Manual Car Jack for High Profile Vehicles

A Baccalaureate thesis submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

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ABSTRACT

Automotive jacks have been around for years and there are dozens of different styles, sizes and weight capacities. There are also very expensive hydraulic lift systems that can be purchased to lift all 4 points of the car up.

The design of the manual car jack/stand will allow the user to be able to achieve greater lift from a conventional household car jack. This jack/stand will be able to lift the vehicle that has a higher than stock frame rail. This can occur on vehicles that have aftermarket lifted suspensions or vehicles with a large amount of suspension travel. This will then allow the individual to work on it in their driveway without needing an expensive, space consuming lift.

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

Automotive jacks have been around for years with dozens of different styles, sizes and weight capacity. When typically working on a vehicle with a frail rail that is not at stock height, items would have to be used to increase the usable height of the jack. There is an alternative to this, which is an expensive automotive hydraulic lift that lifts the whole vehicle at four contact points all at the same time.

The design of the manual car jack/stand will allow the user to be able to increase the usable height of existing car jacks without using items such as bricks, blocks, or pieces of scrap metal. This jack will be able to lift a vehicle that is high profile with more than typical suspension travel, thus allowing the individual to work on it in their driveway without needing an expensive, space consuming lift.

CUSTOMER FEATURES

Features that sets this product apart from others include:

- Safe/strong
- Easy to move
- Easy to adjust/ operate
- Easy to store
- Light in weight
- Aesthetically pleasing

Objectives:

This car jack/stand will be able to lift vehicles safely and with ease so that the operator can change/ rotate tires on vehicles with high profiles or flexible suspensions. Lastly, this product should be able to be used with different styles car jacks to accommodate customers that already may have different car jacks. These may include scissor jacks and rolling hydraulic jacks.

DESIGN

RESEARCH

Car jacks have had many advancements from worm gear scissor jacks to hydraulic lifts. The issue that arises with most car jacks is that they are not designed for vehicles that have had aftermarket parts added to the stock vehicle. These types of vehicles will be able to articulate to a point where the maximum lift height of the jack (typically 19-23 inches) will not be able to lift the vehicles tires off the ground. To achieve the extra height that is needed to lift the vehicle off of the ground, something needs to be added either above or below the jack. Typically, a block of wood or a cinderblock is used to achieve the extra height. With more and more people adding aftermarket parts to their vehicles, there will be an increased need for people to be able to work on their vehicles safely.

Initial research includes the following products and others that are not depicted. Product (1) is a typical jack stand that you can purchase at your local auto parts stores. This product is simply a device to hold the weight of the vehicle while working. This can only be removed once the weight of the vehicle is lifted by the car jack. Product (2) is a hydraulic rolling jack that can also be purchased at your local auto parts stores. This product is used by most car enthusiast due to its ease of use, rapid pump features for quick lofting and lowering, and its lifting height. These jacks come in two typical maximum lifting heights of 19 ¾ inches and 23 ¾ inches. These heights work for most vehicles, but when the vehicle can articulate with lots of suspension travel this is not high enough.

(1)

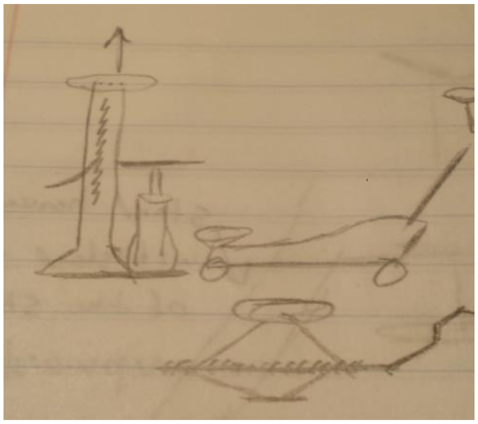
(2)

DESIGN PROCESS

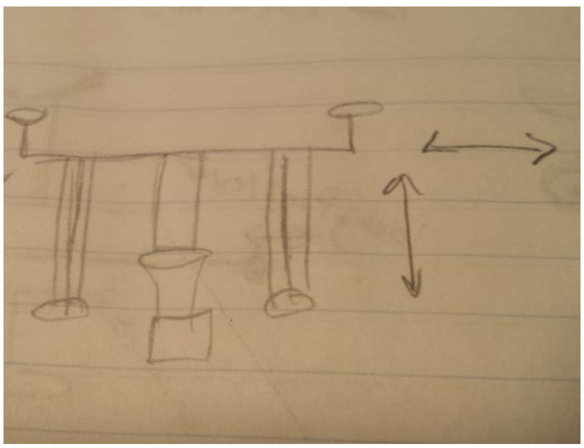
The design process was all centered around the core principle that this product needed to be safe, functional and cost effective all at the same time. This means reducing material thickness to an acceptable and safe thickness, and adding structural support where needed. To narrow down what kind of jack and stand combination would encompass these features, sketches of possible designs were made. Then determined what features could be functional and incorporated. If they were not functional or feasible, then those were eliminated. The parts that were feasible were transferred to the next idea etc. This is the flow of the *Design Alternatives* section.

Once the process started to narrow to a design that was safe, functional and achieved all my design specifications, the design was brought into a solid model using Solidworks. This is where the design was altered to make all the components and features mesh into one fully functional and fully defined model. Multiple revisions on some components were made and documented in the Appendix section.

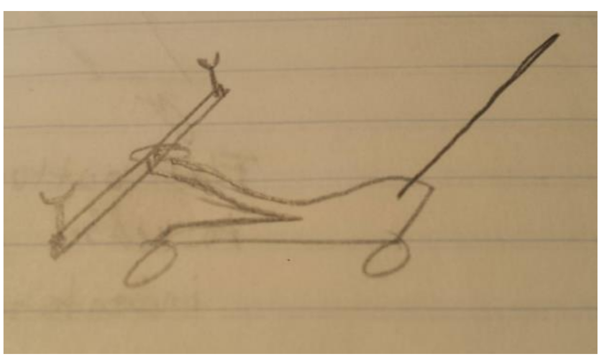
DESIGN ALTERNATIVES



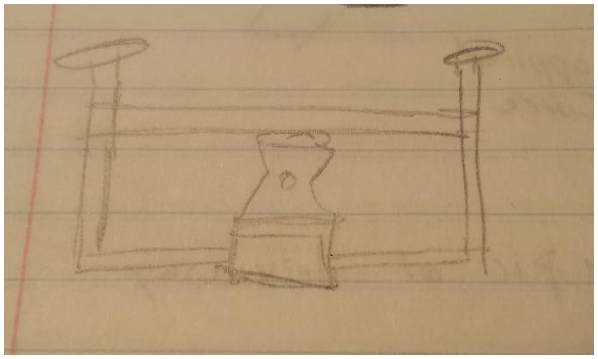
- Car Jack with jack point on side.
- Accommodate all jacks
- Bad with bending moment
- Tough to manufacture



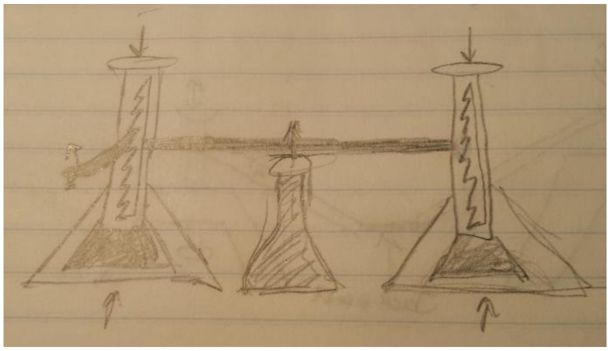
- Car Jack with jack point in the middle
- Accommodate all jacks
- Two supporting polls to stabilize structure
- Two contact points
- Collapsible



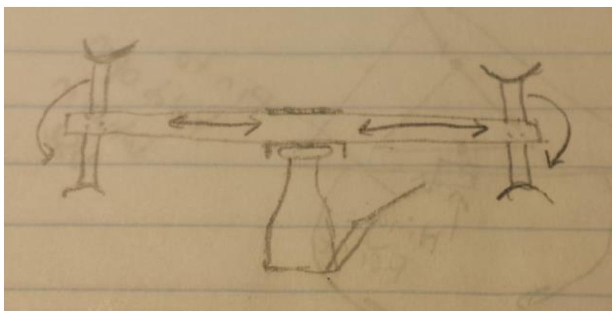
- Mounting bar to roller-type jack
- Non-universal device
- Two contact points
- Collapsible



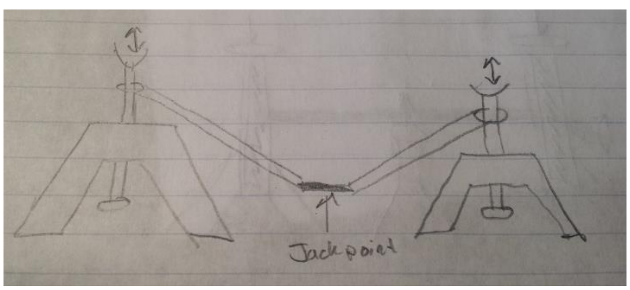
- Jack goes on top of block instead of on the ground
- Limits variety of jacks that can be used to bottle and scissor type
- Cumbersome
- Difficult to manufacture



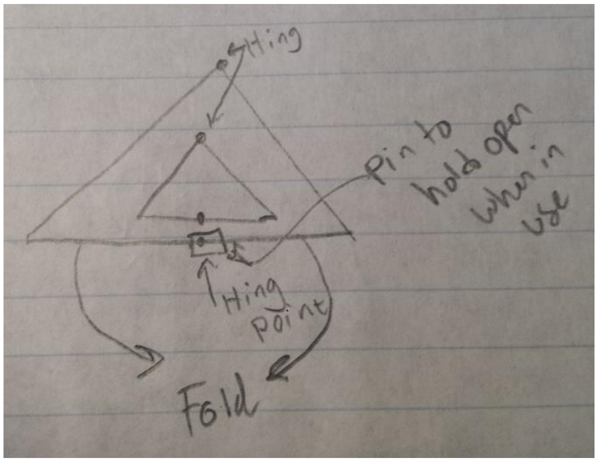
- Car Jack with jack point on side.
- Accommodate all jacks
- Bad with bending moment
- Tough to manufacture



- Single Jack contact point
- Collapsible
- Use of multiple jack
- Swivel ends for two different types of contact points on the car
- Two contact points on the vehicle



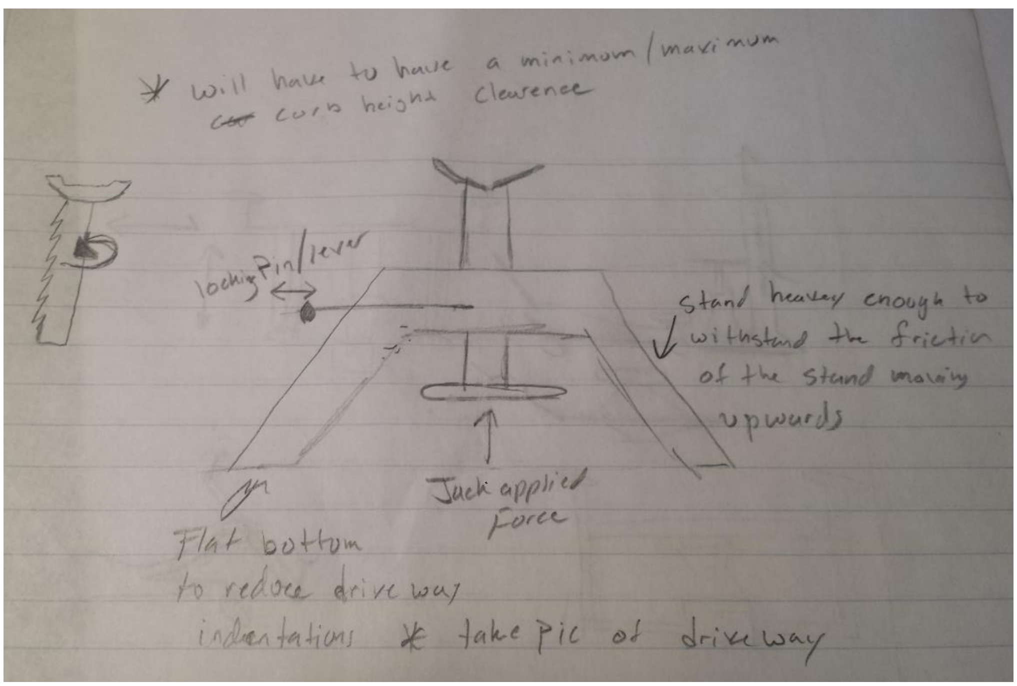
- Pyramid style jack and jack stand combination
- Two contact points on the vehicle
- One central jack point
- Possible issue with pinching on jack stand post



