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Electrathon Vehicle: Steering

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Electrathon Vehicle: Steering

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ABSTRACT

The Electrathon Vehicle project is an ongoing project that dates back to 2012. The Electrathon Vehicle began as a frame and three wheels when given to the EV club. In past projects the vehicle has had frame and suspension work. The current design is only partially assembled and does not allow for any steering in the vehicle. A steering system needed to be developed in order for the vehicle to be controlled while a person is sitting in the seat. A steering system was designed that could withstand the force of maneuvering the vehicle in excess of 30 mph. This was done using cantilever beam analysis (a beam sticking out of a wall with a weight on it), shear and moment diagrams (shows where the maximum stress is in the beam in a graph type format), torque analysis (a shaft being twisted with a certain amount of force on one end and the other end fixed in place), and shear bolt analysis (required force to break a bolt). The analysis on the steering system concluded that the parts would be able to withstand the projected forces being put on them. The steering system needed to be able to turn within a 50 foot radius with a person in it. The calculated results were confirmed to be able to withstand the forces. The Electrathon Vehicle was able to turn within a 50 foot radius.

1: INTRODUCTION

A) Description:

Currently, Central Washington University has an Electric Vehicle (EV) in progress. It is a single seated vehicle that is designed to compete against other electric vehicles from high schools, universities, companies, and even at home do-it-yourselfers. The vehicle needs a steering system in order to control the vehicle. Currently the EV consists of a frame, three wheels, front arms and shocks, rear shock assembly, and a carbon fiber body. The frame was developed and built in the 2009-2010 academic year. The rear-wheel drive motor and drive system were developed during the 2010-2011 academic year. The designer is responsible for designing, building, and analyzing a steering system that is able to control the vehicle.

B) Motivation:

The motivation for this project is the steering system for the Central Washington University Electrathon Electric Vehicle (EV). In past projects the vehicle has had frame and suspension work, but the current design is only partially assembled does not allow for any steering in the vehicle.

The Steering column needs to strong and sturdy yet lightweight. For this reason, the designer will look at multiple materials, such as Aluminum 6061-T6, AISI 1020 plain carbon steel, and other metals. All of these metals can work but the goal is to optimize for the design requirements, so the type of metal needs work with the design requirements and cost to manufacture in order to be successful.

C) Function Statement:

To design, build, and field a car for the 2018/2019 Electrathon America electric vehicle design competition.

The intended design will incorporate a steering column, steering wheel, Pittman arm, and tie rods. The steering column will allow the user to rotate the wheels left and right while still and while moving.

D) Requirements:

In order for the steering column to be successful it must serve three purposes: allow the vehicle to be easily maneuvered with any of the Electrathon teammates, turn both wheels simultaneously, and be sturdy enough to withstand the forces put on by the driver and forces applied while turning.

In the 2018/2019 Electrathon America Handbook there are specific design rules and design guidelines that are set to ensure the safety of the driver and to help in designing some small aspects of different components. The handbook states that most Electrathon vehicles weigh over 350 pounds with driver, ballast, and battery. The vehicle that is being designed is a little bigger and heavier than most vehicles, so it is estimated that the new vehicle will weigh around 500 pounds.

The design requirements from the 2018/2019 Electrathon America handbook are as follows:

1. Steering must permit a turning circle diameter of less than 50 feet curb to curb. (7)
2. Any steering system must be well constructed and provide reliable steering action without looseness or binding. (7)

The designer for the steering system now sets the design requirements from this point.

3. The device must be able to withstand 230lbs of force without buckling

4. The entire assembly must not exceed 100lbs
5. With the vehicle sitting on its own weight, the steering wheel must be able to be turned using at most 30 lbs. of force while in motion.
6. The steering column does not deflect more than .0875" with an applied load of 100lbs.
7. Cost less than $500 to manufacture
8. Keep the occupant in full control of the vehicle.
9. Must conform to Electrathon America guidelines

E) Success Criteria:

The success of this project is dependent on whether it can turn effectively within a 50 foot radius with testing, have the steering column withstand the forces, and perform well. It would also be successful if the vehicle is ready to race in the Electrathon America Competition this following year.

F) Scope of this effort:

The scope of this project is designing the steering system so that it connects the steering spindle to the Pittman arm, and the Pittman arm to the steering column so that the driver can maneuver the vehicle. The scope will also involve all of the analyses to see what the dimensions and materials the parts should have. This project will also include the manufacturing and assembly of the steering system. Then finally the testing of the steering system to ensure all of the criteria was met and the system functions well.

G) Engineering Merit:

In order to design the steering column to fit the stated design requirements several equations will be used. Equilibrium equations $\mathbf{\Sigma F_x=0}$, $\mathbf{\Sigma F_y=0}$ and $\mathbf{\Sigma M_o=0}$ will be used to determine resultant forces and moments in the x-axis and the y-axis. After that use the equation $\boldsymbol{\sigma}\mathbf{=Mc/I}$ to determine the allowable radius of tubing needed for the steering column. Next look at the force it takes to turn the wheel using the weight of the vehicle and weight of the driver and the coefficient of friction of rubber on the ground. The equation for force being used is $\mathbf{F=N\mu}$ then this can translate that to torque on the shaft by using $\mathbf{T=F*d}$. Next check that the answer is close by using the equation $\mathbf{T=\mu N^{3/2}/3P^{1/2}}$ where P is the tire pressure. Analysis will also be done with stresses in the tie rods and also the bolts holding the tie rods.

H) Benchmark:
There are two EV's in the school right now. The past senior projects will be used as a benchmark and then improve upon them.

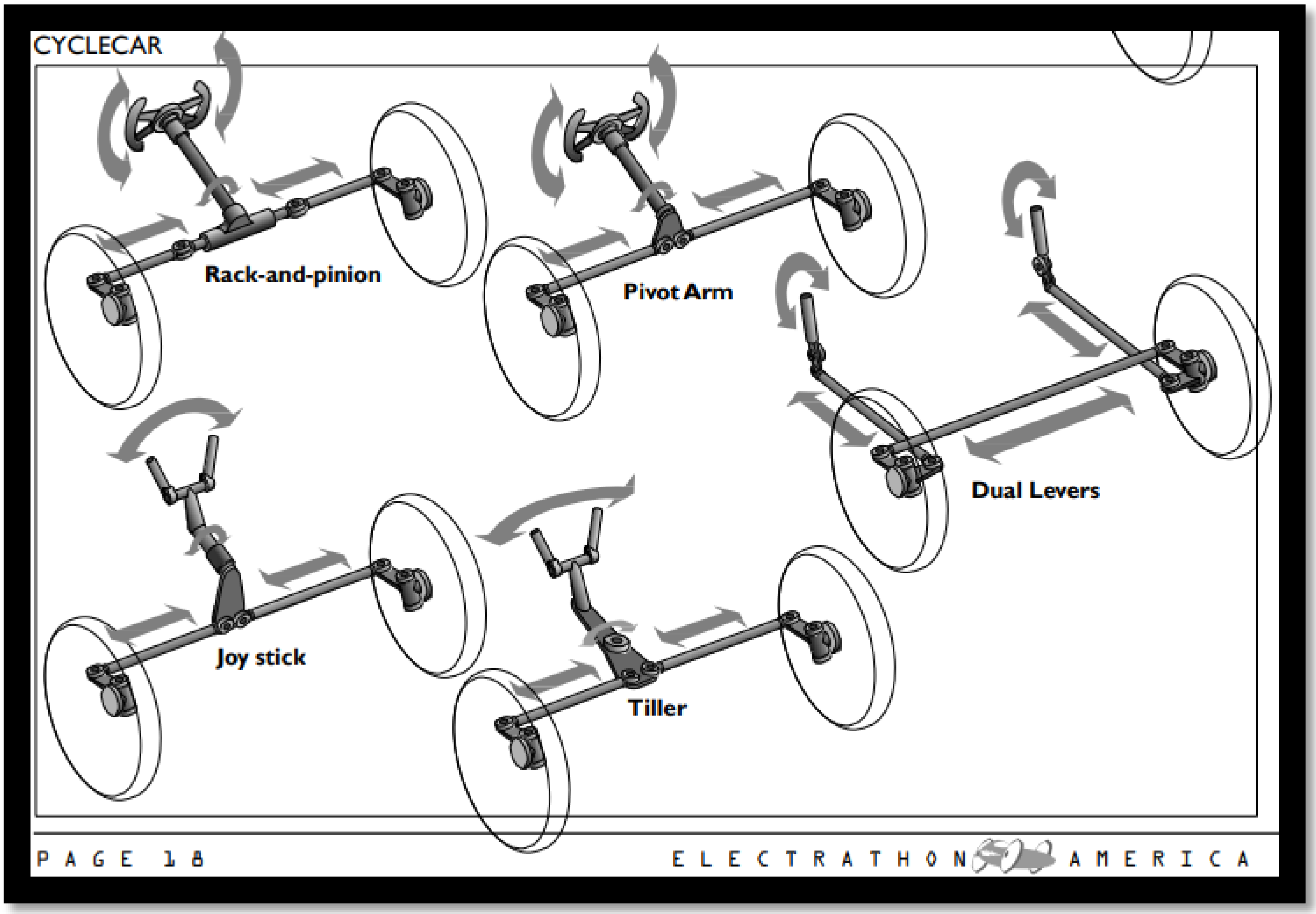
DESIGN & ANALYSIS

a. Approach

There are many ways to make the steering system. Making it as simple and easy to manufacture is the best option. The intended design will include a steering column, steering wheel, tie rod arms, and a Pittman arm. The steering column will be held by two bearings that are attached to mounting points on the EV's frame, then the tie rods will connect the steering spindles and Pittman arm.

b. Design Description

The total length of the steering column will be 48 inches from the steering wheel to the Pittman arm. The Pittman arm will be 6 inches tall and a quarter inch thick. The steering column will be one inch round by 1/8 inch thick aluminum 6061-T6. The two bearings will have a one inch inner bore so that the steering column is able to fit on the inside. The design was also inspired by the Electrathon America Handbook on steering systems. The design being made will closely resemble the pivot arm sketch shown in the diagram below.



c. Benchmark

The most important goal for the steering column is that is able to turn the vehicle within a 50 foot radius, and to be able to withstand a force of 200lbs on the steering wheel. If the steering system can't turn within the radius, it does not meet the guideline, which means the vehicle can't race. If the steering system can't withstand the 200lbs, it will not be able to steer the vehicle, deeming it in-operable.

d. Performance Predictions

It is predicted that the steering system will be able to turn the steering spindles 45 degrees or more while in motion and not in motion. Also, it is predicted that the steering column will be able to turn the wheels while sitting with less than 30lbs.

e. Description of Analyses

The whole steering system needs to be analyzed because it needs to be able to withstand the forces being applied to the system itself. In order to analyze the whole system, individual components had to be analyzed. In section G it goes into depth about the specific pages.

f. Scope of Testing and Evaluation

The steering system will be tested by seeing if it will turn in a 50 foot radius making sure it meets specifications. The steering column will also be tested to see if it will actually hold the amount of force described in the analysis. This will most likely be a strain gauge connected to the steering column while a force is being applied.

g. Analyses
A-1. In order to find to find the force on the wheels the approximate weight needed to be assumed. Assuming the most weight with one passenger would be about 550lbs. The weight multiplied by the coefficient friction, divided by the three wheels gives the force on each wheel.
A-2. Once the force on the wheel was found, analysis could be done to solve for the torque on the shaft. The size of the contact patch was estimated, then the torque equation could be used to find out how much torque it would take rotate the wheel, which was 66 pound-inches. Once that was known the Force= Torque/Distance equation could be used to find the Torque on the shaft. This turned out to be around 80 pound-inches.
A-3. The torque found in A-2 could then be used along with the size of the steering wheel to determine how much force it takes to turn the steering wheel, which turned out to be 12.3 pounds of force.
A-4. The diameter was needed for the steering column of the Electrathon vehicle. The equation $\tau=Tc/J$ for the shaft diameter could be used given certain variables are assumed. This would be for a solid shaft.
A-5. When going through the calculations it showed the shaft only needed to be .26 inches diameter. Next calculations needed to be done to see if in fact a tubular shaft could be used in order to lighten the steering system. Roughly the same equation as in the shaft could be used except with a different J value. This showed if a one inch tube was used the wall could be .019 inches thick.
A-6. The thickness of .019 inches would work for torsion, but analysis was needed to look at the bending stress to see what kinds of forces were exerted on the shaft.
A-7, A-8. The forces were found by looking at the maximum moments (Appendix 7-8) and doing Pythagoreans theorem to find the maximum moment.
A-9. The turning radius was found by using the Ackerman angle and solving using the 50ft radius requirement.
A-10. The steering column was analyzed to see if it could withstand the load at the Pittman arm location. It turned out to be well within the range given the load.
A-11. The Pittman arm was then analyzed given the forces found in the analysis above, which showed that we Pittman arm would be able to withstand the forces being applied.
A-12. The tie rods needed to not deflect within .01 inches. Based off the analysis the rods should not deflect.
A-13. A bolt analysis had to be done for the bolts that connect the bearings and the mounting plates. This showed that the bolts were significantly strong enough to hold the 200lb force on the bolt. This analysis is the same for both the upper and lower mounting plates.

h. Device: Parts, Shapes and Conformation

Some of the parts not completely referenced in the analysis would be the steering wheel. This is because the steering wheel will most likely be bought. All that is needed is the approximate length or radius of the steering wheel.

i. Device Assembly, Attachments

Currently there is no assembly completed but once it is it will be located in Appendix B.

j. Tolerances

The tolerance for the shaft length and tie rod lengths are going to be +/- .01 inches and the tolerance for the diameter of the column will be +/- .001. This is so the column will fit into the bearing securely. These will be measured using precise measuring tools.

k. Risk

The steering system has a lot to do with risk. If the part fails there is possibility that the vehicle will not be able to drive, and possibly result in injury or death of the driver. This is why the analysis is done, so that the product or design being made making is safe.

