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Adjustable Short Throw Shifter (ASTS)

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ADJUSTABLE SHORT THROW SHIFTER (ASTS)

F.B Engineering Group (FBEG)

Proposal for Adjustable Shifter

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Design: Adjustable Shifter

Design: Adjusted Frame

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INTRODUCTION

Description

Every manual transmission vehicle has a shift lever for changing gears. The problem is that the shifting linkage is setup up for one kind of driving. Numerous vehicles have multiple settings for the suspension to adapt to varying driving scenarios (i.e. cruising, sport, track). No vehicle currently has an adjustable short throw shifter (ASTS) that can accommodate drag racing, drifting, sports car racing, rallying, off-roading, or casual driving. The design of the ASTS solves this problem by moving the central axis of rotation of the shifter up two inches, permitting the adjustment of the shifting throw between 20 and 40%. The swivel joint, at the central axis of rotation, is increased in size for the threaded sleeve to be press fit on the inside. Adjustments to the amount of throw are made from inside the vehicle because the threaded rod travels up and down the sleeve. For safety reasons the new shifter is also required to meet the same safety standards as the stock model shifter in the test vehicle, a 2005 Ford Mustang GT. The shifter must withstand a load of 50 lbs. with less than 0.5-inch deflection. Testing demonstrated it would support a 100 lbs. load with less than 0.5-inch deflection. The final design met all the requirements and performed with a throw reduction of 20-50% and providing an adjustability of throw within a tenth of an inch, thus allowing for max versatility and personalization from the customer.

Motivation

The motivation of this project was the problem/lack of versatility and interchangeability of other shifters. The lack of one's ability to custom fit, so to speak, or to create the right feel with their stock shifter or any other aftermarket shifter. No customer should ever feel bonded by the restraints of the product provided but empowered. This project will allow individual freedom as the ASTS can be changed at any time to meet their own desire.

Function

The function of the ASTS is to transmit force at different angles to the transmission shifting linkage suppling the connection into different gears.

Requirements:

The new design is required to:

- Adjust to decrease the throw between 20%-40% for shorter shifts.
- Adjustable from inside the car in under 60 seconds.

- The Safety Factor must be the same or better than 2005 - 2009 Ford Mustang GT manual transmission factory shifter
- Reduce the force required to shift by a factor 10%
- The shifter must withstand a load of 50 lbs. with less than 5% deflection

Engineering Merit

The engineering in this project will arrive from the requirement for similar safety factors. This requirement will be a calculation of the stress on the shaft. The other requirement that needs calculation will be the shifters ability to withstand 50 lb. force with less than five percent deflection. The design also requires a press-fit calculation for design of the internal diameter (ID) of the swivel joint and the outside diameter (OD) of the threaded sleeve.

Scope

Will include:

- Design of adjustable rod to transmission rod (accounting for rotation)
- Design of sleeve holding rod
- Design of exterior part of shaft to hold shifter knob
- Design of larger ball joint and higher placement
- Design for thread locking
- Selection of ball joint size
- Manufacturing of parts
- Stress on shaft and adjustable rod
- Shaft and rod material selection
- Deflection of rod under load

Benchmark

The proof of concept is that the design will be tested on a 2005 Mustang GT. The vehicle has its own stock shifter. There is also a short throw shifter made by Hurst. Beating the stock and short throw shifter in their lack of ability to adjust will be the benchmark. Another benchmark reduce the amount of throw more than the short throw shifter.

Success Criteria

This project will be considered a success when:

- The force required to shift is less than 10% of the stock.
- The forces applied to the shaft cause no visible deflection.

- The ability to adjust from inside the cockpit is complete.
- The vehicle is driven and shifts with the new ASTS.

DESIGN

Conception

The design was created based upon the idea from Dustin Braun. The initial idea (Appendix B4-1) was to go under the vehicle and change the distance of throw using locking channels. The second design (Appendix B4-2) was to thread the ball joint, which in turn was a failure due to the driver's inability to twist the ball joint or spin the rod due to the linkage attached to the transmission. The third design (Appendix B4-3) was a solution to not being able to rotate the Ball Joint or Internal Threaded Rod (ITR). In Table B4-1 (Appendix) the depth of these designs investigated more thoroughly in a decision matrix, showing the reason why the fourth Design (Figure 1) was chosen to 3D print as a prototype. The prototype showed rotation, rigidity, and product construction problems. This led to the fifth design which was manufactured and constructed. The final Design, the birth of this design has been accompanied with challenges, failures, and continuous redrawing's. The only change to the final design shown in Figure 2 is that of the linkage attachment.

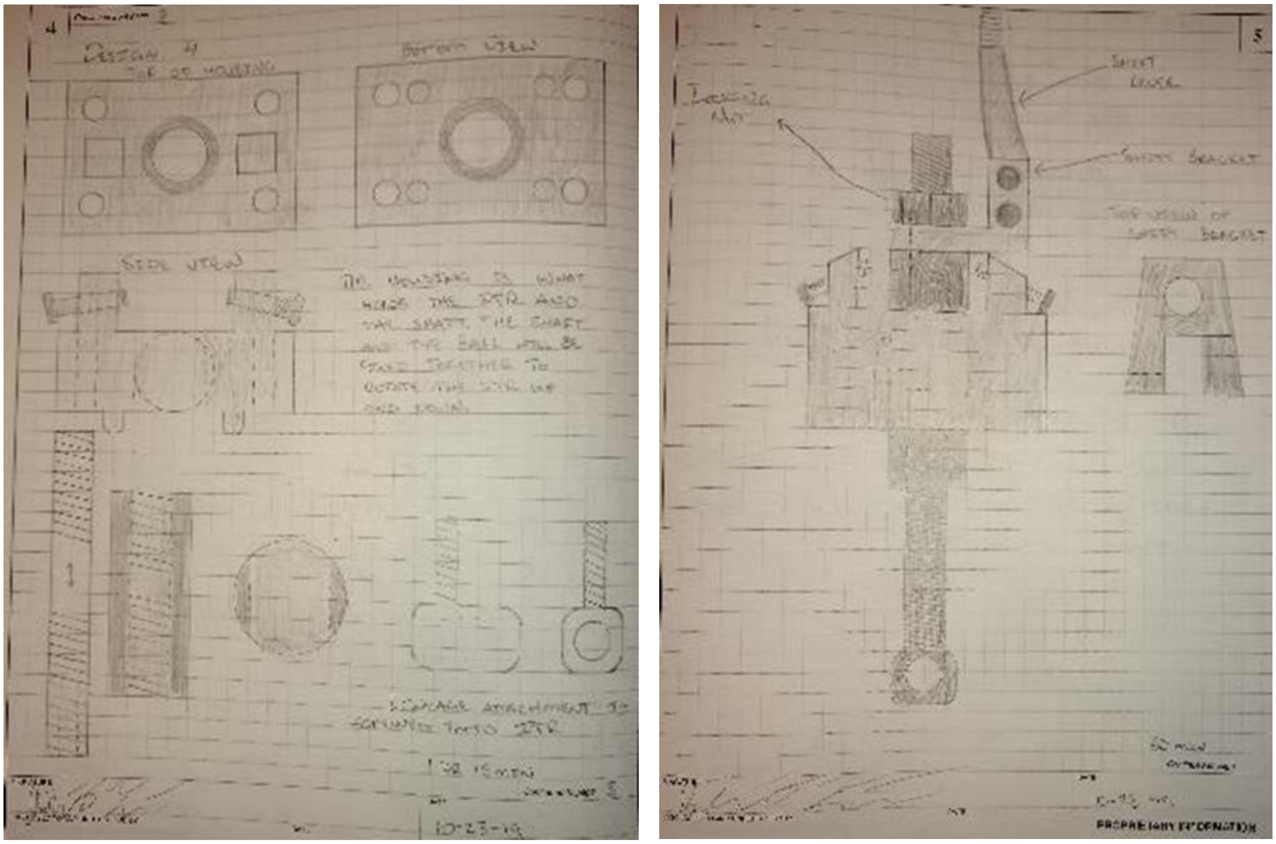
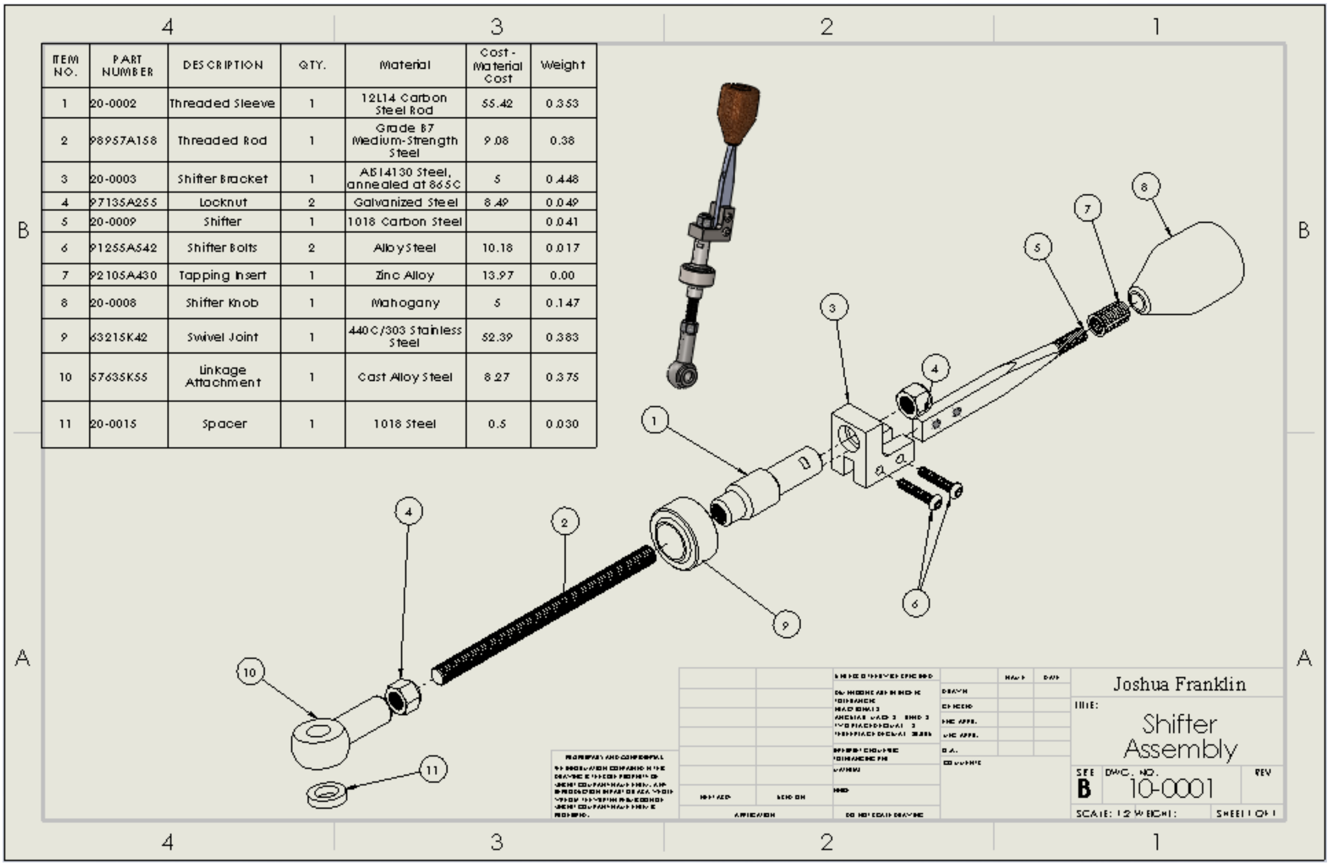


Figure 1

Design Description

The result of this design will consist of 11 parts. The parts are the: Threaded Rod, Ball Joint, Threaded Sleeve, Shifter, Shift Bracket, Locking Nut, and Linkage Attachment (etc. Shown in Figure 4). The Swivel Joint will be inside of Dustin Braun's Housing Assembly. The swivel joint is the point of origin as well as the fixed component. The threaded sleeve is then press fit into the swivel joint allowing for full rotation within the housing assembly. The threaded rod is then tightened through the sleeve to allow for adjustment to be made to the height of the linkage attachment. A Locknut is then put on the bottom side of the threaded rod followed by the linkage attachment. The locknut on the bottom is meant to be tightened down onto the linkage attachment to fix its angle and orientation. A spacer will be place on the unmachined side of the linkage attachment upon installations. The top portion of the assembly begins by putting the shifter bracket through the threaded rod and seeding it on



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	Material	Cost - Material Cost	Weight
1	20-0002	Threaded Sleeve	1	12L14 Carbon Steel Rod	55.42	0.353
2	98957A158	Threaded Rod	1	Grade B7 Medium-Strength Steel	9.08	0.38
3	20-0003	Shifter Bracket	1	AISI 4130 Steel, annealed at 865C	5	0.448
4	97135A255	Locknut	2	Galvanized Steel	8.49	0.049
5	20-0009	Shifter	1	1018 Carbon Steel		0.041
6	91255A542	Shifter Bolts	2	Alloy Steel	10.18	0.017
7	92105A430	Tapping Insert	1	Zinc Alloy	13.97	0.00
8	20-0008	Shifter Knob	1	Mahogany	5	0.147
9	63215K42	Swivel Joint	1	440C/303 Stainless Steel	52.39	0.383
10	57635K55	Linkage Attachment	1	Cast Alloy Steel	8.27	0.375
11	20-0015	Spacer	1	1018 Steel	0.5	0.030

Figure 2

top of the sleeve. A locknut will then tighten down the shifter bracket to the rest of the assembly to fix its angle and orientation (Appendix B2-2C). A shifter will then match hole up centered inside of the shifter bracket. This shifter bracket and shifter will be tightened together using 1" long ¼-20 threaded locknut. The tapping insert is then tightened into the shifter knob and the shifter is tightened into the shifter. The construction will be put together as shown in Figure 2.

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ANAYLYSES

Stock Analysis

Current Stock

Meeting the current stock safety factors is the most important requirement. “Engineers, in the fulfillment of their professional duties, shall: … Hold paramount the safety, health, and welfare of the public (Code of Ethics for Engineers).” Analyzing the values of the current 2005 Mustang Stock shifter as shown in Figure 3. The first analysis is of the actions on the current rod. The Rod itself can move until it hits its circular rim. This rim is located above the Ball joint to stop the shifter from jamming the linkage into gear. The location of the rim on the rod is 6 inches from the top. This allows for a static scenario where the force can be calculated and used to find the rest of the properties of the rod.

Figure 3

Yield

After analysis the Stock rod has a yield force of 104 lb_f (Appendix A1-1). This force was found using the yield strength of AISI 1020 Steel as the assumed material, yield stress was 50,800 psi. Using the yield stress and modulus of elasticity to find the deformation of the object's equation (Mott, Robert L et al) and the maximum sheer with yield stress. The deformation at yield was 0.09 inches (Appendix A1-2). The maximum shear at yield stress was 1362 psi (Appendix A1-2). The amount of allowed Torque for the entire length of the shaft was will 623 lb_f*in, with a 0.0357 Rad. of Torque (Appendix A2). The importance of these calculations is to create a new design that exceeds or matches these very calculations.

Allowable

After testing and collecting data the amount of actual force it takes to shift the Shift Lever is 7 lb_f. Overall the purpose of this force is to show eventually what the designed Safety Factor to yield was. The whole system itself has a ball joint in the middle with linkage attached 1.75 inches below the ball joint. Appendix A3 shows the amount of force acting on the ball joint and the translating force of the 7 lb_f of the Linkage. The force allowed translates down to the linkage allowing the force on the Ball

Joint to be 39 lb_f and the force on the linkage to be 32 lb_f (Appendix A3). With the 7 lb_f being the deciding factor the difference between allowable and yield can be found. The Stress allowed is 3422 psi (Appendix A4-1) in comparison to 50,800 psi (Appendix A1-1). The allowed Deflection at 7 lb_f is 0.0061 inches (Appendix A4-2) in comparison to 0.09 inches (Appendix A1-2). Finally, the Shear is allowed is 92 psi (Appendix A4-2) versus the 1362 psi (Appendix A1-2) of the yield.

Design Analysis

This new design is required to adjust from inside the cockpit and to have the same safety factor as the current stock model. This design is required to withstand the forces listed above and improve or be equivalent to the current model. The current Internal Rod as shown in Figure 2 Item Number 2 is a Grade 8 rod meant to withstand a tensile strength of 150,000 psi. The current 6 inch shifter and bracket are currently designed to the same force required from the stock shifter (Appendix A7,A9). The 6-inch Shifter revision model is designed to withstand a force of 31,900 psi and the material chosen for it to be made from has a Low Carbon Steel Grade 1006-1026 with a yield strength of 60,000 psi. This current design has been analyzed to meet the standard requirements for using the threaded sleeve and rod to adjust the thread from inside the cockpit. It has been designed to be better in safety than the current stock model.

Other Analyses

These analyses included ways or needs for manufacturing. For example, the shifter itself after its first redesign (Appendix B3-6B) needed to be created to withstand the same force as the stock shifter. There were several different sized shifters made for testing, assembly, and product modifications. These shifters are shown in Appendix B3-6B through B3-6D. The only analysis that was necessary for this series of shifters was to design the force requirement to the longest one. Appendix A5 analyzes a 12 in long shifter. This length of shifter is redesigned in over and over in size until a stress value approximate to the stress of 50,800 psi or higher was met. The problem was solved when a 3/8” by 5/8” shifter stress was found at 60,300 psi. The shifter also needed to make sure that the holes would withstand the force place on them at 6 inches higher than the stock model (Appendix A6). The holes can withstand the force without breaking on the load only putting a maximum stress of 43,700 psi. The final portion of analyses for the shifters was check the stress for the shortest shifter which showed the max stress would be 15,200 psi. This analysis showed that the shifters would be safe for use under the stress yield of 65,000.

Appendix A8 summarizes the necessary manufacturing fit required for the object. This is illustrated in the tolerance found on the Threaded Sleeve (Appendix B3-2A). This press fit required a very tight tolerance and required a force of 14.5 ksi to press fit this FN3 Drive Fit Class. This was then adjusted to the change the angle of the shaft to allow shifting. Unfortunately, the class fit for the new Threaded sleeve was not calculated but was watched over by Matt Burvee to make sure the correct fit was accomplished.

METHODS AND CONSTRUCTION

This project has been conceived, designed, and analyzed by the collaborative efforts of Dustin Braun and Joshua Franklin. Both co-designers, working with the help of Central Washington University (CWU), created and then recreated the different designs that make up the ASTS today. This Final design (Appendix B2-3) was created to be designed, manufactured, and assembled at CWU. The constraints of design were to make sure that the material was machinable. Braun and Franklin only pursued avenues of design that allow them to gain the most experience and simplicity for easy manufacturability of the product. They chose this method of design and manufacturing for easy distribution as well as the improvement of their design, for any hinderances would be found by them in the manufacturing phase. The project will be the best version Braun and Franklin can create.

Construction

This device itself was brought up in conception by Braun to be hand assembled. This assembly for distribution purposes was thought by both designers to be the best product result. All the parts will have to be manufactured. The design of the ASTS was to minimize the amount of un-standardized parts. The idea of constructing the design was to reduce waist on the FBEG products side. The parts talked about below are listed in Appendix C. This project is made up of 11 different parts as shown in Figure 2.

The Swivel Joint (Appendix B3-4B) is the center of the assembly This piece is the immovable object that is the only attachment part that Franklin has that ties to Dustin Braun. This Large 1-inch internal diameter swivel joint will allow for a large angle of rotation. This is a Corrosion Resistant Lubrication-Free Swivel Joint. It is purchased from McMaster and doesn't require any manufacturing except to have the Threaded Sleeve press fit within it.

The Threaded Sleeve will start out as a 1 $^{1}/_{8}$" Ultra-Machinable 12L14 Carbon Steel Rod. This rod will then be machined to the drawing 22-0002 (Appendix B3-2B). This part has a high tolerance and will be placed on the lathe to be machined, bored, and tapped slowly. The sleeve will then be press fit into the swivel joint 55-0006 (Appendix B3-4B). This will be pressed using a hydraulic press. Once placed perfectly within the sleeve it will remain forever. This is the only part of the project Franklin and Braun believe that the customer will not be able to accomplish so it is done in construction before final assembly.

The Grade 8 Threaded rod is carefully put into a clamping system to be cut to the correct length drawing 20-0001 (Appendix B3-1B). This device can be cut with a bandsaw, Hack saw, or a file. This is the only manufacturing required of the Threaded Rod as its purpose is to hold up the Linkage attachment and travel up and down the threaded Sleeve. The other use of this rod is to clamp down the Shifter Bracket to the shaft to allow for proper shifting.

The Linkage attachment is a High-strength Rod End Blank (Appendix B3-7C). This piece will have to be machined down to meet the 20-0014 drawing specification (Appendix B3-7C). The shaft will have to be cut off using a bandsaw, hacksaw or lathe. The end of the shaft will have to be bored or drilled to then tap through 1.5 inches. The center of the rod end will be drilled in the impression mark at 0.625 inches. Once side of the rod end will be machined down 0.03125 inches to match the stock part perfectly center. This will be threaded but before will have a nut threaded (Appendix B3-12) onto the rod before it so that when placed in line with the linkage rod it can be clasped in placed to not unthread during vibration.

The Shifter Bracket and Shifters will all be made from 1018 Steel. Shifter Bracket will be milled by continuously flipping sides on the mill to give it a perfect shape. This started as a block of 2" steel that needed to be cut then machined down to the dimensions shown in drawing 20-0003 (Appendix B3-3B). The drill press will be used to drill the holes on datum A. These holes will be marked using Die then stamped and drilled. After drilling the holes will then be taped. The Larger hole at the base of the drawing will be end milled out for proper accuracy. The shifter will be seeded onto the long upright part of the Threaded sleeve with the threaded rod through the hole. The Nut in 55-0004 (Appendix B3-12) will be tightened down over the shifter bracket to hold tight the threaded sleeve to not allow for adjustment up and down as well as to hold the shifter bracket perpendicular to the threaded rod.

The Shifters as shown in Appendix B3-6B-D and are tapered. The stock rectangular bars are cut to length. Stock is then placed in a 4-jaw chuck lathe. The chuck allows for concentricity of the end to be machined to a cylinder then threaded using a dye. The taper is by using the top angle adjustment of the cutter to push the cutter at a given angle creating the taper affect around the rectangular stock. The holes are drilled using the same process as the shifter bracket and then tapped. These devices can be interchanged by lining up the holes on the shifter bracket and then taking the shifter bolts (Appendix B-9) tightening the shifter into the shifter bracket.

The shifter knob is a piece of mahogany that will be created on a wooden lathe in CWU woodshop. This piece could not have been properly made without the proper instruction and safety lesson from Scott Calahan. The design itself is a classic as shown in 20-0008 (Appendix B3-8B). This is a meant to be bored to have the Tapping Insert (Appendix B3-13) placed in the lower end to allow for it to thread on and off each shifter. The top portion is bored open for a classic mustang pin to be epoxied into the top. The mahogany piece will be finished with a Gun Oil for a rough but great finish.

The wrench adjustment tool. The limited space allowed in the center console where the shifter will go required a custom wrench. This wrench needed to be flatter than a regular wrench to fit the slots in the threaded sleeve. This required the wrench to be ground down to the measurement with an equal thickness on each side of the center axis. Then the wrench needs to be formed in a way that when turning the Threaded sleeve would not hit the center console of the vehicle. The wrench required to be bent using heat. The wrench was pressed into a vise grip heated up and then bent down into opposing 90-degree angles. This form makes a "Z" frame wrench. The only manufacturing issues are that the accuracy for bending at the exact distances. This is due to the technique used to bend the wrench. Instead of bending using a vise grip and heat it would have been better to use a hydraulic bending machine.

The Spacer is created using a cylindrical shaft. The shaft was lathed to the OD of the spacer. Then the spacer was bored to fit perfectly of the linkage rod. The Small Spacer (Appendix B3-15B) is set with internal tolerances. Once bored a mark was made using a caliper to set the exact distance within thousands of an inch. Once marked the spacer was separated from the rest of the shaft using a parting tool on the lathe. The Spacer is made to fit a bushing on the inside that are standard for the vehicle. This project will be constructed from start to finish in this order. The project can be assembled and disassembled in every aspect except the swivel joint and the threaded sleeve. These to pieces once placed together can never be separated. This project was designed for this reason for interchangeability. This will allow for future parts to be chosen or for customizations to be made. Also, if there is any failure of any parts they can be easily remade and disassembled.

Benchmark

The Benchmark for all the materials is to meet all their dimension requirements 100%. Another benchmark is that the material would be within 5% of the Strength it was either purchased at or made from. The whole project will be a success if it simply fits in the vehicle, shifts, and adjusts throw within 5% of required thrown. The design will produce 10% more reduction in throw that the short throw shifter.

Performance Predictions

The reduction in thrown of the device is predicted to be 5% greater and will be tested conforming to ASTS standard procedures. It will also 100% outperform its competitors in its ability to adjust throw.

TESTING METHOD

The Shifter assembly as shown in Figure 2 (Appendix B2-3) will be tested. It is going to be testing for beating all the requirements and to meet any of the benchmarks set for the product. Things that will be needed is a pound scale, measuring tape, stopwatch) protractor, private road, and the 2005 Mustang. The product itself will have to be installed inside the car.

Method/Approach

The information needed to evaluate the success of the project will be listed below. Things that will be tested for:

- Shortest and Longest Distance of Throw (Measuring Tape)
- Smallest and Largest angle of movement (protractor)
- Engages each gear (Vehicle)
- Full allowed rotation of shaft, no unwanted interference (Vehicle)
- Install difficulty (Stopwatch)
- Interchangeability of parts difficulty (Stopwatch)
- Force required for Long shifter (Pound Scale)
- Force required for medium shifter (Pound Scale)
- Force required for short shifter (Pound Scale)
- Difficulty of changing throw (Stopwatch)
- Testing allowed distance for rod to travel downward doesn't hit drive shaft

Test Procedure Description

For this shifter to be tested, it will have to be installed into the 2005 Mustang. Installation Procedure has been outlined by Dustin Braun in Appendix G1-Installation Procedure. The vehicle will be taken onto a private road for performance examination. The vehicle will complete the tests shown above in the method/approach section.

For Test One the shifter knob to the swivel joint will be measured by measuring tape. This will be recorded for the 6", 8", and 10" shifters. The angle reading will come from the magnetic locator attached to the side of the shifter at each gear with three different adjustments in at different times of the test. This data will then be put in excel (Table G2-1) and will formulate the distance that the shifter knob was required to travel. The performance of this device shall succeed and is predicted to be higher 5% higher reduction in throw.

For Test Two Part One a timer begins and the ¾ inch wrenched is used to loosen the locking nut. Once the locking nut is removed the shifter assembly is removed and the adjustment is made and then components reinstalled. The second part is the shifter assembly shall be disassembled using a 3/16" Hex Key. This will simply be to change the assembly of shifter height. The shifter knob will be unassembled and then new assembly components will be reinstalled. All recorded times will be stored in Table G2-2. The prediction for this test will complete the adjustability within 60 seconds and that is what its predicted to accomplish.

Test Three uses 3 different sized 6", 8", and 10" shifters. The Force required to shift into gear will be measured using pound scale and slow-motion application on a phone. This data will then be put in excel and an average for each will be formulated and stored into Table G2-3. The prediction for this test is to reduce the force required to shift by 10%.

Deliverables (Summary of data produced in testing Compared to prediction)

When this test one was performed the magnetic angle locater only held values within a tenth of a degree. This was measured in 55 different variations ranging at angles of 17.5°-2.8° (Table G3-1). The Arc length of is calculated using the distance of the central axis as the radius and the angle to find the distance of throw. Using $Arc_{length} = 2\pi r\left(\frac{\theta}{360}\right)$ to compare to the stock model shifter and Hurst shifter to find the percent reduction. Range of adjustability allowed for an arc length of 1.8-0.48 inches (Table G3-1). Success for this test would have been a reduced throw between 20-40%. This test clamed success by achieving a Reduction of stock by a percentage of 38-66% (Table G3-1). This also met the benchmark by reducing more throw than the Hurst shifter by 0-44% of its throw (Table G3-1). This test demonstrates the upper and lower limits of operations for the device. The shifters capability to change adjustment and customization for the customer is beyond successful. The demonstration performed shortly after install was consistent of swift effortless shifts that were short and easy. This devices versatility seems to the hallmark of its capability.

Test Two was performed the stopwatch only held values within a hundredth of a second. This was measured in 20 different variations ranging at times of 39.28-73.48 seconds (Table G3-2). The only calculation will be the sum of all the trials divided by the number of trials and an average of those averages from part one and two of this test. Success for this test would have been any form of adjustment inside the cockpit in less than 60 seconds. This test clamed success by achieving an average of 47.28 seconds for part one and 52.72 seconds for part two (Table G3-2). A total average of 50.00 seconds (Table G3-2) from part one and two was found concluding the success of the device. This test demonstrates the adjustability of the device. The shifters capability to change adjustment and customization for the customer is beyond successful. The testing was also complete by other different operators to allow for a better average. This devices versatility seems to the hallmark of its capability. Test Two Successful.

Test Three was performed the pound scale only held values within a hundredth of a pound. This was measured in 30 different variations ranging at angles of 2.22-7.1 lb_f (Table G3-2). The only calculation will be the sum of all the trials divided by the number of trials and an average of those averages from part one and two of this test. Success for this test would have been any form of force to shift 10% less than stock. This test clamed success by achieving an average of 4.305 Lbs. which is 37.71% less than Stock model (Table G3-2). The force required can range depending on shifter an average of 3.44-4.92 lb_f (Table G3-2). For a Reduction between 28.9-50.1% less force for the individual shifters average (Table G3-2). This product succeeded for each shifter but succeeded beyond the requirement by shifting 50% less than the stock shifter. This test demonstrates the upper and lower limits of operations for the device. The shifters capability to change adjustment and customization for the customer is beyond successful. The demonstration performed shortly after install was consistent of swift effortless shifts that were short and easy especially with the shifters force being 37% less than stock. This devices versatility seems to the hallmark of its capability.

BUDGET

This project will be managed in terms of parts and allotted time to work on each part. There are several risks with this project. The largest risk is the mustang, which the owner holds a value of $6000. Making sure that the analysis is correct and that all the ways the vehicle could be damaged are covered by a safety factor in analysis. The other risk of the project would be the cost due to the values of the parts because of their quality. Any parts that are not made to their specifications will have to be redone. There is a risk of allotted time allowed vs the amount of time to finish the project. Running the risk of either not finishing to create a quality product or finishing without a quality product is going to be a factor which is substantiated.

Part Purchasing

The parts list in Table C (Appendix C) is the list of parts that will be required to build this device. The Parts list itself is just a place holder to make sure that all the parts that are needed are either ordered or manufactured. The Budget in Table D (Appendix D) shows the parts, found location and cost. The Budget itself specifies that only 3 parts are going to be ordered from a different site of the other 10 parts. The most important part is going to be the prototype. This part is purchased separate from the others, the order came from amazon. The Wooden PLA was the most important because it reduces the cost of labor, time, and therefore money. The reason this reduces cost is because printing the project will show problems in manufacturing and design. These problems are fixed with less time and money due to the printed prototype.

The Drill Tap will be bought from MSC Industrial Supply Company. This part itself will make take the part that is a shaft drill it out and then tap with this specific tool. The Mahogany was another part that was going to have to be purchased from another location but was donated by Kelson Mills. This part will be lathed in the woodshop to create the wooden handle. All the other parts will be purchased from McMaster. The other parts will have a larger portion with the project and their designed purposes are stated up in the construction section.

Due to the change of the design the from design 3-6 the taking away of product linkage attachment to a purchased ball joint and then to a blank rod end. This increased the amount of cost of the project. At first the purchase of a ball joint saves the project labor time, but then happened to be one of the flaws in testing. The part didn’t allow for the device to shift into every gear. The linkage attachment had to be redesigned costing the project another $8.27 and 3 hours of labor. The spacers seen in drawing 20-0012-0013 (Appendix B3-14 to 15A) had to be recreated as their hole sized was incorrect. The bushing would not fit in that size of hole. Requiring another bushing to be made only costing 1 hours’ worth of labor. No parts cost required because new spacer 20-0014 (Appendix B3-15B) was machined from the scrap of the threaded sleeve like the spacers before it. Other decisions to the budget involved a larger swivel joint which costed more than the original by $21.30. The increase in the size of the swivel joint in turn increased the size and price of the threaded sleeve allowing for the angle of adjustment needed to shift. This was not price out in the beginning of the budget plan but was changed before purchasing.

The final Budget came in under cost as seen in Table D2 shows the actual spent cost. The $232.08 spent was under budget despite some of the setbacks in parts. The reason for this is due to the CWU machine shop purchasing the drill tap for their shop and allowing the use of this tool. The use of some of the scrap steel to machine the threaded sleeve was also a save to the budget as those parts had to be machined again. Another reason for being under budget was the removing of retaining rings and lock washers from the project due to the change in design. The budget came in at a total of $68.53 less than expected.

Outsourcing Labor

Currently there is no outsourcing of labor, all the labor will be done in the F.B.E.G. The manufacturing will be done by the companies own interns at CWU.

Labor

Joshua Franklin and Dustin Braun head this project. There are being paid $15 per hour. There are required to begin with creation through completion of this Project. The price of their labor is fair due to their inexperience in the field.

Estimate Total Project Cost

The total time it will take to complete the project itself will be 500 hours from start to finish. The current cost of parts is $300.60. The estimated labor cost is $7500. The current estimated total of the project will cost $7800.60. This final cost will include all parts and labor for: manufacturing, purchasing, documentation, testing, and designing the project.

Funding Source(s)

The only source of funding is from FB Engineering Group.

SCHEDULE

This project consists of designing, creating, manufacturing, testing, and documenting the completed product within a 9-month period. This project will outline have specific deadlines that meet the standards of any given project with the load of the two engineers working it. Table E (Appendix E) outlines the schedule that will be followed throughout this 9-month period as shown in Table 1.

Tasks

Over the 9-month schedule the object is to finish specific sections in allotted time. As shown below in Figure 1, one of the sections, the Proposal Outline is supposed to be finished by the first week of December. Other sections that are to be completed are:

- Analyses
- Documentation
- Proposal Modifications
- Parts Construction
- Device Construction
- Device Evaluation
- 495 Deliverables

Table 1

TASK: ID	Description	Est. (hrs)	Actua (hrs)	%Comp.	S	October	November	Dec
1	Proposal*							
1a	Outline	3	2	99		$		
1b	Intro	3	4	99		$		
1c	Methods	3	0.25	50				$
1d	Analysis	5	0.5	25				$
1e	Discussion	4	0	0				$
1f	Parts and Budget	7	4	20				$
1g	Drawings	4	3.92	80				$
1h	Schedule	5	1	10				$
1i	Summary & Appx	3	0	0				$
	subtotal:	37	15.7	42.5556				

These specific sections have their own required finish date as well as an estimated hour. This schedule is set to be accomplished in less than a 500-hours. This is the schedule the ASTS is set to and will be managed by Joshua Franklin.

The schedule in the proposal was made in order to follow the operation of the project to its succession. The objectives that this project had failed at producing were the setbacks that the project succumb to. The first experience that this project failed in was a proper or great design. The design portion needed to be summited within a certain amount of time. The project itself went through 6 different design phases before this submitting was required. These designs are a culmination of Appendix B2 through Appendix B4 as the final Design. This overall design changed throughout the entire project right up until the testing was completed. This project also receives shipping setbacks as companies had some delay in the arrival time of some products that were ordered. The other problems that were issued in this project were not finishing manufacturing for some of the products as they required the exact dimension of another to be made for press-fit purposes or hole location purposes. Things that took more time than expected: performing evaluation, website, test plan, and analyses had a part to the problems with the schedule.

Setbacks from the analyses came with the continue design changes in the beginning as the analyzing the new design was the analysis to acquire. Once the fourth design was chosen then the analyses began. The reason Franklin waited to do the analyses was because to him it seemed pointless to analyze something that wouldn't have worked in the first place. One could say that design was the thing that became a scheduling problem in the beginning.

The website was a real of testing Franklin was not diverse in. This portion of the project took time to learn and research to create. Franklin experienced his adolescence in creating and designing a website. Even though this took more time than Franklin had expected his schedule was not to far behind.

The test plan and prepping required more than just creating a test plan but creating test sheets and accomplishing the evaluation in a proper and thorough manner. Franklin felt the insistent need to make sure that every video and picture would be captured at the right time and every procedure written out. This test planning set back the project 5 hours more than expected.

The final setback was the evaluation of the product. The setback was caused by COVID-19. The reason was due to the meeting of people to be ill-advised. The problem with this advisement was that Franklin and Braun needed to meet to test the product. In turn they waited a little longer to test. The second setback came when the Linkage attachment only allowed the car to travel into third and fourth gear. This was then remedied by ordering another part and manufacturing a new linkage attachment (Appendix B3-7C). This took time and more money but then allowed them to do the rest of the testing that could not be accomplished during the first session.

Overall the Franklin struggle in the beginning keeping things on time but regained in the end working to stay on schedule and finishing on time.

PROJECT MANAGEMENT

Human Resources

Human resources are embellished by the engineers working on the ASTS. Ted Bramble and Matt Burvee are two faculty members at CWU that a big part to the success, quality, and ease of manufacturing this project. Both Have dedicated countless hours to improve, mentor, and consult on this project. They are invaluable members that are appreciated and used wisely.