- Folding feature on pyramid style jack and jack stand combination
- Locking pin when in use to keep system open

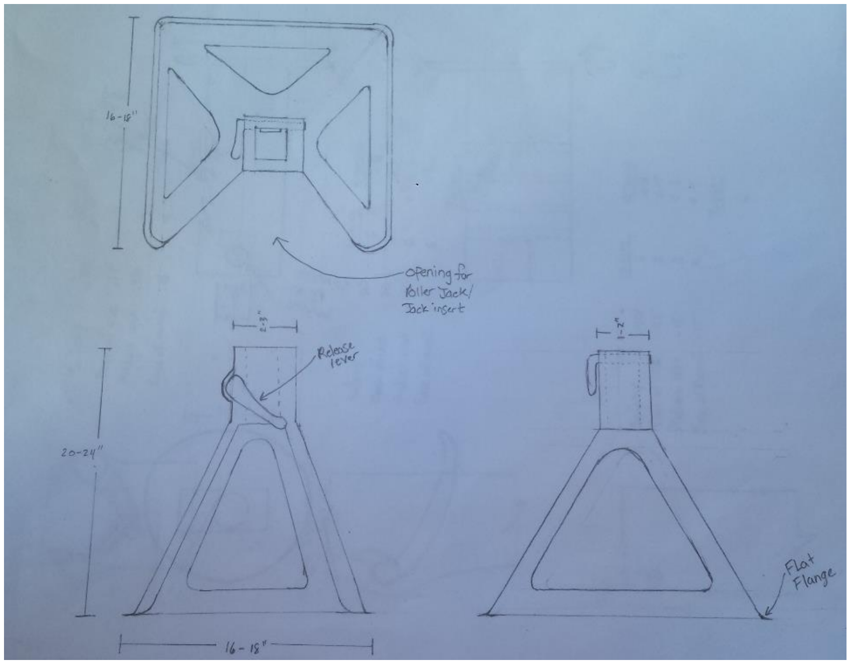
DESIGN SELECTION

BASE/ CONCEPT SELECTION

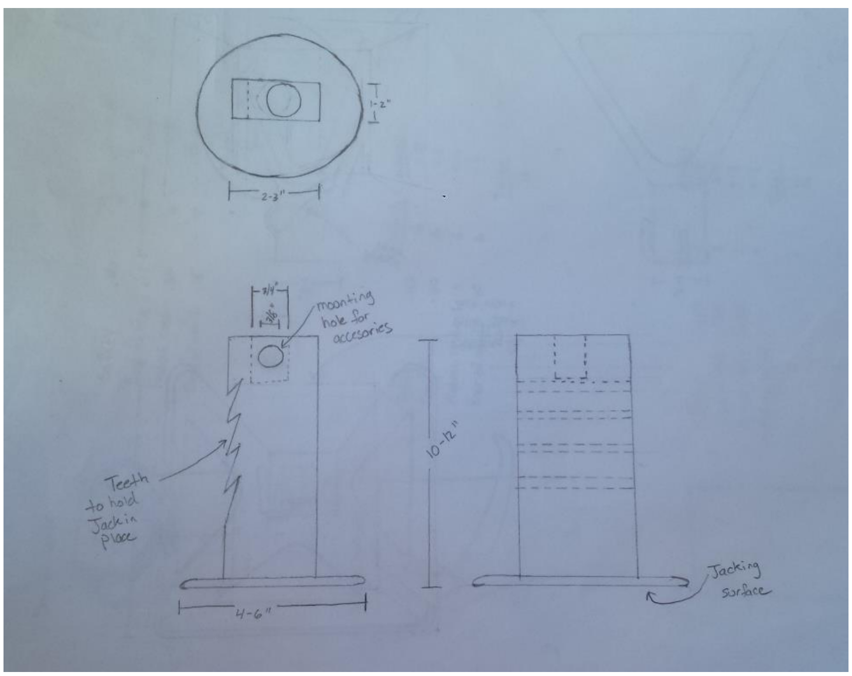


Concept Section Sketch

The selected product is a pyramid style jack and jack stand combination with one contact point on the vehicle. This product will be able to be used with most major jacks on the market today including scissor and rolling hydraulic style. The product will feature an opening for the jack to be placed inside of the pyramid to be able to contact the lifting post located in the center of the jack stand. The post will feature a locking mechanism that will hold the lifting post at the desired height.



Concept Detail Drawing of Base and Lever

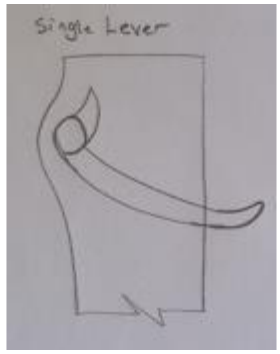


Concept Detail Drawing of Post and Contact Plate

Concept Detail Drawing of Base and Lever and *Concept Detail Drawing of Post and Contact Plate* are preliminary sketches that were used to make the Solidworks drawings. Within Solidworks, a fully defined and functioning model will be created in order to test fit, strength and functionality.

LEVER SELECTION

Design 1



Design 2

Design 3

		Design 1		Design 2		Design 3	
Parameter	Weight	Rating	Total	Rating	Total	Rating	Total
Safety	0.6	6	3.6	5	3	3	1.8
Ease of use	0.2	2	0.4	7	1.4	3	0.6
Product Cost	0.1	2	0.2	7	0.7	8	0.8
Ease of Manufacturing	0.1	2	0.2	7	0.7	8	0.8
Sum of Weight and Rating	1		4.4		5.8		4

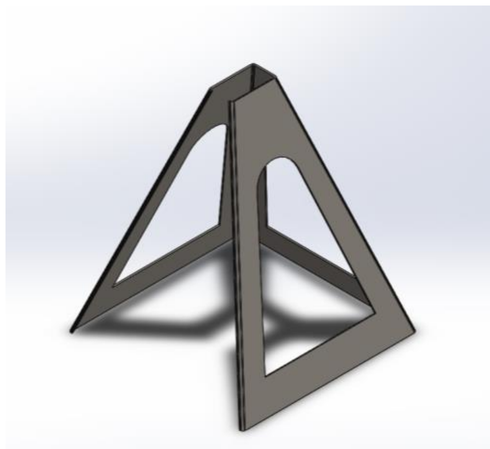
Table 1: Weights and rating table

From the table 1, the single lever (design 2) was determined to be the best type of locking/ release for this system. The single lever design fulfilled all the engineering parameters that were laid out for this design to be successful. The ratings were determined by how safe, how easy to use the system is, how much the product would cost, and how easy it would be to manufacture. These factors were taken into consideration and then given a rating on a scale from 1-10. This rating was then multiplied by the weight and summed.

Initial Design

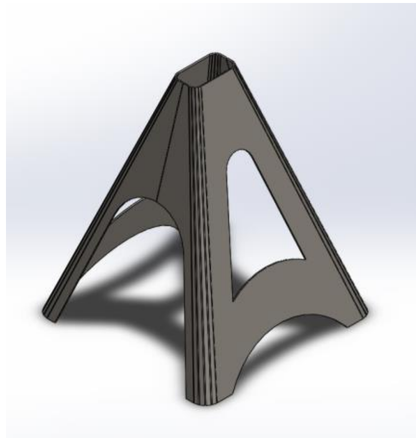
Multiple designs and revolving design modifications were made while making the solid model in Solidworks. The revolving design modifications worked as follows:

1. Model design of multiple concepts
2. Assemble concepts
3. Test for fitment, aesthetics, and feasibility
4. Repeat steps 1-3 if the concept fails



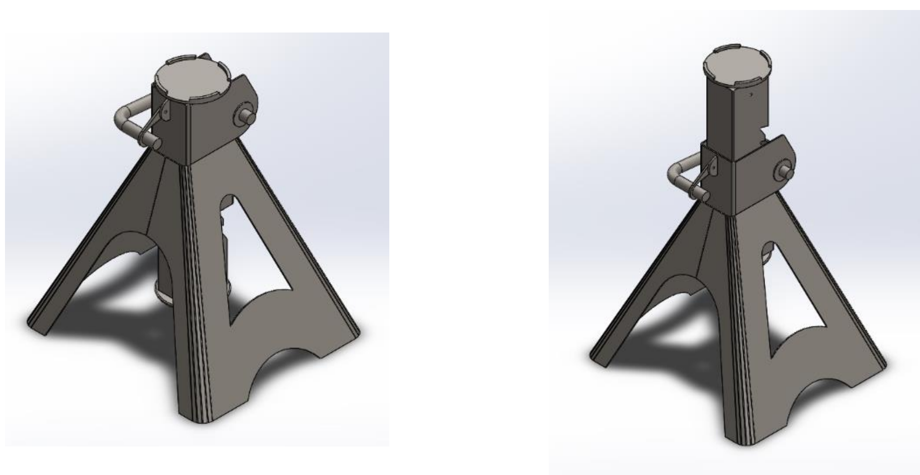
Revision 1

Revisions were captured after they had been determined that they will not function and satisfy the engineering characteristics. Revision 1 was initially made from the concept that was hand drawn in the *Base/ Concept Selection* category. This concept featured an open front to allow the user to insert the jack, tall tapered structure, and open ports for weight reduction and design aesthetics. This revision was eventually modified due to the open front design and the open ports allowing for too much bending which caused the structure to butterfly open when a loading force was applied to the top of the structure.



Revision 2

Revision 2 aided in correcting the problems that arose in revision 1. Revision 2 featured a slightly larger top to make the loading force move down the walls of the structure rather than trying to flatten he structure. Also, the side ports were rounded to decrease point loading on sharp corners. The side ports were then made to be smaller to increase the amount of material on the walls thus slightly increasing the strength of the structure. Then the front of the front of the structure was modified. A front wall section was added where the jack would be placed. Due to ease of manufacturing concerns, the base was then split into two sections which will be welded together. This is all depicted in above.



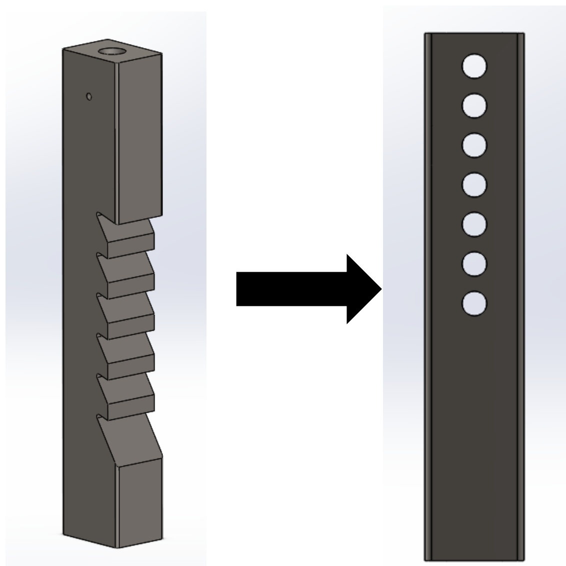
Initial Final Design (Revision 3)

Revision 3 is the culmination of all the revisions and design alterations that were made. This revision consists of a shorter, more ridged, and stronger design. The base is made up of two pieces and welded together. The front opening will be able to accommodate different kinds of jacks. The opening is wide and tall enough that a hydraulic style jack will be able to roll in and contact the base and extend up without hitting the jack stand.

PRODUCT REDESIGN

After fully defining the initial design, Solidworks was used to predict the total weight of the system at 130 pounds. This would prove to be unacceptable and would not satisfy the customer and engineering requirements. A redesign of the ratcheting style locking post and the post was needed to decrease the weight of the system.

The post was the first component to be redesigned. The solid steel 3x5 inch post was where most the weight issues were concentrated. This post was changed from a solid steel post to a hollow square tube post.

