Spring 4-27-2015

Collapsible Bicycle Frame

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By

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INTRODUCTION

Motivation

There are many situations where people could choose to ride a bicycle, whether it is to go to school, to a job, to meet with friends, or just for recreational purposes. However, once people reach their destination and have a break between their trips, they are left with a bicycle with little means of storing it while they go about their day. Some people buy a bike lock so that they can secure it in a safe location, while others may just lean it against a wall or even roll it into the building with them. However, according to FBI statistics there were about 190,703 stolen bicycles in 2013 alone and bringing the bicycle in buildings takes up space and having a kick stand does not guarantee that the bicycle will remain upright; especially if it is nudged by people who are attempting to move past because of the amount of space the bicycle takes up. Traveling is also expensive already, and for those who travel by plane may wish to take the bicycle with them and not want to rent an expensive vehicle when they reach their destination. The motivation for this project is to come up with a solution so that the bicycle is secure but also compact and small so that people can bring the bicycle on a plane as carry-on, and not be an inconvenience with the bicycle weight and size.

Function Statement

A device is needed that will:

1. Function like a standard adult bicycle
2. Be able to collapse to increase storage space
3. Make the bicycle lighter for carrying
4. Be easily collapsed and extended to form the bike frame

Requirements

The device must:

1. The requirement for the bicycle frame is to have a weight of no more than 15 lbs
2. Be able to sustain a load of up to 180 lbs at the seat when bike is fully extended
3. The bicycle frame must fit in the maximum size carry-on bag listed by American Airlines standard
    a. Dimensions of 22 inches long, 14 inches wide, and 9 inches tall (http://www.aa.com/i18n/travelInformation/baggage/carryOnAllowance.jsp)
4. Must cost less to get materials and build than the $900 Dahon Dash P18 listed by Rakuten.com
5. All components must not deflect more than 1/32 of an inch in any direction when the load is applied

Engineering merit

This device will require analysis of the tubes of the frames. When a load is present on this device, it will bend certain tubing and put others under compression or tension which will cause stress. It is using analysis of these factors that it will determine if the design will fail under that load due to too much stress. Equations that will be used are the equations of equilibrium to determine the forces and the equations of moments on each component. Each component will have a force or moment applied therefore it is important to determine the stress of each component. This will be calculated using the stress equations. Depending on the component, whether it is in tension, compression or bending there will be deflection which will affect the bicycle frame and will also need to be calculated to ensure the success of the project. More information about the process will be provided in the analysis section.

Scope of Effort

The majority focus on this project is to take a normal bicycle frame and engineering the frame into a collapsible frame. This will require stress analysis of frame parts to make sure that when the bicycle is being used it will not fail to loading. Evaluation will only be considered for the frame tubes of the bicycle frame. This will require obtaining a bicycle frame and chopping up necessary components which will be replaced with parts that have been machined or obtained by other means. The frame joints will be the main focus for stress analysis since those location will be first to fail under stress. If the frame design is to use hinges for joints to allow being collapsible, then they will be bought or fabricated. Another frame design is to use telescoping of the tubes which will be obtained by buying standard tubing by a metal material distributor and machining holes for pins. The pins will have stress by shear and will be calculated appropriately for the size needed for the design.

Success Criteria

This project will be successful if the bicycle is completely functional, such as being able to withstand static loading without failing by falling apart due to too much load on the frame. This will be tested by placing a load onto the seat and observing the deflection. Once that is complete the bicycle frame will then be collapsed and placed inside a travel bag with the maximum dimensions listed by American Airline which is 22 inches x 14 inches x 9 inches. The frame will then be re-extended fully. If the bicycle frame can achieve this then it will be a successful project.

DESIGN & ANALYSIS

Approach: Proposed Solution

The design for this project is a standard bicycle frame with joints and telescoping tubes that allow for the bicycle to be collapsed. As a requirement the bicycle must sustain a load and maintain that load, however another requirement is that the bicycle be lighter, weighing no more than fifteen pounds. Therefore, an approach is to replace most of the steel tubing with less dense material, such as aluminum. The material chosen is aluminum 6061 T6 round tube stock because of its density, which will help in making the frame mass lighter without losing too much in the material’s strength; also this material is common in the use of ultralight bicycle frames. The frame will also include telescoping tubes for the down, seat, and top tubes which will be secured by pins when extended. There will also be rail locking hinges along the back of the frame for the chain and seat stays which will allow the back of the frame to fold inward. An analysis will be taken for the entire frame to determine the reaction forces of the wheels back onto the frame which is needed to put the frame in equilibrium