METHODS AND CONSTRUCTION

i. Description

The start of this project revolves around the steering column. It will be mounted in between two bearings which are most likely going to be welded on the frame or bolted on to the frame. The steering wheel will be mounted closest to the driver while the Pittman arm will be mounted on the opposite side. There will be one bolt going through the Pittman arm that will connect the tie rods to the steering column. The tie rods will then connect to the steering spindles in order for the wheels to rotate. The bearings allow the steering column to rotate, which rotates the Pittman arm, which moves the tire rods that turn the steering spindles and allows the wheels to turn.

ii. Drawing Tree

The drawing tree is located in appendix B. First it will start with the steering column, cutting it down to size. Then manufacturing of the mounting points for the bearings will be done. Next the Pittman arm will be made and mounted on the shaft. Then the tie rods will be mounted on the steering spindle. Finally, the steering wheel will get mounted on the steering column and the assembly will be complete.

iii. Parts list and labels

The parts to be able to manufacture the steering system can be found in Appendix C. They also have their identification labels associated to them, so they are easily trackable. Most of the bolts, nuts, and materials were provided by the machine shop. This allowed the budget to be well below the initial budget of $300.

iv. Manufacturing issues

Some manufacturing issues might be connecting the steering wheel to the steering column. There are different ways to do this such as welding or bolting screws to the shaft and steering wheel.
Other than that, there will be much welding in the design. The Pitman arm might have a tubular shaft that connects to the steering column which would be welded.
One manufacturing issue that occurred was with the lower and upper mounting plates. These plates were designed and made into Dxf. files in order to allow the plasma cutter to cut the shapes needed. When using the plasma cutter, the tip of the plasma cutter touched on the lower corner where the fillets would be. This caused the steel plated to shift on the surface it was sitting on. This caused some unwanted shifts in the design. The plates had to be grinded in order for them to work. Something that could be done to alleviate this issue would be to not have the fillets at the lower corner of the plates.
Welding came in very handy when mounting the plates instead of bolting the plates. Another part of the assembly that was to be welded on was the Pittman arm. The problem with the design to have the Pittman welded was that once that arm was welded, there would be no way to take the arm off or adjust the design in any way. Instead of that, a new solution was designed in order to make the Pittman arm movable and detachable. This proved to be a good solution because a new issue occurred in manufacturing the vehicle in which the Pittman arm had to be re-adjusted.
The last manufacturing change made to the Electrathon Vehicle was the steering wheel. Originally the steering wheel was supposed to be mounting plat that was bolted to the steering column. The design change that was made was to have the steering wheel detachable so that the driver was able to sit down into the EV easier. This design proved to be a good design change because the size of the steering wheel was to large for the driver to get into the vehicle before the adapter was put into place.

TESTING METHOD

i. Introduction

Testing will be done by putting a 200 lb load applied to the end of the steering column and measuring strain using strain gauges to see if the test results come out close to the analyzed data. Also stress analysis on the tie rods will be done to see if they are able to withstand the forces on them. Then to measure if the vehicle can turn within the 50-foot radius, it will have some type of chalk on the ground that measures a 50-foot radius and the team will try to turn the vehicle within those parameters.

ii. Method/Approach

The steering column will most likely need a strain gauge in order to test some of the requirements that have been set in place. Calipers will be needed to measure diameters of different shafts and bearings. Then probably some tape measures to measure the 50-foot radius the vehicle will need to turn in.

iii. Test Procedure description

The Electrathon team will most likely be testing certain things in the parking lot outside of Hogue Hall. There is a possibility of using the air fields close to campus that are used by the school in order to test. There are also rooms in the Hogue building that have equipment that are available for use. Such as strain gauges, the Instron load testing machine, and impact testers. Not to say that all of the equipment in the lab will be used, but there is quite a lot of testing that can be done.

SCHEDULE

The schedule is a high-level Gantt chart describing everything that this project entails. It can be found in appendix E. This will be updated as the project moves through the various stages of its life. This gives a good idea on what kind of to work to put into the project and gives a look on all the things needed to do in order to stay on track and get the project done in a timely fashion.

DISCUSSION

The mounting plates for the steering column have a couple issues when manufacturing. There are a couple choices that are available. One method of construction would be to drill the holes out with a drill press. The problem is that the drill could walk ever so slightly making the part out of tolerance. The way this manufacturing issue is solved is by instead of drilling the quarter inch thick steel plate, it would be plasma cut. The plasma cutter allows for the most accurate and precise cuts because it basically prints the image of the drawing on the steel. This will most likely be the method used in this project.

One manufacturing issue that came to light when constructing this project was the Pittman arm. The Pittman arm is what the tie rods connect to, for the vehicle to steer. Originally the Pittman arm was to be made from aluminum in the original design. When actually making the Pittman arm it turned out that it was going to be tremendously expensive and hard to manufacture. So instead of making it out of roughly five inches by two-inch block of aluminum (B-1) which was to be bolted onto the steering column, it is now going to be made out of two inches by quarter inch steel; that will be welded onto the steering column (B-7).

When going through the welded Pittman arm design it was concluded that the steering column needed to be removable. Another design change was needed to accommodate the design needs. Instead of welding the Pittman arm to the steering column, a collar needed to be welded on the Pittman arm (B-8) that also fit over the steering column. Then a concentric hole would be drilled through the collar and the steering column, so a pin could be put through in order to take the Pittman arm on and off. The reason the Pittman arm is not welded on the shaft is so that the steering assembly can still be disassembled and assembled when needed. If the Pittman arm was welded on it would be extremely hard to modify the design as needed. This includes potentially lengthening and shortening the shaft for different size drivers.

Another design change was that the lower mounting plate (B-4) be welded to the frame. This was a more reasonable design change because the lower mounting plate did not need to be taken off and on, and drilling the holes would be very difficult making concentric. Therefore, the lower mounting plate was welded on the inside edges, making the steering column more rigid and also immune to bolts loosening by vibration, which is a definite plus; design wise.

The steering column (B-2) was modified to have some though holes at the ends in order to have certain components welded to or bolted through.

The lower mounting plate (B-4) along with the upper mounting plate (B-3) was slotted through from the bottom in order for the steering column to be raised from beneath and easily adjusted. The bearings (B-5) are also able to be removed from the mounting plates if needed.

The steering wheel adapter (B-9) needed a slug on the inside (B-10) of the steering column in order for the steering wheel and the steering column to be concentric when welded. On the other end of the column another part was made similar to B-10 in order for the Pittman arm collar to be attached (see B-11). This design was thought of after the steering wheel was ordered and the adapter was in hands. This was an exceptionally exquisite design option because after the attachment was welded on, the steering wheel was completely concentric to the steering column.

The whole steering assembly (B-6) was made in order to ensure that all parts fit together in a reasonable fashion.

CONCLUSION

The Electrothon vehicle steering system has been designed to exceed the requirements and has had saftey factors taken into account so that the vehicle is safe. Most of the testing will take place in spring quarter so there is no testing data to put in at the moment. The steering system consists of about five individual parts. The steering system has been created to withstand 200lbs of force put on the end of the steering wheel, which will be tested in the spring quarter. The testing will consist of stress and strain guages, along with calculating and testing what the overal defection will be.

The Electrathon Vehicle constucted in the winter was all in all very successful. The onnce bare bars of a frame is now a functioning rolling frame with seat, motor and steering capabilities. The steering system is able to move the front wheels. Looking at the steering system in that respect merrits a successful project. Three major points on why this project was a success this winter quarter is because before the frame was not able to move the wheels simoultaneoulsy, it did not have any mounting points for a steering column, and it did not have a detachable steering wheel to allow for the driver to get in and out of the vehicle; now it has all of those components.

ACKNOWLEDGEMENTS

A large thanks goes to professor Charles Pringle, Dr. John Choi, and Dr. Craig Johnson for helping me with the project and taking his time to help with all the questions that were had up to this point. There was a lot. They're expertise and advise as the construction of this project continues will be graciously be taken into consideration next quarter. Another big help for the project that made things possible was club senate, which gave $1500 dollars to the club.

REFERENCES

Mott, Robert L., 2004. Machine Elements in Mechanical Design, Fourth Edition.
    Pearson Prentice Hall

APPENDIX A

Appendix A-1

Lathan [illegible]	MET 489	11/29/18

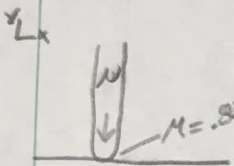
Given: Coefficient of friction, Rubber on dry concrete

$\mu = .85$

Weight of Vehicle $= 550\,lbs = N$

Find: Force it takes to rotate wheels

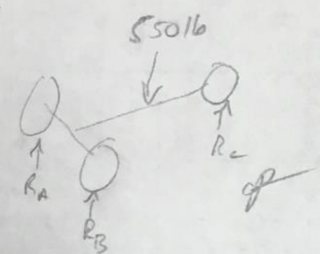
Solution:



$\Sigma F = N\mu = 550(.85)$

$F = \dfrac{550(.85)}{3} = 155.83\,lbs$ on each wheel (static)

FBD



Appendix A-2

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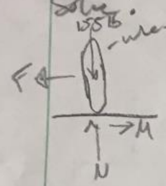
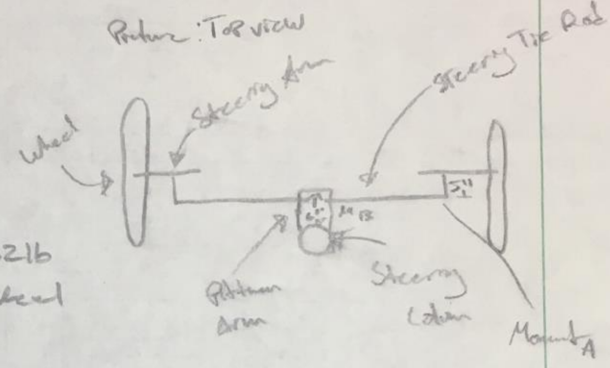
Given: Force on wheel

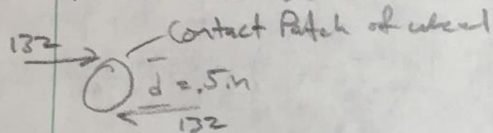
Find: Torque on shaft.

Solve:

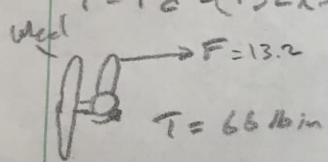




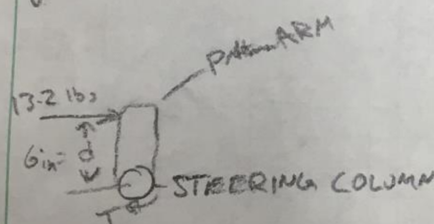
$F = NM = (155\,lb)(.85) = 132\,lb$



$T = Fd = (132)(.5) = 66.1\,lb/in$



$T = Fd \Rightarrow F = T/d = \frac{66\,lb\,in}{5\,in} = 13.2$



$T = Fd = (13.2\,lb)(6\,in) = 79.2\,lb\,in$

Another Equation To find Force

$$T = \frac{MN^{3/2}}{3(P)^{1/2}} = \frac{(1.00)(155\,lbf)^{3/2}}{3(85)^{1/2}} = 69.7\,lb\,in$$

tire pressure

$\boxed{\text{Torque on shaf is Roughly 80 lb-in.}}$

Appendix A-3

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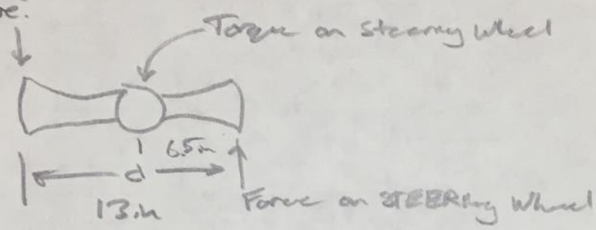
Given: Torque on shaft = 80lb·in

Find: Force it takes to turn the steering wheel

Solve:



$T = Fd$

$F = T/d = \dfrac{80\,\text{lb in}}{6.5\,\text{in}} = 12.3\,\text{lb}_f$

Appendix A-4

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Given: max Torque to withstand = 80 lb-in F

Saftey factor = 2 $\quad T = 80\,lb \cdot in$

$S_y = 21{,}000\,psi$

Find: shaft diameter

Solve: $\tau_{max} = Tc/J \qquad J = \pi D^4/32$

Assume Aluminum 6061-T4

Shear Modulus = 3770 ksi

Shear strength = 24,000 psi

$.5(S_y)$ = Value of shear $\qquad S_y = 21{,}000\,psi$

Pg. 189

$.5(21000\,psi) = 10{,}500\,psi \qquad 10{,}500\,psi\,(S.F)$

S.F = 2 $\qquad 10{,}500(2) = 21{,}000\,psi$

$$\tau_{max} = \frac{T(D/2)}{\pi D^4/32} = \frac{32T(D)}{\pi D^4(2)} = \tau_{max}$$

$$\tau_{max}(D^4) = \frac{16TD}{\pi} \qquad D = \sqrt[3]{\frac{16(80\,lb \cdot in)}{\pi(21000\,lb/in^2)}}$$

$$D^4 = \frac{16TD}{\pi(\tau_{max})} \qquad \boxed{D = .26\,in}$$

$$D^3 = \frac{16T}{\pi(\tau_{max})}$$

$$D = \sqrt[3]{\frac{16T}{\pi(\tau_{max})}}$$

Appendix A-5

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Given ; $\tau_{max} = \frac{\tau}{S.F}$

$S.F = 2$

$C_1 = 1''$

$S_y = 21,000 \text{ psi}$

$\tau = 21,000 \text{ psi} (.5) = 10,500$

Find: Wall Thickness of tube.

