California Polytechnic State University, San Luis Obispo

The Quadricycle

Hand and Foot Cycle

December 2010

Sponsors:

Scott Davis, Client
Dr. Kevin Taylor, Cal Poly Kinesiology Department

Tetrasource Cycle Designs:

Marissa Chin: mchin@calpoly.edu
Parker Drennan: pdrennan@calpoly.edu
Spencer Nelson: spnelson@calpoly.edu
Kevin Reidy: kreidy@calpoly.edu

Team Advisor:

Sarah Harding: sthardin@calpoly.edu

Table of Contents

List of Figures and Tables

Abstract

This report documents the design process from concept generation to manufacturing for a hand and foot powered cycle named the Quadricycle. The Quadricycle project is a joint effort at California Polytechnic State University in San Luis Obispo between the mechanical engineering and kinesiology departments. The project objectives are to design a portable cycle that can be powered by hands and feet simultaneously in order to provide recreation and rehabilitation for a person with a disability. This project is funded under a grant by the National Science Foundation (NSF).

Chapter 1 Introduction

Daily tasks can be a challenge for people with physical disabilities, and one of the most important of those is getting a sufficient amount of exercise. For our senior project we are tasked with designing and manufacturing a hand and foot powered cycle to be used for exercise and mobility by our customer, Scott Davis of Atascadero, California. The main objective of this project is to build a cycle that Mr. Davis can power predominantly by hands and upper body strength, but also allow a cycling motion and some power input by foot in order to get a full body exercise.

Our team, TetraSource Cycle Designs, consists of teammates Marissa Chin, Parker Drennan, Spencer Nelson, and Kevin Reidy. We are currently all mechanical engineering seniors working under advisor, Professor Sarah Harding of the Mechanical Engineering Department and supervisor, Dr. Kevin Taylor of the Kinesiology Department, both at California Polytechnic State University in San Luis Obispo, California. Our goal is to provide Mr. Davis with a quality product that will allow him to have freedom and mobility while exercising. Our stakeholders in this project include our advisor, supervisor, client, future athletes with disabilities, and the National Science Foundation providing the grant.

Chapter 2 Background

The spinal cord is the main column of nerve tissue connecting the brain to the rest of the body. When the spinal cord is injured, depending on the location of the injury, the patient can have varying levels of paralysis. People with spinal cord injuries may face challenges due to varying levels of functional ability, but like everyone, still need plenty of exercise.

Scott Davis, our sponsor and client for this project, has a C5 level spinal cord injury which is approximately at the deltoid/bicep height. Due to the location of his injury, he had very limited use of his arms and legs. He spent several months at a program called Project Walk and through rigorous rehabilitation he was able to regain a significant amount of upper body and leg muscle control.

In order to achieve an appropriate amount of daily exercise, a hand and foot powered cycle is ideal for Mr. Davis. While there are many companies who design and manufacture hand cycles and recumbent cycles, there are few that produce a product that meets Mr. Davis' needs. The main design feature that

will differentiate our cycle from anything else on the market today is that it will allow parallel hand and foot power, adapted to Mr. Davis' abilities.

Our project is very similar in scope to the Hand and Foot Powered Cycle (FAHC1) by Life Element Designs, a senior project that concluded in December, 2009. The goal of Life Element Designs was to design a cycle for their customer John P. Lee. Mr. Lee, like Scott Davis, has limited muscle control due to a spinal cord injury, however no two injuries are alike, and therefore our cycle will be adapted to Mr. Davis. By studying the final product as well as the design process for the FAHC1, we hope to determine what aspects of the final design to incorporate into our cycle.

Life Element Design's first prototype is shown below Figure 2-1 Life Element Designs FAHC1 is a tricycle that incorporates a method for parallel hand and foot power. Steering is performed by way of a rack and pinion system operated by the hand bars. The major difference between our design and the FAHC1 will be the method of hand power. Our design will incorporate a crank and hand "pedal" configuration.

Figure 2-1 Life Element Designs FAHC1

To prepare for the design process we have researched some of the current products available today that aim to solve a similar problem. Many companies build hand cycles and recumbent bikes and some even build a hybrid of the two. The different designs and configurations range from upright sitting position to kneeling to an almost flat leaned back position. Each configuration has its strengths and are chosen based on the desired use.

Figure 2-2 Invacare® Top End® Force 'R'

For example, a hand powered tricycle made by Invacare, the "Top End Force R" model (Figure 2-2), is a low slung cycle in which the rider sits leaning backward at approximately a 45 degree angle. The feet are supported by a rest attached to the front wheel assembly. Steering, braking and power delivery are accomplished through the hand crank mechanism. The Top End Force R is clearly a racing and sport cycle where aerodynamics and weight are a major concern.

Figure 2-3 The Berkel Bike Pro

The BerkelBike Pro, made by the company BerkelBike, is by contrast a hand and foot powered cycle made for casual and leisure exercise use, as opposed to competition (Figure 2-3). The purpose of the company and their product is to allow people who have spinal cord injuries to exercise the muscles that they no longer have control over. According to the company and its founder, Rik Berkelmans, electrical stimulation of these muscles by way of Functional Electrical Stimulation will hinder their atrophy. The rider sits upright, and the feet are placed into the pedals. The electrical stimulation of muscles allows them to contribute to the cycle power and is provided by a device called 'impuls', which is fitted to the rider in a pair of shorts.

On the other end of the spectrum of recumbent bikes lies the popular "tadpole" trike configuration. The term tadpole generally refers to trikes that have two front wheels, one foot powered rear wheel, and are steered by linkages and handles placed to the rider's sides. One reasonably priced example of this style of cycle is the TerraTrike® Path model shown in Figure 2-4. The entry level Path is powered through a 3 or 8 speed drivetrain and is stopped by two front disc brakes.

Figure 2-4 The TerraTrike® Path

One very unique design that we reviewed during our research was a one-off tricycle designed by Kerry McLean called the All Body Workout (ABW) Trike, shown in Figure 2-. According to a website devoted to his creations, Mr. Mclean originally designed and built the machine for a man with a disability. The design incorporates a hand crank and a foot crank that simultaneously power the single rear wheel, while steering is accomplished by rocking the seat about a pivot located just below.

Figure 2-5a The McLean All Body Workout Trike

Figure 2-5b The McLean ABW Trike Steering Demonstration

The common trait that all of these designs share is that they are supported by a strong foundation of research and take advantage of their users strengths. During our concept development phase, we considered the design features that each of these models uses to accomplish steering, braking, and power delivery.

Chapter 3 Design Development

3.1 Specifications

Our overall goal for the hand and foot cycle is to design and build a cycling device that our client, Scott Davis, can use while being able to transport easily.

From our initial meeting with Mr. Davis and the kinesiology department, we prepared a list of requirements and specifications:

- The cycle must be powered mainly by hands, specifically in a circular, synchronized, prone pedaling motion; the feet must move in a cycling motion as well and allow for parallel cycle power. We will accomplish this by using a chain drive mechanism that connects the hand crank to the foot crank.

- Gears should be similar to a normal bike (21 speeds is one typical configuration; we can have less). Mr. Davis mentioned how, unlike a bicycle rider, a hand cycle rider lacks the ability to use body weight to gain a torque advantage. Therefore a low (under drive) gear is necessary and will be considered in order to climb hills or start moving from an idle position.

- Ease of assembly and disassembly is very important. Our initial goal is for the cycle to weigh less than 50 lbs for portability and have push button release wheels for quick disassembly. The cycle must have the ability to be taken apart in some capacity, and must fit into a typical vehicle or truck bed.

- Flywheel Concept: As mentioned by the kinesiology team, a flywheel might be useful to include on the foot crank. A flywheel, with the help of hand power, would allow the feet to recover from the pedaling extremities quicker using momentum to keep the rider's feet moving. Although the hand crank should provide enough momentum for the feet when in motion, additional analysis will be needed to see if the flywheel will be helpful.

- Upgradeable: If cost and time permits, the cycle will be equipped with an electric assist motor for climbing up steep inclines and/or resting tired muscles. Also, we hope to be able to add some health diagnostic equipment to the bike such as a heart rate monitor.

Table 1 is a tabular representation of the technical requirements for our project.

Table 1 Technical Specifications for the Quadricycle

Spec #	Parameter Description	Requirement or Target	Tolerance	Risk	Compliance
1	Weight	50 lbs	MAX	H	A, I
2	Turning Radius	12 feet	± 2 feet	M	A, T, I, S
3	Ride Height	5 inches	+ 3 inches	M	A, I, S
4	# of Wheels	3 wheels	EXACT	L	S
5	Cycle Width	25 inches	± 5 inches	M	I, S

There are three levels of risk, (H)igh, (M)edium, and (L)ow for reaching these goals. For compliance, A represents Analysis, T represents testing, I represents Inspection, and S represents similar designs. We have decided that weight is our highest risk (most difficult) item to accomplish. All specifications listed are based on already developed high-end hand cycles. All other specifications can be seen on our Quality Function Deployment (QFD) analysis sheet attached in Appendix A.

The QFD "House of Quality" table in Appendix A weighs our customer's needs and requirements with our own specifications (developed from the customer's needs). Each need is compared with each specification and rated on the value of importance between the two. Weights are added to each need based on the importance to the customer. Based on our analysis, specifications such as weight, size, material selection, and width are the most important factors when building the Quadricycle. Specifications such as wheel diameter, turning radius, and camber may have less of an impact on the overall design of our cycle.

3.2 Concept Generation

We used numerous concept generation methods to ensure a wide range of ideas were generated. The first method was to create a morphological attributes list. A morphological attributes list consists of brainstorming all the possible configurations of the sub-components of the cycle. A list of ideas for each attribute was generated, whether it was practical or not. After completing the morphological attributes list, we randomly connected ideas from each category to generate a concept design. This process was very useful because it allowed us to think beyond existing combinations that we had found during our research. Many of the feasible concepts that we generated from this method combined features from different cycles, which we wouldn't have initially thought would work together.

Another concept we applied was a list of alternative actions. The purpose of this method is to guide the designer in new directions by listing random verbs that apply to the goal of the project. In our case, we used action words like pedal, turn, push, pull, rotate, lengthen, and shorten. With each action verb, we

carefully thought about how we were to accomplish each verb with our cycle. This method helped with brainstorming ideas for each sub-assembly.

The last method we tried using was S.C.A.M.P.E.R. (Substitute. Combine. Adapt. Modify. Put to other uses. Eliminate. Rearrange or Reverse.) This method has the designer think of ways to alter existing concepts. Since we found an abundance of existing hand and/or foot cycle ideas, this method was very applicable to our concept generation. With our budget and the availability of used cycle parts in mind, altering an existing cycle design seemed very appropriate for our task. However, even with the "rearrange" part of the method, it was hard to develop a completely different layout of the cycle, which led us back to limited ideas. The product of our initial brainstorming sessions was five distinctly different concepts.

3.2A Modified Existing Hand Cycle with Foot Pedaling

This design will involve the modification of an existing hand cycle frame provided by our customer, Scott Davis. The hand cycle is a simple Top End® hand cycle with fork steering similar to the steering on a regular bicycle shown in Figure 3-1. All of the driving power is located on the front wheel attached to the fork steering. The braking lever is mounted to the hand pedals, and the entire braking system is mounted to the front fork steering. The major modification involves adding foot pedals and coordinating the power delivery with the existing hand power supply.

Figure 3-1 Donor Hand cycle: Top End® "Action Simply Smart"

3.2B Seat Steering Tricycle

The seat steering concept, shown in Figure 3-2, is a unique idea involving the rider's core muscles to provide the act of turning. Unlike our other concepts, this cycle has 1 rear wheel and two front wheels. Hand and foot power is routed by chain to the back driving wheel. The seat is mounted on a "steer shaft" that is attached to the front wheel kingpins by tie rods. The foot pedals are positioned in front of the front wheels. Stiffness in the turning seat shaft is provided by two or more torsion springs attached to the moving shaft that allow the seat to return to the upright position easily.

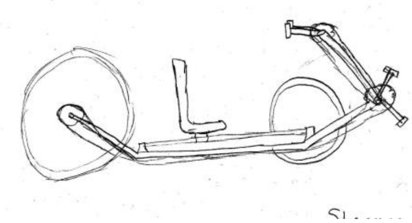


Figure 3-2 Seat Steer Sketch

3.2C Delta Leaning Steer

The lean steering concept is similar to the seat steering concept. The rider uses core muscles to lean the entire front frame in making a turn. The swiveling frame is accomplished by a swivel joint located behind the seat along the frame. This joint allows the entire front end of the bicycle to lean into a turn and allows the rider to be in

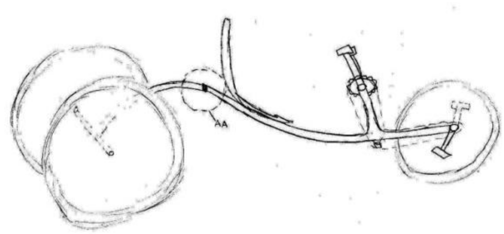


Figure 3-3 Delta Lean Steer Sketch

line with the driving pedals at all times.

3.2D Hand Front Power, Foot Rear Power

This design is similar to the first concept; however, the hand power is routed to the front wheel and the foot power is routed to the rear wheels. Having separate driving wheels provides more variation in power between the hands and feet. The steering is provided by fork steering as in concept #1. The brake levers are attached to the hand pedals.

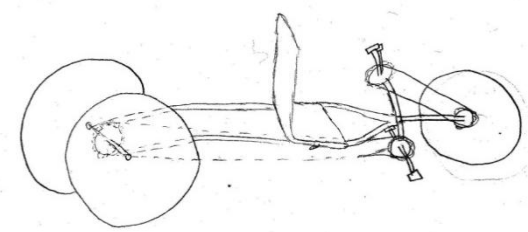


Figure 3-4 Hand Front, Foot Rear Power Sketch

3.2E Rowing Bike

This design is another extremely unique concept. This concept uses rowing motion in the hands and feet to provide power. Similar to a rowing exercise machine, the hand and feet spin flywheels that, in turn, provide motion to the driving wheels. Normal rowing bikes sold commercially are steered by leaning like a conventional bicycle. It is unclear at this point how this concept would steer.

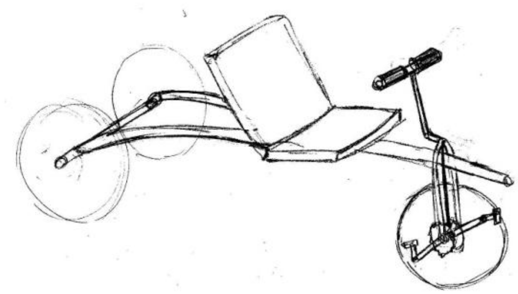


Figure 3-5 Rowing Bike Sketch

3.3 Concept Evaluation

After generating our five concepts, we used a decision matrix, shown in Figure 3-6 to compare them side by side against our needs and specifications. First we listed all the specifications for the cycle provided by our sponsor and from our background research. For each specification, we evaluated its importance and rated it on a scale from 1-6 (6 being very important). At first, a three-point scale was used for weight ranging from somewhat important (1) to extremely important (3). The weighted importance was doubled to show larger differences between designs and allowed for other not as important specifications to be included at lower weighted values. Every concept was judged based on how it would potentially meet the specifications. The datum for our matrix is the Life Element Designs FAHC1. It was difficult to find a production cycle that closely meets our specifications. The FAHC1 was chosen as the datum because it is a student designed cycle that was built for a similar purpose to ours. Each cycle concept was graded with -1, S, and 1, which indicated how well the concept met the specification compared to the datum: 1 = better, s = the same, -1 = less. The value for each concept was multiplied by its specification's importance and a total was summed for each.

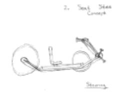
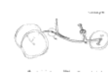
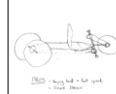
Quadricycle Concepts		Datum : FAHC1	Modified Existing Hand Cycle (1Fr, 2Rr, FWD)	Seat Steer (2Fr, 1Rr, RWD)	Delta Leaning Steer Pivots Behind Seat (1Fr, 2Rr, FWD)	Hand Front Power Foot Rear Power (1Fr, 2Rr, AWD)	"Rowing" Bike (1Fr, 2Rr, RWD)
Specification	Importance						
Light Weight <50lbs	5	D	1	1	1	-1	1
Portable	4		1	1	1	-1	s
Storable	3	A	1	1	1	1	1
Durable - Road Use, Occasional Curbs	3		s	s	-1	s	s
Safe	6	T	1	s	-1	-1	-1
Ease of Manufacture	4		-1	-1	-1	-1	-1
Comparable Power Transmission to Regular Bicycle multiple gearings	4	U	1	1	-1	-1	-1
Independently usable (compatible for people with disabilities)	6		1	1	1	-1	1
Cost of Production	1	M	s	s	-1	-1	s
Comfortable	4		s	1			
Repairable (off the shelf parts) potential	4		1	-1	-1	-1	-1
circular, synchronized, prone, pedaling motion	6		1	1	1	1	s
Aesthetics	2		s	1	1	1	1
Stability Potential	2		s	s	1	1	1
Ease of Dissasembly	4		1	1	1	1	1
Advantage to Customer's Strengths (Upper body vs. Lower Body Strength)	2		1	1	1	1	1
Total			40	32	12	-15	6

Figure 3-6 Quadricycle Decision Matrix

Upon completion of this analysis, three of the concepts could be eliminated quickly. The Delta Leaning Steer Cycle scored low because its specific lean steer design could potentially be unsafe and has inherent complexities that would make it difficult to manufacture. The Rowing Bike doesn't meet Mr. Davis' need for the circular, synchronized, prone cycling motion. The hand front power-foot rear power cycle was clearly the lowest mainly because it promises challenges to portability and disassembly. Also, the weight of the cycle will be higher with this power train configuration.

3.4 Top two concepts

The two highest scoring design concepts were the Modified Existing Hand Cycle and the Seat Steer Cycle. Since both concepts scored well above the others, we had to consider other factors to choose one over the other.

Based on preliminary analysis, the Modified Existing Hand Cycle concept seemed to adequately meet our basic design requirements. The addition of foot power, foot pedal, and sprocket, could be accomplished using off the shelf bicycle parts. The frame is made from lightweight aluminum making transport easy, and we could incorporate disassembly features such as removable wheels and seat as well as folding components.

The Seat Steer concept also meets our project requirements sufficiently. Like most recumbent bikes, it would use an inherently stable two front wheel design. This concept could incorporate the same disassembly methods as mentioned for the modified hand cycle. To keep the weight within specification, the frame would be constructed of aluminum. Despite the material choice, the seat steering mechanism will undoubtedly make this design heavier than the modified hand cycle but not prohibitively so.

After an extensive analysis of the Modified Existing Hand Cycle (performed during the final three weeks of the Winter 2010 quarter), we concluded that the complexities and potential problems associated with this concept make it an impractical choice. As a result, we chose to proceed in the development of the Seat Steer concept, beginning with the construction of a preliminary concept prototype, shown in Figure 3-7, to test the practicality of the seat steering mechanism.

Figure 3-7 Seat Steer Prototype

While the prototype has no drive train, foot pedals and a handle were provided to simulate the feet placement and leverage that the rider could use to shift his weight on the seat. The steering action was tested by coasting down a slight hill. The steering mechanism on the prototype functioned well and provided us with tremendous insight with which we could move forward with a more refined design.

3.5 Preliminary Analysis

One of our main concerns for this concept was that an adequate turning radius would be available with the rider leaning at a comfortable angle. Based on the available recumbent turn radius of about 9.5 ft, we calculated the appropriate linkage lengths to accomplish this with a seat angle of about 20 degrees. We then built the prototype shown in Figure 3-7 to those specifications and had our customer, Scott Davis, sit in the seat to test it. From this simple test, we determined a maximum lean angle of 15 degrees would be appropriate.

To ensure that adequate torque and traction would be available to climb hills, we performed a preliminary statics analysis of the overall cycle. Assuming a typical value for the coefficient of friction,

we calculated that our proposed configuration would supply enough traction to climb at least a 13% grade.

We also performed a force analysis on the drive train. Our calculation told us that using the existing 1.33:1 low gear ratio with a 2:1 hand and foot reduction would result in adequate mechanical advantage to climb a 15% grade. Since the variables such as steepest hill grade, maximum applied hand and foot force, and coefficient of friction between the tire and asphalt are somewhat subjective or difficult to determine, we have created a spreadsheet so that we can change the values and quickly see the effect of changing design parameters. A sample of these calculations can be found in Appendix D.

To help visualize limb motion and human-machine interaction, we constructed a solid model of our concept in SolidWorks®, a computer aided design (CAD) program. We obtained a human SolidWorks® model and modified it to have the same arm and leg dimensions as our customer, Scott Davis. This analysis has provided us with invaluable insight into how our design will be restricted by arm, hand, and leg movement. Figure 3-8 shows a SolidWorks® drawing of the human model with our design.

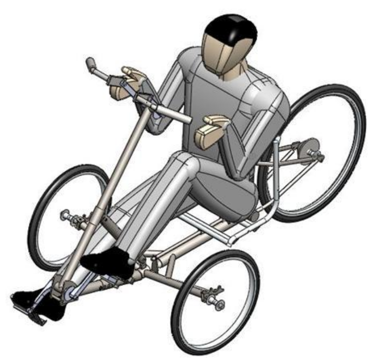


Figure 3-8 SolidWorks Model of Quadricycle Concept with Human Model

Chapter 4 Description of Final Design

4.1 Overall design

As described in the concept generation section (3.2), our final design is based on the Seat Steer concept. Figure 4-1 is a SolidWorks® drawing of our final design. The basic three wheeled cycle layout is similar to a traditional foot powered recumbent cycle, but includes many provisions to allow for parallel hand and foot power. Since the hands and feet will both be involved in powering the cycle, steering will be accomplished by leaning the seat a maximum of 15 degrees to horizontal. The seat is connected to the front wheels through a series of rods and linkages. The cycle has been divided into 5 subsystems (frame, steering, drivetrain, seat, and brakes) which are described in detail in the following sections. Refer to Appendix C for technical drawings of each subassembly. Appendix G contains manufacturer drawings and data for any “off the shelf” parts used on the Quadricycle.

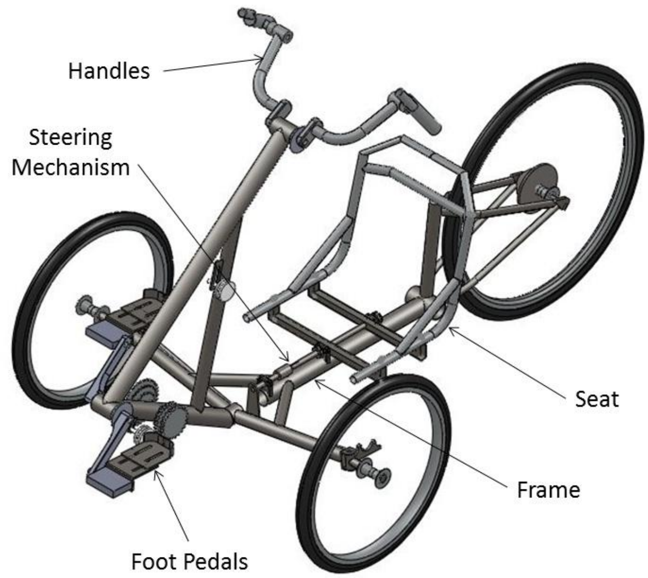


Figure 4-1 Final Quadricycle Design

4.2 Detailed Design Description

Frame

Since our concept closely resembles a foot powered recumbent cycle, the frame design process began by studying several of these cycle on the market today. The basic recumbent frame consists of a single tube that runs down the center of the cycle, two tubes extending out to the front wheels, and some form of stay for mounting of the rear wheel. Our frame design, shown in Figure 4-2, is similar but includes a triangular cutout section for the accommodation of the steering mechanism, and will incorporate a bicycle rear stay.

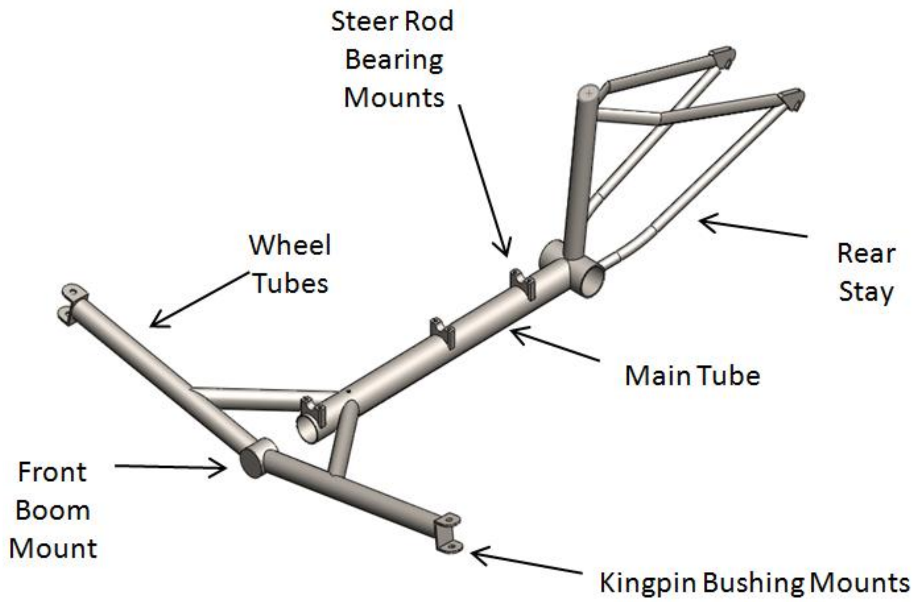


Figure 4-2 Frame Assembly

The main frame tube diameter was chosen as 1.75 inch outer diameter with a 0.065 inch wall thickness. This is the same diameter tube as is used on comparable recumbent cycles on the market, and will provide adequate stiffness for the expected loading.

The front wheel tubes and the tubes that make up the triangular shape in the front will have loads applied from the foot pedal boom. The tubing dimensions are based on similar recumbent tricycle designs since our design has the same track width and wheelbase. The wheel tubes will be 1.25 inch outer diameter, with a 0.065 inch wall, and the two support tubes will be 1.25 inch outer diameter with a 0.065 wall thickness.

The kingpin mounts and the wheel tubes were designed based on the geometry of the TerraTrike® spindles that will be used to mount the front wheels. The wheel tubes are inclined at an angle of approximately 12 degrees to account for the centerpoint angle built into the hub/spindle part. A more detailed description of this part and the required geometry is below in the steering section.

The rear stay will be taken from a salvaged mountain bike and modified as necessary to obtain the geometry shown in Figure 4-2. Traditional recumbent cycles have a fixed seat which is incorporated into the rear stay, however since our seat must move, the stay requires a vertical post to connect all of the tubes.

We chose to use an existing bike frame stay to accomplish the rear wheel mounting. There are two reasons for this. First, this version of the Quadricycle is a prototype and we do not know the exact optimum geometry for the rear wheel mount. The testing phase of this project will show us what rear frame geometry is appropriate, and future versions of the Quadricycle may use a fully fabricated stay

assembly when the optimum geometry has been determined. Secondly, the bicycle stay saves time and cost in manufacturing.

Steering

Basic Operation

Steering is accomplished through a rocking motion of the seat. Figure 4-3 shows the Quadricycle in the turning position with a seat angle of 15 degrees. The seat is mounted directly to a ½ inch diameter solid rod that transmits the steering rotation to the front wheels via a vertical steering bracket and tie rods as shown in Figure 4-4.

Figure 4-3 The Quadricycle with a 15 Degree Seat Lean

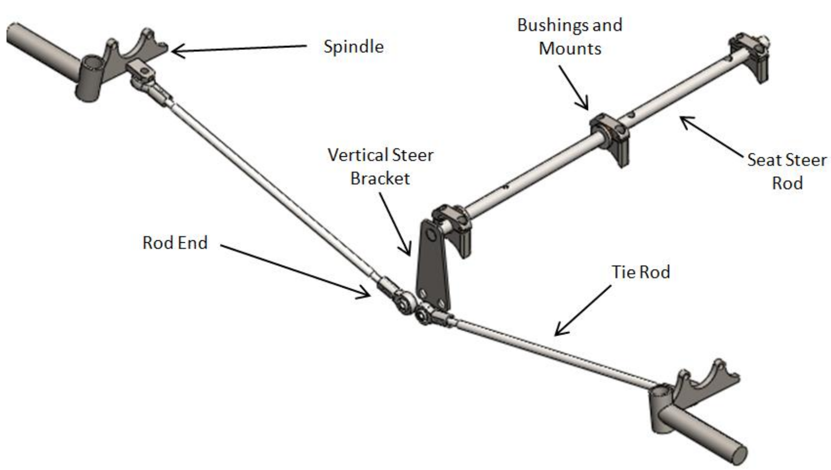


Figure 4-4 Steering Assembly

The steer rod is mounted to the frame using bronze bushings and steel mounts. Since disassembly of the Quadricycle steering system is necessary, the bushing mounts are split and the caps can be removed to allow the rod and seat to be completely removed from the cycle. Thrust loads are transmitted between the seat and the steering rod via stainless steel split shaft collars that will be installed on the rod and press closely against the bronze bushing vertical face. The vertical steer bracket shown in Figure 4-4 is pinned to the rod and bolted in place with a ½ inch stainless steel nut. The seat frame (not shown in Figure 4-4) will be welded to the steer rod.

Ackerman Steering Compensation

Any four or three wheeled vehicle with two wheels in the front requires steering geometry compensation for maximum stability during turns. As the vehicle executes a turn, the inside wheel makes a smaller radius arc than the outer wheel and as a result the angles that the wheels make relative to the chassis are different. Compensation can be made to account for this and is commonly referred to as Ackerman compensation. If compensation is not made for these required angles, excessive tire scrub and instability will occur. For the Quadricycle, this compensation is performed by locating the tie rod mounting points appropriately.

The front wheels are mounted to a hub/spindle that is based on the TerraTrike® recumbent part shown in Figure 4.5. This replacement part is used for many different TerraTrike® models, and will be used on the Quadricycle with slight modification. Due to differences in the Ackerman compensation design for these TerraTrike® models, the tie rod mounting point will need to be moved.

Figure 4-5 TerraTrike® spindles and modification

Centerpoint Angle

Another important aspect of wheel geometry is the centerpoint angle. The purpose of this angle is so that the steering axis line of action passes directly through the contact patch between the tire and the road as shown in **Error! Not a valid bookmark self-reference.**. This geometry, also known as "zero scrub radius", minimizes the impact that road irregularities such as bumps and potholes have on the steering. A more extensive discussion of these topics

Figure 4-6 Centerpoint Angle

can be found in *Fundamentals of Ground Vehicle Dynamics* by Thomas D. Gillespie.

Drivetrain

The Quadricycle drivetrain delivers parallel hand and foot power to the rear wheel via chains and sprockets. The drivetrain consists of all of the parts shown in Figure 4-7 highlighted in blue.

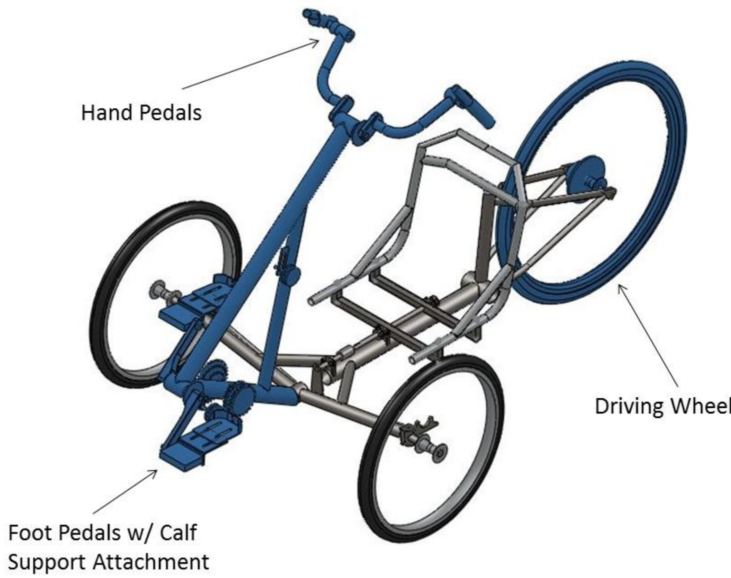


Figure 4-7 Quadricycle Drivetrain

Figure 4-8 Hand and Foot Pedal and Bottom Bracket Configuration

There were several design aspects that had to be accounted for in the design of the drivetrain. One, the user needed to get into the trike without interfering with the drivetrain. For this, an adjustable bracket

was designed to allow the top bar of the drive train to move out of the way. Another concern with the drive train was making sure the hands and the feet did not interfere when pedaling. Extensive SolidWorks modeling was done to ensure our customer, Scott, could fit into the trike without any unwanted interference when pedaling.

There are a total of three bars that make up the framework of the drive train (Figure 4-8). The bottom bar that connects the frame to the rest of the drive train is a single chromoly steel tube. Two bars, one short and one long, extend upward and are welded to the bottom bar. These three bars form a triangle shape, with the long bar extending further. The top end of the long bar marks the position of the hand crank. The formation of the three bars can be seen in Figure 4-8.

The chain is routed from the hands to the feet on the left side through two chain rings of equal size. On the right side, the chain is routed from a 3 speed chain ring on the foot crank to an 8 speed cassette on the rear driving wheel. We have implemented a way to have the hand and feet pedaling motion independent of each other. DaVinci Tandems® has developed a device for independent driving with an intermediate shaft. This intermediate shaft has two single-speed freewheels that allow the feet to pedal independently from the hands. Although costly, this allows our client to ride the cycle smoothly. The chain routing concept is illustrated in Figure 4-9.

Figure 4-9 Chain Routing

The foot and hand pedals consist of several specialty components. The foot pedals consist of a regular pedal with an attachment for calf support. The actual calf support is a plaster cast molding and will be molded specific to our customer in the building process.