Physical Resources

Matt Burvee is the manager of the machine shop at CWU where most of the manufacturing process will take place. His permission to use the shop is of the highest value as it allows for all the milling, lathing, CNC work, grinding, drilling, cutting, and press fit work to take place.
Scott Calahan runs the wood shop. Calahan is allowing the lathe work for the shifter knob to happen in his woodshop which is a valuable source of labor so that the part itself will not have to be outsource. Jeff Wilcox is allowing the engraving of some of the parts to be done by the laser machine. This will add to the quality of the products as they become higher in value and are needed for the creation of a project like this.

Soft Resources

Companies like Microsoft are invaluable to a project like this. Creating a space for a document such as the Word document this was written on to the countless tables from excel that have propelled this project to the quality of documentation that it has acquired. Solid-Works is a large part of this project as without it no parts would be created or designed as they are in Appendix B. The tools and usage of McMaster has been invaluable as their allowing of shared files of parts has allowed for easy understanding of the parts and their dimension as well as the ability to recreate the product based upon the documents they share.

Financial Resources

A Donation has been received by a Kelson Mills. Mills donated a piece of mahogany that is the shifter knob.

DISCUSSION

Design Evolution / Performance Creep

This project began with a discussion. Franklin and Braun decided that they wanted to work on a project together. Not just any project. They both wanted to create something they had never created before. Beginning brainstorming different ideas from a shallow boat launch trailer to the ASTS. As class began on the first day of the quarter Braun looked over at Franklin and said wait a second. Changing the entire plan for their senior year. After several minutes Braun designed Figure 4. This initial design was the catalyst for the entire project. Braun and Franklin then created their own separate portion of the project. Braun worked on the housing as his job was to lift the swivel joint 2 inches higher. Franklin then had to create the adjustability component. This portion of adjustment when through 6 different designs. This evolution is stated in the design conception section as well as in the success and failures below. Also stating why this design didn't work and why the final design was best design for this project.

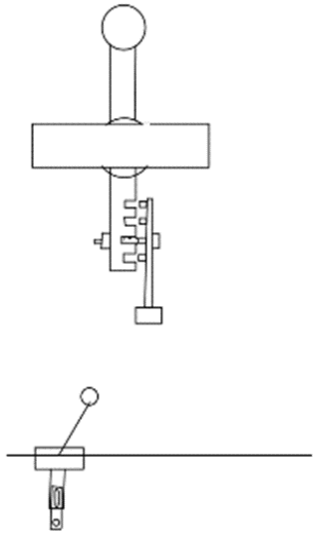

Figure 4

Project Risk Analysis

The projects biggest risk was to ruin the 2005 Ford Mustang. This vehicle not only had a real-world value of $6500. This Mustang also has a sentimental value that makes it priceless to the owner. The largest pressure was to make sure that the safety factors for this project were correct. Making sure that the material is correct and has the right proprieties to make sure that they still have the strength to withstand the stress place on the different components. Franklin had to make sure that his product wasn't going to harm or ruin this vehicle in any way.

Success/Failures

The press-fit for this swivel joint and the threaded sleeve were perfect. This success was due to the help of Matt Burvee. This press fit required a large amount of work that was slow, methodical, and precise. The piece also perfectly fit into Braun's Design allowing for more rotation like predicted. Failures were things like the original design. This design wouldn't allow for full rotation of the shaft that was necessary to make large enough shifts. This was remedied using a large swivel joint with an offset step shaft to create more rotation.

The only unattachable components will be the swivel ball joint and sleeve (Appendix B3-4,5). The swivel joint will be purchased and then manufactured to fit into the housing for tight tolerances. There was a mistake in the amount of angle of movement to shift. The original plan was to take the Ball Joint Sleeve (Appendix B3-5) and create chamfer on the inside that would allow for a larger angle. Matt Burvee suggested a safer solution which was to buy a larger Swivel Joint assembly. This larger Swivel joint will allow for the same angle rotation. The plus side of having a larger Inside Diameter (ID) will allow for the Threaded Sleeve to be lathed down to have a 1-inch section press fit into the piece with a smaller diameter for larger degree movement (Appendix B3-4B)

The original design of the Threaded Sleeve (Appendix B3-2A) was to have retaining ring (Appendix B3-11) that would hold the Sleeve from moving up and down. Burvee's suggestion for the Swivel joint also came with the knowledge that the retaining rings wouldn't be necessary, and they would only decrease the angle of movement of the Threaded Rod. The concept of Appendix B3-2B was created. Another setback was that the threaded rod didn't want to travel through the entirety of the sleeve. A portion had to be drilled to allow for the rod to travel all the way through the sleeve.

The Grade 8 Threaded rod is received (Appendix B3-1). A concern that began early on was that the material is so hard that it might not be able to be drilled and then tapped on one end. After consulting Burvee he thought of a great ball joint (Appendix B3-7B) that could be used so that the TR didn't need to be tapped and then threaded (Appendix B3-1B).

The Linkage Attachment, 20-0007 (Appendix B3-7A), was to be a small block which will be lathed at first to create that ¼"-20 thread from drawing. Once machined the cylinder will then be set to a dye and will be given threads. The Linkage attachment was going to be complex and to be extremely precise. To solve many issues that had risen Burvee's previous suggested saved this from being a problem. The Linkage attachment would then go from difficult part to manufacture to an even better part as a ball joint (Appendix B3-7B). Unfortunately, this ended up failing during testing. This ball joint would only allow the shifter to move into third and fourth gear. This problem was solved using 20-0014 (Appendix B3-7C) which made sure that the linkage rod would not rotate around the linkage attachment. This then allowed for the shifter to travel into all gears.

The shifter itself was a part that was designed to be pleasing to the eye but a difficult concept to manufacture. The shifter original was a sleek and well tapered concept as shown in Appendix B3-6A. A much simpler design was created as shown in Appendix B3-6B through B3-6D. This takes the tapered concept and simplifies it to a shorter taper distance. This part itself did have machine problems as zeroing in this product on a metal lathe can be quite tedious. The hole locations are also very important as they must match up perfectly with the shifter bracket. Another issue with lathing a rectangular object is the interrupted cutting. Interrupted cuts create a lot of issues in terms of the project staying zeroed and symmetry. Looking at the shifter one might be able to notice a 1-2-degree linearity problem. After lathing the edges that were cut had to filed down more to give the shifter a better look and even cut throughout the taper.

The Lock washers (Appendix B3-10) ended up just being unnecessary for the tension required of the shifter bracket and shifter. The lock washers also pushed out the shifter bolts more, so they were rid of immediately to reduce the distance the bolts pushed out.

The final part as shown in Figure 2 is drawing 20-0008 (Appendix B3-8). The only problem is that the tapping insert might create a brittle end by threading the wood on the end. The problem during manufacturing is that due to the cheap material while threading the insert in the hex nut broke. This solution was solved by the grinding off the remaining material so make it look smooth.

Next phase

The next phase of this project would be to create a lighter easier to assemble system. Other parts of the next phase would include create a new boundary of parameters instead of using the Safety factors of the stock system for the design. An attempt to make it sleeker or more appealing to the eye would also be a goal.

CONCLUSION

This Project from start to finish was about learning how to create as an Engineer. Franklin and Braun Spent their time on learning as inventors how to create an idea of their own. This project is only a concept. This concept is one that proves that a design can be made that will allow for the adjustment of throw for a vehicle. From the initial design to the final design all have allowed for the adjustability of throw. This design is the first of its kind and has never been created before. The model as shown in Figure 3 meets the functional requirements of adjusting and other requirements set.

ASTS Market Readiness

How far is this product away from production? This project conceptualized adjustability of throw. Unfortunately, this device was made for a genre of Mustangs. The only way to create something at this level of production would be to analyze the most popular transmission and create something similar or future transmissions and adjust to its requirements. This concept would have to be re-conceptualized to fit multiple transmissions and then marketed to only the higher luxury or aftermarket of vehicles. This product is still in the beginning stages of design as improvements can be made.

Analysis to Success

The success of this project is due to the analysis of the original shifter. The structural integrity and strength needed to be duplicated or improve on for this model to be a successful. The success was in knowing how to analyze the failure points of this design. Then to improve or match the that same strength. The model created nearly double the internal shaft safety factor with a stress yield of 120,000 psi. This model if anything is absolute overkill in terms of analytically meeting the safety requirements. Another model could eventually be created as to see how far lowered the safety factor and still not effect performance.

Performance

This project was required to and expected to meet all the requirements. The device simply adjusted inside the cockpit and to shift the vehicle into all gears. This device accomplished those function and succeeded at more:

Predicted Performance/Requirements	Actual Performance
○ Adjust to decrease the throw between 20%-40% for shorter shifts (was predicted to travel from 20-50%).	✓ This test clamed success by achieving a Reduction of stock by a percentage of 38-66%.

- Adjustable from inside the car in under 60 seconds (No Prediction).
- The Safety Factor must be the same or better than 2005 - 2009 Ford Mustang GT manual transmission factory shifter (50,800 psi required)
- Reduce the force required to shift by a factor 10% (No Prediction).
- The shifter must withstand a load of 50 lbs. with less than 5% deflection (No Prediction).

✓ A total average of 50.00 seconds from part one and two (Appendix G1-Test Two) was found concluding the success of the device.

✓ Internal Threaded Rod with a Yield Stress of 120,000 psi.

✓ For a Reduction between 28.9-50.1% less force for the individual shifters average.

✓ Analyses show less than 1% deflection (Appendix A6,9)

This product performed with success in the required areas and went beyond even to meet the benchmark of this project by beating the short throw shifter by reducing its throw by 50%. This project met the budget and the schedule to the final due date. Most importantly this device made for a smooth and fun drive.

ACKNOWLEDGEMENTS: FOR GIFTS, ADVISORS AND OTHER CONTRIBUTORS

Matt Burvee, Ted Bramble-Advisor and Contributor

Burvee is the manager of the machine shop at CWU where most of the manufacturing process will take place. Their permission to use the shop is of the highest value as it allows for all the milling, lathing, CNC work, grinding, drilling, cutting, and press fit work to take place. Burvee also gifted small metals, nuts to this project as well. Both Bramble and Burvee dedicated their time to this project.

Scott Calahan-Contributor

Calahan runs the wood shop. Calahan is allowing the lathe work for the shifter knob to happen in his woodshop which is a valuable source of labor so that the part itself will not have to be outsource.

Jeff Wilcox-Contributor

Wilcox is allowing the engraving of some of the parts to be done by the laser machine. This will add to the quality of the products as they become higher in value and are needed for the creation of a project like this.

Kelson Mills-Gift

Mills donated a piece of mahogany that is the shifter knob.

CWU-Contributor

CWU is the reason that classes and people like these are here to help create, develop, and manufacture products like the ASTS. This project would not have been successful or inventible without the contributions that this education system has made to creating a program that can teach students how to become true engineers.

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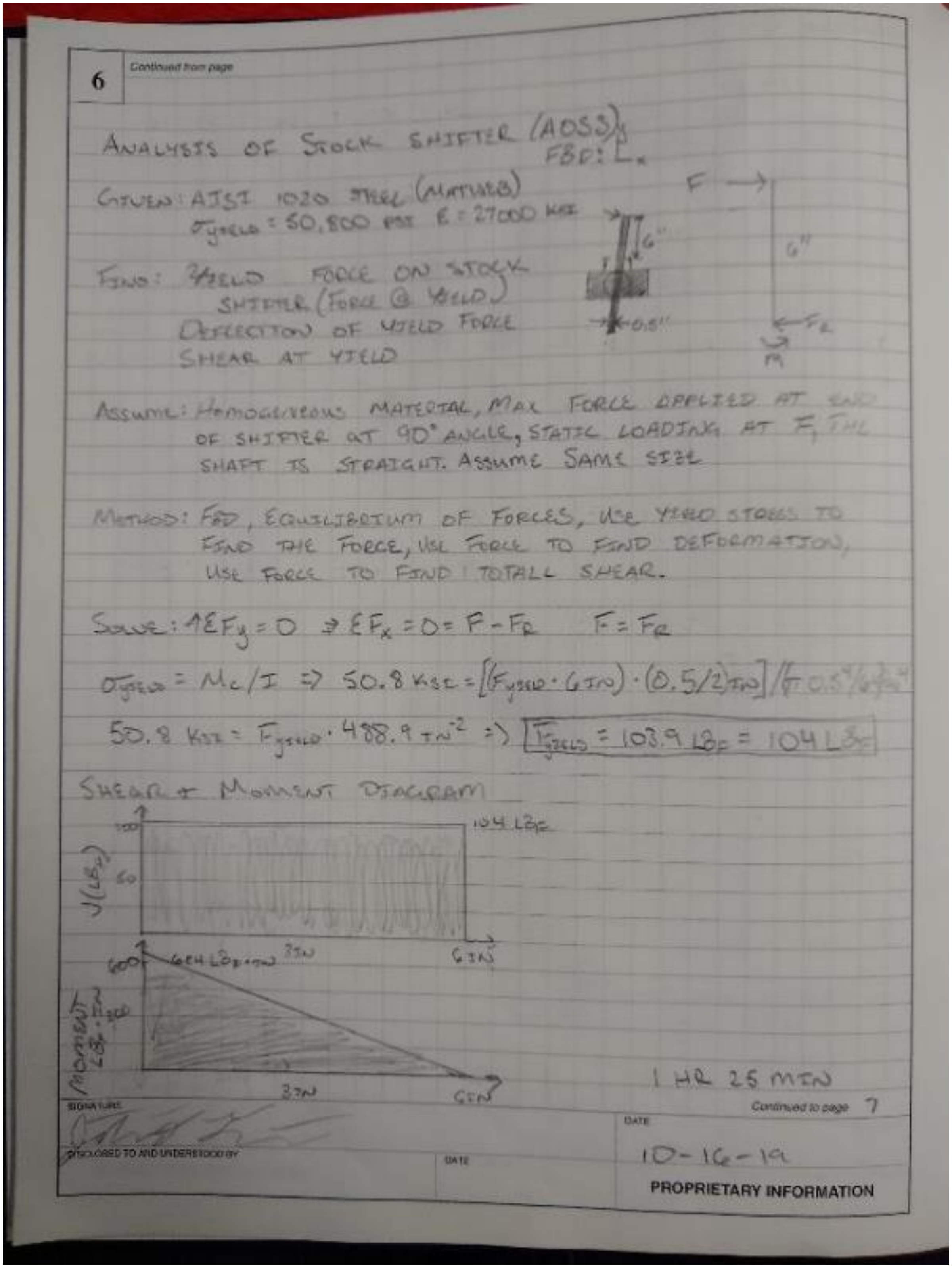
APPENDIX A-ANALYSES

Appendix A1-Analysis of Stock Shifter (AOSS) Yield



Appendix A1-2 AOSS Yield Force

Continued from page 6

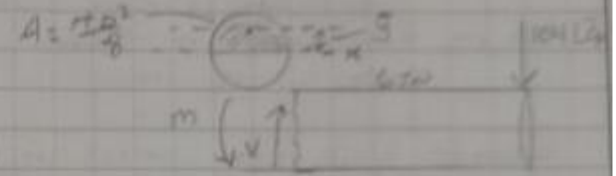
7

DEFORMATION APPENDIX TABLE A14-2 PAGE 803 OPTIONA (MEMD 6TH EDITION)

$y_B = y_{MAX} = -PL^3/3EI$ MAX DEFLECTION AT YIELD

$y_{MAX} = [-104\ LB_F \cdot (6\ IN)^3] / [3 \cdot 27000\ KSI \cdot 3.07E\text{-}3\ IN^4]$

$\boxed{y_{MAX} = 0.09\ IN}$



TOTAL SHEAR

$F = F_R = V = 104\ LB_F$ (PAGE 6)

$\tau = VQ/IT = [104\ LB_F \cdot (0.125 \cdot (\pi\ 0.5^2/8))\ IN^3] / [3.07E\text{-}3\ IN^4 \cdot 0.5\ IN]$

$\boxed{\tau_{TRANSVERSE} = 831.99\ PSI \doteq 832\ PSI}$

$\tau_{DIRECT} = F/A_S = 104\ LB_F / (\pi\ 0.5^2/4)\ IN^2 = 529.6\ PSI$

$\boxed{\tau_{DIRECT} = 530\ PSI}$

TOTAL SHEAR

$\tau_{TOTAL} = 832\ PSI + 530\ PSI = 1362\ PSI$

$\boxed{\tau_{TOTAL} = 1362\ PSI}$

45 MIN

Continued to page 8

SIGNATURE

DATE 10-17-19

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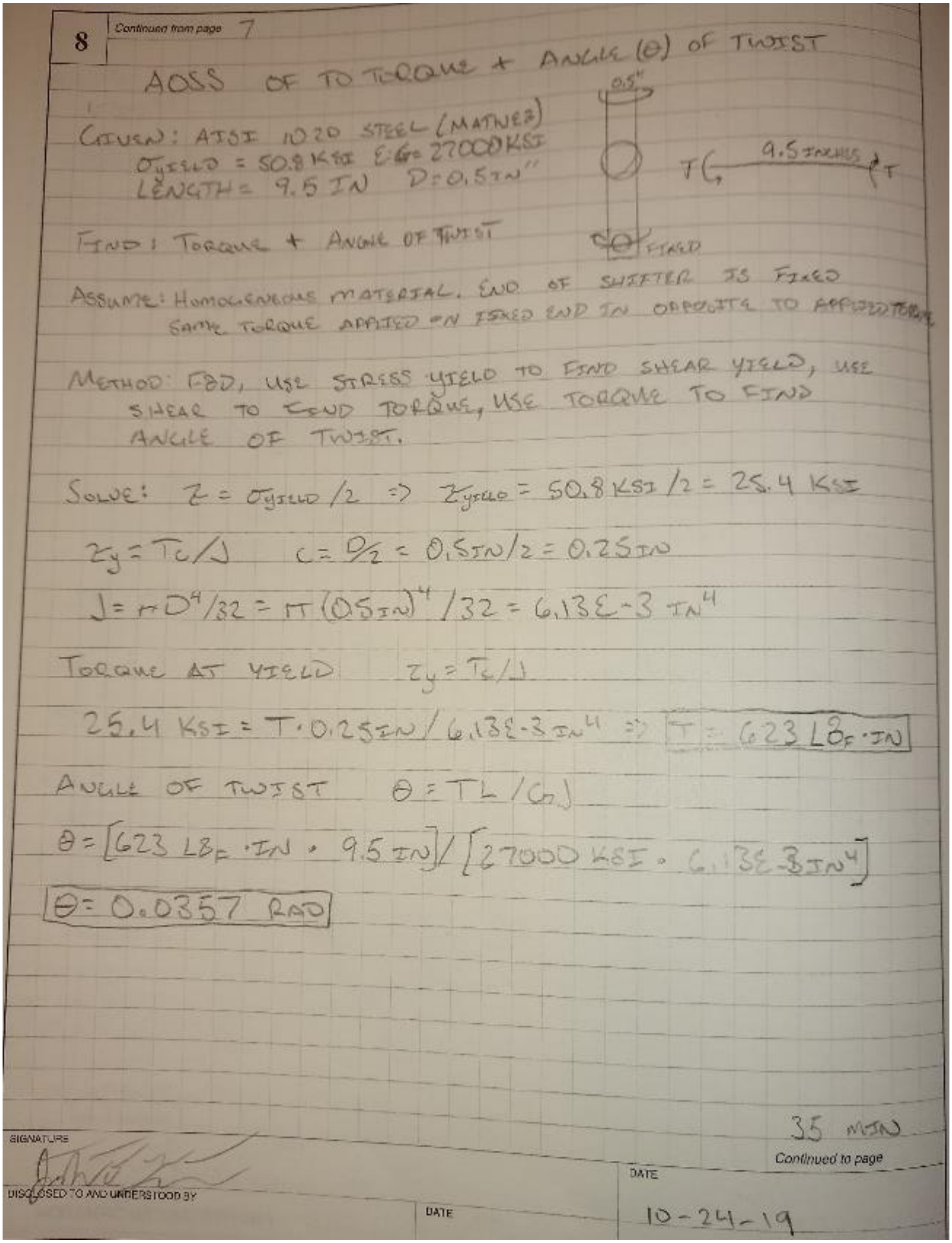
DATE

PROPRIETARY INFORMATION

Appendix A1-3 AOSS Yield Shear & Deflection

Appendix A2-AOSS Torque on Internal Rod



8 Continued from page 7

AOSS OF TO TORQUE + ANGLE (θ) OF TWIST

GIVEN: AISI 1020 STEEL (MATWEB)
σ_{yield} = 50.8 KSI E:G= 27000 KSI
LENGTH = 9.5 IN D = 0.5 IN"

FIND: TORQUE + ANGLE OF TWIST

ASSUME: HOMOGENEOUS MATERIAL. END OF SHIFTER IS FIXED
SAME TORQUE APPLIED ON FIXED END IN OPPOSITE TO APPLIED TORQUE

METHOD: FBD, USE STRESS YIELD TO FIND SHEAR YIELD, USE SHEAR TO FIND TORQUE, USE TORQUE TO FIND ANGLE OF TWIST.

SOLVE: $\tau = \sigma_{yield}/2 \Rightarrow \tau_{yield} = 50.8\ \text{KSI}/2 = 25.4\ \text{KSI}$

$\tau_y = Tc/J \quad c = D/2 = 0.5\ \text{IN}/2 = 0.25\ \text{IN}$

$J = \pi D^4/32 = \pi(0.5\ \text{IN})^4/32 = 6.13E\text{-}3\ \text{IN}^4$

TORQUE AT YIELD $\tau_y = Tc/J$

$25.4\ \text{KSI} = T \cdot 0.25\ \text{IN}/6.13E\text{-}3\ \text{IN}^4 \Rightarrow \boxed{T = 623\ \text{LB}_F \cdot \text{IN}}$

ANGLE OF TWIST $\theta = TL/GJ$

$\theta = [623\ \text{LB}_F \cdot \text{IN} \cdot 9.5\ \text{IN}]/[27000\ \text{KSI} \cdot 6.13E\text{-}3\ \text{IN}^4]$

$\boxed{\theta = 0.0357\ \text{RAD}}$

35 MIN

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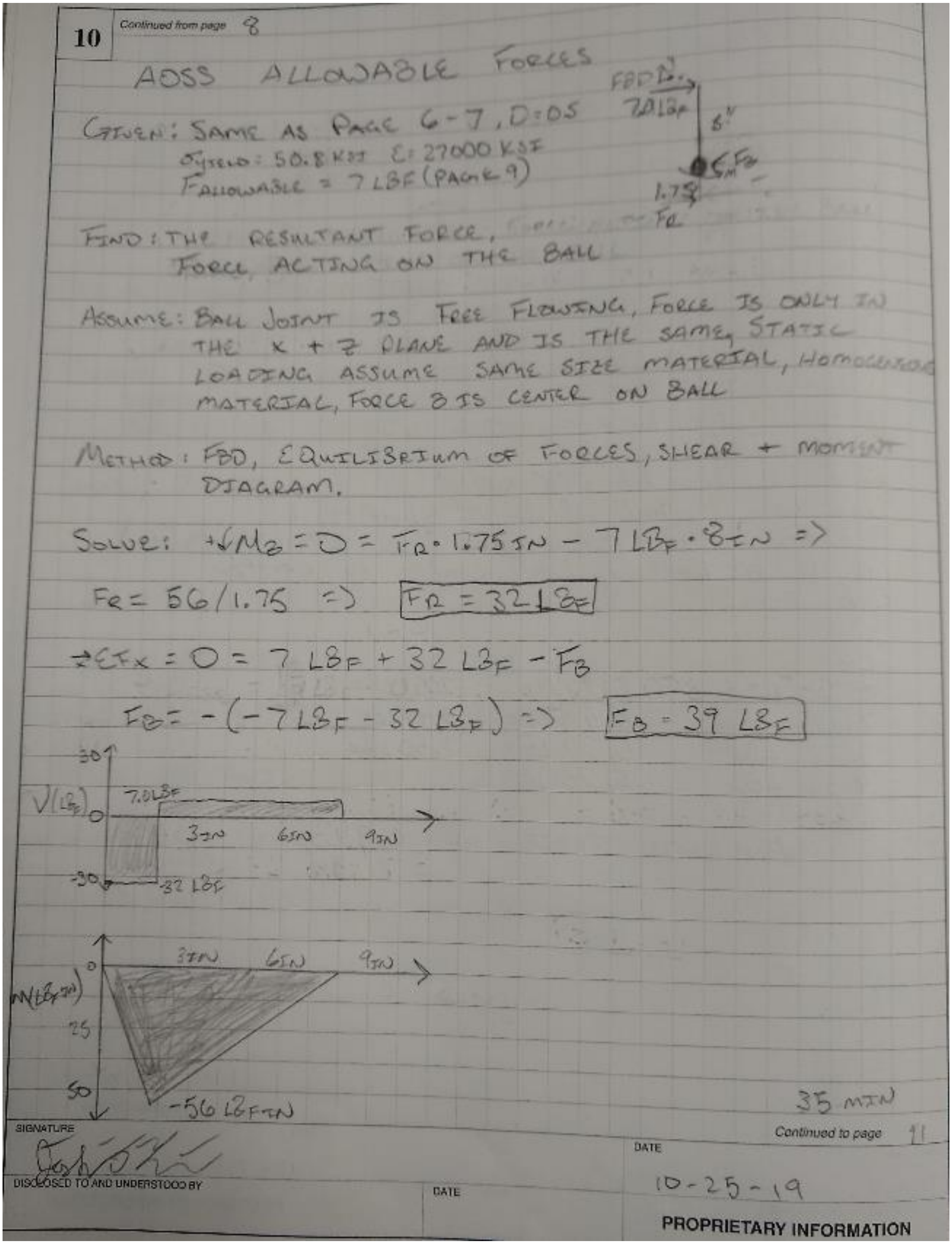
Appendix A2 AOSS Torque & Angle of Twist

Appendix A3-AOSS Forces on Ball Joint and Linkage Attachment


10 Continued from page 8

AOSS ALLOWABLE FORCES

GIVEN: SAME AS PAGE 6-7, D=.05
σ_{YIELD} = 50.8 KSI E = 27000 KSI
$F_{ALLOWABLE}$ = 7 LBF (PAGE 9)

FIND: THE RESULTANT FORCE, FORCE ACTING ON THE BALL

ASSUME: BALL JOINT IS FREE FLOWING, FORCE IS ONLY IN THE X + Z PLANE AND IS THE SAME, STATIC LOADING ASSUME SAME SIZE MATERIAL, HOMOGENEOUS MATERIAL, FORCE B IS CENTER ON BALL

METHOD: FBD, EQUILIBRIUM OF FORCES, SHEAR + MOMENT DIAGRAM.

FBD: 7.0 LBF, 8", F_B, 1.75", F_R

SOLVE: $+\circlearrowleft M_B = 0 = F_R \cdot 1.75\,IN - 7\,LB_F \cdot 8\,IN \Rightarrow$

$F_R = 56/1.75 \Rightarrow \boxed{F_R = 32\,LB_F}$

$\rightarrow \Sigma F_x = 0 = 7\,LB_F + 32\,LB_F - F_B$

$F_B = -(-7\,LB_F - 32\,LB_F) \Rightarrow \boxed{F_B = 39\,LB_F}$

V (LBF): 30, 0, -30; 7.0 LBF; -32 LBF; 3 IN, 6 IN, 9 IN

M (LBF-IN): 0, 25, 50; 3 IN, 6 IN, 9 IN; -56 LBF-IN

35 MIN

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Continued to page 11

PROPRIETARY INFORMATION

Appendix A3 AOSS Forces Acting on Linkage Attachment and Ball Joint

Appendix A4-AOSS Allowable Forces

Continued from page 10

11

AOSS STRESS, DEFORMATION, TOTAL SHEAR

GIVEN: SAME AS PAGE 6-7 + PAGE 10 7.0 LBF   FBD ... THE SAME ON PAGE 6

FIND: ALLOWABLE STRESS, DEFORMATION + SHEAR + COMPARE TO YIELD VALUES ON PAGE 6-7.

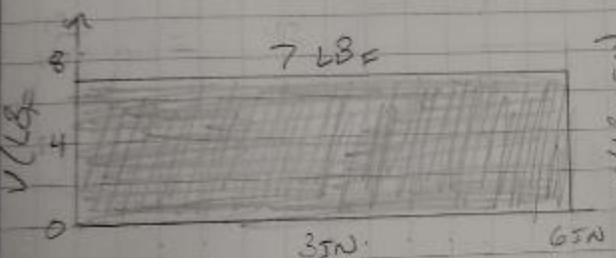
ASSUME: SAME AS PAGE 6

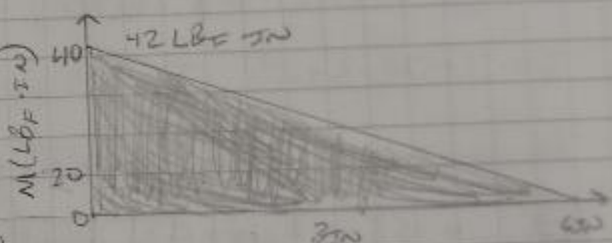
METHOD: FBD, EQUILIBRIUM FORCES, SHEAR + MOMENT, DEFORMATION + TOTAL SHEAR.

SOLVE: $+\uparrow \Sigma F_y = 0 = F - F_R = 7.0\ LB - F_R \Rightarrow F_R = 7.0\ LB_F$ (PAGE 6)

$+\circlearrowleft M = -7.0\ LB_F \cdot 6\ IN + M = 0 \quad M = 42\ LB_F \cdot IN$

$C = 0.5\ IN/2 = 0.25\ IN \quad I = (\pi D^4/64)\ IN^4 = (\pi 0.5^4/64)\ IN^4 = 3.07E\text{-}3\ IN^4$





STRESS ALLOWABLE $\sigma_{ALLOW} = Mc/I$

$\sigma_{ALLOW} = [42\ LB_F \cdot IN \cdot 0.25\ IN] / [3.07E\text{-}3\ IN^4]$

$\boxed{\sigma_{ALLOW} = 3422\ PSI}$

σ_{ALLOW} 3422 PSI < σ_{YIELD} 50,800 PSI ✓

15 MIN

Continued to page 12

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PROPRIETARY INFORMATION

Appendix A4-1 AOSS Allowable Stress

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Continued from page 11

DEFORMATION APPENDIX TABLE A14-2 PAGE 803
OPTION A (MEMD 6TH EDITION

$y_B = y_{max} = -PL^3/3EI$ MAX DEFLECTION ALLOWABLE FORCE

$y_{ALLOW} = [-7\ LB_F \cdot (6\ IN)^3] / [3 \cdot 27000\ KSI \cdot 3.07E\text{-}3\ IN^4]$

$E = 27000\ KSI$ (PAGE 6) $I = 3.07E\text{-}3\ IN^4$ (PAGE 11)

$\boxed{y_{ALLOW} = 0.0061\ IN}$ $y_{ALLOW} = 0.0061\ in < y_{YIELD} = 0.09\ IN$ ✓

ALLOWABLE TOTAL SHEAR

USING ILLUSTRATION ON PAGE 7 BUT 7 LBF INSTEAD.

$F_{ALLOW} = 7\ LB_F = V$ $\tau_{TRANSVERSE} = VQ/IT$

$Q = (0.125\ IN)(\pi\, 0.5^2/8)\ IN^2) = 0.0123\ IN^3$

$I = 3.07E\text{-}3\ IN^4$ $T = 0.5\ IN$

$\tau_{TRANSVERSE} = [7\ LB_F \cdot 0.0123\ IN^3] / [3.07E\text{-}3\ IN^4 \cdot 0.5\ IN]$

$\boxed{\tau_{TRANS} = 55.99\ psi = 56\ PSI}$

$\tau_{DIRECT} = F/A_s = 7\ LB_F / [\pi\, 0.5^2/4]\ IN^2 = 35.7\ PSI$

$\boxed{\tau_{DIRECT} = 36\ PSI}$

$\boxed{\tau_{TOTAL} = 56\ PSI + 36\ PSI = 92\ PSI}$

$\tau_{ALLOW} = 92\ PSI < \tau_{YIELD\ TOTAL} = 1362\ PSI$ ✓

25 MIN

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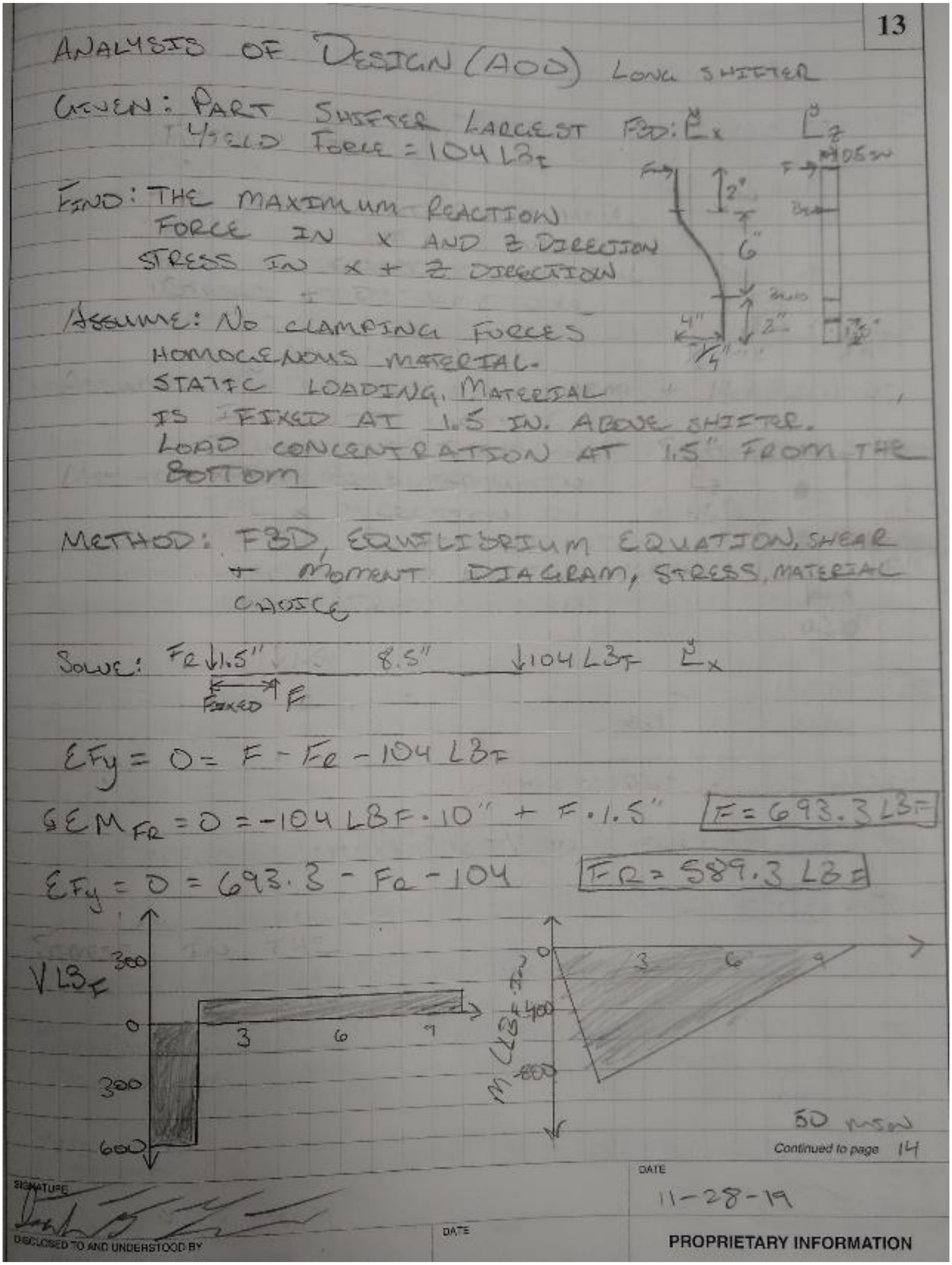
DATE 10-25-19

Appendix A4-2 AOSS Allowable Shear and Deflection

Appendix A5- Analysis of Design (AOD) Long Shifter



13

ANALYSIS OF DESIGN (AOD) LONG SHIFTER

GIVEN: PART SHIFTER LARGEST YIELD FORCE = 104 LBF

FBD: $\llcorner_x$ $\llcorner_z$

FIND: THE MAXIMUM REACTION FORCE IN X AND Z DIRECTION STRESS IN X + Z DIRECTION

ASSUME: NO CLAMPING FORCES HOMOGENOUS MATERIAL. STATIC LOADING. MATERIAL IS FIXED AT 1.5 IN. ABOVE SHIFTER. LOAD CONCENTRATION AT 1.5" FROM THE BOTTOM

METHOD: FBD, EQUILIBRIUM EQUATION, SHEAR + MOMENT DIAGRAM, STRESS, MATERIAL CHOICE

SOLVE: $F_R \downarrow 1.5''$ $8.5''$ $\downarrow 104$ LBF $\llcorner_x$

FIXED $\uparrow F$

$\Sigma F_y = 0 = F - F_R - 104$ LBF

$\Sigma M_{FR} = 0 = -104\text{ LBF} \cdot 10'' + F \cdot 1.5''$ $\boxed{F = 693.3\text{ LBF}}$

$\Sigma F_y = 0 = 693.3 - F_R - 104$ $\boxed{F_R = 589.3\text{ LBF}}$

50 MSW

Continued to page 14

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Appendix A5-1 AOD Long Shifter Forces

14 Continued from page 13

AOD LONG SHIFTER

STRESS IN THE x DIRECTION

$M = 884$ LBF·IN $I = \frac{1}{12} \cdot 0.5 \cdot 0.25^3 = 6.51E{-4}$ IN^4

$\sigma = Mc/I = 884$ LBF $\cdot (0.25/2)$ IN $/ 6.51E{-4}$ IN^4

$\sigma = 170$ KSI

STRESS IN THE Z DIRECTION

$M = 884$ LBF·IN $I = \frac{1}{12} \cdot 0.25 \cdot 0.5^3 = 0.0026$ IN^4

$\sigma = Mc/I$ 884 LBF $\cdot (0.5/2) / 0.0026$ IN^4

$\sigma = 85$ KSI

ONLY STEEL BARS AT THIS SIZE ARE HARDENED. CANNOT USED HARDENED STEEL BECAUSE IT WONT BE MACHINEABLE.