Solution;

$$\tau_{max} = \frac{\tau}{N} = \frac{10,500}{2} = 5251 \text{ psi}$$

$$\tau_{max} = Tc/J \qquad J = \frac{\pi}{32}\left(c_1^4 + c_2^4\right)$$

$$\tau_{max} = \frac{Tc_1}{\frac{\pi}{32}\left(c_1^4 + c_2^4\right)}$$

$$c_1^4 + c_2^4 = \frac{Tc_1}{(\pi/32)(\tau_{max})}$$

$$c_2^4 = \frac{Tc_1}{(\pi/32)(\tau_{max})} - c_1^4$$

$$c_2 = \sqrt[4]{\frac{Tc_1}{\pi/32(\tau_{max}}}$$

$$c_2 = \sqrt[4]{\frac{(30 \text{ lb·in})(1''/2)}{(\pi/32)(5251 \text{ psi})}} = .98''$$

Wall thick $= 1'' - .98''$

$\boxed{\text{Wall Thic} = .019''}$

So 1/8 inch thick would work.

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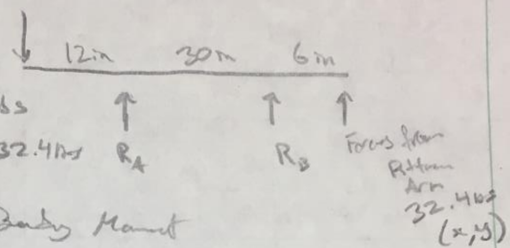
Bending Stress Analysis

Given:

Force on steering wheel (200lbs) (x, z)

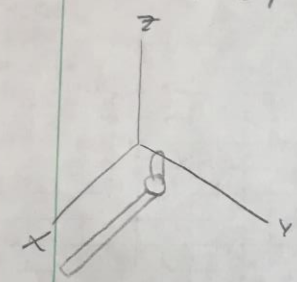
Assume all forces in the same Plane



Force steering wheel = 200lbs

Force on Pitman Arm = 32.4lbs

Find: R_A, R_B, Max Bending Moment



The bending Moment at A is the resultant moment of the x and z planes.

Refer to Steering Column Analysis (x-z) and (x-y) Planes.

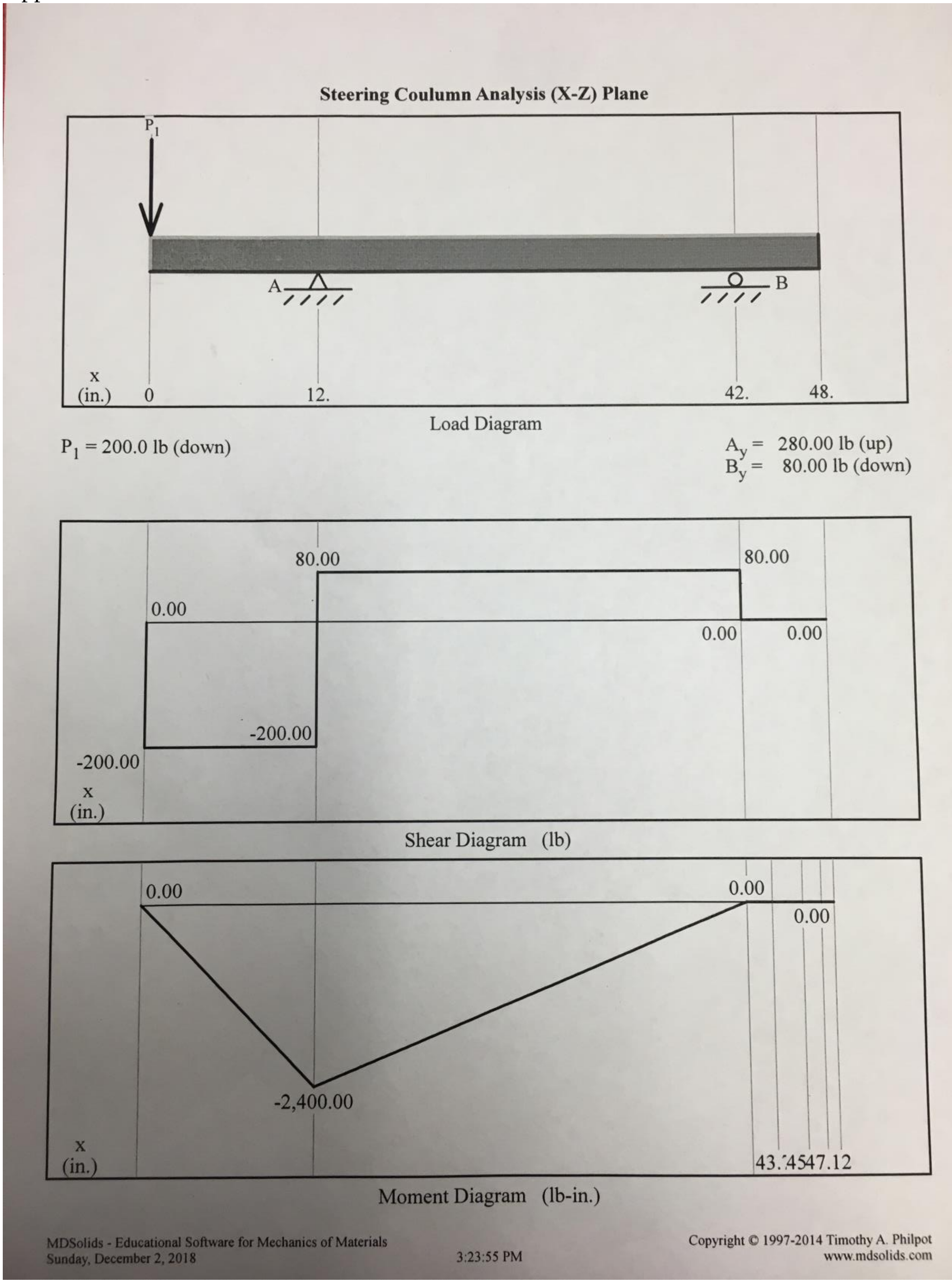
$$M_A = \sqrt{M_{Ax}^2 + M_{Az}^2} = \sqrt{0^2 + (2400\text{lb-in})^2} = \boxed{2400\text{lb-in}}$$

The bending Moment at B is the resultant of the x, z planes

$$M_B = \sqrt{M_{Bx}^2 + M_{Bz}^2} = \sqrt{(194.4\text{lb-in})^2 + 0^2} = 194.4\text{lb-in}$$

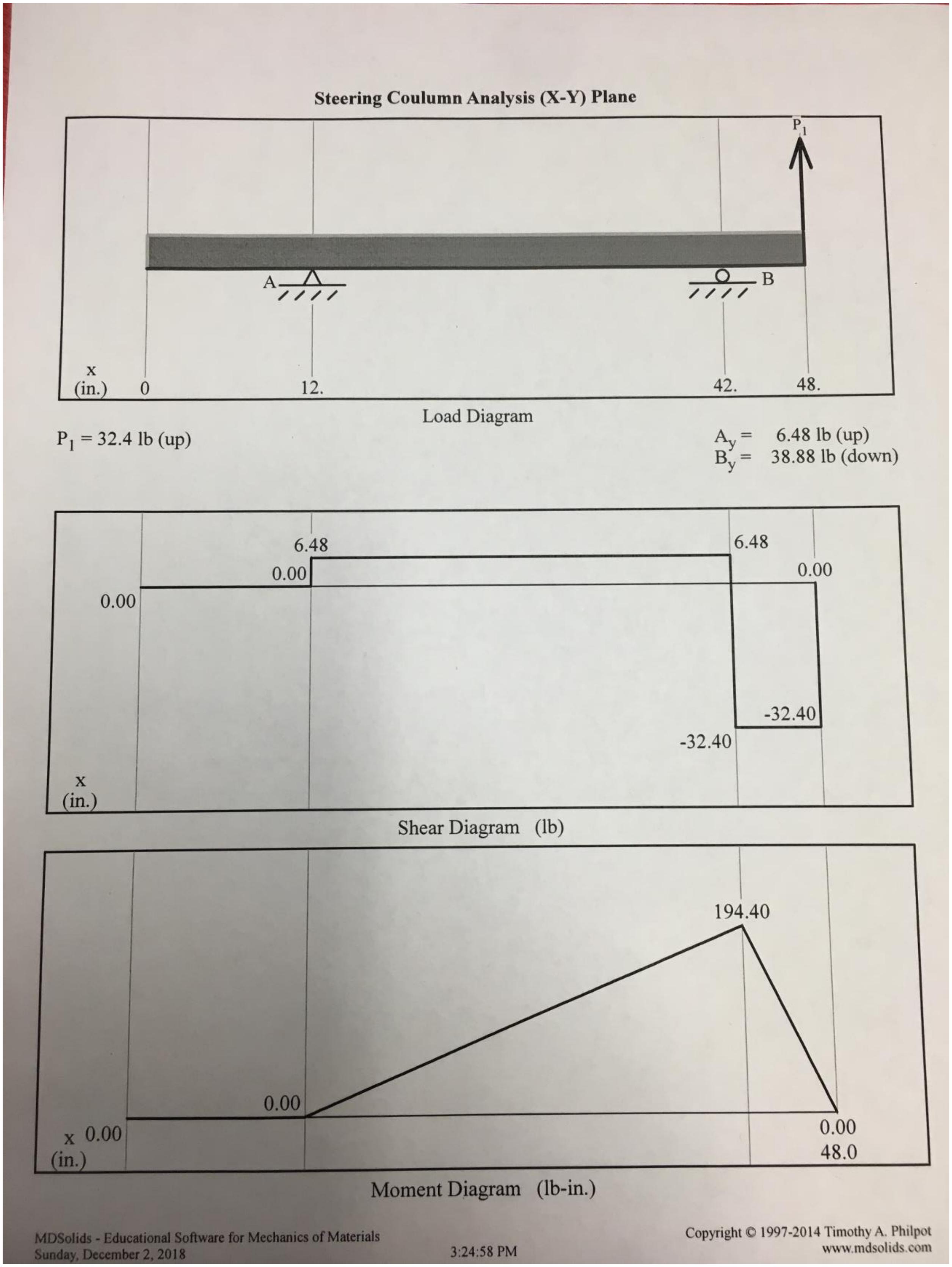
The bending Moment at A will be the deciding factor.

Appendix A-7



Steering Coulumn Analysis (X-Z) Plane
P1
A
B
x
(in.)
0
12.
42.
48.
Load Diagram
P1 = 200.0 lb (down)
Ay = 280.00 lb (up)
By = 80.00 lb (down)
80.00
80.00
0.00
0.00
0.00
-200.00
-200.00
x
(in.)
Shear Diagram (lb)
0.00
0.00
0.00
-2,400.00
x
(in.)
43.74547.12
Moment Diagram (lb-in.)
MDSolids - Educational Software for Mechanics of Materials
Sunday, December 2, 2018
3:23:55 PM
Copyright © 1997-2014 Timothy A. Philpot
www.mdsolids.com

Appendix A-8



Steering Coulumn Analysis (X-Y) Plane
P1
A
B
x
(in.)
0
12.
42.
48.
Load Diagram
P1 = 32.4 lb (up)
Ay = 6.48 lb (up)
By = 38.88 lb (down)
6.48
0.00
0.00
6.48
0.00
-32.40
-32.40
x
(in.)
Shear Diagram (lb)
194.40
0.00
x 0.00
(in.)
0.00
48.0
Moment Diagram (lb-in.)
MDSolids - Educational Software for Mechanics of Materials
Sunday, December 2, 2018
3:24:58 PM
Copyright © 1997-2014 Timothy A. Philpot
www.mdsolids.com

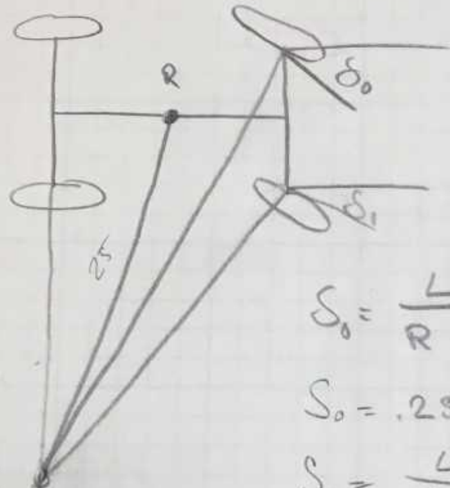
Lathan Hadaspagh | MRT 489t | 10/26/18

Ackerman Angle for Car

given: 50 ft curb to curb.

t = distance apart = 33in = 2.75 ft

L: 79 = 6.58ft



$$\delta_0 = \frac{L}{R + \frac{t}{2}} = \frac{6.58\text{ft}}{25\text{ft} + \frac{2.75\text{ft}}{2}}$$

$$\delta_0 = .25$$

$$\delta_1 = \frac{L}{R - \frac{t}{2}} = \frac{6.58}{25 - \frac{2.75}{2}} = .27$$

δ_0 true angle = Arctan (δ_0) = 14°

δ_1 true angle = Arctan (δ_1) = 15.6°

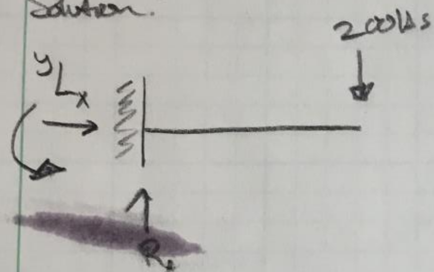
Lathan [illegible] | MET 489 | 12/4/18

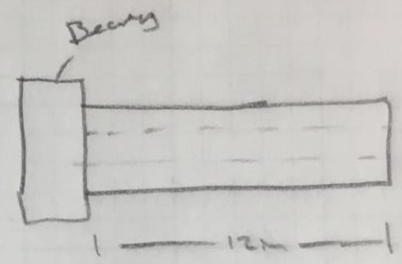
Given: Load on the end of the Steering Column

$P = 200lbs$

Find: σ_{max}, and if the shaft size will be able to withstand the force.