With the selected cassette and chain ring, the Quadricycle will be able to achieve a low gear of 22:34 and a high gear of 44:11. This means that in low gear, the user will be able to transmit approximately 130 ft-lb of torque if 150 lb of force is given at the hand and foot pedals combined. In high gear, the user will be able to travel at a speed of approximately 28mph with a 90rpm cadence.

Analysis was done on the top and bottom bars to ensure deflection was kept to a minimum. Given a rider can exert a maximum of 200 pounds of force on the crank arms, the maximum deflection on the

bottom bar was found to be approximately .0002” and .125” on the top bar which is acceptable for our application. All detailed calculations can be seen in Appendix D.

The hand pedals were designed to provide the maximum amount of leverage that would be possible with a standard off the shelf hand pedal design while also allowing sufficient room to avoid knee interference. Figure 4-10 shows the hand pedal design.

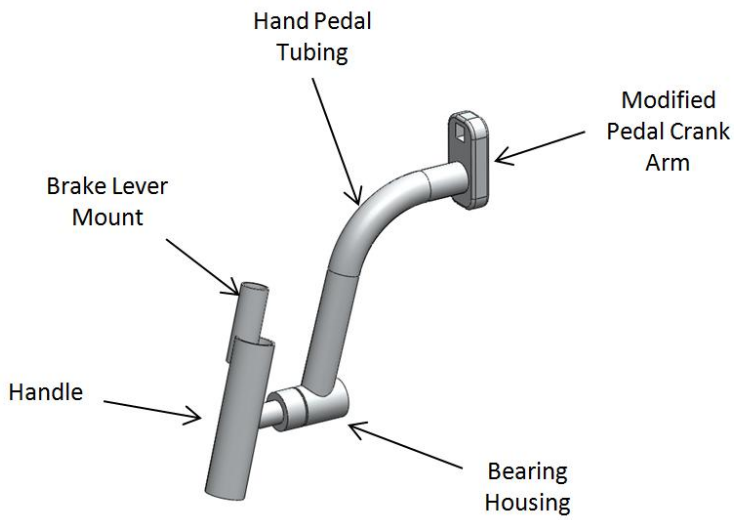


Figure 4-10 Hand Crank Assembly

A simple statics analysis was performed to show that a tubing diameter of 1.0 inches with a wall thickness of 0.065 inches would perform sufficiently without failure or significant deflection.

Seat

Our main goal for the seat was to be lightweight, comfortable, and also sturdy enough to handle the lean steer motion. The seat is roughly based on seat frames for existing lightweight recumbent cycles. Recumbent cycle brands including Greenspeed, Catrike, and ICE Bikes all use metal tubes for the skeleton-shape of the frame. Our seat design has a similar frame shape to the Greenspeed recumbent cycles, except with certain modifications to allow seat steering. The bottom support bars have holes drilled to mount the steering rod to, as shown on Figure 4-11.

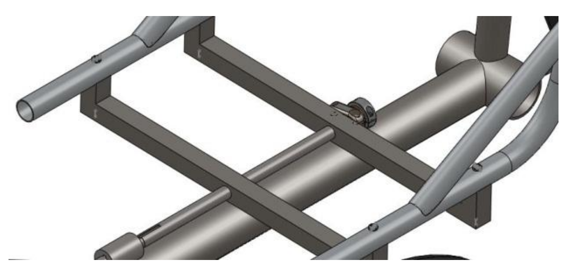


Figure 4-11 Bottom Brackets Attached to Steering Rod

The bottom bracket is welded to the steering rod, which is the only permanent connection to the bike frame itself. A mesh cover is used to wrap around the metal frame, which provides the seat support for the rider. The seat mesh is shown in Figure 4-12.

Figure 4-12 Seat Mesh and Foam on Seat Frame

Another key addition to the seat frame is the spring assistance. Springs will be attached from the seat to the frame to ensure leaning support and return assistance. Based on a static analysis with a 15 degree lean angle and a 160 lb rider, we have determined that a spring constant of 11.9 lbf/in and a spring length of 4 inches. This calculation can be found in Appendix D.

Brakes

We chose to use two front mechanical disc brakes, as shown in Figure 4-13, primarily because they will provide the best stopping power for the tricycle. When stopping any ground vehicle, the majority of the available traction to provide stopping force comes from the front wheel(s). This means that the front wheels should be performing the majority or all of the braking. With this knowledge we have determined that two front disc brakes would be satisfactory, versus the alternative of one rear disc brake or one brake per wheel (due to higher cost). This is also the configuration used by most entry level trikes on the market today.

Figure 4-13 Mechanical Disc Brake

4.3 Material, Geometry and Component Selection

One of our main design objectives for the Quadricycle is to incorporate as many commercially available off the shelf components (COTS) as possible and to avoid custom made parts whenever possible. Using this objective as a guide, our final design incorporates many parts that can be found at any local bicycle repair shop. However, since we are building the Quadricycle from the ground up, many components such as the frame, seat, steering parts, drivetrain mounts, and various other brackets will be fabricated.

Frame

The frame material we chose to use is 4130 chromoly steel. This alloy is a commonly used bicycle and recumbent frame material since it provides adequate stiffness and strength, while maintaining low manufacturing cost. The main manufacturing benefit is that it is easily cut and welded, and requires no post-welding heat treatment. Aluminum was another option for frame material, but because of the difficulty in manufacturing that it introduces as well as its higher initial cost, we determined that chromoly would be a better choice.

Steering

The material we will use for the steering rod and vertical bracket is 304 stainless steel. Stainless steel is an appropriate choice for these components because of its corrosion resistance. They will be unpainted and exposed to the elements, while all other steel components will be painted. Steel is stiff enough to support the seat and transmit the steering torque and forces within the required deflection specifications. Stainless steel rod ends will be used to connect the tie rods to the vertical bracket and the spindles.

The spindles we chose for the Quadricycle are off the shelf components that will require a small modification to be able to function properly with our steering geometry. These spindles were an appropriate choice for several reasons:

- OEM quality part which is easily serviced with off the shelf replacement bushings.
- Includes mounting point for disc brake calipers, saving us valuable manufacturing time.
- Compatible with the wheels we chose (made by the same company) and have the proper centerpoint angle built in.

Drivetrain

There are an extensive amount of components that go into the drive train to allow simultaneous hand and foot motion. For the framework, 4130 chromoly tubing was selected for its relative stiffness, strength, and cost. The tubing selected is 1.75” outer diameter and .049” thickness. For our application, the deflections are acceptable using this size tubing. The top tube is sized at 35” in length. The bottom tube is sized at 20” in length, and the intermediate telescoping tube is sized to be 16” in length when in use and longer when adjusted. All components such as cranksets, bottom brackets, chain, derailleurs, shifters, wheels, and hubs are off the shelf components and can be purchased at any bicycle retailer. The selection of off the shelf components for the drivetrain was weighted on cost effectiveness and durability for our given price range.

Hand Pedals

The hand pedal material chosen was 6061 T-6 aluminum for its high strength to weight ratio and excellent weldability.

Seat

The seat frame material is made of T6-6061 Aluminum. T6-6061 Aluminum is an alloy commonly used for the seat frame material because it is lightweight but provides the proper amount of stiffness and strength for the load exerted on it. The bottom bar support material is 304 stainless steel. Although

heavier, steel is about twice as strong as aluminum. Because of the high bending load in this part, the mounts need to be of greater strength.

The supporting springs we have chosen are 4" Type 302 Stainless Steel, hook end, extension springs. The cycle has two springs attached to the seat, each with a spring constant of 11.29 lbs/in, which supports the distributed weight during lean steering.

Brakes

The brakes we have chosen are dual front disc, Avid model BB5. They will be actuated by a dual pull handle such as the model shown in Figure 4-14. The dual pull handle is required to actuate both brakes with one lever because one hand will need to be free to actuate the shifter. These parts are very good quality replacement bicycle parts, are inexpensive to replace, and can be found at any local bicycle shop.

Figure 4-14 Dual Pull Hand Lever

Wheels

The front wheels we have chosen are 20 inch TerraTrike replacement wheels and tires. Since we are using TerraTrike hubmount replacement spindles, these wheels are an appropriate match. The rear wheel will be a standard 26 inch mountain bike wheel. The 26 inch size provides additional high gear to help attain a higher top speed.

4.4 Cost analysis

Table 2 is a cost summary of the parts and materials that were required to build the Quadricycle, organized by subsystem. A comprehensive list of parts and labor, quantity, and cost is located in Appendix F.

Table 2 Bill of Materials and Cost for the Quadricycle

SUBSYSTEM COST BREAKDOWN	
Drivetrain	$1,117.97
Wheels	$243.60
Brakes	$161.73
Seat	$364.91
Frame	$123.30
Steering Components	$311.25
Fixtures/Material/Labor	$188.53
Shipping	$163.72
TOTAL COST:	**$2,675.01**

The original Quadricycle project budget was $2000. At the conclusion of the design phase a preliminary bill of materials was created and we determined that our design could be manufactured for no less than $2500. The additional cost was primarily due to the DaVinci Tandems® independent drive system. Earlier in the design phase this part was not considered necessary, as the hand and foot motion was to be synchronized.

When manufacturing was well underway the budget required further expansion to $2700 to accommodate deviations from the original design. Some of these were changes to the hand pedal concept, steering system upgrades, new longer cable and housing for the brakes and shifters, modifications to the drivetrain geometry, and various extra hardware parts.

We have taken a conservative approach to choosing replacement bicycle parts; we are specifying parts that are not high end but rather "recreational" level. The reason for this is so that replacements will be inexpensive, if needed. These parts may easily be upgraded to higher quality ones for future Quadricycle versions.

4.5 Safety Considerations

When operating the Quadricycle, a few safety considerations must be taken into account similar to those when riding a two-wheeled bicycle. Listed below are some safety concerns that should be known when riding to maintain one's safety.

- The wheels and tires on the Quadricycle are as sturdy as a normal bike. Take caution when going off of curbs or when encountering other large road obstructions.

- At this time, a sprocket guard has not been placed on the upper crankset. Take caution when braking quickly as the sprocket is located the same level as the rider's face.

- Make sure all idler wheels are tensioned correctly, and make sure all chains are set properly in the idler wheels to ensure chain doesn't slip of fall off of the guided track.

- At this time, a parking brake has not been included. Please take caution when entering into the seat.

- The Quadricycle is not a fixed gear at the driven wheel and therefore can roll backwards down a hill if brakes or torque to the wheels is not applied correctly. Prepare in advance to avoid rolling backwards down a hill.

- For safety reasons, do not take turns at a speed that you are not comfortable taking, and do not ride up hills that have more than a 12% grade.

- Obey all other rules of road as you would on a standard bicycle.

4.6 Maintenance and Repair

The Quadricycle has been designed with the goal of ease of maintenance and repair. Normal preventive maintenance actions are similar to those a typical bicycle and can ideally be performed by the end user or a qualified bicycle repair technician. All of the replacement bicycle parts that have been specified in Table 3, bill of materials, can be purchased through any local bicycle repair shop.

The seat mesh can be found in stores or any online store that carry Greenspeed recumbent cycle parts. There is either the navy blue or yellow 18-hole seat fabric, and either will work for the Quadricycle. The bungee cord is a standard replacement cord for the Greenspeed seat fabric and can be purchased through the same vendor as the mesh.

4.7 Analysis Results

Our final design satisfactorily meets most of our specifications outlined in chapter 3.1, which have been repeated here for convenience. Table 3 shows the technical specifications and our current compliance.

- *The cycle must be powered mainly by hands, specifically in a circular, synchronized, prone pedaling motion; the feet must move in a cycling motion as well and allow for parallel cycle power. We will accomplish this by using a chain drive mechanism that connects the hand crank to the foot crank*.
    - The specification for cycling motion has been met. We have not been able to design the drivetrain such that independent pedaling of the hands and feet is possible.
- *Gears should be similar to a normal bike (21 speeds is one typical configuration; we can have less). Mr. Davis mentioned how, unlike a bicycle rider, a hand cycle rider lacks the ability to use body weight to gain a torque advantage. Therefore a low (under drive) gear is necessary and will be considered in order to climb hills or start moving from an idle position.*
    - We have determined that while using a common size chain ring and cassette, we can achieve our goal of a sufficiently low gear by using approximately a 2:1 reduction in the hand and foot chain rings and sprockets. See Appendix D for the details of this calculation.
- *Ease of assembly and disassembly is very important. Our initial goal is for the cycle to weigh less than 50 lbs for portability and have push button release wheels for quick disassembly. The cycle must have the ability to be taken apart in some capacity, and must fit into a typical vehicle or truck bed.*
    - While the cycle has the ability to be disassembled, the goal of 50 lb weight might not be met due to the required mass of the frame and drivetrain components.

- *Flywheel Concept: As mentioned by the kinesiology team, a flywheel might be useful to include on the foot crank. A flywheel, with the help of hand power, would allow the feet to recover from the pedaling extremities quicker using momentum to keep the rider's feet moving. Although the hand crank should provide enough momentum for the feet when in motion, additional analysis will be needed to see if the flywheel will be helpful.*
    - Currently our design does not incorporate a flywheel device. However, due to the constraint mentioned above, the feet and hands will be synchronized so that maintaining foot momentum with a flywheel device is unnecessary.

To analyze the deflections of the hand and foot boom, a 95th percentile male strength was used based on research from FAA William J. Hughes Technical Center *f.tc.**faa**.gov/**tech**notes/dot_**faa**_ct_05_15.pdf.* Given a maximum hand force of 80 pounds total and a foot force of 100 pounds total, basic statics analysis was completed to determine a worst possible case for deflection in the top and bottom bars. With the selected tubing size of 1.75" outer and 1.65" inner diameter, the deflection on the bottom bar is .0002" and the deflection on the top bar is .125". We feel that these values are acceptable for the purpose of these components. Detailed analysis can be seen in Appendix D.

Table 3 shows an evaluation of some of the technical specifications for the Quadricycle.

Table 3 Evaluation of Technical Specifications

Spec #	Parameter Description	Requirement or Target	Tolerance	Quadricycle design concept	Status
1	Weight	50 lbs	MAX	57	Not met
2	Turning Radius	12 feet	± 2 feet	10	met
3	Ride Height	5 inches	+ 3 inches	6 inches	met
4	# of Wheels	3 wheels	EXACT	3	met
5	Cycle Width	25 inches	MAX	32	Not met

Chapter 5 Product Realization

The Quadricycle prototype was built between June and December 2010. The subsystems: frame, seat, drivetrain, brakes, wheels, and steering were constructed or assembled independently as all team members were in different locations over the summer. During the fall quarter, the completed subsystems were assembled. The following sections describe the techniques and

Figure 4-15 Frame tube notching tool

processes that were used for the manufacture of each subsystem, as well as the changes that were made to the original design.

5.1 Manufacturing Process

Frame

After all of the raw materials for the frame were acquired, the tubes that make up the frame assembly were cut to length and notched to the correct angle using hole-saws and a tubing notcher shown in Figure 4-15. In this figure, the tube is securely mounted in the vise, while the holesaw makes a mitered cut.

Various other small parts, such as the wheel mounts, were cut, shaped, and drilled by hand using various tools such as a grinder, band saw, and drill press.

In order to properly align all of the tubes during the welding process, a simple frame jig was designed, shown in Figure 5-1, that would maintain the front and rear wheel alignment during tube welding. The jig platform is a sheet of medium density fiberboard (MDF) which was chosen because of its flatness. The vertical posts that hold the wheels mounts securely are construction strut commonly used to mount fluid piping and electrical conduit. Because of its modular nature and the ability to be adjusted easily to a wide range of positions, this material was a good choice for our jig.

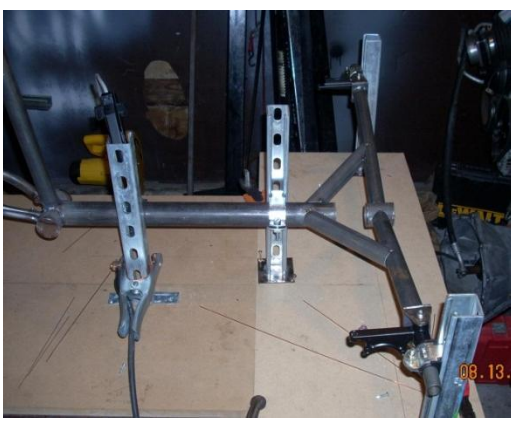


Figure 5-1 Frame Jig

The rear portion of the frame that secures the rear wheel (stay) was taken from a salvaged mountain bike, as mentioned earlier. The mountain bike stay required very little modification in order to conform to our design geometry. These modifications were made using common hand tools.

With the frame tubes held securely in the jig, each joint was tack welded (Figure 5-2), and the alignment was checked one final time. The welding process used to join all of the tubes in the frame was Gas Tungsten Arc Welding (GTAW), also commonly referred to as Tungsten Inert Gas (TIG) welding. TIG welding is the preferred welding process for joining Chromoly alloy tubes and provides sufficient strength for our application.

Figure 5-2 The Frame tubes tack weld.

When all of the joint welds were complete, the frame assembly was removed from the jig and the steering parts, wheels, and tires were installed in order to verify correct alignment. Figure 5-3 shows the Quadricycle "rolling assembly" just following welding of the frame.

Figure 5-3 Quadricycle rolling assembly.

Steering

The steering system manufacturing process began by cutting the steer-rod to length. The steer rod is a 2 piece length of ½ inch type 304 stainless steel solid bar. The front section and rear section are connected by a shaft coupler using a square keyway shown in Figure 5-4.

Figure 5-4 The finished steer rod. (Left) rear section welded to the seat frame.
(Right) front section welded to the vertical bracket that transmits steering force to the wheels via the tie rods.

The 1/8" square key-way was machined into the shaft to accommodate the coupler using a vertical milling machine. The vertical steer bracket was cut from a 1/8" thick sheet of type 304 stainless steel using a plasma cutter and holes were drilled with a drill press. The vertical bracket was then welded to the steer rod and the coupler was installed. Finally, the seat frame was fitted onto the rod, properly aligned, and welded in place.

The shaft is mounted to the frame by three steel mounts shown in Figure 5-. These mounts were made by fabricating three "bases" from ½ inch thick steel plate and welding a steel shaft collar to them.

Figure 5-6 steer rod assembled with coupler

Figure 5-7 Steer shaft mounts are composed of a steel collar welded to a "base" which is welded to the frame tube.

The spindles that transfer the steering action from the tie rods to the wheels were Terratrike® replacement parts and only required a small modification to account for Ackerman compensation as described in section 4.2. Figure 5-5 shows one of the spindles with the tie rod mount welded in place providing the necessary steering geometry.

Figure 5-5 Modified TerraTrike® spindle with the tie rod attached to the new tab

The next piece of the steering system to be manufactured was the tie rods. The tie rods were made by cutting a 5/16 inch stainless steel bar to length and welding a threaded stainless steel rod onto each end (Figure 5-6). Next, a rod-end was installed at each end of the tie rods and locked in place by nuts.

Figure 5-6 Finished tie rod assembly.

Finally, a seat stopping bracket was added to the frame to adjust and limit the maximum steer angle. This part consists of a small bracket and a bolt with two nuts that stop the seat frame from moving when the travel limit is reached, as seen in Figure 5-7. The bolt can be adjusted to give different maximum steer angles.

Figure 5-7 Seat stopper

Seat

The seat fabrication was performed by Tom Hauth during the months of June to September 2010. The seat frame was made from 7/8 inch T6-6061 Aluminum round tubing. The tubing was cut to length and then welded together as shown on the part drawing #400A. See Figure 5-9 for seat frame welding.

Figure 5-8 Complete seat frame assembly.

Figure 5-9 Seat Frame Final Welding

After welding the seat together, 1/4" holes were drilled at the four points shown on drawing #401. These four holes are for the screws that join the bottom brackets to the seat frame. To keep these screws from shearing the seat frame, aluminum plugs were made to slide into the seat frame. The aluminum plugs were sized at a diameter of 0.745 inches to fit inside the seat frame tubing. Once sized, these four plugs were slid into the seat frame and a hole was drilled through. This is done one at a time to easily align the plug hole with the seat frame hole. Once each plug hole was drilled and tapped with ¼-20 UNC threads, it was imperative to use a zip tie to keep these aligned. This process was repeated until all four plugs were completed.

The next step was to manufacture the bottom brackets. The bottom brackets were made of ¾" 304 stainless steel square tubing. The tubes were cut to length and welded together. After, two holes were drilled in each bracket, as shown on drawing #404, for the connecting screws to go through. Next, a ½" hole was drilled through the middle of each bottom bracket for the steering rod to go through.

Once both brackets were completed, the next step was to join the seat frame and bottom brackets together. This was carefully done by removing the zip ties from the seat frame, but ensuring that the screw was placed before the plugs could move. After the screws were in place, the seat was finished. See Figure 5-12 for the complete seat assembly.

After the seat was assembled, it was aligned with the steering rod on the frame. The steering rod was fed through the bottom bracket holes and the rod was welded in place.

After the seat was aligned with the frame, the seat mesh and foam were assembled onto the seat frame. The seat mesh didn't fit well with the custom design, so folds had to be made at the bending points of the seat to get the smoothest surface. Figure 5-10 shows the wrinkles that occur and the fold that is necessary for a smoother surface.

Figure 5-10: Folds in mesh.

Figure 5-11: Extra foam on top

The foam lies between the mesh and the frame. Starting from the bottom of the seat, the edge of the foam and the edge of the seat mesh were lined up with the edge of the seat frame bars. The bungee cord was strung in a criss-cross formation through the mesh holes which tightened the seat mesh and foam around the seat frame to create a sturdy surface to sit on. Once the mesh was tightened around the seat frame, the extra foam protruded from the top of the seat as shown in Figure 5-11.

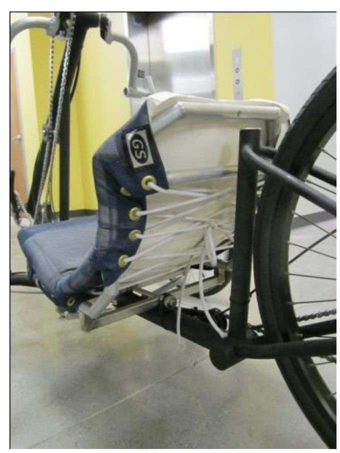


Figure 5-12 Bungee Cord Formation

The excess foam coming from the top was trimmed to the edge of the seat mesh. After the seat foam was cleanly fitted and trimmed, and the bungee cord was tightened all the way, the seat was complete. Figure 5-15 shows how the bungee cord is strung through and the foam trimmed to length.

Drivetrain

The main components of the drive train were constructed over the summer at teammate Parker Drennan's residence in Illinois. These components consisted of the three 1.75" x .059" thickness 4130 tubes, two bottom bracket shells, a front shifter mount, and a shell for the DaVinci drive system.

The initial tubes were cut to lengths specified by SolidWorks modeling. Our team accurately drew the bike in SolidWorks how we had it originally designed, and then fit a human model to determine lengths and angles. We left the lengths of the tube longer than expected to make room for error, if any.

To cut the tubes, a portable band saw and a vise was used for an adequate cutting accuracy. To notch the tubes, a drill press and a vise was used. The drill press was fit with a 1.75" drill bit to drill out notches for the bottom bracket shells, and the press was fit with a 1.5" drill bit to drill out the hole for the DaVinci drive system shell.

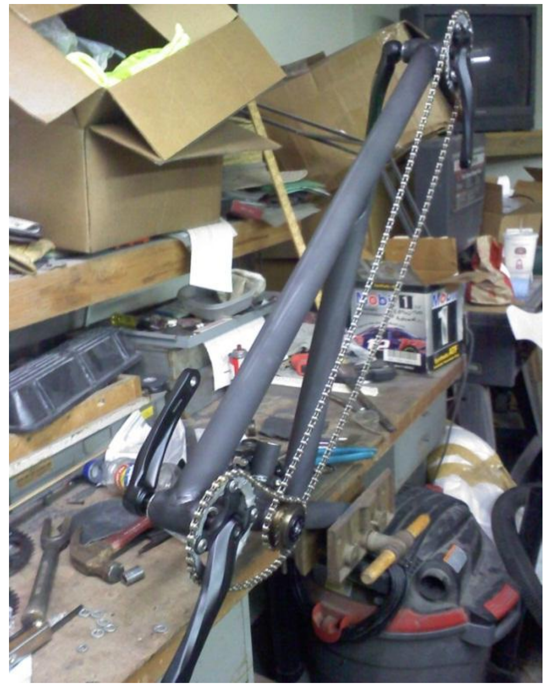


Figure 5-13 Preliminary Fabrication and Assembly in Illinois.

The bottom tube was cut to 25" in length. The bottom tube was then notched on one side for the foot bottom bracket shell. The other end of the tube was left flat to match up to the frame. The 1.5" hole was then drilled for the DaVinci drive system shell. The foot bottom bracket and DaVinci shells were then welded into the bottom tube permanently. The top tube connecting the two bottom brackets was then cut to a length of 35". The top tube was then notched on both sides and the bottom bracket shell for the hand was welded in. The top tube was then welded to the bottom bracket shell for the feet. An intermediate tube was notched and welded in between the two tubes for added support. The shells holding the actual bottom brackets were then welded into the prefit 1.75" diameter tubes on the drivetrain frame. These shells were aligned properly to assure each would align with a certain gear on the DaVinci Drivetrain system.

Figure 5-14: Idler arms added for tension in the two chain lengths.

Components were then installed into the drivetrain frame. First the two bottom brackets were installed with the cranksets. The cranksets had to be modified by removing two of the chain rings (the largest and the smallest) from each crankset and spacers added to provide proper alignment. The DaVinci system was then installed and chain was added to correct lengths.   A picture of the preliminary fabrication and assembly is shown in Figure 5-13.

There are a few things to note at the conclusion of preliminary stages of fabrication in Illinois. First, the chains on the hand and foot cranks were initially too loose. Idler wheels were necessary to ensure the chain did not slip when pedaling. Second, with the proposed drive configuration, the cranksets are installed backwards. Thread locking compound is required to ensure the crankset bolts don't loosen during operation.

The drivetrain was then shipped to Millbrae, CA where Kevin and Parker welded the frame and drivetrain pieces together. The drivetrain was welded to the frame at an angle of 20 degrees.

During fall quarter, our team continually met with our sponsor to resize the geometry of the drivetrain. Several trial and error attempts were made to ensure the proper fit for our client. The main concerns were the length from the seat to the foot pedals and the length from our client's shoulders to the hand pedals. Proper knee to hand pedal clearance had to be maintained as well.

The final geometry after sizing was complete includes an 18.5" bottom tube, 30.5" top tube, and a 30 degree angle from the frame. The intermediate tube was removed and a smaller 1.25" x .065" thickness tube was installed. For all other measurements, see Appendix C for detailed drawings.

Idler pulleys were also installed along the length of the bike to provide tension and alignment for the large length of chain that transmits power from the DaVinci mechanism to the drive wheel. This can also be seen in Figure 5-14.

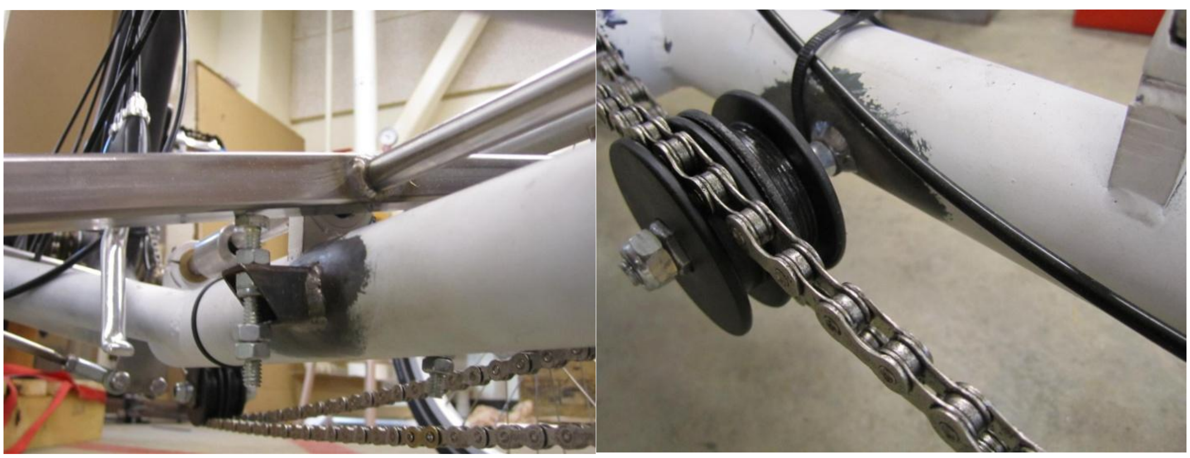


Figure 5-15: Idler wheel guides attached along the length of bike provide tension and alignment for the chain passing from the DaVinci System to the rear drive wheel.

The hand pedals were made from 6061 T6 aluminum bar stock and tubing and use existing foot pedal cranks to connect to the hand pedal "bottom bracket". The process of manufacturing these pedals

began by bending two pieces of 1 inch aluminum tube on a 3 inch radius to approximately a 105 degree angle, which was performed by Gentry Welding and Fabrication of San Luis Obispo. Next, the parts used to house the bearings and mount the handles were machined on a manual lathe, and the handles were cut to length from 1.25 inch aluminum tubing. After all of the individual components were fabricated and prepared, all of the parts were welded together by Kevin Williams of the Cal Poly IME department. Finally, the bearings were installed and a retaining mechanism using set screws was utilized to keep the bearings in place. Figure 5-16 shows the hand pedals before and after final assembly. The installed hand pedals can be seen in Figure 5-17.

Figure 5-21 shows the completed Quadricycle as of December 2, 2010.

Figure 5-16 Hand Pedals Before and After Final Assembly

Figure 5-17 Hand pedals installed onto frame

Figure 5-18: Final assembly as presented at the senior design expo on December 2, 2010.

5.2 Deviation from original Design

During the manufacturing and testing process, we discovered several features of the Quadricycle that required a design change. The deviations from the original design were required because the strength or quality of the part was inadequate, the part was difficult or impossible to manufacture with the available resources, or the part failed to meet the design requirements.

Steering

Several modifications were made to the original steering system design described in section 4.2. The original design was a single piece shaft mounted with three bushings. The original method for attaching the vertical bracket was to pin the bracket through a hole drilled in the shaft and secure the assembly with a ½ inch nut. This method, shown on the left in Figure 5-19, failed to provide smooth operation and failed shortly after its initial test. To correct this deficiency, the bracket was welded to the shaft and the split shaft design using a shaft coupler was employed to facilitate bushing replacement. This revised design has proven to provide acceptable results.

Figure 5-19: Original steer rod design (left) failed quickly after its initial test. The re-designed steer rod is shown on the right.

Figure 5-20 Shaft collar with bushing installed. Note the gap between the upper and lower halves of the collar.

The seat steer rod bushing support mounts were originally designed to be machined out of a single piece of steel plate. Due to the lack of machine shop resources during the time that manufacturing occurred over the summer, a new design was implemented that was more appropriate for the available tools. The new design (Figure 5-23) uses a shaft collar that has a 5/8 inch bore similar to the outside diameter of the bushing. The drawback to this design is that the collars cannot be tightened fully without crushing the bearing. This is due to the inherent design of the shaft collar, the purpose of which is to lock into a shaft. The solution to this problem requires a thread locking compound to be used when the steering system is assembled to prevent the bolts from loosening.

Seat

When our client tested the seat, it was very upright and uncomfortable. This was due to the lack of angle on the bottom of the seat. In order to create an angle on the bottom of the seat, as well as more support for the upper part of the legs, a ramp was made to insert on the bottom of the seat. This created more of an angle on the bottom as well as extended the support on the bottom by about 4 inches forward. The ramp was made out of polyurethane foam, which is a common foam material that surfboards are made from. Polyurethane foam is a lightweight, stiff foam material that can be easily shaped. The ramp was sanded to a ramp shape and small leg grooves were sanded down to add comfort. To complete the seat, the seat foam and the seat mesh were assembled onto the seat frame and over the seat ramp to complete the seat. The seat ramp is shown in Figure 5-21.

Figure 5-21: Seat Ramp Installation

Figure 5-22: Additional thin seat foam.

The addition of the ramp created a hard surface for the rider to sit on. Softer and lighter foam was added to the bottom of the seat to create a softer cushion on the bottom. This relieved some of the pressure on the flat board of the ramp. Figure 5-22 shows the additional thin foam placed on the bottom of the seat ramp for increased comfort.

The top horizontal bar across the seat created a pressure point on the spine, and prevented the rider from leaning back to a comfortable position. To fix this we repositioned the top bar at a slight angle. We cut and re-welded the top bar so that it gave more room to lean back. The difference between the original and fixed top bar can be seen in Figure 5-23.

Figure 5-23: Top bar modification

Drivetrain

The drivetrain differs greatly from the original final design in May. The biggest factor was cost. It was costly to have an adjustable drivetrain that could also be independently powered by hands and feet. For this senior project, the adjustability of the drivetrain was determined to be more costly and harder to fabricate, so this feature of the design was eliminated. This eliminated the telescoping tubes, linear bearing, pinned joints, angle bracket, and any locking mechanisms needed that would have been required for a fully adjustable drivetrain.

Figure 5-24: (Left) Original design concept. (Right) Final design concept without full assembly.

5.3 Manufacturing Recommendations

Frame

One lesson learned from the frame manufacturing process was that considerable welding time and skill was required to complete some of the welded joints. Future modifications of the Quadricycle frame design should focus on methods to reduce the difficulty and quantity of the welds. This would save cost in manufacturing as the fabricator could complete the frame assembly in less time.

Steering

The seat steer rod bushing support mounts should be manufactured as originally designed. As mentioned above, current design is not ideal but was chosen for convenience and ease of manufacturing over the summer.

