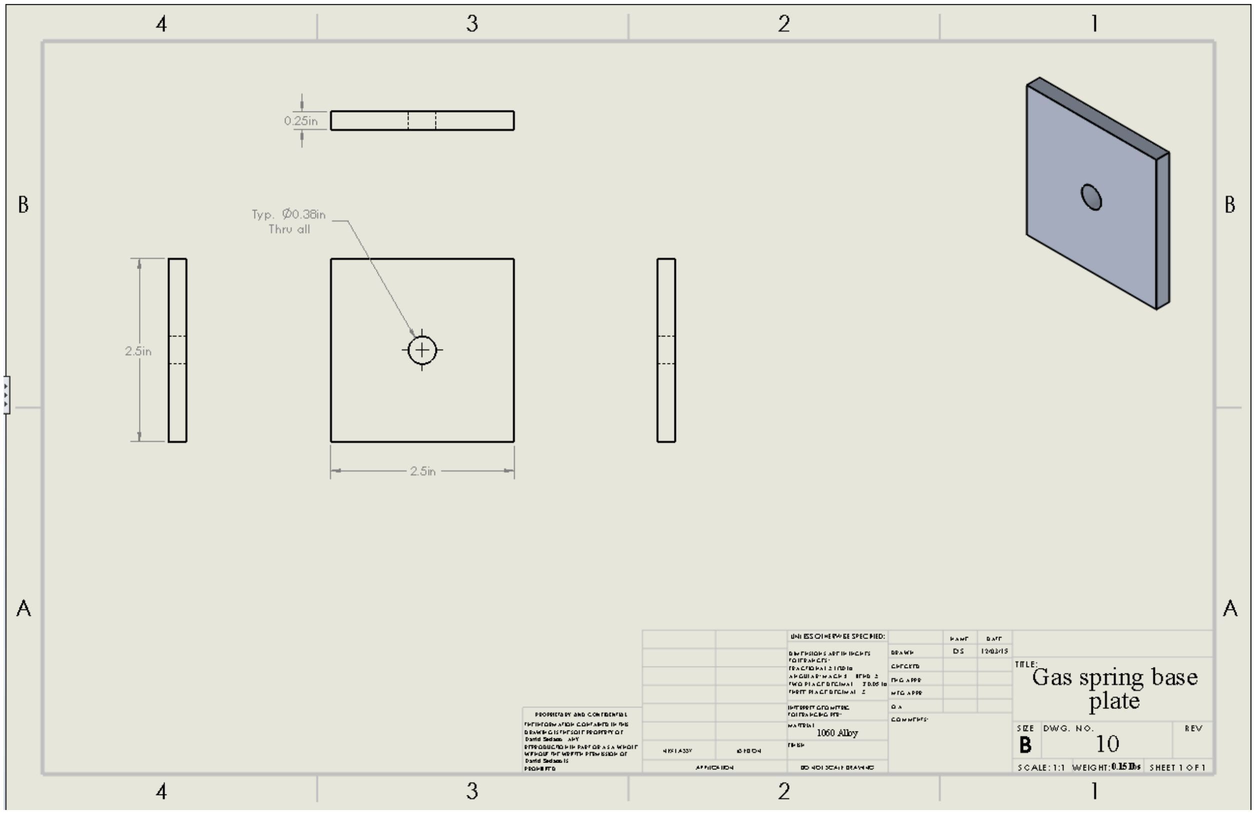
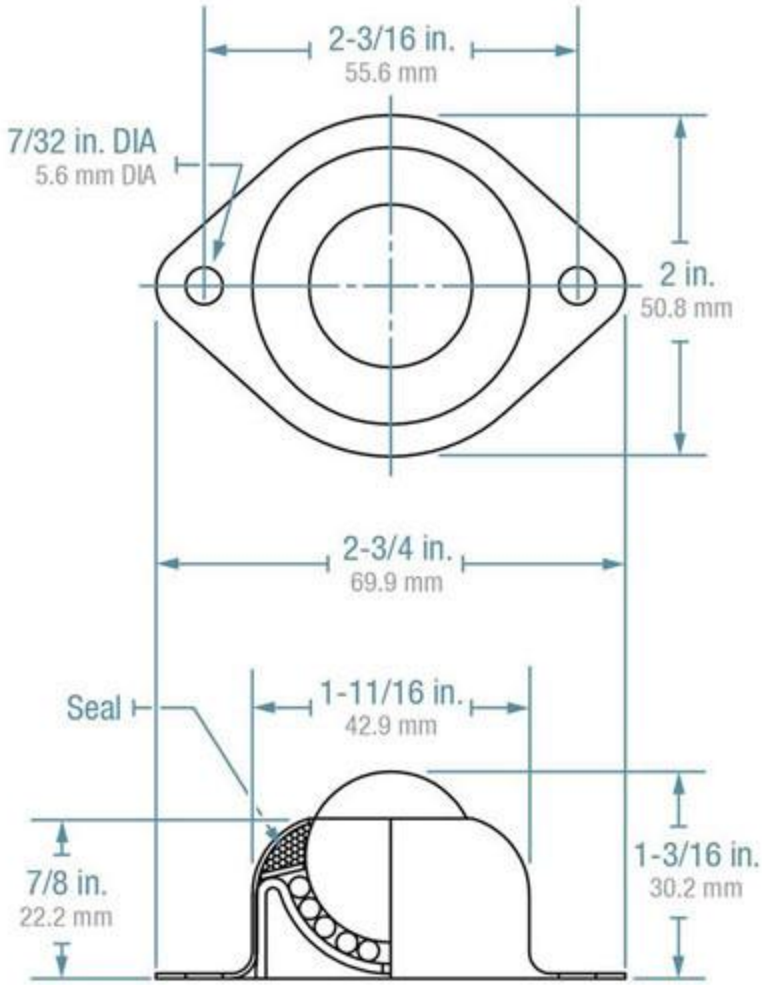