Solution:





Equilibrium Equations:

$\Sigma F_y = 0 = R_{Ay} - 200lbs \therefore \quad R_{Ay} = 200lbs$

$\Sigma F_x = 0$

$\Sigma M_A - (200lbs)(12in) \therefore \; M_A = 2400 lbs$

Assume A36 steel $S_y = 36{,}000$ - failure

$N = \frac{\sigma_{fail}}{\sigma_d} \Rightarrow \sigma_d = \frac{\sigma_{fail}}{N} = \frac{36000}{2} = 18000psi$

Assume $I_x = .135in$

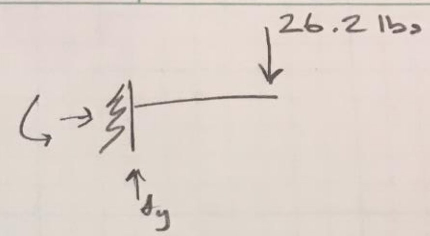
$\sigma = \frac{Mc}{I} = \frac{2400lb\,in\,(.75in)}{.135\ in^4} = 13{,}333.33\ psi$

$\boxed{13{,}333\,psi > 18\,000\ psi}$ ✓

Appendix A-11

Lathan Holmgren | MET 489 | 12/3/18

Pitman Arm Analysis



Given: $F = 26.4$ lbs

$A = 2'' \times .25''$

Find: will it be able to withstand the forces Applied?

Solve: $\Sigma F_y = 0 = R_{Ay} - 26.2\text{ lbs} \therefore R_{Ay} = 26.2\text{ lbs}$

$\Sigma F_x = 0$

$\Sigma M_A \qquad M_A - 26.2\text{ lbs}(4.5\text{ in}) = 0$

$M_A = 117.9\text{ lb-in}$

Assume 6061-T6 Aluminum $\quad S_y = 21{,}000$ psi $\quad N = 2$

$$\sigma_{dy} = \frac{21{,}000}{2} = 10{,}500\text{ psi}$$

$$\sigma = \frac{Mc}{I} = \frac{117.9\text{ lb-in}(1'')}{\frac{1}{12}(2'')(.25'')^3} = 1676.8\text{ psi}$$

$\boxed{1676.8\text{ psi} < 10{,}500\text{ psi}}$ ✓ The arm will be able to support the forces.

Lathan Holegrip | MET 489 | 12/5/18

Tie Rod Analysis

Given: Modulus of Elasticity = 10×10^6 psi

Axial Load = 26.4 lbs

OG Length = 24"

Cross sec. Area = $\pi(.125)^2 = .049 \text{ in}^2$

Find: deformation.

$$\text{Deformation} = \frac{(\text{Axial Load})(\text{OG Length})}{(\text{Elasticity})(\text{Cross sec. Area})}$$

$$= \frac{(26.4 \text{ lbs})(24 \text{ in})}{(10 \times 10^6 \text{ lbs/in}^2)(.049 \text{ in}^2)}$$

Deformation = .001 inches

The metal shaft shall not deform within .01 inches.

$\boxed{.01" > .001}$ ✓

Lathan Halagappa | MET 489 | 3-12-19

Given: Forces 200lb Existing holes Ø's for bolts

$\tau = \frac{F}{A}$

Find: Max shear forces at each bolt

Solve:

Forces from bearing = 200lbs f

Area of Bolt = 3/8 in diameter

$$\frac{\pi d^2}{4} = A = \frac{\pi (3/8)^2}{4} = \boxed{.11 in^2}$$

$$\tau = \frac{200 lbs}{.11 in^2} = \boxed{1810.8 psi}$$

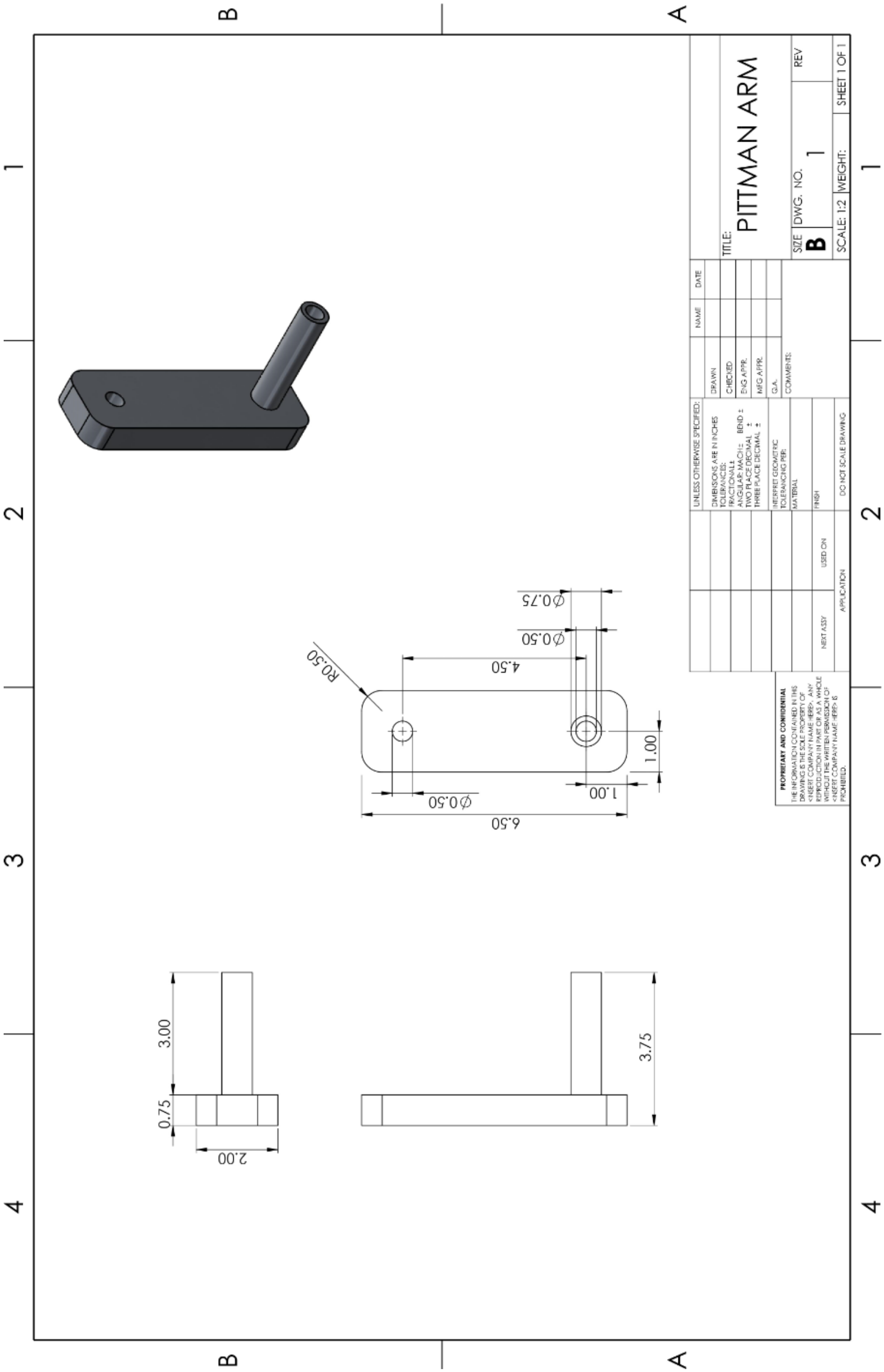
Yield strength of 6061 Aluminum Bolt = 35,000psi