Seat

To avoid the ramp addition, the seat could be improved by extending and angling the bottom bars. The change to the top bar of the seat frame helped a lot and would be best if all seats were manufactured with the bent back bar. To add comfort, the seat could be about 2 inches wider. As the seat is now, the rider is sitting on top of the side bars, which causes the rider to sit more towards the front than anticipated.

If the seat was made wider, the width of the mesh would have to be considered. The mesh used worked perfectly to cover the sides, but it would've been better to wrap all the way around. Because of the custom bends in the seat, it would be recommended to cut and sew the mesh to look more aesthetically cleaner.

The foam used was good because it was dense and gave padding over the aluminum bars, however additional padding would be better for the bottom of the seat. Since the foam is so dense, it is still stiff on the bottom. More spongy foam for just the bottom of the seat is necessary for additional comfort.

Chapter 6 Design Verification (Testing)

Our DFMEA (Design Failure Mode Effects Analysis) and DVP&R (Design Verification Plan and Report) are tools used by product design industry to ensure that one's products meet the requirements and specifications of the consumer and guarantee that the final product will not break or fail in any way. The DFMEA shown in Figure 6-1 describes many ways in which our design can fail as well as quantifying the severity of the failure. By proactively identifying these failure modes, we have designed the cycle to prevent them from occurring.

Design Failure Mode and Effects Analysis

Date: 5/16/10 Project: The Quadricycle

Team: Tetra Source

Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s)/Mechanism(s) of Failure	Occur	Current Controls Prevention	Current Controls Detection	Detec	RPN	Recommended Actions
Drives Wheels	Chain Breaks	Leg Harm, No Movement	8	Too much tension in chain/ too much slack in chain causing lash/Wear	1	Tension to specifications/Check life rating.	Regularly Inspect slack in chain	1	8	Replace chain/Give slack recommendation for user
	Derailer(s) Breaks/Slips	No Movement, No Gear Change	6	Not Aligned Properly/Wear	4	Check alignment/Life Ratng	Inspect alignment/Check for cracks	1	24	Adjust alignment/Replace derailer
	Too Much Effort Required	No Movement	6	Not Geared Right/Derailer System Fail	5	Above and Calculations/Testing	Above and Strength Testing	3	90	Adjust gear ratios?/Replace derailer
	Derailer Cable/Control Fails	No Movement, No Gear Change	7	Too much tension on cable/Wear	1	Check tension/Life	Check Tension, Wear	1	7	Tighten/Loosen cable… Replace cable
Stops Bike	Caliper Fails	Bodily Injury, No Stopping Power	9	Pad Wear/Environment/Caliper Wear	3	Pad life/Caliper life/Weather Conditions	Inspection	4	108	Replace Pads/Replace or fix caliper/Find better pads for weather or recommend not using in rain, etc.
	Too Much Effort Required	Injury, Not enough stopping power	6	Not setup correctly	5	Check tension/Caliper placement	Inspection	3	90	Adjust tension/Align caliper correctly
	Brake Cable Fails	Injury, No Stopping power	8	Not enough/Too much tension, Wear	2	Check tension/Wear	Inspection	1	16	Adjust tension/Replace cable.
Steers Bike	Steering Misaligned	No Steering, Injury	6	Ackerman Steering Not Correct/Steering Angles not accurate	2	Check angles and measure with	Inspection/Self test handling	5	60	Adjust tie rods, fix triangle, re-adjust steering angles.
	Bump Steer	Wobbling, Injury	8	Steering angles not accurate	2	Check angles and	Inspection/Self test	5	80	Re-adjust steering angles.
	Large Turn Radius	Difficult Handling	6	Ackerman Steering Not Correct/Steering Angles not accurate	2	Check angles and measure	Inspection/Self test handling	5	60	Adjust tie rods, fix triangle, re-adjust steering angles.
Rides Comfortably	Uncomfortable Seat	Uncomfortable	3	Pushes against back/shoulders, sharp corners	10	Self-test seat	Self-test	1	30	Avoid sharp corners, add foam padding, rebuild seat completely
	Stear Wobble	Uncontrollable stearing and potential injury	5	Unstable vehicle dynamics, bad tires	8	Test, check calculations, re-test, rebuild	Testing for stability	3	120	Check dynamic calculations, rebuild, retest
	Gears Slipping	Possible injury	4	Gears misaligned	8	Check alignment	Test for alignment	1	32	Make sure all gears are properly aligned within a given tolerance
Travels Quietly	Bearings Fail	Difficult to power, noisy	5	Inadequate lubrication, not properly specified	1	Careful install and lubrication, check life rating	Field testing	6	30	Check life rating for bearings, replace, install and lubricate properly
	Gears Misaligned	Difficult to power, noisy	3		8	Check alignment	Self inspection	4	96	Make sure all geras are properly aligned within a given tolerance
	Tires Rubbing	Noisy, premature tire/brake failure	5	Brakes misaligned, incorrect tire size	6	Check brake alignment, self inspect	Inspection, test prototype	5	150	Re-install brakes correctly or adjust to fit, replace with smaller/thinner tires

Figure 6-1 Design Failure Mode and Effects Analysis

Testing of the Quadricycle is broken into several parts. These parts include drive train, steering, braking, comfort, and noise reduction. Testing was performed throughout the fall quarter in parallel with the final stages of manufacturing and assembly. All of the testing was conducted on the Cal Poly campus. The following is a brief summary of all tests that were performed on the Quadricycle to ensure safety and function. The detailed DVP&R can be seen in Appendix E.

- The chain, derailleur, and brake line tension tests make sure these components have the perfect amount of tension. Too much tension will cause the components to work improperly. All function in any of the parts would be lost if there is too little tension in the lines.

- The derailleur test ensures the Quadricycle will not suddenly slip to unwanted gears, which can cause pain in the arms and legs. If properly installed, the derailleur should shift smoothly without problems.

- The Quadricycle must never require more than fifty pounds of force to drive. Using the gear ratio test, the cycle's higher gear ratios were tested to guarantee this force requirement is met.

- The brake squeeze test allows our team to analyze the force required to brake the Quadricycle. Adjustments were made to the brakes after initial installation and as of the final testing, function acceptably. The brakes will also be tested to confirm that the Quadricycle can stop at a fixed distance for a given speed.

- A Steering test was performed to ensure steering angles were designed correctly, and also to make sure that things like 'bump steer' do not occur.

- All other part performance, such as chain guides, were tested by several ride sessions performed throughout the quarter.

- Excessive noise in the Quadricycle can be annoying. The cycle was ridden in the early assembly stage to determine any causes of excess noise. Figure 6-2, shows team member, Spencer Nelson riding the Quadricycle during an initial test.

Figure 6-2: Ride testing the Quadricycle

- The user should feel comfortable when riding the Quadricycle for extended periods of time. The seat test ensured that the seat comfort is adequate for long periods of use.
- The drivetrain geometry must be fitted to our client's specific needs to ensure that the risk of injury or fatigue is minimized. Figure 6-3 is a picture of measurements taken to determine optimum geometry.

Figure 6-3: Resizing the drivetrain geometry to fit to client's needs.

Test Results

All testing met criteria specified in the DVP&R except the seat, noise, and the steer triangle. At first the seat was completely unacceptable. Wedges were inserted into the bottom of the seat to provide incline and the top back bar was moved further back to provide a slight recline. These adjustments made the seat okay to ride for longer periods of time.

The noise is a problem that is unfortunately unavoidable with the components selected. With a larger budget, plastic idler wheels would have been avoided, and less noisy wheels with teeth would have been selected instead.

The steer vertical bracket also failed during the first stages of testing. This was because of a misalignment between the bracket, tie rods, and wheels. This problem was fixed, and the steer vertical bracket did not fail later testing.

Figure 6-4: Scott Davis ride testing the finished design.

Chapter 7 Conclusion and Recommendations

Throughout the design and manufacturing process, we have identified several areas of the Quadricycle that could be improved if future versions are produced. While we feel that the finished Quadricycle prototype is fully functional, several features that were included in the original design were not implemented, either due to time or budget restrictions. If the Quadricycle design is to be improved or a second prototype is to be built, we make the following recommendations organized by subsystem.

Frame:

The frame geometry satisfactorily meets the given design requirements for wheelbase and track width. The frame also has proven to perform well in ride quality and handling tests, which are subjective in nature. During these tests we have observed, however, that the stiffness of the rear wheel mount (wheel stay) could be improved. A thorough analysis of the expected cornering loads is required to determine the optimum tubing dimensions.

One major technical specification for the Quadricycle that we failed to meet was the weight requirement of 50 lbs. Since the frame/drivetrain assembly is the single heaviest part of the cycle, it makes sense to analyze it to find areas for weight savings. The material thickness chosen for the frame was based on similar recumbent bike frame tubing dimensions. Using modern stress analysis tools and worst case expected loading, the tubing sizes for a future Quadricycle frame could be optimized, which could lower the overall weight of the frame.

Steering

Overall, the performance of the steering system meets the basic requirements for turn radius, and lean angle. One unanticipated problem with the steering is the presence of backlash due to the coupler between the front and rear steer shafts. This coupler is necessary for our design to facilitate replacement of the bushings that support the shaft. We have found during our tests that the backlash can be minimized if a locking compound is used when installing the setscrew on the coupler, however an ideal future steering design should attempt to minimize or eliminate the backlash completely. This could be accomplished if a single piece steer shaft were used.

Seat

The seat meets the given design requirements for the seat steering concept. The design allows free side to side leaning movement and stays clear from any arm circling motion. Although it meets the compact design requirement, one major complication was the support for the upper thigh area. The addition of the foam ramp was sufficient; however, it added more stiffness to the seat than necessary. The seat foam is very dense, which acts as a support surface for the seat, but doesn't help the bottom where there is the most force. Taking this into consideration, a layer of softer foam was added to the bottom, which all together made the seat heavier than desired.

For future designs, modifying the seat frame to have an angled bottom and extending the front further forward would increase the comfort and leg support. It is recommended that the seat foam is kept as dense as the existing foam because softer foam may not give as much support for the rest of the body. However, softer foam can be added on the bottom for more comfort. Another design issue to consider is the width of the seat frame. For a more general public, a width of about 16 inches would be better to account for various sizes of people. The largest single issue is the ease of ingress / egress to the cycle. During our testing phase, we observed that having an open space on the sides of the seat and allowing the seat to lean made it easier for our client. In earlier design concepts, we considered putting retractable arm rests to help our client lift himself from the seat. We also considered locking the seat in place so that it would be a stable support. These should still be considered in future designs to help resolve this issue.

Overall, the design of the seat worked well for our design concept. The ramp additions and foam additions were necessary and improved the riding experience for our client.

Drivetrain

As mentioned above, the largest single issue is the ease of ingress / egress to the cycle. During our testing phase, we observed that our customer has difficulty getting positioned in the cycle and requires assistance to get out. The early design concept for the front drivetrain tubes was to use pin jointed, telescoping tubes so that the hand pedals could be moved out of the way. Future Quadricycle design could implement this telescoping tube idea.

The sprocket guard for the upper chain ring is currently not present. Without this, the user could easily stop abruptly and injure his/her face. A simple chain guard made for professionally built hand and foot cycles should work properly.

At the conclusion of this project, the front derailleur is non-existent. The installation and alignment of the derailleur was not possible due to a lack of clearance and the angle of the drivetrain from the frame. Although the rider cannot shift the front chainring between gears, we have found that there is adequate gearing through the rear wheel to provide enough power or speed for now.

During the testing phase, one main weak area was noticed with the hand pedal design. A moment load is placed on the bearings, which may cause excessive wear over time of the aluminum parts resulting in excessive play in the handle joint. As of this time we have no suggestion as to how to improve this design or eliminate the problem.

References

Fundamentals of Ground Vehicle Dynamics [Book] / auth. Gillespie Thomas D.. - Warrendale : Society of Automotive Engineers, 1992.

Hand & Foot Powered Cycle Design Report, Life Element Designs [Report] : Senior Project Final Report / auth. Alex Arsene Edwin Diego, Nathaniel Hague , Denver Schaffarzick. - 2009.

handcycle & recumbent bike & tricycle [Online] / auth. BerkelBike BV. - 2008. - January 23, 2010. - http://www.berkelbike.com/.

Invacare Product Catalog – Top End Force R Handcycle [Online] / auth. Invacare. - 2010. - January 23, 2010.

Shigley's Mechanical Engineering Design, Eighth Edition [Book] / auth. Budynas Richard G. and Nisbett J. Kieth. - New York : McGraw Hill, 2008.

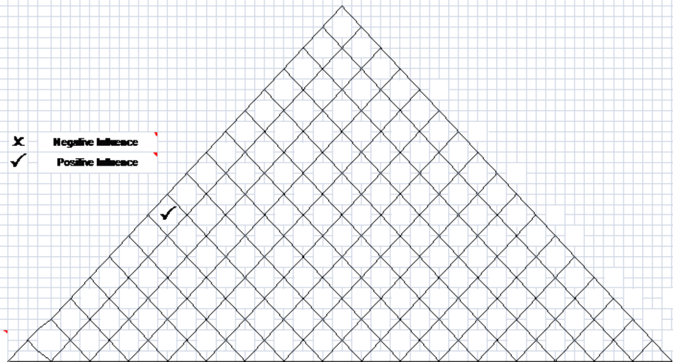
The McLean all body workout trike|Inventor of the McLean Wheel Monocycl [Online] / auth. McLean Kerry. - 2009. - February 17, 2010. - http://www.mcleanmonocycle.com/Kerry_McLeans_Machines/ABW_Trike.html.

Varna Innovation and Research - Superior Handcycles [Online] / auth. Varna Innovation and Research Corporation. - 2008. - January 23, 2010. - http://www.varnahandcycles.com/.

Appendices

Appendix A: QFD "House of Quality"

✗ Negative Influence
✓ Positive Influence



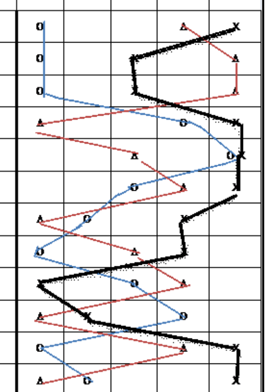
Customer Description
1 = Scott Davis
2 =

Relative Importance or Weight

Engineering Metrics or Requirements

Customer Attributes, Needs, Requirements, or Demanded Quality		Must weigh less than 50 lbs	Length from front to back tire	Frame must be within 1-2 in/ft from the floor	Angle of Seat Position	Turn Radius must be within 16-18 ft	Material must withstand stress/torsion	Shocks must have a stiffness	Braking system - brake force	Wheel Diameter	Number of Wheels	Width of cycle	Camber	Cost - $2000 limit					
Light Weight	9	9	3							3	9	3		9					
Portable	7	9	9							3	3	9							
Storable	8	9	9		1					3	3	9							
Durable - Road Use, Occasional Curbs	7	1					9	9		1			1	3					
Safe	10		3	3	1	3	9	3	3	1	1	3							
Comfortable	8		3	3	9			9				3							
Comparable Power Transmission to Regular Bicycle	8	3				3			9	3			3						
Independently usable (compatible for people with disabilities)	10	3		9	9									3					
Cost Effectiveness	5	3	3	3			9	3	3		9	3	9	9					
Repairable (off the shelf)	7						9	9	9		9		9						
circular, synchronized, prone pedaling motion	7				9	3			3				3						
Aesthetics	5		3		3		9				3		3	1					
Direction of Improvement																			
Measurement Units		Pounds	Inches	Inches	Inches	Radians/Degrees	Pounds per Square Inch	Measurement Unit # 7	Pounds	Inches	#	Inches	Degrees	Dollars					
Total		292	246	159	258	75	306	243	201	113	259	231	175	182					
Percentage		11.6%	9.0%	5.8%	9.4%	2.7%	11.1%	8.9%	7.3%	4.1%	9.4%	8.4%	6.3%	6.6%					
Delighted or Ideal Target Specification Values																			
Disgusted or Marginal Target Specification Values																			
Technical Importance																			

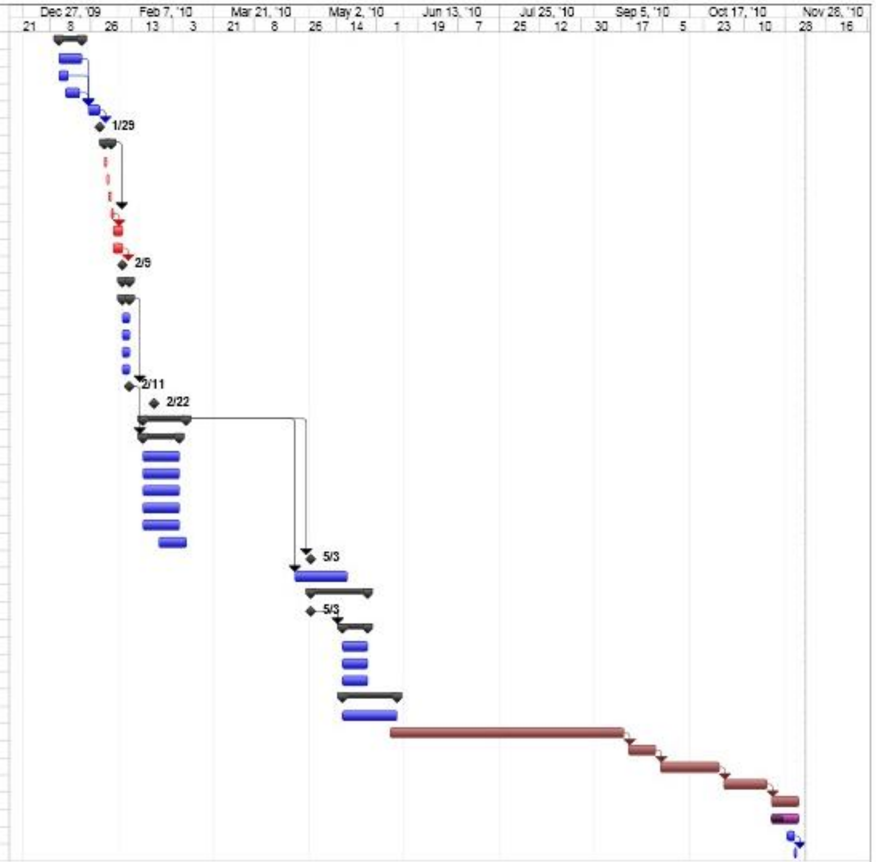
O Life Element Designs
X Top End Force R
Δ Berkel



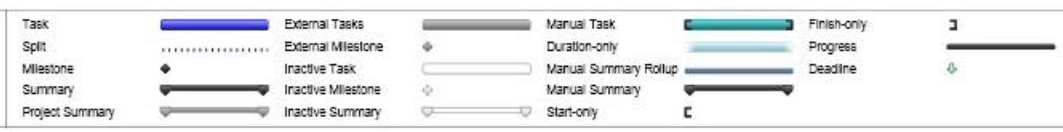
QFD "House of Quality" for the TetraSource Quadricycle

Appendix B: Project Timeline

ID	Task Name	Duration	Start	Finish	Predecessors
1	**Hand and Foot Cycle Assignment**	**8 days**	**Tue 1/12/10**	**Thu 1/21/10**	
2	Background Research/Scope	8 days	Tue 1/12/10	Thu 1/21/10	
3	Needs and Specification Analysis	4 days	Tue 1/12/10	Fri 1/15/10	
4	Quality Function Deployment Assessment	4 days	Fri 1/15/10	Wed 1/20/10	
5	Proposal Preparation	5 days	Mon 1/25/10	Fri 1/29/10	4,3,2
6	Present Proposal to Sponsor	0 days	Fri 1/29/10	Fri 1/29/10	5
7	**Idea Generation**	**3 days**	**Mon 2/1/10**	**Wed 2/3/10**	
8	Morphological Attribute List	1 day	Mon 2/1/10	Mon 2/1/10	
9	List of Alternative Actions	1 day	Tue 2/2/10	Tue 2/2/10	
10	Scamper Method	1 day	Wed 2/3/10	Wed 2/3/10	
11	Feasability Analysis	1 day	Thu 2/4/10	Thu 2/4/10	7
12	Review Design Concepts	2 days	Fri 2/5/10	Mon 2/8/10	11
13	Formulate Design Decision Matrices	2 days	Fri 2/5/10	Mon 2/8/10	
14	Concept Review Presentation	0 days	Tue 2/9/10	Tue 2/9/10	13
15	**Concept Design Report Preparation**	**3 days**	**Tue 2/9/10**	**Thu 2/11/10**	
16	**1st Order Analysis**	**3 days**	**Tue 2/9/10**	**Thu 2/11/10**	
17	Modeling	3 days	Tue 2/9/10	Thu 2/11/10	
18	Materials	3 days	Tue 2/9/10	Thu 2/11/10	
19	Manufacturing	3 days	Tue 2/9/10	Thu 2/11/10	
20	Serviceability	3 days	Tue 2/9/10	Thu 2/11/10	
21	Finalize Initial Concept Design	0 days	Thu 2/11/10	Thu 2/11/10	16
22	Concept Design Report Due	0 days	Mon 2/22/10	Mon 2/22/10	
23	**Technical Presentation Preparation**	**13 days?**	**Thu 2/18/10**	**Mon 3/8/10**	
24	**2nd Order Analysis**	**12 days**	**Thu 2/18/10**	**Fri 3/5/10**	21
25	FEA	12 days	Thu 2/18/10	Fri 3/5/10	
26	CAD	12 days	Thu 2/18/10	Fri 3/5/10	
27	2D Detail Drawings	12 days	Thu 2/18/10	Fri 3/5/10	
28	Sources/Manufacturer Costs	12 days	Thu 2/18/10	Fri 3/5/10	
29	Manufacturing Plan (Production Order)	12 days	Thu 2/18/10	Fri 3/5/10	
30	Create PowerPoint for Presentation	8 days?	Thu 2/25/10	Mon 3/8/10	
31	Critical Design Review	0 days	Mon 5/3/10	Mon 5/3/10	23
32	Design Report Draft	17 days?	Mon 4/26/10	Tue 5/18/10	23
33	**Procurement**	**19 days**	**Mon 5/3/10**	**Thu 5/27/10**	
34	Approval for Funding	0 days	Mon 5/3/10	Mon 5/3/10	
35	**Order Parts**	**9 days**	**Mon 5/17/10**	**Thu 5/27/10**	34
36	Long Lead Parts	9 days	Mon 5/17/10	Thu 5/27/10	
37	Critical Parts	9 days	Mon 5/17/10	Thu 5/27/10	
38	1st Parts	9 days	Mon 5/17/10	Thu 5/27/10	
39	**Design**	**18 days**	**Mon 5/17/10**	**Wed 6/9/10**	
40	Look at "extras"	18 days	Mon 5/17/10	Wed 6/9/10	
41	Manufacturing	75 days	Mon 6/7/10	Fri 9/17/10	
42	Testing	10 days	Mon 9/20/10	Fri 10/1/10	41
43	Refinement	20 days	Mon 10/4/10	Fri 10/29/10	42
44	Second Round of Prototype Testing	15 days	Mon 11/1/10	Fri 11/19/10	43
45	Build/Fix Prototype	10 days	Mon 11/22/10	Fri 12/3/10	44
46	Write Final Design Report	10 days?	Mon 11/22/10	Fri 12/3/10	
47	Create Poster for Design Expo	3 days	Mon 11/29/10	Wed 12/1/10	
48	Design Exposition	1 day	Thu 12/2/10	Thu 12/2/10	47



Project: Gantt Chart v2
Date: Tue 12/7/10



Page 1

Appendix C: Technical Drawings

Drawing Table of Contents

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	100	FRAME ASSEMBLY	1
2	200	STEERING ASSEMBLY	1
3	300	DRIVETRAIN ASSEMBLY	1
4	400	SEAT ASSEMBLY	1

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL 6061 T-6 Al

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	MC	12-05-10
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE

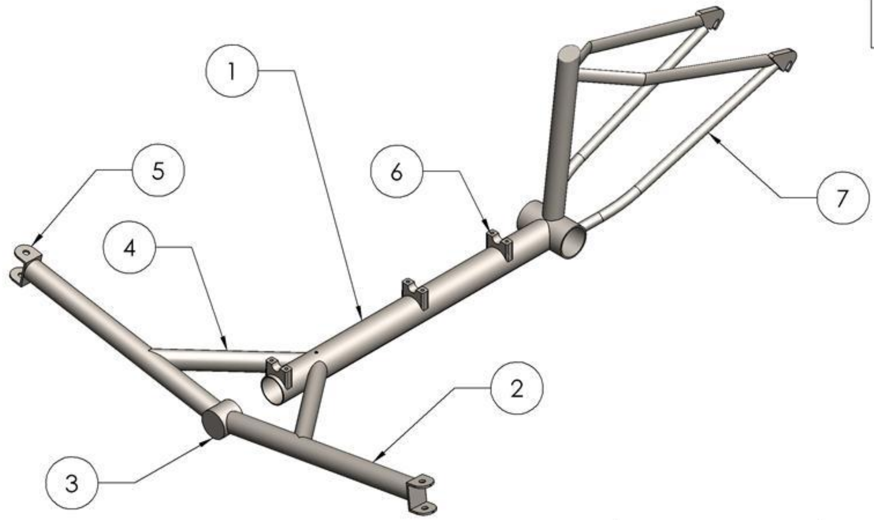
FULL ASSEMBLY
ISOMETRIC VIEW

SIZE A | DWG. NO. 001 | REV

SCALE: 1:12 | WEIGHT: | SHEET 1 OF 1

5 4 3 2 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	101	MAIN TUBE	1
2	102	WHEEL MOUNT TUBE	2
3	103	FRONT BOOM MOUNT TUBE	1
4	104	FRONT TRIANGLE TUBE	2
5	105	KINGPIN BUSHING MOUNT	2
6	207	BUSHING MOUNT BOTTOM	3
7	-	REAR STAY	1



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	KR	5-12-10
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

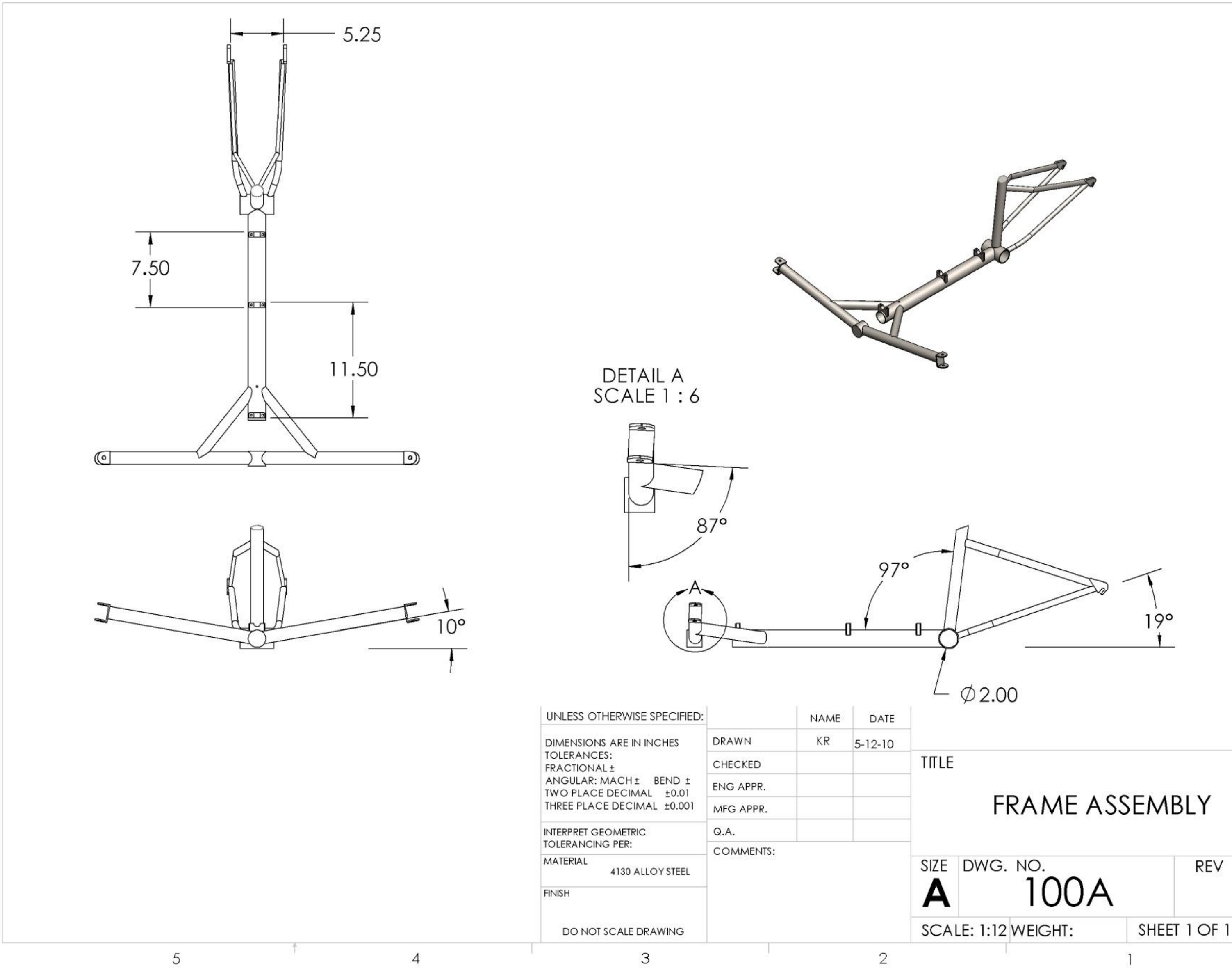
TITLE:

FRAME ASSEMBLY

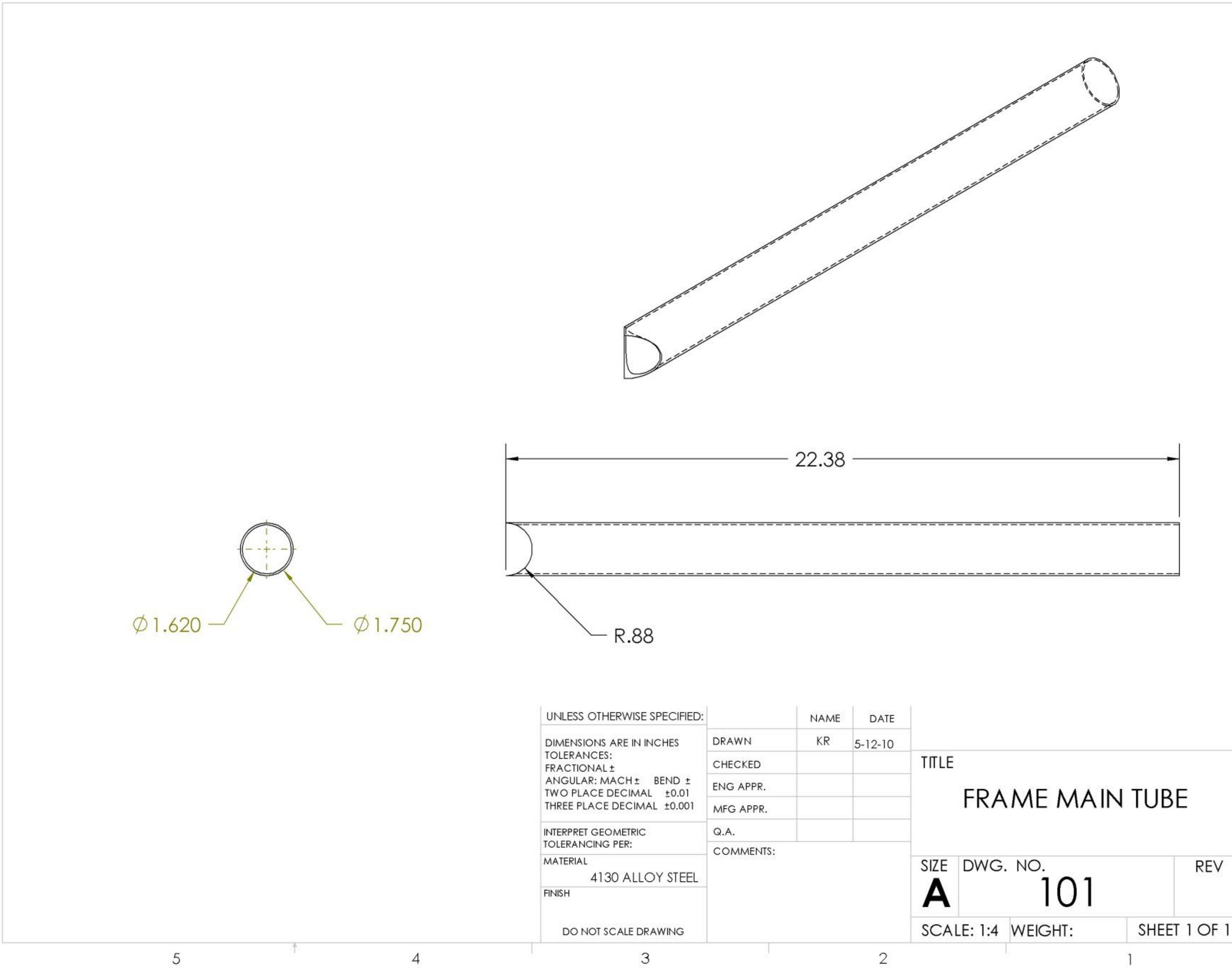
SIZE A DWG. NO. 100 REV

SCALE: 1:8 WEIGHT: SHEET 1 OF 1

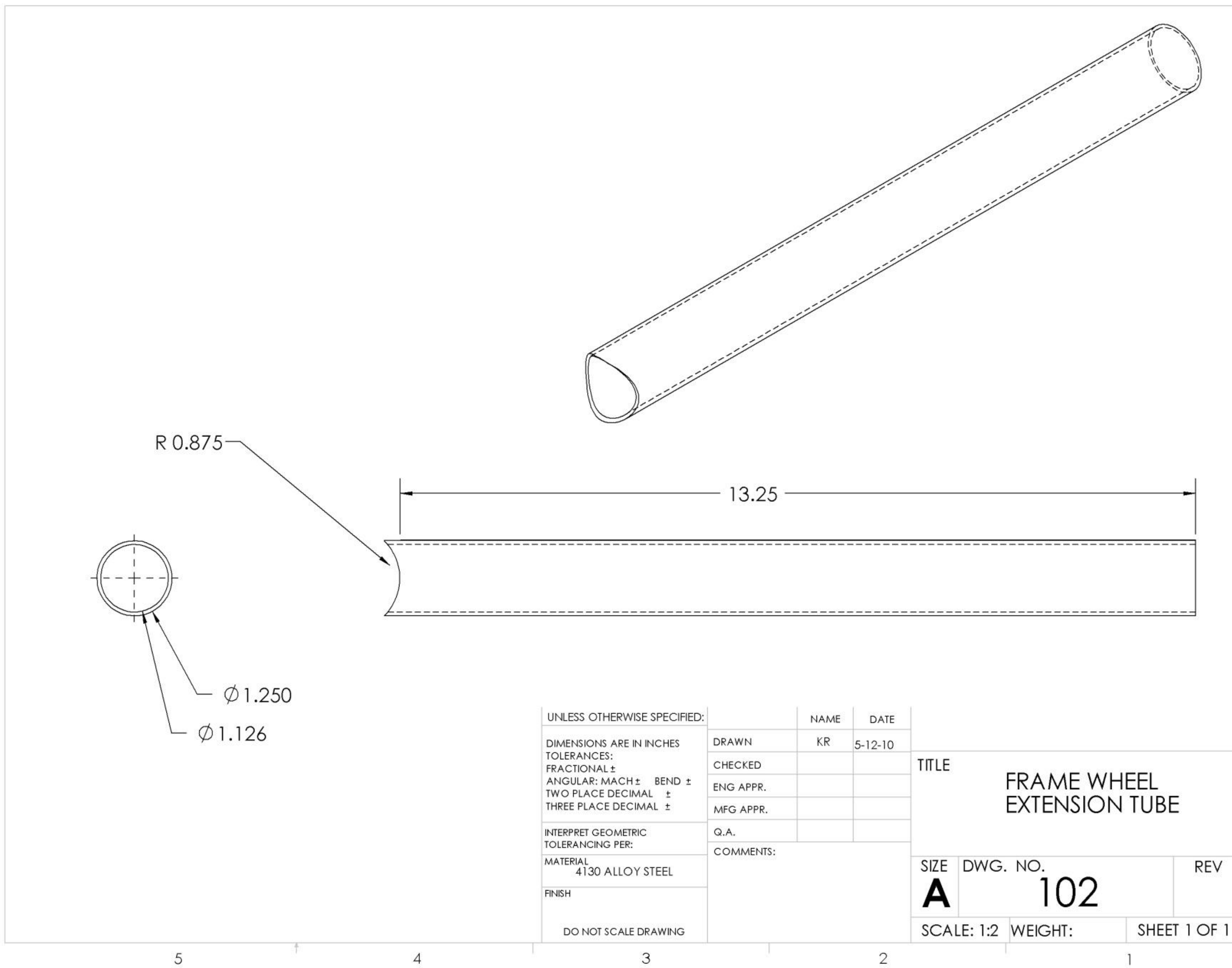
5 4 3 2 1

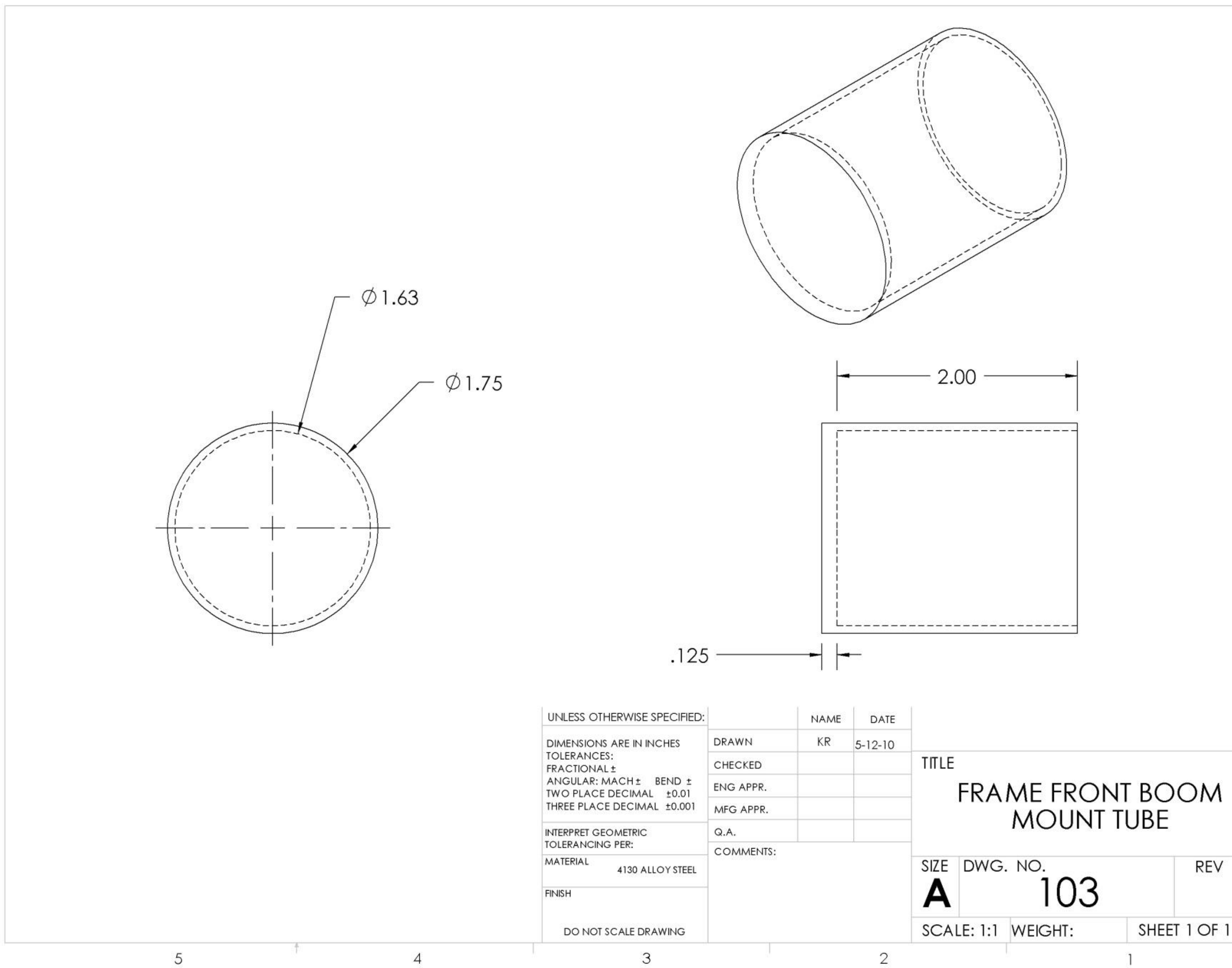


5.25
7.50
11.50
10°
DETAIL A
SCALE 1 : 6
87°
97°
19°
A
Ø2.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL 4130 ALLOY STEEL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN KR 5-12-10
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE
FRAME ASSEMBLY
SIZE A
DWG. NO. 100A
REV
SCALE: 1:12
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1

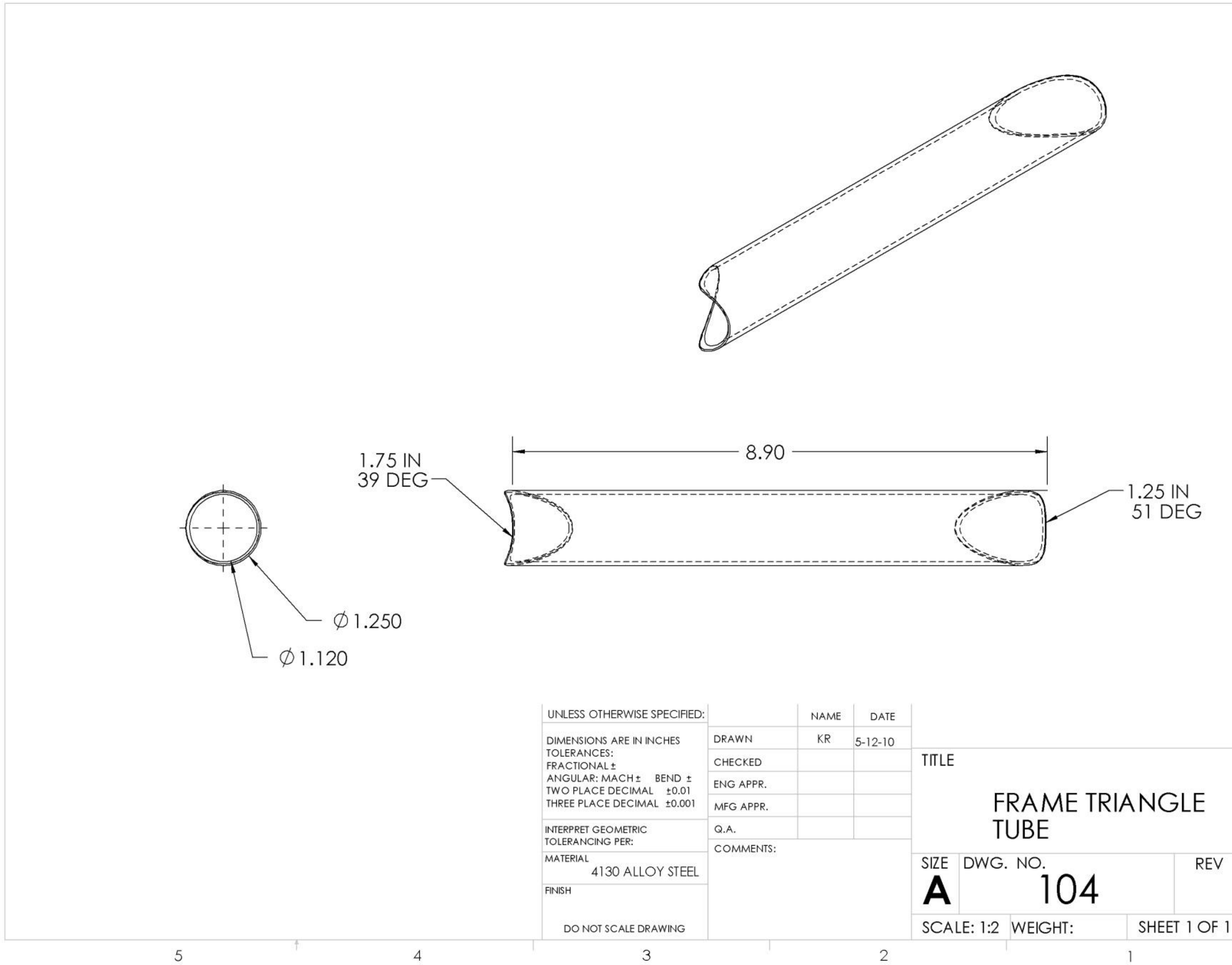


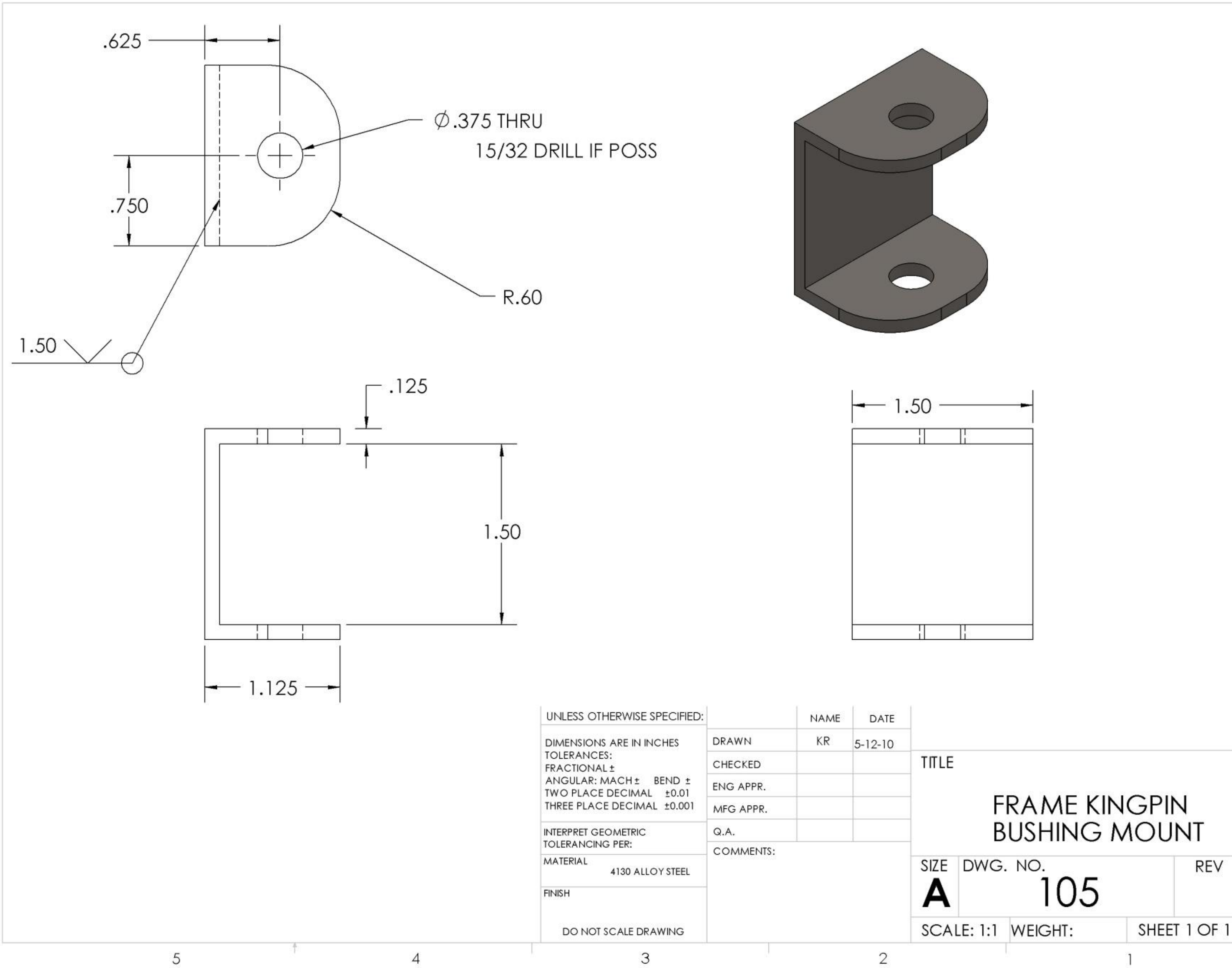
22.38
Ø1.620
Ø1.750
R.88
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
4130 ALLOY STEEL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
KR
5-12-10
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE
FRAME MAIN TUBE
SIZE
A
DWG. NO.
101
REV
SCALE: 1:4
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1


R 0.875
13.25
Ø1.250
Ø1.126
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
4130 ALLOY STEEL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
KR
5-12-10
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE
FRAME WHEEL EXTENSION TUBE
SIZE
A
DWG. NO.
102
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1

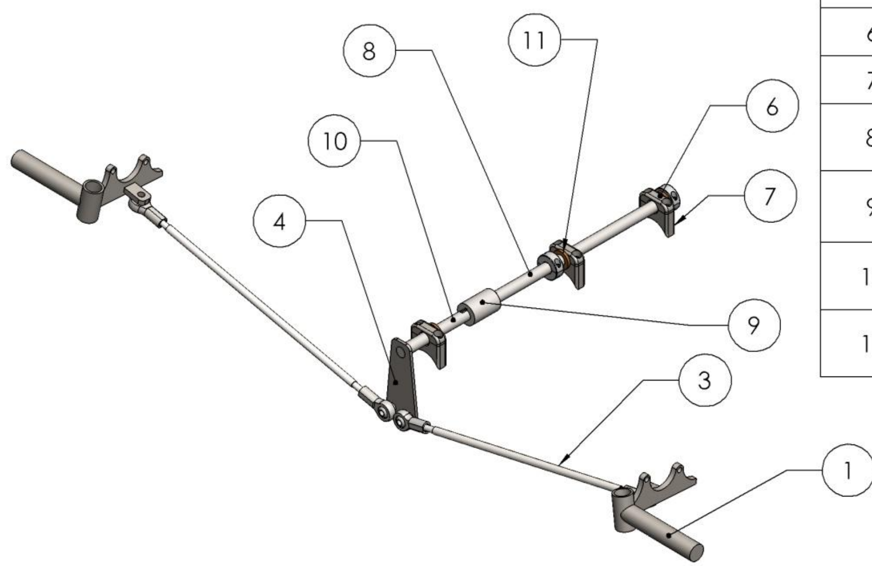


Ø1.63
Ø1.75
2.00
.125
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL 4130 ALLOY STEEL
FINISH
DO NOT SCALE DRAWING
NAME DATE
DRAWN KR 5-12-10
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE
FRAME FRONT BOOM MOUNT TUBE
SIZE A
DWG. NO. 103
REV
SCALE: 1:1 WEIGHT: SHEET 1 OF 1
5 4 3 2 1


8.90
1.75 IN
39 DEG
1.25 IN
51 DEG
∅1.250
∅1.120
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
4130 ALLOY STEEL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
KR
5-12-10
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE
FRAME TRIANGLE TUBE
SIZE
A
DWG. NO.
104
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1


.625
∅.375 THRU
15/32 DRILL IF POSS
.750
R.60
1.50
.125
1.50
1.125
1.50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC
TOLERANCING PER:
MATERIAL
4130 ALLOY STEEL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
KR
5-12-10
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE
FRAME KINGPIN
BUSHING MOUNT
SIZE
A
DWG. NO.
105
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	201	SPINDLE	2
3	204	TIE ROD	2
4	205	STEER ROD VERTICAL LINKAGE	1
6	206	BUSHING MOUNT TOP	3
7	207	BUSHING MOUNT BOTTOM	3
8	208	REAR STEER ROD	1
9	6099K41	COUPLER	1
10	210	FRONT STEER ROD	1
11	1677K9	BUSHING	3



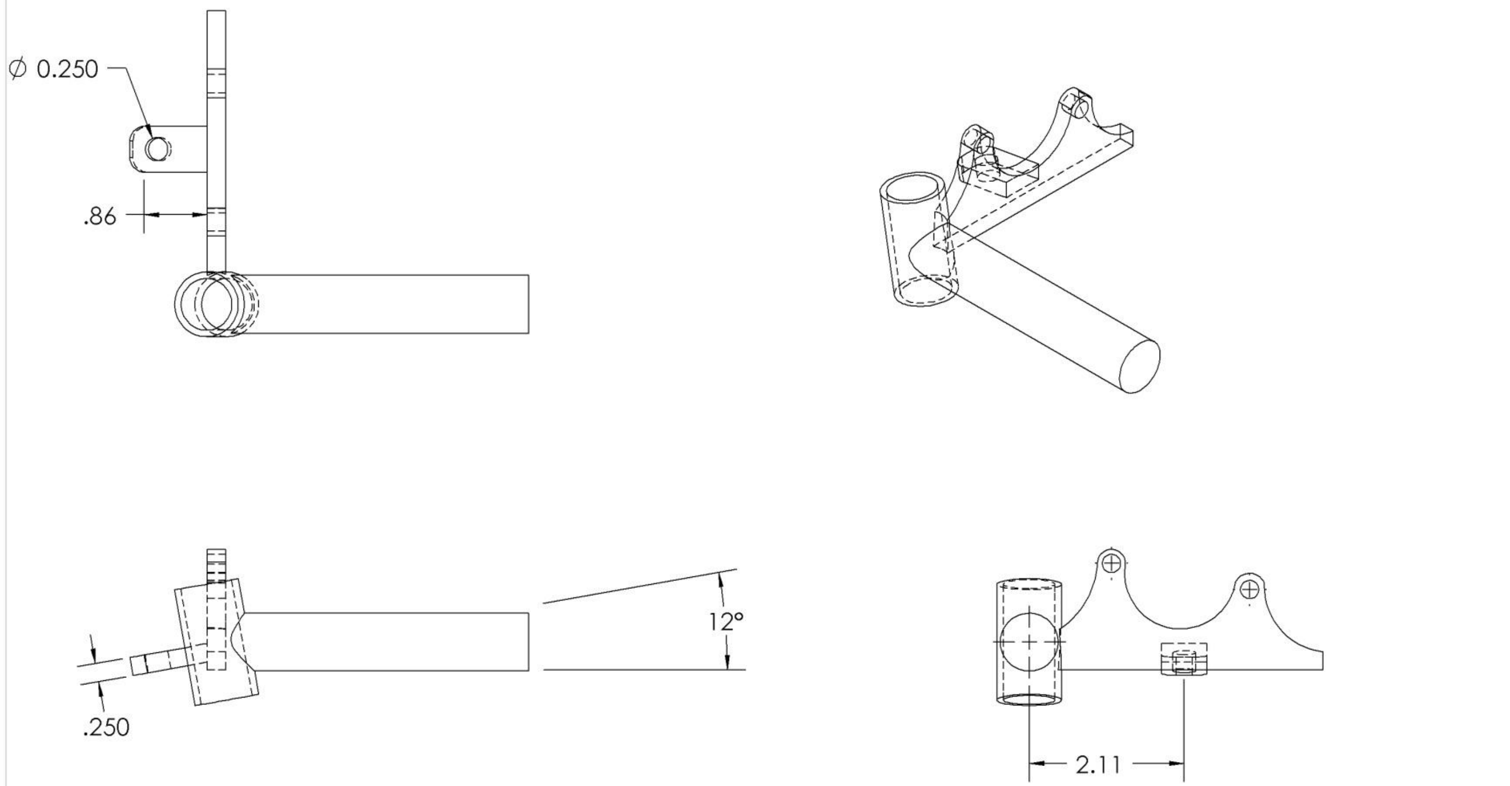
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.001	DRAWN	KR	5-12-10
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL	COMMENTS:		
FINISH			
DO NOT SCALE DRAWING			

TITLE

STEERING ASSEMBLY

SIZE	DWG. NO.		REV
A	200		
SCALE: 1:6	WEIGHT:	SHEET 1 OF 1	

5 4 3 2 1



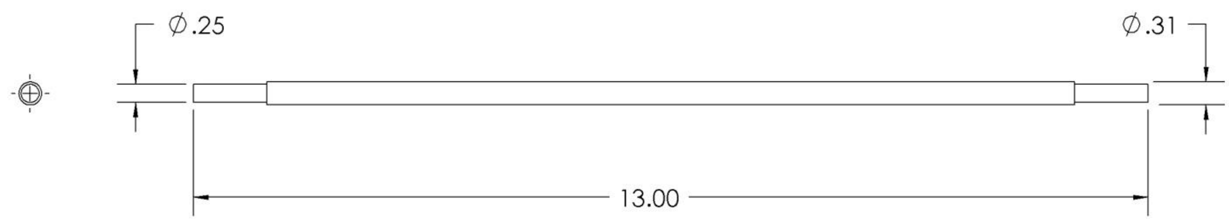
NOTE: DIMENSIONS PROVIDED ONLY
FOR MODIFICATION PURPOSES.
BOTH SPINDLESHAVE SIMILAR DIMENSIONS

UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.001	DRAWN	KR	5-12-10
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL STEEL	COMMENTS:		
FINISH			
DO NOT SCALE DRAWING			

TITLE
MODIFIED SPINDLE

SIZE	DWG. NO.	REV
A	201	
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1

5 4 3 2 1



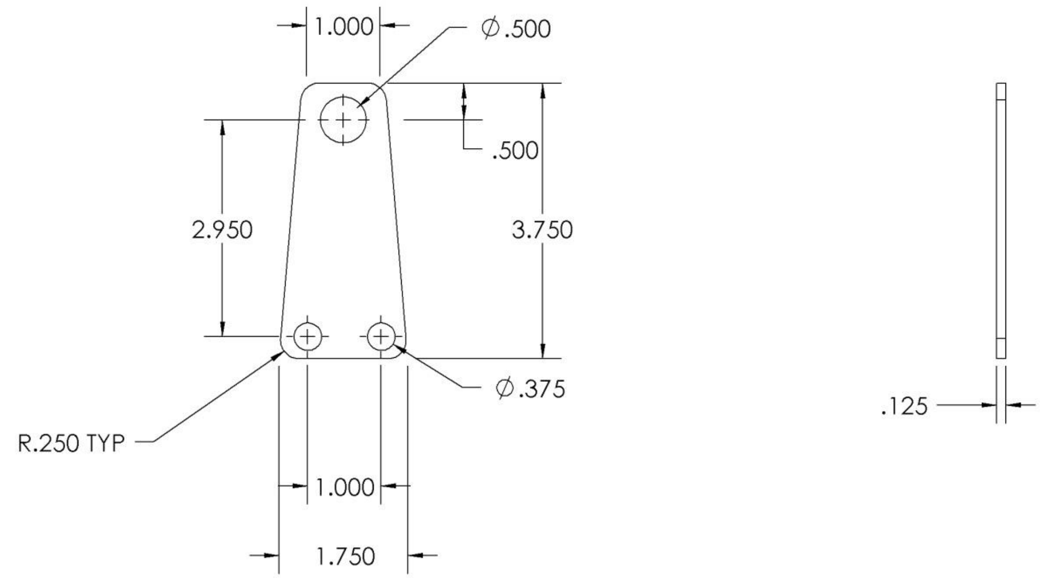
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	KR	5-12-10
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL 1018 MILD STEEL	COMMENTS:		
FINISH			
DO NOT SCALE DRAWING			

TITLE:

STEERING TIE ROD

SIZE	DWG. NO.	REV
A	204	
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1

5 4 3 2 1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±0.001

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
304 STAINLESS

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	KR	5-12-10
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

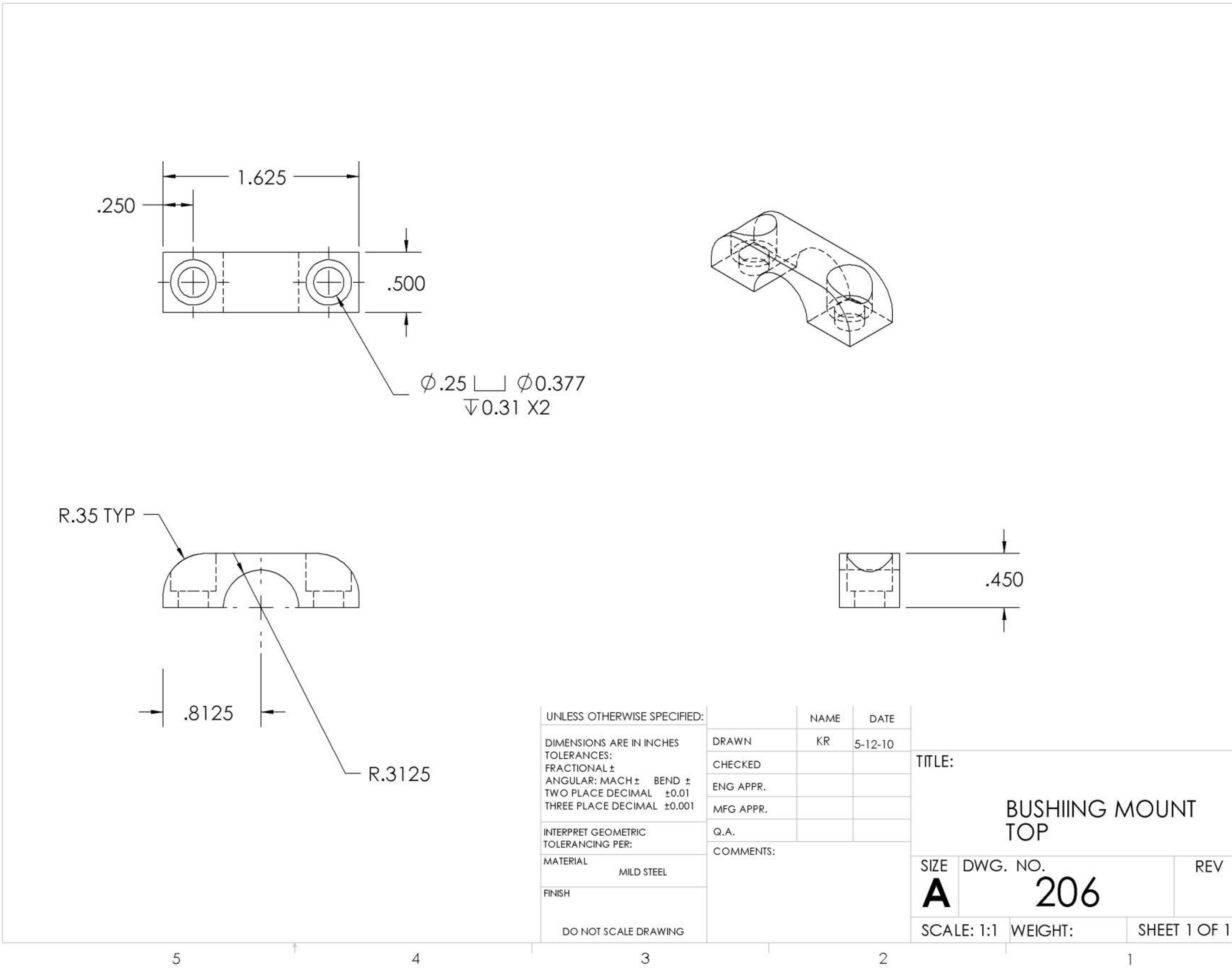
COMMENTS:

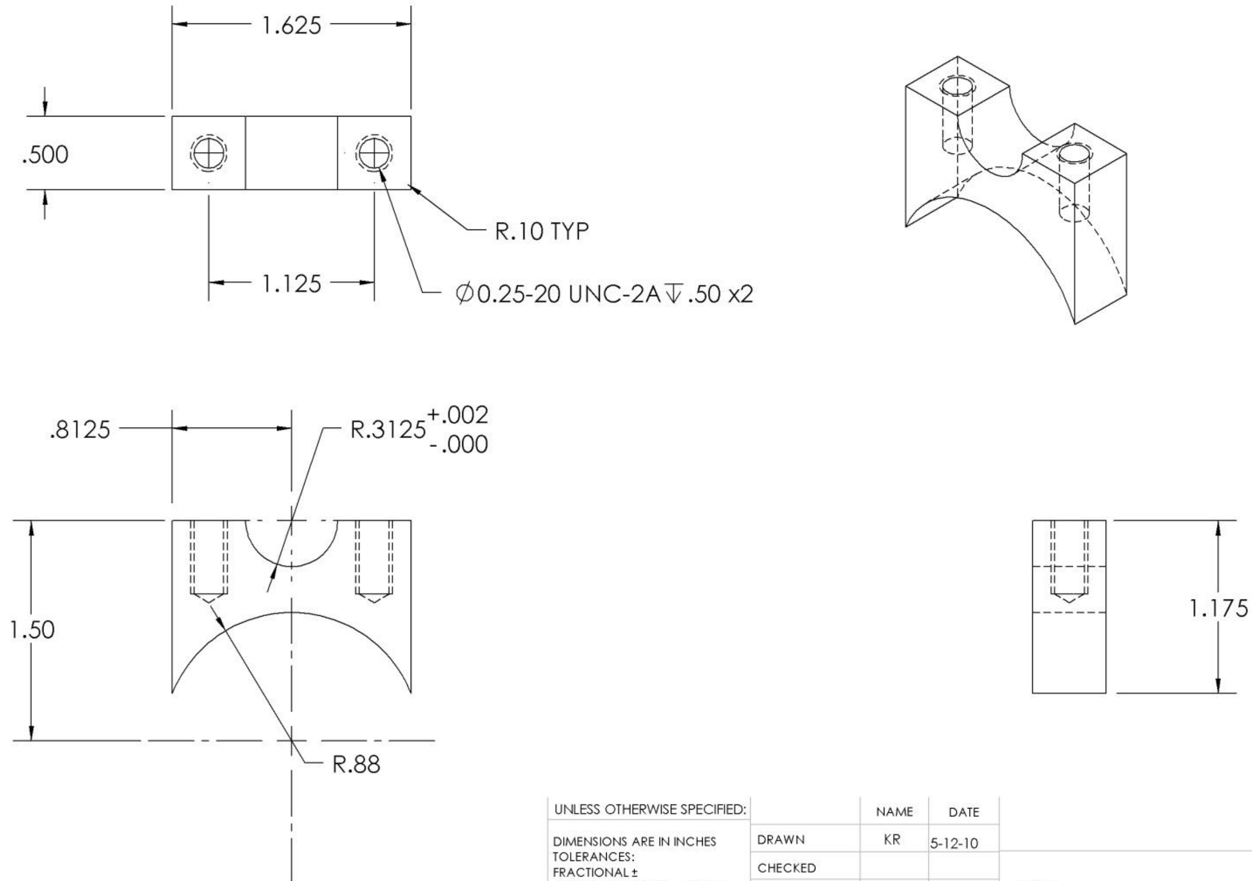
TITLE:

VERTICAL STEER BRACKET

SIZE	DWG. NO.	REV
A	205	

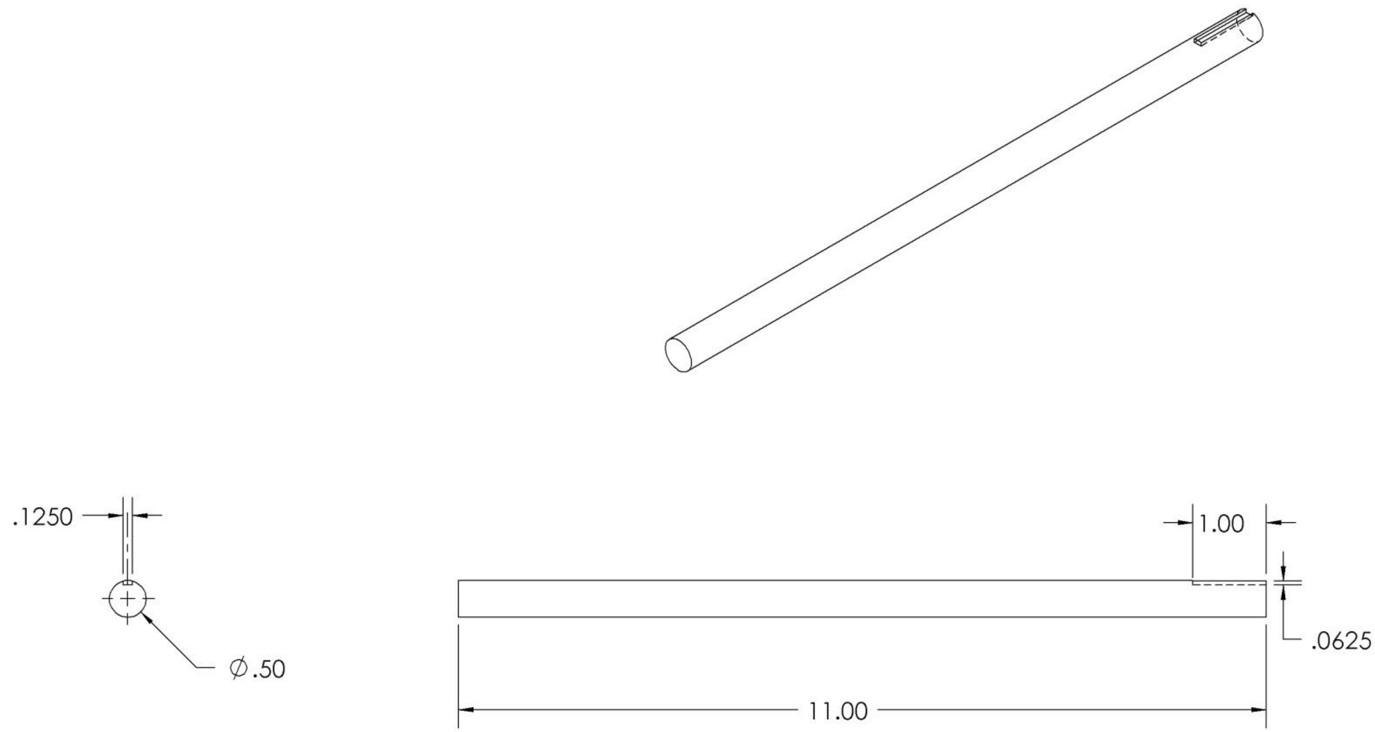
SCALE: 1:2 SHEET 1 OF 1


1.625
.250
.500
Ø.25 ⌴ Ø0.377
↧0.31 X2
R.35 TYP
.8125
R.3125
.450
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
MILD STEEL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
KR
5-12-10
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
BUSHIING MOUNT TOP
SIZE
A
DWG. NO.
206
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ±0.1 THREE PLACE DECIMAL ±0.001	DRAWN	KR	5-12-10	
	CHECKED			TITLE: STEER SHAFT BUSHING MOUNT BOTTOM
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL 1018 Mild Steel	COMMENTS:			SIZE A DWG. NO. 207 REV
FINISH				
DO NOT SCALE DRAWING				SCALE: 1:1 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

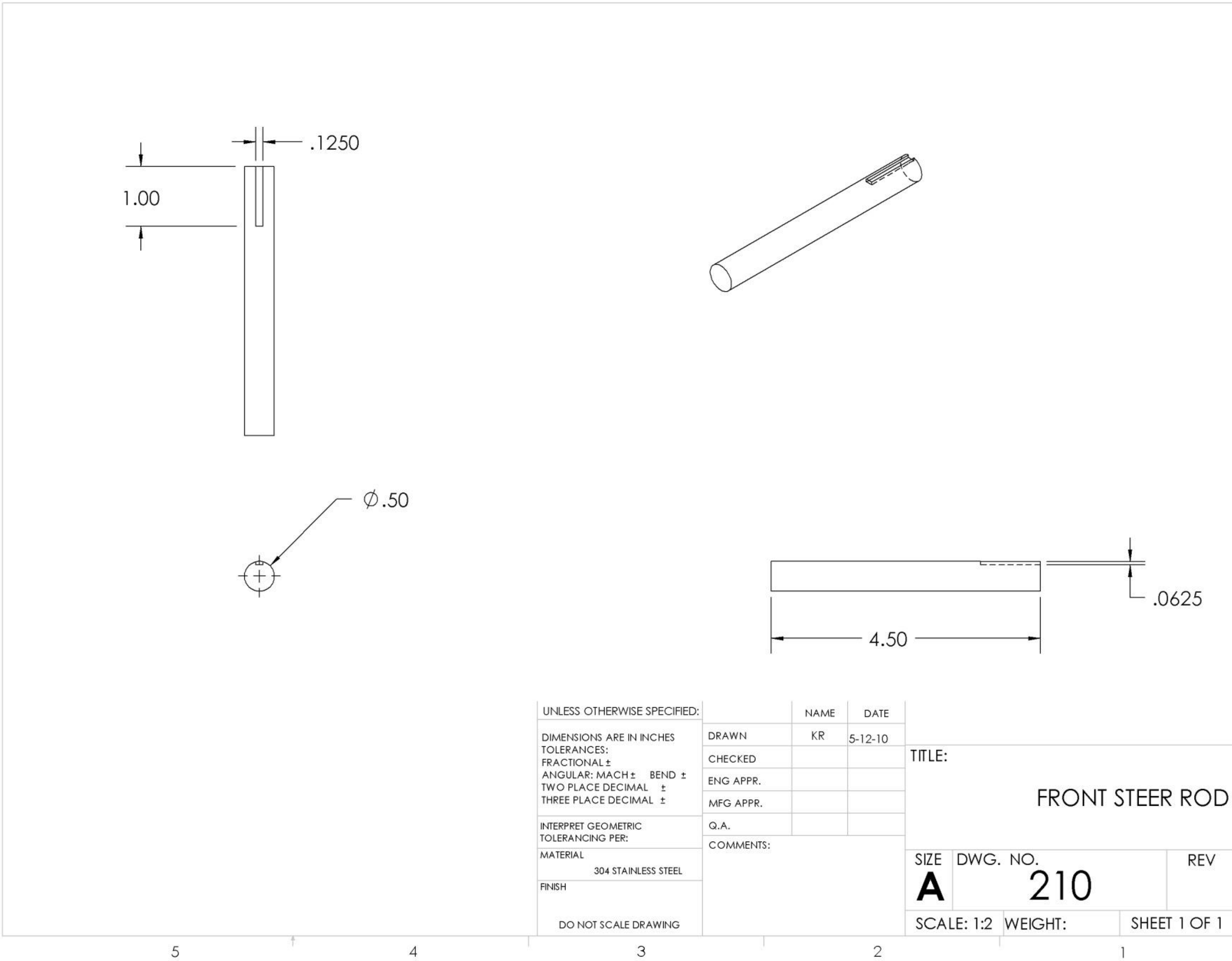


UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	KR	11-27-10
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL 304 STAINLESS STEEL	COMMENTS:		
FINISH			
DO NOT SCALE DRAWING			

TITLE: REAR STEER ROD

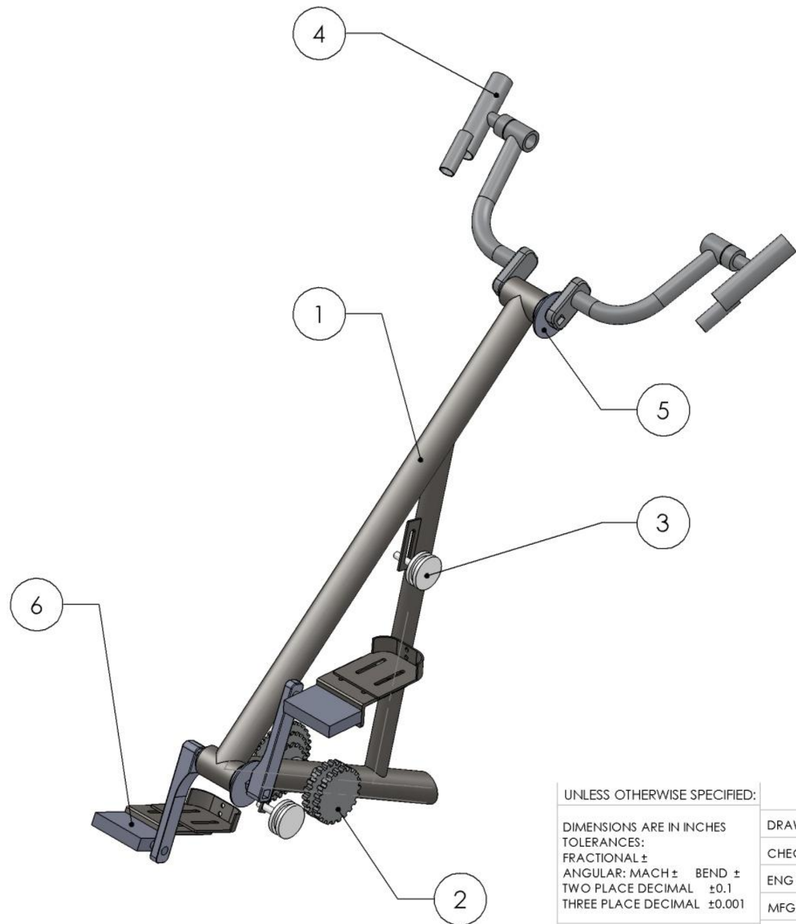
SIZE	DWG. NO.	REV
A	208	
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1

5 4 3 2 1



.1250
1.00
∅.50
.0625
4.50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
304 STAINLESS STEEL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
KR
5-12-10
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
FRONT STEER ROD
SIZE
A
DWG. NO.
210
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	301	DRIVETRAIN FRONT BOOM TUBING	1
2	302	DaVinci DRIVE	1
3	303	IDLER WHEEL	2
4	304	HAND CRANK ASSEMBLY	2
5	305	CRANK AND SPROCKET	2
6	306	FOOT CRANK ASSEMBLY	2

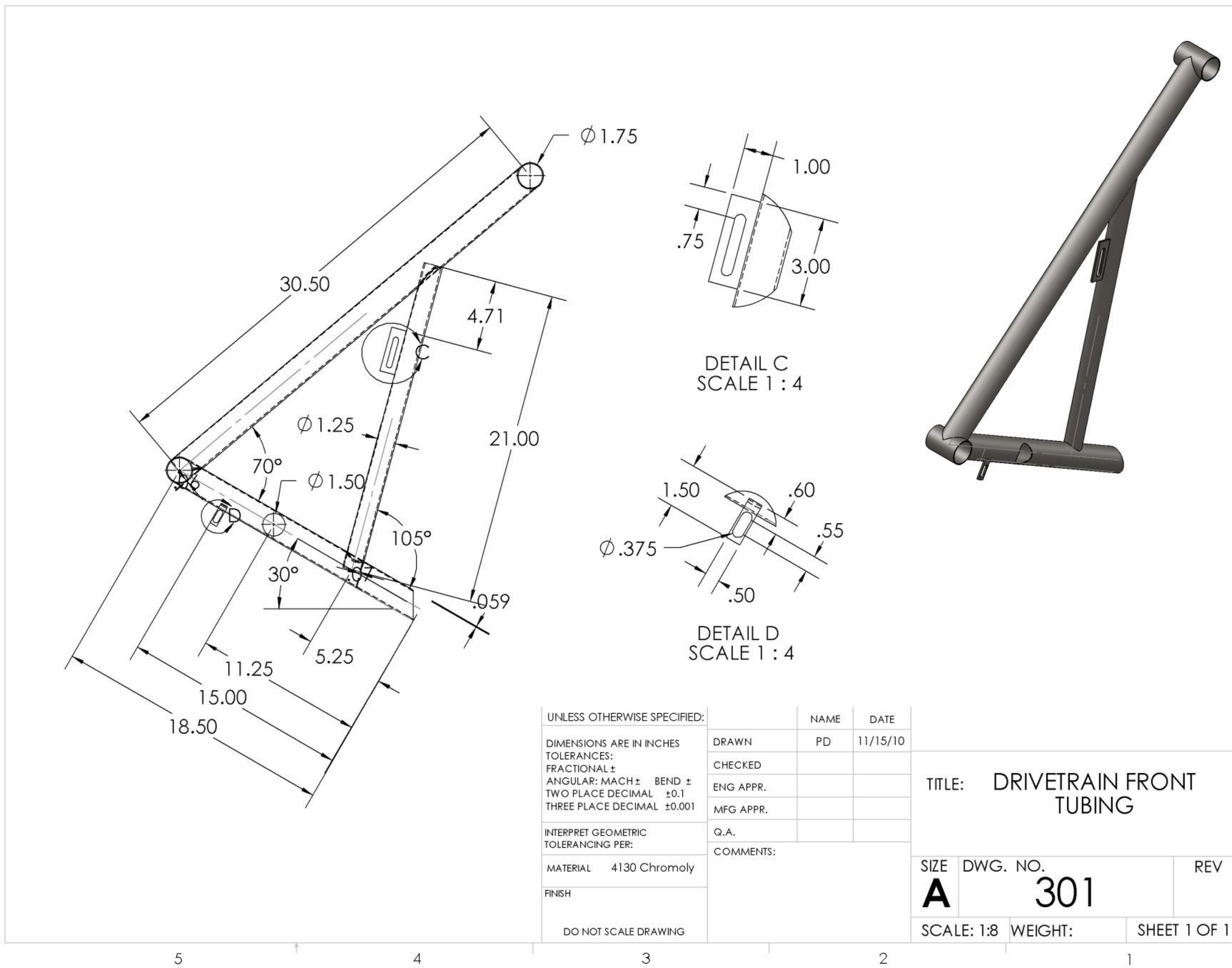


UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ±0.1 THREE PLACE DECIMAL ±0.001	DRAWN	PD	11/15/10
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL	COMMENTS:		
FINISH			
DO NOT SCALE DRAWING			

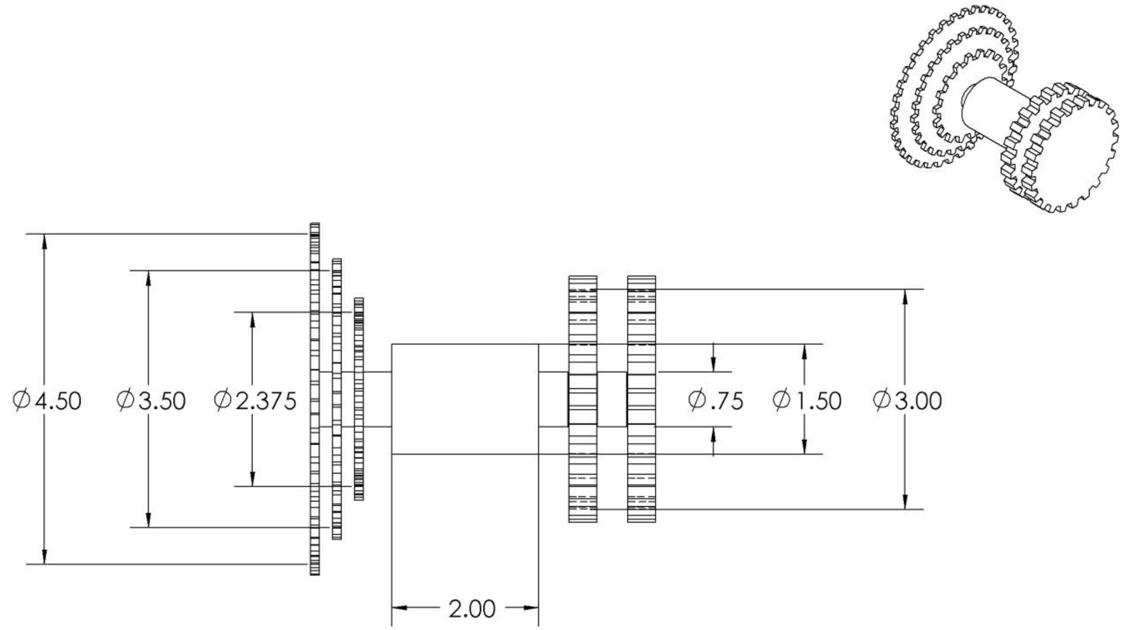
TITLE: DRIVETRAIN ASSEMBLY

SIZE	DWG. NO.	REV
A	300	
SCALE: 1:8	WEIGHT:	SHEET 1 OF 1

5 4 3 2 1



∅1.75
30.50
4.71
21.00
∅1.25
70°
∅1.50
105°
30°
.059
5.25
11.25
15.00
18.50
C
D
1.00
.75
3.00
DETAIL C
SCALE 1 : 4
1.50
.60
.55
∅.375
.50
DETAIL D
SCALE 1 : 4
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.1
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL 4130 Chromoly
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN PD 11/15/10
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE: DRIVETRAIN FRONT TUBING
SIZE A
DWG. NO. 301
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.1
THREE PLACE DECIMAL ±0.001

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL Aluminum

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	PD	11/15/2010
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

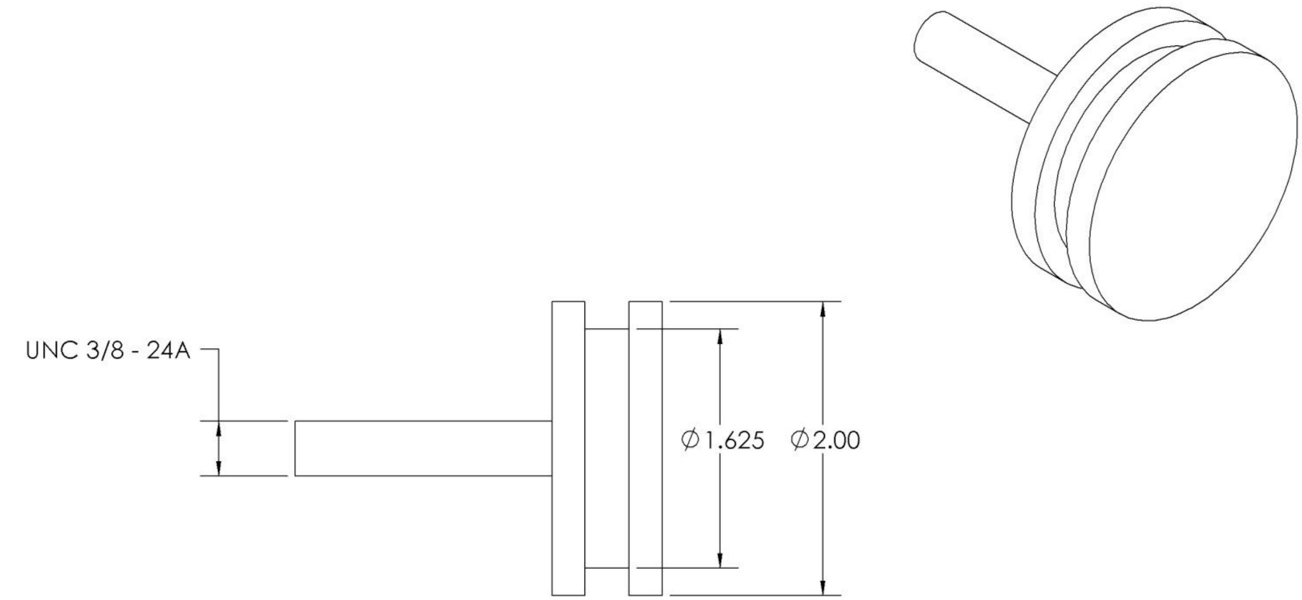
COMMENTS:

TITLE: DaVinci Drive System by DaVinci Designs

SIZE	DWG. NO.	REV
A	302	

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

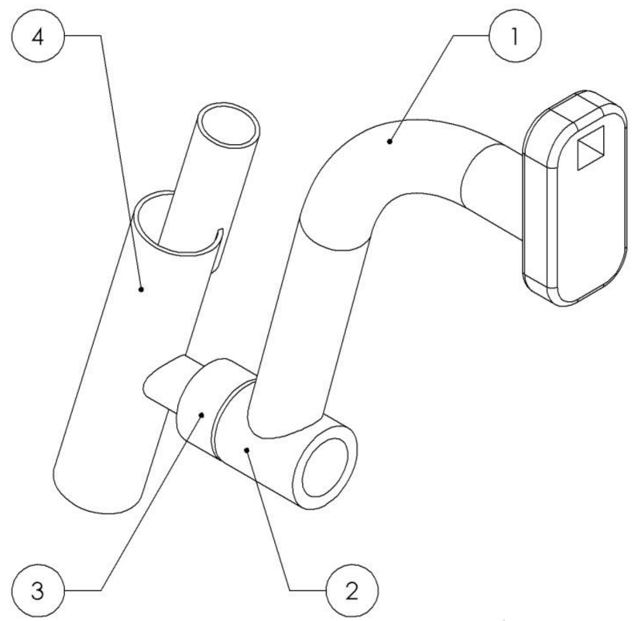
5 4 3 2 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ±0.1 THREE PLACE DECIMAL ±0.001	DRAWN	PD	11/15/10	
	CHECKED			TITLE: Idler Wheels
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL Plastic	COMMENTS:			SIZE A DWG. NO. 303 REV
FINISH				
DO NOT SCALE DRAWING				SCALE: 1:1 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	304A	HAND CRANK TUBING	1
2	304B	HAND CRANK BEARING HOUSING	1
3	304C	HAND CRANK HANDLE BASE	1
4	304D	HAND CRANK HANDLE SHAFT	1



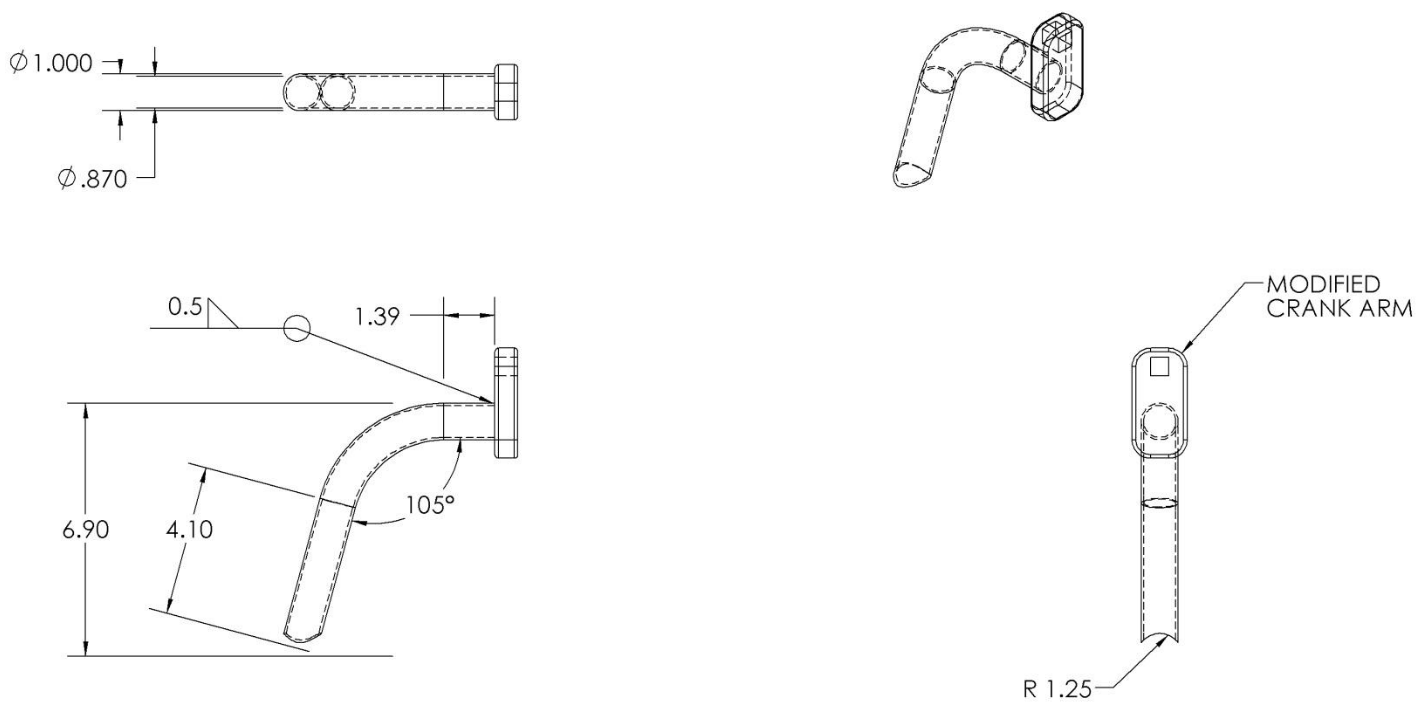
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.001	DRAWN	MC	12-05-10
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL 6061 T-6 Al	COMMENTS:		
FINISH			
DO NOT SCALE DRAWING			

TITLE

HAND CRANK ASSEMBLY

SIZE	DWG. NO.	REV
A	304	

SCALE: 1:2 WEIGHT: SHEET 1 OF 1



NOTE: CRANK ARM MOUNT IS SHOWN FOR REFERENCE ONLY. ACTUAL PART DIMENSIONS AND APPEARANCE MAY VARY

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL 6061-T6 AL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	KR	11-27-10
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

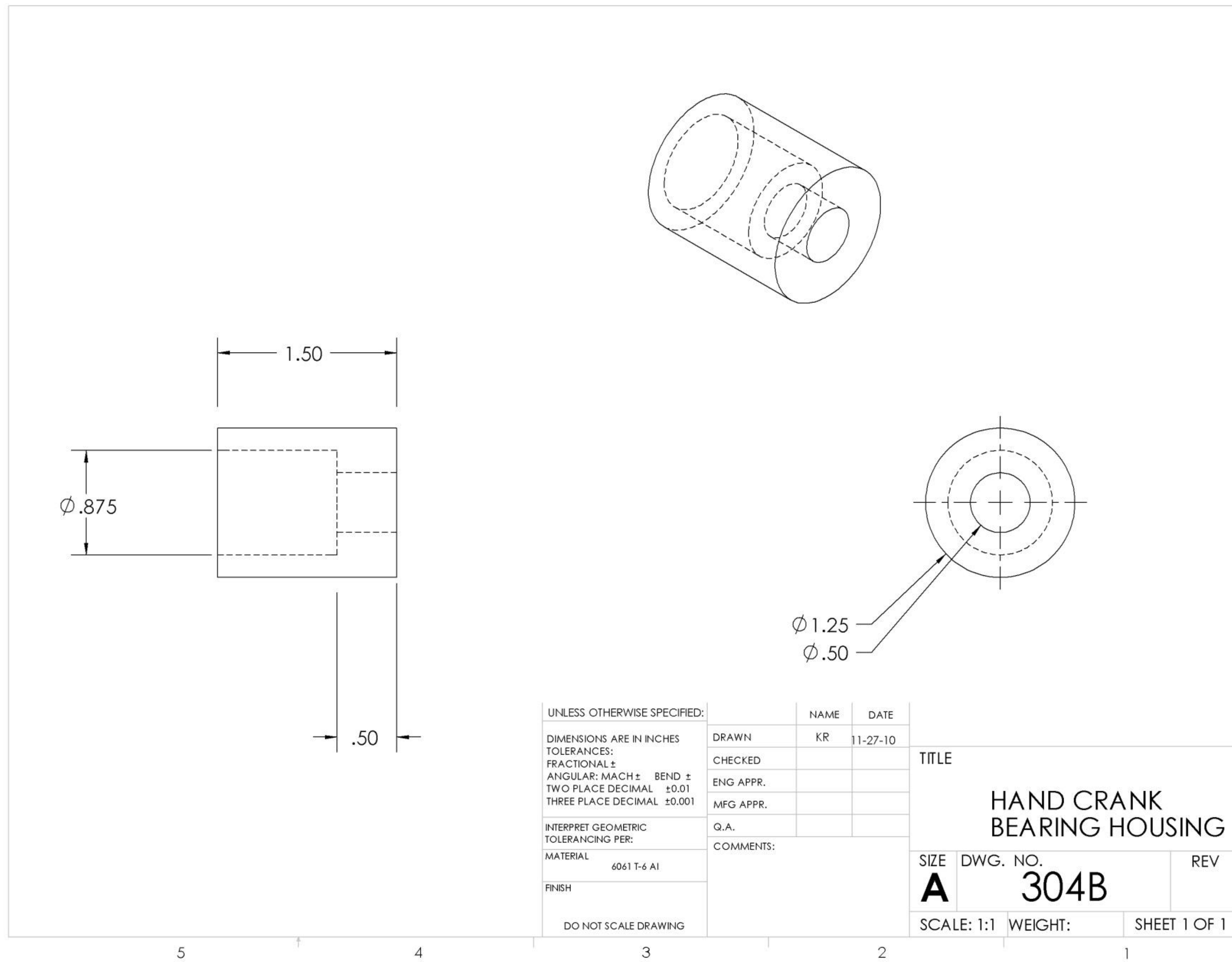
TITLE

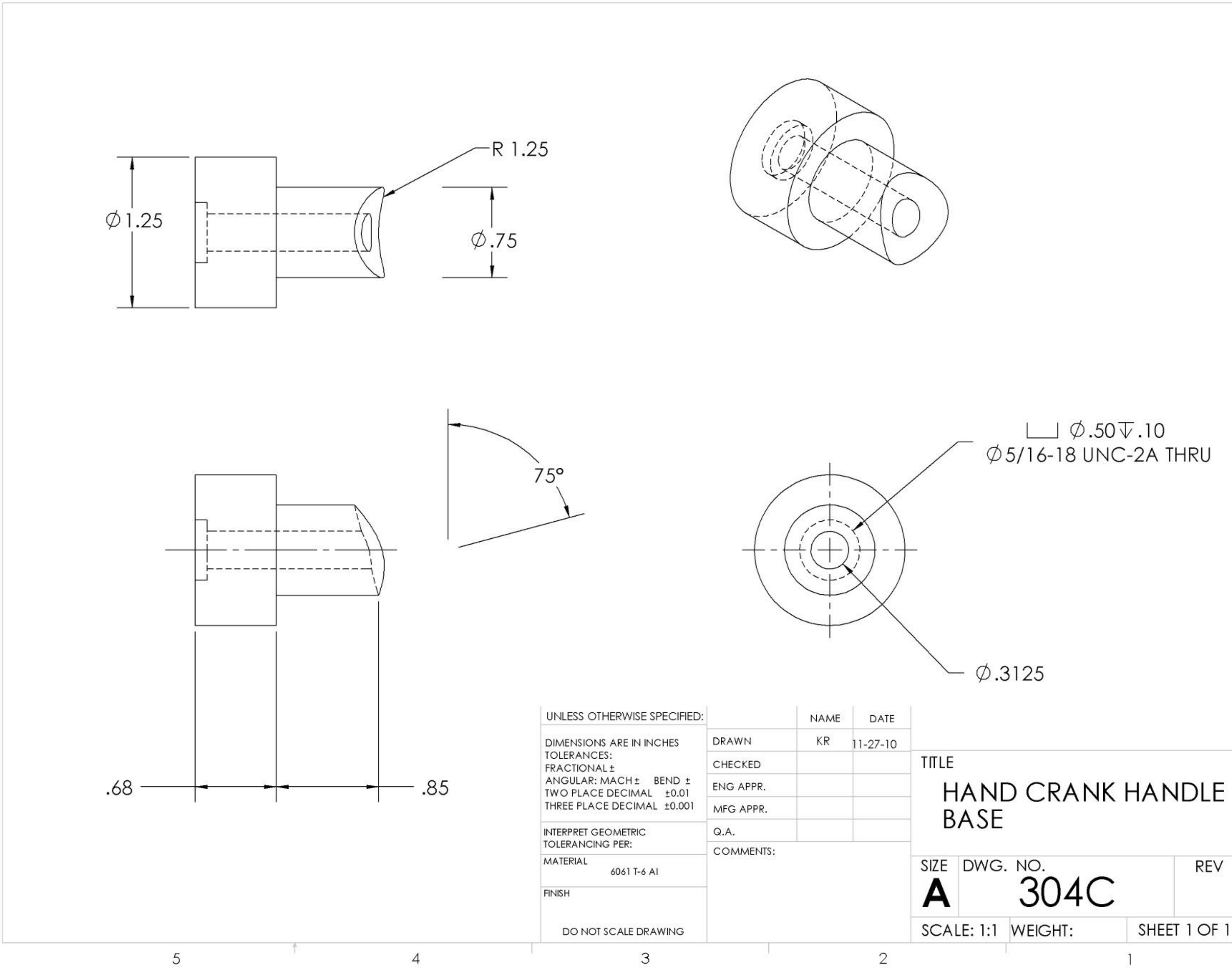
HAND CRANK TUBE

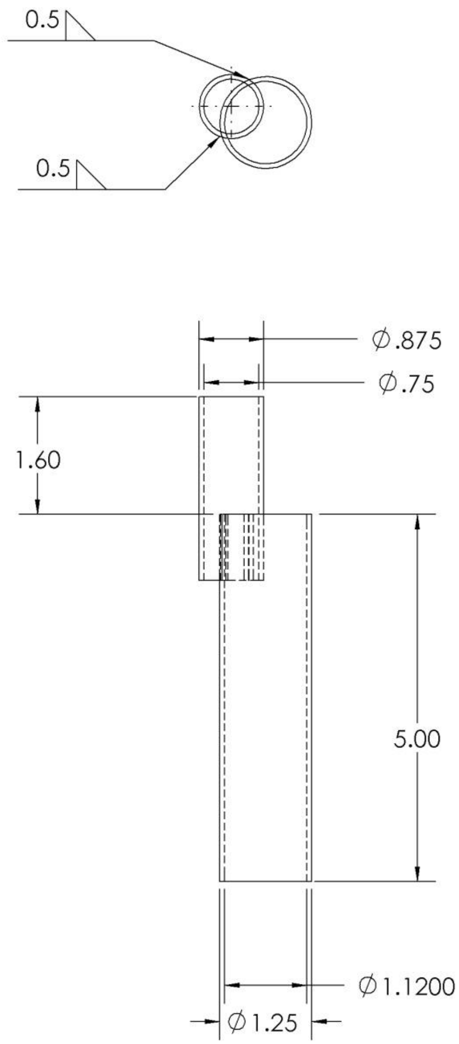
SIZE A DWG. NO. 304A REV

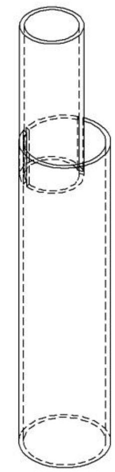
SCALE: 1:4 WEIGHT: SHEET 1 OF 1

5 4 3 2 1


1.50
Ø.875
.50
Ø1.25
Ø.50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 T-6 Al
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
KR
11-27-10
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE
HAND CRANK
BEARING HOUSING
SIZE
A
DWG. NO.
304B
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1