REDESIGN THICKNESS WILL BE 3/8" AND WIDTH WILL BE 5/8"

STRESS IN x DIRECTION

$\sigma = Mc/I = 884$ LBF $\cdot (0.375/2)$ IN $/ (\frac{1}{12} \cdot 0.625 \cdot 0.375^3)$ IN^4

$\sigma = \boxed{60.3 \text{ KSI}}$

STRESS IN Y DIRECTION

$\sigma = Mc/I = 884$ LBF $\cdot (0.625/2)$ IN $/ (\frac{1}{12} \cdot 0.375 \cdot 0.625^3)$ IN^4

$\sigma = \boxed{36.2 \text{ KSI}}$

1095 SPRING STEEL (76.1 KSI)

2 HRS

Continued to page 15

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DATE 12-2-19

Appendix A5-2 AOD Long Shifter Stress

AOD LONG SHIFTER

15

GIVEN: New DESIGN 3/8" x 5/8" FBD PAGE 13
AISI 1095 STEEL
YIELD STRENGTH = 76.1 KSI $E = 29.7 \times 10^6$ PSI

FIND: SHEAR TOTAL 1.5" FROM THE BOTTOM
+ DEFLECTION

ASSUME: PAGE 13

METHOD: PAGE 13, DEFORMATION, TOTAL STRESS

SOLUTION: DEFORMATION APPENDIX TABLE A14-2 pg 803
OPTION A (MCMD 6TH EDITION)

$y_B = y_{max} = -PL^3/3EI$ MAX DEFLECTION AT YIELD LOADING

$y_{YIELD(X)} = -104\ LB_F \cdot 8.5\ IN / 3 \cdot 29.7 \cdot 10^6\ PSI \cdot 0.00275\ IN^4 = \boxed{0.0086\ IN}$

$y_{(YIELD(Z))} = -104\ LB_F \cdot 8.5\ IN / 3 \cdot 29.7 \cdot 10^6\ PSI \cdot 0.00763\ IN^4 = \boxed{0.0013\ IN}$

TOTAL SHEAR X + Z DIRECTION ∴ 3/8" 5/8" V 8.5"

$V_x = V_z = 104\ LBF$

$\tau_{TRANSVERSE\ X} = [104\ LB_F \cdot ((3/8 \div 4)(5/8 \cdot (3/8 \div 2)\ IN^3))] / 0.00275\ IN^4 \cdot 5/8\ IN = 664\ PSI$

$\tau_{TRANSVERSE\ Z} = [104\ LB_F \cdot ((5/8 \div 4)(3/8 \cdot (5/8 \div 2)\ IN^3))] / 0.00763\ IN^4 \cdot 3/8\ IN = 665\ PSI$

$\tau_{DIRECT} = F/A = 104\ LB_F / 3/8" \cdot 5/8" = 443.73\ PSI$

$\tau_{TOTAL\ X} = \boxed{1107\ PSI}$
$\tau_{TOTAL\ Y} = \boxed{1108\ PSI}$

DOESNT EXCEED THE MATERIAL STRESS

35 MIN

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DATE

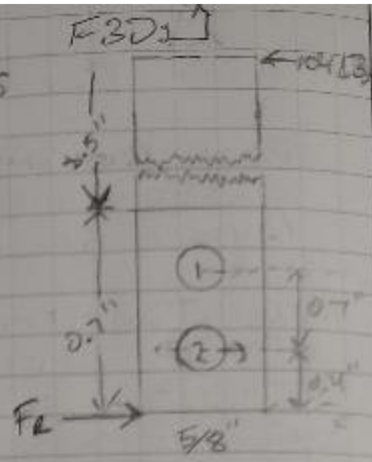
PROPRIETARY INFORMATION

Appendix A5-3 AOD Long Shifter Shear and Deformation

Appendix A6-AOD Long Shifter Holes

16 Continued from page 15

AOD LONG SHIFTER HOLE ANALYSIS



GIVEN: MATERIAL 1095 SPRING STEEL, PLATE WITH HOLE EQUATION FROM (MEMD 6TH EDITION PAGE 812)

$\sigma_{nom} = 6M w / (w^3 - d^3) t$

FIND STRESS AROUND THE HOLES DUE TO BENDING.

ASSUME: NEGLECT THE SECOND HOLE WHILE DOING THE CALCULATION FOR THE OTHER. ASSUME NO IMPERFECTIONS & STATIC LOADING. FIXED AT HOLES NEGLECT FORCES IN THE X DIRECTION. NO FORCE AT HOLE 1.

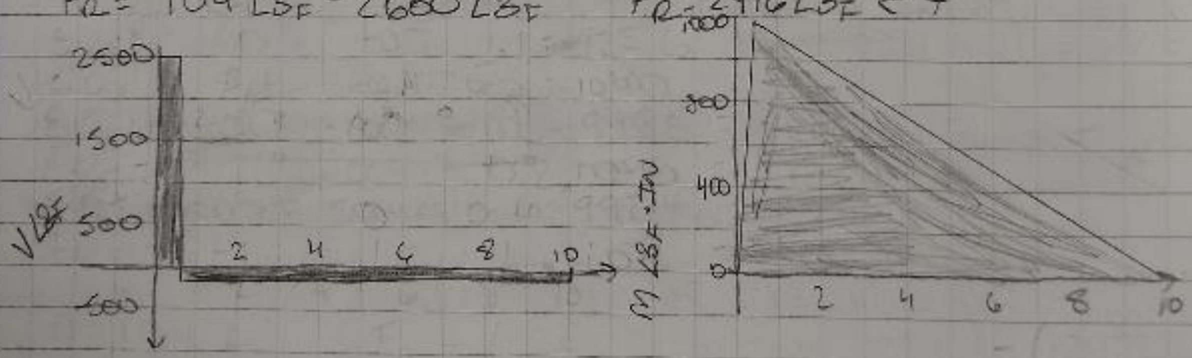
METHOD FIND MOMENT AT EACH HOLE USING THE SAME 104 LBF. USE EQUATION IN THE GIVEN.

SOLVE $F_1 = 0$ $+\uparrow \Sigma F_y = 0 = 104\ LB_F - F_2 - F_R$ $\quad F_R = 104\ LB_F - F_2$

$+↺\Sigma M_1 = 0 = 104\ LB_F \cdot 8.9'' + F_2 \cdot 0.7'' + F_R \cdot 1.1''$

$0 = 104\ LB_F \cdot 8.9'' + F_2 \cdot 0.7'' + (104\ LB_F - F_2) \cdot 1.1''$ $\quad F_2 = 2600\ LB$

$F_R = 104\ LB_F - 2600\ LB_F$ $\quad F_R = 2496\ LB_F \leftarrow +$



1 HR 50 MIN

Continued to page 17

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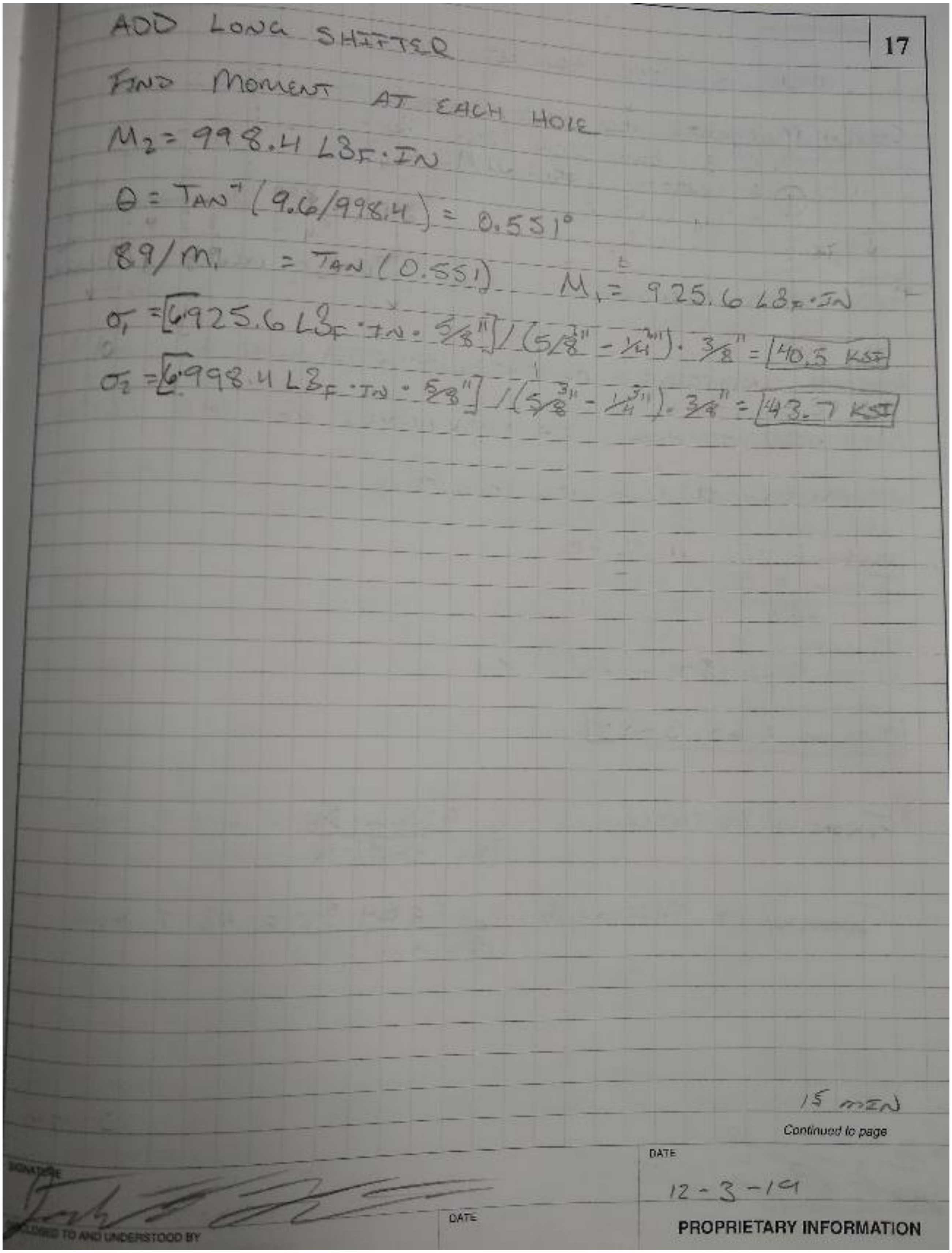
Appendix A6-1 AOD Long Shifter Holes Forces


17

AOD LONG SHIFTER

FIND MOMENT AT EACH HOLE

$M_2 = 998.4\ LB_F \cdot IN$

$\theta = TAN^{-1}(9.6/998.4) = 0.551^\circ$

$89/M_1 = TAN(0.551)$ $M_1 = 925.6\ LB_F \cdot IN$

$\sigma_1 = [6 \cdot 925.6\ LB_F \cdot IN \cdot 5/8''] / (5\,3/8'' - 1\,3/4'') \cdot 3/8'' = \boxed{40.5\ KSI}$

$\sigma_2 = [6 \cdot 998.4\ LB_F \cdot IN \cdot 5/8''] / (5\,3/8'' - 1\,3/4'') \cdot 3/8'' = \boxed{43.7\ KSI}$

15 MIN

Continued to page

DATE 12-3-19

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PROPRIETARY INFORMATION

Appendix A6-2 AOD Long Shifter Holes Stress

Appendix A7-AOD Shifter Bracket Holes

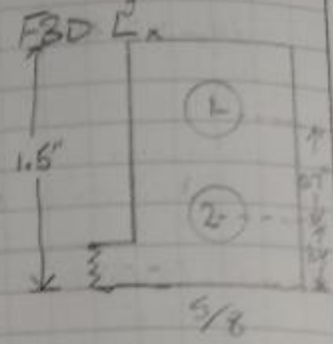
18 Continued from page

AOD SHIFTER BRACKET HOLE

GIVEN: MOMENTS AT HOLES FROM PAGE 16 FOR 17. GIVEN EQUATION PAGE 16 FOR HOLE ANALYSIS. $\sigma_{nom} = 6M_w/(w^3-d^3)t$

$M_1 = 925.6$ LBF·IN $M_2 = 998.4$ LBF·IN

$t = 0.25$



FIND: STRESS AROUND THE HOLE DUE TO BENDING.

ASSUME: HOMOGENOUS MATERIAL, STATIC LOADING.

METHOD. BENDING IN THE PLANE OF THE PLATE.

$$\sigma_{1nom} = \frac{6 \cdot 925.6\ LB_F \cdot IN \cdot 5/8}{(5/8^3 - 1/4^3) \cdot 1/4}$$

$$\boxed{\sigma_{1\,nom} = 60.8\ KSI}$$

$$\sigma_{2nom} = \frac{6 \cdot 998.4\ LB_F \cdot IN \cdot 5/8}{(5/8^3 - 1/4^3) \cdot 1/4}$$

$$\boxed{\sigma_{2\,nom} = 65.5\ KSI}$$

$$\sigma_{1\,nom}\ \text{W/ 3/8 THICKNESS} = \frac{6 \cdot 925.6 \cdot 5/8}{(5/8^3 - 1/4^3) \cdot 3/8} = 40.5\ KSI$$

$$\sigma_{2\,nom}\ \text{W/ 3/8 THICKNESS} = \frac{6 \cdot 998.4 \cdot 5/8}{(5/8^3 - 1/4^3) \cdot 3/8} = 43.7\ KSI$$

30 MIN

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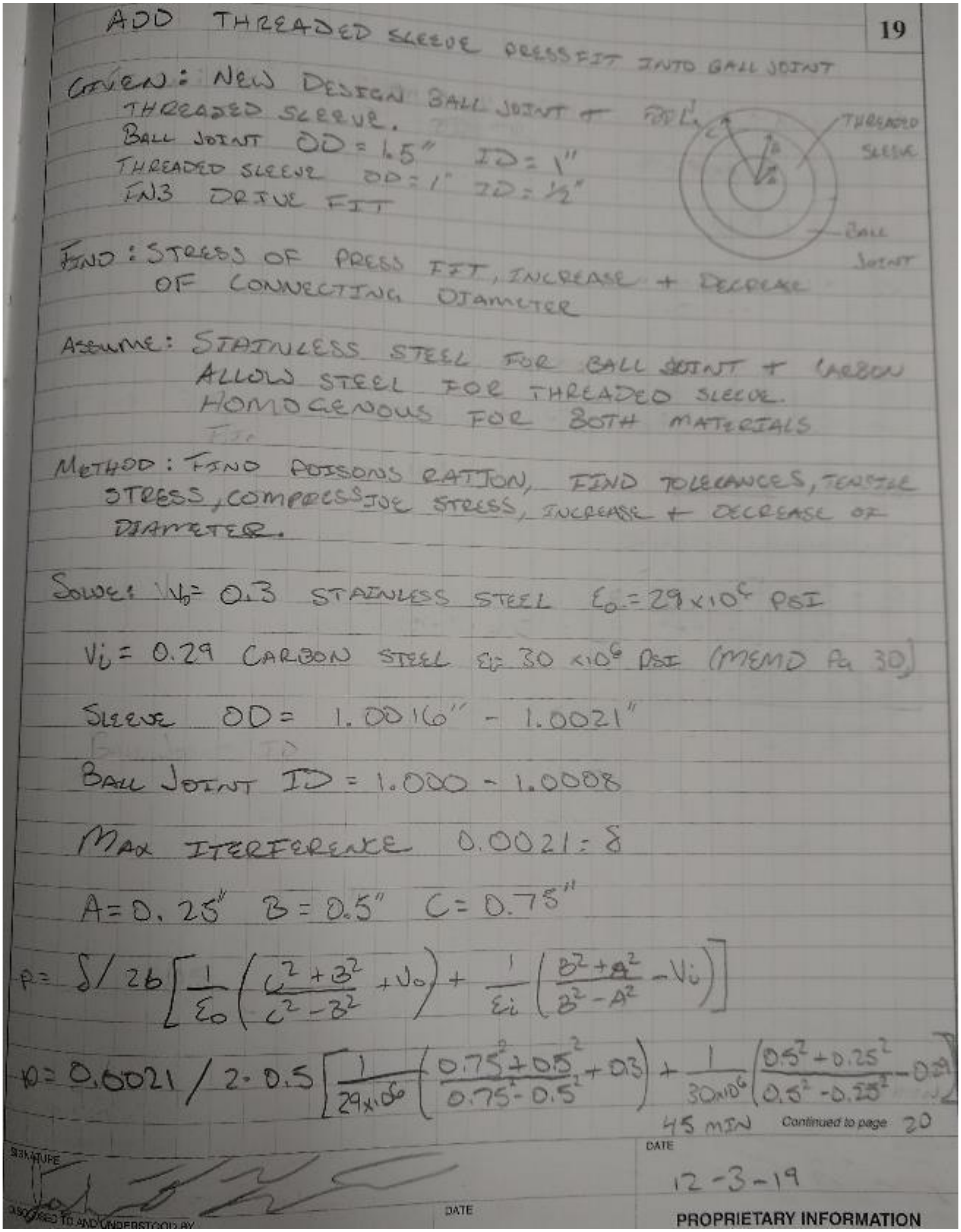
Appendix A7 AOD Shifter Bracket Holes

Appendix A8-AOD Press Fit Swivel Joint



AOD THREADED SLEEVE PRESSFIT INTO BALL JOINT

19

GIVEN: NEW DESIGN BALL JOINT + THREADED SLEEVE.

BALL JOINT OD = 1.5" ID = 1"

THREADED SLEEVE OD = 1" ID = ½"

FN3 DRIVE FIT

FIND: STRESS OF PRESS FIT, INCREASE + DECREASE OF CONNECTING DIAMETER

ASSUME: STAINLESS STEEL FOR BALL JOINT + CARBON ALLOW STEEL FOR THREADED SLEEVE. HOMOGENOUS FOR BOTH MATERIALS

METHOD: FIND POISONS RATTON, FIND TOLERANCES, TENSILE STRESS, COMPRESSIVE STRESS, INCREASE + DECREASE OF DIAMETER.

SOLVE: $V_o = 0.3$ STAINLESS STEEL $E_o = 29 \times 10^6$ PSI

$V_i = 0.29$ CARBON STEEL $E_i = 30 \times 10^6$ PSI (MEMO Pg 30)

SLEEVE OD = 1.0016" - 1.0021"

BALL JOINT ID = 1.000 - 1.0008

MAX ITERFERENCE 0.0021 = δ

A = 0.25" B = 0.5" C = 0.75"

$$p = \delta / 2b \left[\frac{1}{E_o}\left(\frac{C^2 + B^2}{C^2 - B^2} + V_o \right) + \frac{1}{E_i}\left(\frac{B^2 + A^2}{B^2 - A^2} - V_i \right) \right]$$

$$p = 0.0021 / 2 \cdot 0.5 \left[\frac{1}{29 \times 10^6}\left(\frac{0.75^2 + 0.5^2}{0.75^2 - 0.5^2} + 0.3 \right) + \frac{1}{30 \times 10^6}\left(\frac{0.5^2 + 0.25^2}{0.5^2 - 0.25^2} - 0.29 \right) \right]$$

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Appendix A8-1 AOD Press Fit Swivel Joint

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AOD

$$P = 0.0021 / 2 \cdot 0.5 \left(1 \cdot 10^{-7} + 4.5^{?} \times 10^{-6}\right) = \boxed{14.5\ \text{KSI}}$$

TENSILE STRESS

$$\sigma_o = P\left(C^2 + B^2 / C^2 - B^2\right) = 14.5\ \text{KSI}\left(0.75^2 + 0.5^2 / 0.75^2 - 0.5^2\right) = \boxed{37.7\ \text{KSI}}$$

$$\sigma_i = -P\left(B^2 + A^2 / B^2 - A^2\right) = -14.5\ \text{KSI}\left(0.5^2 + 0.25^2 / 0.5^2 - 0.25^2\right) = \boxed{-24.2\ \text{KSI}}$$

INCREASE DIAMETER

$$\delta_o = \frac{2BP}{E_o}\left[\left(\frac{C^2 + B^2}{C^2 - B^2}\right) + V_o\right] = \frac{2 \cdot 0.5 \cdot 14.5\ \text{KSI}}{29 \times 10^6\ \text{PSI}} \cdot \left[\frac{0.75^2 + 0.5^2}{0.75^2 - 0.5^2} + 0.3\right]$$

$$\boxed{\delta_o = 0.00145\ \text{IN}}$$

DECREASE DIAMETER

$$\delta_i = \frac{2BP}{E_i}\left[\frac{B^2 + A^2}{B^2 - A^2} - V_i\right] = \frac{2 \cdot 0.5 \cdot 14.5\ \text{KSI}}{30 \times 10^6\ \text{PSI}}\left[\frac{0.5^2 + 0.25^2}{0.5^2 - 0.25^2} - 0.29\right]$$

$$\boxed{\delta_i = 0.00067\ \text{IN}}$$

30 MIN

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Continued to page

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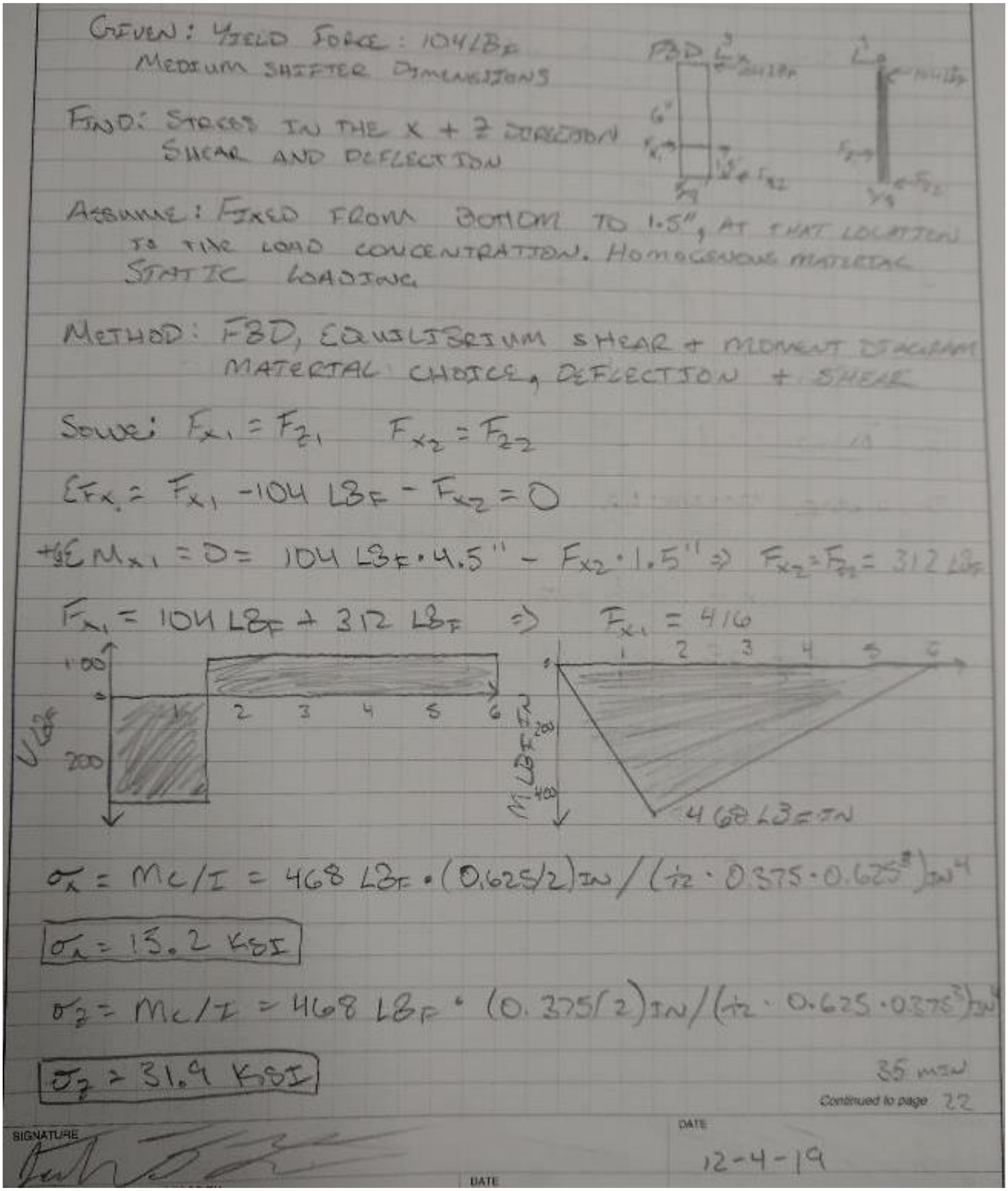
Appendix A8-2 AOD Press Fit Swivel Joint

Appendix A9-AOD Short Shifter



GIVEN: YIELD FORCE: 104 LBF
MEDIUM SHIFTER DIMENSIONS

FIND: STRESS IN THE X + Z DIRECTION
SHEAR AND DEFLECTION

ASSUME: FIXED FROM BOTTOM TO 1.5", AT THAT LOCATION IS THE LOAD CONCENTRATION. HOMOGENOUS MATERIAL
STATIC LOADING

METHOD: FBD, EQUILIBRIUM SHEAR + MOMENT DIAGRAM
MATERIAL CHOICE, DEFLECTION + SHEAR

SOLVE: $F_{x_1} = F_{z_1}$ $F_{x_2} = F_{z_2}$

$\Sigma F_x = F_{x_1} - 104\ LB_F - F_{x_2} = 0$

$+\circlearrowleft \Sigma M_{x_1} = 0 = 104\ LB_F \cdot 4.5'' - F_{x_2} \cdot 1.5'' \Rightarrow F_{x_2} = F_{z_2} = 312\ LB_F$

$F_{x_1} = 104\ LB_F + 312\ LB_F \Rightarrow F_{x_1} = 416$

$\sigma_x = Mc/I = 468\ LB_F \cdot (0.625/2)\,IN / (\tfrac{1}{12} \cdot 0.375 \cdot 0.625^3)\,IN^4$

$\boxed{\sigma_x = 13.2\ KSI}$

$\sigma_z = Mc/I = 468\ LB_F \cdot (0.375/2)\,IN / (\tfrac{1}{12} \cdot 0.625 \cdot 0.375^3)\,IN^4$

$\boxed{\sigma_z = 31.9\ KSI}$

35 MIN

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Appendix A9-1 AOD Short Shifter Stress

22

Continued from page 21

AOD MEDIUM SHIFTER

MATERIAL 1018 LOW CARBON STEEL

YIELD STRENGTH = 54 KSI

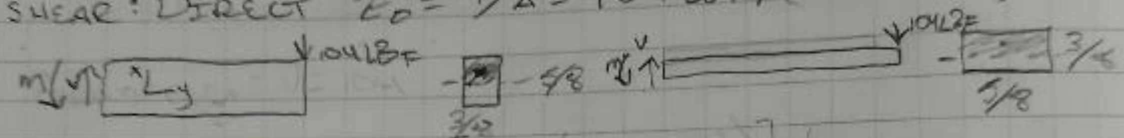
DEFLECTION APPENDIX TABLE A14-2 Pg 883 (MEMD 6ED)

$y_a = y_{max} = -PL^3/3EI$

$y_x = -104\,LBF \cdot (4.5^3)\,IN^3 / 3 \cdot 30\times10^6\,PSI \cdot 0.0027\,IN^4 = \boxed{0.038\,IN}$

$y_z = -104\,LBF\,(4.5^3)\,IN^3 / 3 \cdot 30\times10^6\,PSI \cdot 0.0096\,IN^4 = \boxed{0.011\,IN}$

SHEAR: DIRECT $\tau_D = F/A = 104\,LBF / (0.375 \cdot 0.625) = 443.7\,PSI$



TRANSVERSE SHEAR PAGE 15 VALUES

$\tau_{TRANSVERSE\,x} = 665\,PSI$

$\tau_{TRANSVERSE\,z} = 664\,PSI$

$\boxed{\tau_{TOTAL\,x} = 1108\,PSI}$
$\boxed{\tau_{TOTAL\,y} = 1107\,PSI}$

25 MIN

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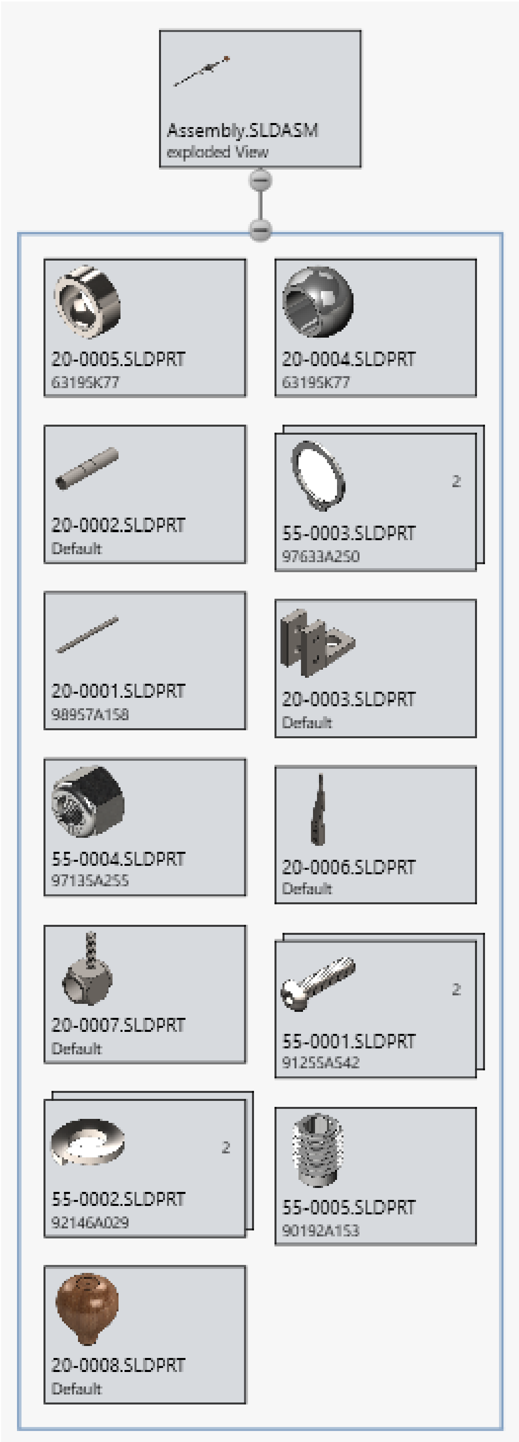
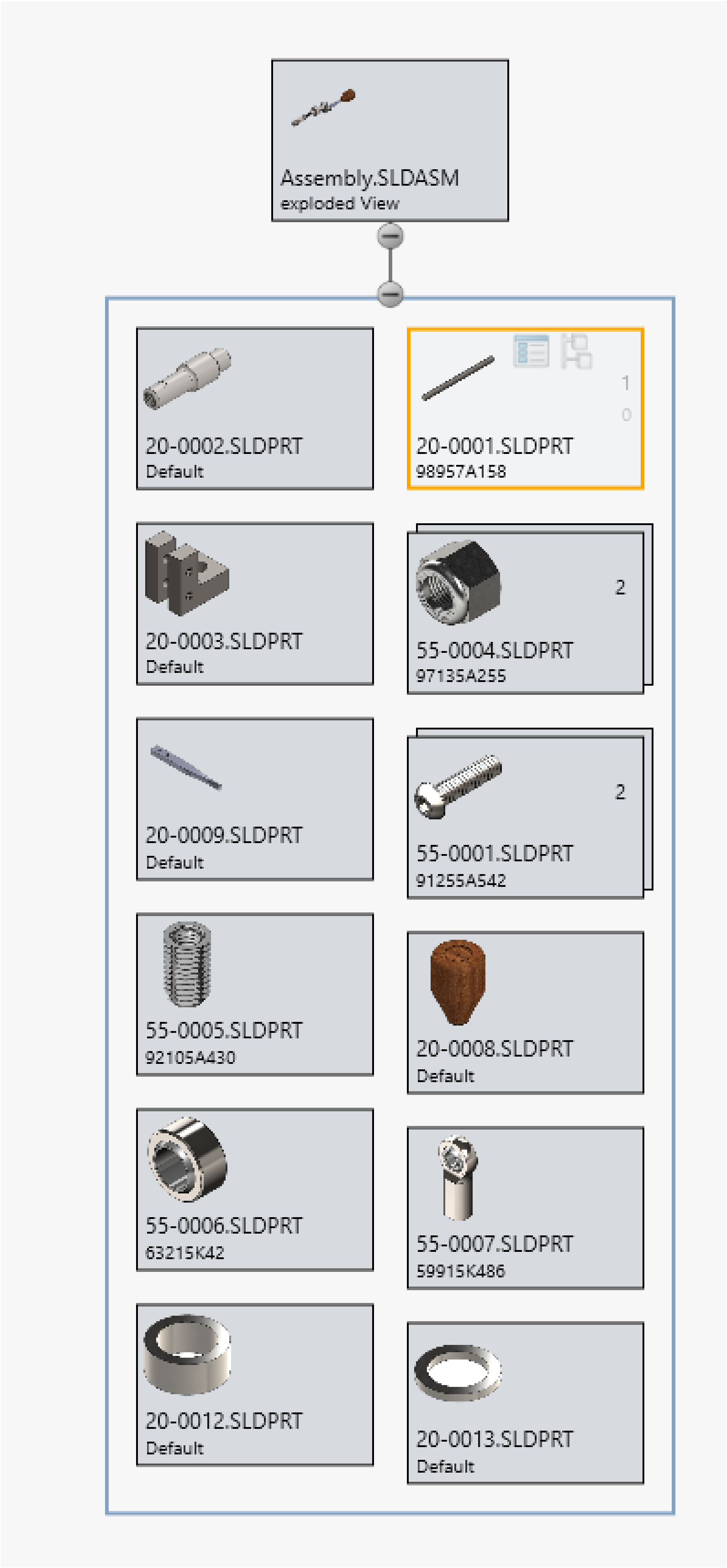
Appendix A9-1 AOD Medium Shifter Shear and Deflection