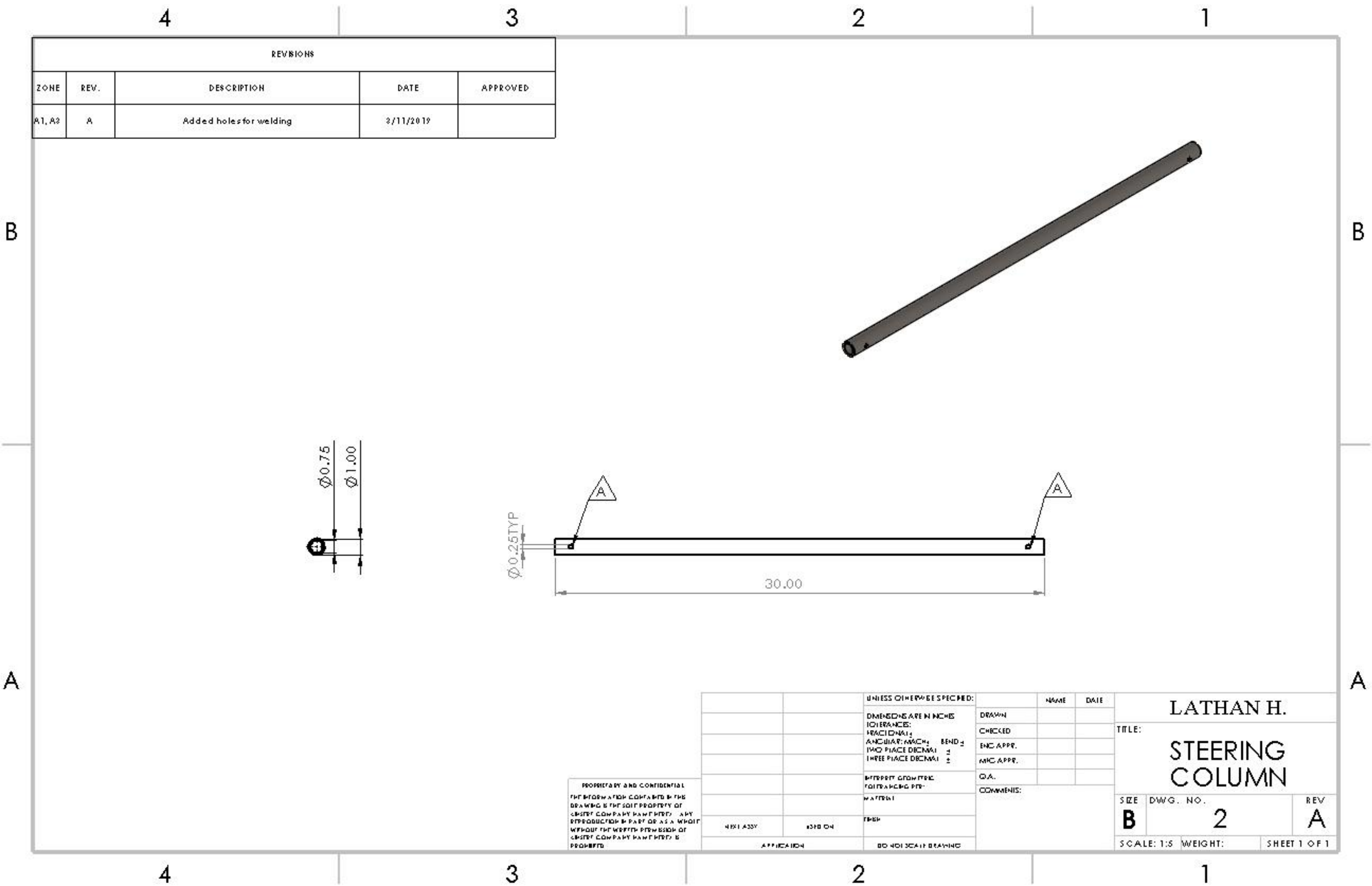
$$\boxed{35,000 > 1810.8 psi}$$ ✓

The bolt will withstand the load applied

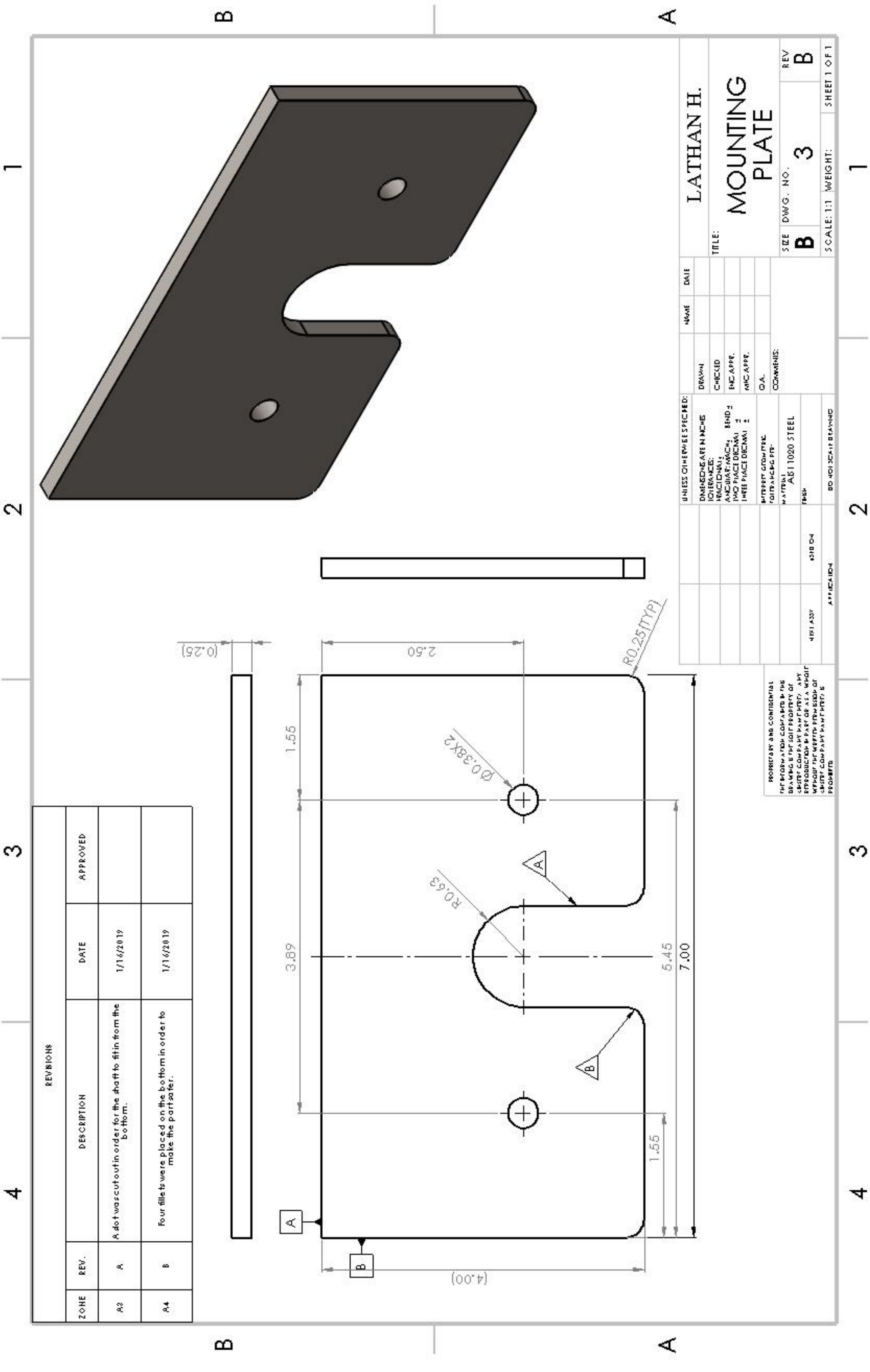
APPENDIX B

Appendix B-1

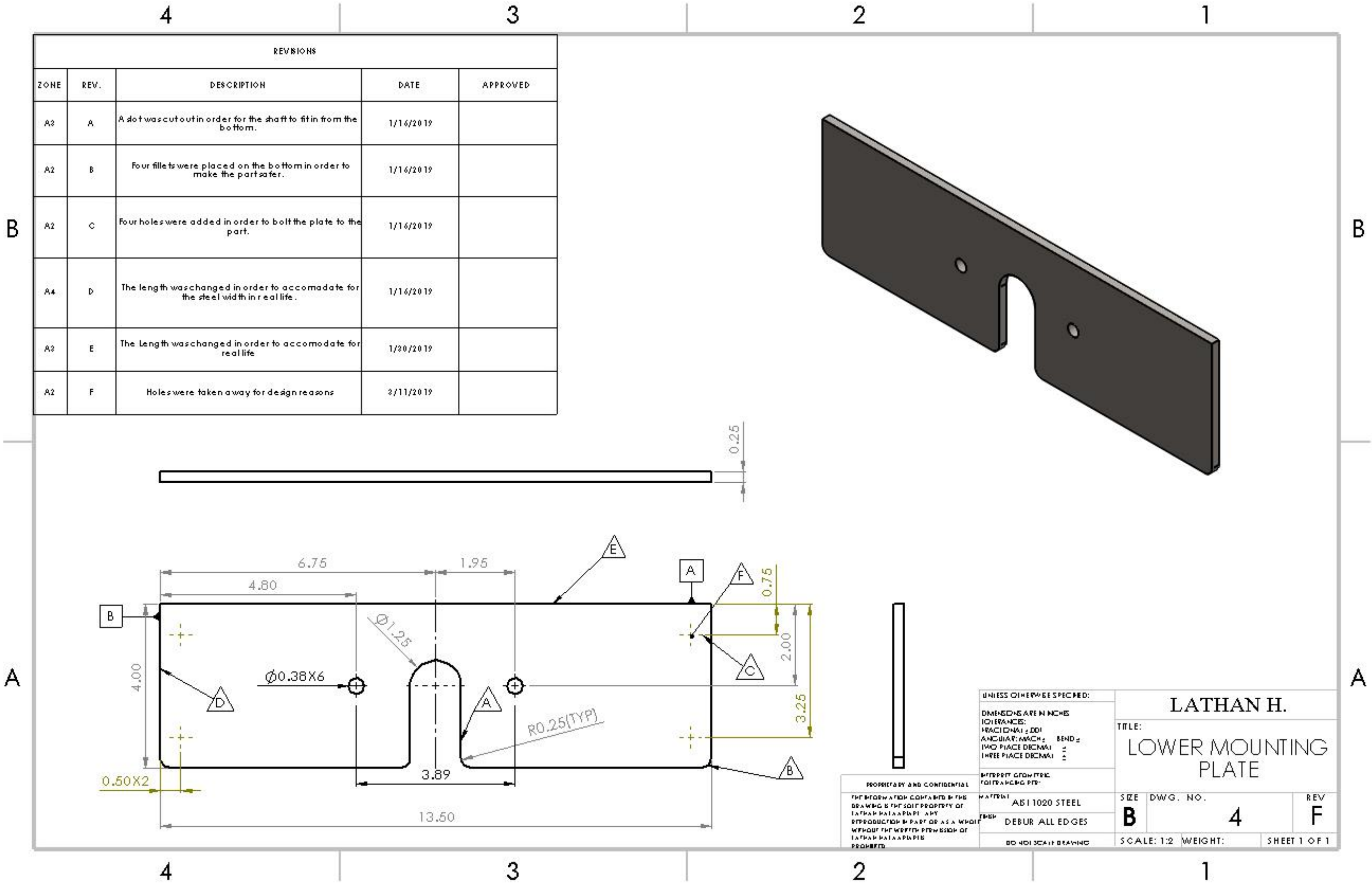



REVISIONS
ZONE | REV. | DESCRIPTION | DATE | APPROVED
A1, A3 | A | Added holes for welding | 3/11/2019 |
Ø0.75
Ø1.00
Ø0.25TYP
30.00
A
A
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
PROPRIETARY AND CONFIDENTIAL
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
LATHAN H.
TITLE:
STEERING COLUMN
SIZE B
DWG. NO. 2
REV A
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1

Appendix B-3


REVISIONS
ZONE
REV.
DESCRIPTION
DATE
APPROVED
A3
A
A slot was cut out in order for the shaft to fit in from the bottom.
1/16/2019
A4
B
Four fillets were placed on the bottom in order to make the part safer.
1/16/2019
(0.25)
2.60
R0.25(TYP)
1.55
Ø0.38X2
3.89
R0.63
5.45
7.00
1.55
(4.00)
A
B
UNLESS OTHERWISE SPECIFIED:
AISI 1020 STEEL
DO NOT SCALE DRAWING
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
LATHAN H.
TITLE:
MOUNTING PLATE
SIZE
B
DWG. NO.
3
REV
B
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1

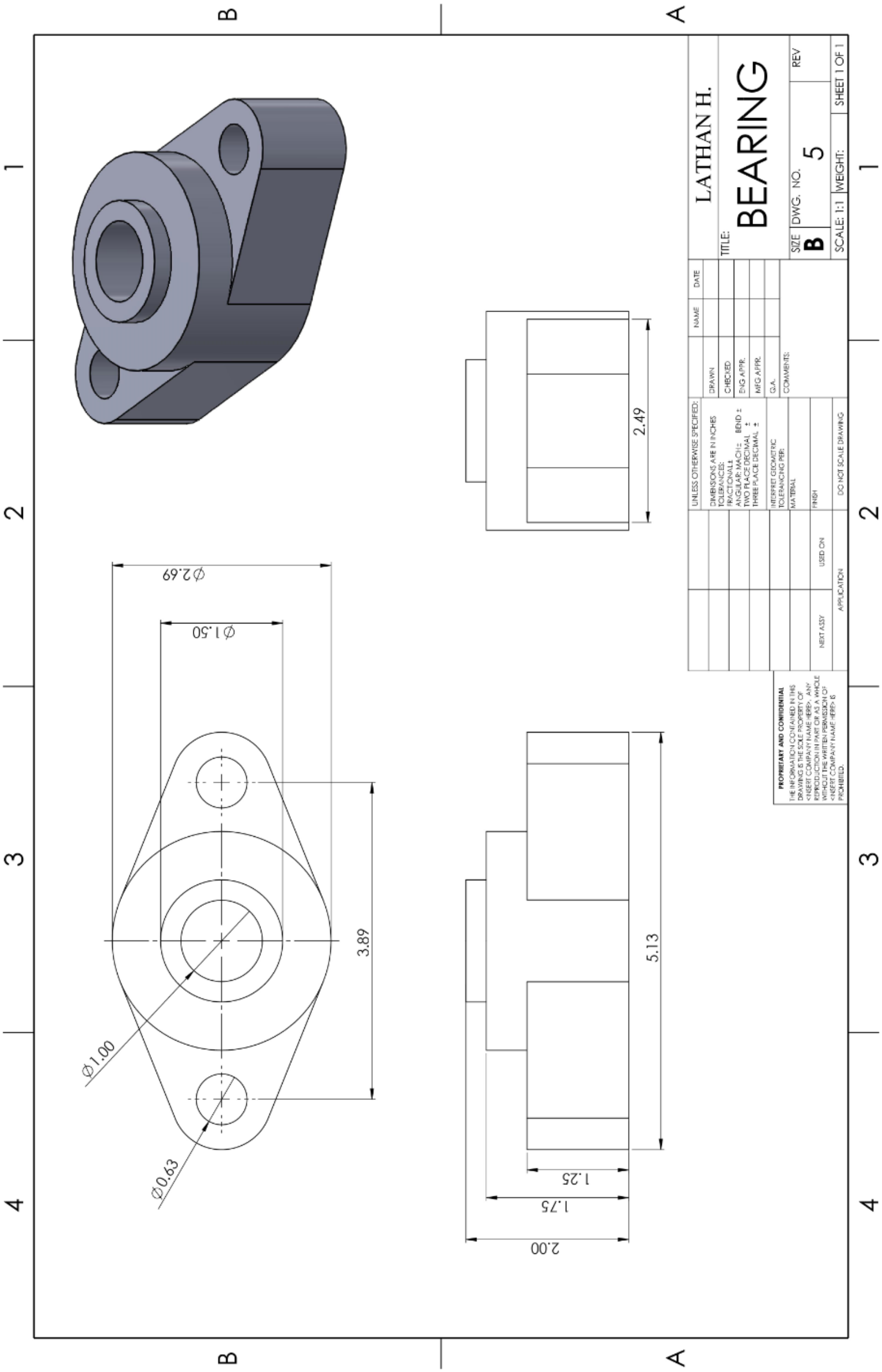
Appendix B-4



REVISIONS

ZONE	REV.	DESCRIPTION	DATE	APPROVED
A3	A	A slot was cut out in order for the shaft to fit in from the bottom.	1/16/2019	
A2	B	Four fillets were placed on the bottom in order to make the part safer.	1/16/2019	
A2	C	Four holes were added in order to bolt the plate to the part.	1/16/2019	
A4	D	The length was changed in order to accomadate for the steel width in real life.	1/16/2019	
A3	E	The Length was changed in order to accomodate for real life	1/30/2019	
A2	F	Holes were taken away for design reasons	2/11/2019	

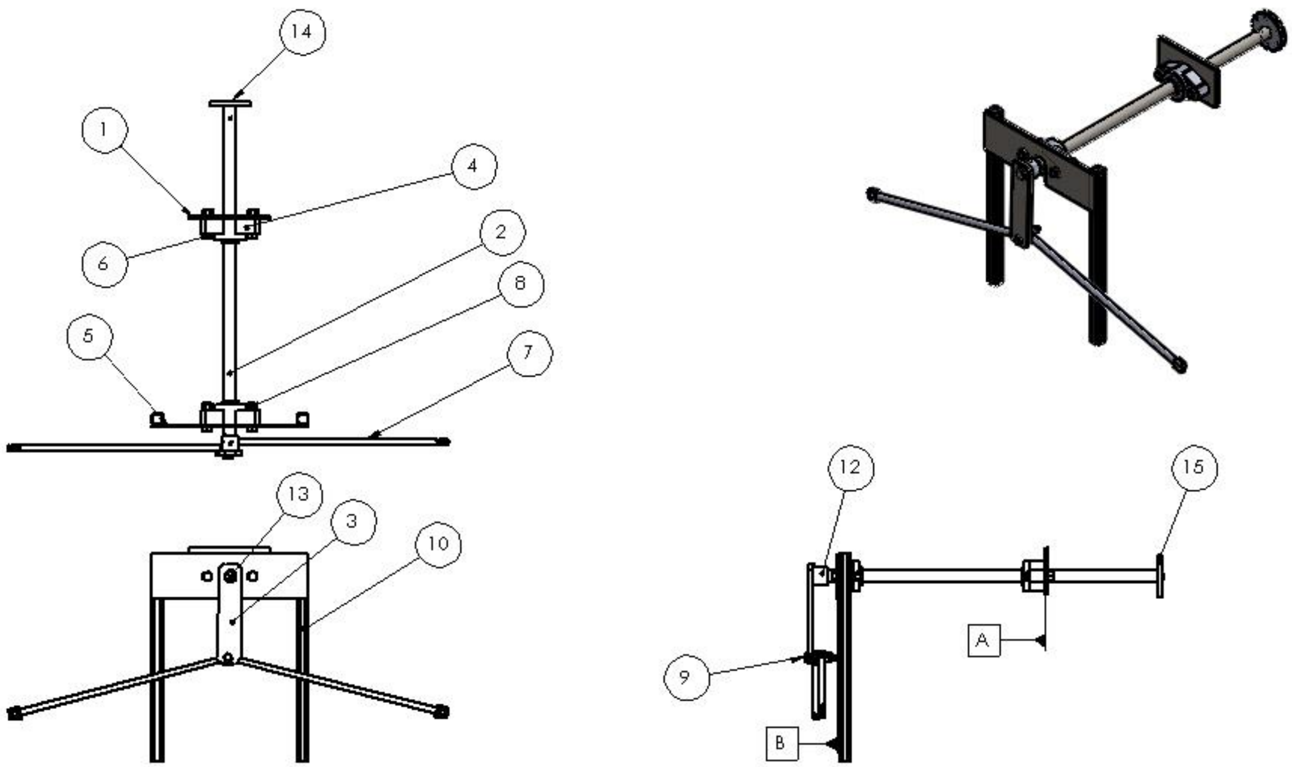
Appendix B-5



LATHAN H.
TITLE:
BEARING
SIZE
B
DWG. NO.
5
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
MATERIAL
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
2.49
Ø2.69
Ø1.50
3.89
5.13
Ø1.00
Ø0.63
1.25
1.75
2.00