R 1.25
∅1.25
∅.75
75°
⌴ ∅.50↧.10
∅5/16-18 UNC-2A THRU
∅.3125
.68
.85
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 T-6 Al
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
KR
11-27-10
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE
HAND CRANK HANDLE BASE
SIZE
A
DWG. NO.
304C
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1





UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.001	DRAWN	KR	11-27-10
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL 6061 T-6 Al	COMMENTS:		
FINISH			
DO NOT SCALE DRAWING			

TITLE

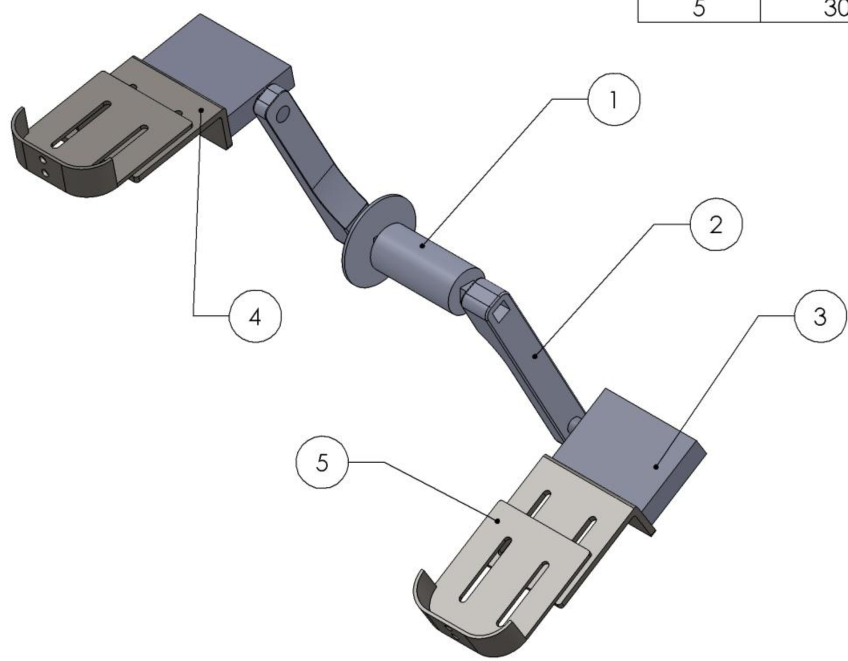
HAND CRANK
HANDLE SHAFT

SIZE	DWG. NO.	REV
A	304D	

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	305A	CRANK AND SPROCKET	1
2	305B	CRANK ARM	2
3	305C	PEDAL	2
4	305D	FOOT PEDAL BLOCK BOTTOM	2
5	305E	FOOT PEDAL BLOCK TOP	2



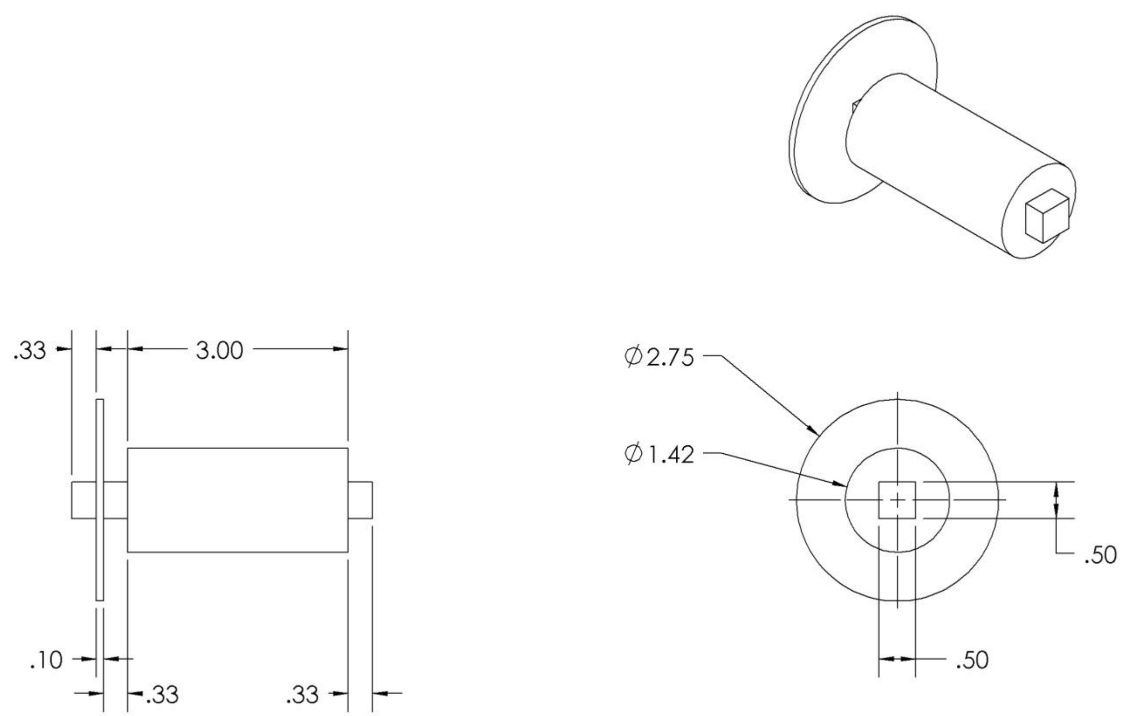
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.001	DRAWN	MC	12-05-10
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL 6061 T-6 Al	COMMENTS:		
FINISH			
DO NOT SCALE DRAWING			

TITLE

FOOT CRANK ASSEMBLY

SIZE	DWG. NO.	REV
A	305	
SCALE: 1:8	WEIGHT:	SHEET 1 OF 1

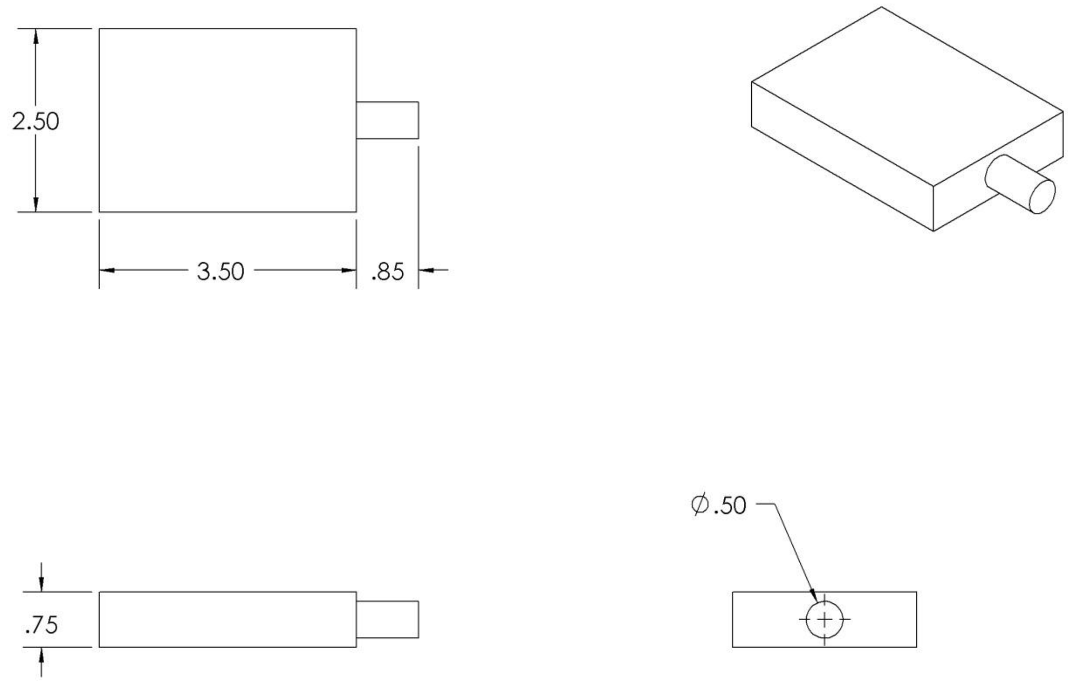
5 4 3 2 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.001	DRAWN	MC	12-05-10
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL 6061 T-6 Al	COMMENTS:		
FINISH			
DO NOT SCALE DRAWING			

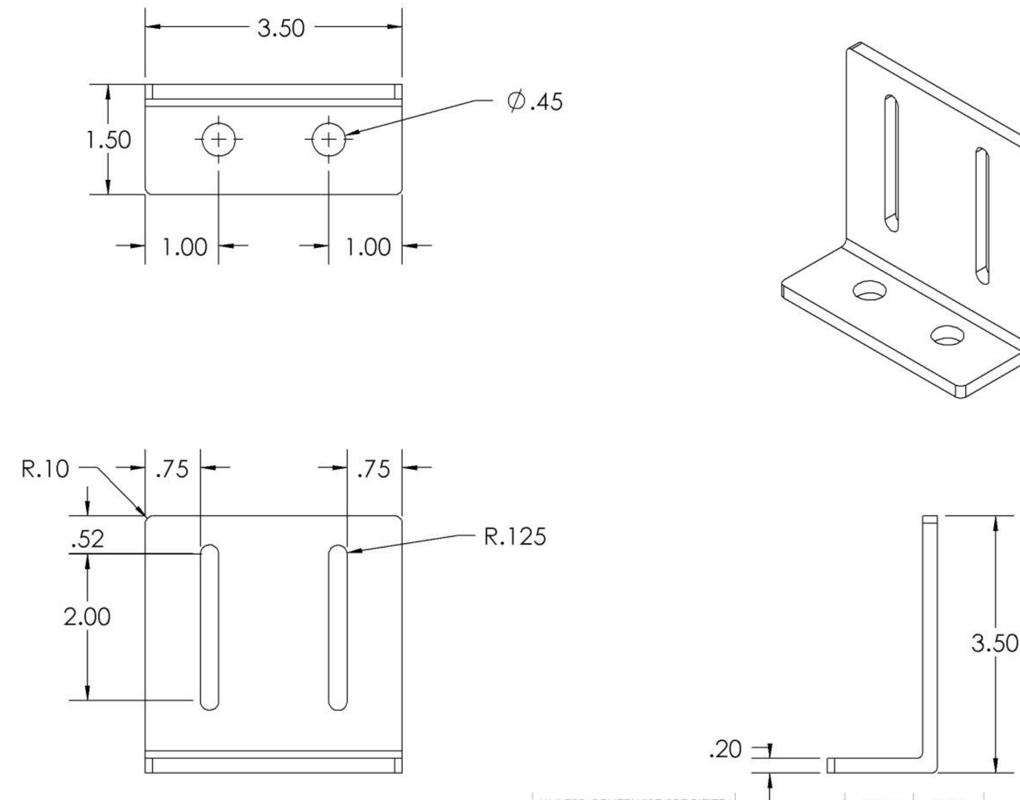
TITLE		
CRANK AND SPROCKET		
SIZE A	DWG. NO. 305A	REV
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1

5 4 3 2 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.001	DRAWN	MC	12-05-10	
	CHECKED			TITLE
	ENG APPR.			PEDAL
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL 6061 T-6 Al	COMMENTS:			SIZE A DWG. NO. 305C REV
FINISH				
DO NOT SCALE DRAWING				SCALE: 1:2 WEIGHT: SHEET 1 OF 1

5 4 3 2 1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.001

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL 6061 T-6 Al

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	PD	05-01-10
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

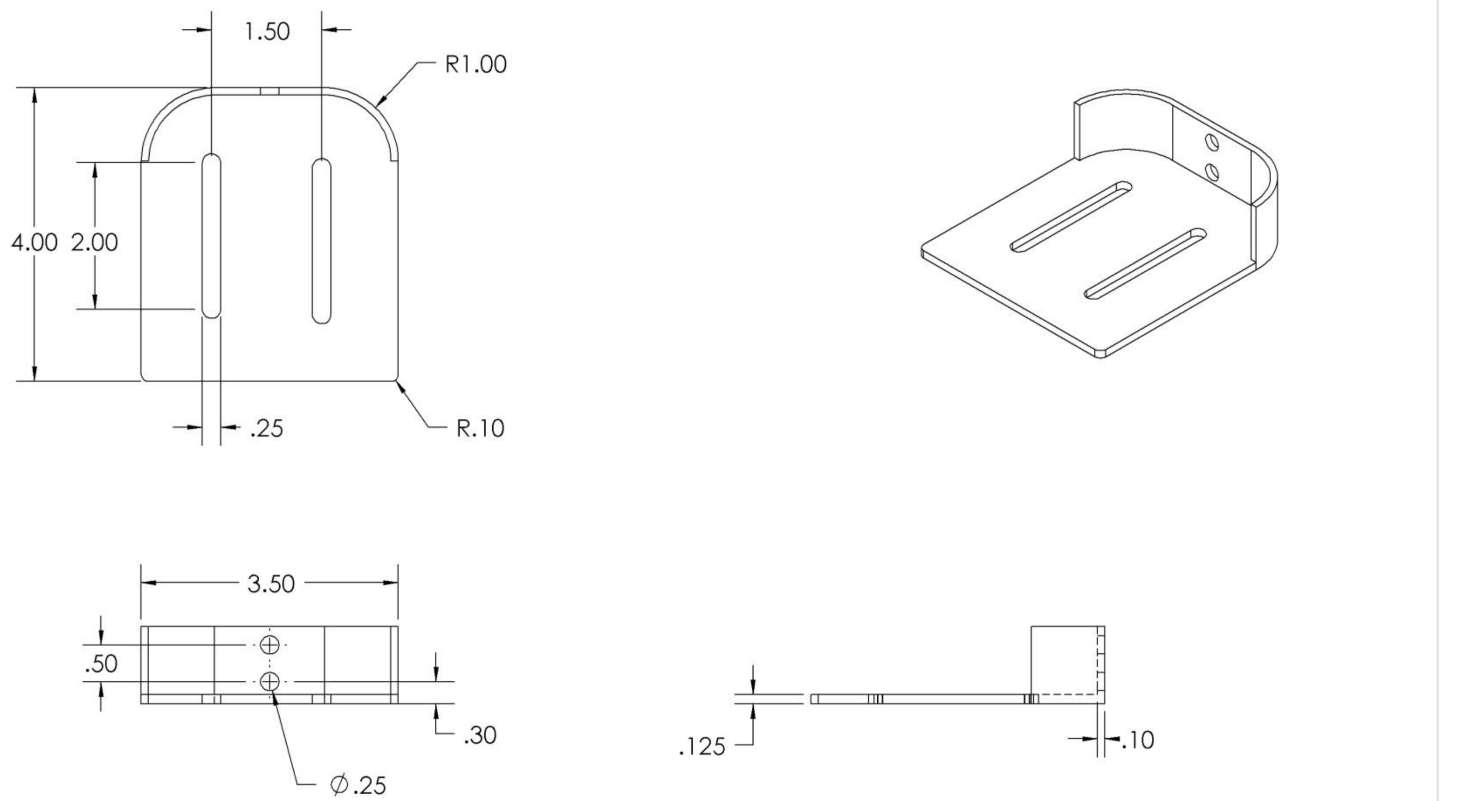
TITLE

FOOT PEDAL BLOCK BOTTOM

SIZE A DWG. NO. 305D REV

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

5 4 3 2 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.001	DRAWN	PD	05-01-10
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL 6061 T-6 Al	COMMENTS:		
FINISH			
DO NOT SCALE DRAWING			

TITLE

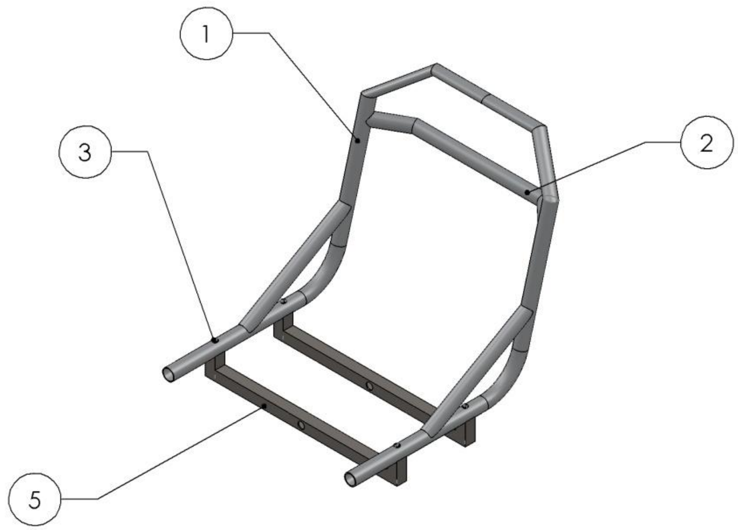
FOOT PEDAL BLOCK TOP

SIZE	DWG. NO.	REV
A	305E	

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	401	SEAT FRAME	1
2	402	BACK SUPPORT BAR	1
3	91793A207	TYPE 18-8 STAINLESS STEEL BINDING HEAD SLOTTED MACHINE SCREW	4
4	403	SIDE SUPPORT BAR	2
5	404	BOTTOM SUPPORT BRACKET	2



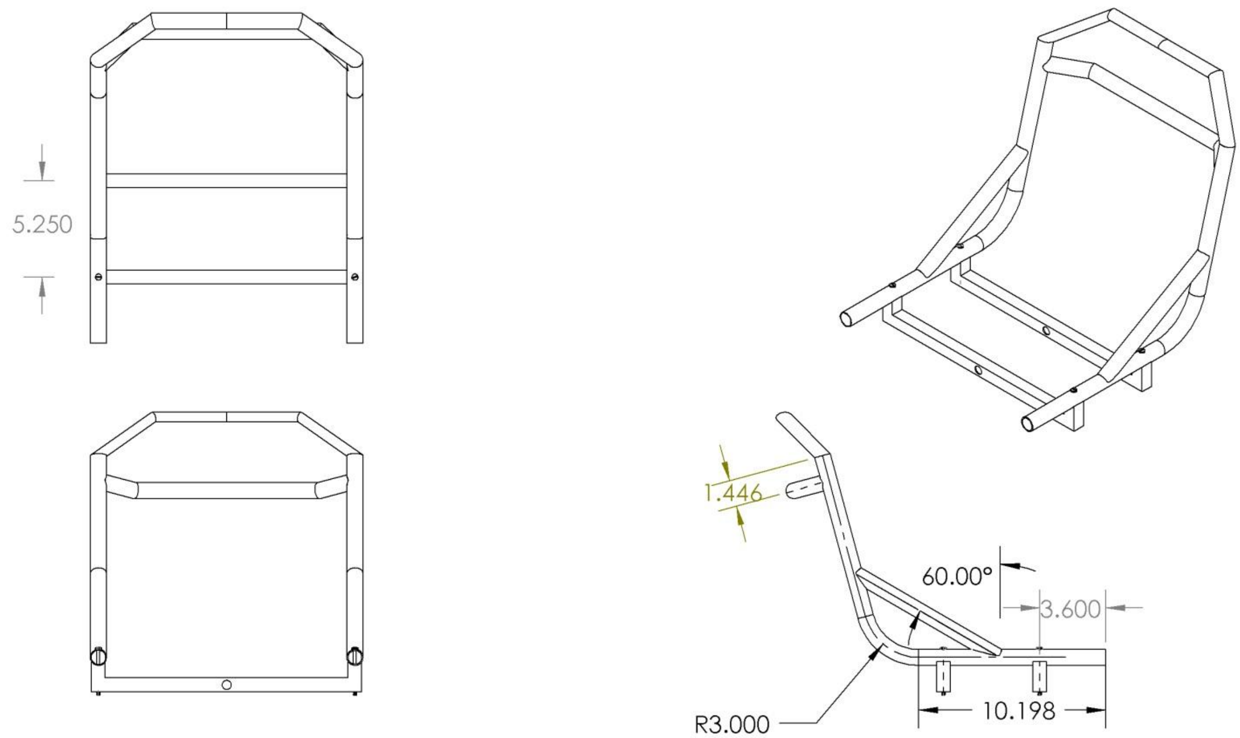
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.001	DRAWN	MC	12-05-10
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL 6061 T-6 Al	COMMENTS:		
FINISH			
DO NOT SCALE DRAWING			

TITLE

SEAT FRAME ASSEMBLY

SIZE	DWG. NO.	REV
A	400	
SCALE: 1:8	WEIGHT:	SHEET 1 OF 1

5 4 3 2 1



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

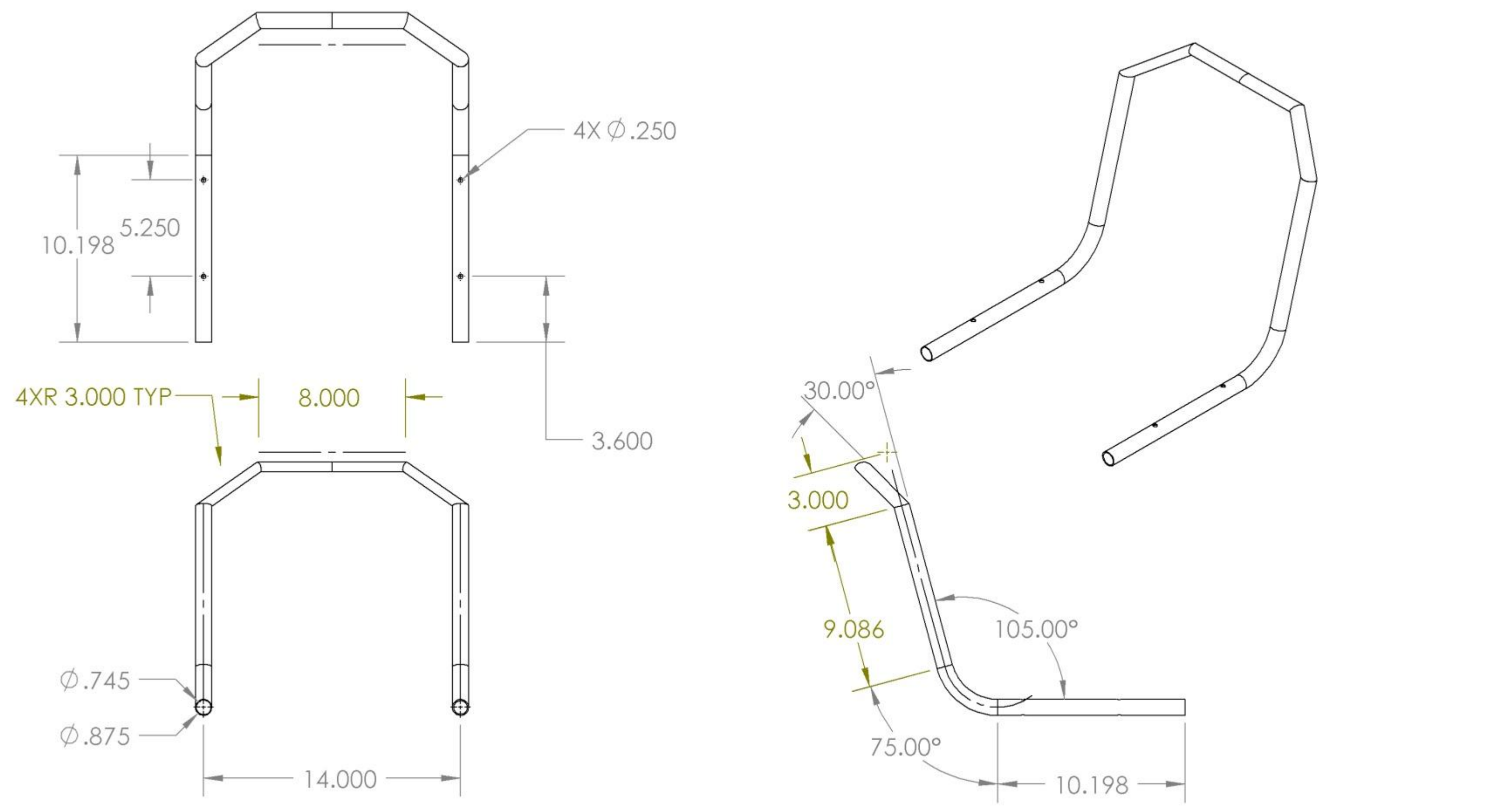
PROPRIETARY AND CONFIDENTIAL

THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

TITLE: SEAT FRAME ASSEMBLY

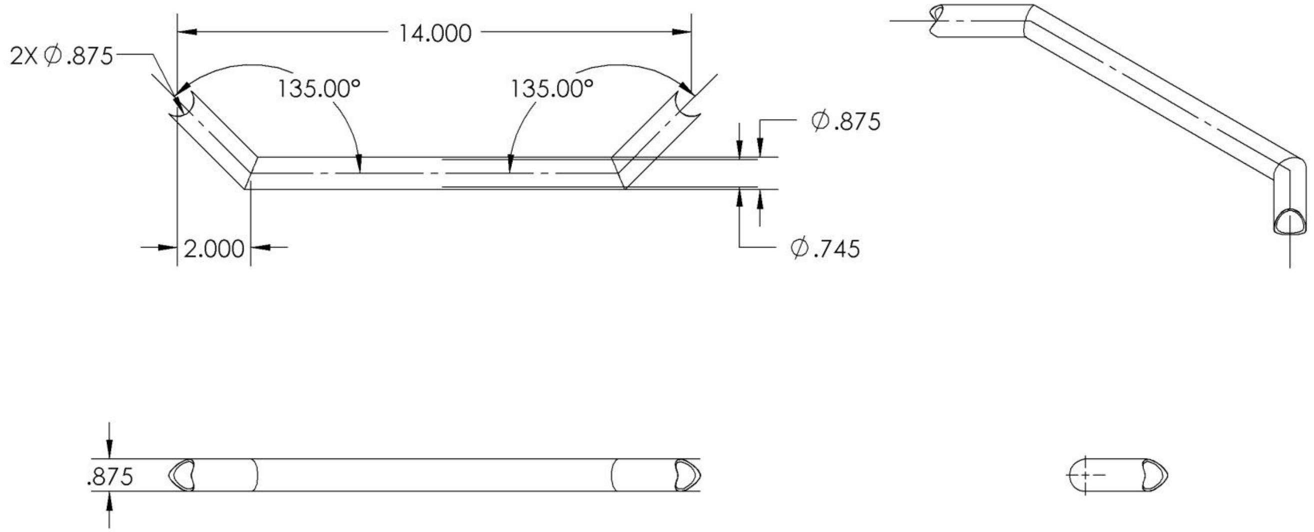
SIZE	DWG. NO.	REV
A	400A	

SCALE: 1:8 WEIGHT: SHEET 1 OF 1



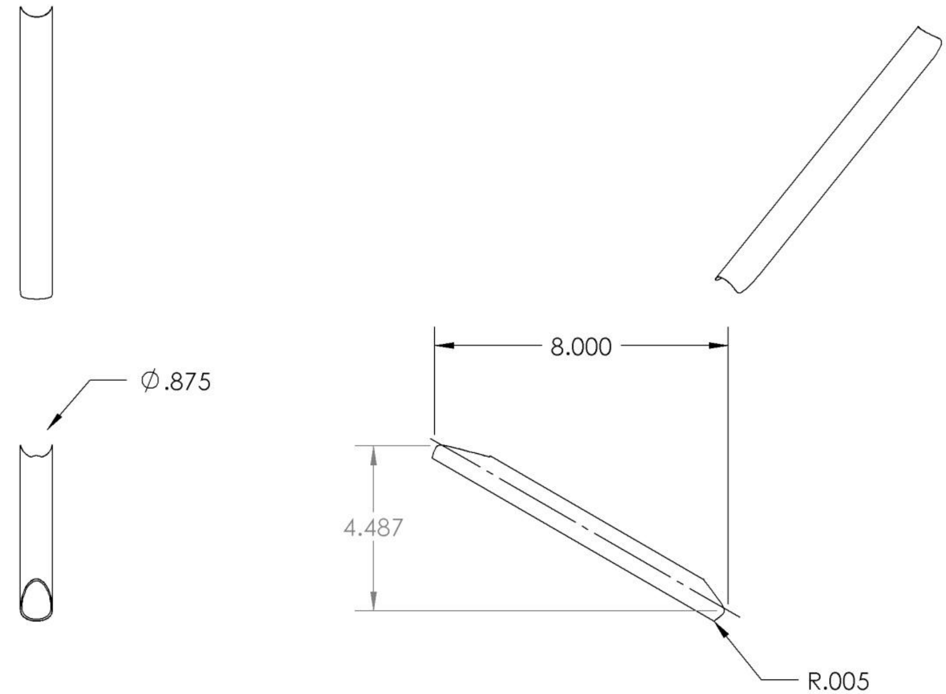
		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE: SEAT FRAME
			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL 6061-T6 Aluminum	COMMENTS: 7/8" 6061-T6 Tubing Wall Thickness = 0.065			SIZE A DWG. NO. 401 REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:8 WEIGHT: SHEET 1 OF 1

5 4 3 2 1



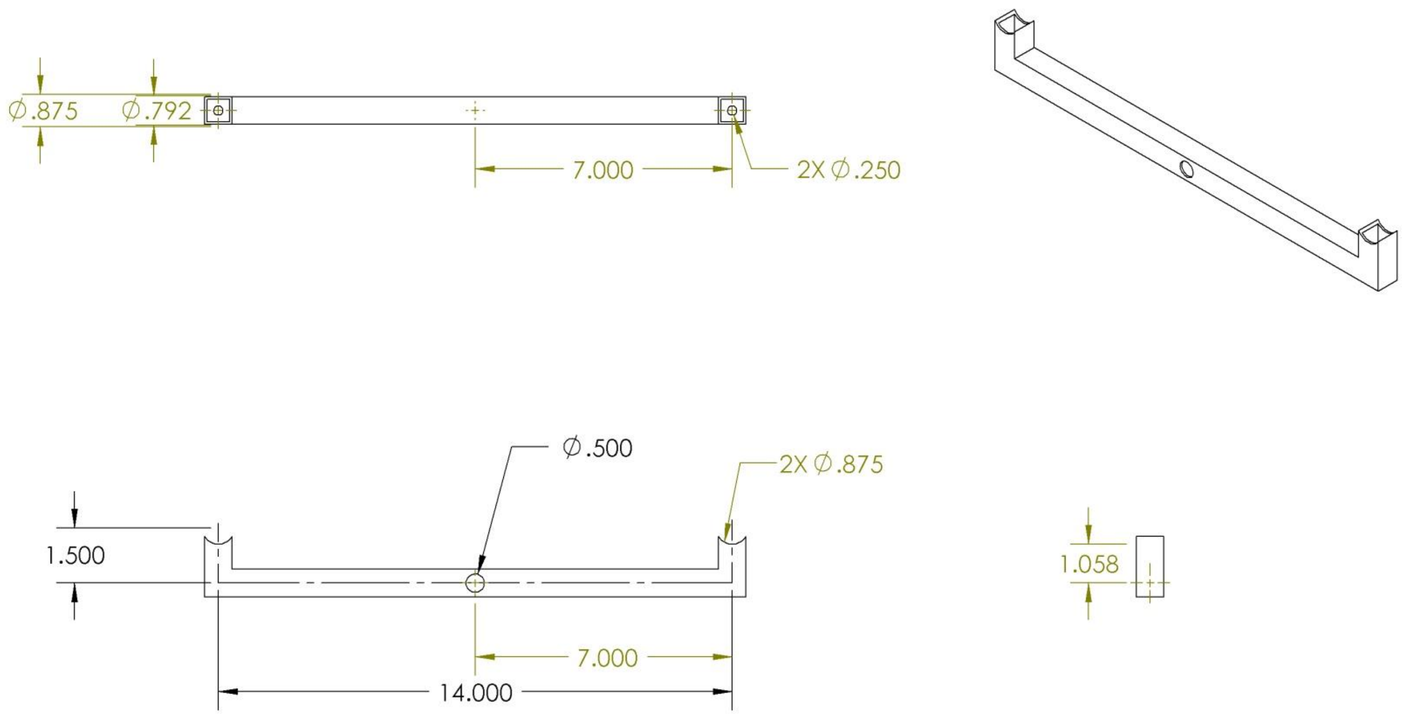
		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE: BACK SUPPORT
			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL 6061-T6 Aluminum	COMMENTS: 7/8" 6061-T6 Tubing Wall Thickness: 0.065			SIZE A DWG. NO. 402 REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:4 WEIGHT: SHEET 1 OF 1

5 4 3 2 1



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			
			CHECKED			TITLE: SIDE BAR
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL 6061-T6 Aluminum	COMMENTS: 7/8" 6061-T6 Tubing Wall Thickness: 0.065			SIZE A DWG. NO. 403 REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:4 WEIGHT: SHEET 1 OF 1

5 4 3 2 1



UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
4130 Chromoly Steel

FINISH

DO NOT SCALE DRAWING

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

COMMENTS:
7/8" 4130 Steel Tubing
Wall Thickness: 0.083

NEXT ASSY | USED ON

APPLICATION

TITLE: Bottom Support Bar

SIZE A | DWG. NO. 404 | REV

SCALE: 1:4 | WEIGHT: | SHEET 1 OF 1

5 4 3 2 1

Appendix D: Preliminary Analyses

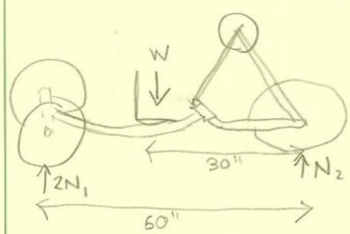
Appendix D-1
overall cycle Statics

1/2

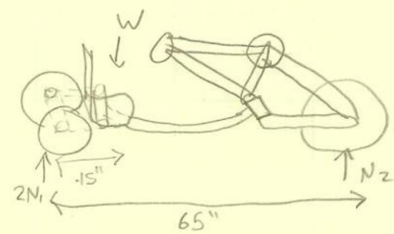
Change of Traction Calculation

Need: Weight & Dimensions

Original



Modified



Weight ≈ 50lb bike + 150lb man

$N_1 = 60\,lb_f$ each tire (rear)
$N_2 = 80\,lb_f$

$N_1 = 76.9\,lb_f$ on each tire (rear)
$N_2 = 46.2\,lb_f$

Moving seat back and extending frame causes the normal force on the driving wheel to decrease by almost 50%.