Image B-11: Base plate for gas spring

Appendix C

Hudson 1" Carbon Steel Main Ball with 2 Hole Flange Carbon Steel Housing BT-1CS, 2"W
Price: $2.09
Capacity 75 lbs. -> 7/elevator unit

http://www.globalindustrial.com/p/material-handling/conveyors/ball-transfer/1-inch-carbon-steel-main-ball-with-two-hole-flange-carbon-steel-housing-2-inch-w?infoParam.campaignId=T9F&gclid=CIqC37-WuckCFYqGfgodjGEM_A



Note: This product will be used to absorb the axial force created by the torque on the elevator unit.

Image C-1: Carbon Steel bearing

ZFE® Universal Exercise Bike Bicycle Cycle Pedal Strap Home Gym Life Cycle Pack of 2pcs

Price: $7.37

- Material: Rubber
- Color: Black
- Width(the widest): 1.57in
- Length: about 11in
- Quantity: 2pcs

http://www.amazon.com/dp/B00PKZRZC6?m=A10KLLHVS5CFSW&ref_=v_sp_widget_detail_page

Image C-2: Rubber foot straps

Label	Part Name	Quantity
0	Skeleton	1
1	Frame RL	1
2	Elevator Unit	2
3	Frame LL	1
4	Lockable Gas Spring	2
5	Support plate RL	1
6	Support plate LL	1
7	Rubber padding	2
8	Rollers	6
9	Secure strap	2
10	Base support for gas springs	2
11	Epoxy Glue	1
12	Collet	2
13	screws	28
14	Post screws	4
15	L-brackets	8
16	L-safe lock	2
17	Spray paint	1