Description

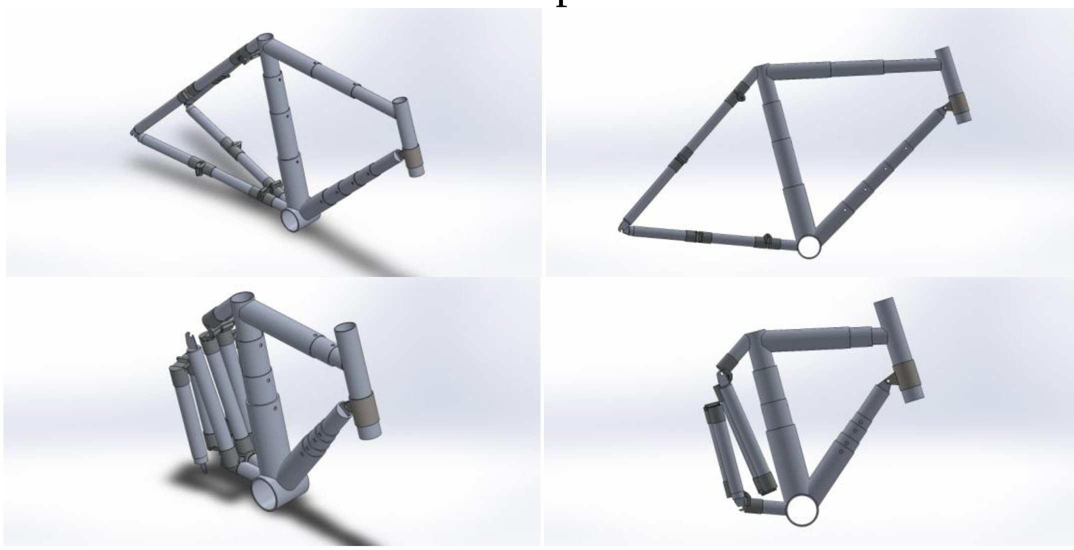

Figure: B-1a Rendering (top left), B-1b Rendering (top right), B-1c Rendering (bottom left), B-1d Rendering (bottom right). Figures located in Appendix B.

To start the process of collapsing, the seat tube, down tube, and top tube will be telescoped. These tubes will allow the frame to lower in height and length. This will be achieved by removing the steel sections of the frame and purchasing aluminum 6061 T6 round tube stock and cutting them to lengths to replace the previous tube that was removed. The tops and bottoms of the tubes, when looking at the side profile, will be machined to have a hole through the entire tube which will serve as a guide for pins to keep the telescoping assembly from collapsing until the pins are removed. The process will be the same for the top tube and the down tube, as shown in Figure B-1a through d.

The tube dimensions that are used for this frame design are based on the dimensions of the original tubes of the frame. However, stress analysis will test to see if replacing the steel material with the aluminum 6061 with similar dimensions will keep the device from failing or if the dimensions will need to be changed to accommodate the stresses tubes. Refer to Figures A-3 through A-7 which shows the tubing stresses in reference to their dimensions.

How the telescoping will work is to match the outside diameter of the previous tubes with the inside diameter and machine them to fit. For example, the bottom seat tube that will guide the telescoping tubes has an outside diameter of 2.25 inches and an inside diameter of 2 inches, the next tube will be the next size down in size with a 2 inch outside diameter and an inside diameter of 1.75 inches. These two tubes will have a tight fit so turning the outside diameter of the 2 inch outside diameter tube to have a 0.002 inch tolerance between the tubes should make the telescoping slide more smoothly together. Each tube will progressively be longer than the last so that when collapsing a portion of each tube will be visible and not completely hidden away inside the wider tubes, this will make it easier to re-extend the assembly. Figure 1 below shows the other tube sizes that will be used and the dimensions:

Table 1: Tube Dimensions

Seat Telescope Tube (4 pieces)	**Dimensions (ODxWallxID)**	**Length**
Top Tube	1.5”x0.125”x1.25”	8”
2nd Tube	1.75”x0.125”x1.5”	7”
3rd Tube	2”x0.125”x1.75”	6”
Bottom Tube	2.25”x0.125”x2”	4”
Down Telescope Tube (5 pieces)	**Dimensions (ODxWallxID)**	**Length**
Top Tube	0.75”x0.125”x0.5”	10.5”
2nd Tube	1”x0.125”x0.75”	8.5”
3rd Tube	1.25”x0.125”x1”	6.5”
4th Tube	1.5”x0.125”x1.25”	4.5”
Bottom Tube	1.75”x0.125”x1.5”	2.5”
Top Telescope Tube (4 pieces)	**Dimensions (ODxWallxID)**	**Length**
Head Tube side	0.75”x0.125”x0.5”	9.5”
2nd Tube	1”x0.125”x0.75”	7”
3rd Tube	1.25”x0.125”x1”	4.5”
Seat Tube side	1.5”x0.125”x1.25”	2”