Assuming: $\mu_s = .75$ (rubber on asphault)

Old Traction Force

$F_t = \mu_s N$

$F_{t_0} = 60\,lb_f$

Modified Traction Force

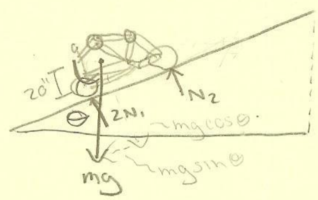
$F_t = \mu_s N$

$F_t = 35\,lb_f$

D-2 | | | 2/2

Uphill climb (Gear ratio test)

Assumes Symmetric bike design, can simplify as 2-D problem.



θ Dependent Normal Forces

$$mg\cos\theta = 2N_1 + N_2$$

$$mg\sin\theta < \mu_s N_2$$

$$N_2 = \frac{15\ mg\cos\theta - 20mg\sin\theta}{65}$$

$$N_2 = mg(.23\cos\theta - .31\sin\theta)$$

$$mg\sin\theta < \mu_s mg(.23\cos\theta - .31\sin\theta)$$

$\mu_s \approx .75$ (rubber on asphalt)

$$\sin\theta < .17\cos\theta - .23\sin\theta$$

$$1.23\sin\theta < .17\cos\theta$$

$$\tan\theta < .17/1.23$$

$$\tan\theta < .13 \quad \text{(13\% grade)}$$

Comments:

The point at which the wheel begins to slip is at 13% grade, which is steep. Moving the seat back causes the 15" mg cosθ term to decrease, and moving the seat up causes the 20mg sinθ to increase. Lengthening the frame causes the denominator to increases. All of these adjustments cause the N_2 value and thus the amount of traction to decrease. The original frame can climb approximately a 30% grade (if the rider is powerful enough).

D-3 Drivetrain Analysis 1/5

Problem: Given a known hand force and foot force, determine the final drive ratio required to climb a given grade hill.

- Compare to lowest gear ratio present now.
- Enter equations in excel so that variables can be changed to show
  a) the effect of moving center of gravity (CG)
  b) determine what hand and foot crank and sprocket length/diameters are required.

Sample calculation based on the following values:

$M_{cyc} = 50$ lbm — mass of cycle

$M_{rider} = 150$ lbm — mass of rider

$X_{cg} = 20$ in — horizontal coordinate of CG

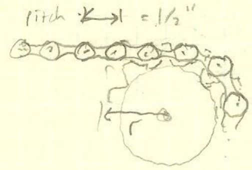
$y_{cg} = 24$ in — vertical coord. of CG

$r_1 = 2.546$ in, $r_2 = 1.910$ in — sprocket radii, see next page

$r_3 =$ unknown, $r_4 =$ unknown — solve for $\frac{r_4}{r_3}$

WB = 65 in. — wheelbase

determination of sprocket radius

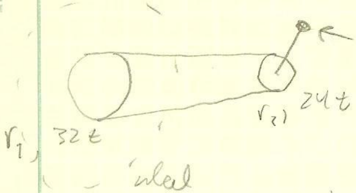


$r_1 \rightarrow$ 32 teeth w/ $\frac{1}{2}$ in pitch

$2\pi r_1 = 32 \cdot \frac{1}{2}"$

$r_1 = 2.546$ in

currently, the low gear



$r_2 \rightarrow$ 24 tooth sprocket

$r_2 = 1.910$ in

- grade = 15%

$\theta = \tan^{-1}(0.15)$

$\theta = 8.5°$

$D = 24"$ wheel diameter

$F_{hand} = 40$ lbf total force applied by hands

$F_{feet} = 50$ lbf total force applied by feet

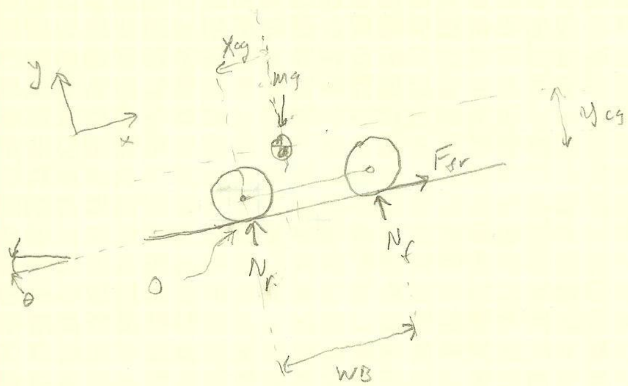
$\mu_s = 0.8$ - approximate coefficient of static friction between rubber & asphalt

$l_h = 7$ in - hand crank length

$l_f = 6$ in - foot crank length

D-5 3/5

Static cycle analysis 2: Determine maximum force



$M = M_{cyc} + M_{rider}$

$M = 200 \text{ lbm}$

x_{cg}, y_{cg} } variables to study effects on F_{fr}

$\Sigma M_O = 0$

$N_f \cdot WB + mg\sin\theta\, y_{cg} - mg\cos\theta\, x_{cg} = 0$

$$N_f = \frac{mg\cos\theta\, x_{cg} - mg\sin\theta\, y_{cg}}{WB}$$ } choose $x_{cg} = 15''$, $y_{cg} = 24''$

$$N_f = \left(\frac{200}{32.17}\text{slug} \cdot 32.17\frac{ft}{s^2}\right)\left[\cos(8.5)\left(\frac{20}{12}\right)ft - \sin 8.5\left(\frac{24}{12}ft\right)\right]\frac{1}{65/12\, ft}$$

$N_f = 50 \text{ lbf}$

$\Sigma F_x = 0$

$F_{fr} - mg\sin\theta = 0$

$F_{fr} = mg\sin\theta$

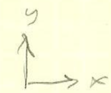
$\Sigma F_y = 0$

$mg\cos\theta - N_r - N_f = 0$

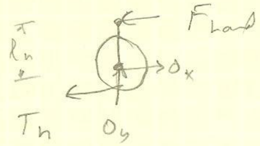
$N_r = 150 \text{ lbf}$

$F_{fr} \le \mu_s N_{fr}$

$F_{fr_{max}} = (0.8)\, 50 \text{ lbf} = 40 \text{ lbf}$



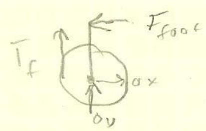
hand FBD



$$\Sigma M_o = 0$$

$$F_h l_h - T_h r_4 = 0 \quad (1)$$

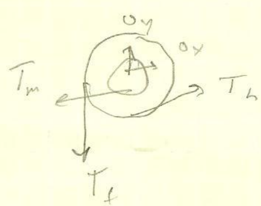
Foot FBD



$$\Sigma M_o = 0$$

$$F_{foot} l_f - T_{foot} r_4 = 0 \quad (2)$$

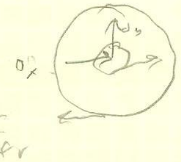
intermediate FBD



$$\Sigma M_o = 0$$

$$T_h r_3 + T_f r_3 - T_m r_2 = 0 \quad (3)$$

wheel FBD



$$\Sigma M_o = 0$$

$$T_m r_1 - F_{fr}\left(D/2\right) = 0 \quad (4)$$

use eqns 1-4 solve for $\frac{r_4}{r_3}$

D-7 5/5

$$F_h l_h - T_h r_4 + F_f l_f - T_f r_4 = 0$$

① + ② $$F_h l_h + F_f l_f - r_4 (T_h + T_f) = 0$$

$$r_4 = \frac{F_h l_h + F_f l_f}{T_h + T_f}$$

③ $$T_h r_3 + T_f r_3 - T_m r_2 = 0$$

$$r_3 = \frac{T_{main}\, r_2}{T_h + T_f}$$

from previous calc: $$T_{main} = \frac{mg \sin\theta\, D/2}{r_1}$$

$$\Rightarrow \frac{r_4}{r_3} = \frac{F_h l_h + F_f l_f}{(T_h + T_f)} \cdot \frac{r_1 (T_h + T_f)}{mg \sin\theta\, \frac{D}{2} \cdot r_2}$$

$$\frac{r_4}{r_3} = \frac{(F_h l_h + F_f l_f) r_1}{mg \sin\theta \frac{D}{2} \cdot r_2}$$

$$\frac{r_4}{r_3} = \frac{\left[(40\,lbf)\left(\frac{7}{12}\right)ft + 30\,lbf\left(\frac{9}{12}\right)ft\right]}{200\,lbf\,(\sin 8.5)\,ft} \cdot \frac{2.546\ in}{1.910\ in}$$

$$\boxed{\frac{r_4}{r_3} = 2.18}$$ ⇒ ratio of hand/foot input & output sprockets

Components of Drivetrain

Hand & Foot Independent Motion

DaVinci Tandem's ICS Drivetrain...

Hand Crank

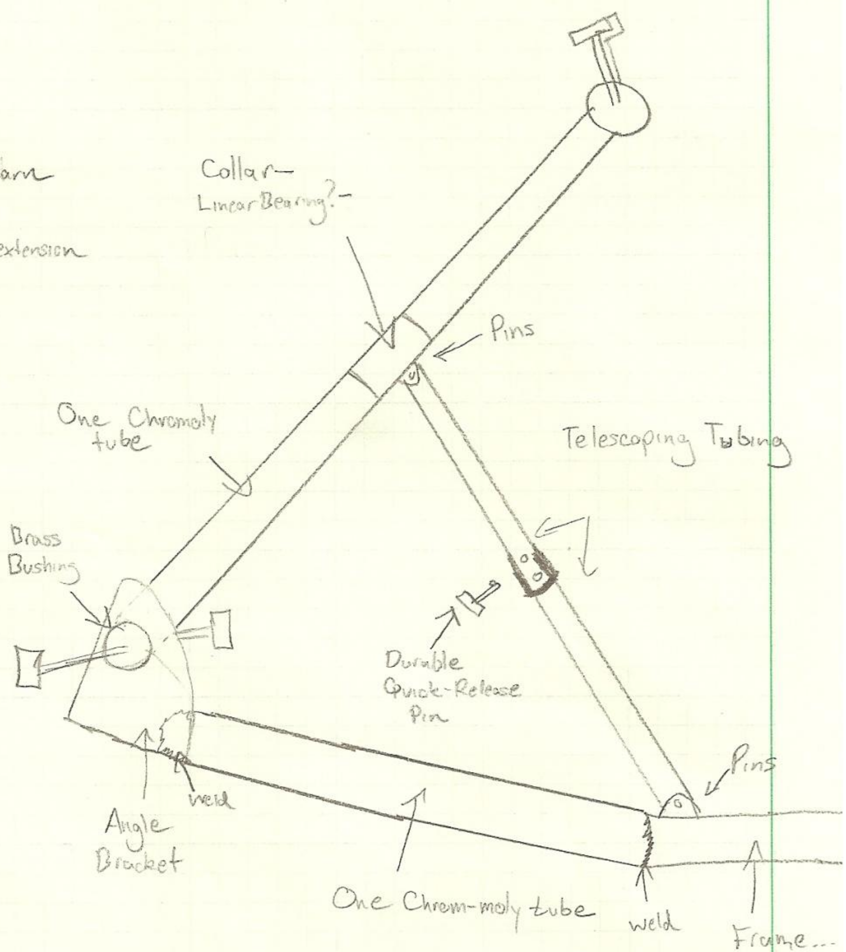
One Crankset
Two Custom Handle Bars
Grips
Bearings
Bolts

Foot Crank

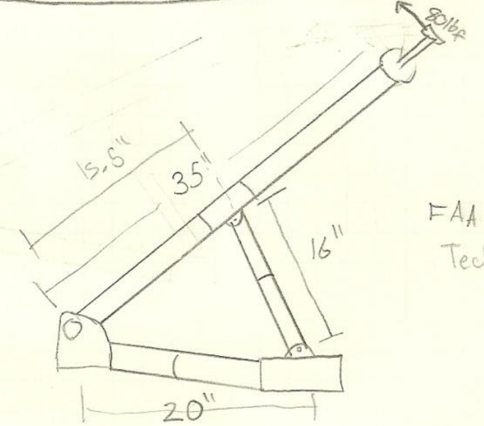
Crankset
1 Chainring w/ crankarm
Cast Molding Kit
Extra metal for foot extension
 - Bolts

Other Material

Rear Wheel
Cassette
Rear/Front Deraileur
Chain
Chain Guard Tube
Idler Guides



Drivetrain Beam Deflection

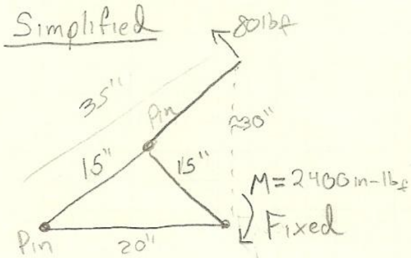


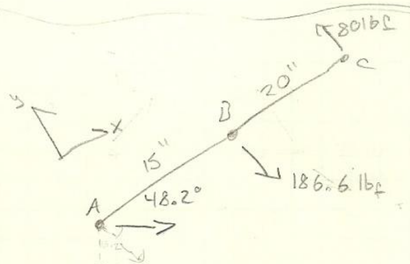
Mainly worried about deflection in the 35" long bar.

Max Arm Strength 80lbf

FAA William J. Hughes Tech. Center

Simplified





$\circlearrowleft + \Sigma M_A = 80lb_f(35") - B(15") = 0$

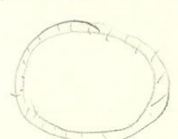
$B = 186.6 lb_f$ tension

$A \approx 106$ lbf left over

−79.5 lbf compression

−71.0 lbf upward on bar

Tube Cross Section



OD = 1.75"

ID < 1.65"

Thickness > .05"

$I = \frac{\pi}{64}(OD^4 - ID^4)$

$I = .0965"^4$

Chromoly Tubing

$E = 29 \times 10^6$ psi

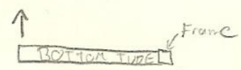
$\rho = .283$ lbf/in.³

Tube Weight

≈ 6.05 lbf

Deflection

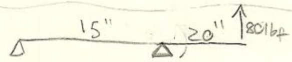
BOTTOM



$y_{max} = \frac{Fl^3}{3EI} = \frac{71lb_f(20")}{3(29\times10^6 psi)(.0965"^4)}$

$y_{max} = .0002"$

TOP TUBE



$y_c = \frac{Fa^2}{3EI}(l+a) = \frac{80lb_f(20")^2}{3EI}(35")$

$y_c = .133"$

Deflects ≈

TOPS 35502

Gear Ratios

Bicycle Size Tires

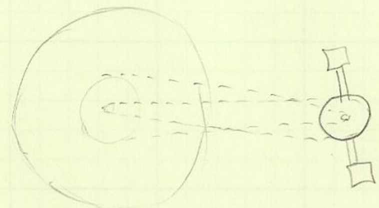
20" – 22" – 24" – 26"

Cassette Size

9 speed – ≈ 11–34T
11–32T

8 speed – ≈ 11–32T
11–30T
11–30T

7 speed – 11–28T
12–32T



Low Gear
≈ .66 (22:34)

High Gear
≈ 4.0 (44:11)

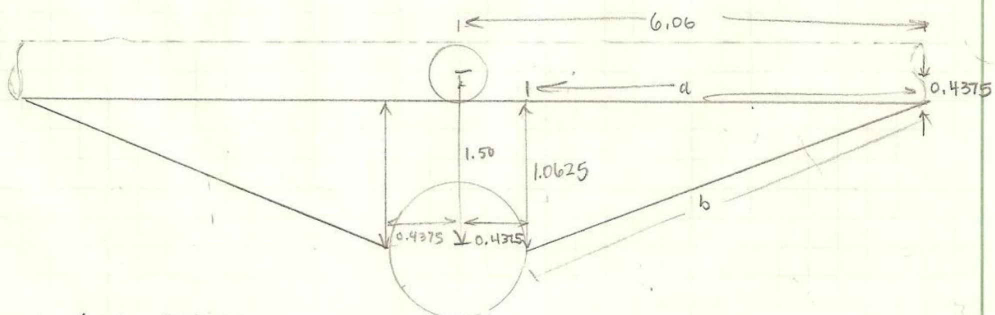
3 speed Front Chainring

Typical Sizes – 42/32/22
48/38/28 ??
44/32/22

At 90 rpm cadence
Back wheel is spinning at 360 rpm, with 26" wheel, this translates to ≈ 27.8 mph

Hand & Feet Combined (150 lbf total force), We expect about an available +130 ft-lb of torque in low gear...

UNTILTED CALCULATION OF SPRING LENGTH. (UNITS: INCHES)



$a = 6.06 - 0.4375$

$= 5.6225$ in

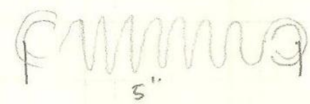
$b = \sqrt{1.0625^2 + a^2}$

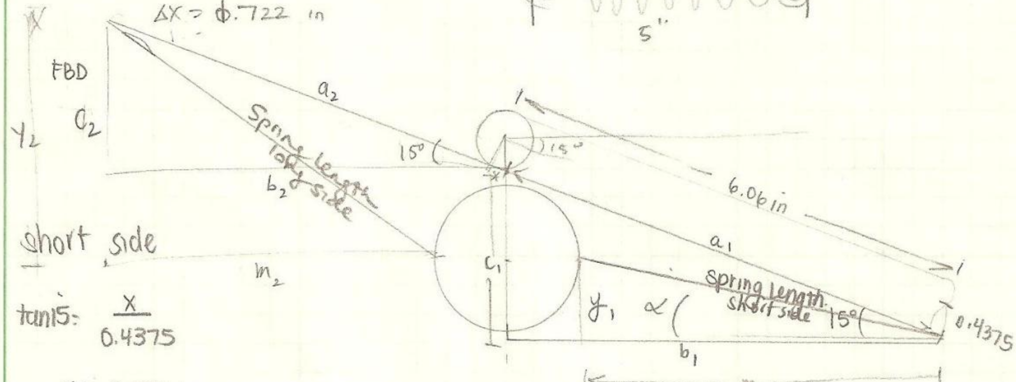
$= 5.722$ in

$\Delta X = 5.722 - 4.''$

$\Delta X = \phi.722$ in

ASSUME ORIGINAL SPRING LENGTH ~~IS 5" OVERALL.~~ 4" LENGTH INSIDE ENDS





short side

$\tan 15 = \frac{x}{0.4375}$

$x = 0.1172$ in

$a_1 = 6.06 - x = 5.9428$ in

$c_1 = \sqrt{a^2 - m^2}$

$= \sqrt{5.9428^2 - 5.3028^2}$

$c_1 = 2.683$ in

$\cos 15 = \frac{b_1}{a_1}$

$b_1 = 5.740$ in

$y_1 = c_1 - 1.50$

$= 1.183$ in

$m_1 = b_1 - 0.4375$

$= 5.740 - 0.4375$

$m_1 = 5.3028$ in

$\alpha = \tan^{-1}\left(\frac{y_1}{m_1}\right)$

$\alpha = 12.576°$

$\text{spring length}_{short} = \sqrt{y^2 + m^2}$

$= \sqrt{1.183^2 + 5.3028^2}$

$= 5.433$

change in length from original

$\Delta X_1 = 5.433 - 4$

$= ~~0.433~~$ in 1.433.

long side

$a_2 = 6.06 + x$

$= 6.1772 \text{ in}$

$\cos 15 = \frac{b_2}{a_2}$

$b_2 = 5.9667 \text{ in}$

$m_2 = b_2 - 0.4375$

$m_2 = 5.529 \text{ in}$

$c_2 = \sqrt{a_2^2 - b_2^2}$

$= \sqrt{6.1772^2 - 5.9667^2}$

$= 1.5988 \text{ in}$

$y_2 = c_2 + (1.50 - 0.4375)$

$= 1.5988 + (1.50 - 0.4375)$

$= 2.6613 \text{ in}$

spring length long $= \sqrt{y_2^2 + m_2^2}$

$= \sqrt{2.6613^2 + 5.529^2}$

$= 6.136 \text{ in}$

$\beta = \tan^{-1}\left(\frac{y_2}{m_2}\right)$

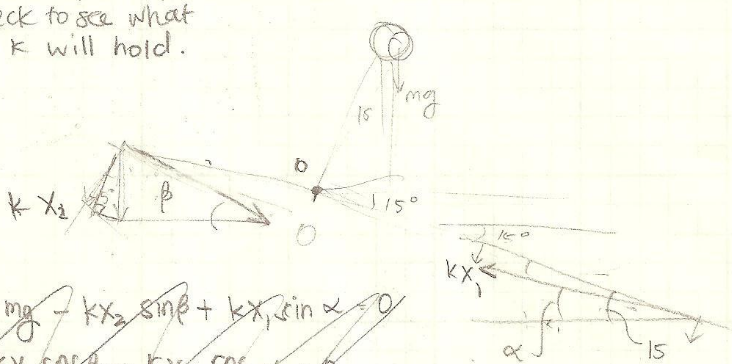
$= 25.703$

change in length from original

$= 6.136 - 4$

$\Delta x_2 =$ ~~2.1362 in~~ 2.136

check to see what k will hold.



~~$\Sigma F_y = mg - kx_2 \sin\beta + kx_1 \sin\alpha = 0$~~

~~$\Sigma F_x = kx_2 \cos\beta - kx_1 \cos\alpha = 0$~~

$\Sigma M_O = (kx_2 \sin\beta)(6.06)\cos 15° - mg(1.50 \sin 15) - kx_1 \sin(15 - \alpha)(6.06) = 0$

$(6.06)k(2.1362)(\sin(25.703))\cos 15° - 160(1.50)(\sin 15) - k(0.433)\sin(15 - 12.56)(6.06)$

$(2.384)k - 62.117 - (0.11)k = 0$

~~k = 20.71~~

$10.845 - 62.117 \; 0.735 \; k =$

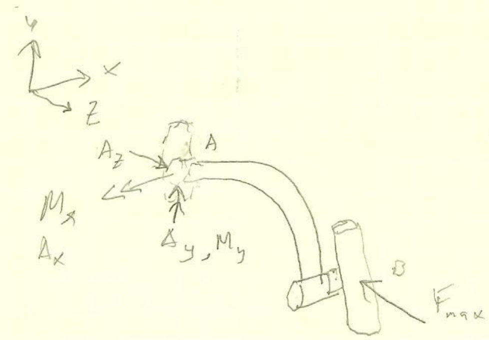
Part # 94135K33

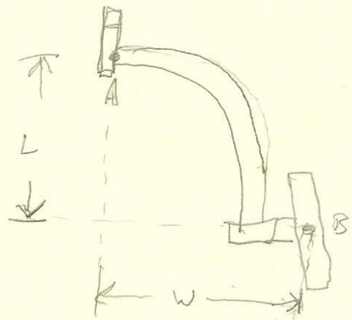
Extension spring of 5.24 ... k = 11.29 lb/in

should be 4" overall length

Hand pedal statics analysis

FBD





Find forces/moments at Joint A

$$\sum M_{y\,axis} = 0$$

$$F_{max} W + M_y = 0 \Rightarrow M_y = -F_{max} W$$

$$\sum M_{x\,axis} = 0$$

$$F_{max} L + M_x = 0 \qquad M_x = -F_{max} L$$

~~$\sum F_x = 0$~~ ~~$\sum F_y = 0$~~ $\sum F_z = 0 \Rightarrow F_{max} = A_z$

$$M_{max} = \sqrt{M_x^2 + M_y^2}$$

$$= \sqrt{F_{max}^2 L^2 + F_{max}^2 W^2}$$

$$M_{max} = F_{max}\sqrt{L^2 + W^2}$$

Find • the total deflection of the hand pedal.
• Safety factor against yield

given: • 6061-T6 aluminum tube 1" OD, 0.065 wall
• $F_{max} = 100$ lbf
• $\omega = 6.5$ inches
• $L = 7$ inches

$S_y \approx 40{,}000$ psi (rough estimate)
$E \approx 10$ Msi
$G \approx 3.9$ Msi

assume: ignore shear stress due to A_z, only from torsion

stress at A due to M_y

$$\sigma_z = \frac{M_y z}{I_z}$$

$$I_z = \frac{\pi}{64}\left(D_o^4 - D_i^4\right)$$

$$= \frac{\pi}{64}\left(1.0^4 - 0.87^4\right) in$$

$$I_z = 0.02097 \text{ in}^4$$

$M_y = -F_{max} L = -100 \text{ lbf} \cdot 7 \text{ in}$

$M_y = -700$ inlbf

$z = 0.5$ in

$$\Rightarrow \sigma_z = \frac{-700 \text{ inlbf} (0.5 \text{in})}{0.02097 \text{ in}^4}$$

$\sigma_z = 16{,}691$ psi

3/4

$\tau = \frac{TR}{J}$ $\qquad T = M_x = F_{max} L$

$T = 100\,lbf \cdot 7\,in$

$T = 700\,in\,lbf$

$R = 0.5\,in$

$J = I_z + I_y = \frac{\pi}{32}(D^4 - d^4)$

$= 0.04194\ in^4$

$\tau = \frac{700\,in\,lbf \cdot 0.5\,in}{0.04194\,in^4}$

$\tau = 8{,}345\ psi$

$\Rightarrow \tau_{max} = \sqrt{\left(\frac{\sigma_z}{2}\right)^2 + \tau_{yz}^2}$

$= \sqrt{\left(\frac{16{,}691}{2}\right)^2 + (8345)^2}$

$\tau_{max} = 11{,}802\ psi$

$\tau_{max} = \frac{S_y}{2n}$ $\qquad$ (5-3) shigley

$n = \frac{40{,}000\ psi}{2 \cdot 11{,}802\ psi}$

$\boxed{n = 1.7}$

deflection due to M_x (w_1)

$W_1 \approx \phi L$ $\qquad l = 6.5\,in$, $J = 0.04194\,in^4$

$G = 3.9\,msi$

$w_1 = \frac{Tl(L)}{JG} = \frac{700\,in\,lbf\ 6.5\,in}{(0.04194\,in^4)(3.9\,msi)} \cdot (7\,in)$

$w_1 = 0.0278\ in$

Deflection due to M_y (cantilever beam w/ end load)

$$z_{max} = w_2 = \frac{Fl^3}{3EI}$$

$l = 6.5\ in$

$F = 100\ lbf$

$E = 10\ msi$

$I = 0.02097\ in^4$

$$w_2 = \frac{100\ lbf \cdot (6.5\ in)^3}{3(10\ msi)(0.02097\ in^4)}$$

$$w_2 = 0.0437\ in$$

$$w_t = w_1 + w_2 = 0.0278\ in + 0.0437\ in$$

$$w_t = 0.0715\ in$$

Conclusion: $n = 1.7$ is acceptable for our application

$w = 0.0715\ in$ is acceptable deflection under the worst case load.

Appendix E: Design Verification Plan

DESIGN VERIFICATION PLAN AND REPORT

CUSTOMER: Scott Davis
TEAM: Tetrasource: Hand
REPORT DATE:
COMPONENT / ASSEMBLY: HandFoot Cycle
DEPT.
PLAN ORIGINATOR:
MANAGER:
REPORTING ENGINEER:

TEST PLAN

TEST REPORT

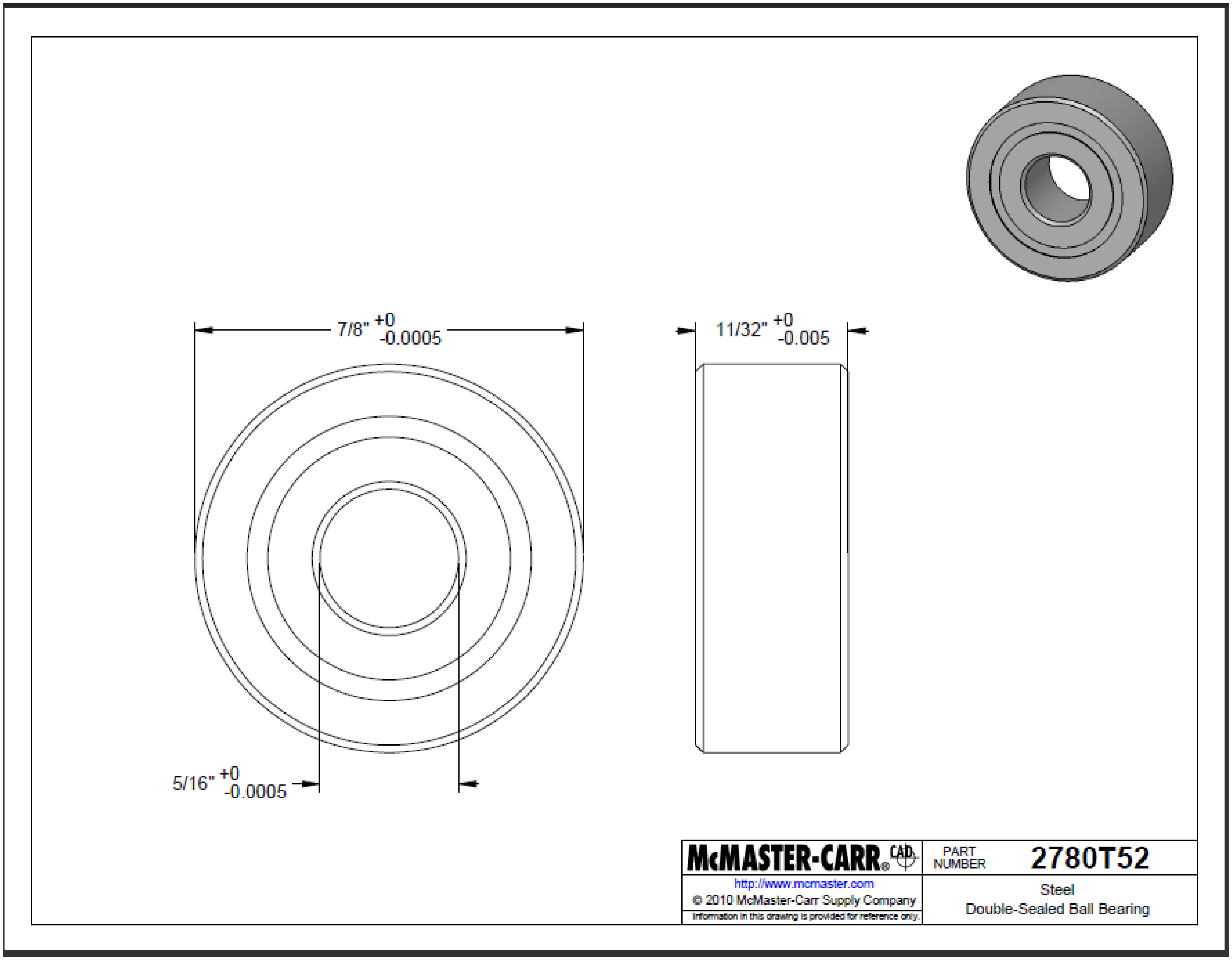
Item	Test Description	Acceptance Criteria	Test	TIMING		TEST RESULTS			NOTES
				Start date	Finish date	Test Result	Quantity Pass	Quantity Fail	
1	Chain Tension Test- Flex driving chain when installed on the bike to check for proper tension.	Less than .25" of slack in the chain.	Parker	9/15/2010	11/30/2010	Acceptable	X	-	
2	Derailer Test- While riding trike, run through all the gears to make sure there is smooth transition.	No 'sudden' transitioning between gears, and no slipping or derailer 'confusion'.	Spencer	10/30/2010	11/30/2010	Acceptable	X	-	
3	Gear Ratio Test- While riding trike, run through gears to ensure effort required is not over exertion.	No more than 50 pounds of force total required to pedal bike from a stop.	Kevin	10/30/2010	11/15/2010	Good	X	-	
4	Derailer Tension Test- When installed, check tension in derailer cable to ensure proper installation.	Cable tensioned to the manufacturer's recommended specification.	Spencer	10/15/2010	11/1/2010	Good	X	-	
5	Brake Test- Accelerate bike to 20mph and pull brake with an adequate braking force to test stopping distance.	At 20mph, the bike stops within 20 feet.	Kevin	10/30/2010	11/15/2010	Good	X	-	
6	Brake Squeeze Test- Pull brake lever and inspect caliper 'reaction' distance.	At a complete squeeze, caliper will be fully engaged to wheel. Wheel will be unable to move when given an adequate amount of torque.	Spencer	10/30/2010	11/30/2010	Good	X	-	
7	Brake Tension Test- Flex brake cable to check tension.	An adequate amount of force required to create any slack in the brake cable.	Spencer	10/30/2010	11/30/2010	Good	X	-	
8	Turn Radius- Turn bike at given seat angle of 15 degrees and measure turning radius.	Turning radius should be less than 9 ft.	Kevin	10/30/2010	11/30/2010	Acceptable	X	-	Turn radius at 15 degrees of lean is about 10 feet, however more angle is possible so the minimum radius is_____
9	Seat Test- Sit in seat and inspect for long-term comfortability.	Seat is comfortable for rides longer than one hour of use.	Marissa	9/15/2010	11/30/2010	Okay	X	-	
10	Stability Test- Accelerate bike to 15-20mph and make several turns to	Bike does not tip if taking a street corner at 15 mph.	Kevin	10/30/2010	11/30/2010	Good	X	-	
11	Noise Test- Accelerate bike to maximum speed of 20mph and listen for excess/abnormal noise.	Bike does not create any noise other than that of normal bicycle operation.	Parker	10/15/2010	11/30/2010	Okay	X	-	Excessive noise from Delrin idlers noted. Possibly upgrade idlers to improve this
12	Frame Weld Break Test- Measure angle of deflection at each frame	Deflection causing maximum deflection in frame of more than .25" is unacceptable.	Kevin	9/15/2010	11/15/2010	Acceptable	X	-	
13	Steer Triangle Strength Test- Ride Bike and test extreme angles to ensure steer triangle strength.	Seat at extreme angles does not cause the triangle to flex or bend.	Spencer	10/1/2010	10/30/2010	Poor	-	X	Change triangle and extend steer rod to avoid triangle failure.