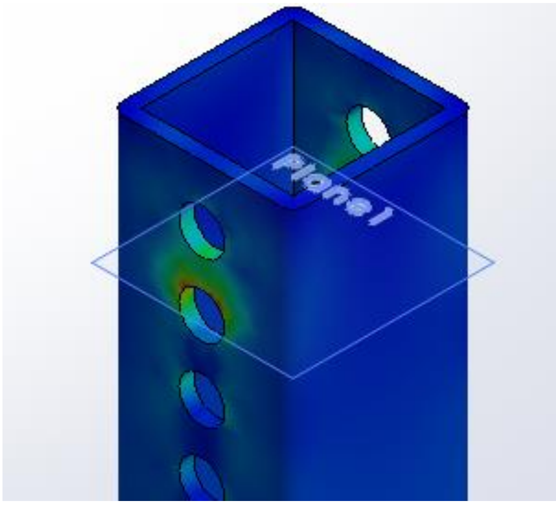


Weight = 29.30 lbs Weight = 11.40 lbs

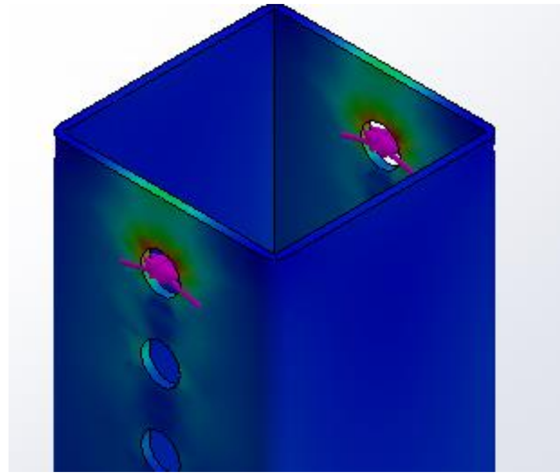
The design choice to switch to a hollow square tube did not allow for the previously designed ratcheting locking mechanism. The change to the hollow square tube made the locking mechanism to have to change to a simpler design. The least favorable pin locking mechanism was the best match for the hollow square tube. To accommodate for the new hollow square tube, the ratchet house was replaced with a square sleeve and there was a need for an additional supporting brace to be inserted due to the loss of stability with the change of the ratcheting housing.

FINITE ELEMENT ANALYSIS (FEA)

The finite element analysis (FEA) was performed on the key components of the system. This was used to determine if the component was structurally sound and able to withstand the forces applied. The applied force that was used for these components was a 10,000-pound static force applied where the force would be concentrated in a loaded scenario (pink arrows). This load was determined by the curb weight of my test vehicle at approximately 5,000 pounds and a safety factor of 2, resulting in a 10,000 pound load. The main components that were evaluated in FEA fared well to the 10,000-pound load.

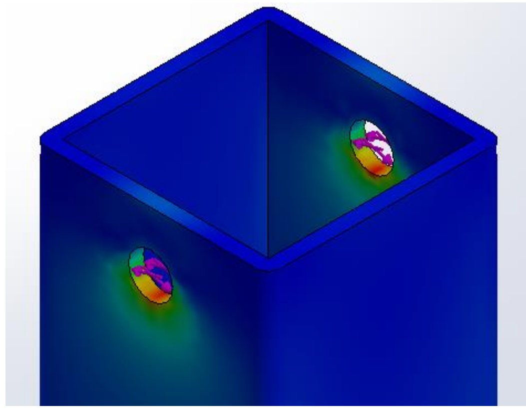


FEA 1: 13x3x0.25 Inch Square Tune 1020 Cold Rolled Steel



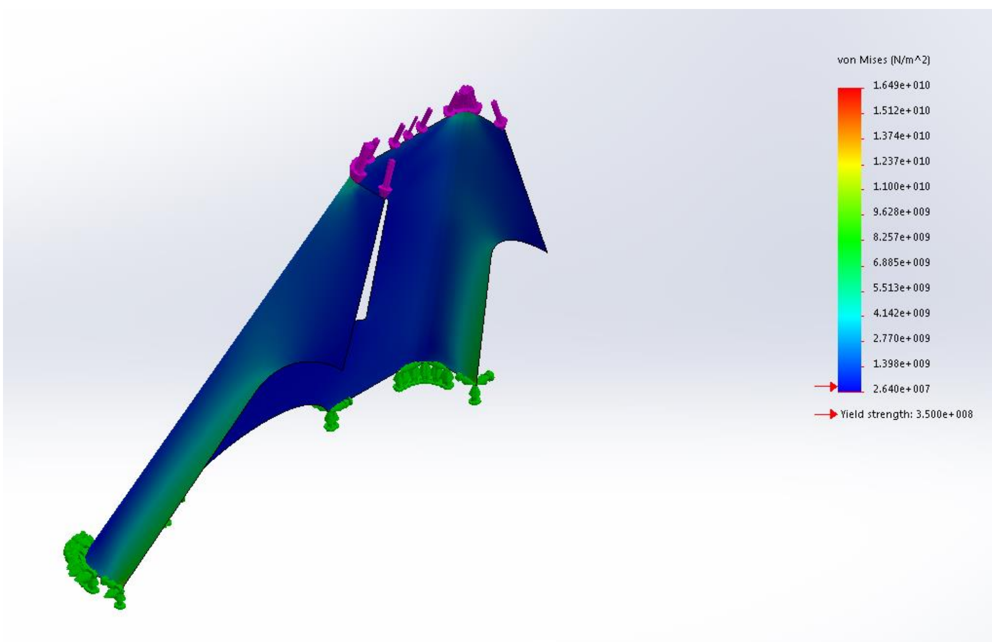
FEA 2: 3x3x0.125 Inch Square Tune 1045 Cold Rolled Steel

Two materials and thicknesses were tested in FEA to determine at what point the material would fail. FEA determined that with the same outer dimension of 3x3 inches and same size hole at 0.75 inches, the wall thickness needed to be 0.25 inches with 1020 cold rolled steel and 0.125 inches with 1045 cold rolled steel. The maximum yield stress that occurred for the 0.25 inch 1020 cold rolled steel was 206,000,000 N/m^2 with a maximum yield stress before plastic deformation of 350,000,000 N/m^2. The maximum yield stress that occurred for the 0.125 inch 1045 cold rolled steel was 455,100,000 N/m^2 with a maximum yield stress before plastic deformation of 530,000,000 N/m^2. The increased strength of the 1045 cold rolled steel allowed for half the wall thickness. For this project, 1020 cold rolled steel was the only financially and available option to use. For the rest of the FEA calculations, 1020 cold rolled steel was assumed as the material.



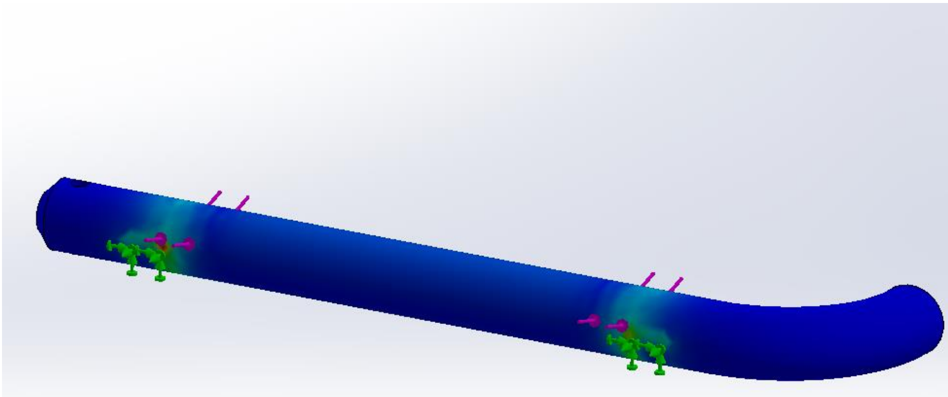
FEA 3: Post Sleeve

The maximum yield stress that occurred for the 0.25 inch 1020 cold rolled steel post sleeve was 212,800,000 N/m^2 with a maximum yield stress before plastic deformation of 350,000,000 N/m^2. The highest amount of concentration was located at the bottom of the hole where the pin would be resting in a loaded condition. No plastic deformation occurred when loaded and this design was determined to be acceptable for use.



FEA 4: Base Stress

FEA did not represent the stresses properly on the base piece. This is due to the unrealisic constrainets and scenerio that Solidworks assumes. Witht this, Solidworks assumes that the structure will be loaded soalely on the 11 guage sheet at the very top. But in reality, there is another piece that will mirror it and a support piece that will prevent twisting and aid in keeping the struture from collapsing. This FEA study determined that the maximum yeaild stress was 16,490,000,000 N/m^2 wich is well above the yeild strength of the material it 350,000,000 N/m^2. With the above conditions of the support and improper loading in FEA, the base was determined to be able to fair the load based on market research. Typical jack stands are made from 10 to 14-gauge sheet metal. From this, the 11 gauge sheet metal was determined to be suitable for this design.



FEA 5: Pin

The pin was assumed to be in double shear due to the sleeve pushing up on the buttom of the pin and the post pushing down on the top of the pin. This will occur on both ends of the pin as well. The 10,000 pound load was dustributed equally between the two loading locations. Due to the nature of the drawing and the assumed FEA conditions, there was a drastically high stress concentration directly on the shear plane. This is an unrealistic condition and was eliminated from the calculations. The maximum stress concentration that occurred was 794,200,000 N/m^2. This is higher than the maximum yeails stress of 1020 cold rolled stell but this is due to the above scenerio and was eliminated from the calculations. The pin was then determined to be accetable to use in the design.

FABRICATION

Fabrication of the base was a 5-step process. Initially this was thought to be a 2-step process, but with the machinery available 3 extra steps were needed. The steps to fabricate the base included:

- Plasma cutting 11-gauge sheet metal to shape
- Cutting 2-inch relief cuts along the bed lines to decrease material to be bent
- Bending the sheet metal at 10-20 degree each per 5 bend lines
- Tig welding relief cuts closed
- Grinding surface flat

Relief Cuts

Tig Fill Welds

Finish Grinding

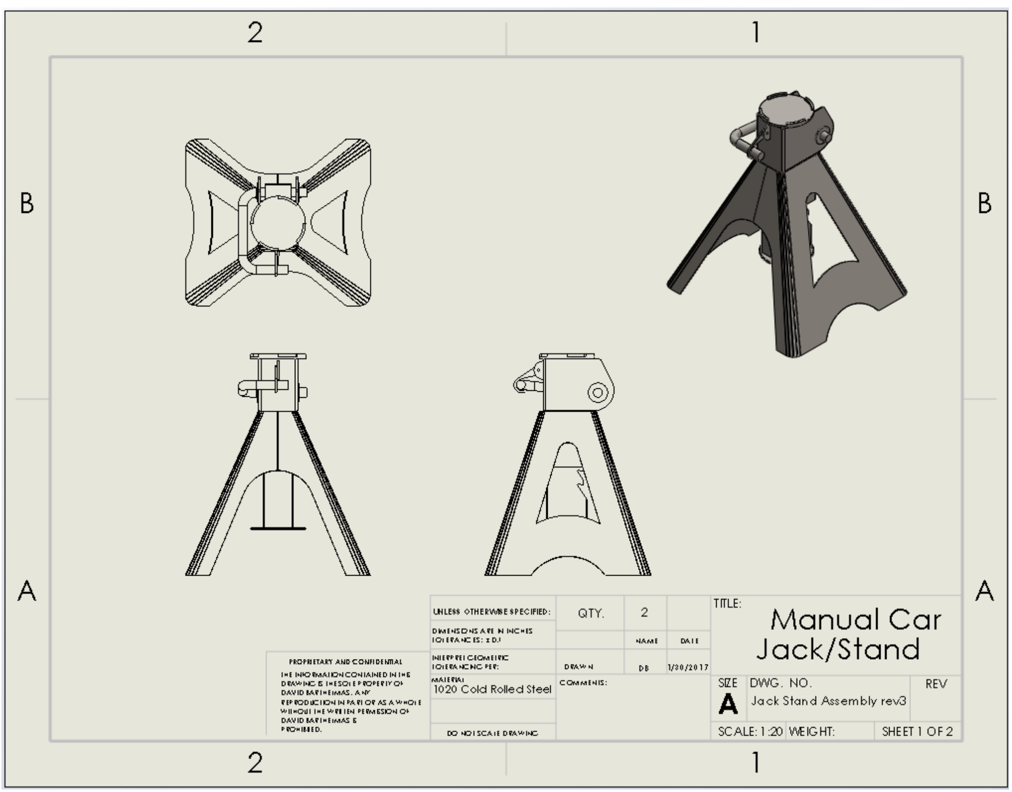
After both frame pieces were finished and grinded smooth, the two pieces were spot welded so that the structure sat flat. After the seam was welded, the brace was welded to the sleeve and primed. The sleeve and brace needed to be primed and painted before fitted inside of the base frame due to limited access to that area after fully assembled. Once the sleeve is inserted in the base and welded, the jack post contact is welded to the post. This was then primed and painted as well in the areas that will be contained in the sleeve when fully assembled. Then the end effector contact is welded to the post after the post is slid through the sleeve.