Image C-3: Parts list

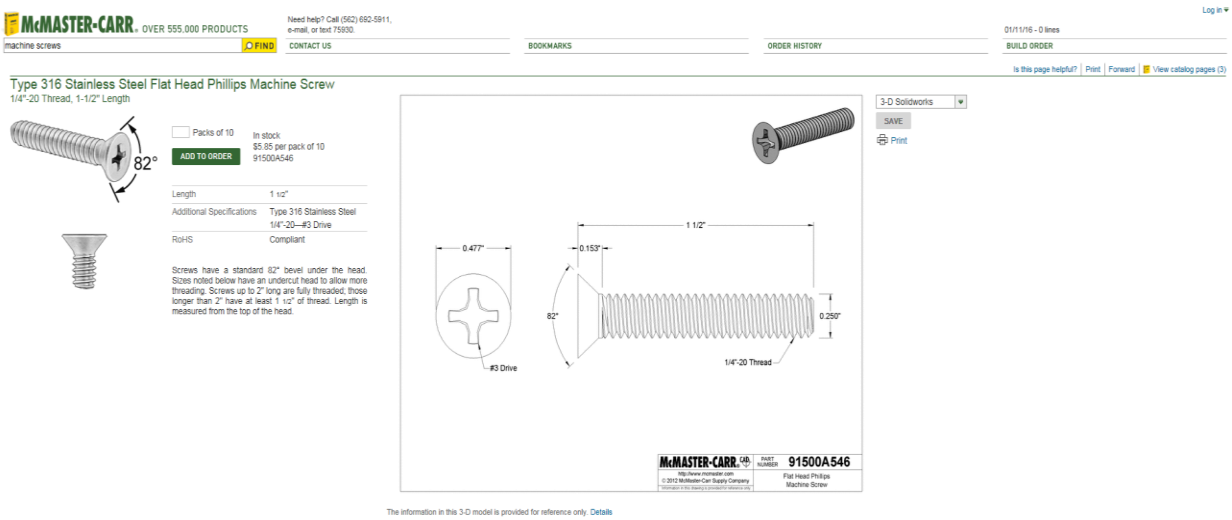


Image C-4: Flat head screw to assemble elevator unit & support plate

Appendix D

Label	Part Name	Quantity	Cost of Components	Location	Readiness	Material
0	Skeleton	1	$37.00	Western Metals	Arrived	1/8 gauge sheet metal & 0.5 in. dia. rods
1	Frame RL	1	$50.00	e-voniks	Arrived	Acrylic extruded sheet
2	Elevator Unit	2	$30.00	e-voniks	Arrived	Acrylic extruded sheet
3	Frame LL	1	$50.00	e-voniks	Arrived	Acrylic extruded sheet
4	Lockable Gas Spring	2	$71.96	Chairpartsonline	7 days	Steel
5	Support plate RL	1	$0.00	CWU scraps	Here	Alumium
6	Support plate LL	1	$0.00	CWU scraps	Here	Alumium
7	Rubber padding	2	$41.58	Rubber Sheet Roll (RSR)	7-10 days	General purpose rubber
8	Rollers	6	$12.54	Globalindustrial.com	Arrived	Carbon steel
9	Secure strap	2	$2.10	ACE Hardware	Here	polypropylene
10	Base support for gas springs	2	$0.00	RSR-remaining scraps	Here	General purpose rubber
11	Epoxy Glue	1	$6.00	Ranch and Home	Here	Glue
12	Collet	2	$0.00	CWU scraps	Here	Aluminum pipe
13	screws	28	$14.00	Ranch and Home	Here	Aluminum 10-24 x 1/2
14	Post screws	4	$3.00	Ranch and Home	Here	Aluminum 8-32 x 3/8
15	L-brackets	8	$0.00	Home Scraps	Here	Aluminum sheet metal
16	L-safe lock	2	$15.00	Ranch and Home	Here	Aluminum-1/8 gauge
17	Spray paint	1	$0.00	Home resource	Here	Paint
		Actual Total	**$333.18**			

Image D-1: Expected Budget

Thanks for Your Order

Your order ID is **#13989**.