Appendix B-6

ITEM NO.	DESCRIPTION	QTY.
1	Mounting Plate	1
2	Steering Column	1
3	Pittman Arm V2	1
4	Bearing	2
5	Lower Mounting Plate	1
7	Tie Rod	2
8	HTNUT 0.5000-20-D-N	4
9	HFBOLT 0.4375-20x2.25x1.125-N	1
10	Square Tube Mounting Bracket	2
12	Pittman arm collar	1
13	Pittman arm attachment	1
14	Steering wheel atatchment	1
15	Steering wheel adapter	1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± .003
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

DRAWN: NATHAN H
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:

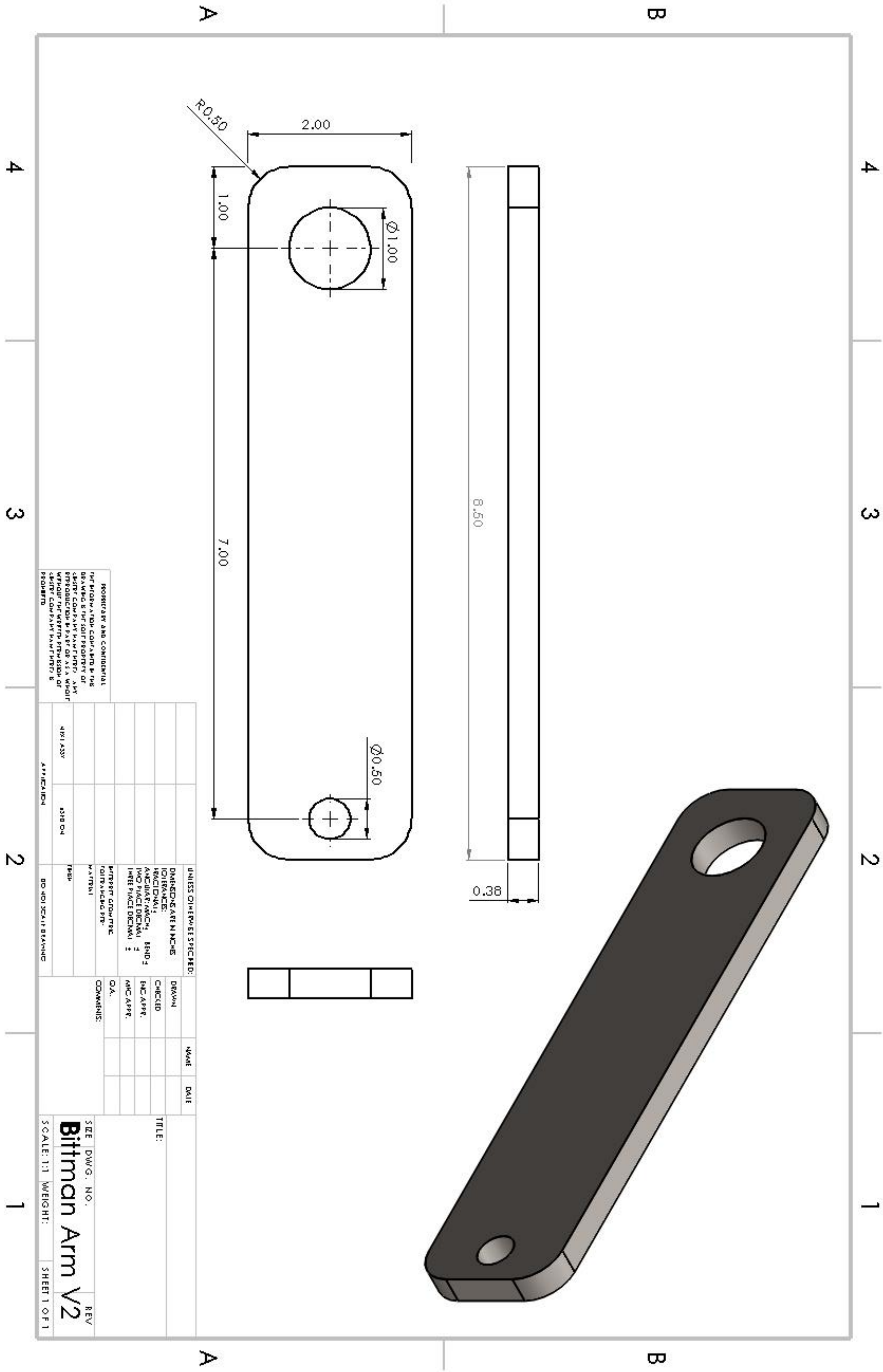
TITLE: STEERING ASSEMBLY

SIZE B | DWG. NO. 1 | REV

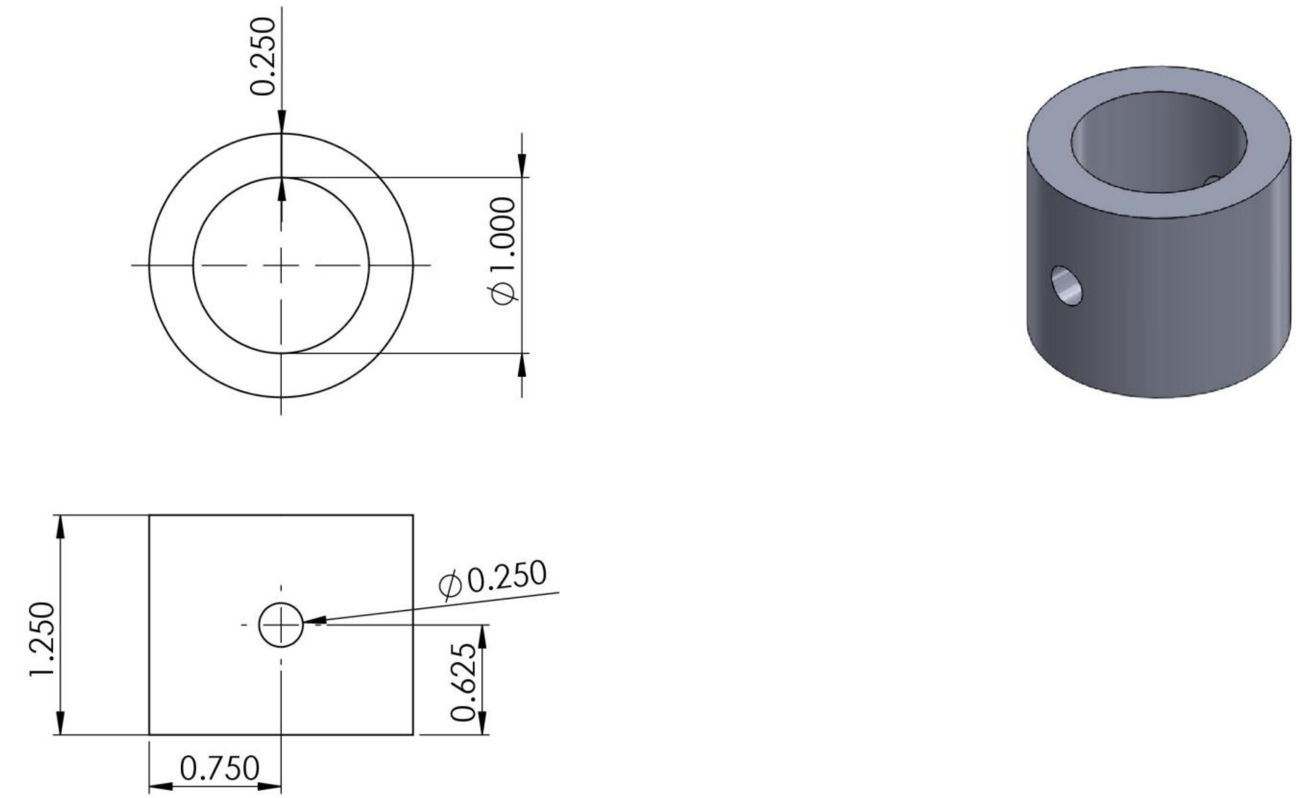
SCALE: 1:10 | WEIGHT: | SHEET 1 OF 1

DO NOT SCALE DRAWING

Appendix B-7


R0.50
2.00
1.00
Ø1.00
7.00
Ø0.50
8.50
0.38
TITLE:
Bittman Arm V2
SIZE
DWG. NO.
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
UNLESS OTHERWISE SPECIFIED:
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL

Appendix B-8



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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

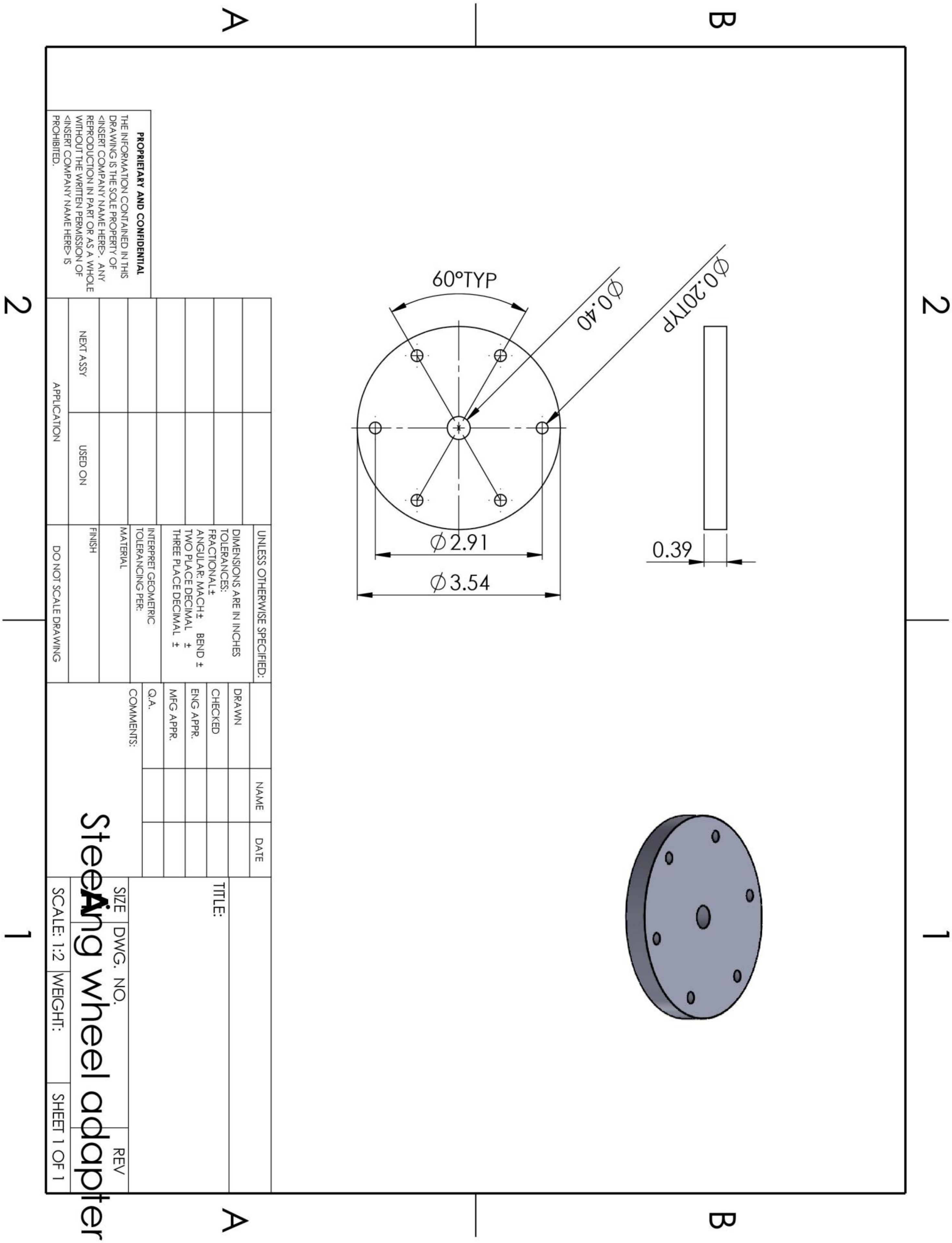
COMMENTS:

TITLE: PITTMAN ARM COLLAR

SIZE A | DWG. NO. 1 | REV

SCALE: 1:1 | WEIGHT: | SHEET 1 OF 1

Appendix B-9


60°TYP
Ø0.40
Ø0.20TYP
Ø2.91
Ø3.54
0.39
PROPRIETARY AND CONFIDENTIAL
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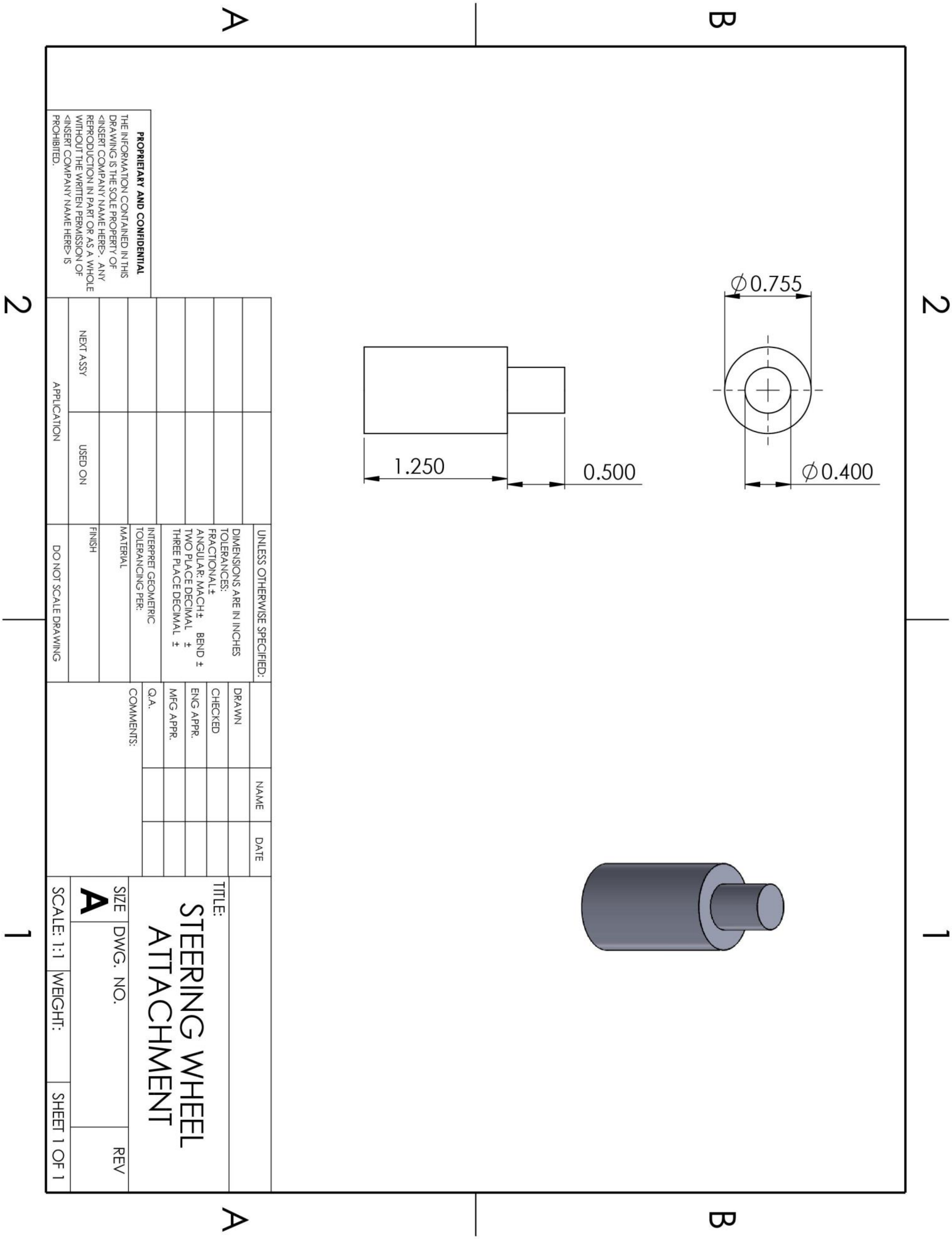
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Steering wheel adapter
SIZE
A
DWG. NO.
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
A
B
2
1



Ø0.755
Ø0.400
1.250
0.500
PROPRIETARY AND CONFIDENTIAL
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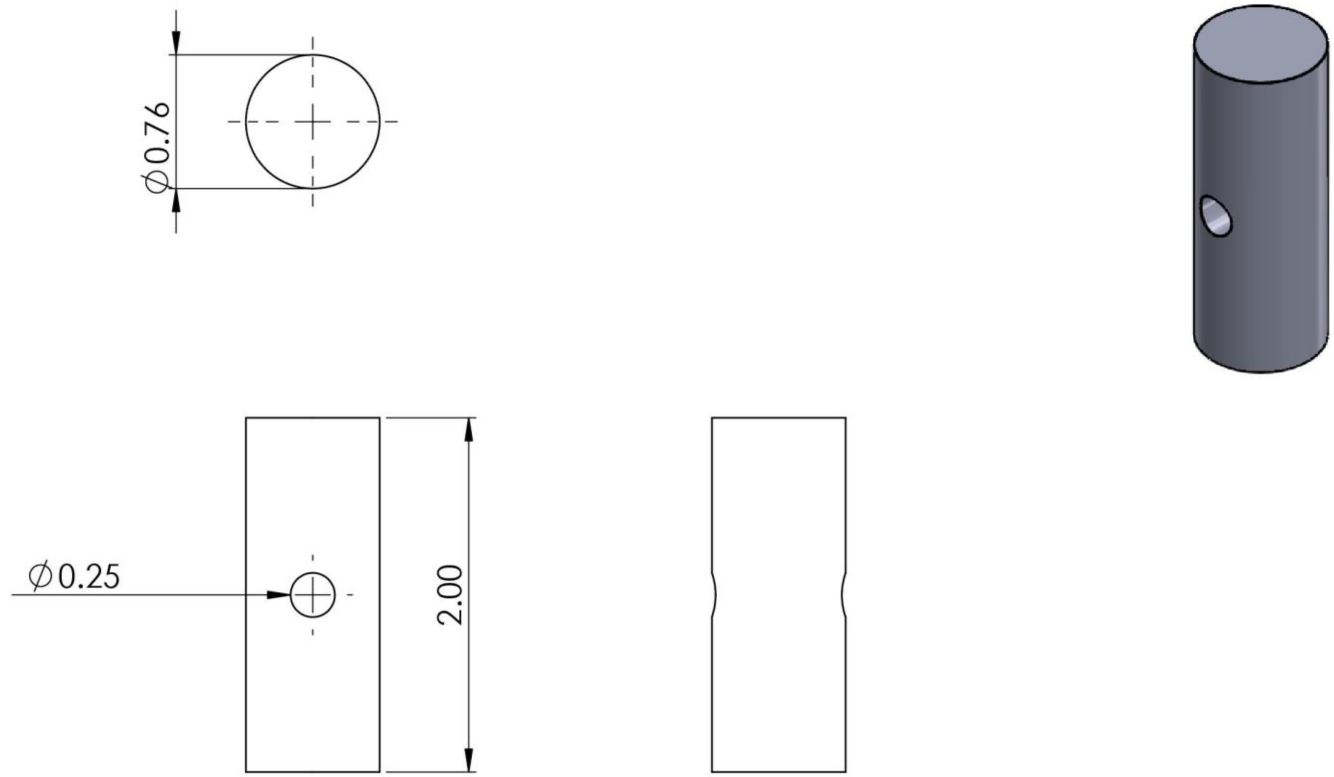
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
STEERING WHEEL ATTACHMENT
SIZE
A
DWG. NO.
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1

Appendix B-11



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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

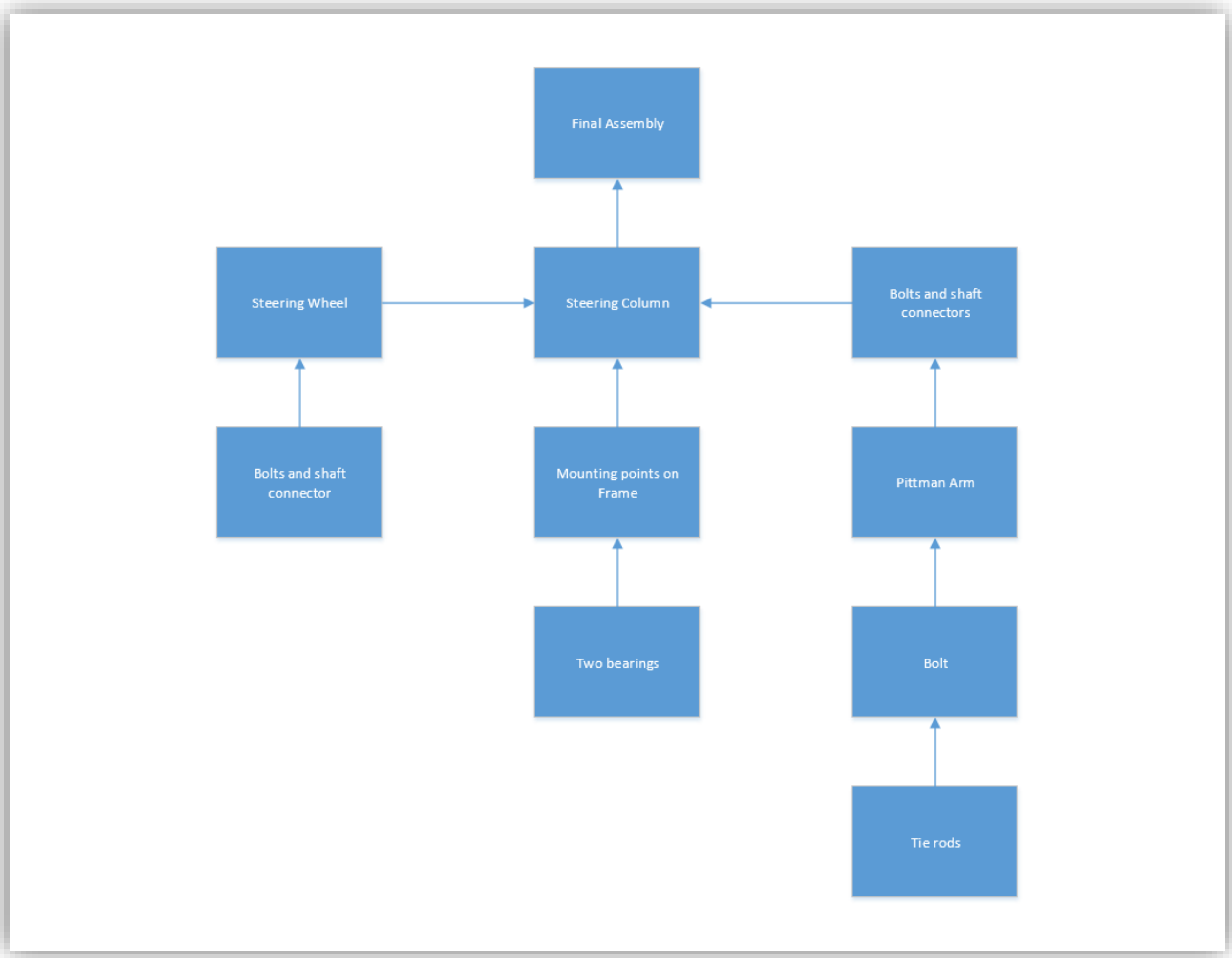
TITLE:

Pittman Arm Attachment

SIZE	DWG. NO.	REV
A		

SCALE: 1:1 | WEIGHT: | SHEET 1 OF 1

Appendix B-12



APPENDIX C – Parts List and Costs

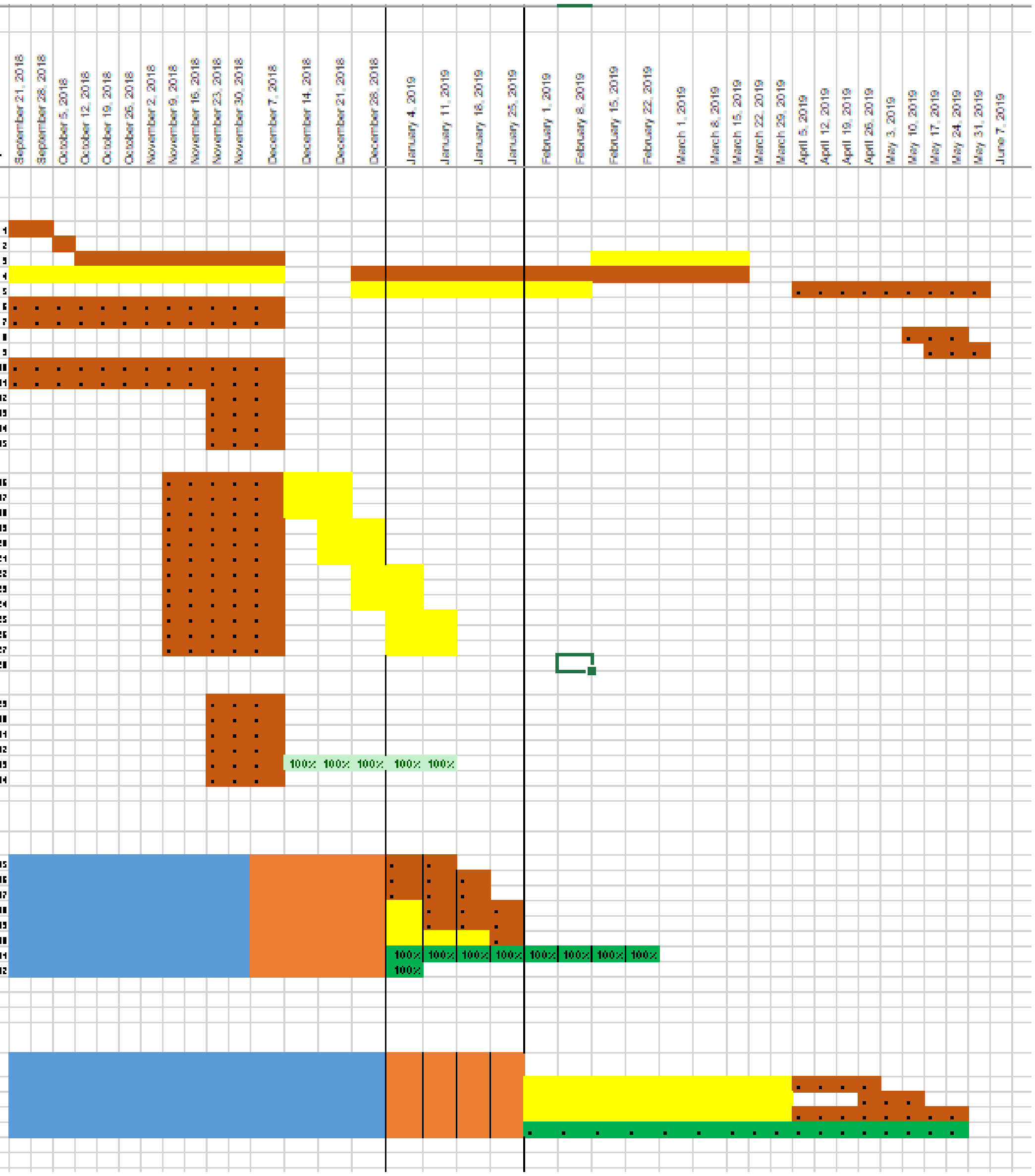
Part Ident	Part Description	Source	Estimated Cost	Actual Cost
7767T371	Steering column	mcmaster.com	$20.26	$3.45
6544K76	Mount for steering column and bearings.	mcmaster.com	$90.61	$0.00
92620A401	For attaching to spindle and Pittman arm	mcmaster.com	$16.25	$0.00
8364T2	Tie rods stock	mcmaster.com	$27.93	$0.00
	Pittman arm	Metals in the Shop.	$0.00	$0.00
	Coupling Nuts	Woods Ranch and home	$9.08	$9.08
	Ready rod for tie rods	Mcmaster Carr	$9.18	$9.18
	Bearings	Zoro.com	$35.29	$35.29
	Steering wheel	Amazon.com	$31.43	$31.43
	Quick release adapter	Amazon.com	$20.51	$20.51
			Total cost: $173.76	$108.94

APPENDIX D – Budget

The budget for this project should be no more than $300 dollars. This estimated budget is the worst case scenario of all the parts needed being glossily overpriced. The estimated cost of the entire Electrathon Vehicle project should not cost over $3000 dollars. All the parts and materials together came out to a grand total of $108.94. This came well within the proposed budget of $300. This is because the materials were found locally, therefore shipping was cheaper and less expensive. A lot of the materials were also provided by the machine shop, with excess material they had. The most amount of money spent was on the bearings that the steering column sits on. This was a surprise because usually the raw materials ordered over the internet would end up costing more. All in all, the project was roughly $200 under budget. This allows for more money to be put towards other parts of the total Electrathon Vehicle project. Staying under budget for this part of the project was very important because the EV club that was started for this project only got $1500 for the whole club. The steering system was very successful in staying under budget and getting the project done.