<u>Spot Weld Frame Level</u>

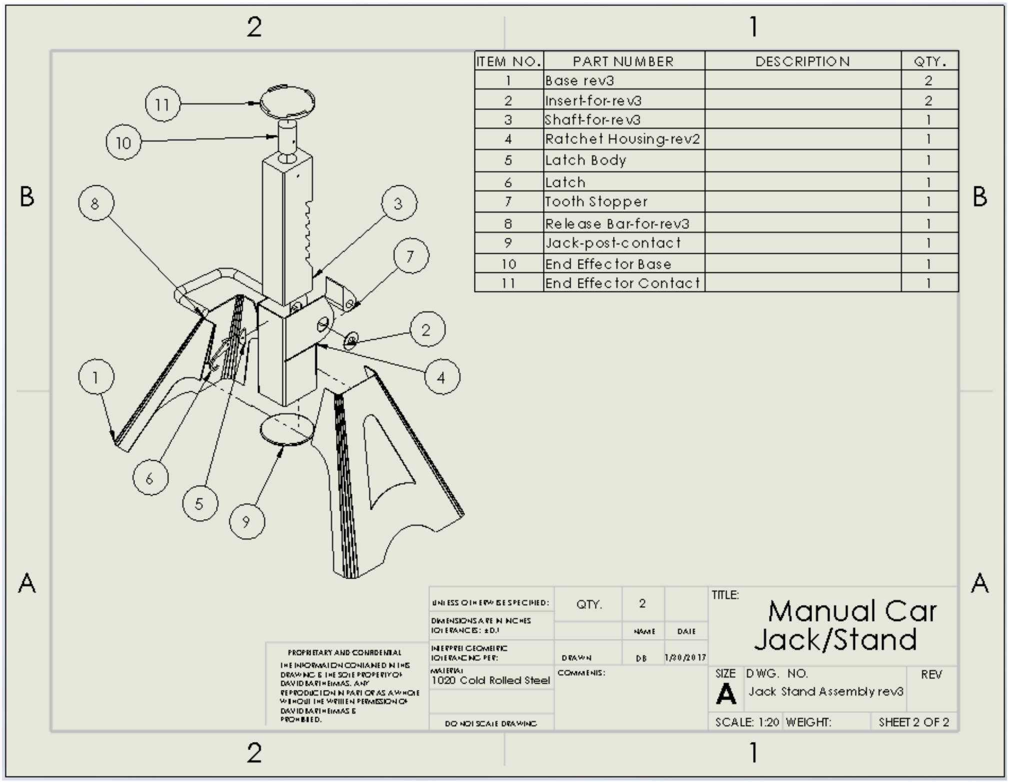
<u>Prime and Paint Sleeve and Brace</u>

<u>Post With 7 Height Selections</u>

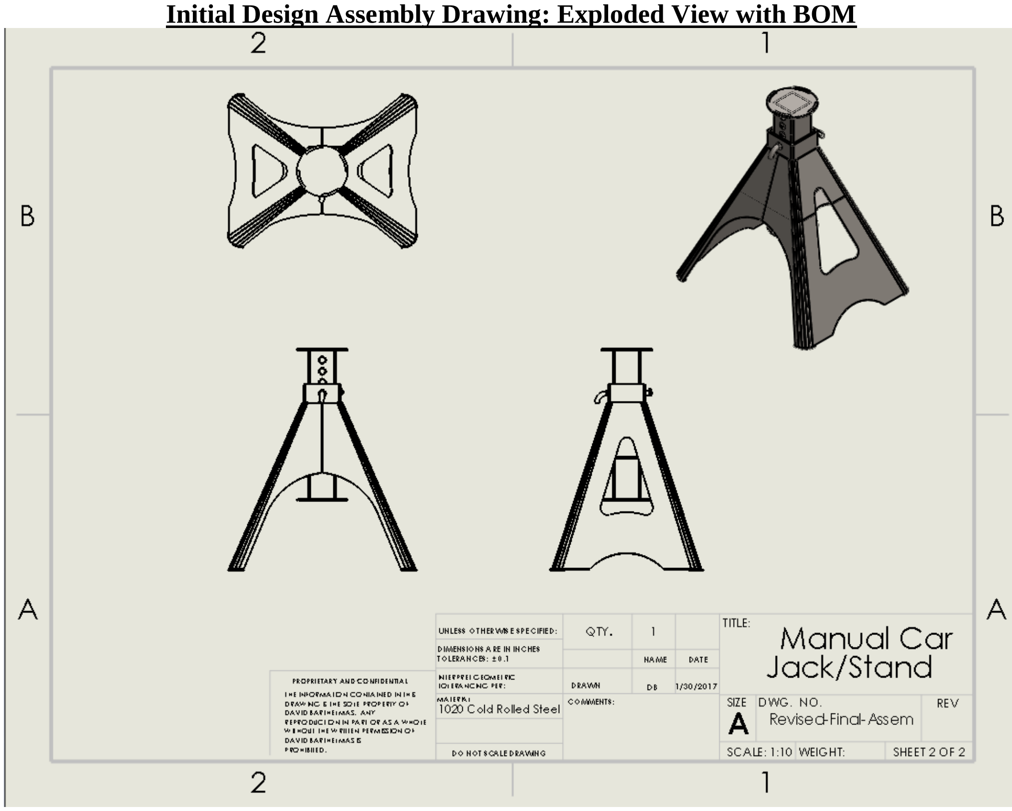
ASSEMBLY DRAWINGS



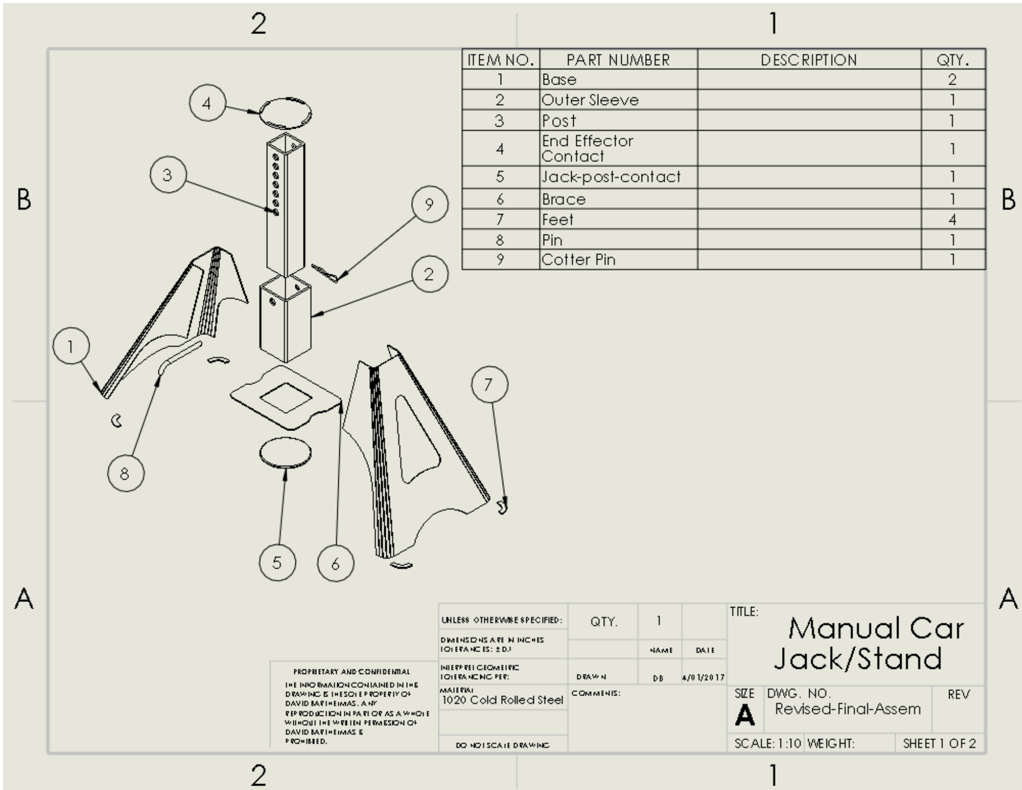
<u>Initial Design Assembly Drawing: Fully Assembled</u>



Initial Design Assembly Drawing: Exploded View with BOM



Final Design Assembly Drawing: Fully Assembled



Final Design Assembly Drawing: Exploded View with BOM

CONCLUSION

The conclusion from the research, design, design selection, and FEA is that all the components are strong enough to withstand the forces needed for the jack stand assembly to function properly. Each key individual part was put through the required tests to establish its functionality and safety. Therefore, it can be said that once the individual parts are assembled as one unit, it will be just as strong, if not stronger.

The initial design of the jack stand with the solid rectangular post weighed 130 pounds and was determined to not be feasible for the needed application. After the redesign, the system weighed 30 pounds. This weight is better suited for the application of the jack stand.

After fabrication and product testing, there are a couple changes that could be made in order to make the product function better for the operator. First off, 1045 cold rolled steel would be a better option for this product due to its increased structural strength. This will allow for the wall thicknesses to be decreased by half, which will then decrease the overall weight of the product. A key feature of the design is the alignment of the holes for the locking pin. This was an issue with the product that was produced due to the substantial gap between the sleeve and the post. If this could be reduced to allow for better meshing, the system would operate much better.

PROJECT MANAGEMENT

The following schedule is subject to change.

		Duration (days)	Finish
Senior Design I			Friday, Oct 7
	Start Design		
	First Draft Proposal		Friday, Sept 30
	Final Draft Proposal		Monday, Oct 7
Senior Design II			Friday, Dec 12
	Start Senior Design		
	Complete Budget Research		Friday, Oct 21
	Draft Design Ideas		Friday, Oct 21
	Compile Design Ideas		Friday, Oct 21
	Select Design		Friday, Nov 4
	Budget Final Design		-
	Prepare For Presentation		-
	Design Presentation		Jan, 1
Senior Design III			
	Design Report to Advisor		-
	Demonstrate To advisor		-
	Start Senior Design III		-
	Manufacture		Apr, 1
	Function Test		-
	Tech Expo		Tuesday, Apr 12
	Project Presentation		-
	Submit Report to Library		-
	Final Day of Senior Design III		Friday, Apr 27

Table 1: Tentative Schedule

Item	Price	Actual
Steel	$ 300	250
Welding	-	
Hardware	$ 100	125
Machining	100-500	
Total	400-800	375

Table 2: Budget

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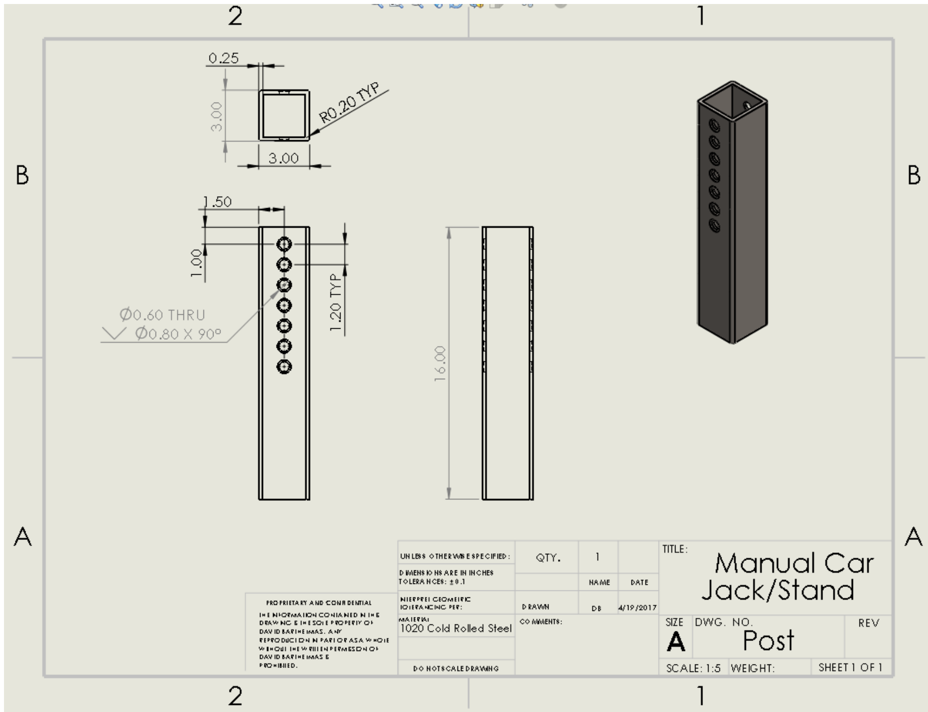
1. ASEDeals Automotive Service Equipment. *ASEDeals Automotive Service Equipment Web Site.* [Online] [Cited: September 26, 2016.] http://www.asedeals.com/jacks/aluminum-jacks/ranger-aluminum-racing-jack-rfj-4000al/.