APPENDIX B-DRAWING

Appendix B1-Drawing Tree

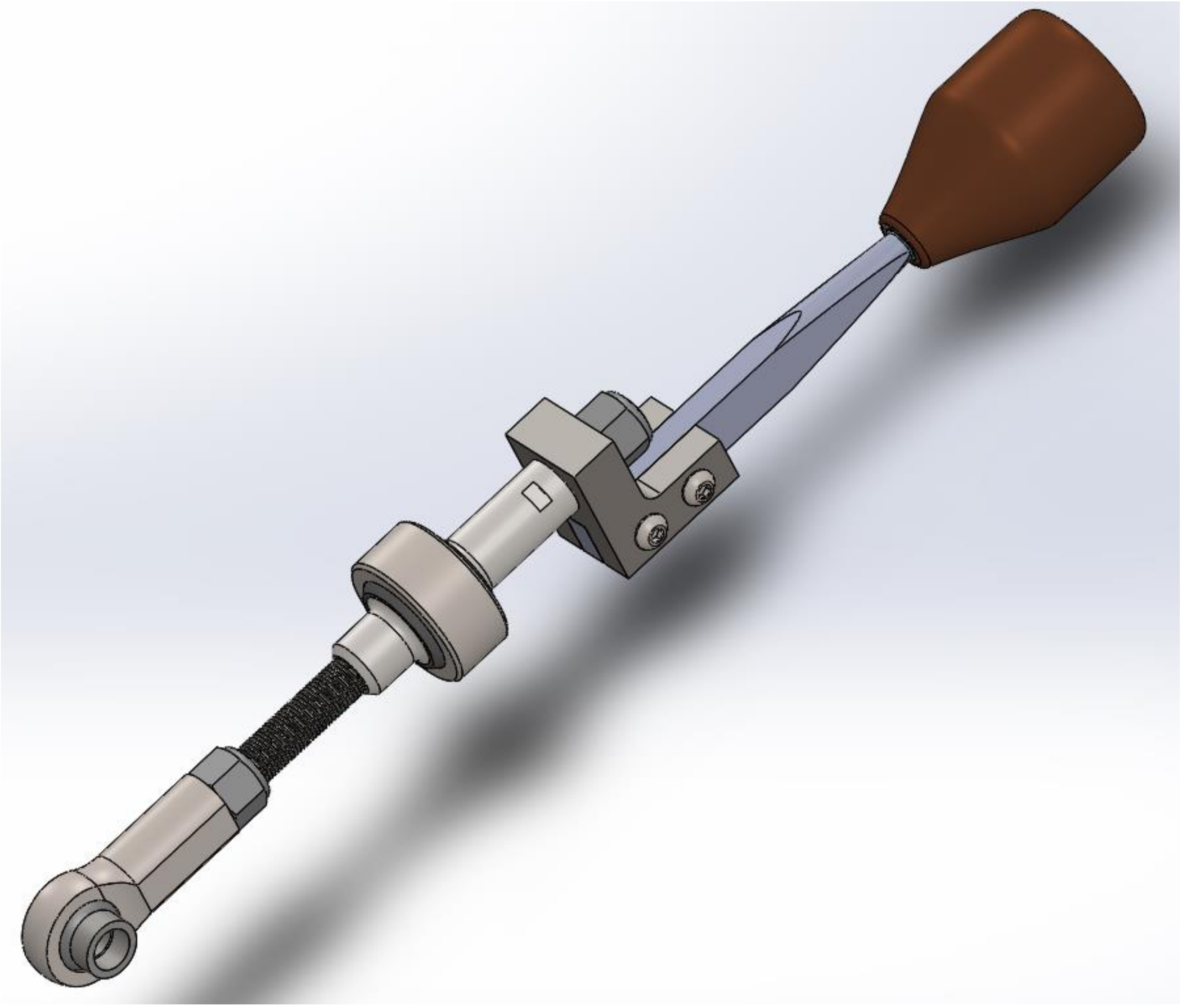


Appendix B1-A

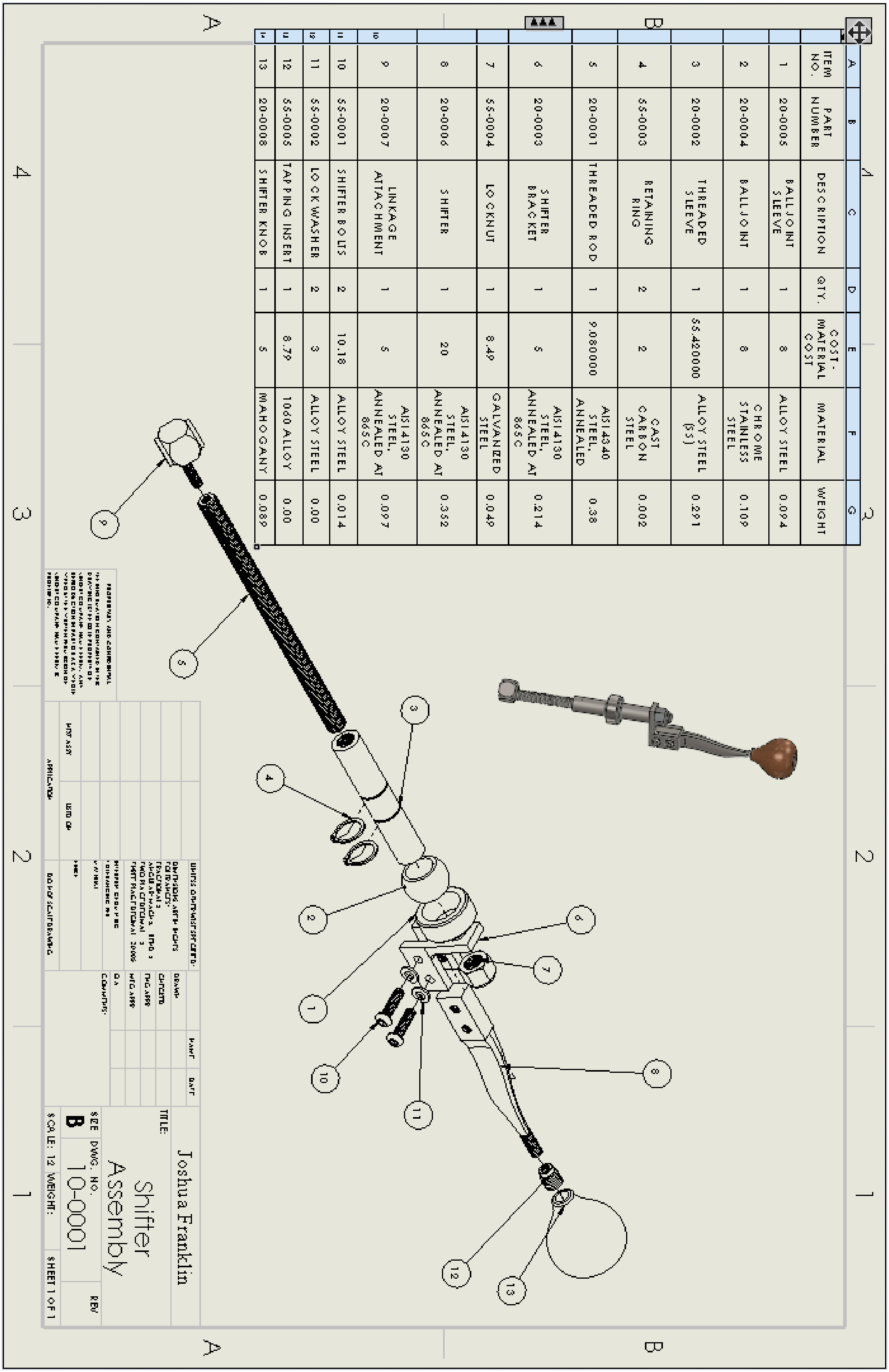


Appendix B1-B

Appendix B2-Assembly

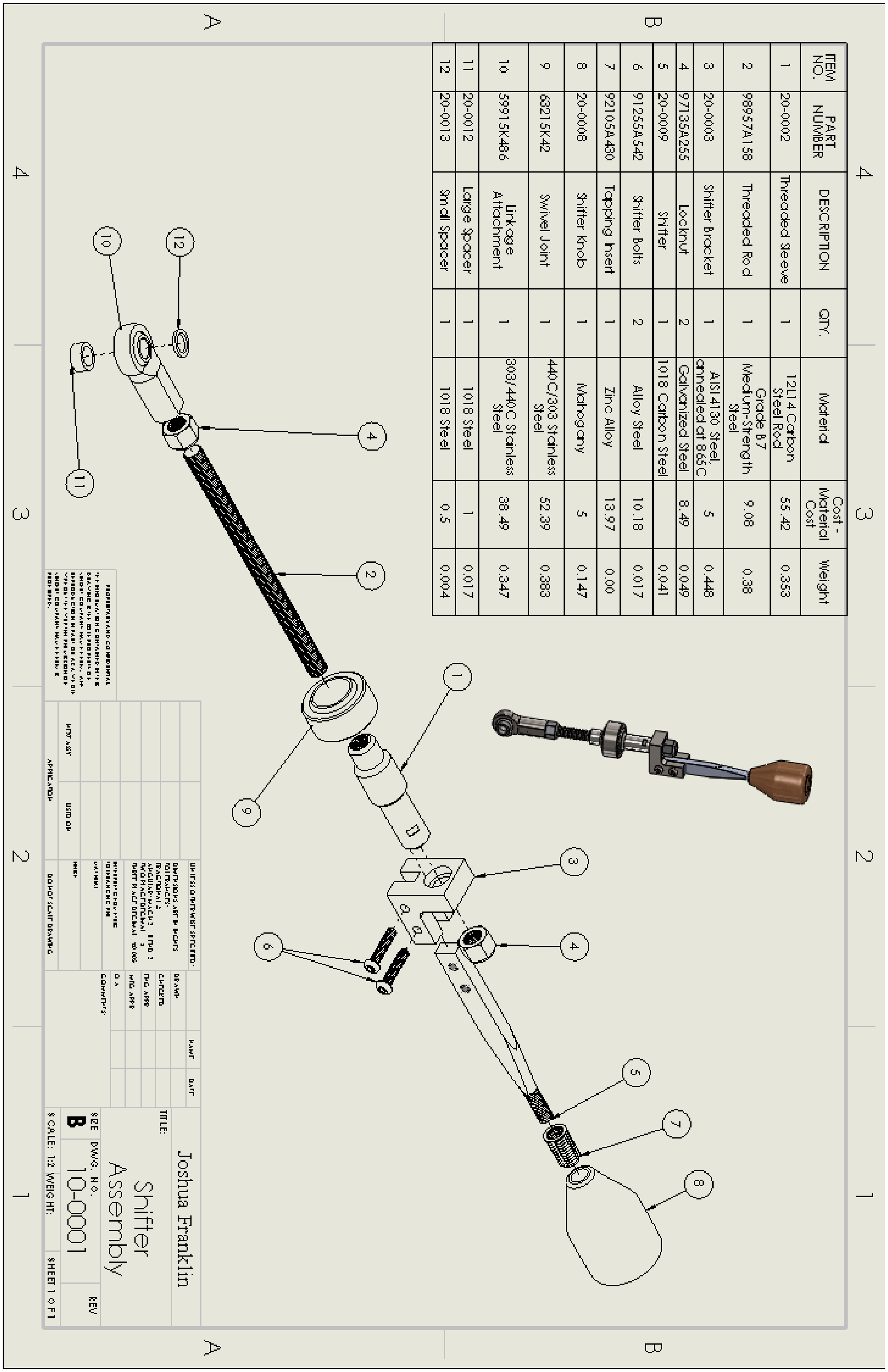


Appendix B2-1B Shifter Assembly



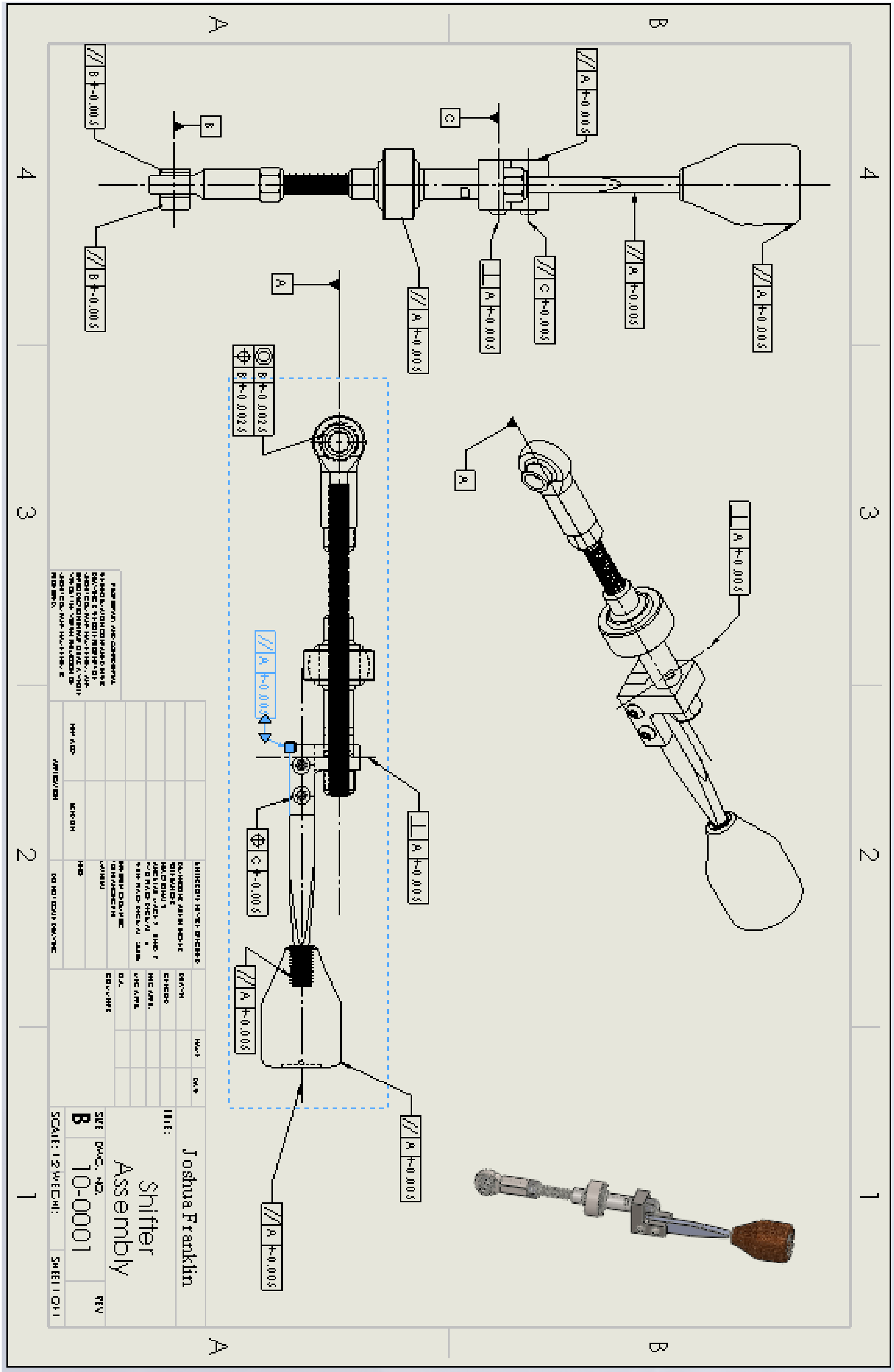
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	COST - MATERIAL COST	MATERIAL	WEIGHT
1	20-0005	BALL JOINT SLEEVE	1	8	ALLOY STEEL	0.094
2	20-0004	BALL JOINT	1	8	CHROME STAINLESS STEEL	0.109
3	20-0002	THREADED SLEEVE	1	$5.420000	ALLOY STEEL (SS)	0.291
4	SS-0003	RETAINING RING	2	2	CAST CARBON STEEL	0.002
5	20-0001	THREADED ROD	1	9.080000	AISI 4340 STEEL, ANNEALED	0.38
6	20-0003	SHIFTER BRACKET	1	5	AISI 4130 STEEL, ANNEALED AT 865C	0.214
7	SS-0004	LOCKNUT	1	8.49	GALVANIZED STEEL	0.049
8	20-0006	SHIFTER	1	20	AISI 4130 STEEL, ANNEALED AT 865C	0.352
9	20-0007	LINKAGE ATTACHMENT	1	5	AISI 4130 STEEL, ANNEALED AT 865C	0.097
10	SS-0001	SHIFTER BOLTS	2	10.18	ALLOY STEEL	0.014
11	SS-0002	LOCK WASHER	2	3	ALLOY STEEL	0.00
12	SS-0005	TAPPING INSERT	1	8.79	1060 ALLOY	0.00
13	20-0008	SHIFTER KNOB	1	5	MAHOGANY	0.089

Appendix B2-2A Assembly Drawing

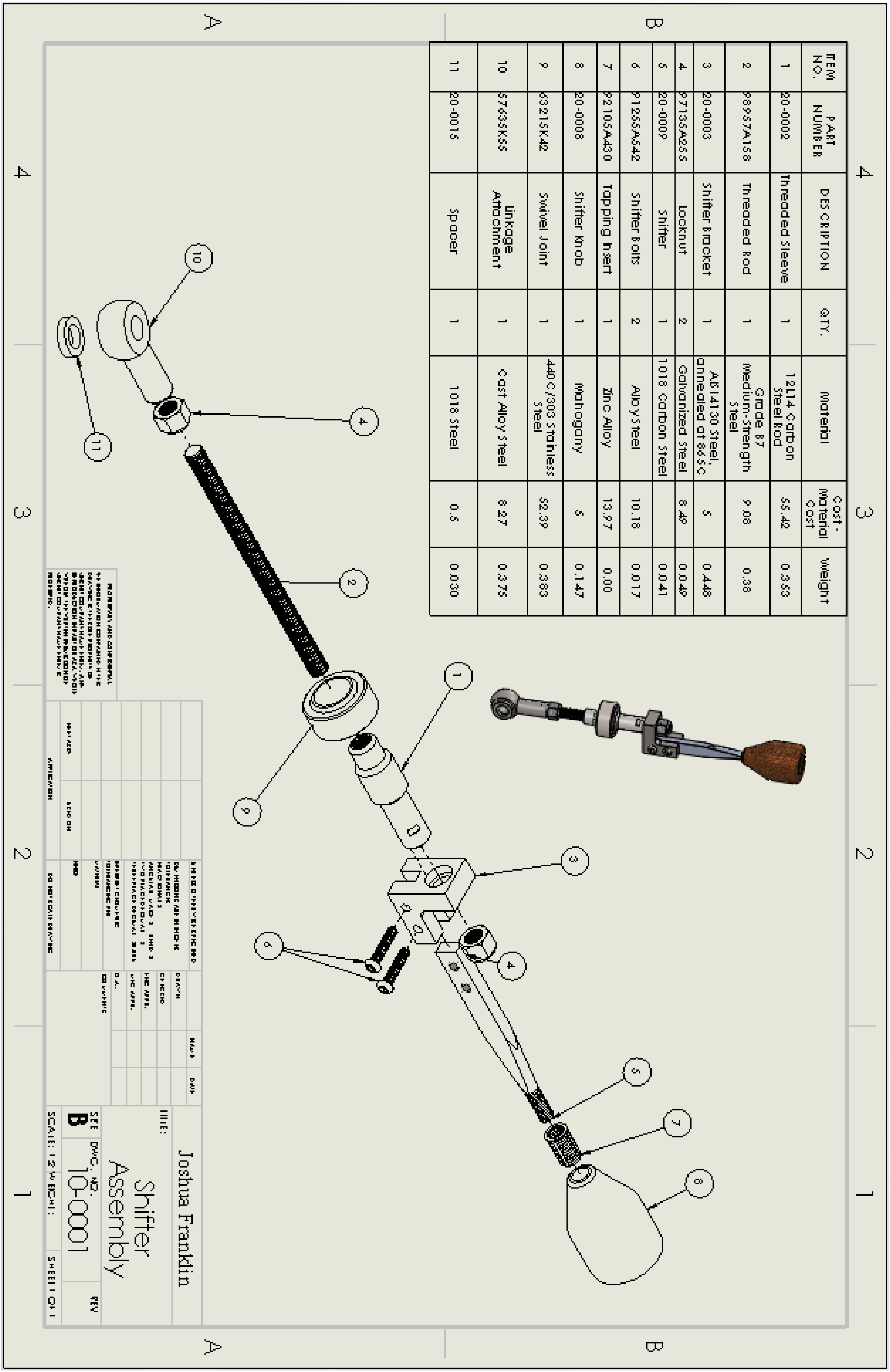


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	Material	Cost - Material Cost	Weight
1	20-0002	Threaded Sleeve	1	12L14 Carbon Steel Rod	55.42	0.353
2	98957A158	Threaded Rod	1	Medium-Strength Grade B7 Steel	9.08	0.38
3	20-0003	Shifter Bracket	1	AISI 4130 Steel, annealed at 865C	5	0.448
4	97135A255	Locknut	2	Galvanized Steel	8.49	0.049
5	20-0009	Shifter	1	1018 Carbon Steel		0.041
6	91255A542	Shifter Bolts	2	Alloy Steel	10.18	0.017
7	92105A430	Tapping Insert	1	Zinc Alloy	13.97	0.00
8	20-0008	Shifter Knob	1	Mahogany	5	0.147
9	63215K42	Swivel Joint	1	440C/303 Stainless Steel	52.39	0.383
10	59915K486	Linkage Attachment	1	303/440C Stainless Steel	38.49	0.347
11	20-0012	Large Spacer	1	1018 Steel	1	0.017
12	20-0013	Small Spacer	1	1018 Steel	0.5	0.004