APPENDIX E – Schedule

Estemated Duration (Hours)	Actual Duration (Hours)	Task	Task Number
		Fall Quarter	
		Proposal	
3		Introduction	1
2		Outreach Summary	2
60		Design & Analisys	3
40		Methods & Construction	4
40		Testing	5
20		Budget/ Schedule/ Project Mc	6
20		Discussion	7
5		Conclusion	8
3		Acknowledgements	9
45		Appendix A (Green Sheets)	10
15		Appendix B (Drawings)	11
3		Appendix C (Parts List)	12
3		Appendix D (Budget)	13
3		Appendix E (Schedule)	14
2		Appendix J (Safety)	15
		Analisys	
2		A1	16
2		A2	17
3		A3	18
3		A4	19
2		A5	20
3		A6	21
2		A7	22
3		A8	23
3		A9	24
3		A10	25
3		A11	26
3		A12	27
2		A13	28
		Design	
1		Steering Column	29
1		Pittman Arm	30
1		Tie Rod	31
0.5		Steering wheel	32
2		Mounting bracket	33
2		Lower mounting bracket	34
		Winter Quarter	
		Construction	
		Steering column	35
		Pittman Arm	36
		Tie Rod	37
		Steering wheel	38
		Mounting bracket	39
		Lower mounting bracket	40
2	2	Steering Assembly	41
2	2	Parts List	42
		Spring Quarter	
		Testing	
5		Function Test	
5		Weight Test	
5		Modifications	



Personal Schedule Description

Winter 2018-2019
Week 1: <u>1/3/19-1/6/19</u>
TASK# 41 HRS: 2 COMMENTS:
Worked on the solid works assembly for my steering system. I got the bill of materials drawing done and perfected the model.

TASK# 42 HRS: 2 COMMENTS:
Got the parts list done and getting ready to order the parts needed to make the order for the materials.

TOTAL TIME: 4 Hrs.

SUMMARY OF PROGRESS:
Basically, I got the solid works designs done and I'm getting ready to order the parts for my project

Week 2: <u>1/7/19-1/13/19</u>
TASK# 33 HRS: 2 COMMENTS:
Revised my mounting plate drawing to accommodate for an assembly issue that could occur.

TASK# 34 HRS: 2 COMMENTS:
Worked on the design of the lower mounting bracket to accommodate for an assembly issue that could occur.

TOTAL TIME: 4 Hrs.

SUMMARY OF PROGRESS:
I did some revisions on my designs accommodate for an assembly issues that could occur.

Week 3: 1/14/19-1/20/19
TASK# 34+35 HRS: 5 COMMENTS:
Revised my lower mounting plate drawing and also finished my steering assembly to 100% complete.

TASK# 44 HRS: 2 COMMENTS:
Talked to Matt Burvee about possible places to gather material from. There is the school which has material and also Western supply which also has material.

TOTAL TIME: 4 Hrs.

SUMMARY OF PROGRESS:
Fully completed the drawings for the steering column and also found out where to get material for the assembly.

Week 4: 1/21/19-1/27/19
TASK# 36 HRS: 2 COMMENTS:
Bought the steering column and measured out where to cut the metal.

TASK# 42 HRS: 4 COMMENTS:
Talked to Matt Burvee about possible places to gather material from. There is the school which has material and Western supply which also has material. I spent time looking for the correct bearings and other assembly parts.

TOTAL TIME: 6 Hrs.

SUMMARY OF PROGRESS:
Moved into the manufacturing side of the project and actually getting somewhere to be able to build the assembly parts.

Week 5: 1/28/19-2/3/19
TASK# 36 HRS: 2 COMMENTS:
Bought the steering column and measured out where to cut the metal.

TASK# 39 HRS: 4 COMMENTS:
Ordered the steering wheel and quick release adapter for the EV.

TOTAL TIME: 6 Hrs.

SUMMARY OF PROGRESS:
Moved into the manufacturing side of the project and actually getting somewhere to be able to build the assembly parts.

Week 6: 2/4/19-2/10/19
TASK# 39 HRS: 3 COMMENTS:
Plasma cut the mounting plate and also cute it to length.

TASK# 40 HRS: 3 COMMENTS:
Cut the lower mounting plate to size and also plasma cut it.

TOTAL TIME: 6 Hrs.

SUMMARY OF PROGRESS:
Moved into the manufacturing side of the project and actually getting somewhere to be able to build the assembly parts.

Week 7: 2/11/19-2/17/19
TASK# 39 HRS: 3 COMMENTS:
Plasma cut the mounting plate and also cute it to length.

TASK# 40 HRS: 3 COMMENTS:
Cut the lower mounting plate to size and also plasma cut it.

TOTAL TIME: 6 Hrs.

SUMMARY OF PROGRESS:
Moved into the manufacturing side of the project and actually getting somewhere to be able to build the assembly parts.

Week 8: 2/18/19-2/24/119
TASK# 41 HRS: 3 COMMENTS:
Fit the lower mounting bracket to the frame, and also moved the EV frame down to the welding shop.

TASK# 42 HRS: 3 COMMENTS:
Did analysis on bolts that are going to be on the project to order them.

TOTAL TIME: 6 Hrs.

SUMMARY OF PROGRESS:
Finishing up what needs to be ordered for the EV, and also am starting to fit parts to the vehicle.

Week 9: 2/25/19-3/3/19
TASK# 41 HRS: 3 COMMENTS:
Started the holes to put in the mounting bracket.

TASK# 42sss HRS: 2 COMMENTS:
Gathered the bolts needed for the assembly of the project.

TOTAL TIME: 5 Hrs.

SUMMARY OF PROGRESS:
Fit the rest of the parts to the vehicle.

Week 10: 3/4/19-3/10/19.
TASK# 42 HRS: 20 COMMENTS:
Welded the lower mounting plate and upper mounting plate to the frame. Welded the quick release hub for the steering wheel to the steering column. Bolted the bearings on to the lower and upper mounting plates. Got the Pittman arm ready to weld and got the eyes for the tie rods ready to be attached to the tie rod bar.

TASK# 39 HRS: 2 COMMENTS:
Connected the steering wheel to the quick release hub and mounted both the hub and the steering wheel to the frame.

TOTAL TIME: 22 Hrs.

SUMMARY OF PROGRESS:
Completed the project to as far as I could without the suspension being complete.

Total Hours: 69 Hours

Schedule discussion

Nothing in this EV project started on time. It took quite a while to get funding, and when the EV club got funding, the parts needed to be ordered. This was quite a delay in the process. This set the whole team back. The steering system heavily relies on the suspension being done, there were some issues regarding certain aspects being done which pushed things back a little, but what could be finished was finished. In total the steering system compiled a mass of 69 hours. Which was over the predicted 50 hours on the project. This isn't as bad as one might think and is actually fairly close to the projected 50 hours.

APPENDIX F – Expertise and Resources

Expertise:

- Professor Charles Pringle
- Dr. Choi
- Dr. Johnson

Resources:

- Machine Shop
- Welding Shop

APPENDIX G – Testing Data

	Radius Turned	Within 50 Ft Radius?
Test 1	38ft	Yes
Test 2	36ft	Yes
Test 3	37ft	Yes

Spring test trial	Force
1	67.6
2	66.9
3	68.3

APPENDIX H – Evaluation Sheet

	Radius Turned	Within 50 Feet?
Test 1		
Test 2		
Test 3		

Spring test trial	Force
1	
2	
3	

Summary/overview:
The Electrathon vehicle needs to be able to turn within a 50 foot radius. The test outlined in this procedure will allow anyone to recreate the test by following the steps.
Specify time:
There isn't a certain time limit involved in turning a vehicle.
Duration:
There isn't a specified duration the vehicle needs to turn in.
Place:
An area of parking lot or wide area of flat land big enough for the vehicle to turn in.
Resources needed:
Electrathon Vehicle, Chalk, 50 foot long string/tape measure, a rod or steak in ground to use as center of semi-circle.
Specific actions to complete the test:
Step 1: Make a semi-circle using 50 foot tape measure/string and chalk.
Step 2: Draw a line going from one end of the semi-circle to the center of the circle.
Step 3: Start Electrathon vehicle behind the line made to the center of the circle.
Step 4: Attempt to turn vehicle via push power, within the chalked line made.
Step 5: Record if the Electrathon Vehicle could turn within the 50 foot radius.
Risk:
No risk involved in this type of test.
Safety:
This type of test is very safe.
Discussion:
This should be a very simple test to determine if the Electrathon Vehicle can turn in a 50 foot radius.

Test Procedure 2 Summary/overview:
The Electrathon vehicle needs to be able to turn within a 50 foot radius. The test outlined in this procedure will allow anyone to recreate the test by following the steps.
Specify time:
There isn't a certain time limit involved in turning a vehicle.
Duration:
There isn't a specified duration the vehicle needs to turn in.
Place:
An area of parking lot or wide area of flat land big enough for the vehicle to turn in.
Resources needed:
Electrathon Vehicle, Chalk, 50 foot long string/tape measure, a rod or steak in ground to use as center of semi-circle.
Specific actions to complete the test:
Step 1: Make a semi-circle using 50 foot tape measure/string and chalk.
Step 2: Draw a line going from one end of the semi-circle to the center of the circle.
Step 3: Start Electrathon vehicle behind the line made to the center of the circle.
Step 4: Attempt to turn vehicle via push power, within the chalked line made.
Step 5: Record if the Electrathon Vehicle could turn within the 50 foot radius.
Risk:
No risk involved in this type of test.
Safety:
This type of test is very safe.
Discussion:
This should be a very simple test to determine if the Electrathon Vehicle can turn in a 50 foot radius

Deliverables:

The parameters were what was listed above, nothing was needed to calculate because it is a turning radius and weight requirement. The success for this would be that the vehicle could turn easily and effectively. The EV failed in this because it locks while turning fully to the left or right and is very hard to turn back. Part of the problem is initially the suspension was not set up properly for the vehicle to turn.
This could be fixed by redoing the suspension and putting more thought into it in the beginning.

Force Test:

This test was done in order to compare the analytical data to real life data. In this test a spring gauge was used in order to measure the amount of force the steering wheel needed to turn. A slow motion camera was used to see at what exact time the steering wheel turned, and what force correlated to that time. The maximum amount of force averaged over three different trials were around 67 lbs of force. When compared to the analytical data we are far off. The calculated data showed that it would only take 12.3 lbs of force to turn the wheel. That is about 445% error with my calculations. This was because assumptions were made about the wheel being perpendicular with the ground and the wheels being parallel to each other.

Force Test Data:
This was the maximum force it took to turn the wheel. This was taken using slow-mo video to find where the maximum force was when the wheels turned.

Lathan Halaapiapi

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Objective

I am excited for the opportunity to be a part of a team in the evolving field of manufacturing to improve processes and equipment so that a company may be more productive in their work. Beyond the education and knowledge of mechanical engineering, I bring a range of hands-on experience with machining equipment as well.

Skills

- Metal Fabrication
- Machining
- SolidWorks
- AutoCAD
- Destructive and non-destructive testing
- Microsoft Excel
- Microsoft PowerPoint
- Microsoft Word
- Manage Multiple Assemblies
- Mechanical Design
- Strengths of Materials
- Problem Solving
- Strong Written and Verbal Communication

Achievements

- Maintained a cumulative 3.5 GPA at Central Washington University

Education

Central Washington University Ellensburg, WA, United States **September 2015-June 2019**
Bachelor of Science - Mechanical Engineering Technology

Work Experience

Deryl Groen Construction Everson, WA **July 2015-2018**
General Laborer
Assisted in building wood and metal structures, along with house additions, greenhouses, decking, and siding.

Central Washington University Ellensburg, WA **September 2017-2018**
Resident Assistant
Provided paraprofessional advising to undergraduate students in three distinct residential environments. Developed and conducted programs on diversity, chemical abuse, personal development, relationships, security, and academic performance. Managed administrative tasks including room condition reports, maintenance requests, incident reports, and the room change process. Enforced college policy.

Organizations

- American Society of Mechanical Engineers
- Poly Central

JOB HAZARD ANALYSIS
{Insert description of work task here}

Prepared by: Lathan Halaapiapi	Reviewed by: Approved by:

Location of Task:	Hogue Hall
Required Equipment / Training for Task:	Hand tools
Reference Materials as appropriate:	Machine Elements in Mechanical Design

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
☒	☐	☒	☒	☒	☒	☒
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
	Cut Steering shaft to size	Metal shavings flying	Eye protection
	Welding parts to Shaft	Light emitted may cause blindness, also Extreme heat	Gloves, welding mask, protective clothing