Shipping Address

David Sedano
CWU
Central Washington University 400 E. university way Hogue tech. BLD
Ellensburg, Washington 98926
United States
(509)-901-1389

Billing Address

David Sedano
CWU
2203 N. Brooksfield st.
Ellensburg, Washington 98926
United States
(509)-901-1389

Order Instructions/Comments

I would like for the parts to be shipped as soon as possible? Please e-mail me once the parts have been shipped and expected arrival date. Thank you so much, David Sedano sedanod@cwu.edu

Your Order Contains...

Cart Items	SKU	Qty	Item Price	Item Total
Stool Height Gas Lift Cylinder, Black - 10" Travel - S6120	S6120	2	$26.99 USD	**$53.98 USD**
			Subtotal:	**$53.98 USD**
			Shipping:	**$17.99 USD**
			Grand Total:	**$71.97 USD**
			Payment Method:	Credit Card

chairpartsonline.com
http://www.chairpartsonline.com/

Image D-2: Lockable gas springs receipt

2/4/2016 RUBBER SHEET ROLL

RSR Psalm 104
RubberSheetRoll

RUBBER SHEET ROLL
PO BOX 171
SHIPPENSBURG, PA 17257

717.530.1612
info@rubbersheetroll.com

ALL STOCK ITEMS HAVE TO BE CUT BEFORE SHIPPING, READ BELOW:

Please allow 1 to 2 weeks for delivery UPS GROUND.

PLEASE VERIFY THAT YOU READ THE DIMENSIONS CORRECTLY ON OUR WEB SITE!!! MOST DIMENSIONS ARE IN INCHES DENOTED BY A " SYMBOL.

If you need the order to ship sooner or need a more specific date, please call 866-832-6006 and one of our knowledgeable representatives will be able to help you.

Print this page for confirmation.

This order information has also been e-mailed to sedanod@cwu.edu.

The following payment information has been recorded:

Order #: 18901
Date entered: Thursday, February 4, 2016
Payment Method: Credit/Debit Card

GENERAL PURPOSE RUBBER, .500 X 12.00" X 12.00" $ 20.79
Quantity: 2
Item total: $ 41.58

Order Total: $ 41.58

Credit Card Information:

Visa
David G. Sedano
xxxx-xxxx-xxxx-0729

Customer Information:

David G. Sedano
2203 N. Brooksfield st.
Ellensburg , WA 98926
(509) 901-1389
sedanod@cwu.edu

Shipment Information:

David Sedano
Central Washington University
400 E. university way Hogue tech. BLD.
Ellensburg, WA 98926
(509) 901-1389

Return to Home Page

| |

https://secure.prestobiz.com/cgi-bin/store20.prestostore.com/store/thankyou.pl?ref=rsrstore&fm=&or=13496342&rd=&rdf= 1/2