Appendix B2-2B Assembly Drawing

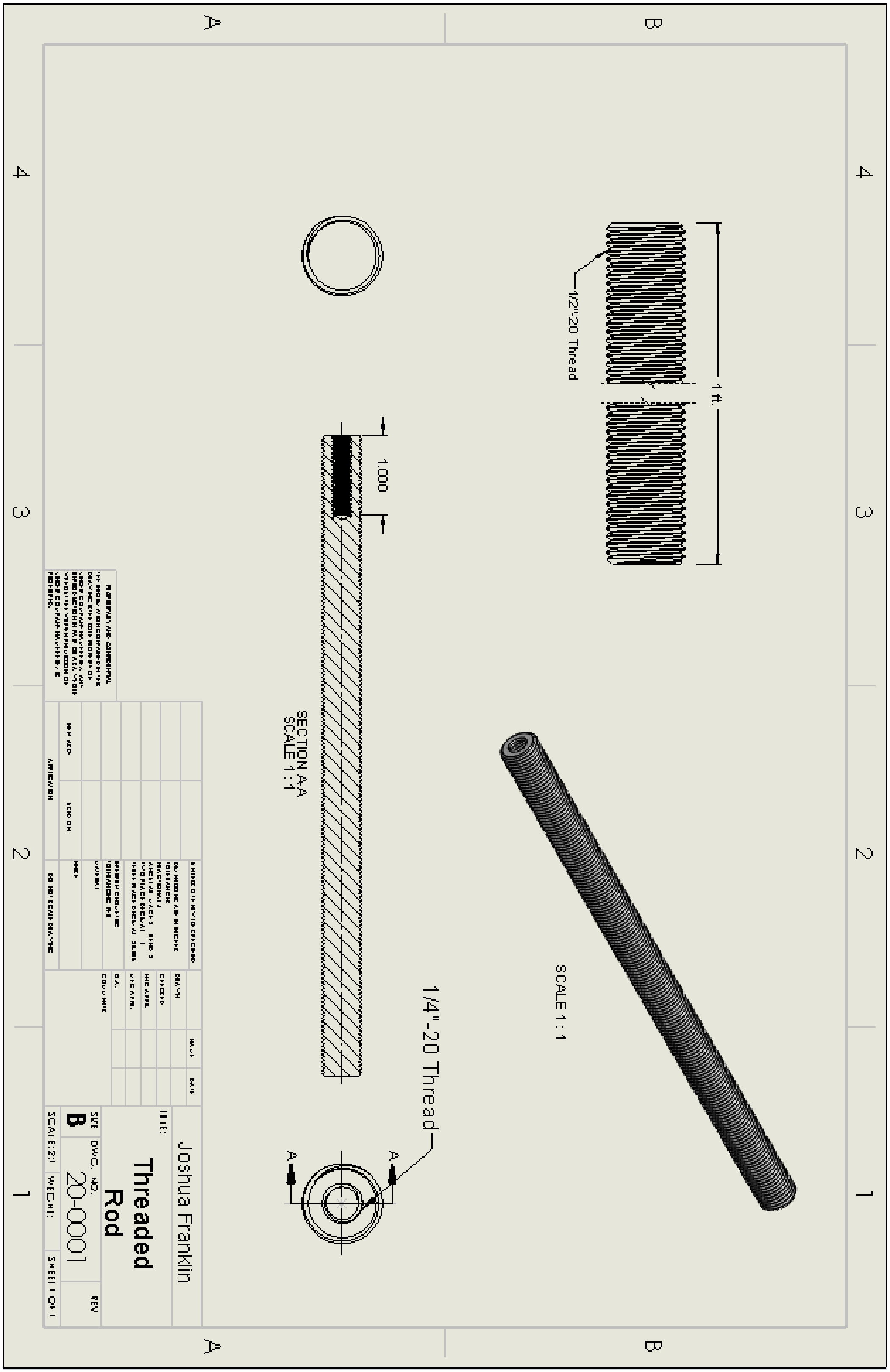


Appendix B2-2C Assembly Drawing

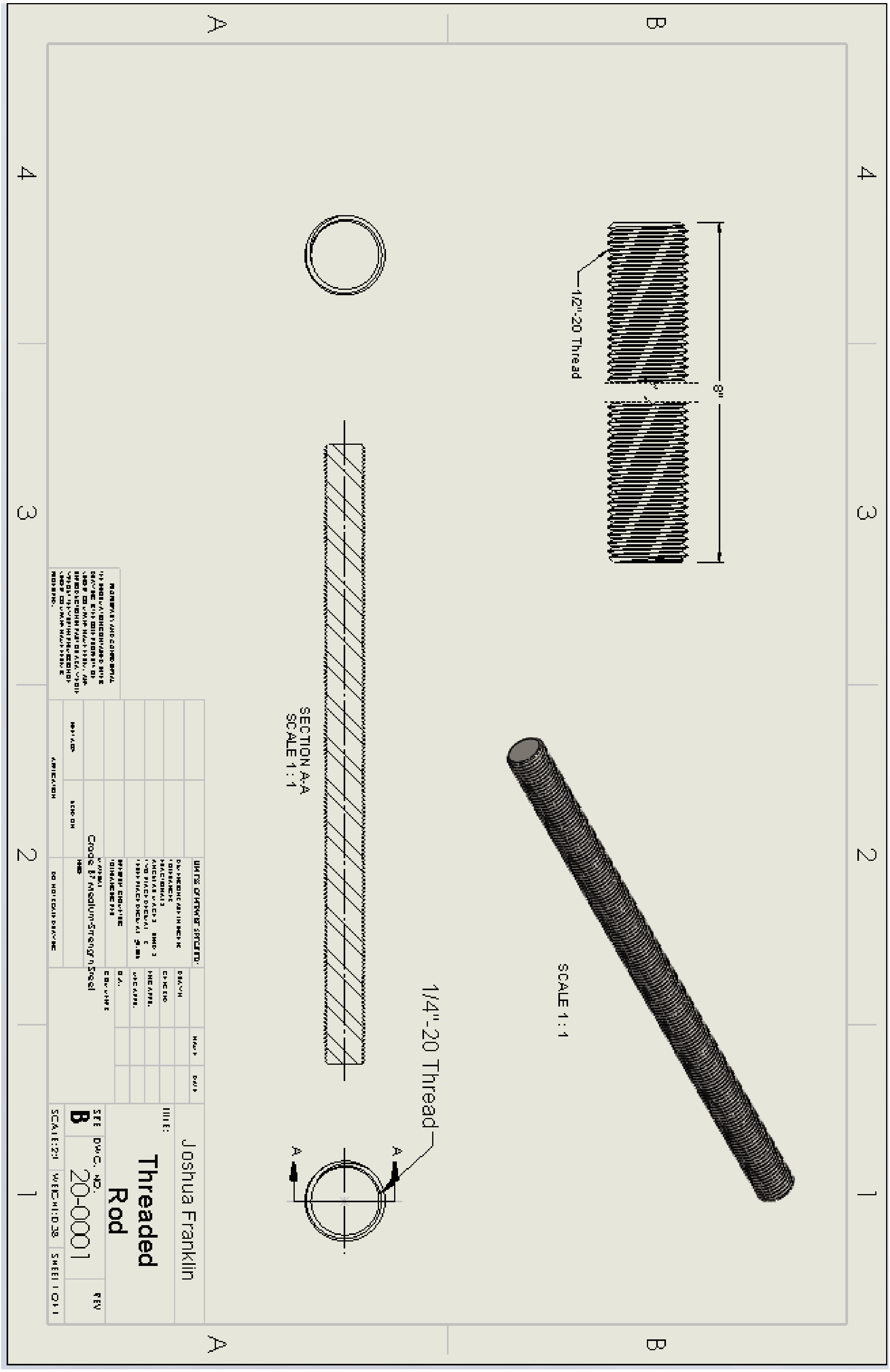


Appendix B2-3 Assembly Drawing

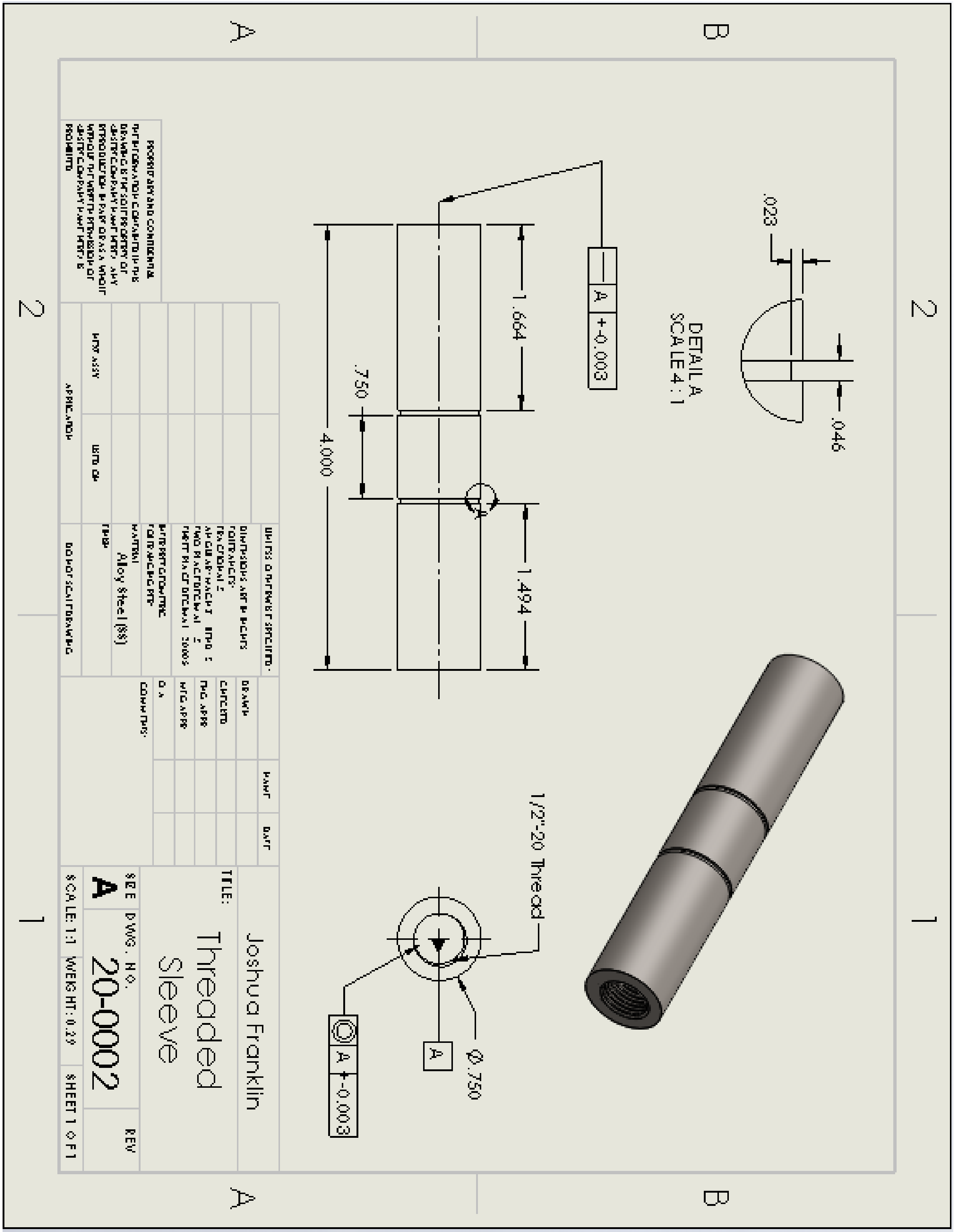
Appendix B3- Parts



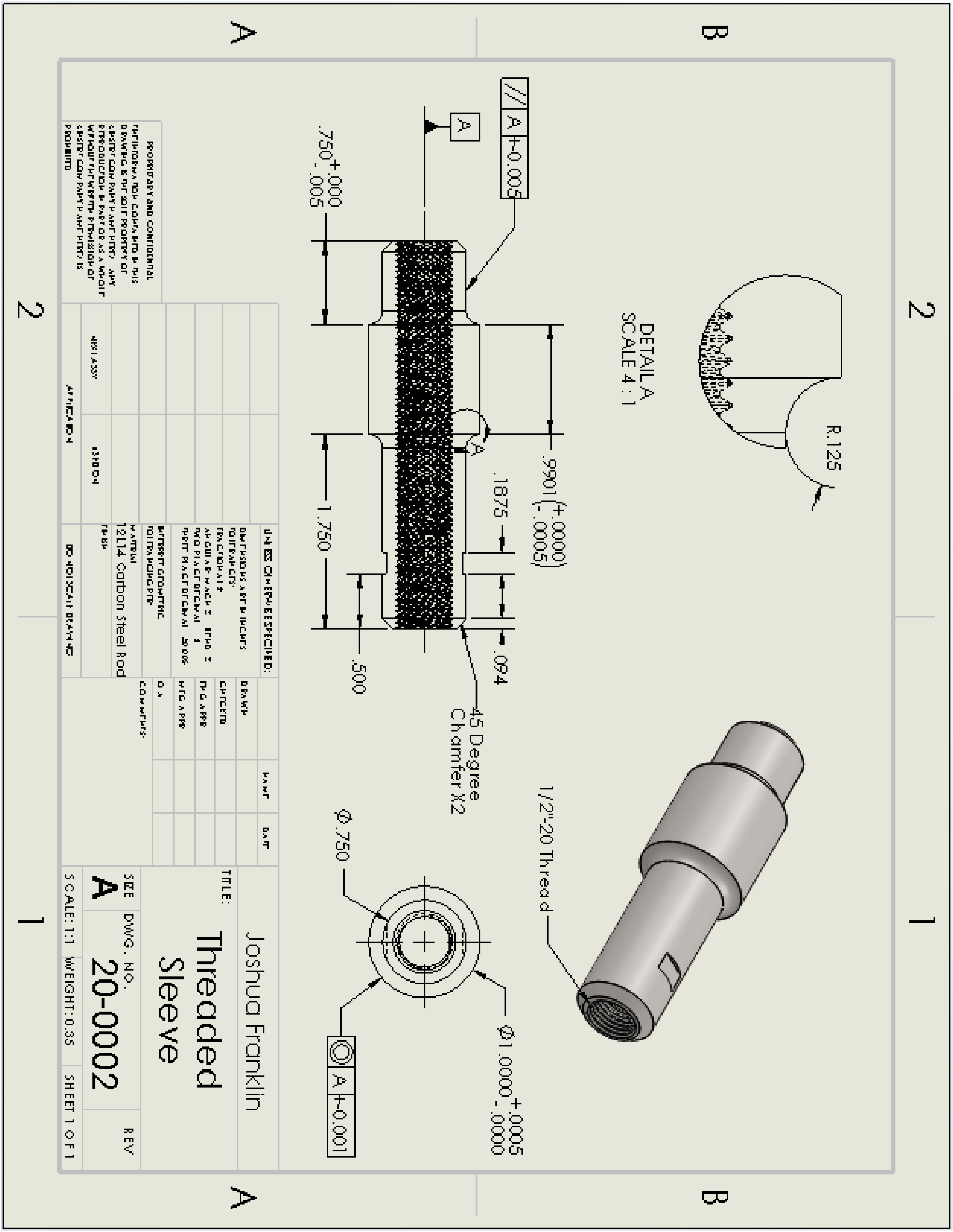
Appendix B3-1A Threaded Rod



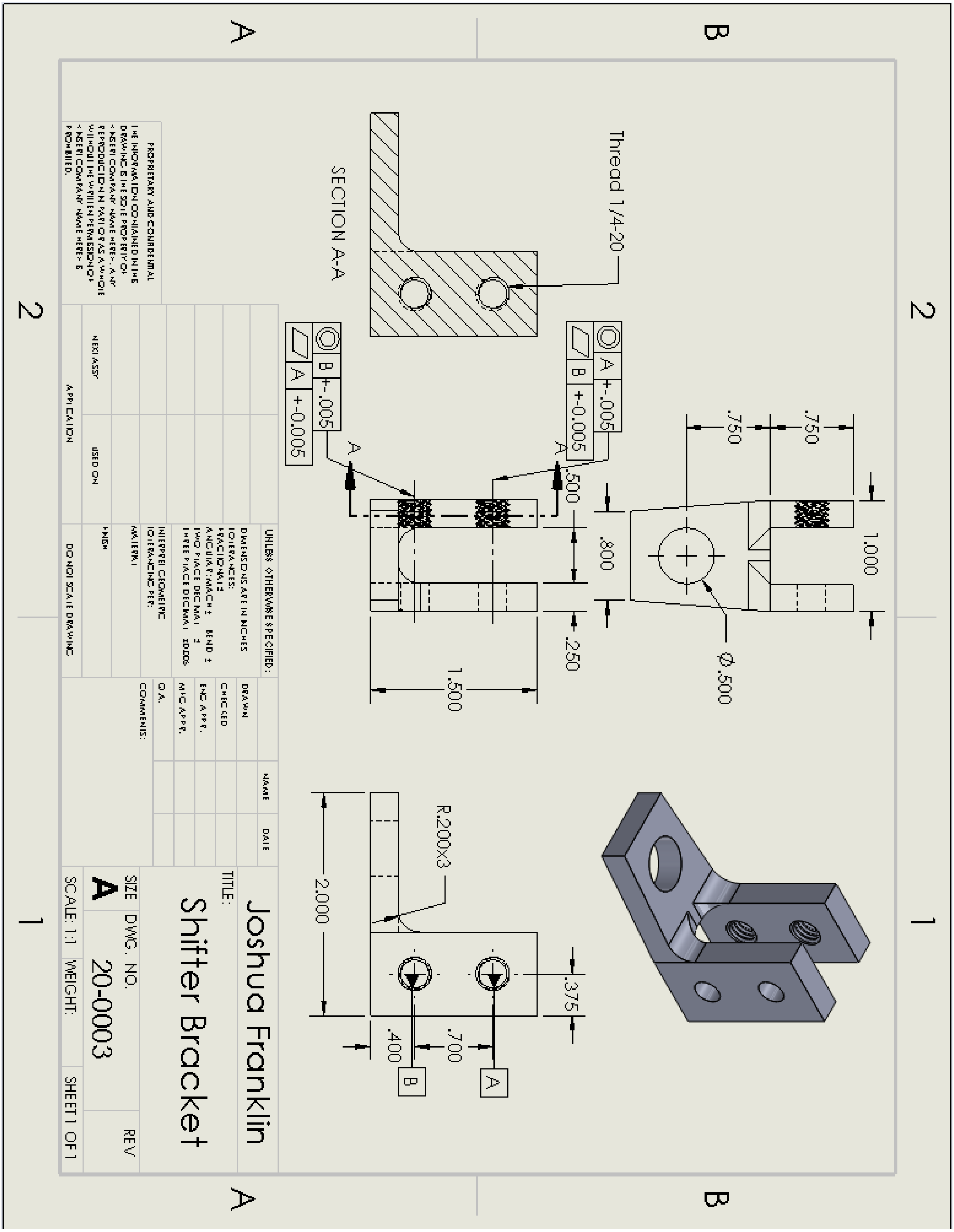
Appendix B3-1B Threaded Rod



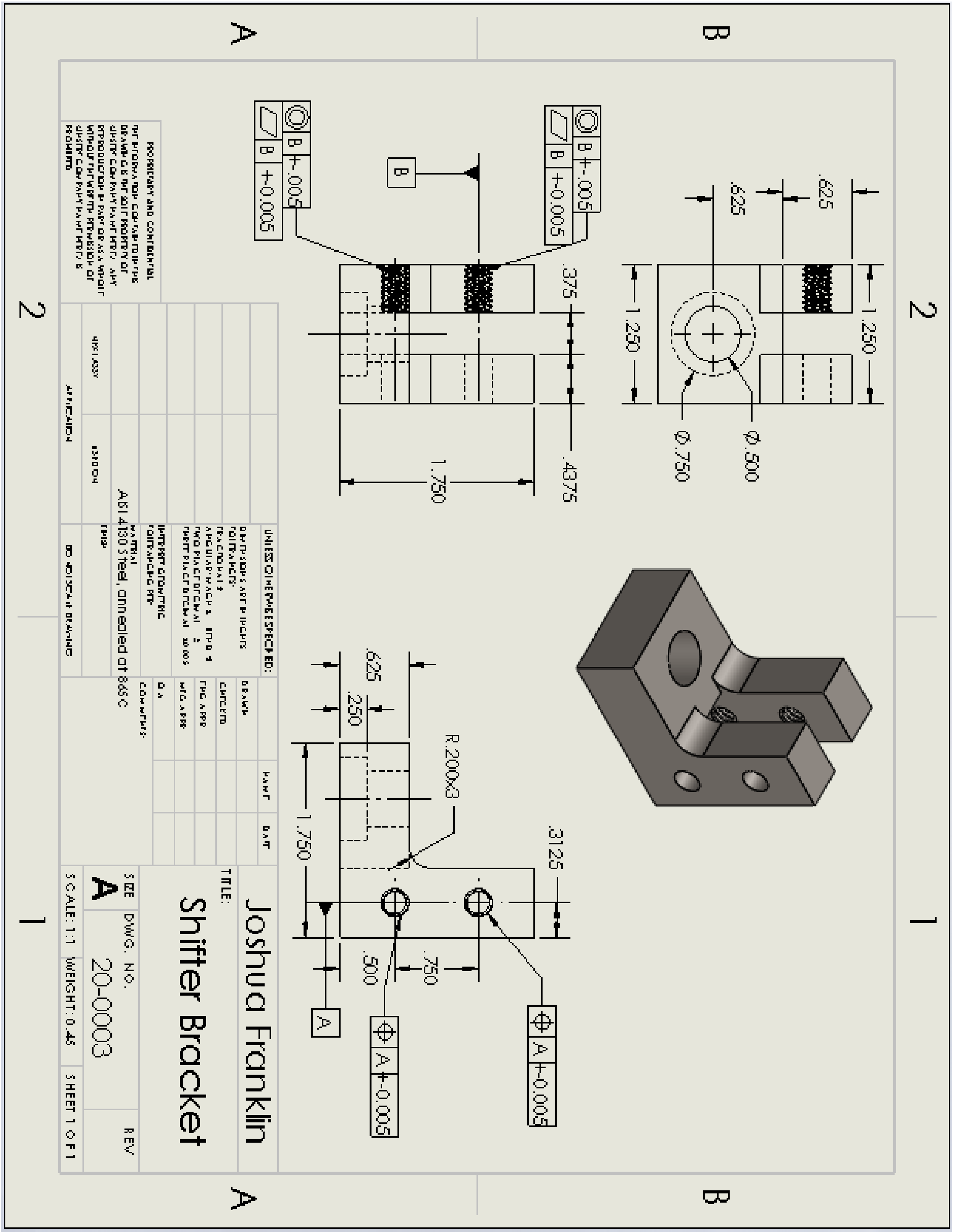
Appendix B3-2A Threaded Sleeve



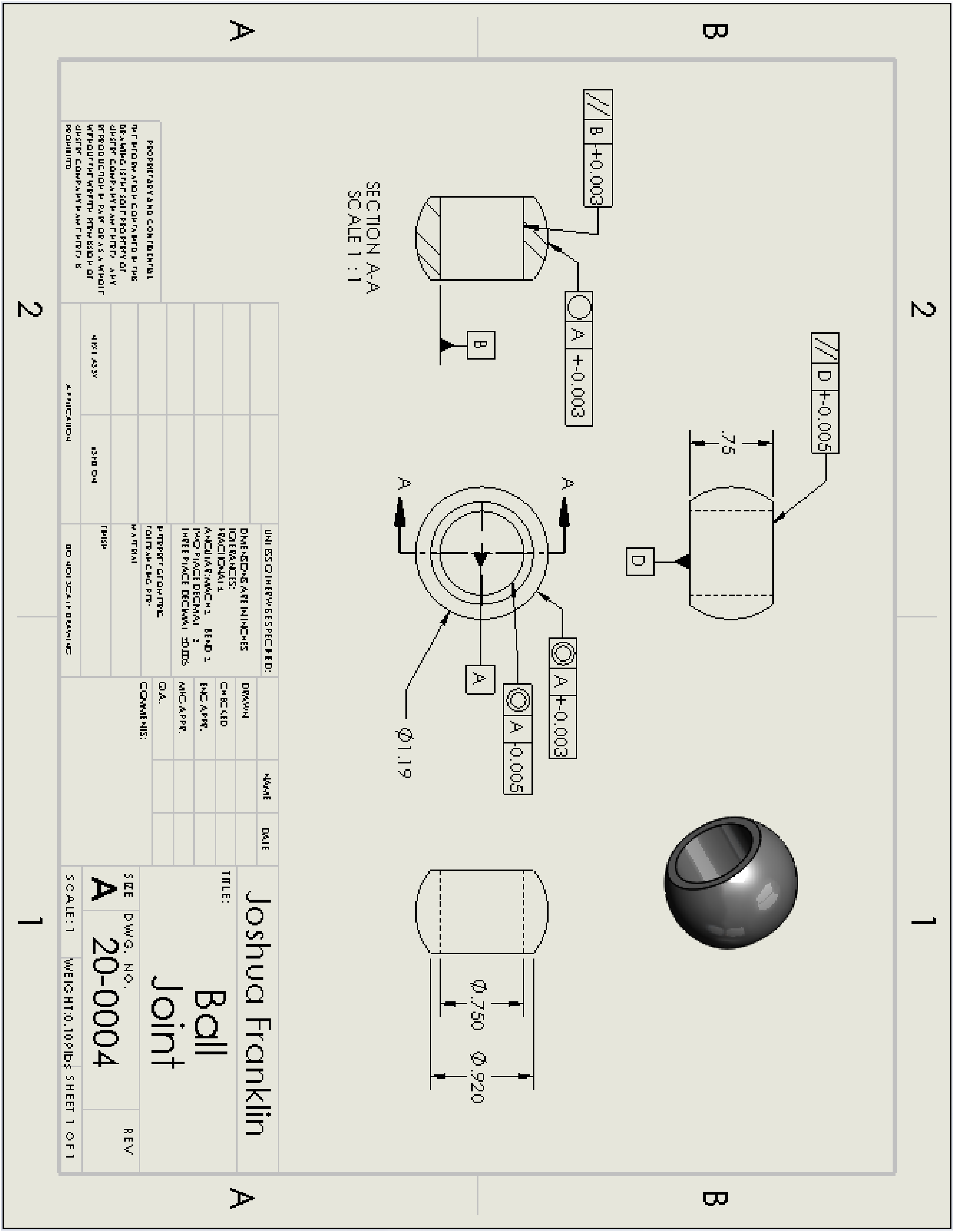
Appendix B3-2B Threaded Sleeve



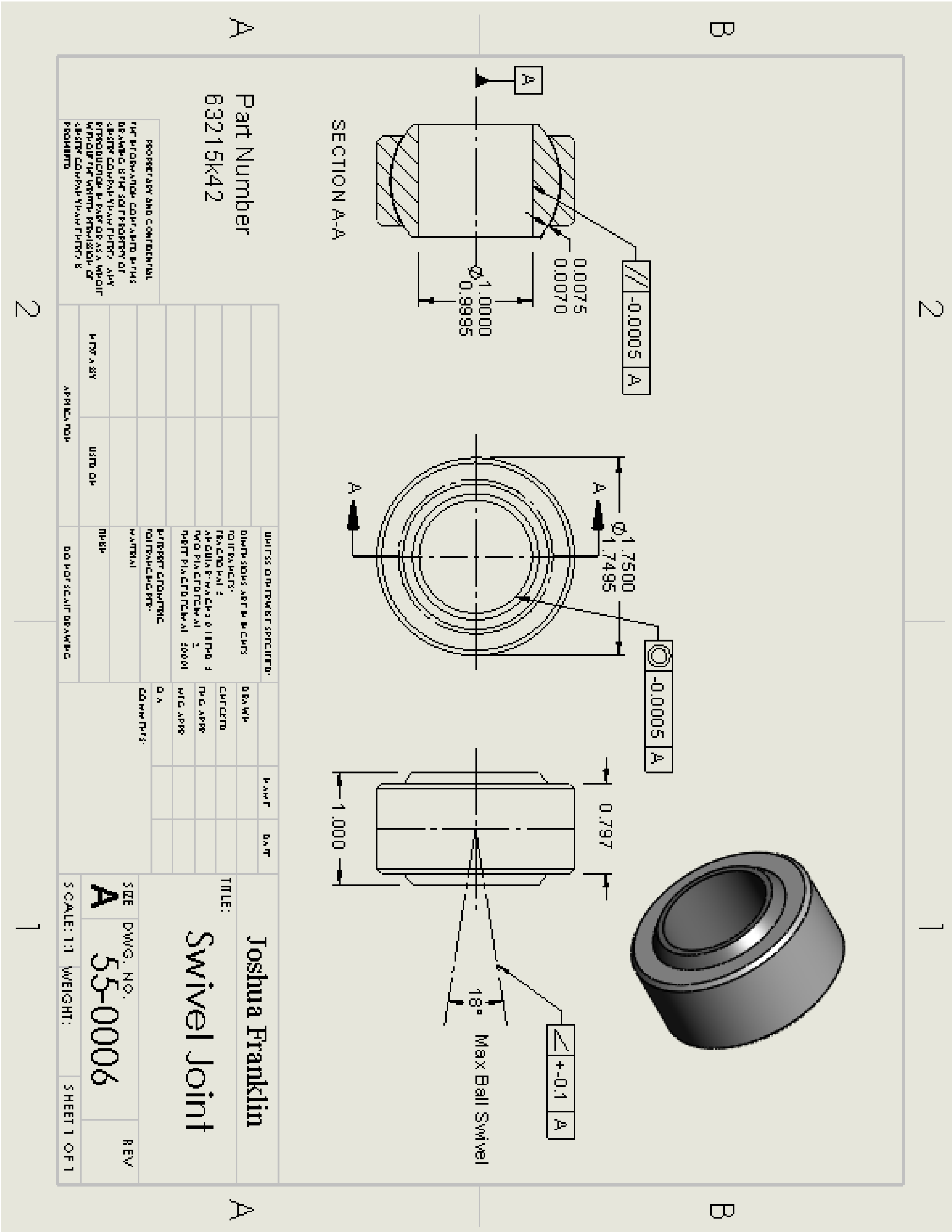
Appendix B3-3A Shifter Bracket



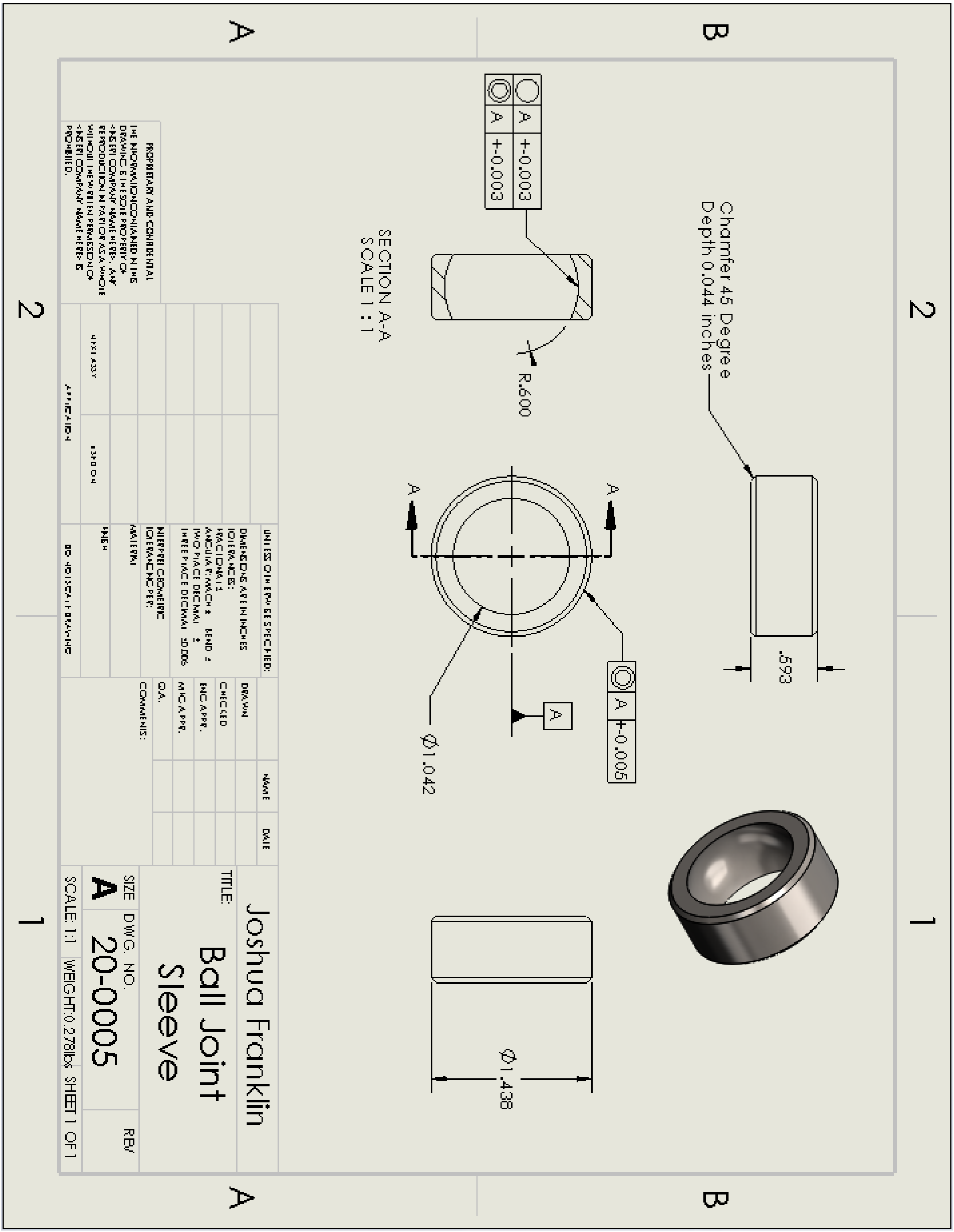
Appendix B3-3B Shifter Bracket



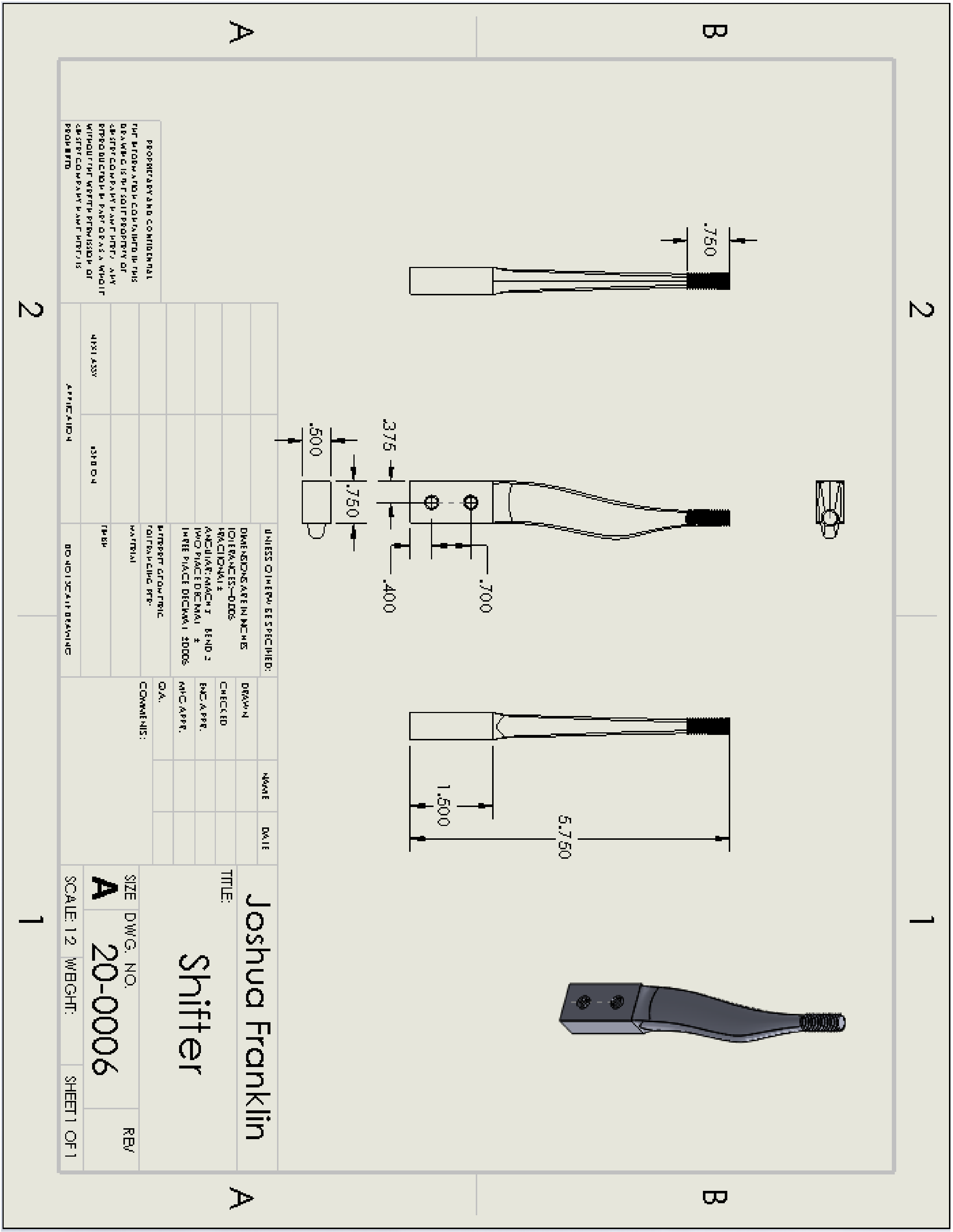
Appendix B3-4A Ball Joint



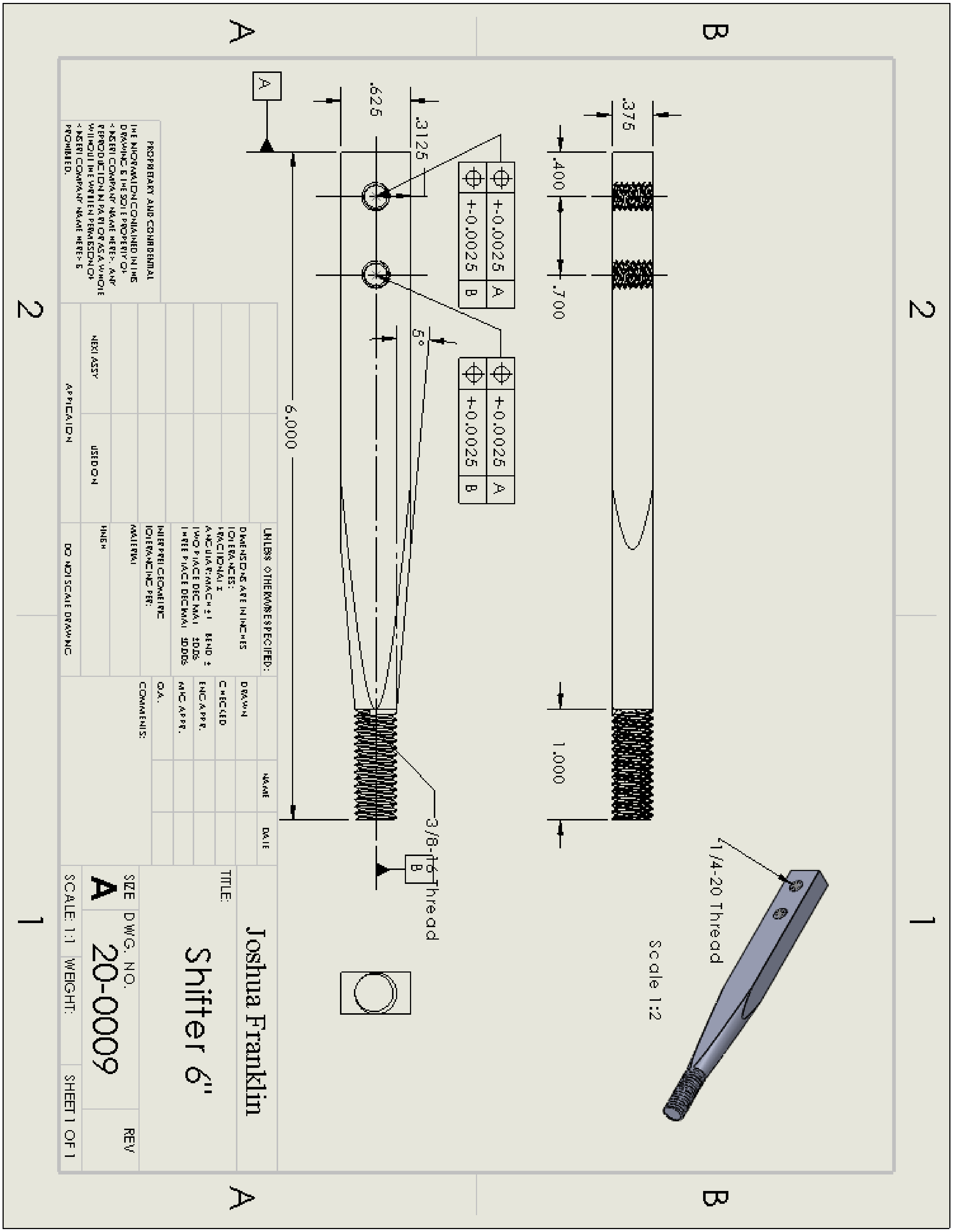
Appendix B3-4B Ball Joint



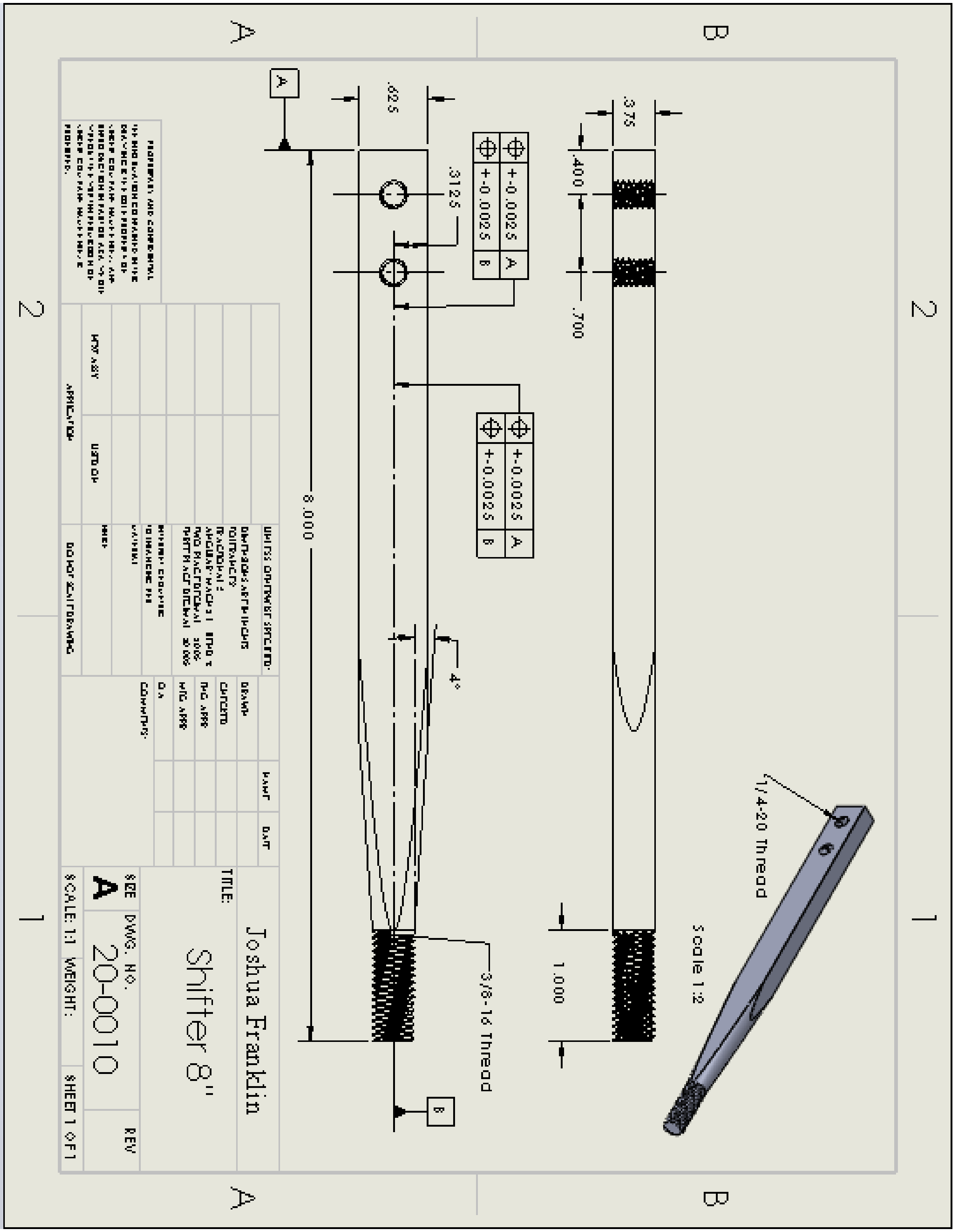
Appendix B3-5 Ball Joint Sleeve (Replacement is Appendix B3-4B)