Hinges will be strategically placed to keep the frame from resisting the collapsing process. For instance, the chain stay and the seat stay, which will resist the change in geometry. The chain stay and seat stay will be two separate parts that is pin connected by the axle of the back tire. This part will be an overlapping rear derailleur hanger.

To further the process of condensing the volume of the frame, a rail tube locking hinge, as shown in Figure B-2, will be placed at the tube stem where the seat tube and the stays intersect. The hinge is a one directional hinge which will allow the chain stays to fold upwards and the seat stays to fold downwards. After the hinge, another tube will protrude outwards which will then fork into the chain stays and seat stays which another locking tube hinge will be placed halfway towards the tire end which will allow the right side stays to fold towards the right side and the left stays to the left. An image of design is shown in Figure B-1.

When the frame is collapsed the dimensions should be no more than about 1 foot in length and 10 inches tall and no more than 3 inches in depth. This does not include the seat, tires, handlebars, forks, crank and gears. The extended frame design is accepting of these components but was not included in the collapsing frame design and will require removing these components before collapsing the device.

Benchmark

The more difficult part of this project is making the bicycle frame collapsible into such a small volume while retaining the frame’s structural integrity and the effectiveness as a bicycle. Dahon bikes have many designs in their versions of collapsible bicycle frames. The Dahon Dash P18, which costs around $899.99, uses a typical standard bicycle frame set up with the exception that the Dash P18 folds together by taking the shaft guide of the handle bars set up and placing them on a seated shaft. This makes the handle bars easily moved and twisted around so that when the bicycle is completely folded, there are no parts coming out of the folded assembly. The seat can also move up and down using a twist relief lever, located at the top of the seat tube of the frame, and allows for the bicycle to be more compact. In the final part of the folding process of this bicycle is to take a hex key and insert it in the key slot located at the center of the top and down tube. This releases the frame splitting it into two parts and allowing it to be folded.

Figure 1: Dahon Dash P18 foldable bicycle

Price range: $998.00 to $1135.00 by bicycle hero (http://www.bicyclehero.com/us/dahon-dash-p18-folding-bike-bicycle-cloud.html#.VFVi_WdxiY8)

Predictions

Using the SolidWorks model to calculate the volume of each part and using the density of aluminum 6061 T-6 which is 0.0975 lb/in^3, it was calculated that the entire bicycle frame would weigh approximately 18 lbs. This is a little over the required 15 lbs but still within the range for success for the project. In the Figures: D-1, D-2, and D-3. It was concluded that the frame will have dimensions with length of 22.03 inches, width of 6.44 inches, and a height of 15.97 inches.

Description of Analysis

All the components of the bicycle frame will be under stress when a load is applied which will be analyzed with free body diagrams of each component individually and calculations of the forces being applied to each component (reference Appendix A for all calculations). This will help in determining the max stress areas which will determine if an adjustment needs to be made in the design as well the material for the components.

To start the process of analysis the stress equations will be used for the entire frame to determine the reaction forces of the wheels back onto the frame. The tubes, joints and hinges of the frame will then be calculated individually using the results of the load and reaction forces given in the analysis of the entire frame. The equations that will be used are:

$\sum F_{XY} =$

$\sum M_{AB} =$

Since the part the frame will be using telescoping, some of the frame tubing and pins will have double shear forces applied. The equilibrium equations will help in determining their force value and can be used to determine the shear stress of the pins. The vertical shear equation that will be used to calculate the shear stress of the pins is:

$$\tau_{max} = \frac{V}{2A}$$

Due to the load, the tubing of the frame will also succumb to stress deformations from tension/compression or bending. The equations that will calculate these values are:

$$Normal\ Stress: \sigma = \frac{P}{A}$$

$$Hooke's\ Law: \sigma = E\varepsilon$$

$$Strain: \varepsilon = \frac{\delta}{L}$$

$$Flexure\ Formula: \sigma = \frac{Mc}{I}$$

$$Beam\ Deformations\ Equations$$

$$Stress\ Concentration\ Equations$$

Scope of Testing and Evaluation

To test the device against failure from loading, a jig will support the bicycle to ensure that the frame stays upright and a weighted container with loads similar to that calculated will be strapped on top of the seat and crank pedals. During the static load test deflection measurements will be taken using a ruler that reads in 1/32 of an inch to ensure that the bicycle frame stays within the required deflection range. The next part of testing is to pull the pins from the telescoping tubes and fold the chain and seat stays and see if they can fit into a 22”x14”x19” carry-on bag. The final test is to weigh the frame and determine if the weight of the frame weighs less than 15 pounds. This will be done by a person holding the frame and weighing them and the frame on a scale and then taking another weight measurement without the frame and subtracting the difference.