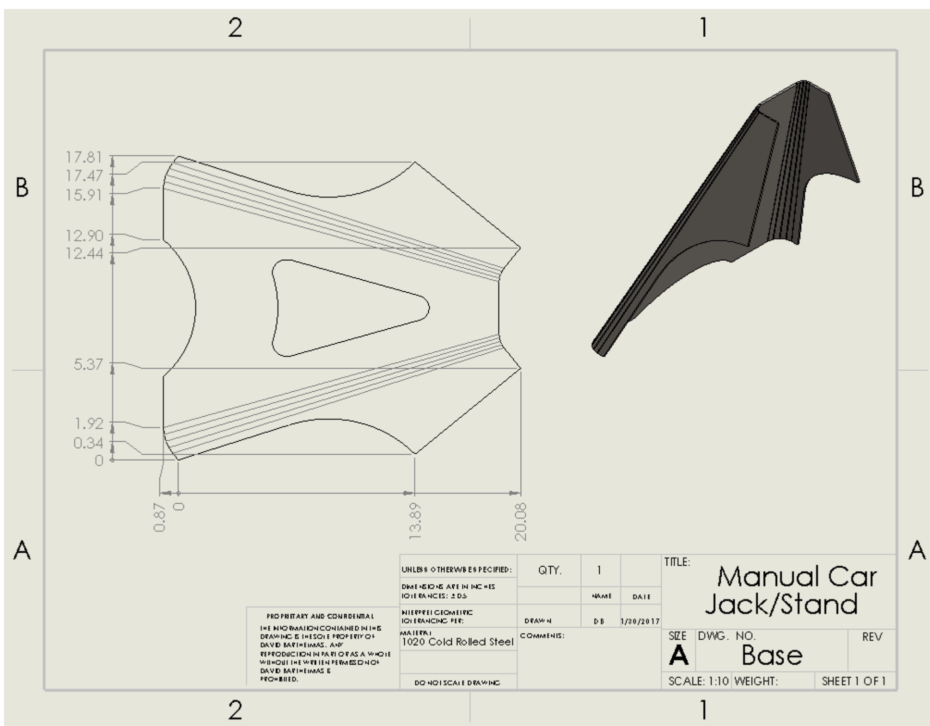
2. Harbor Freight Tools. [Online] 2016. [Cited: 09 26, 2016.] http://www.harborfreight.com/6-ton-jack-stand-set-38847.html.