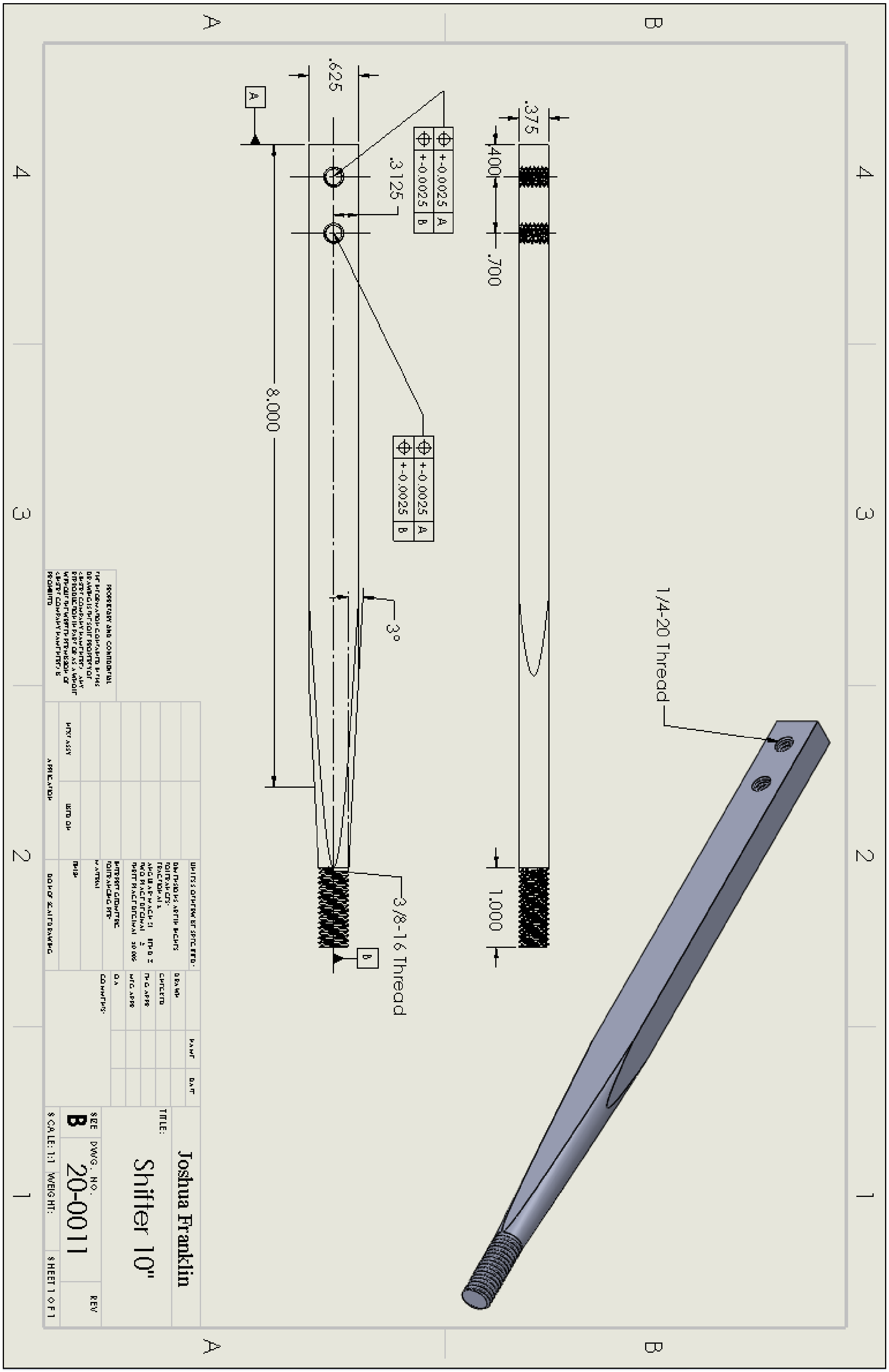
Appendix B3-6A Shifter



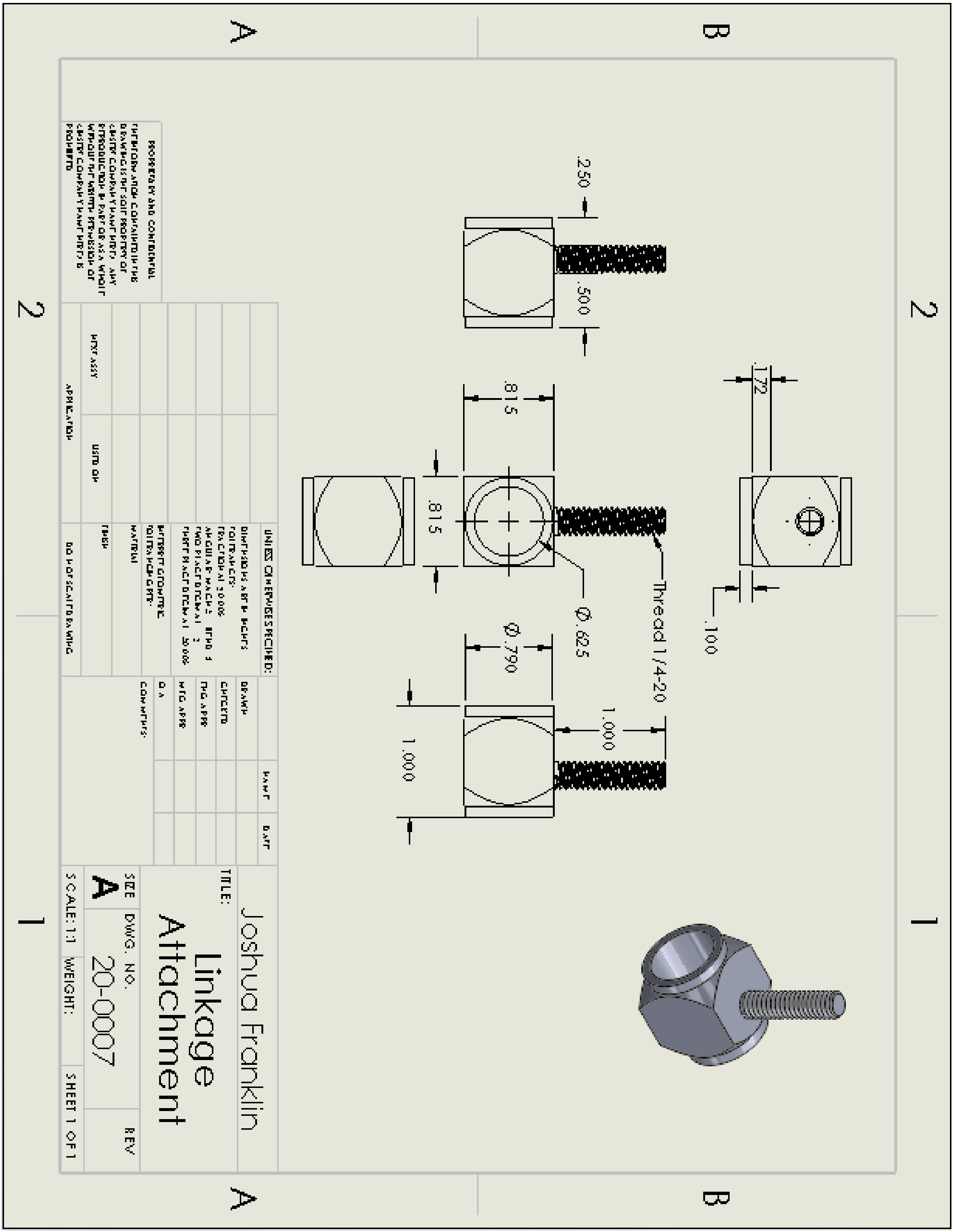
Appendix B3-6B 6" Short Shifter



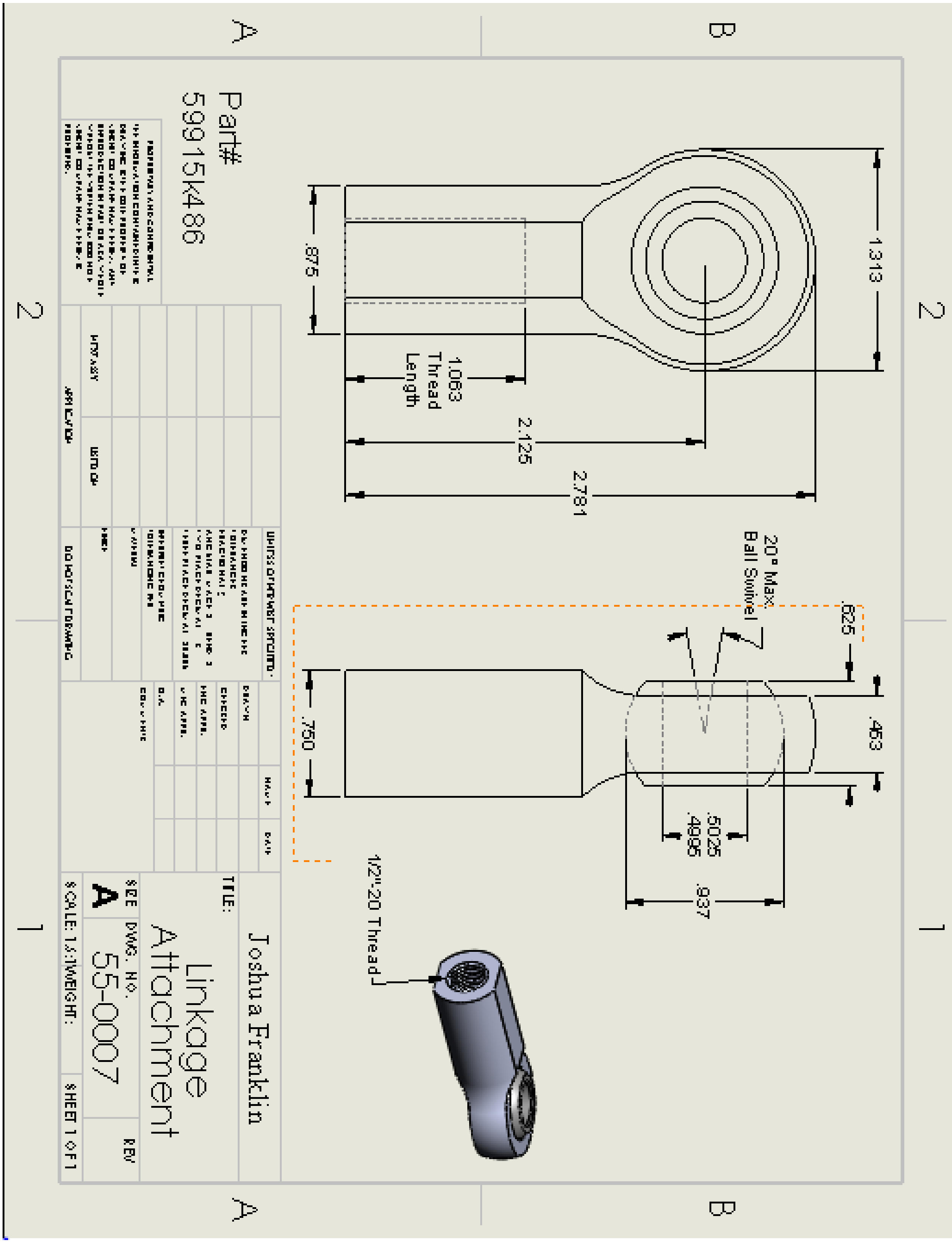
Appendix B3-6C Medium Shifter



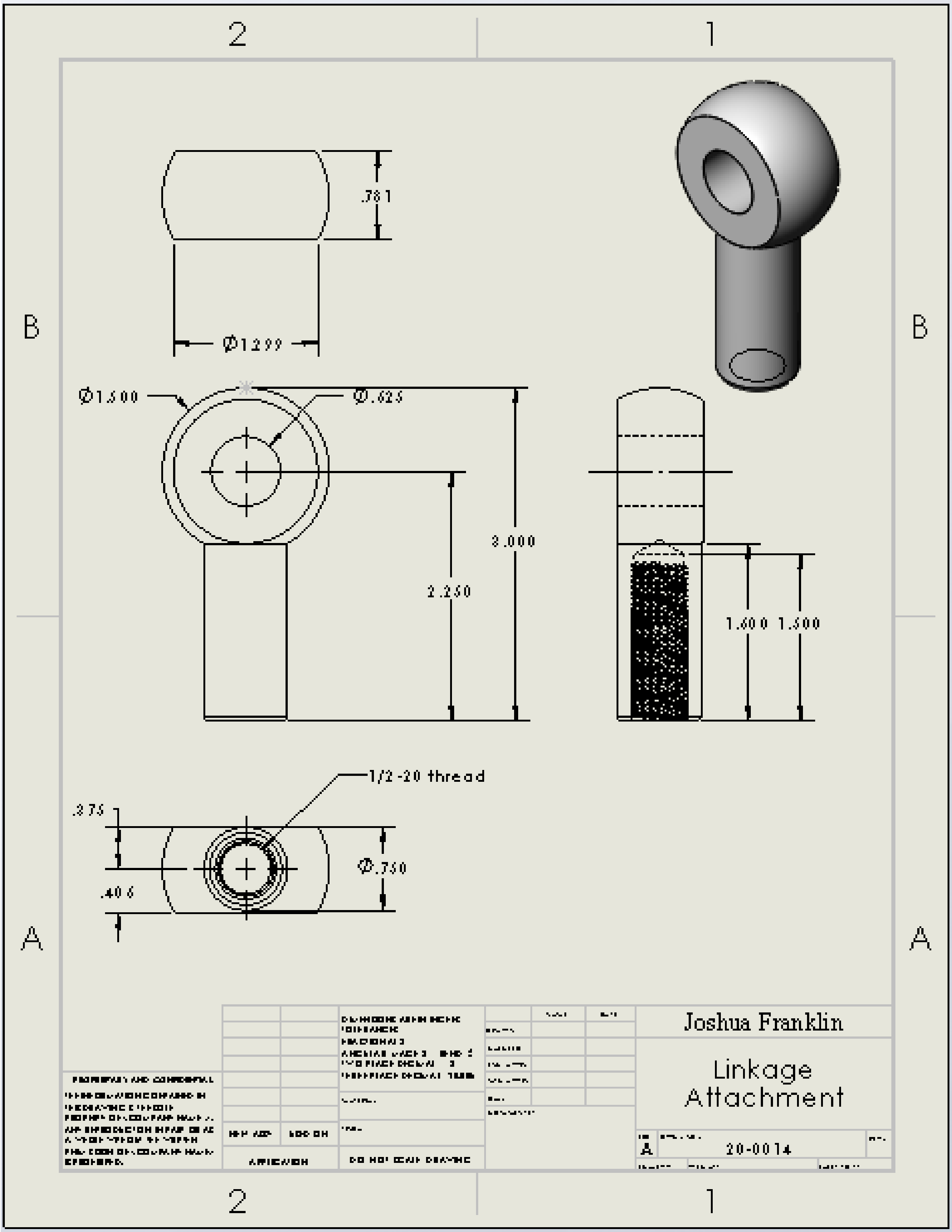
Appendix B3-6D Long Shifter



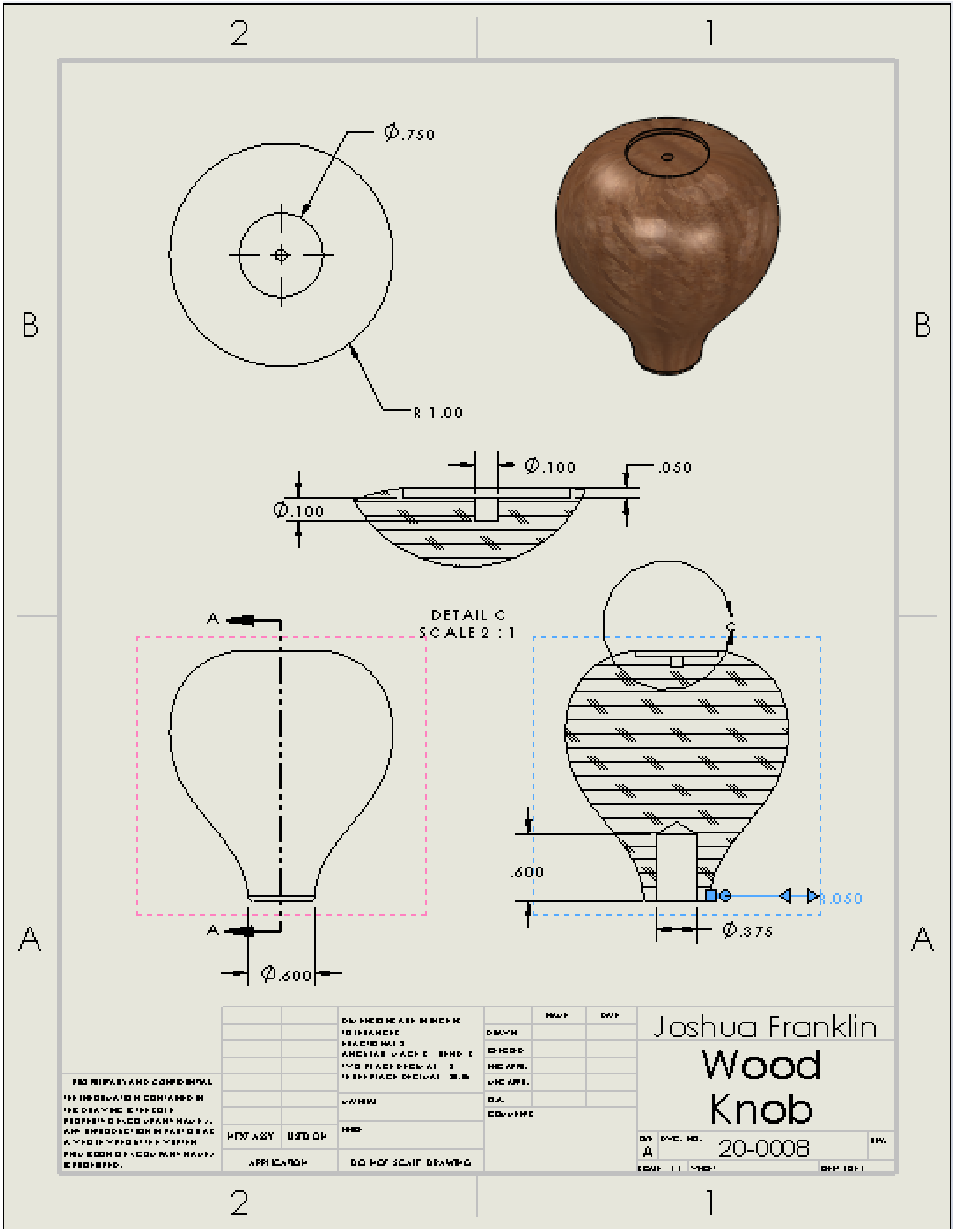
Appendix B3-7A Linkage Attachment



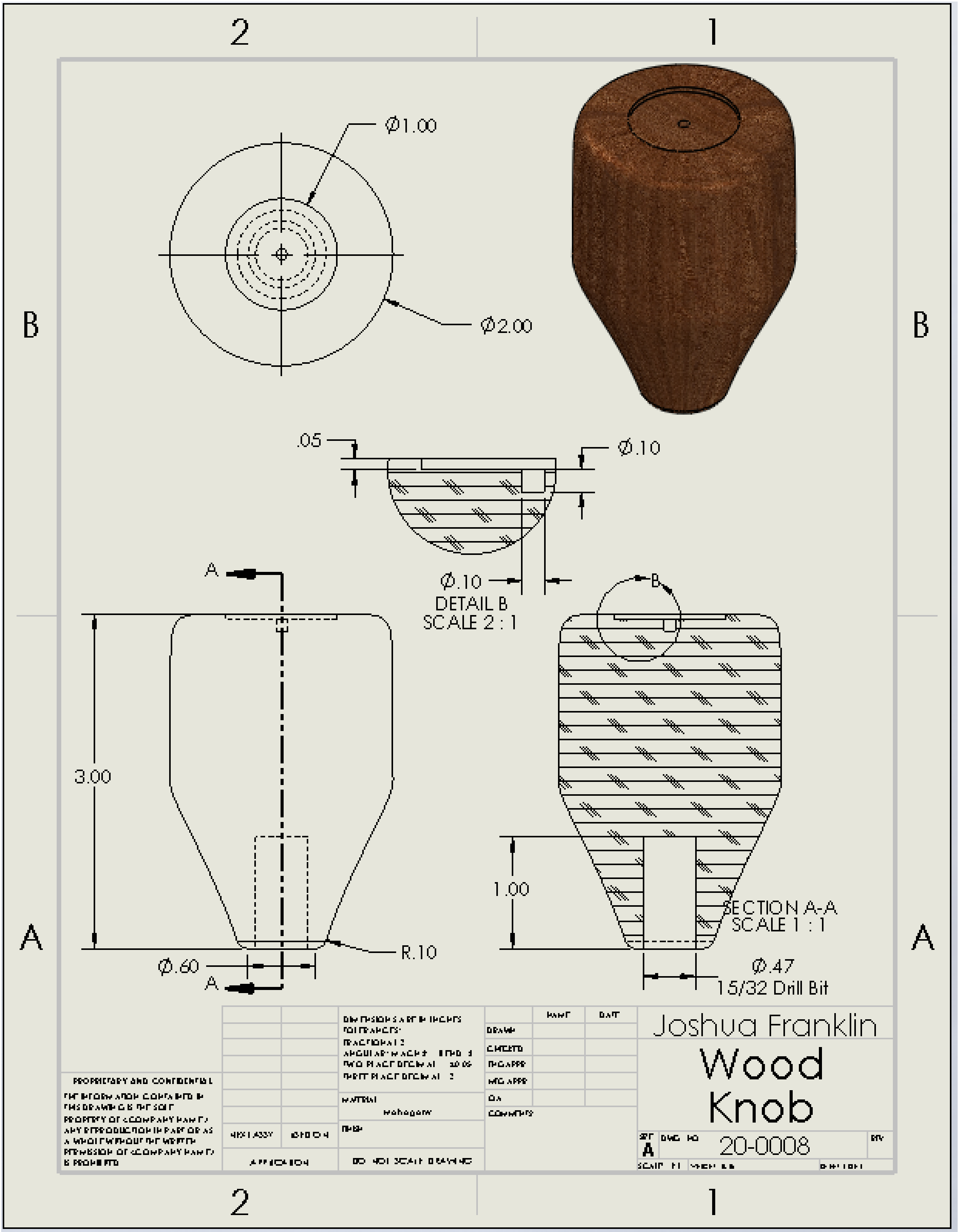
Appendix B3-7B Linkage Attachment



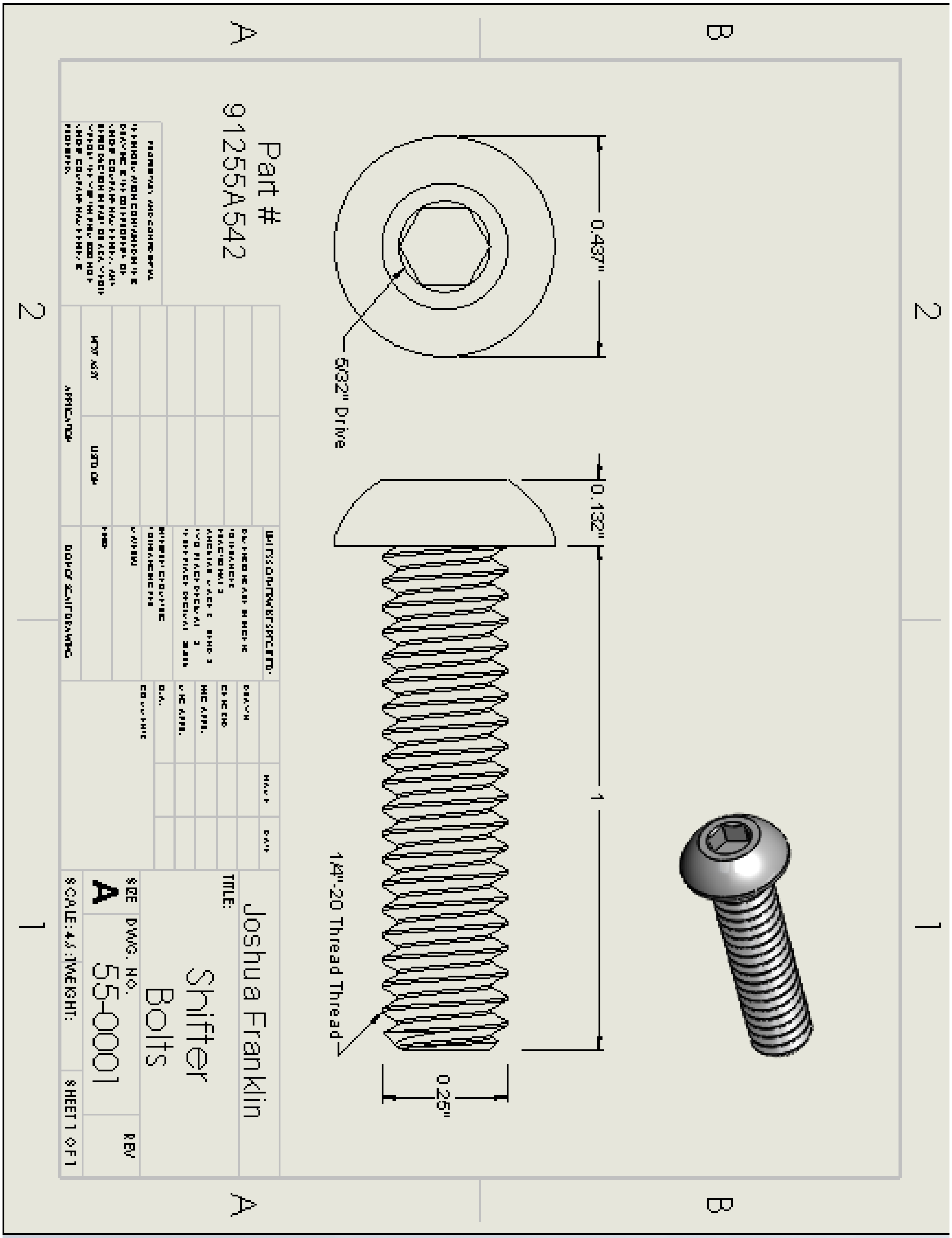
Appendix B3-7C Linkage Attachment



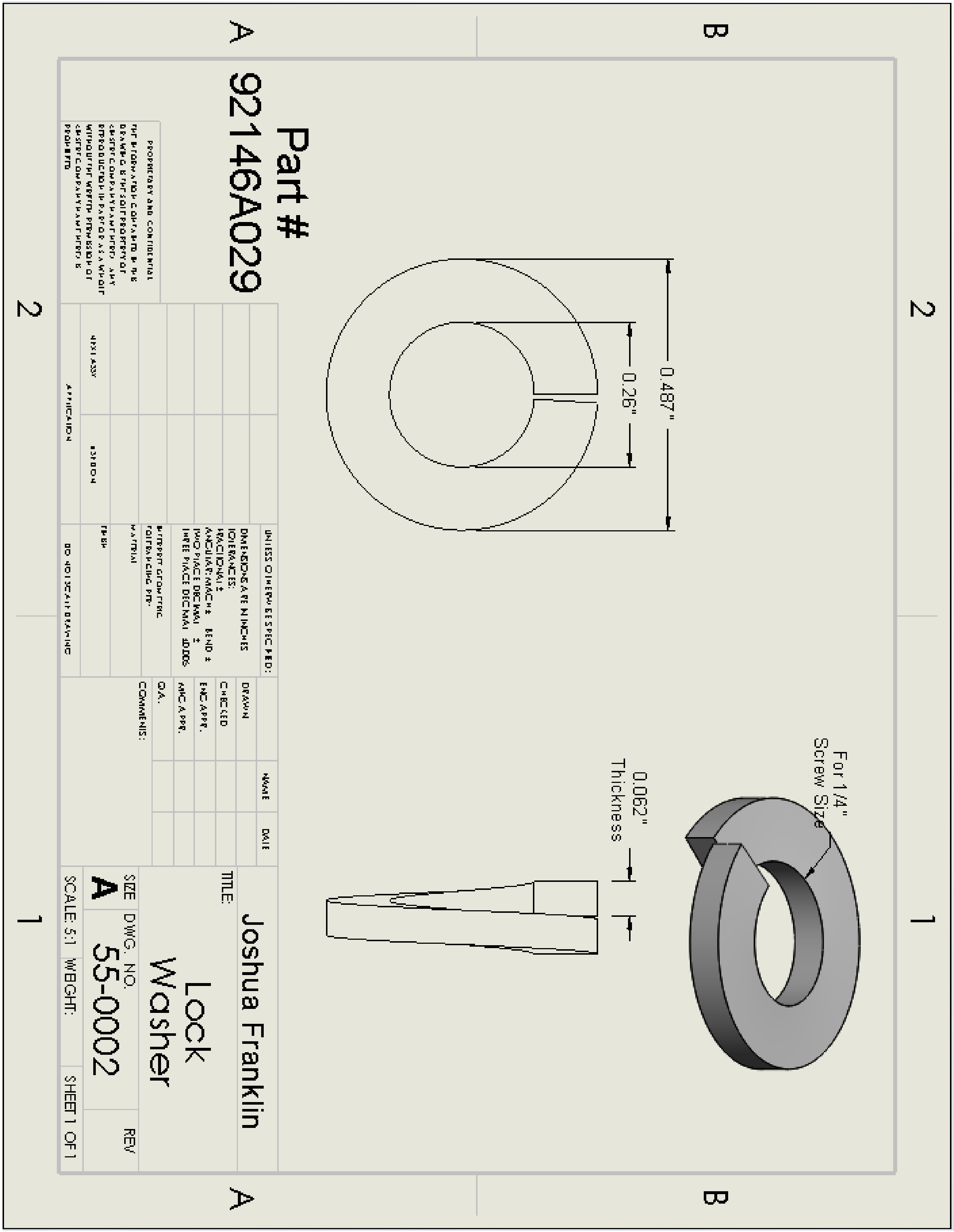
Appendix B3-8A Shifter Knob



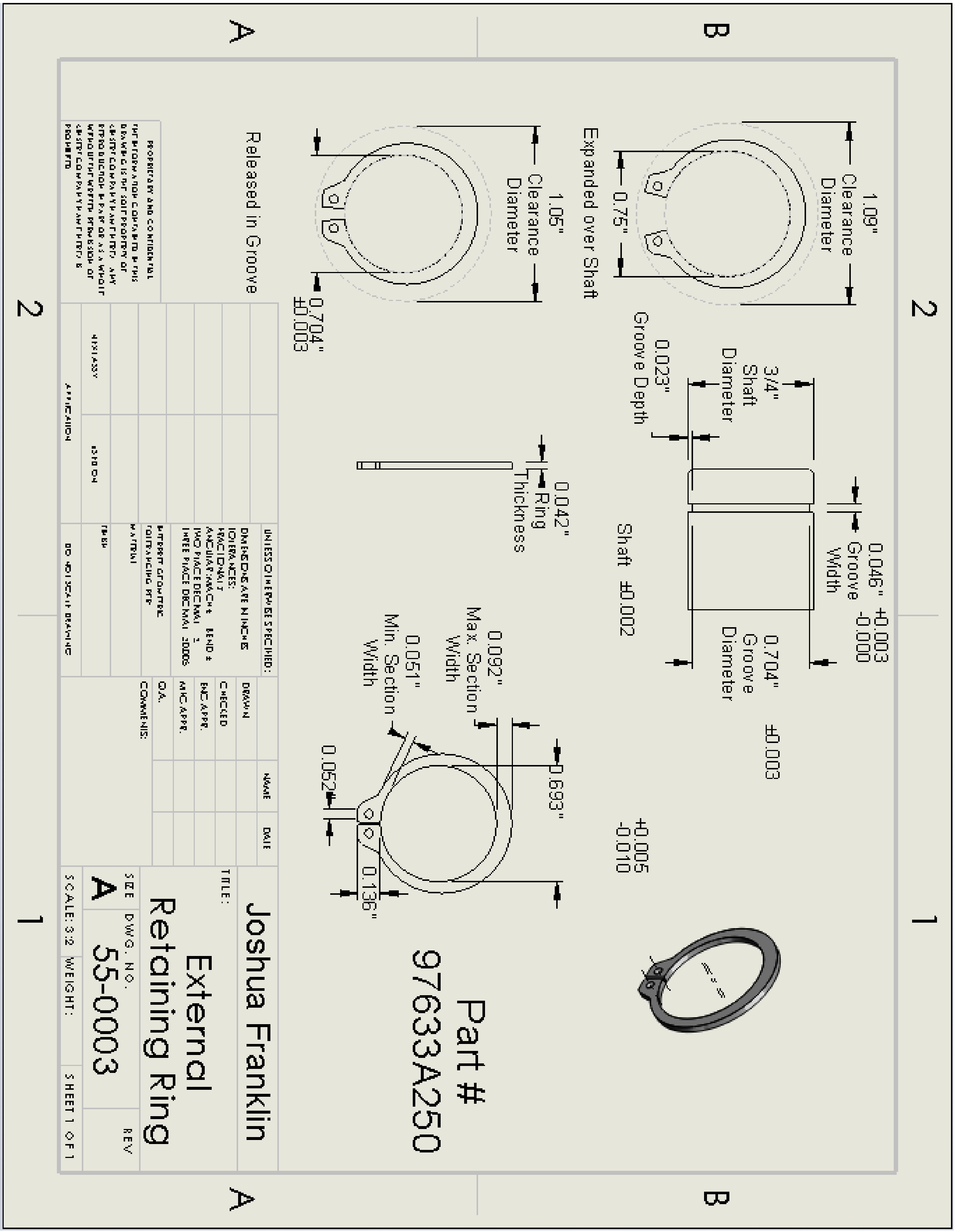
Appendix B3-8B Shifter Knob



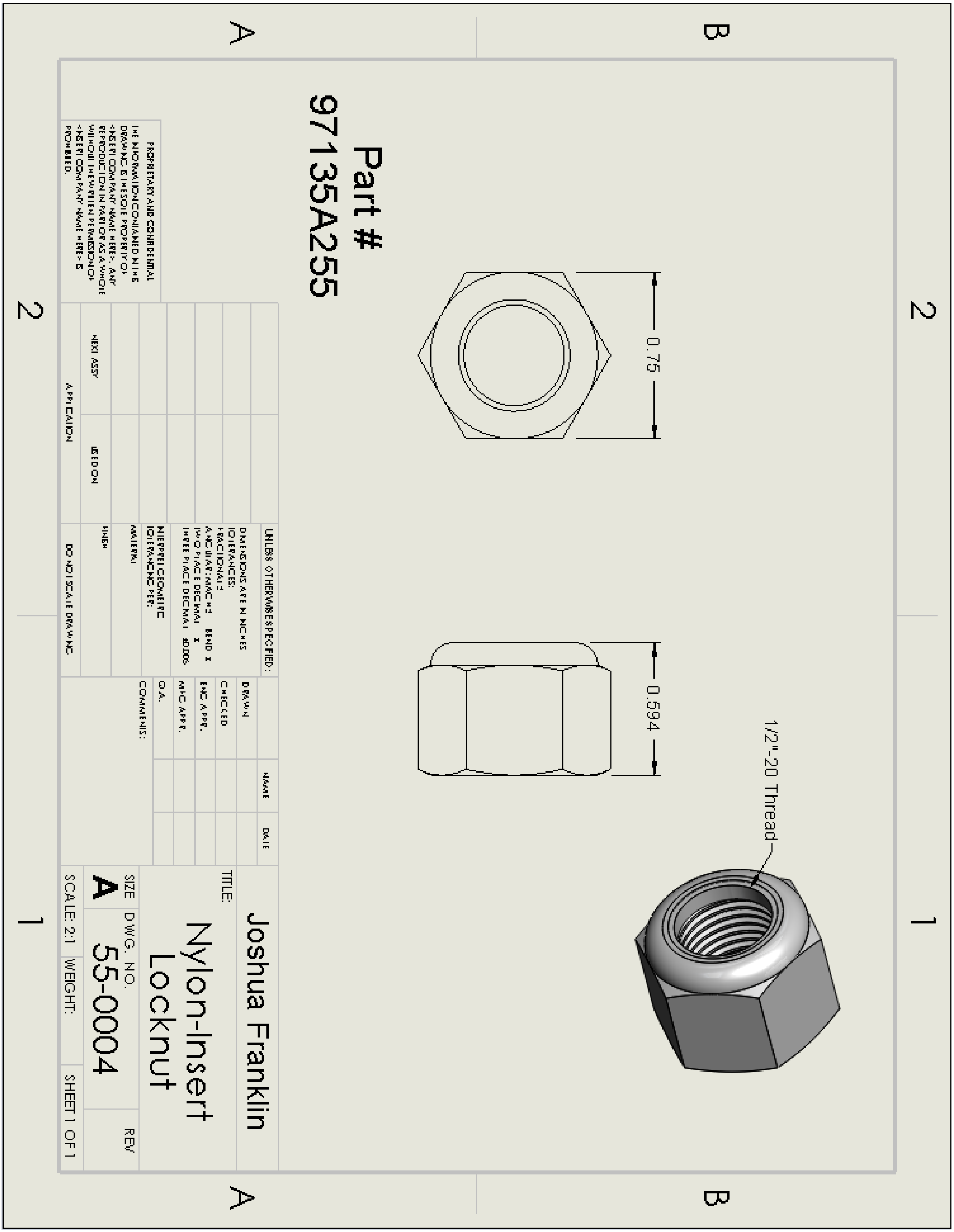
Appendix B3-9 Shifter Bolts



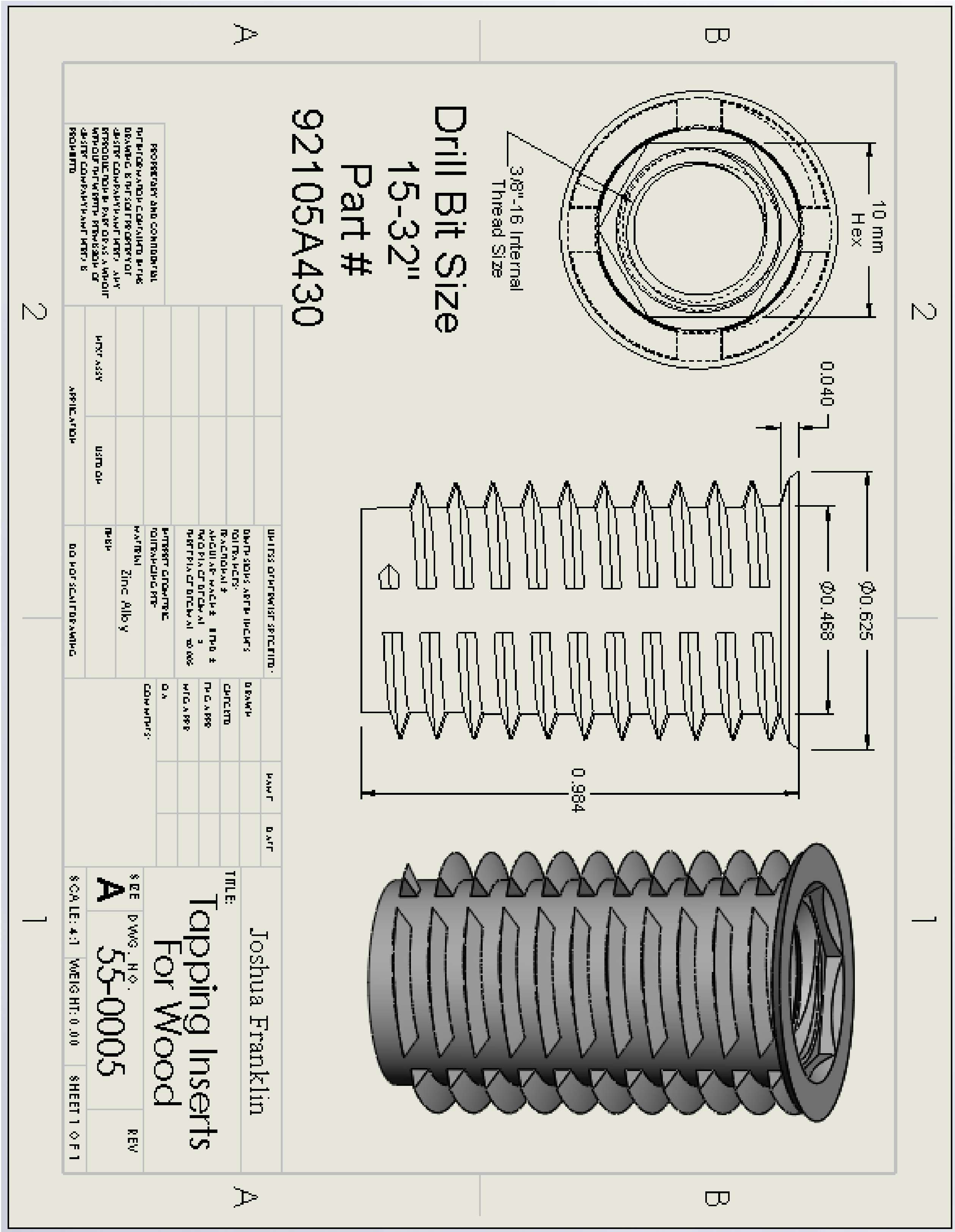
Appendix B3-10 Lock Washer



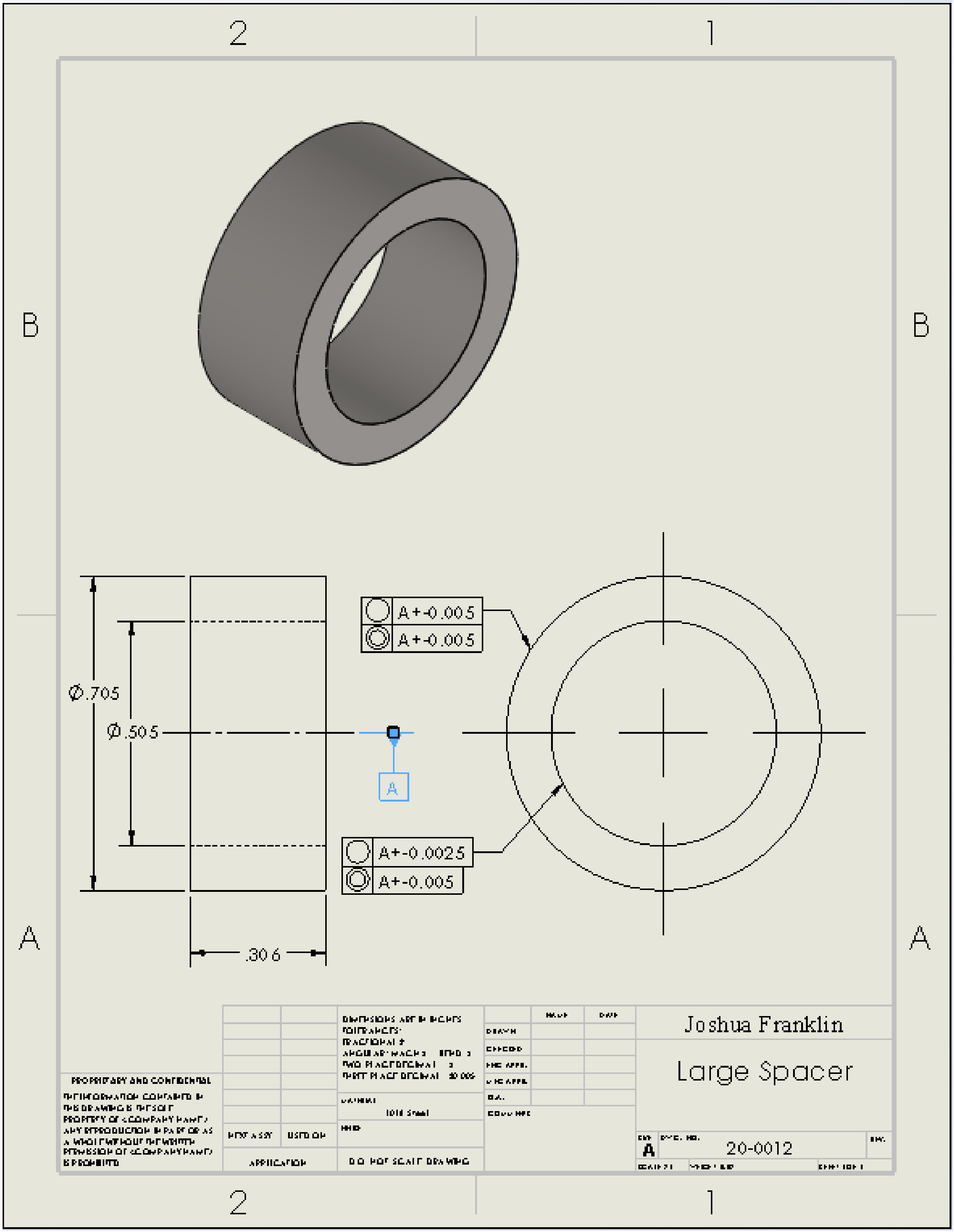
Appendix B3-11 Retaining Ring



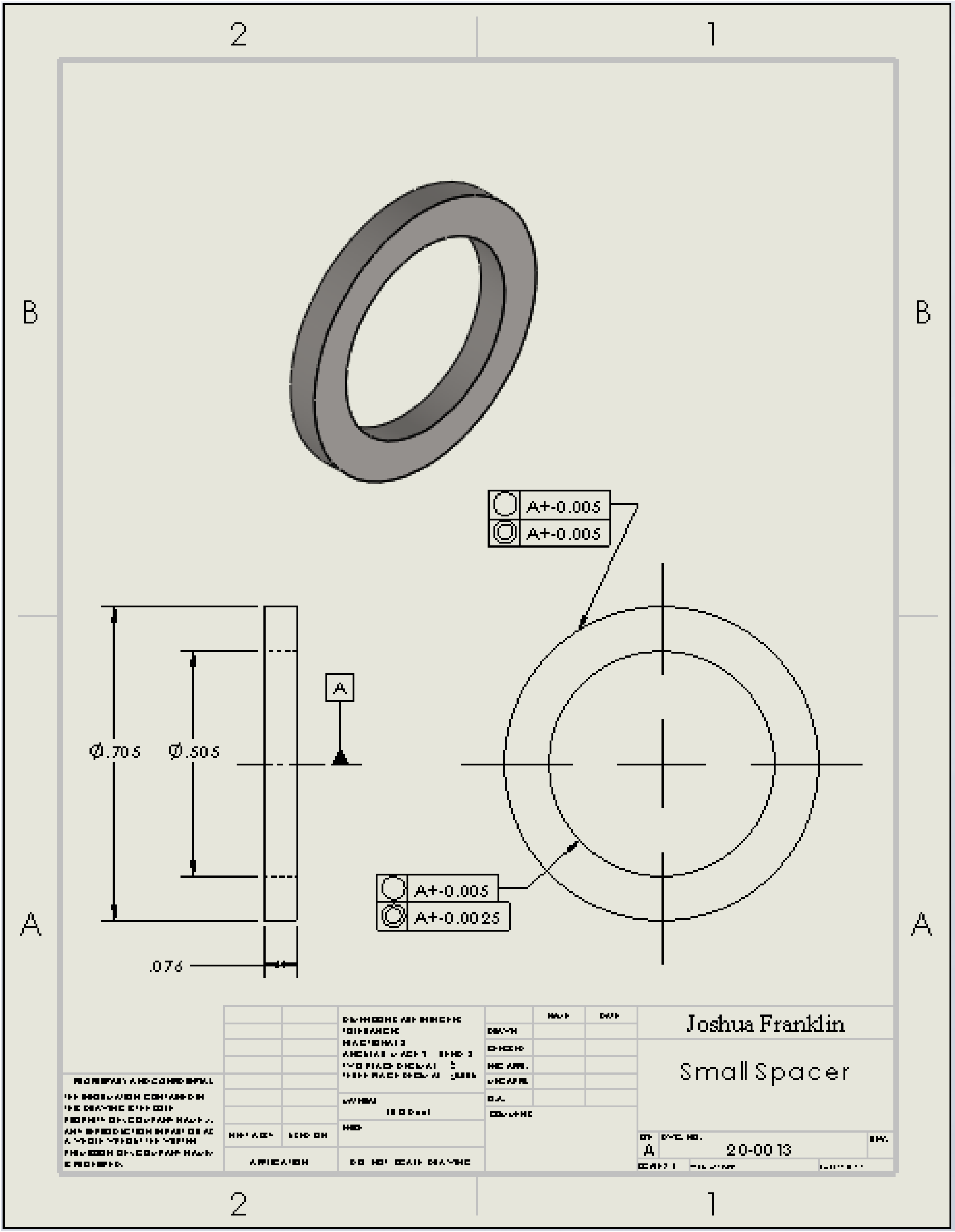
Appendix B3-12 Locking Nut



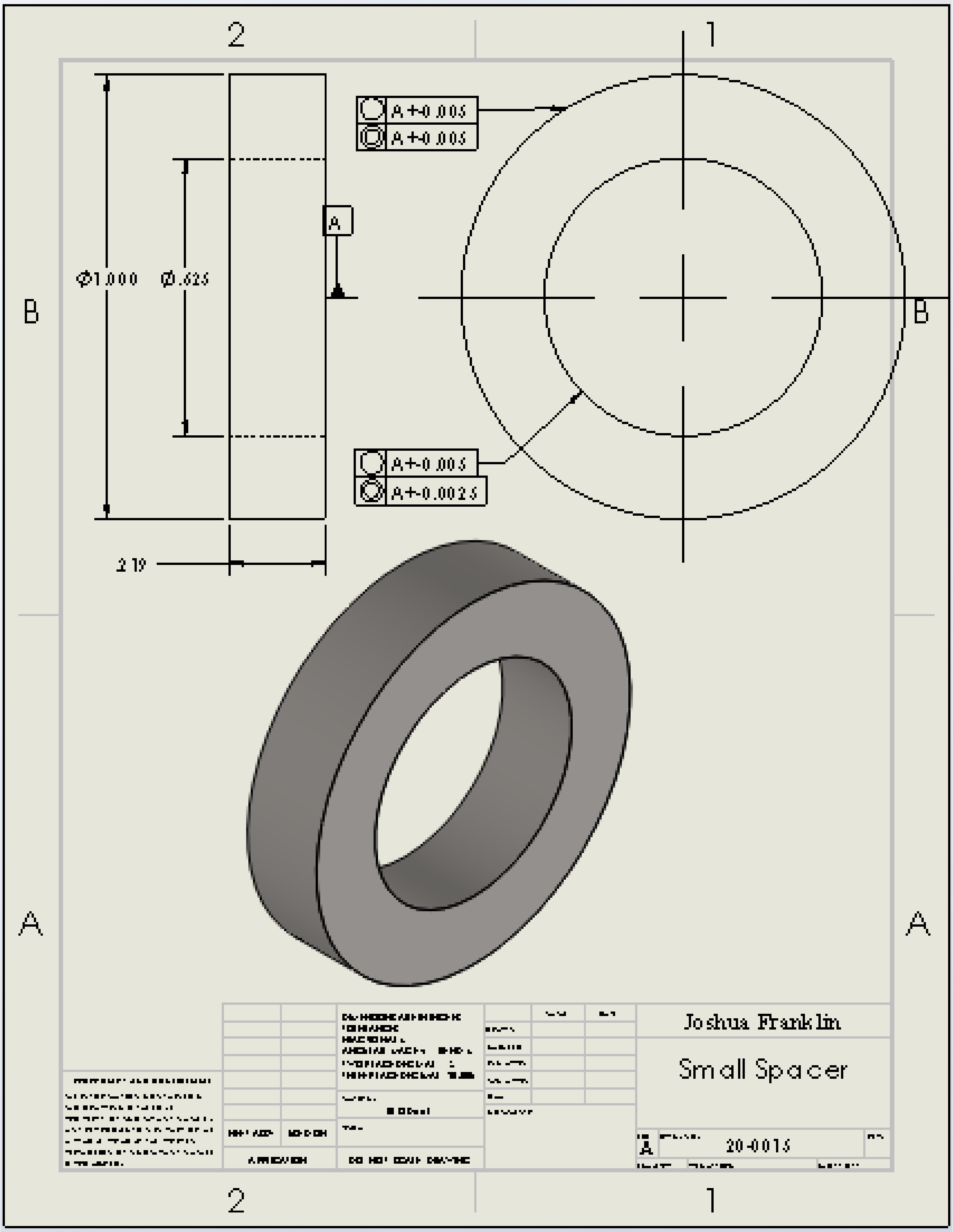
Appendix B3-13 Tapping Insert



Appendix B3-14 Large Spacer

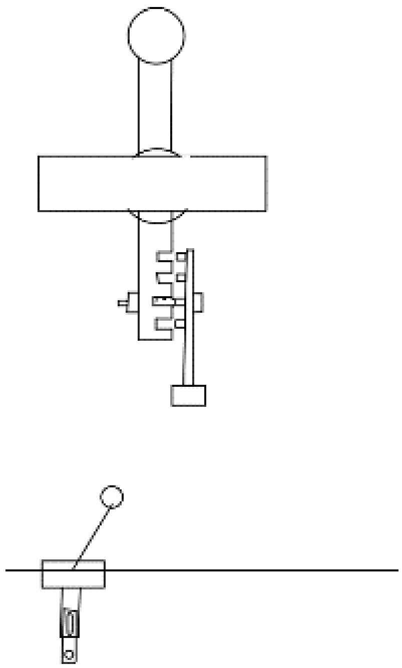


Appendix B3-15A Small Spacer

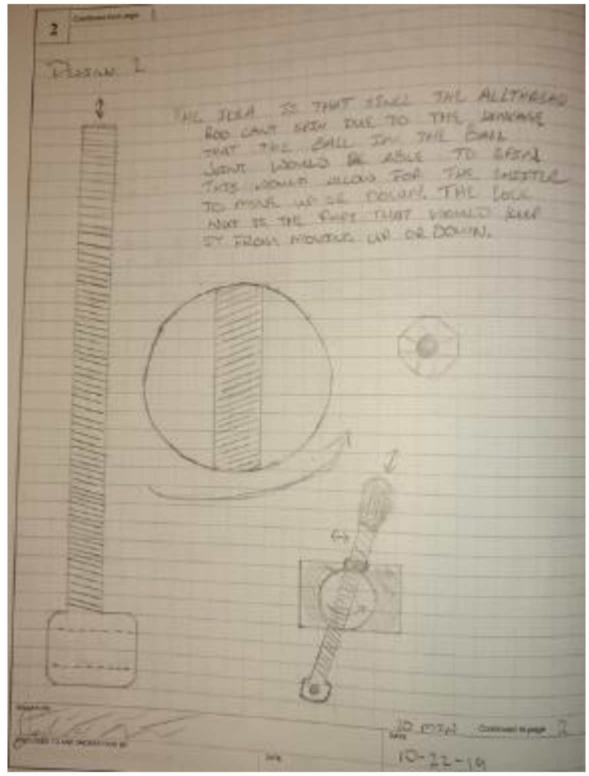


Appendix B3-15B Small Spacer

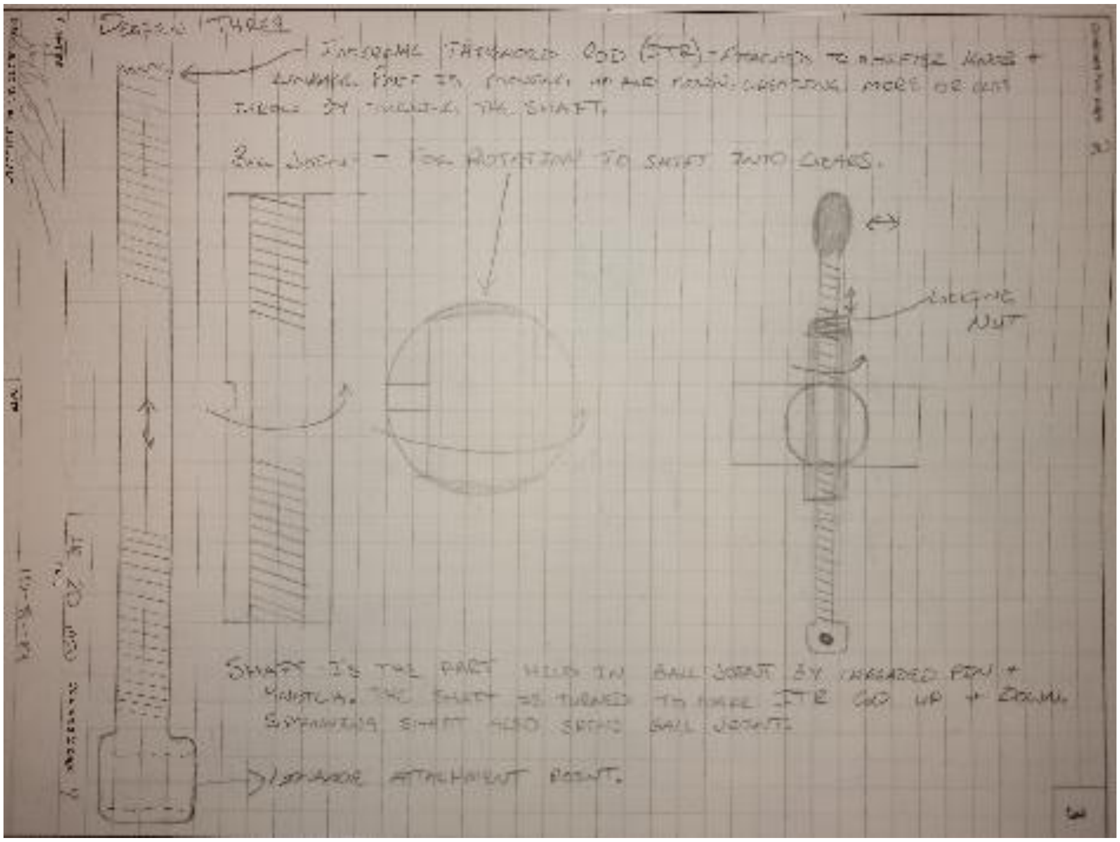
Appendix B4 Design



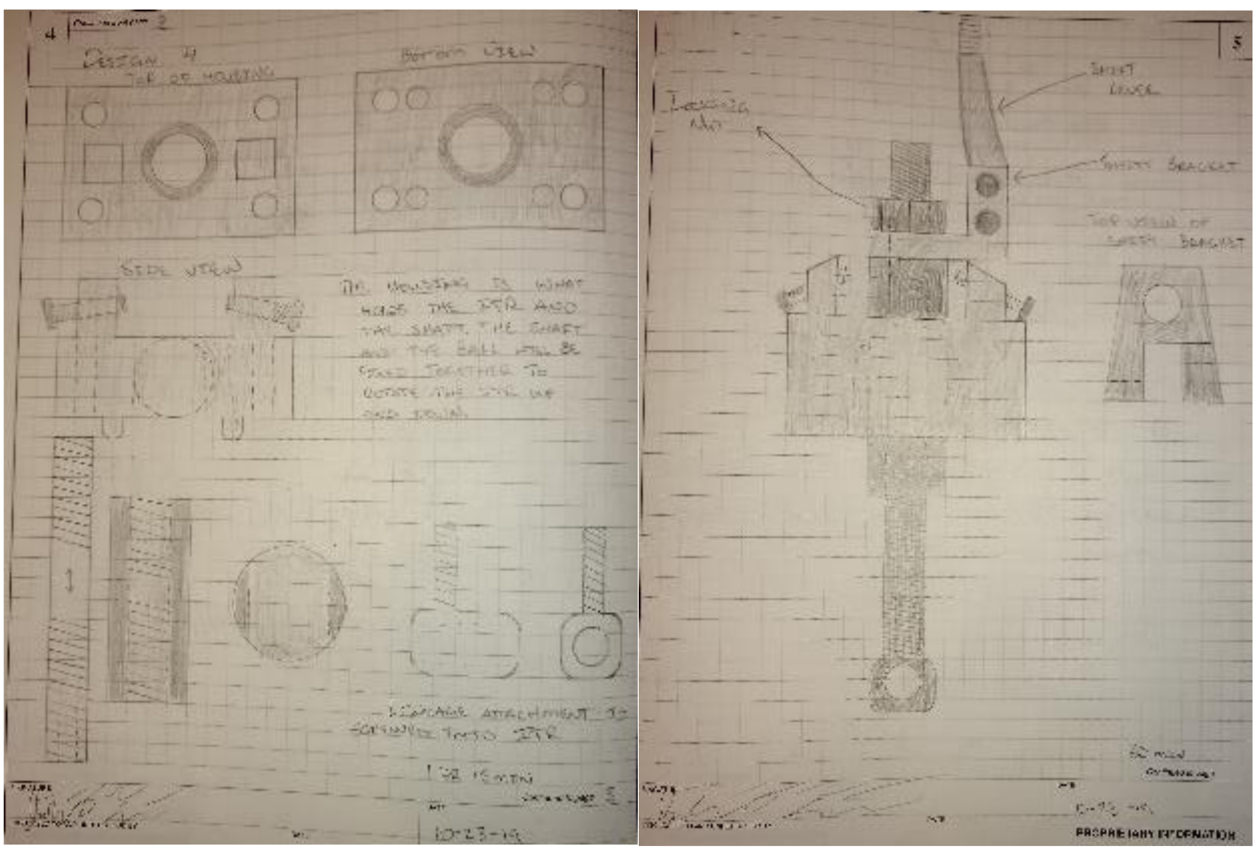
Appendix B4-1 Concept Design



Appendix B4-2 Threaded Ball Design



Appendix B4-3 Shaft Adjustment Design



Appendix B4-4 Shaft Adjustment with Bracket Shift lever and Threaded Linkage Attachment

Table B4-1 Decision Matrix

Decistion Matrix

Deciding Best Design

Criterion	Weight	Best Possible	Design		Design		Design		Design		
	1 to 3	3	Figure A-1	Score x Wt	Figure A-2	Score x Wt	Figure A-3	Score x Wt	Figure A-4	Score x Wt	
Cost (Less $)	1	3	2	2	3	3	2	2	1	1	
Weight (Less LB)	3	9	2	6	3	9	2	6	2	6	
Precision Quality	2	6	3	6	2	4	2	4	2	4	
Confidence Design Meeting Requirements	3	9	1	3	2	6	2	6	3	9	
Throw Reduction	3	9	1	3	2	6	2	6	3	9	
Less Complexity	2	6	2	4	1	2	1	2	1	2	
Total	12	36		24		30		26		31	
NORMALIZE THE DATA (muliply by fraction, N)		2.777777778		66.66666667		83.33333333		72.2222222		86.111111	Percent
										77.083333	Average
										9.1778831	Std Dev.
Decide if Bias is Good or Bad		Good Bias:	Standard Deviation is two or more digits				Yes				
		Poor Bias:	Standard Deviation is one or less digits				No				
			You can change the criteria, weighting, or the projects themselves…								

Weighting/Scoring Scale			
1	66.66666667	Figure A-1	Worst (too costly, low confidence, too big, etc.)
2	72.22222222	Figure A-3	Median Values, or Unsure of actual value
3	83.33333333	Figure A-2	Best (Low Cost, high confidence, etc.)
4	86.11111111	Figure A-4	Very Best (Low Cost, High Confidence, Lowest Throw, etc.)

Comments:	
Figure A-1	First Desgin itself is the most precise, but it doesn't meet all the requirements.
Figure A-2	Second Design Did quite well as the complexity to spin the Ball Joint was just the thing that made it second. This was the cheapest brest second option.
Figure A-3	Third Design just made the design to complex and didn't work the best for the overall design. This design did do a great job of meeting the Requirments.
Figure A-4	This Final option collects the best from the second and third design to create a more precise and most amount of throw.

APPENDIX C-PARTS LIST

Appendix C1-Parts list

Table C1-Parts List

Name	Parts	Material Type
Threaded Rod	1/2"-20 Thread Size, 1 Foot Long	Grade B7 Medium-Strength Steel Threaded Rod
Threaded Sleeve	3/4" Diameter 1 ft	Low-Carbon Steel Rod 1018
Swivel Joint	Lubrication-Free, 3/4" ID, 1-7/16" OD	Alloy Steel Material, Chrome-Plated Bearing Steel Ball
Drill Tap	1/2-20 UNF, 4 Flute Plug Hand Pulley Tap	Unknown
Steel Bar for Shifter	3/4" Thick, 3/4" Wide	4140 Alloy Steel Bar
Shifter Screws	1/4"-20 Thread, 1" Long	Black-Oxide Alloy Steel
Locknut	Nylon-Insert Locknut 1/2"-20 Thread Size	Grade 8 Fastener
Retaining Ring	3/4" OD, Black-Phosphate 1060-1090 Spring Steel	Black-Phosphate 1060-1090 Spring Steel
Tapping Insert	Tapping Inserts for Hardwood	Zinc-Plated Steel
Shifter Knob	Mahogony Block	Mohogony
Lock Washer	1/4" Screw Size, 0.26" ID, 0.487" OD	18-8 Stainless Steel
Prototype	Wood PLA	PLA

Appendix C2-Decision Matrix of Parts

Table C2-1

Senior Project - Shifter and Bracket

Score: 0 to 10 (best)

Criterion	Weight	5	1.4140 Alloy Steel Bar		High-Strength 1045 Carbon Steel Bar		Ultra-Corrosion-Resistant Grade 2 Titanium Bar		Oversized Shock-Resistant S7 Tool Steel Bar	
	1 to 5 (must)	Best Possible	1	Score x Wt	2	Score x Wt	3	Score x Wt	4	Score x Wt
Price	4	20	5	20	4	16	1	4	3	12
Yeild Strength	5	25	4	20	5	25	2	10	3	15
Excess	2	10	4	8	3	6	4	8	1	2
Length	2	10	4	8	4	8	4	8	4	8
Confidence	4	20	4	16	3	12	4	16	3	12
Trust	3	15	4	12	4	12	4	12	4	12
Machinability	4	20	3	12	4	16	3	12	4	16
Total	24	100		96		95		70		77
NORMALIZE THE DATA (muliply by fracti		1		96		95		70		77
								84.5	Average	
								13.02561579	Std Dev.	
Decide if Bias is Good or Bad		Good Bias:	Standard Deviation is two or more digits				Good? Then you're done.			
		Poor Bias:	Standard Deviation is one or less digits				Poor? Then change something!!!			
			You can change the criteria, weighting, or the projects themselves...							

Weighting/Scoring Scale	
1	1.4140 Alloy Steel Bar
2	High-Strength 1045 Carbon Steel Bar
3	Oversized Shock-Resistant S7 Tool Steel Bar
4	Ultra-Corrosion-Resistant Grade 2 Titanium Bar

Criterion	
Price	Cost of material. High values are low costs.
Yeild Strength	The value of strength in ksi
Excess	The ammount of excess material
Length	does it meet the required length
Confidence	Confidence in the material
Trust	in the company to diliver the product and material correctly
Machinability	the ability to machine easily

Table C2-2

Senior Project - Threaded Rod

Criterion	Weight	5	1/2"-13 ASTM A307 Grade A, Coarse Thread, Zinc		1/2"-13 ASTM A193 B7 Medium-Strength		1/2-20 Grade B7 Medium-Strength Steel	
	1 to 5 (must)	Best Possible	1	Score x Wt	2	Score x Wt	2	Score x Wt
Price	4	20	5	20	4	16	3	12
Yeild Strength	5	25	1	5	4	20	5	25
Excess	2	10	2	4	2	4	2	4
Thread Strength	3	15	3	9	3	9	4	12
Length	2	10	4	8	4	8	4	8
Confidence	4	20	3	12	3	12	3	12
Trust	3	15	2	6	4	12	4	12
Density	2	10	2	4	4	8	4	8
Total	25	125		68		89		93

Score: 0 to 10 (best)

NORMALIZE THE DATA (muliply by fracti	0.8	54.4	71.2	74.4		
				66.66666667	Averag	
				10.74305978	Std Dev	

Decide if Bias is Good or Bad	Good Bias:	Standard Deviation is two or more digits	Good? Then you're done.
	Poor Bias:	Standard Deviation is one or less digits	Poor? Then change something!!!
		You can change the criteria, weighting, or the projects themselves...	

Weighting/Scoring Scale

1	1/2-20 Grade B7 Medium-Strength Steel
2	1/2"-13 ASTM A193 B7 Medium-Strength
3	1/2"-13 ASTM A307 Grade A, Coarse Thread, Zinc

Criterion

Price	Cost of material. High values are low costs.
Yeild Strength	The value of strength in ksi
Excess	The ammount of excess material
Thread Strength	Course vs fine that course has a lesser strength than fine
Length	does it meet the required length
Confidence	Confidence in the material
Trust	in the company to diliver the product and material correctly
Density	Comparison between different densities.

Comments:

I found that the trunst I have comes from a more Fine thread as well as that the 1 threaded rod didn't even give a yeild strength.

Table C2-3

Senior Project - Threaded Sleeve

Score: 0 to 10 (best)

Criterion	Weight	5	4140 Alloy Steel Rotary Shaft		Low-Carbon Steel Rod 1018		Oversized High-Speed M2 Tool Steel Rod		Oversized Wear-Resistant D2 Tool Steel Rod		High-Strength Grade 5 Titanium Rod	
	1 to 5 (must)	Best Possible	1	Score x Wt	2	Score x Wt	3	Score x Wt	4	Score x Wt	5	Score x Wt
Price	4	20	2	8	5	20	1	4	4	16	2	8
Yeild Strength	5	25	4	20	2	10	3	15	2	10	5	25
Excess	2	10	5	10	2	4	1	2	1	2	5	10
Length	2	10	5	10	4	8	4	8	4	8	4	8
Confidence	4	20	4	16	2	8	2	8	2	8	4	16
Trust	3	15	3	9	3	9	3	9	3	9	3	9
Machinability	4	20	3	12	4	16	3	12	4	16	1	4
Total	24	100		85		75		58		69		80

NORMALIZE THE DATA (muliply by fracti	1	85	75	58		69	80
				73.4	Average		
				10.45466403	Std Dev.		

Decide if Bias is Good or Bad	Good Bias:	Standard Deviation is two or more digits	Good? Then you're done.
	Poor Bias:	Standard Deviation is one or less digits	Poor? Then change something!!!
		You can change the criteria, weighting, or the projects themselves...	

Weighting/Scoring Scale

1	4140 Alloy Steel Rotary Shaft
2	High-Strength Grade 5 Titanium Rod
3	Low-Carbon Steel Rod 1018
4	Oversized Wear-Resistant D2 Tool Steel Rod
5	Oversized High-Speed M2 Tool Steel Rod

Criterion

Price	Cost of material. High values are low costs.
Yeild Strength	The value of strength in ksi
Excess	The ammount of excess material
Length	does it meet the required length
Confidence	Confidence in the material
Trust	in the company to diliver the product and material correctly
Machinability	the ability to machine easily

APPENDIX D-BUDGET

Table D1-Budget

Budget	Parts							
Parts #	Name	Parts	Material Type	Yeild Strength	Quantity	Cost ($)	Tax ($)	Shipping ($)
20-0001	Threaded Rod	1/2"-20 Thread Size, 1 Foot Long	Grade B7 Medium-Strength Steel Threaded Rod	105 ksi	1	9.08	0.75	Unknown
20-0002	Threaded Sleeve	1 1/8" Diameter 1 ft	Ultra-Machinable 12L14 Carbon Steel Rod	#VALUE!	1	19.11	1.59	Unknown
20-0004,5	Swivel Joint	Lubrication-Free, 1" ID, 1-3/4" OD	Corrosion-Resistant Swivel Joint	47850 lbs	1	52.39	4.35	Unknown
0	Drill Tap	1/2-20 UNF, 4 Flute Plug Hand Pulley Tap	Unknown	Unknown	1	42.28	4.57	12.79
20-0003,6,7	Steel Bar for Shifter	3/4" Thick, 3/4" Wide	4140 Alloy Steel Bar	60 ksi	1	26.81	2.23	Unknown
55-0001	Shifter Screws	1/4"-20 Thread, 1" Long	Black-Oxide Alloy Steel	120 ksi	10	10.18	0.84	Unknown
55-0004	Locknut	Nylon-Insert Locknut 1/2"-20 Thread Size	Grade 8 Fastener	Unknown	10	4.58	0.38	Unknown
55-0003	Retaining Ring	3/4" OD, Black-Phosphate 1060-1090 Spri	Black-Phosphate 1060-1090 Spring Steel	3750 lbs	100	12.8	1.06	Unknown
55-0005	Tapping Insert	Zinc Alloy Tapping Inserts for Softwood	Flanged, 3/8"-16 Thread Size, 63/64" Installed L	Unknown	25	13.97	1.16	
20-0008	Shifter Knob	Mahogony Block	Mohogony	Unknown	1	0	0.00	0
55-0002	Lock Washer	1/4" Screw Size, 0.26" ID, 0.487" OD	18-8 Stainless Steel	unknoqn	100	3.68	0.31	
0	Prototype	Wood PLA	PLA	Unknown	1	31.41	2.61	0
	Linkage Attachment	1/2"-20 Internal Thread	Corrosion-Resistant Ball Joint Rod End	4700 lbs	1	38.49	3.19	
						264.78	23.04	12.79
					Total	300.6075		

Table D2-Final Cost

Budget	Parts							
Parts #	Name	Parts	Material Type	Yeild Strengt	Quantity	Cost ($)	Tax ($)	Shipping ($)
20-0001	Threaded Rod	1/2"-20 Thread Size, 1 Foot Long	Grade B7 Medium-Strength Steel Threaded R	120 ksi	1	9.08	0.7536	Unknown
20-0002	Threaded Sleeve/S	1 1/8" Diameter 1 ft	Ultra-Machinable 12L14 Carbon Steel Rod	54 ksi	1	19.11	1.5861	Unknown