Image D-3: General Purpose Rubber receipt

Appendix E

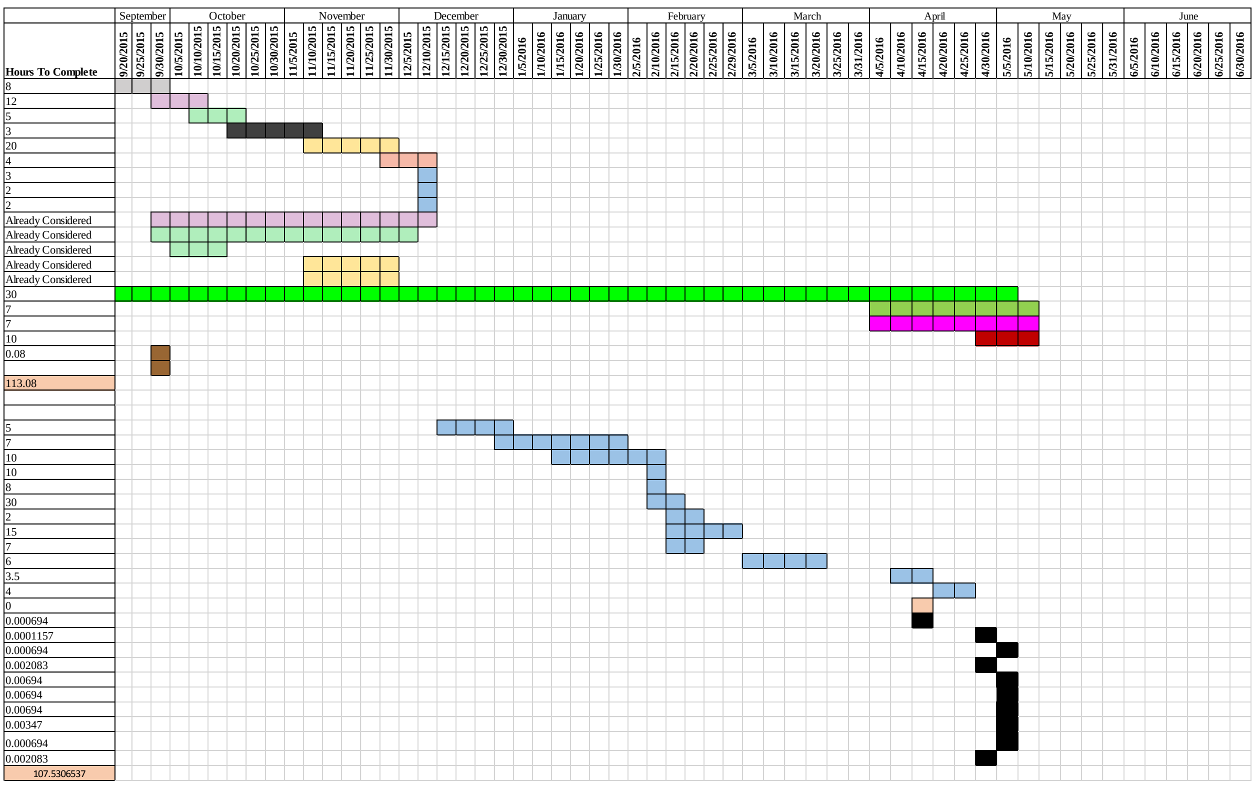


Image E-1: Schedule

Key		
	Upper hand	Perk (pro)
	Lower hand	Non-perk (con)
	(*)	Successful during testing /over-achieved
	(x)	Failed during Testing/not applicable

Name	Cost	Perk 1	Perk 2	Perk 3	Perk 4	Perk 5	Perk 6	Perk 7	Perk 8	Perk 9	Perk 10	Total # of perks (successful)
Pneumatic Leg Extension	$ 333.18	(*)Stability-up to 25 degrees	(*)Stilt mounting duration-10 seconds	(*)Light weight-17.5 lbs.	(x)Extension-18 inches	(*)Weight capacity-280 lbs.	(*)Operation sustainability (each foot)	(*)Lockable gas spring encounter of 44-330 lbs.	(*)Grip/shock absorption	(x)Cost-efficient	(x)Safe to operate	7 perks-7 superior
Bon Tool 14-644-B5 Dura	$ 314.72	(x)lack of stability-less cross-sectional area	(x) Stilt mounting duration- 1 minute	(*)Light weight-not specified	(*)Extension-14 inches	(*)Weight capacity-225 lbs.	(x)Operation sustainability (each foot)	(x) non Lockable gas spring design (retract complex)	(*) Grip-material (not mentioned)	(*)Cost-efficient	(*)Safe to operate	6 perks-3 superior

Name	Cost	Perk 1	Perk 2	Perk 3	Perk 4	Perk 5	Perk 6	Perk 7	Perk 8	Perk 9	Perk 10	Total # of perks (successful)
Pneumatic Leg Extension	$ 333.18	(*)Stability-up to 25 degrees	(*)Stilt mounting duration-10 seconds	(*)Light weight-17.5 lbs.	(x)Extension-18 inches	(*)Weight capacity-280 lbs.	(*)Operation sustainability (each foot)	(*)Lockable gas spring encounter of 44-330 lbs.	(*)Grip/shock absorption	(x)Cost-efficient	(x)Safe to operate	7 perks-7 superior
GypTool Adjustable Height Professional Drywall	$ 164.59	(x)lack of stability-less cross-sectional area	(x) Stilt mounting duration- 1 minute	(x)Heavy weight-28.6 lbs.	(*) Extension 64 inches	(x) Weight capacity not specified	(x) Weight capacity not specified	(x) non Lockable gas spring design (retract complex)	(*) Grip-material (not mentioned)	(*)Cost-efficient	(*)Safe to operate	4 perks-3 superior