Analysis

Approach

To start analysis on this device, the reaction forces of the tires onto the frame when a load is applied must be known. Figure A-1a shows a free body diagram of the entire frame structure. When the reaction forces of the tires are calculated then each component can be analyzed for forces being applied and the stresses that follow. The deflection due to the loads can also be calculated which will affect the welds of the frame joints. This will help in determining if the design is sufficient enough to withstand the load.

Design

In order to make sure the design will not fail, a safety factor of 3 will be used for the entire frame. This value was selected because the load and the reaction forces due to that load will distribute throughout the entire frame and cause stress deformations in the components. Using this safety factor will limit the deformations of the material the save the frame from critical stresses which will cause the device to fail. The tubing of the frame design was chosen based on the original frame but will be adjusted according to the stresses and deformations applied with the material change.

Calculated Parameters

It was determined that in order to resist the downward 180 lbf load at the seat tube and the 25 lbf at the crank tube the reaction force of the tires onto the fork/head tube would be an upward 128.2 lbf and an upward 76.8 lbf on the derailleur hanger. Since most of the joints are welded it was ideal to treat each component of the frame as a fixed joint member, which using these numbers the components in the frame assembly can be calculated using free body diagrams and equilibrium equations which are shown in Appendix A-1. Figure 2 below shows all the calculated forces from Appendix A:

Table 2: Force Values

Component	Force (lbf)	Analysis
Seat Stay (2x)	158.4	Compressive
Chain Stay (2x)	104.8	Tension
Seat Tube	63.2	Compressive
Top Tube	88.4	Compressive
Down Tube	114.6	Tension

*note: refer to Appendix A for the exact calculations of the forces of each member and Appendix B for drawing dimensions for all tubes of the frame

Most of these components are under compressive and tension stresses; however there will also be deformation due to bending as well.

Starting with the chain stay tube, by looking at Figure A-1a, it was determined that this component is put under pure tension. This can be seen by creating a stress element on the center surface of a right hand view the chain stay shown in Figure A-2 using the information provided by Figure A-1a. The chain stay tube will have locking rail hinges, as shown in Figure B-2, but when the frame is fully extended the axle of the hinge will allow for the middle faces to be touching which will transfer the forces and stresses throughout the entire component. Therefore the component can then be calculated using the normal stress equation. The area of a tube is: $A = \pi D t$, "D" is the outside diameter of the tube and t is the wall thickness. The tube dimensions were not calculated but predesigned to fit the original bicycle frame and it is using the stress equations in relation to the yield strength of the material that it will be determined if the tube dimensions has too much stress on the component and needs to be re-designed. The reaction force given by Figure A-1 in Appendix A shows that the chain stay has a reaction force of 104.8 lbf which is in tension therefore the stress can be calculated as:

$$\sigma = \frac{P}{A} = \frac{104.8\ lbf}{\pi(1\ in)(0.125\ in)} = 266.7\frac{lbf}{in^2}$$

Using the aluminum 6061 T6 material that was chosen for this component the strain can be calculated from this stress value by using Hooke's Law:

$$\sigma = E\varepsilon => \varepsilon = \frac{\sigma}{E} = \frac{266.7\,\frac{lb}{in^2}}{10000 * 10^3\ \frac{lb}{in^2}} = 26 * 10^{-6}\,\frac{in}{in}$$

Finally, since the strain is now known, the displacement of the tube can be calculated given the length of the tube from the bicycle frame:

$$\varepsilon = \frac{\delta}{L} => \delta = \varepsilon L = 26 * 10^{-6}\,\frac{in}{in}(18.5\ in) = 0.493 * 10^{-3}\ in$$

This shows that due to the compressive force on the seat stay that once the 180 lb load is applied, the tube will displace by tension of about 0.000493 inches. The deformation value from the load produces a small value and is below the requirement value of 1/32 of an inch. However, it is in the interest of this project to apply a factor of safety to ensure the frame holds under the load. It was decided that a safety factor of three will be used for the duration of this project. Since the ultimate strength of the aluminum 6061 T6 is about 45000 psi then the allowable stress is 15000 psi.

$$F.S. = \frac{\sigma_{Failure}}{\sigma_{Allowable}} => \ \sigma_{Allowable} = \frac{\sigma_{Failure}}{F.S.} = \frac{45000\ psi}{3} = 15000\ psi$$

Since the stress of each seat stay was only 266.7 psi then this component is well within the allowable stress limit. The other components in the assembly are calculated in a similar manner and are shown in Appendix A.