20-0004,5	Swivel Joint	Lubrication-Free, 1" ID, 1-3/4" OD	Corrosion-Resistant Swivel Joint	47850 lbs	1	52.39	4.3484	Unknown
20-0003,6	Steel Bar for Shifter	3/4" Thick, 3/4" Wide	4140 Alloy Steel Bar	60 ksi	1	26.81	2.2252	Unknown
55-0001	Shifter Screws	1/4"-20 Thread, 1" Long	Black-Oxide Alloy Steel	120 ksi	10	10.18	0.8449	Unknown
55-0004	Locknut	Nylon-Insert Locknut 1/2"-20 Thread Si	Grade 8 Fastener	Unknown	10	4.58	0.3801	Unknown
55-0005	Tapping Insert	Zinc Alloy Tapping Inserts for Softwood	Flanged, 3/8"-16 Thread Size, 63/64" Installec	Unknown	25	13.97	1.1595	
20-0008	Shifter Knob	Mahogony Block	Mohogony	Unknown	1	0	0	0
0	Prototype	Wood PLA	PLA	Unknown	1	31.41	2.607	0
	Linkage Attachment	3/4" Shank Diameter, 3-1/2" Shank Cen	High-Strength Rod End Bolt Blank	125 ksi	1	8.27	0.6864	
	Linkage Attachment	1/2"-20 Internal Thread	Corrosion-Resistant Ball Joint Rod End	4700 lbs	1	38.49	3.1947	
						214.29	17.786	0
					Total	232.08		

APPENDIX E-SCHEDULE

Table E-Schedule

DEFINE HOW THE STUDENTS SHOULD INDICATE STARTING EARLY/LATE AND FINISHING EARLY/LATE
X to indicate work

EXAMPLE SCHEDULE FOR SENIOR PROJECT:
NOTE: STUDENTS MUST MAKE THEIR OWN SCHEDULE!!!!!!!!!!!!!
PROJECT TITLE:Adjustable Short Throw Shifter
Principal Investigator.:Joshua Franklin

Finished	$
Finished Late	X
Correct Start Time	
Started on Time	
Started Late	

Note: March x Finals
Note: June x Presentation
Note: June y-z Spr Finals

S | October | November | Dec | January | February | March | April | May | June

TASK: ID	Description	Duration Est. (hrs)	Actual (hrs)	
1	Proposal*			
1a	Outline	3	2	$
1b	Intro	3	4	$
1c	Methods	3	0.25	$
1d	Analysis	5	0.5	$
1e	Discussion	4	0	$
1f	Parts and Budget	7	4	$
1g	Drawings	4	3.92	$
1h	Schedule	5	1	$
1i	Summary & Appx	3	0	$
	subtotal:	37	15.67	
2	Analyses Anaylysis of Stock Shifter (AOSS) Analyses of Design (AOD)			
2a	AOSS Yeild Force	2	1.45	X
2b	AOSS Yeild Stress, Deformation, Total Shear	1	0.75	X
2c	AOSS Yeild Torque & Angle of Twist	0.5	1.6	X
2d	AOSS Allowable Forces, Stress, Def. & Shear	1.5	1.25	X
2e	AOSS Allowable Stress Deformation and shear	0.5	0.7	$
2f	AOSS Data Measurments	2	1.6	$
2g	AOD Long Shifter	3	3.4	X
2h	AOD Long Shifter, Hole Analyses	2	2.1	X
2i	AOD Shifter Bracket Hole Analysis	0.5	0.5	X
2j	AOD Press Fit	1	0.75	X
2k	AOD Medium Shifter	1	1	X
2l	Design Matrix	1	1.25	$
2m	Shifter and Bracket Matrix	1	0.75	X
2n	Threaded Rod Matrix	1	1	$
2o	Threaded Sleeve Matrix	1	1	$
	subtotal:	19	19.1	
3	Documentation			
3a	20-0001	0.5	1.5	$
3b	20-0002	1.5	1.75	$
3c	20-0003	2.5	2.15	$
3d	20-0004	1.5	1.25	$
3e	20-0005	1.5	1.25	$
3f	20-0006	2	3	$
3g	20-0007	3	2.25	$

3h	20-0008	2	2.5
3i	55-0001	0.5	0.5
3j	55-0002	0.5	0.5
3k	55-0003	0.6	0.5
3l	55-0004	0.5	0.5
3m	55-0005	0.75	0.5
3n	12-0001	10	8
	subtotal:	27.35	26.15
4	Proposal Mods		
4a	Project Robot Schedule	15	17.25
4b	Project Robot Part Inv.	5	3
4c	Crit Des Review*	10	8
	subtotal:	30	28.25
7	Part Construction		
7a	Mentor Meeting	15	17.5
7b	Ordering Parts	2	1.25
7c	Threaded Rod	1	2
7d	Threaded Sleeve	8	8.5
7e	Revising Drawings ASME(14.5)	3	4
7f	Methods and Construction	1	2
7g	Shifters	4	6.25
7h	Shifter Knob	6	4.2
7j	Linkage Attachment	1	3
7k	Shifter Bracket	5.5	5.2
7m	Budget	3	1
7n	Assembly	6	6
7o	Spacers	2	2.5
7p	Wrench	1	4
7q			
7r			
7s			
7t			
7u	Task#9	0	0
	subtotal:	58.5	67.4
9	Device Construct		
9a	Assemble Joshua Components	4	5.5
9b	Assemble Whole Project	3	4.5
9e	Take Dev Pictures	2	2.25
9f	Update Website	8	6.25
	subtotal:	17	18.5
10	Device Evaluation		
10a	List Parameters	2.5	3
10b	Design Test&Scope	3	2
10c	Obtain resources	2	1.6
10d	Make test sheets	2	3
10e	Plan analyses	1	1.5
10g	Test Plan*	10	15
10h	Perform Evaluation	10	12
10i	Take Testing Pics	3	3
10h	Update Website	7.5	8
	subtotal:	41	49.1
11	495 Deliverables		
11a	Get Report Guide	3	2
11b	Make Rep Outline	3	4
11c	Write Report	20	18
11d	Make Slide Outline	5	4.5
11e	Create Presentation	10	10.25
11f	Update Website	15	12
11g	Jump Drive	4	3
	subtotal:	60	53.75

Total Est. Hours= 289.85 277.92 =Total Actual Hrs

Labor$ 15 4348

7500

Note: Deliverables*

- Draft Proposal
- Analyses Mod
- Document Mods
- Final Proposal
- Part Construction
- Device Construct
- Device Evaluation
- 495 Deliverables

APPENDIX G-TESTING REPORT

Appendix G1-Test Report

Test 01

Introduction

Requirements:

It is required that the throw will adjust to between 20%-40% of shifts.

Parameters of Interest:

This test is interested in the distance of travel the shifter knob makes between 2 gears and into neutral. This will be trailed at 3 different adjustments with three different shifter sizes.

Predicted Performance:

It is predicted that the travel for all three different shifters will reduce up to 50 % of the highest distance of throw.

Data Acquisition:

The data acquired will be the angle of adjustment between each shift and the heights of the shifter knobs from each different length shifter. This will be done using a magnetic angle locater and a measuring tape. The Data will be recorded into Excel and then will be formulated into the distance of travel.

Schedule:

This test was performed on Friday April 17, 2020. See Gantt chart in APPENDIX E in main report for other schedule details.

Method

Resources:

The resources for this test is very minimal but the most important component was provided by Scott Calahan of CWU, this device was the Magnetic Angle Locator. The vehicle with the installed Adjustable Short Throw Shifter (ASTS) and a measuring tape. Assess to the vehicle will be the location.

Data Capture:

Data Capture is very straight forward. The length of the shifter arm is measured. The angle at each gear with three different adjustments will also take place using the magnetic angle locator.

Test Procedure Overview:

The shifter knob to the swivel joint will be measured by measuring tape. This will be recorded for the 6”, 8”, and 10” shifters. The angle reading will come from the magnetic locator attached to the side of the shifter at each gear with three different adjustments in at different times of the test. This data will then be put in excel and will formulate the distance that the shifter knob was required to travel.

Operational Limitations:

The movement of the device into each gear is the main operation that will be measured. The measurement of the angle and length of the shifter will determine the adjusted throw. The limitation is the height measure from the center of the swivel joint to the shifter knob will be difficult due to the parts in the way. Measurements will have to measure from those specific parts to create a base measurement to go from.

Precision/Accuracy:

The precision of height measurement will be within a quarter of an inch. The accuracy and precision to measure the angle at each gear is 0.1 degrees per the device’s capability.

Data Storage/Manipulation/Analysis:

The measurements will be stored on paper, translated to excel, then formulated to receive travel to each gear. Graphs then will show distance of travel for each gears, shifters, and adjustments.

Data Presentation:

Data is presented in graph and a percent of range reduced throw.

Test Procedure

Summary/Overview:

This project is designed for the reduction of throw. This test will measure the distance of travel for individual shifter length at different adjustment levels to show that this device performs by reducing the throw by 40% or more. The ASTS will be tested inside the vehicle recording the measurements required. For this test, one person will measure and record the angles of shifters.

Time/Duration:

This test will take roughly 2 hours as there will be a total of 48 different measurements.

Place:

This test took place inside the vehicle.

Resources Needed:

- ASTS
- ¾” Wrench or Socket
- Measuring Tape
- Magnetic Angle Locator
- 10 mm Allen Key
- Z Frame Wrench

- Shifter Knob
- The 3 different type Shifters

Procedure:

1. Ensure installation was done correctly and fastened. Referencing installation of ASTS in Appendix G1 provided by Dustin Braun
2. Install shifter bracket onto ASTS by sliding the half inch hole over the threaded Rod and fitting the slot over the threaded sleeve. Align Slot in bracket facing parallel with the vehicle.
3. Press firmly on the shifter bracket, measure from the top face of the shifter bracket to the top of the threaded Rod. This measurement should read ¾" of an Inch. If adjustment is needed use step ___ to adjust until the measurement reads 0.75 inches.
4. Take the ½"-20 Locknut and tighten the nut clockwise with the ¾" Wrench or Socket until it touches the shifter bracket. Leave the wrench or socket on nut.
5. Take custom Z Frame Wrench and put it into the slot on the threaded sleeve. Use the Z frame wrench and the ¾" Wrench or Socket to fully tighten the shifter bracket. Do not rotate the Z frame wrench hold in place while rotating the ¾" wrench clockwise until tight. Then remove Wrenches
6. Choose one of the shifter lengths to begin testing.
7. Take Shifter bracket and place the shifter inside of slot, line up the holes for the 1 ¼" Socket Head Screws. Tighten screws using a 10 mm Allen Key through shifter bracket and shifter for a tight fit.
8. Install Shifter knob by rotating clockwise on the top of the shifter.
9. Place the vehicle in Neutral.
10. Record measurement from the top face of the shifter bracket down to the swivel joint. Then add half of an inch to this measurement.
11. Measure from the top face of the shifter bracket to the top of the shifter knob.
12. Take the two measurement and add them together to equal the height from central axis of rotation to the top of the shifter knob, record total.
13. Attach Magnetic Angle Locator to the flat surface on the shifter above the threaded rod. Zero the angle locater.
14. Record the angle in this progression
    a. First gear
    b. Second gear
    c. Third Gear
    d. Fourth Gear
    e. Fifth Gear

15. Once angles are recorded place Z frame wrench into slot on threaded sleeve holding in place with no rotation. Take the ¾" wrench and place it over the locknut and rotate counter-clockwise to loosen the nut off the threaded rod. Leave Z frame wrench in slot.
16. Hold Shifter bracket in place while rotating Z frame wrench to the middle adjustment height for the average throw.
17. Repeat steps 4-5 for tightening down shifter bracket.
18. Repeat 10-12 to make sure the height is still similar.
19. Repeat steps 13-18 to record all angle data and then adjust throw to highest level.
20. Once all data is collected for the first shifter choice. Take 10 mm Allen Key rotate counter-clockwise the 1 ¼" Socket Head Screws to remove the shifter.
21. Rotate the shifter knob counter-clock to uninstall from shifter.
22. Then repeat steps 6-20 for the last two shifter sizes.