Name	Cost	Perk 1	Perk 2	Perk 3	Perk 4	Perk 5	Perk 6	Perk 7	Perk 8	Perk 9	Perk 10	Total # of perks (successful)
Pneumatic Leg Extension	$ 333.18	(*)Stability-up to 25 degrees	(*)Stilt mounting duration-10 seconds	(*)Light weight-17.5 lbs.	(x)Extension-18 inches	(*)Weight capacity-280 lbs.	(*)Operation sustainability (each foot)	(*)Lockable gas spring encounter of 44-330 lbs.	(*)Grip/shock absorption	(*)Cost-efficient	(x)Safe to operate	8 perks-8 superior
MARSHALLTOWN The Premier Line SKY2118 Skywalker 2.1	$ 513.71	(*) Adjustable ankle spring	(*)Stilt mounting duration- 45 seconds	(*)Light weight-46.78 lbs.	(*)Extension-30 inches	(x) Not mentioned	(x) Not mentioned	(x)Turn & turn mechanism (retract complex)	(*) Rubber sole for higher traction	(x)Cost-efficient	(*)Safe to operate	6 perks-6 superior

Name	Cost	Perk 1	Perk 2	Perk 3	Perk 4	Perk 5	Perk 6	Perk 7	Perk 8	Perk 9	Perk 10	Total # of perks (successful)
Pneumatic Leg Extension	$ 333.18	(*)Stability-up to 25 degrees	(*)Stilt mounting duration-10 seconds	(*)Light weight-17.5 lbs.	(x)Extension-18 inches	(*)Weight capacity-280 lbs.	(*)Operation sustainability (each foot)	(*)Lockable gas spring encounter of 44-330 lbs.	(*)Grip/shock absorption	(*)Cost-efficient	(x)Safe to operate	8 perks-6 superior
Magnesium Adjustable Drywall Stilts	$ 229.00	(x)lack of stability-less cross-sectional area	(x) Stilt mounting duration- 1 minute	(*)Light weight-14 lbs.	(*)Extension-40 inches	(*)Weight capacity-225 lbs.	(*)Weight capacity-225 lbs.	(x) non Lockable gas spring design (retract complex)	(*) Rubber sole for higher traction	(*)Cost-efficient	(*)Safe to operate	7 perks-5 superior

Image E-2: Device Comparison

Appendix F

Appendix G

Task	Testing comments:	Test method	Results
1:Stability	a). Firm-does not rock b). Tipped over at angle but operational	a). Visual b). Protractor	a). Good b). 25 degrees
2: Stilt mounting duration	This design avoids complexity while mounting. This considers the time to mount and secure oneself and extend to potential height	Stop watch	10 sec, 9 sec, 11 sec
3: Light weight (each stilt)	Scale is calibrated and the device is placed on the weighing scale. These values are values before making the device lighter. Can drill holes on frame to make lighter.	weighing scale. Camera.	17.5 lbs., 17.5 lbs., 17.5 lbs.
X 4: Extension feasibility	Unsuccessful because the elevator unit rubbed on the L-safety lock. Extension height potential is 18 in.	Operator on device. Public tested.	N/A
5: Weight capacity	The operator mounted the device and additional weight was added to max out at 280 lbs. 160 lbs. + 120 lbs. =280 lbs.	Operator, backpack and weights.	Max 280 lbs.
6: Opreration sustainability (each leg)	Test #5 on each leg. While the operator walks, all the weight shifts on each leg. Weight was applied on each stilt.	Operator, backpack and weights.	Max 280 lbs.
7: Lockable gas spring encounter force 44-330 lbs.	As tests #5 & #6 were performed, test #7 was analyzed and tested. The 280 lbs. did not create any height displacement, meaning there is excessive encounter force: A weaker cylinder is required.	Operator, backpack, weights, and ruler.	Max 280 lbs.
8: Grip/shock absorption	Water was poured on the floor and the device was set on wet floor and dragged to see the friction between both surfaces. Grooves can be made on the rubber to increase traction.	Visual method. peumatic Leg Extension and operator	Good traction
x 9: Cost efficient	There was a lists/cost and a device comparison excel spreadsheet that indicated that the device cost more than the devices compared.	Excel spreadsheet	Costs more
X 10: Safe to operate	The device was not able to operate because test #4 failed. The elevator unit rubbed on the L-safe lock, disabling it to operate. Due to this, the device is not considered safe until fixed.	Visual method. Data from other tests.	Needs fix