APPENDIX A

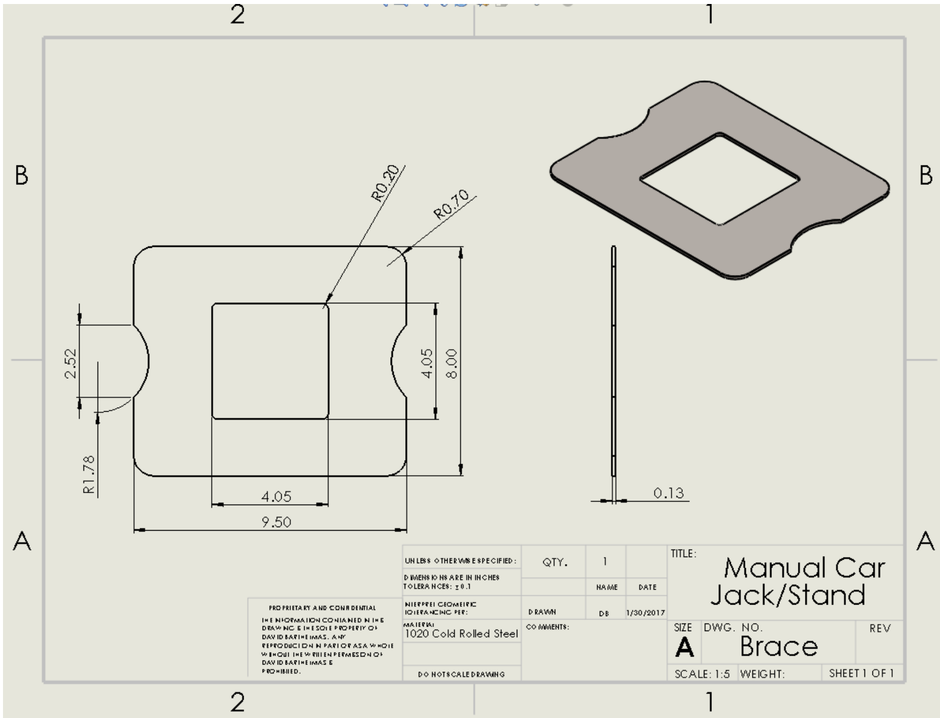
REVISED PART DRAWINGS



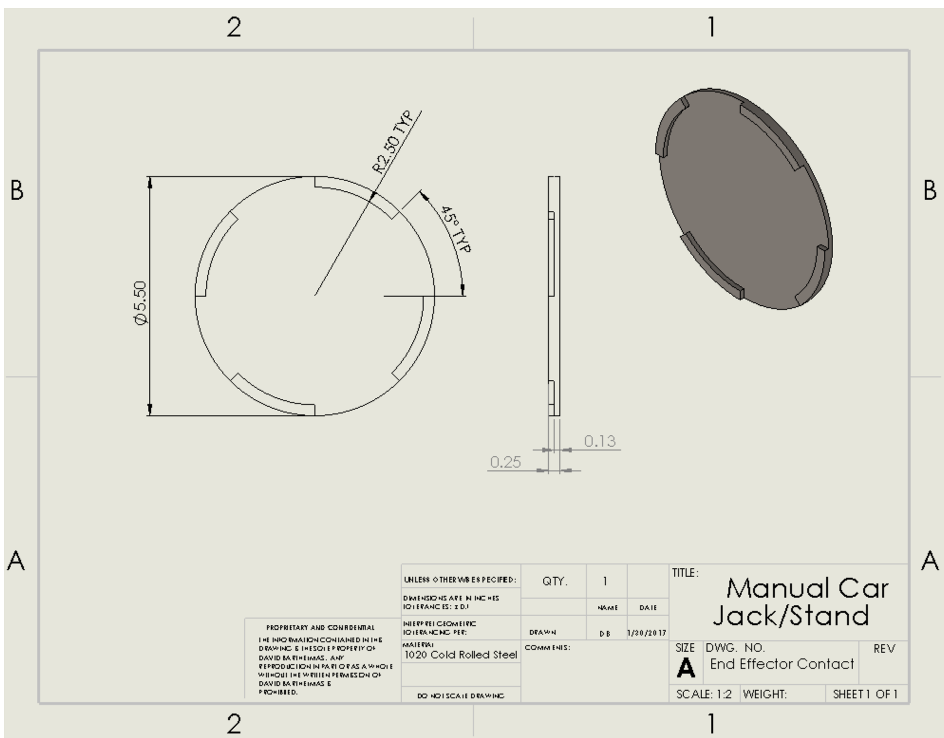
Part Drawing 1: Post



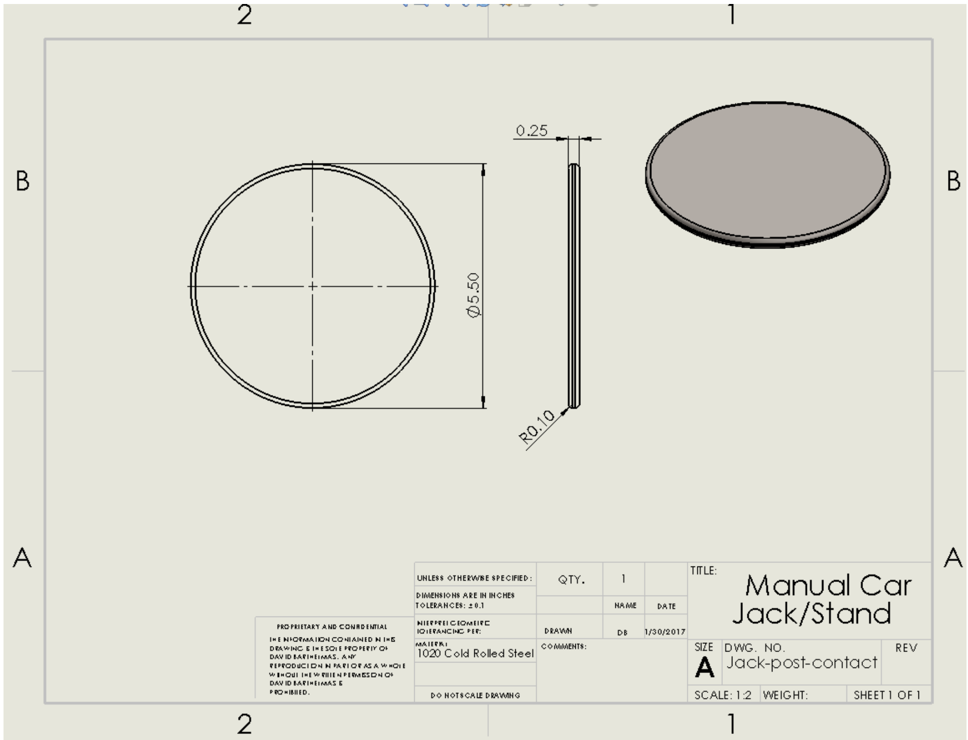
Part Drawing 2: Base



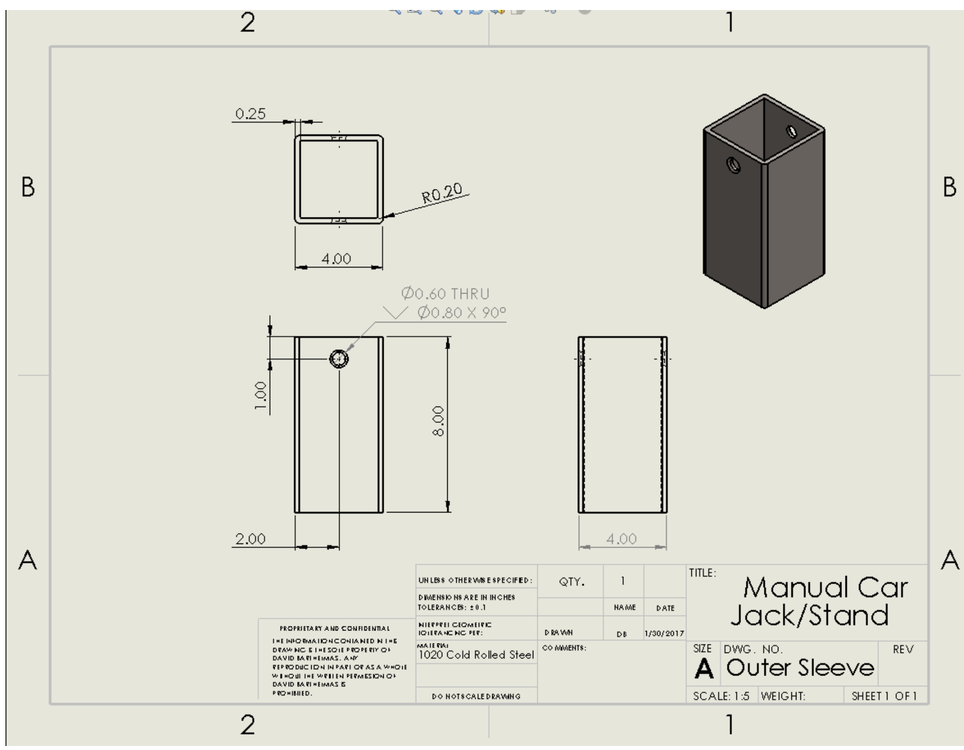
Part Drawing 3: Brace



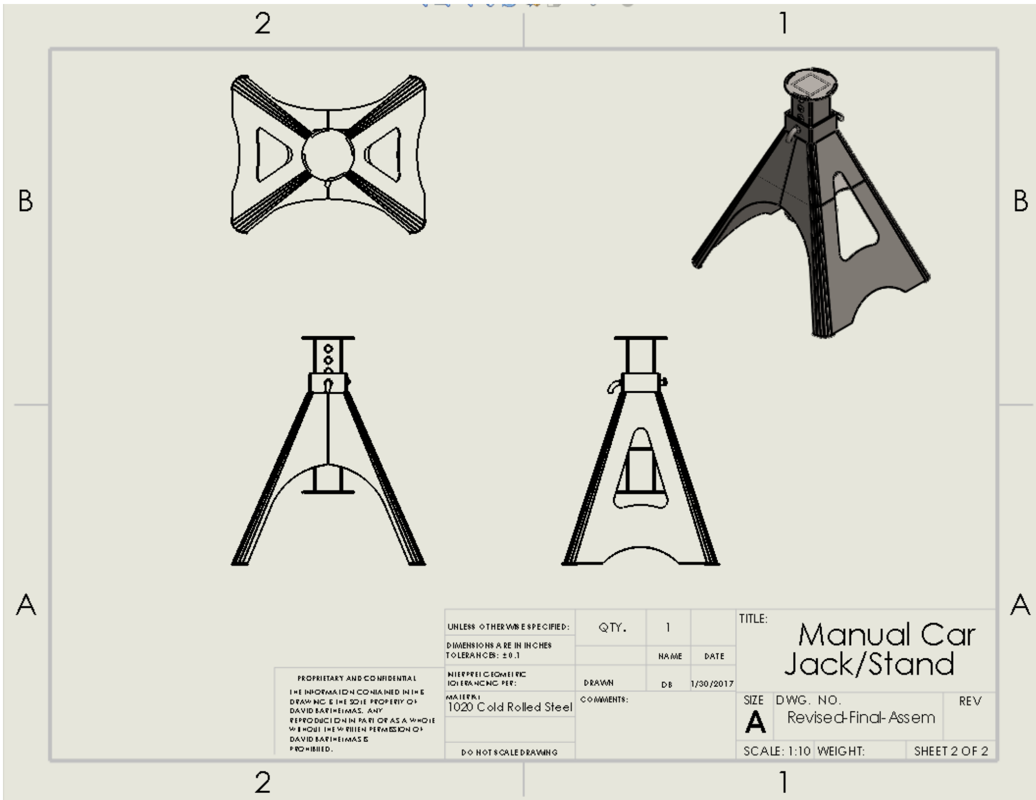
Part Drawing 4: End Effector Contact



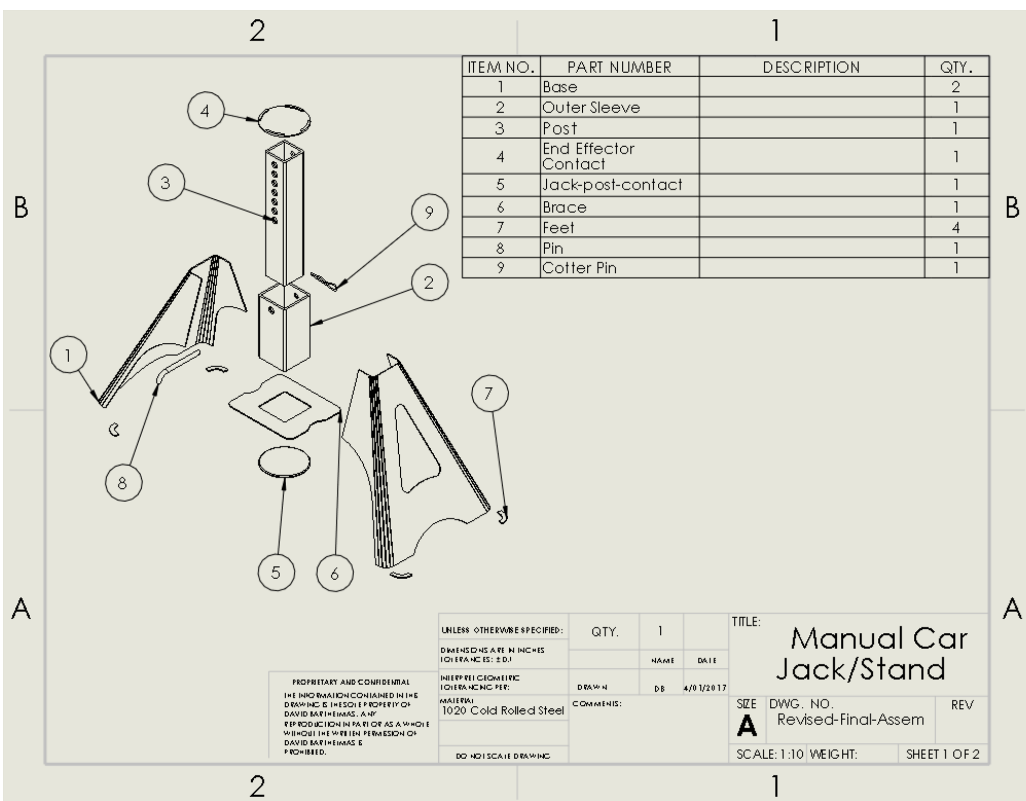
Part Drawing 5: Jack Post Contact



Part Drawing 6: Outer Sleeve