Risk/Safety:

This test will have a lot of pinching points. Wear proper PPE, this test recommends glasses and gloves. Make sure when tightening with the two wrenches that they are close enough in handle distance to interlock hands to avoid pinching of fingers.

Discussion:

This test, and the information above should be enough to accomplish the collection of data necessary.

day of, the operator and assistant should not hesitate to make them.

Deliverables

Parameter Values:

When this test was performed the magnetic angle locater only held values within a tenth of a degree. This was measured in 55 different variations ranging at angles of 17.5°-2.8°.

Calculated Values:

Arc length of is calculated using the distance of the central axis as the radius and the angle to find the distance of throw. Using $Arc_{length} = 2\pi r\left(\frac{\theta}{360}\right)$ to compare to the stock model shifter and Hurst shifter to find the percent reduction. Range of adjustability allowed for an arc length of 1.8-0.48 inches.

Success Criteria Values:

Success for this test would have been a reduced throw between 20-40%. This test clamed success by achieving a Reduction of stock by a percentage of 38-66%. This also met the benchmark by reducing more throw than the Hurst shifter by 0-44% of its throw.

Conclusion:

This test demonstrates the upper and lower limits of operations for the device. The shifters capability to change adjustment and customization for the customer is beyond successful. The demonstration performed shortly after install was consistent of swift effortless shifts that were short and easy. This devices versatility seems to the hallmark of its capability.

Test 02

Introduction

Requirements:

It is required Adjustable from inside the car without removing or replacing anything but the Locking Nut in under 60 seconds.

Parameters of Interest:

This test is interested in the time (seconds) it takes to take change the amount of throw in the shifter. The requirements are that it takes place inside the vehicle.

Predicted Performance:

It is predicted that the adjustment the throw from inside the vehicle in less than 60 seconds.

Data Acquisition:

The data acquired will be the time it takes to remove the Locking nut, remove shifter assembly, and then adjust and reinstall and go. This test will consist of two parts changing the shifter and or adjusting the throw. This test be done using a timer. The Data will be recorded into Excel and then will be formulated into the average adjustability time.

Schedule:

This test was performed on Friday April 17, 2020. See Gantt chart in APPENDIX E in main report for other schedule details.

Method

Resources:

The resources for this test are very minimal because all that is needed is stopwatch, ¾ inch wrench, and a 3/16" Hex Key.

Data Capture:

Data Capture is very straight forward. The length of the time is measured and then averaged.

Test Procedure Overview:

Part One of test two is the timer begins and the ¾ inch wrenched is used to loosen the locking nut. Once the locking nut is removed the shifter assembly is removed and the adjustment is made and then components reinstalled. The second part is the shifter assembly shall be disassembled using a 3/16"

Hex Key. This will simply be to change the assembly of shifter height. The shifter knob will be unassembled and then new assembly components will be reinstalled.

Operational Limitations:

The movement of the device around the Center Console of the vehicle will be the largest limitation. When the vehicle is set in the highest throw a socket will not be able to be used, due to the depth of the socket not being long enough, adding more time to the trial. Other limitations are to change multiple components at a time could prove difficulty when the working space is only a lab.

Precision/Accuracy:

The precision of height measurement will be within a hundredth of a second. The simulation will be the operator is changing or adjusting the device so the operator will begin and end the time simulating driver capability. The precision will be to the operator's ability to adjust the ASTS and the ability to use the stopwatch.

Data Storage/Manipulation/Analysis:

The measurements will be stored on paper, translated to excel, then formulated to receive Average time.

Data Presentation:

Data is numerical and presented in a chart.

Test Procedure

Summary/Overview:

This project is designed for the allow a driver to adjust the throw of the vehicle to his/her comfortability for different driving modes. This test will measure the time it will take for the operator to adjust the throw of the shifter. The ASTS will be tested inside the vehicle recording the measurements required. For this test, one person will start the time and then change or adjust the throw of the shifter and then stop the time.

Time/Duration:

This test will take roughly 1 hours as there will be a total of 20 different measurements.

Place:

This test took place inside the vehicle.

Resources Needed:

- ASTS
- ¾" Wrench or Socket
- 10 mm Allen Key
- The 3 different type Shifters
- Shifter Knob
- Z Frame Wrench

- Stopwatch

Procedure:

1. Ensure installation was done correctly and fastened. Referencing installation of ASTS in Appendix G1 provided by Dustin Braun
2. Install shifter bracket onto ASTS by sliding the half inch hole over the threaded Rod and fitting the slot over the threaded sleeve. Align Slot in bracket facing parallel with the vehicle.
3. Press firmly on the shifter bracket, measure from the top face of the shifter bracket to the top of the threaded Rod. This measurement should read ¾" of an Inch. If adjustment is needed use step ___ to adjust until the measurement reads 0.75 inches.
4. Take the ½"-20 Locknut and tighten the nut clockwise with the ¾" Wrench or Socket until it touches the shifter bracket. Leave the wrench or socket on nut.
5. Take custom Z Frame Wrench and put it into the slot on the threaded sleeve. Use the Z frame wrench and the ¾" Wrench or Socket to fully tighten the shifter bracket. Do not rotate the Z frame wrench hold in place while rotating the ¾" wrench clockwise until tight. Then remove Wrenches
6. Choose one of the shifter lengths to begin testing.
7. Take Shifter bracket and place the shifter inside of slot, line up the holes for the 1 ¼" Socket Head Screws. Tighten screws using a 10 mm Allen Key through shifter bracket and shifter for a tight fit.
8. Install Shifter knob by rotating clockwise on the top of the shifter.
9. Place the vehicle in Neutral.
10. Begin time on stopwatch. This is Part one which will test adjustable time.
11. Z frame wrench into slot on threaded sleeve holding in place with no rotation. Take the ¾" wrench and place it over the locknut and rotate counter-clockwise to loosen the nut off the threaded rod.
12. Remove shifter Assembly and rotate Z frame wrench to the to adjust throw.
13. Install shifter assembly.
14. Repeat steps 4-5.
15. Stop time.
16. Repeat Steps 10-15 for 9 more trials (total of 10 trails).
17. Part Two test changeability of the shifters.
18. Start time
19. Loosen 1 ¼" Socket Head Screws by rotating counterclockwise. Remove shifter from Shifter Bracket.
20. Remove shifter knob from shifter and chose different shifter to reinstall.

21. Repeat Steps 7-8.

22. Stop time.

23. Repeat Steps 18-22 for 9 more trials (total of 10 trails).

Risk/Safety:

This test will have a lot of pinching points. Wear proper PPE, this test recommends glasses and gloves. Make sure when tightening with the two wrenches that they are close enough in handle distance to interlock hands to avoid pinching of fingers.

Discussion:

This test, and the information above should be enough to accomplish the collection of data necessary.

Deliverables

Parameter Values:

When this test was performed the stopwatch only held values within a hundredth of a second. This was measured in 20 different variations ranging at times of 39.28-73.48 seconds.

Calculated Values:

The only calculation will be the sum of all the trials divided by the number of trials and an average of those averages from part one and two of this test.

Success Criteria Values:

Success for this test would have been any form of adjustment inside the cockpit in less than 60 seconds. This test clamed success by achieving an average of 47.28 seconds for part one and 52.72 seconds for part two. A total average of 50.00 seconds from part one and two was found concluding the success of the device.

Conclusion:

This test demonstrates the adjustability of the device. The shifters capability to change adjustment and customization for the customer is beyond successful. The testing was also complete by other different operators to allow for a better average. This devices versatility seems to the hallmark of its capability. Test Two Successful.

Test 03

Introduction

Requirements:

Reduce the force required to shift by a factor 10%

Parameters of Interest:

This test is interested in the force required to shift into a gear. This will be trailed at 3 different adjustments with three different shifter sizes.

Predicted Performance:

It is predicted that the force will be less than 10% of the force required to shift the stock shifter.

Data Acquisition:

The data acquired will be the Lb_f of each shift into gear. This will be done by using a pound scale that will put the shifter reading a force at movement into gear. The data will be recorded into excel.

Schedule:

This test was performed on Friday April 17, 2020. See Gantt chart in APPENDIX E in main report for other schedule details.

Method

Resources:

The resources for this test is very minimal but the most important component was provided by Ted Bramble of CWU, this device was the pound Scale. The vehicle with the installed Adjustable Short Throw Shifter (ASTS) and a Phone with slow-motion capabilities are other requirements. Assess to the vehicle will be the location.

Data Capture:

Data Capture is very straight forward. The reading of the scale as it pulls into gear. This will be capture via phone to give an exact number when the shifter moves into gear out of neutral.

Test Procedure Overview:

Installed ASTS will be used and then tested on with the 3 different sized 6”, 8”, and 10” shifters. The Force required to shift into gear will be measured using pound scale and slow-motion application on a phone. This data will then be put in excel and an average for each will be formulated.

Operational Limitations:

The movement of the device into each gear is the main operation that will be measured. The space inside the vehicle unfortunately does not leave enough room for testing for 1st, 3rd, and 5th gear. The limitation is that the only great measurement available was to just shift in 4th gear. The testing for the stock model and the ASTS will be similar but the measured value won’t be for all gears.

Precision/Accuracy:

The precision of height measurement will be within a quarter of a tenth of a pound. The accuracy and precision to measure the force will be based upon the operator pulling the pound scale perpendicular to the shifter the entire time. The precision of the camera is 20 frames per second so that the measurement will show accurately and precisely when it shifts.

Data Storage/Manipulation/Analysis:

The measurements will be stored on paper, translated to excel, then formulated to receive Average time.

Data Presentation:

Data is numerical and presented in a chart.

Test Procedure

Summary/Overview:

This project is designed for the reduction the force of throw. This test will measure the force for individual shifter length at to show that this device performs against the stock model. The ASTS will be tested inside the vehicle recording the measurements required. For this test, two people will measure and record the force required to shift.

Time/Duration:

This test will take roughly 2 hours as there will be a total of 30 different measurements.

Place:

This test took place inside the vehicle.

Resources Needed:

- ASTS
- 10 mm Allen Key
- Shifter Knob
- The 3 different type Shifters
- Pound Scale
- Slow-motion camera/phone

Procedure:

1. Ensure installation was done correctly and fastened. Referencing installation of ASTS in Appendix G1 provided by Dustin Braun.
2. See Test One Appendix D procedure steps 2-5.
3. Choose one of the shifter lengths to begin testing.
4. Take Shifter bracket and place the shifter inside of slot, line up the holes for the 1 ¼" Socket Head Screws. Tighten screws using a 10 mm Allen Key through shifter bracket and shifter for a tight fit.
5. Install Shifter knob by rotating clockwise on the top of the shifter.
6. Place the vehicle in Neutral.
7. Place hook around top of shifter resting against the bottom of the shifter knob. Make sure the pounds scale is zeroed.
8. The second person get ready with their camera to take a video while the pull travels. The Video needs to start before the tension to the scale is brought.
9. Pull The pound scale slowly until the shifter moves into 4th gear.

10. Stop Video. Review the video in slow motion recording the climax number to move the shifter into 4th gear and record data.
11. Repeat Steps 6-10 for 9 more trials (total of 10 trails).
12. Once all data is collected for the first shifter choice. Take 10 mm Allen Key rotate counter-clockwise the 1 ¼" Socket Head Screws to remove the shifter.
13. Rotate the shifter knob counter-clock to uninstall from shifter.
14. Then repeat steps 2-13 for the last two shifter sizes.

Risk/Safety:

This test will have a lot of pinching points. Wear proper PPE, this test recommends glasses and gloves.

Discussion:

This test, and the information above should be enough to accomplish the collection of data necessary.

Deliverables

Parameter Values:

When this test was performed the pound scale only held values within a hundredth of a pound. This was measured in 30 different variations ranging at angles of 2.22-7.1 lb_f.

Calculated Values:

The only calculation will be the sum of all the trials divided by the number of trials and an average of those averages from part one and two of this test.

Success Criteria Values:

Success for this test would have been any form of force to shift 10% less than stock. This test clamed success by achieving an average of 4.305 Lbs. which is 37.71% less than Stock model. The force required can range depending on shifter an average of 3.44-4.92 lb_f. For a Reduction between 28.9-50.1% less force for the individual shifters average. This product succeeded for each shifter but succeeded beyond the requirement by shifting 50% less than the stock shifter.

Conclusion:

This test demonstrates the upper and lower limits of operations for the device. The shifters capability to change adjustment and customization for the customer is beyond successful. The demonstration performed shortly after install was consistent of swift effortless shifts that were short and easy especially with the shifters force being 37% less than stock. This devices versatility seems to the hallmark of its capability.

Installation Procedure

ASTS Installations

Provided by Dustin Braun

Resources

- Car jack
- 2 jack stands
- 10mm wrench
- 13mm wrench
- Flat head screwdriver

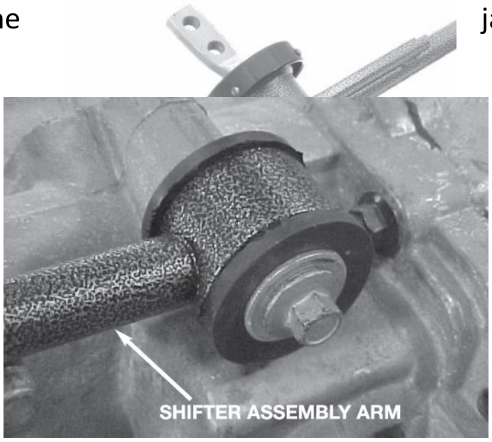
Procedure

Frame Removal

1. Place shifter in neutral position.
2. Work upper part of shift boot out of retainer groove of shifter knob and slide down onto stick.
3. Remove shifter knob from stick by turning counterclockwise.
4. Using both hands, place fingers underneath front outer edges of shifter boot and pull up to release and remove from console (see fig.1). Slide boot up and over shifter stick.

Figure 1

5. Remove large dust boot by pulling out of floor pan opening and sliding up over shifter stick.
6. Raise vehicle with car jack to gain access to the underside of the shifter assembly. Support car with the jack stands.



7. From underneath the car, use a 13mm wrench to remove the hex nut that secures the transmission linkage rod to the bottom of the factory shifter (see fig.2). Disconnect the rod by pulling it out of the shifter stick bottom.
8. With the 10mm wrench, remove the front bolt that secures the shifter assembly arm to the transmission and set aside (see fig.3).
9. Using a 10 mm wrench remove the two hex nuts that secure the rear mount of the shifter assembly to the floor pan and set aside (see fig.4).

Figure 3

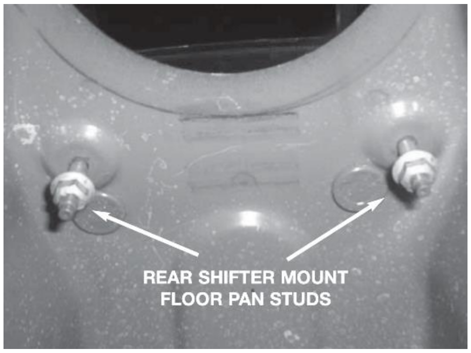


Figure 4

10. From inside the car, carefully pull the shifter assembly out. This is a little bit of a trick so take time, making sure not to scratch or bend center console.
11. Remove the two plastic bushings from the bottom of the shifter. Remove the metal bracket from the rear rubber mount and the two metal-flanged sleeves from the front rubber bushings located in the shifter assembly arm.

ASTS Frame Installation

1. Insert the two bushings from the old frame into the new ASTS frame Long-arm.
2. From inside the car, carefully insert the ASTS Long-arm through the opening in the floor tunnel.
3. From underneath the car, attach Long-arm to the transmission.
4. Insert Short-arm through console and re-attach the rear mount of the shifter assembly to the floor pan studs. Replace the hex nuts previously removed. Using a 10mm wrench or socket, tighten securely.
5. Using a 10mm wrench, tighten the hex bolt that secures the front shifter arm to the transmission.
6. Slide housing through console and attach to Short-arm and Long-arm with ¼-20 bolts.
7. Replace the large rubber dust boot onto the shifter assembly. Check to be sure that boot seals around shifter base and that groove in dust boot is seated properly into floor tunnel.

Time Test Procedure

1. Repeat steps in ASTS Frame Installation 3 times.
2. Record the time it takes for each installation period.
3. Average the results and compare to stock frame install time.

Risks

To avoid any possibility of bodily injury or damage to vehicle, do not attempt shifter installation until confidence that the vehicle is safely secured and will not move or fall from its raised position. Amount of risk can be lowered by adding a second car jack as a safety net once the car is on jack stands.

Appendix G2-Data Forms

Table G2-1 Test One

Hurst Short Throw Shifter						
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear

Angle (°)	0							
Height from Central Axis (in.)	9	Take a Picture of the shift from 3rd to 4th gear						
Distance of Throw (in.)	0	0	0	0	0	0		
Reduction Vs. Stock		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
Stock Model Shifter								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0							
Height from Central Axis (in.)	8.75	Take a Picture of the shift from 3rd to 4th gear						
Distance of Throw (in.)	0	0	0	0	0	0		
10" Shifter Long Throw								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)					Take a Picture of the shift			
Height from Central Axis (in.)	13.93				from 3rd to 4th gear			
Distance of Throw (in.)	0	0	0	0	0	0		
Reduction Vs. Stock		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	Avg	#DIV/0!
Reduction Vs. Hurst		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	Avg	#DIV/0!
10" Shifter Average Throw								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0				Take a Picture of the shift			
Height from Central Axis (in.)	13.93				from 3rd to 4th gear			
Distance of Throw (in.)	0	0	0	0	0	0		
Reduction Vs. Stock		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	Avg	#DIV/0!

Reduction Vs. Hurst		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	Avg	#DIV/0!
10" Shifter Short Throw								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0				Take a Picture of the shift			
Height From Central Axis (in.)	11.93				from 3rd to 4th gear			
Distance of Throw (in.)	0	0	0	0	0	0		
Reduction Vs. Stock		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	Avg	#DIV/0!
Reduction Vs. Hurst		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	Avg	#DIV/0!
8" Shifter Long Throw								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0				Take a Picture of the shift			
Height From Central Axis (in.)	11.93				from 3rd to 4th gear			
Distance of Throw (in.)	0	0	0	0	0	0		
Reduction Vs. Stock		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	Avg	#DIV/0!
Reduction Vs. Hurst		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	Avg	#DIV/0!
8" Shifter Average Throw								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0				Take a Picture of the shift			
Height From Central Axis (in.)	11.93				from 3rd to 4th gear			
Distance of Throw (in.)	0	0	0	0	0	0		
Reduction Vs. Stock		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	Avg	#DIV/0!
Reduction Vs. Hurst		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	Avg	#DIV/0!

8" Shifter Short Throw								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0				Take a Picture of the shift			
Height From Central Axis (in.)	11.93				from 3rd to 4th gear			
Distance of Throw (in.)	0	0	0	0	0	0		
Reduction Vs. Stock		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	Avg	#DIV/0!
Reduction Vs. Hurst		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	Avg	#DIV/0!
6" Shifter Long Throw								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0				Take a Picture of the shift			
Height From Central Axis (in.)	9.93				from 3rd to 4th gear			
Distance of Throw (in.)	0	0	0	0	0	0		
Reduction Vs. Stock		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	Avg	#DIV/0!
Reduction Vs. Hurst		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	Avg	#DIV/0!
6" Shifter Average Throw								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0				Take a Picture of the shift			
Height From Central Axis (in.)	9.93				from 3rd to 4th gear			
Distance of Throw (in.)	0	0	0	0	0	0		
Reduction Vs. Stock		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	Avg	#DIV/0!
Reduction Vs. Hurst		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	Avg	#DIV/0!
6" Shifter Short Throw								

	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0				Take a Picture of the shift			
Height From Central Axis (in.)	9.93				from 3rd to 4th gear			
Distance of Throw (in.)	0	0	0	0	0	0		
Reduction Vs. Stock		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	Avg	#DIV/0!
Reduction Vs. Hurst		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	Avg	#DIV/0!

Table G2-2 Test Two

ASTS												
trail	1	2	3	4	5	6	7	8	9	10		
Adjustment Time (s)											Avg	0
Shifter uninstall/install Time (s)											Avg	0
	Video Of Adjusting Throw					Video of Changing Shifter				Total Average		0

Table G2-3 Test Three

Force Required to Shift	1	2	3	4	5	6	7	8	9	10		
10" Shifter											Avg	
8" Shifter											Avg	
6" Shifter											Avg	
Percent Less than Stock	Avg. total		10" Avg % less		8" Avg % less		6" Avg % less		Avg			

Table G1-1

Average Force to Shift into gears			
Trail	Force (lb_f)	Trail	Force (lb_f)
1	6.25	7	6.37
2	7	8	5.75
3	7.32	9	7.51
4	6.56	10	9.49
5	5.27	11	7.5
6	6.9	Average Force	6.901818

Appendix G3-Raw Data

Table G3-1 Test One

Hurst Short Throw Shifter								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0	7.3	11.3	8.4	9.5	10.3		
Height From Central Axis (in.)	9	Take a Picture of the shift from 3rd to 4th gear						
Distance of Throw (in.)	0	1.14	1.775	1.319	1.492	1.617		
Reduction Vs. Stock		0.426	0.203	0.456	0.435	0.394	Avg	0.3834
Stock Model Shifter								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0	13.1	14.6	15.9	17.3	17.5		
Height From Central Axis (in.)	8.75	Take a Picture of the shift from 3rd to 4th gear						
Distance of Throw (in.)	0	2.000	2.229	2.428	2.641	2.672		
10" Shifter Long Throw								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0	7.4	5.2	5.2	6.7	5.1		
Height From Central Axis (in.)	13.93	Take a Picture of the shift			from 3rd to 4th gear			

Distance of Throw (in.)	0	1.799	1.264	1.264	1.628	1.239		
Reduction Vs. Stock		0.100	0.432986	0.479346	0.383445	0.536	Avg	0.3865
Reduction Vs. Hurst		-0.568	0.287	0.0418	-0.091	0.233	Avg	-0.0194
10" Shifter Average Throw								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0	6.2	4.6	5.1	5	6		
Height From Central Axis (in.)	13.93	Take a Picture of the shift			from 3rd to 4th gear			
Distance of Throw (in.)	0	1.507	1.118	1.239	1.215	1.458		
Reduction Vs. Stock		0.246	0.498	0.489	0.539	0.454	Avg	0.4456
Reduction Vs. Hurst		-0.314	0.369	0.060	0.185	0.098	Avg	0.0798
10" Shifter Short Throw								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0	5.2	5.4	4.3	5	3.9		
Height From Central Axis (in.)	11.93	Take a Picture of the shift			from 3rd to 4th gear			
Distance of Throw (in.)	0	1.082	1.124	0.895	1.041	0.812		
Reduction Vs. Stock		0.458	0.495	0.631	0.60	0.696	Avg	0.5775
Reduction Vs. Hurst		0.055	0.366	0.321	0.302	0.498	Avg	0.3088
8" Shifter Long Throw								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0	7.2	5.9	5.8	6.9	5.1		
Height From Central Axis (in.)	11.93	Take a Picture of the shift			from 3rd to 4th gear			
Distance of Throw (in.)	0	1.499	1.228	1.207	1.436	1.061		
Reduction Vs. Stock		0.250	0.449	0.502	0.456	0.602	Avg	0.4522
Reduction Vs. Hurst		-0.307	0.307	0.084	0.037	0.343	Avg	0.0932

8" Shifter Average Throw								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0	6.6	4.8	5.3	5.7	6.2		
Height From Central Axis (in.)	11.93	Take a Picture of the shift			from 3rd to 4th gear			
Distance of Throw (in.)	0	1.374	0.999	1.103	1.1868	1.290		
Reduction Vs. Stock		0.313	0.551	0.545	0.550	0.516	Avg	0.4956
Reduction Vs. Hurst		-0.198	0.436	0.163	0.204	0.202	Avg	0.1617
8" Shifter Short Throw								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0	5.7	4.4	5.1	4.4	3.2		
Height From Central Axis (in.)	11.93	Take a Picture of the shift			from 3rd to 4th gear			
Distance of Throw (in.)	0	1.186	0.916	1.061	0.916	0.666		
Reduction Vs. Stock		0.406	0.589	0.562	0.653	0.750	Avg	0.5924
Reduction Vs. Hurst		-0.035	0.483	0.195	0.386	0.588	Avg	0.3236
6" Shifter Long Throw								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0	6.7	5.7	5.5	5.8	3.9		
Height From Central Axis (in.)	9.93	Take a Picture of the shift			from 3rd to 4th gear			
Distance of Throw (in.)	0	1.161	0.987	0.953	1.005	0.675		
Reduction Vs. Stock		0.419	0.556	0.607	0.619	0.747	Avg	0.5901
Reduction Vs. Hurst		-0.012	0.443	0.277	0.326	0.582	Avg	0.3234
6" Shifter Average Throw								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0	6.5	4.9	4.8	5.1	5.9		
Height From Central Axis (in.)	9.93	Take a Picture of the shift			from 3rd to 4th gear			

Distance of Throw (in.)	0	1.126	0.849	0.831	0.883	1.022		
Reduction Vs. Stock		0.436	0.619	0.657	0.665	0.617	Avg	0.5992
Reduction Vs. Hurst		0.017	0.521	0.369	0.407	0.367	Avg	0.3368
6" Shifter Short Throw								
	Neutral	1st Gear	2nd Gear	3rd Gear	4th Gear	5th Gear		
Angle (°)	0	5.6	3.9	5.5	4.7	2.8		
Height From Central Axis (in.)	9.93	Take a Picture of the shift			from 3rd to 4th gear			
Distance of Throw (in.)	0	0.970	0.675	0.953	0.814	0.485		
Reduction Vs. Stock		0.514	0.696	0.607	0.691	0.818	Avg	0.6658
Reduction Vs. Hurst		0.153	0.619	0.277	0.454	0.701	Avg	0.4409

Table G3-2 Test Two

ASTS												
trail	1	2	3	4	5	6	7	8	9	10		
Adjustment Time (s)	45.89	45.7	55.42	42	56.45	40.4	41.25	52.15	45.56	48	Avg	47.282
Shifter uninstall/install Time (s)	46.46	45.1	73.48	39.28	52.79	60.45	65.45	42.02	58.78	43.41	Avg	52.722
Video Of Adjusting Throw			Video of Changing Shifter						Total Average			50.002

Table G3-3 Test Three

Force Required to Shift	1	2	3	4	5	6	7	8	9	10		
10" Shifter	2.22	3.8	3.35	3.75	4.15	4.11	3.24	2.64	2.98	4.2	Avg	3.44
8" Shifter	3.71	4.8	5.32	4.33	5.13	3.54	4.71	6.23	3.32	4.46	Avg	4.55
6" Shifter	5.64	7.1	4.17	1.35	3.73	5.08	5.42	4.71	6.09	5.87	Avg	4.91
Percent Less than Stock	Avg. total	0.377	10" Avg % less	0.501	8" Avg % less	0.340	6" Avg % less	0.288	Avg	4.30		

APPENDIX H-RESUME

Joshua D. Franklin

406 South Pearl Street, Ellensburg, WA 98926

(253) 509-3550 | Joshua.Franklin31@yahoo.com

Objective

My objective is to obtain a career opportunity that would improve my experience, skills and further my ability to use my work ethic and professionalism to become an asset to any employer that wishes to employ me.

Skills and Abilities

Labor Skills

- Have experience with small machinery; have operated drills (SDS max, SDS plus), lawn mowers, dump trucks, tractors, forklifts, and have mixed concrete for grout.
- Experience with hands on construction at Puget Sound Naval Shipyard. Demolition of 8" ductile iron water mains and reinstallation for NOVA Group.
- Maintained and serviced properties in need of maintenance or care, at Touchstone Landscape Management, Valet Waste, Centurion Carpet Cleaning.
- AutoCAD Certified
- Completed All Courses of Thermal Fluid Sciences.
- Problems solving skills through various course of physics, statics, strengths, dynamics, and seven different math courses up to Elementary Linear Algebra.
- Machining experience with lathe and mill in class MET&255.
- Flexible schedule, hardworking, fast learning. I strive to never quit until the job is done.

Communication Skills

- I have provided information about new and used vehicles, via phone and email, for customers on and off the clock, at Peninsula Auto Group. Assisted in transitioning customers to sales for purchase and provide quality service before customer arrival.
- I work well in a team or alone. Following and Leading crews for Valet Waste, Touchstone Landscape Management, and Fred Meyer.

Education

Central Washington University, Ellensburg WA 2016-Present
Attending for MET BS & Mathematics Minor

Olympic Community College, Bremerton WA 2013-2016
Associates degree
Cumulative GPA 3.64

Related Courses
English: 101, 102 & 235
Communications: 210 & 220
Mathematics: 141, 142, 151, 152, 163, 254, & 264
Engineering Technology, Safety, & Construction: 160, 311, 312
Mechanical Engineer Technology: 255, 327, 351, 426
Physics: 111-113

South Kitsap High School, Port Orchard WA 2012-2014

High School Diploma Received
Cumulative GPA 3.84

Employment Experience	**Nortech Solutions**, Ellensburg WA Steel Detailer	April 2020-Present
	Mercer Creek Church, Ellensburg WA Building Maintenance	January 2020-Present
	Fred Meyer, Ellensburg WA Freight Crew	July 2017-October 2019
	Valet Waste, Port Orchard WA Driver	July 2016-July 2017
	Centurion Carpet Cleaning, Port Orchard WA Carpet Cleaner	July 2016-July 2017
	Nova Group, Port Orchard WA Laborer	Oct. 2015-July 2016
	Peninsula Auto-Group, Bremerton WA Internet Concierge	Feb. 2015-Oct. 2015
	Touchstone Landscape Management, Gig Harbor WA Landscaper	Aug. 2014-Feb. 2015

Additional Information	10-Hour OSHA Hazard Recognition Training	2015
	Certified Fire Watch Training	2015
	Certified Forklift Training	2015
	Certified Rigging Training	2015
	Awarded for Academic and Athletic Performance	2012-2014
	81 Hours of Community Service	2013
	Technical Educations Department Student of the Year National Society of High School Scholars Member	2013

APPENDIX J-JOB HAZARD ANYLYSIS

JOB HAZARD ANALYSIS
Installation and Manufacturing of Shifter in car

Prepared by: Joshua Franklin	Reviewed by: Dustin Braun Approved by: Dustin Braun

Location of Task:	CWU Machine/Wood shop
Required Equipment / Training for Task:	
Reference Materials as appropriate:	

Personal Protective Equipment (PPE) Required (Check the box for required PPE and list any additional/specific PPE to be used in "Controls" section)						
Gloves	Dust Mask	Eye Protection	Welding Mask	Appropriate Footwear	Hearing Protection	Protective Clothing
X	X	X	☐	X	X	☐
Use of any respiratory protective device beyond a filtering facepiece respirator (dust mask) is voluntary by the user.						

PICTURES (if applicable)	TASK DESCRIPTION	HAZARDS	CONTROLS
	Mixing and applying Epoxy	Chemical Vapor	Wear Appropriate PPE, Gloves, Respirator
	Band Saw	Cutting fingers and hands Avoid contact with blade teeth.	Avoid contact with blade teeth.
		Pinching fingers or hands.	Keep fingers and hands away from pinch points.
		Pinching fingers or hands	Avoid pinch points between guard and housing and between guard and material.
		Injuries from flying Metal	Wear safety glasses or face shield.

		Cutting fingers and hands	Keep fingers and hands away from blade. Use push bar for smaller materials.
	Drill Press	Eye injury from metal debris	Wear eye protection. Do not use compressed air
		Foot injury if the vise falls	Secure the vise on the table with T-pins
		Finger pinching while sliding the vise	Don't let fingers get under the vise unless lifting it from the table. Keep eyes on the task
		Back strain	Don't lean over the table to twist the lock handle.
		Hand injury from the bit	Wear gloves. Don't hold on the end of the bit
		Injury caused by breaking the bit	Feed with the appropriate pressure. Use the appropriate bit for the type of metal. Wear eye protection.
		Eye or skin damage from cutting oil	Use the lowest RPM. Wear eye protection. Wear a long-sleeved shirt.
		Hand injury from the exposed pulley near the feed handle	Make sure a pulley guard is in place. Don't push the feed handle toward the pulley
	Milling	Injury to hands from milling blades	Never disconnect safety shields from milling blades.
		Hearing damage from noise of machine operation	Wear hearing protection, such as ear plugs, if operating machine for periods extending more than 10 minutes.
		Possible eye injury from wire stitches thrown out by milling blade	Wear safety glasses during operation.
		Crushing finger hazard from book clamp	Do not hold book at spine when activating book clamp. Hold book at the face.
	Threading	Slips	Control oil contact with the floor. Wear non-slip shoes. Clean up spills. Use a floor covering or absorbent such as kitty litter.
		Skin or eye injury from the cutting oil in the reservoir	Use nitrile gloves. Use a vacuum cleaner to clean the catch pan. Wear eye protection.
		Hand injury while sliding the pipe through.	Wear leather gloves or similar protection.
		Muscle strain	Position pipe without reaching over the threader.
		Hand injury	Wear leather gloves or similar protection. Keep foot out of the foot safety switch. Don't tighten the clamp while the machine is running.
		Hand injury	Don't drop the reamer on hands while positioning the reamer.
		Hand injury	Keep hand away from the die.
			Don't clean the die or the pipe end with hands. Don't start the machine until the die is set.

		Injuries due to clothes catching on the threader	Don’t wear loose clothing while operating the threader. Keep gloved hands away from the die and the pipe.
		Skin or eye injury from the cutting oil being delivered to the pipe.	Use nitrile gloves. Wear eye protection.
		Metal debris projectiles	Wear long sleeved shirt, gloves, and face
		Burns from metal debris	Wear long sleeved shirt, gloves, and face shield.
		Hand injury from rotating threads	Wear gloves and don’t touch the rotating threads. Use a steel brush or similar instrument to clean the threads.
		Injuries due to clothing catching on the threader	Don’t wear loose clothing while operating the threader. Keep gloved hands away from the rotating pipe.
		Hand injuries from interaction with the pipe vise.	Remove foot from the safety switch, flip the switch off, and ensure the pipe has stopped rotating. Wear gloves.
		Hand injuries from interaction with the pipe vise	Remove foot from the safety switch, flip the switch off, and ensure the pipe has stopped rotating. Keep fingers (gloved) away from the vise jaws.
	Hydraulic Press	Pinch hazards from converging parts	Keep fingers out of any potential pinch zones and out of the way of moving parts.
		Hydraulic Fluid or Oil leaks	Check lines and machine for any holes, puddles under the machine, or lack of oil or hydraulic fluid.
		Broken lines or pressure gauge	Check pressure gauge to see if it moves with the addition of pressure.
		Improper settings for job about to be performed	Make sure the machine is set to the proper specifications for the job being performed.
		Dropping material onto feet	Steel toe shoes to mitigate injury from dropping material.
		Lack of machine guards	Add or adjust machine guards before doing any work.
		Pinch hazards from moving parts	Keep body parts away from press area while the machine is working. Ensure all steps are taken and pressure is off lines before putting hand into the work area.
		Flying debris hazards from the pressure being put on the material being pressed	Pay attention while working on the press.

		Dropping/Falling material	Steel toe shoes to protect feet from falling material.
		Hydraulic fluid/oil spill	Inspect lines after work to see if any leakage had occurred while line was pressurized.
		Line break from over pressurization	Keep safety glasses and gloves on until all steps are complete.
	Metal Lathe	Entanglement in unguarded moving parts.	Inspect guards prior to work.
		Injury due to improper machine operations	Locate and ensure that personal familiarity with all machine operations and control
		Tools and objects can fall and be propelled at the operator.	Remove unsecured tools and objects from the lathe.
		Hand/finger contusion due to tool slippage from securing chuck or collet..	Use correct tool to secure chuck or collet
		Foot injury from dropping chuck/tool.	Wear recommended footwear
		Strain/sprain from transporting heavy and/or awkward chuck	Use mechanical lifting device or get assistance
		Damage to cutting tool and/or spindle drive system	Refer to operations manual and set proper spindle speed for material type/diameter to be machined
		Bodily injury and/or damage to workpiece from incorrect feed rate	Refer to operations manual and set proper lathe speed
		Dull tools and improper height lead to bad surface finishes, out of tolerance parts and potentially a hazardous situation	Use correct and properly sharpened tool
		Hand/finger contusion due to tool slippage from tightening chuck jaws or collet	Use correct tool to secure chuck jaws and collet to workpiece
		Damage to workpiece due to loose and/or off center installation of workpiece into chuck	Ensure workpiece is secure and evenly tightened into chuck or collet. Use dial test to center workpiece.
		Strain/sprain from heavy and/or awkward workpiece	Use mechanical lift or get assistance from coworker
		Damage from chuck key flying off	Never leave key in chuck. For newer models, use spring-loaded or self-ejecting chuck key
		Long workpieces can bend and strike operator	Use workpiece of minimum length or use a bar feed tube to hold workpiece
		Injury to exposed body parts at points of operation	Keep body parts and clothes away from the point of operation
		Eye injury from debris	Wear PPE during operation
		Heat damage to part and cutting tool	Start at low speed and slowly increase to avoid overheating; use coolant
		Injury to exposed body parts at points of operation	Ensure equipment has stopped prior to placing hands near the point of operation
		Strain/sprain from heavy	Use mechanical lift or get assistance from

		workpiece	coworker
		Trip/fall on other tools/materials	Clean work areas
		Foot injury from dropping workpiece	Wear recommended footwear