Image G-1: Testing Spreadsheet

Appendix H

Appendix I

Appendix J

Image J-1: Bon Tool 14-644-B5 Dura-Stilt

Image J-2: GypTool Adjustable Height Professional Drywall

Image J-3: Market stilt risks-unstable, risky and painful

Appendix K

David Sedano

2203 N. Brooksfield St. ♦ Ellensburg, WA 98926 ♦ (509)-901-1389 ♦
sedanod@cwu.edu
https://www.linkedin.com/in/david-sedano-148149a0

Battle uphill struggle with passion and vision

EDUCATION

- Central Washington University, Ellensburg, WA.
  Expected Graduation June 2016
- Majors: Bachelor of Science in Mechanical Engineering Technology, Bachelor of Arts in Spanish
- Study Abroad: Universidad Austral de Chile Summer-Fall 2012

ACHIEVEMENTS

- Central Washington University Grant 2012-2016
- Washington State Need Grant 2009-2014
- Federal Pell Grant 2009-2014
- Semi-professional soccer in Chile, Valdivia Summer-Fall 2012
- Dean's List 2009
- Honors Society at Central Washington University 2009
- CAMP Grant 2009
- CAMP Stipend 2009

MEMBERSHIPS

- Member of AFS at Central Washington University Spring 2016-Present
- Member of ASME at Central Washington University Fall 2013- Present
- Member of SME at Central Washington University Fall 2013- Present
- Member of STAR (Student Transitions & Academic Recourses) 2012-Present
- Member of Central Washington University Men's soccer team Fall 2009-2013
- Member of TRIO (Students Support Services) 2010-2012
- Member of CASA LATINA (Living Learning Community for Latinos) 2009
- Member of CAMP (College Assistance Migrant Programs) 2009
- Member of welding competition team (high school) 2008-2009

WORK EXPERIENCE

- Orchardist Manager/Mechanic 2007-2015

- DTD mentor (CWU Dare to Dream science academy program) June 2013
- Academic mentor (CAMP student mentor) 2013
- Mill Bay Casino Security Officer 2008-2009
- Wapato Point Cellars Cook (Location: Manson WA.) 2007-2008

SKILLS

- Sedanod.wix.com/mechanical-engineer
- Computer: AutoCAD, Solid works, LabVIEW, MDESIGN, Excel, Word, PowerPoint, Proficient in Mac and Windows
- Certified First Aid and CPR AED
- Lathe, Mill, welding equipment, Casting, basic shop operations
- Bi-literate
- Innovative, commutative, leader

VOLUNTEER WORK

- US FIRST (Robotics competition national program) 2015-2016
- Student Panel in Central Washington University 2012-2015
- Inspector-Vex Robotics competition 2014
- Central Washington University recruiter/representative at Manson High School 2010-2012
- Community service project at Central Washington University through the Civic Engagement Center Fall 2009
- LEP (limited English proficiency) Tutor 2008-2009

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