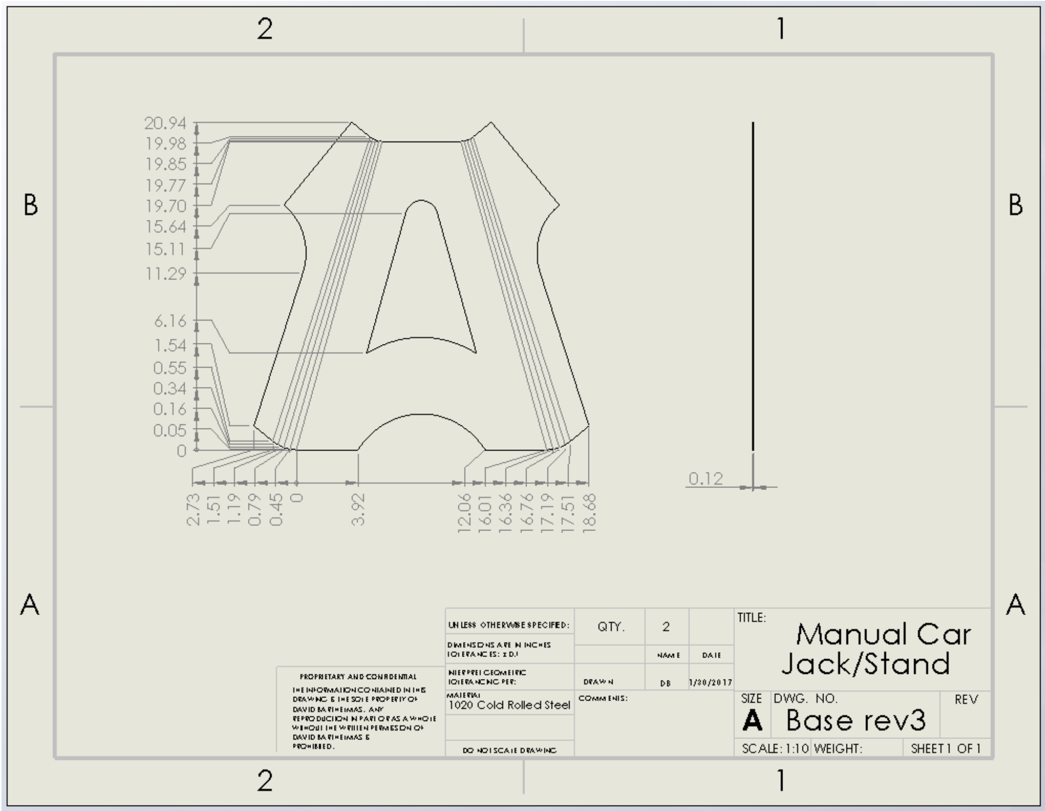
Assembly Drawing 1



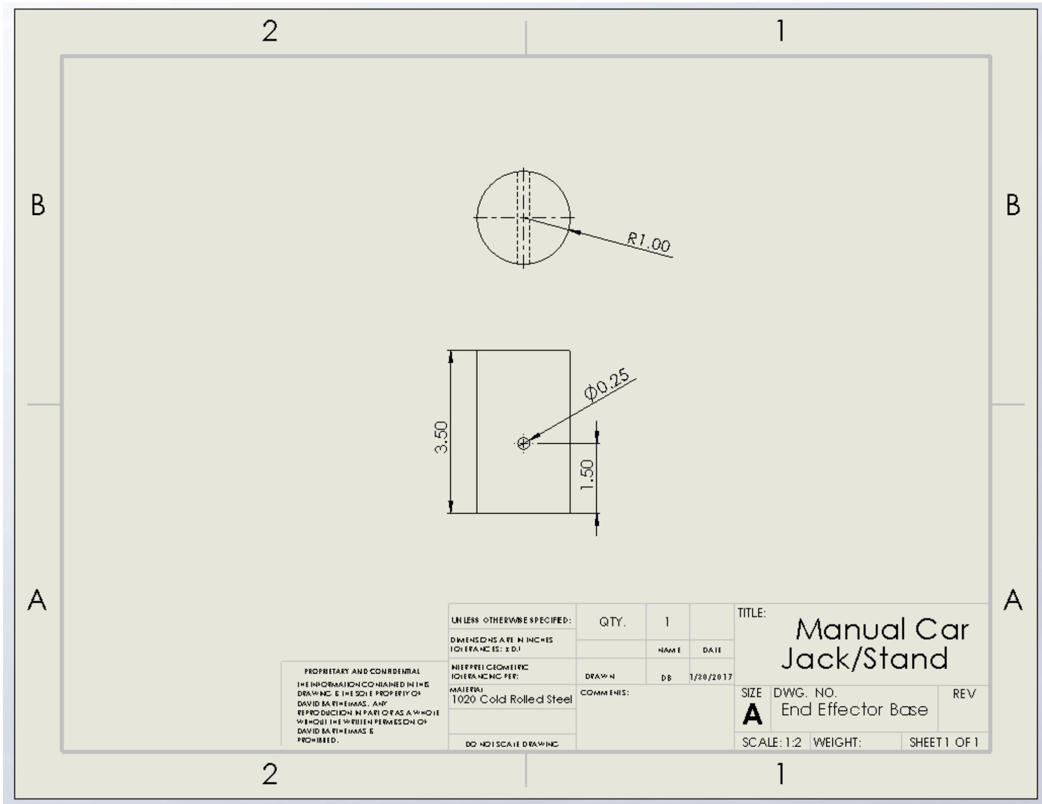
Assembly Drawing 2

APPENDIX B

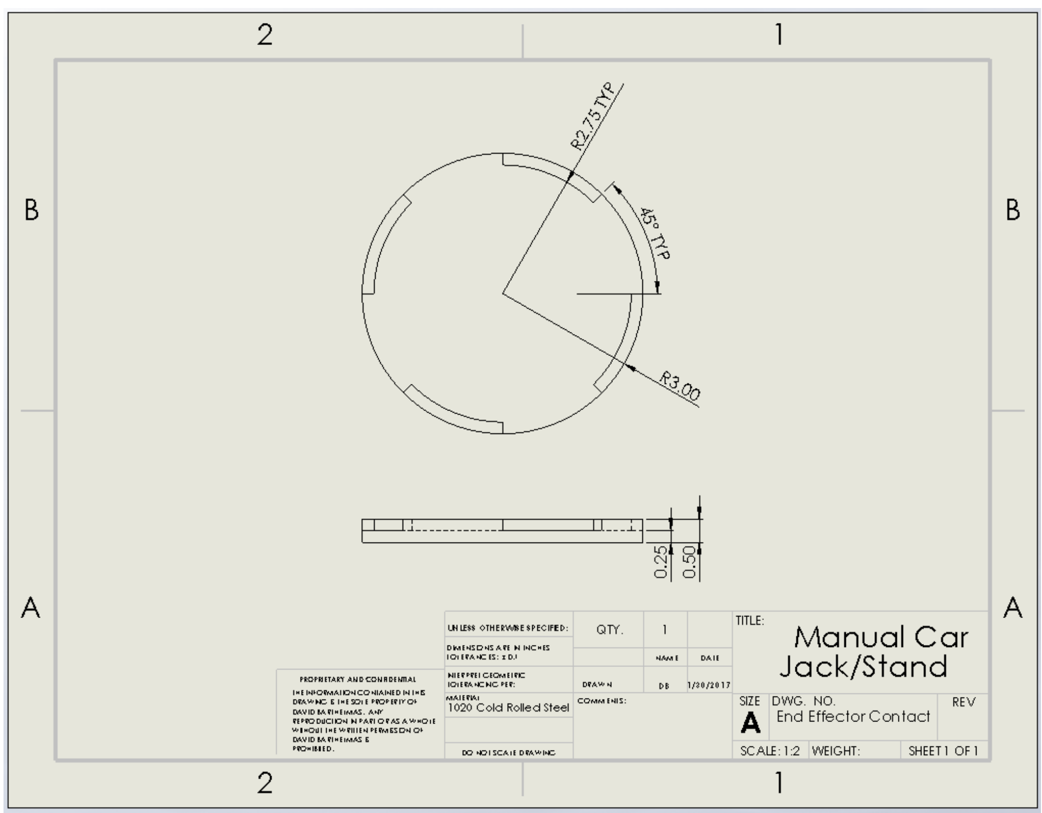
INITIAL PART DRAWINGS



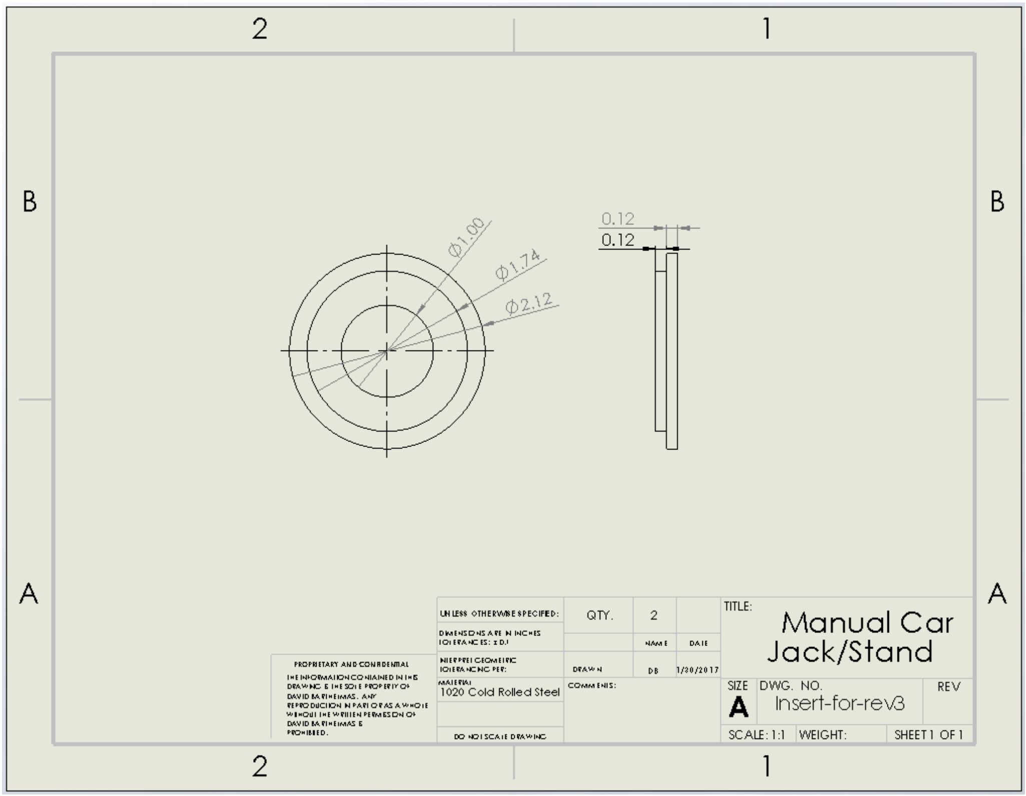
Part Drawing 7: Base Part Drawing



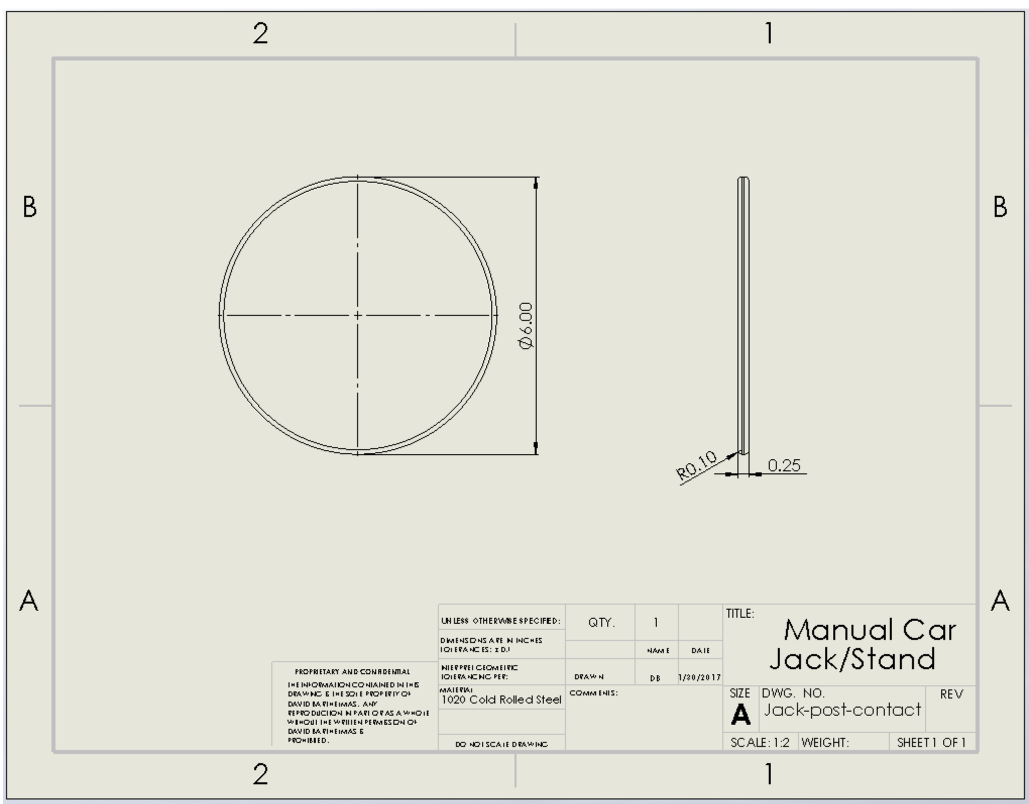
Part Drawing 8: End Effector Base Part Drawing



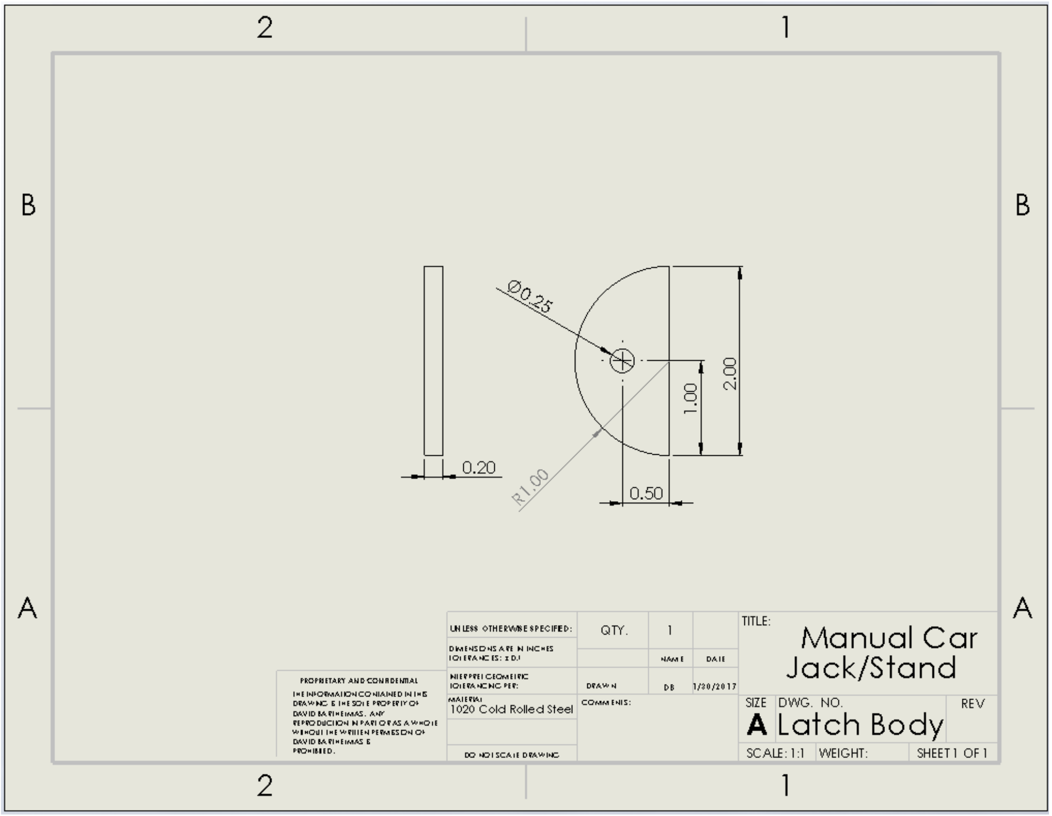
Part Drawing 9: End Effector Contact Part Drawing