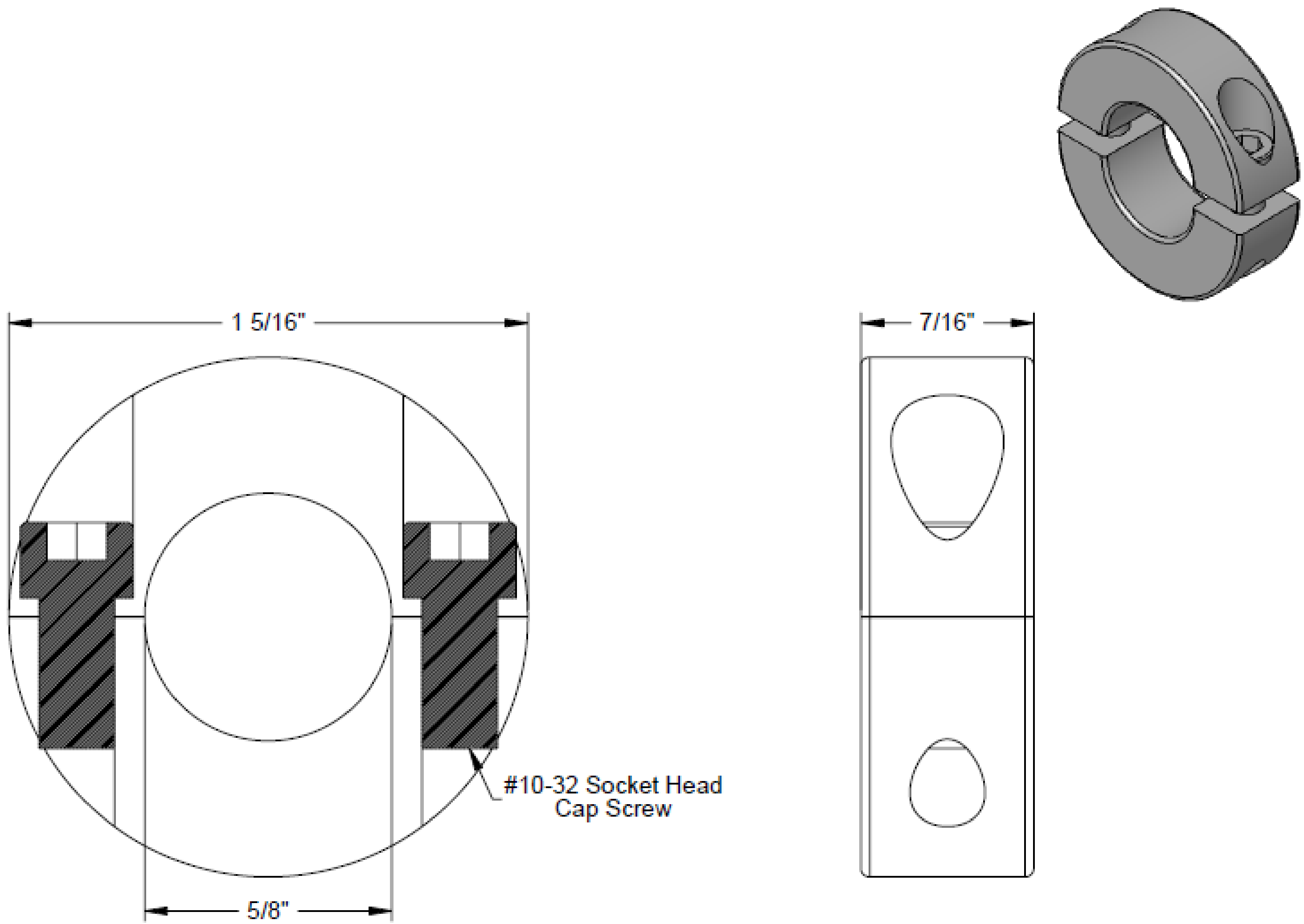
Appendix F: Detailed Cost Analysis

	Bill of Materials				
Subsystem	**Part description**	**qty**	**unit cost**	**total cost**	**source**
Brakes	Avid BB5 Disc Brake kit	1	$100.00	$100	Utah Trikes.com
	Dual pull brake lever	1	$19.95	$20.0	Utah Trikes.com
	Longer Front Brake Cable	2	$7.99	$15.98	Art's Cyclery
	Longer Front Brake Housing	20	$1.29	$25.80	Art's Cyclery
Drivetrain	Cassette	1	*	↓	Art's Cyclery
	Cranksets and Chainrings	3	*		Art's Cyclery
	Rear Derailleur	1	*		Art's Cyclery
	Rear Shifter with Cable and Housing	1	*		Art's Cyclery
	Square Mount Bottom Brackets	2	*	**$306.58**	Art's Cyclery
	Chain	3		↓	Amazon
	Front Derailleur				Amazon
	Foot Pedals			**$76.02**	Amazon
	Delrin Idler and Bearing	6	$11.95	$71.70	Utah Trikes.com
	DaVinci Independent Drive System	1	$462.00	$462.00	DaVinci Designs
	Housing	1	$15.00	$15.00	
	Idler Spacers	4	$0.95	$3.80	
	Longer Rear Shifter Cable	1	$5.99	$5.99	Art's Cyclery
	Longer Rear Shifter Housing	10	$1.29	$12.90	Art's Cyclery
	Aluminum Bar Stock	1	$5.25	$5.25	Aircraft Spruce.com
	Hand Pedal Bearing	2	$10.71	$21.42	McMaster-Carr.com
	Hand Pedal Tubing	1	$3.30	$3.30	Aircraft Spruce.com
	Hand Pedal Tubing	4	$3.15	$12.60	Aircraft Spruce.com
	Hand Pedal Tubing	1	$6.95	$6.95	Aircraft Spruce.com
	Leg Supports/Cleats	2	$32.50	$65.00	
	Plaster Caste Mould	1	$49.46	$49.46	Orthotape.com
Frame	Cross Member Tubing	6	$3.75	$22.50	Aircraft Spruce.com
	Cross Member Junction Tubing	3	$4.50	$13.50	Aircraft Spruce.com
	Front Frame Tubing	7	$7.88	$55.16	Aircraft Spruce.com
	Main Tubing	3	$7.88	$23.64	Aircraft Spruce.com
	Rear Stay Material	1	$8.50	$8.50	existing part + fabrication
Miscellaneous Material and Supplies	Frame Fixture Materials	1	$25.00	$25.00	HD, OSH,etc
	Idler Wheel Mount Material	1	$14.99	$14.99	Orchard Supply Hardware
	Miscellaneous Materials and Abrasives	1	$46.98	$46.98	K-119 tools
	Welding Brushes	4	$2.47	$9.88	Home Depot
	Ideler Wheels and Hardware	6	$0.88	$5.28	Utah Trikes.com
	Hardware (nuts/bolts/washers)	1	$7.85	$7.85	ACE Hardware
	Hardware (nuts/bolts etc.)	1	$5.00	$5.00	ACE Hardware
	Gentry Tube Bending Labor	2	$15.00	$30.00	Gentry Welding and Fab
	Paint and finish materials	1	$43.55	$43.55	FinishMaster, SSF

Subsystem	Part description	qty	unit cost	total cost	source
Seat	Hardware	2	$0.69	$1.38	ACE Hardware
	Nylon Mesh	1	$173.95	$173.95	Hostelshoppe.com
	Seat Base Square Tubing	2	$11.11	$22.22	Onlinemetals.com
	Seat Cushion Foam- sponge	2	$20.00	$40.00	CalPoly KINES dept
	Seat Cushion Foam	2	$40.00	$80.00	CalPoly KINES dept
	Seat Frame Tubing	9	$3.30	$40.90	Aircraft Spruce.com
	Seat Springs	1	$6.46	$6.46	McMaster-Carr.com
Shipping	Onlinemetals Shipping and Tax	1	$11.84	$11.84	Onlinemetals.com
	Aircraft Spruce Shipping and Tax	1	$21.07	$21.07	Aircraft Spruce.com
	McMaster-Carr Shipping and Tax	1	$8.53	$8.53	McMaster-Carr.com
	McMaster-Carr Shipping and Tax	1	$7.22	$7.22	McMaster-Carr.com
	UtahTrikes Shipping and Tax	2	$9.00	$18.00	Utah Trikes.com
	Shipping to CA from IL	1	$79.27	$79.27	UPS
	Aircraft Spruce Shipping and Tax	1	$11.34	$11.34	Aircraft Spruce.com
	McMaster-Carr Shipping and Tax	1	$6.45	$6.45	McMaster-Carr.com
Steering	Hubmount Mount Bracket Material and Steering	1	$11.58	$11.58	Orchard Supply Hardware
	Bearing Mount Material	1	$11.00	$11.00	Alan Steel & Supply Co
	Bearing Mount Screw	1	$6.40	$6.40	McMaster-Carr.com
	Rigid Shaft Key Stock	1	$2.34	$2.34	McMaster-Carr.com
	Rigid Shaft Steer Coupler	1	$22.80	$22.80	McMaster-Carr.com
	Seat Steer Rod	1	$23.00	$23.00	Alan Steel & Supply Co
	Steering Rod Bushing Mount Shaft Collar	3	$3.22	$9.66	McMaster-Carr.com
	Steer Rod Bushing	3	$1.23	$3.69	McMaster-Carr.com
	Steering Rod Shaft collar	2	$8.13	$16.26	McMaster-Carr.com
	Terratrike Hubmount kit	1	$150.00	$150.00	Utah Trikes.com
	Tie Rod Bar Material	1	$7.25	$7.25	Alan Steel & Supply Co
	Tie Rod End	4	$5.50	$22.00	Orchard Supply Hardware
	Tie Rod Screws	1	$8.18	$8.18	McMaster-Carr.com
	Vertical Steer Linkage Material	1	$17.09	$17.09	Onlinemetals.com
Wheels and Tires	Front Axle Bolt	2	$5.95	$11.90	Utah Trikes.com
	Front Tires	2	$24.95	$49.90	Utah Trikes.com
	Front Wheel Tube	2	$5.95	$11.90	Utah Trikes.com
	Stock Aluminum Wheel	2	$84.95	$169.90	Utah Trikes.com
	Rear Wheel and Hub	1	*		Art's Cyclery
	Rear Wheel Tire and Tube	1	*		Art's Cyclery
	Grand Total			**$2,675.01**	

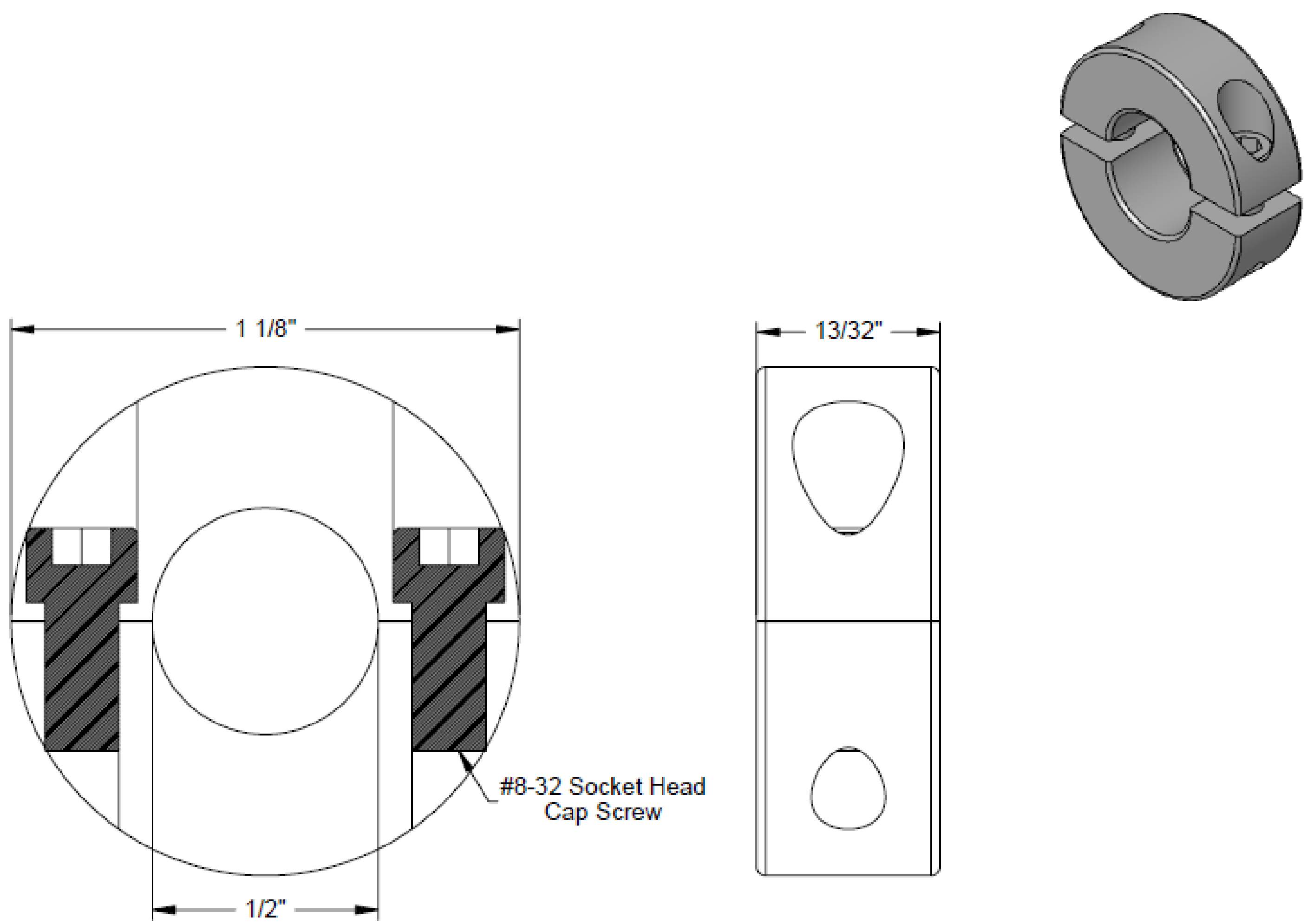
Apppendix G: Manufacturer Data Sheets





McMASTER-CARR CAD	PART NUMBER 6436K15
http://www.mcmaster.com © 2007 McMaster-Carr Supply Company	Black-Oxide Steel Two-Piece Clamp-On Shaft Collar

Unless otherwise specified, dimensions are in inches. Information in this drawing is provided for reference only.



MCMASTER-CARR CAD

PART NUMBER 6436K34

http://www.mcmaster.com

Type 303 Stainless Steel
Two-Piece Clamp-On Shaft Collar

Unless otherwise specified, dimensions are in inches. Information in this drawing is provided for reference only.

www.avidbike.com

AVID® SPECIFICATIONS

HYDRAULIC DISC BRAKES

	INTENDED USE	FINISH	ROTOR SIZES	ROTOR	TRI-ALIGN™ CALIPER POSITIONING SYSTEM™	PAD TYPE	FLUID TYPE*		PAD CONTACT-POINT ADJUSTMENT	SPLIT CLAMP DESIGN / MATCHMAKER COMPATIBLE	POWER RESERVE GEOMETRY™	TOOL-FREE PAD REPLACEMENT	AMBIDEXTROUS	DRIP-FREE BLEEDING	SPECIAL FEATURES	WEIGHT (GRAMS)
ELIXIR™ CR		Black Onyx body Tungsten Gray lever Black Onyx caliper	160 / 185 / 203 140mm rear only	G3 Clean Sweep	•	Sintered	DOT 5.1		•	•	•		•	•	TaperBore Technology Tool-free Contact and Reach Adjust Carbon Lever Available Two-piece caliper Top loading pads	385 with Aluminum blade 375 with Carbon blade
ELIXIR™ R		Mercury Silver body Tungsten Gray lever Mercury Silver caliper	160 / 185 / 203 140mm rear only	G3 Clean Sweep	•	Sintered	DOT 5.1			•	•		•	•	TaperBore Technology Tool-free Reach Adjust Carbon Lever available	375 with Aluminum blade 365 with Carbon blade
JUICY ULTIMATE™		Stealth Black White SID Blue	160 / 185 / 203 140mm rear only	G2 Clean Sweep	•	Organic	DOT 5.1		•	•	•	•	•	•	Carbon lever/reservoir cover Ti hardware	333
CODE™		Galvanized body caliper, black lever - White body, black lever	160 / 185 / 203mm	G2 Clean Sweep	•	Organic	DOT 4		•	•	•		•	•	Four pistons Three cartridge bearing lever pivot Two-piece lever with cam breakaway Up-front access reach adjustment Anchored brake pads	449
CODE™ 5		Dead Moss Gray	160 / 185 / 203mm	G2 Clean Sweep	•	Organic	DOT 4			•	•		•	•	Four pistons Anchored brake pads	447
JUICY 7™		Graphite Gray	160 / 185 / 203mm	G2 Clean Sweep	•	Sintered	DOT 5.1		•	•	•	•	•	•		396
JUICY 5™		Aero Silver	160 / 185 / 203mm	G2 Clean Sweep	•	Sintered	DOT 5.1			•	•	•	•	•		396
JUICY 3™		Satin Black	160 / 185 / 203mm	G2 Clean Sweep	•	Organic	DOT 4				•	•	•	•		404

Unless otherwise noted, weights are for front, 160mm, post mount. Includes lever, caliper and rotor. Other weights are mount-dependent. All Avid disc brakes fit standard disc hub mount. They are compatible with front post and I.S. mounts and rear I.S. mounts. * "Fluid type" refers to the fluid the brake is shipped with. Any Avid hydraulic brake works with either DOT 4 or DOT 5.1.

MECHANICAL DISC BRAKES

	INTENDED USE	FINISH	ROTOR SIZES	ROTOR	TRI-ALIGN CALIPER POSITIONING SYSTEM		PAD TYPE	CALIPER DESIGN	LEVER COMPATIBILITY	PAD ADJUSTMENT	TOOL-FREE PAD REPLACEMENT	WEIGHT (GRAMS)
BB7 MOUNTAIN		Graphite Gray	160 / 185 / 203mm	Roundagon	•		Sintered	Two-Piece	Mountain style	Dual knobs	•	329
BB7 ROAD		Platinum	160 / 185 / 203mm 140mm rear only	Roundagon	•		Sintered	Two-Piece	Road style	Dual knobs	•	329
BB5 MOUNTAIN		Satin Black	160 / 185 / 203mm	Roundagon	•		Sintered	Monoblok	Mountain style	Inboard knob only	•	335
BB5 ROAD		Platinum	160 / 185 / 203mm 140mm rear only	Roundagon	•		Sintered	Monoblok	Road style	Inboard knob only	•	335

Unless otherwise noted, weights are for front, 160mm, post mount. Includes caliper and rotor. Other weights are mount-dependent. All Avid disc brakes fit standard disc hub mount. They are compatible with front post and I.S. mounts and rear I.S. mounts.

KEY: ROAD | CROSS COUNTRY | TRAIL | ALL-MOUNTAIN | FREERIDE | DOWNHILL

LEVERS

	FINISH	SPEED DIAL®	REND ZONE™	QUICK-ADJUST BARREL ADJUSTER	AMBIDEX-TROUS	CAM SPLIT CLAMP	SPECIAL FEATURES	WEIGHT (GRAMS)
SPEED DIAL ULTIMATE	Stealth Black	•	•	•		•	CNC Sealed cartridge	159
SPEED DIAL SL	Aero Silver	•	•		•		Magnesium lever body	150
SPEED DIAL 7	Graphite Gray	•	•		•		Reach Adjust	175
FR-5	Aero Silver or Satin Black		•		•		Reach Adjust Flat ride pull	155

All Avid levers have reach adjustment. All weights per pair. All levers are compatible with mechanical disc brakes and linear-pull brakes.

RIM BRAKES

	FINISH	STAINLESS HARDWARE	PIVOT	PADS	SPECIAL FEATURES	WEIGHT (GRAMS)
SINGLE DIGIT® ULTIMATE	Stealth Black	•	Sealed Bearing	RW 2	Reversible noodle CNC Cartridge bearings	182
SINGLE DIGIT SL	Aero Silver	•	Pivot Sleeve	RW 2	Ti Hardware	165
SINGLE DIGIT 7	Graphite Gray	•	Pivot Sleeve	RW 2	Exclusive noodle boot	185
SINGLE DIGIT 5	Black	•	Pivot Sleeve	208 One-Piece	Cartridge Pad Option Available	210
SINGLE DIGIT 3 (OEM ONLY)	Black		Pivot Sleeve	One-Piece	CP steel hardware	214
SHORTY 6	Mercury Silver	•	Pivot Sleeve	Cross Road Cartridge Pads	Road Style Lever (Red, Force, Rival)	157
SHORTY 4	Mercury Silver	•	Pivot Sleeve	208 One-Piece	Road Style Lever (Red, Force, Rival)	157

All weights include mounting hardware, noodle and boot.

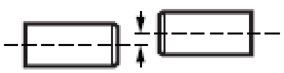
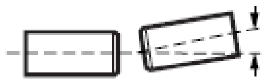
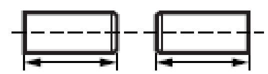
POWERED BY SRAM

Rigid Shaft Couplings

About Couplings and Keyways

Couplings connect two shafts and transfer motion from one shaft to another. They attach via cap screws, set screws, a combination of keyways and set screws, or bushings. There are two main types of couplings: rigid, which allow no shaft misalignment and flexible, which allow some misalignment. Use the charts below as a guide to select the right coupling for your application. For actual performance ratings, please see the individual coupling presentations.

For applications with shaft misalignment, these are the couplings to choose:

Parallel Shaft Misalignment	Angular Shaft Misalignment	Axial Shaft Misalignment
Couplings Best Suited for Starting, Stopping, and Reversing Motions		
Slotted Disc, Double Loop, Pinhole Disc	Beam, Double Loop	Beam, Double Loop, Pinhole Disc
Couplings Best Suited for Transmitting Torque and Power in Alternating-Motion Applications		
Tire, Gear and Sleeve	Tire, Gear and Sleeve	Tire, Multi-Flex

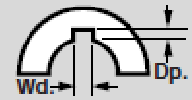
For applications that require high torque capacity, speed, or dampening capacity, these are the couplings to choose:

Torque Capacity	Speed (rpm)	Dampening Capacity
Couplings Best Suited for Starting, Stopping, and Reversing Motions		
Rigid	Bellows, Spider, Servomotor Double Disc	Double Loop, Spider
Couplings Best Suited for Transmitting Torque and Power in Primarily One Direction		
Roller Chain, Gear and Sleeve	Shear, Multi-Flex, Gear and Sleeve	Shear, Tire, Multi-Flex

Torque Capacity—Couplings are rated by the maximum torque they can carry, and sometimes by a limiting or maximum rpm. Maximum torque can be used to determine horsepower (or vice versa) with the formula:

$$hp = \frac{\text{Torque (in.-lbs.)} \times \text{rpm}}{63{,}000}$$

ANSI Keyways—Couplings with keyways give you a more secure hold and are especially good for alternating-motion applications. Keyways follow standard ANSI dimensions listed.



Keyway Dimensions

Coupling Bore	Keyway Wd. × Dp.
ANSI Inch	
5/16″ to 7/16″	3/32″ × 3/64″
1/2″ to 9/16″	1/8″ × 1/16″
5/8″ to 7/8″	3/16″ × 3/32″
15/16″ to 1 1/4″	1/4″ × 1/8″
1 5/16″ to 1 3/8″	5/16″ × 5/32″
1 7/16″ to 1 3/4″	3/8″ × 3/16″
1 13/16″ to 2 1/4″	1/2″ × 1/4″
2 5/16″ to 2 3/4″	5/8″ × 5/16″
2 13/16″ to 3 1/4″	3/4″ × 3/8″
3 5/16″ to 3 3/4″	7/8″ × 7/16″
3 13/16″ to 4″	1″ × 1/2″
ISO-DIN Metric (mm)	
10	3 × 1.4
11, 12	4 × 1.8
14, 15, 16	5 × 2.3
19, 20, 22	6 × 2.8
24, 25, 28, 30	8 × 3.3
32, 35, 38	10 × 3.3
42	12 × 3.3

Set-Screw Shaft Couplings

Without Keyway

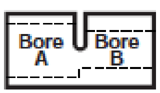
For a positive lock on your shaft, simply slide on one of these couplings and tighten the two set screws.

Couplings with ANSI keyway give you a more secure hold and are especially good for alternating-motion applications. They have standard ANSI keyway dimensions.

Aluminum—Couplings are lightweight, corrosion-resistant, Type 6061-T651 or equivalent aluminum. Set screws are alloy steel. ***Steel***—Couplings are Grade 1215 or equivalent steel. Set screws are alloy steel. ***Type 303 Stainless Steel***—Couplings and set screws are Type 303 stainless steel for excellent corrosion resistance.

				Aluminum				Steel				Type 303 Stainless Steel			
Bore	Lg.	OD	Screw Size	Max. rpm	Max. Torque, in.-lbs.		Each	Max. rpm	Max. Torque, in.-lbs.		Each	Max. rpm	Max. Torque, in.-lbs.		Each
With ANSI Keyway															
1/2"	1 1/2"	1"	1/4"-20	—	—	—	—	3450	473	6412K41	$9.98	3450	473	6099K41	$22.80
5/8"	2"	1 1/4"	5/16"-18	—	—	—	—	3450	1186	6412K42	12.24	3450	1186	6099K42	32.99
3/4"	2"	1 1/2"	5/16"-18	—	—	—	—	3450	1423	6412K43	13.84	3450	1423	6099K43	40.80
7/8"	2"	1 3/4"	5/16"-18	—	—	—	—	1740	1661	6412K44	17.95	1740	1661	6099K44	48.91
1"	3"	2"	5/16"-18	—	—	—	—	1740	3786	6412K45	22.45	1740	3786	6099K45	75.30
1 1/4"	4"	2 1/4"	3/8"-16	—	—	—	—	1740	6310	6412K47	31.10	1740	6310	6099K47	122.91
Without Keyway															
1/4"	3/4"	1/2"	10-32	2029	41	2424K11	$6.21	3450	69	6412K11	5.44	3450	43	6099K21	10.54
5/16"	1"	5/8"	10-32	2029	51	2424K12	7.03	3450	86	6412K12	6.14	3450	54	6099K22	12.19
3/8"	1"	3/4"	1/4"-20	2029	105	2424K13	7.74	3450	178	6412K13	5.04	3450	111	6099K23	12.48
1/2"	1 1/2"	1"	1/4"-20	2029	140	2424K14	8.62	3450	238	6412K14	8.44	3450	149	6099K24	15.97
5/8"	2"	1 1/4"	5/16"-18	2029	276	2424K15	11.30	3450	469	6412K15	10.56	3450	293	6099K25	22.86
3/4"	2"	1 1/2"	5/16"-18	2029	331	2424K16	12.83	3450	563	6412K16	11.92	3450	352	6099K26	28.15
7/8"	2"	1 3/4"	5/16"-18	1024	386	2424K17	16.55	1740	656	6412K17	14.05	1740	410	6099K27	33.70
1"	3"	2"	5/16"-18	1024	441	2424K18	19.07	1740	750	6412K18	15.59	1740	469	6099K28	52.83
1 1/8"	3"	2 1/8"	3/8"-16	1024	695	2424K19	27.95	1740	1181	6412K31	24.53	—	—	—	—
1 1/4"	4"	2 1/4"	3/8"-16	1024	772	2424K21	33.98	1740	1313	6412K32	25.31	—	—	—	—
1 3/8"	4 1/2"	2 1/2"	3/8"-16	1024	849	2424K22	47.67	1740	1444	6412K33	31.62	—	—	—	—
1 1/2"	4 1/2"	2 1/2"	3/8"-16	1024	926	2424K23	72.49	1740	1575	6412K34	42.79	—	—	—	—

Machinable-Bore One-Piece Clamp-On Shaft Couplings

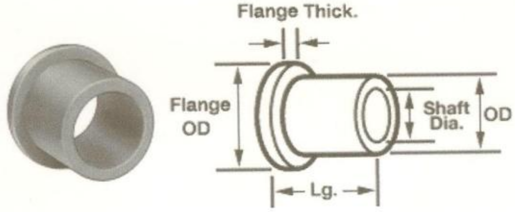


One end (Bore A) has a finished bore; the other (Bore B) can be machined to any size up to the size of Bore A to meet your exact needs. All of these clamp-on couplings offer superior holding power over set-screw couplings, plus they won't damage your shaft. Just slide them onto your shaft and tighten the four socket-head cap screws to secure. Couplings are Grade 12L14 steel. Cap screws are alloy steel.

Note: Not rated for max. rpm.

Bore (A)	Bore (B)	Lg.	OD	Working Torque, in.-lbs.	Screw Size		Each
1/2"	0.235"	1 7/8"	1 1/4"	289	8-32	3084K31	$24.20
5/8"	0.235"	2 1/4"	1 1/2"	490	10-32	3084K32	25.02
3/4"	0.235"	2 5/8"	1 3/4"	1133	1/4"-28	3084K33	32.13
7/8"	0.235"	2 7/8"	1 7/8"	1322	1/4"-28	3084K47	33.20
1"	0.360"	3"	2"	1510	1/4"-28	3084K34	33.89
1 1/8"	0.360"	3 1/4"	2 1/8"	1699	1/4"-28	3084K48	37.02
1 1/4"	0.360"	3 3/8"	2 1/4"	1888	1/4"-28	3084K35	37.89
1 3/8"	0.360"	3 5/8"	2 3/8"	2080	1/4"-28	3084K49	39.04
1 1/2"	0.485"	3 3/4"	2 1/2"	2266	1/4"-28	3084K36	40.13
1 3/4"	0.485"	4 1/2"	3"	4221	5/16"-24	3084K51	47.91
2"	0.485"	4 7/8"	3 1/4"	4825	5/16"-24	3084K52	55.98

Sleeve Bearings



Part Number: **1677K9** $1.23 Each

Material	Bronze
Bronze Type	PTFE/Oil-Lubricated SAE 841 Bronze
Type	Flanged Sleeve Bearings
For Shaft Diameter (Inside Diameter)	1/2"
Inside Diameter Tolerance	-.001" to +.000"
Outside Diameter	5/8"
Outside Diameter Tolerance	-.001" to +.000"
Flange Outside Diameter	7/8"
Flange Thickness	1/8"
Length	3/4"
Length Tolerance	±.005"
Load (P Max)	2,000
Speed (V Max)	1,200
Load at Speed (PV Max)	50,000
Temperature Range	+10° to +220° F
Specifications Met	Not Rated

UtahTrikes.com

Fall Store Hours: Mon-Fri 9-5 (MST), Sat 10-4 , Closed Sun. | 40 S Main St., Payson, UT 84651
Call or email anytime for quick response: Toll Free: 866-446-2065 | Local: 801-804-5810 | trikes@utahtrikes.com

Shopping Cart

Browse by Brand Go | Browse by Category Go | Search Products Go

Home
Trikes
Catalog
Custom Shop
Shipping
Financing
Videos
Articles
Blog
About Us

Product Category: Catalog -> Idlers   View all WizWheelz products

Idler: TerraTrike Stock Delrin Idler with Bearing

Price: $11.95

This item is currently in stock!

TerraTrike Stock Delrin Idler with Bearing - $11.95

Quantity: 1

Buy Now

UtahTrikes.com

Fall Store Hours: Mon-Fri 9-5 (MST), Sat 10-4 , Closed Sun. | 40 S Main St., Payson, UT 84651
Call or email anytime for quick response: Toll Free: 866-446-2065 | Local: 801-804-5810 | trikes@utahtrikes.com

Product Category: Catalog -> Steering Components   View all WizWheelz products

TerraTrike Hubmount Kit

Price: $149.95

This item is currently in stock!

Hubmount Upgrade Kit - $149.95

Quantity: 1

Buy Now

Do you own a TerraTrike version 3.3, 3.4, or 3.5? Are your hubmounts and bushings loose from wear and tear? Upgrade your machine by converting to the TerraTrike Tour hubmounts using