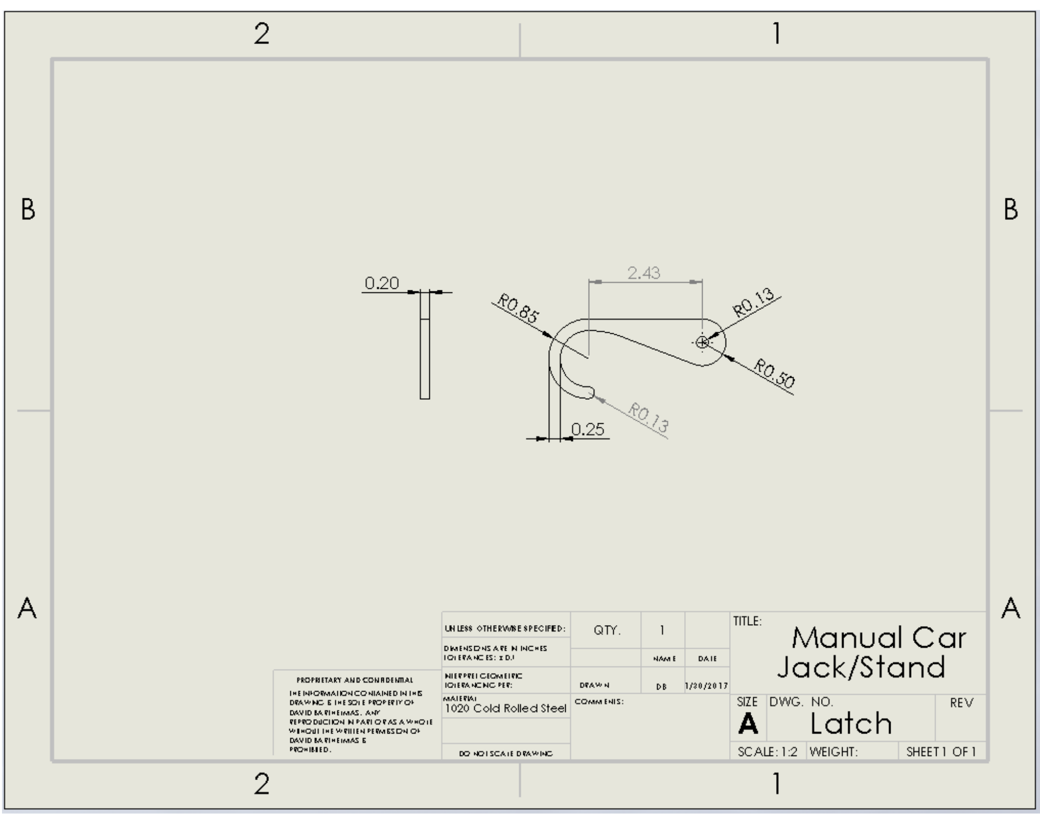
Part Drawing 10: Insert Part Drawing



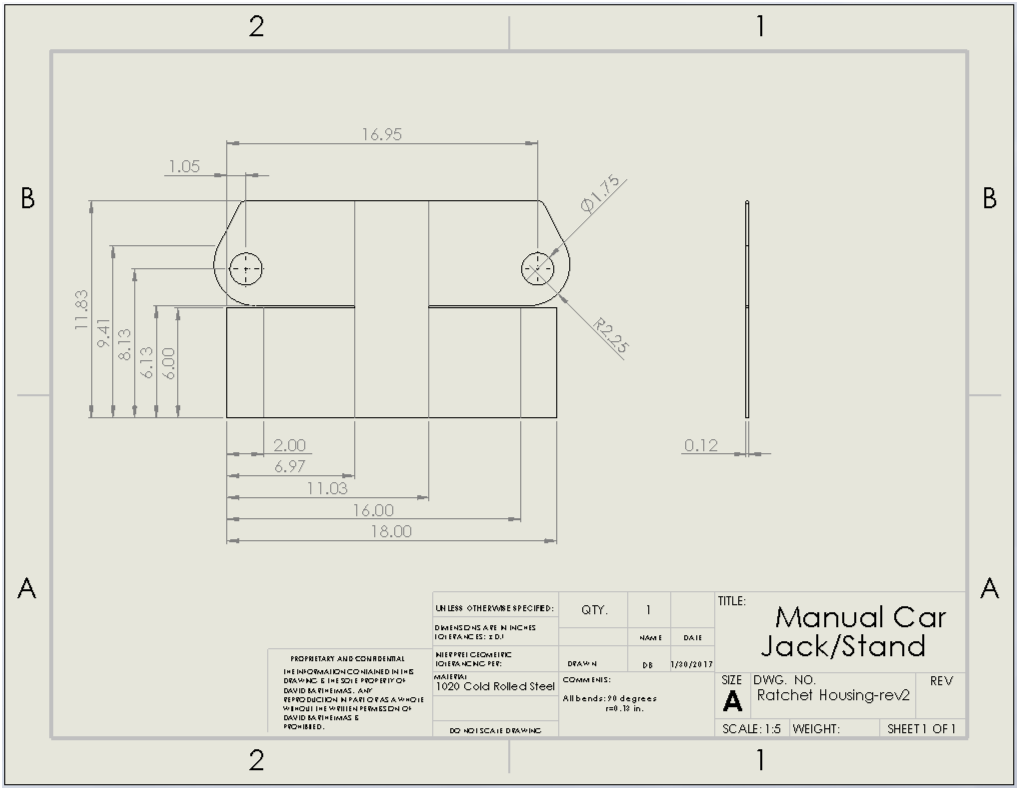
Part Drawing 11: Jack Post Part Drawing



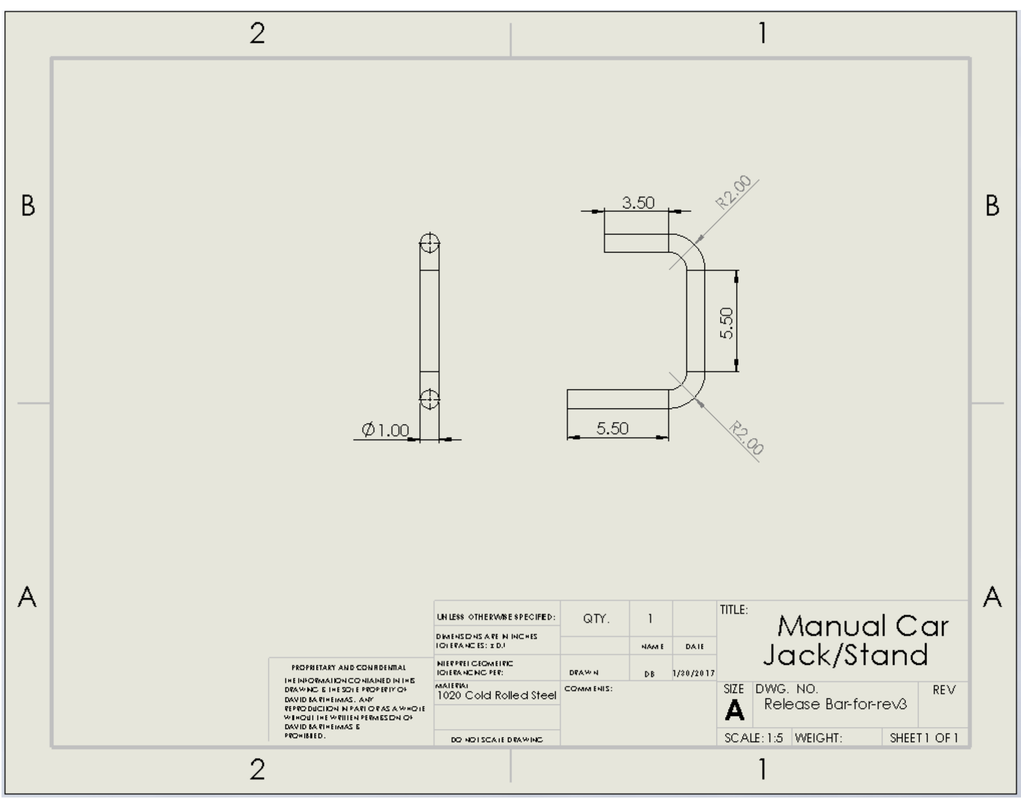
Part Drawing 12: Latch Body Part Drawing



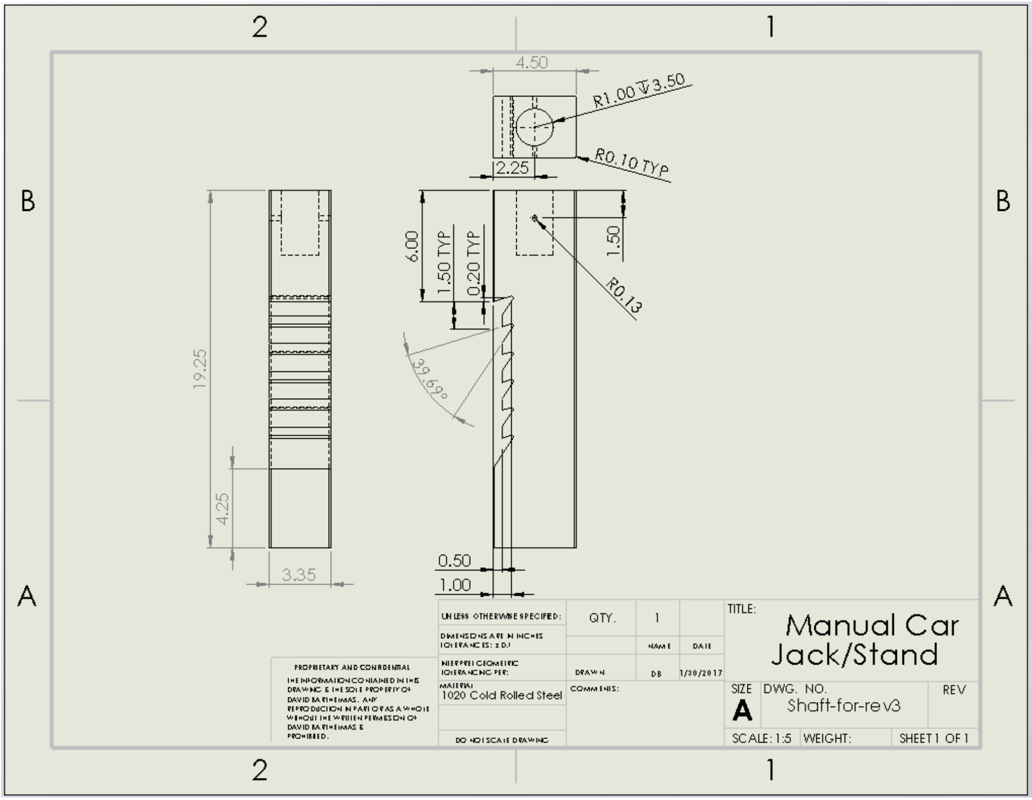
Part Drawing 13: Latch Part Drawing



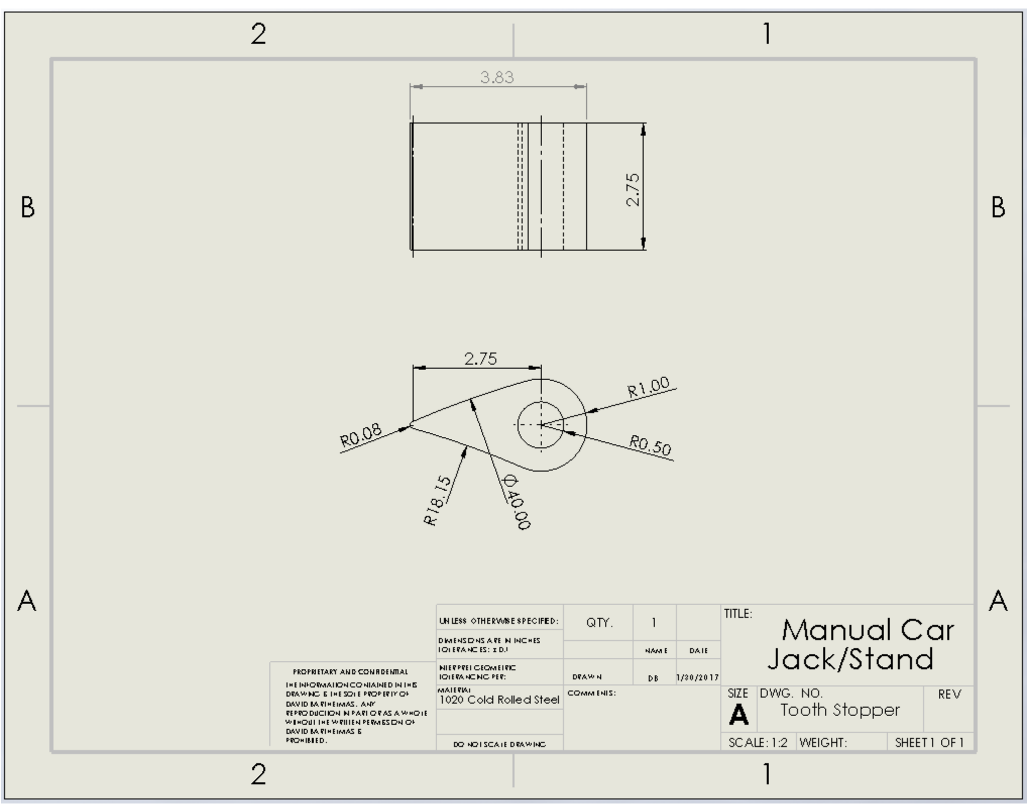
Part Drawing 14: Ratchet Housing Part Drawing



Part Drawing 15: Release Bar Part Drawing



Part Drawing 16: Shaft Part Drawing



Part Drawing 17: Tooth Stopper Part Drawing