Device Assembly

In order to create this frame the original frame will be cut into sections. Once the parts are ordered they will be machined with the necessary holes for the pins and cut so that the ends of the tubing will be able to align with the other tube that it will be welded to. Using a frame jig and careful planning, the frame will be welded to its proper geometry. Since the new design of the frame is based on the original design, the jig will be made to fit the original frame and the bottom of the down and seat tubes of the telescope tubes, which will connect to the crank tube. When the other tubes are machined they will be put together with the rest of the frame while still being held by the jig. The top tube closest to the seat tube will be welded to the top section of the seat tube to which the rest of the top tube sections will be placed in the jig and welded to the head tube. Finally the chain and seat stays will also be placed in the jig to be welded.

Tolerances

The tolerance of the telescoping tubes are crucial in order to maintain a nice smooth sliding motion when the pins are released but not too much which will give the components too much space that they are not properly seated and secure. A minus 0.002 inch tolerance from its original diameter is given for each of the telescoping tubes which should accommodate the requirements. The pins that fit into the guide holes should also have a tolerance of about the same or smaller in order to keep the pins from being too loose and falling out of the holes to which they are seated. Appendix B shows drawings with dimensions and tolerances for each tube.

Technical Risk Analysis

This device comes with a lot of risk due to the material having less yield strength which could lead to fracture or failures of the components of the design and cause injury to the rider or a nearby pedestrian. Loose components could also be an issue and lead to the same results. To avoid such injuries the device components will be properly tested for looseness and the frame as a whole will be tested by placing a weighted container, which will be weighed appropriately, on the seat to simulate a person to test the strength of the frame.

METHODS & CONSTRUCTION

Description

This bicycle frame will be designed and modified from an already made fully functioning frame. The frame will be cut up into sections and replaced by both telescopic and normal tubing that is ordered through a metal distributor. Most of the hinges will be bought through various companies, whereas the derailleur hanger will be machined to appropriate specifications. Once all the materials are obtained they will be machined and/or welded together to build the design. A jig will be built based on the original frame using wood materials donated by Jeff Colby which will be used to get the correct geometry and placement of the frame tubes so that the frame is welded correctly. The crank tube will be the datum which will be used to weld the seat, down and chain stay tubes to the crank tube. The rest of the assembly will be put together one tube at a time and will place hardware such as pins or hinges when appropriate to keep the frame stable.

Drawing Tree

The drawing tree, which is located in Appendix B Figure B-4, shows the entire assembly as well as sub assemblies and parts that pertain to this device. The device is made up of 19 parts and 2 sub-assemblies. The first sub-assembly is the front section of the bicycle frame and in this sub-assembly contains an additional 3 sub-assemblies referred to as the top tube, down tube and seat tube sub assemblies which contains all the relevant parts. The second of the initial sub-assembly is the back section of the bicycle frame. This sub-assembly much like the front sub-assembly contains an additional two sub-assemblies which are the chain stay and seat stay sub assemblies.

Parts List

The parts needed for this project are listed in Appendix C which includes the part number which will signify the parts identification. The list also includes the parts dimensions, quantity and cost. There are a total number of nineteen parts to be machined, which include the four sections of the top tube, five sections of the down tube, four sections of the seat tube, chain stay stem, chain stay tube, seat stay stem, seat stay tube, and two sets of derailleur hangers. The number of parts will be separated into five sub-assemblies which include the top tube, down tube, seat tube, chain stay and seat stay sub-assembly. Other parts such as the head tube, crank tube, the tube hinges, and the pins will be ordered and manufactured to the proper specifications and will require no machining.

Manufacturing Issues

Since most of the material is made of 6061 T6 aluminum, machining should be relatively easy. The telescoping tubes are required to be turned on a lathe and given a tolerance to allow the tubes to be fitted properly but also provide a nice sliding motion to collapse the frame together. The ends of the tubes of the tube assemblies will be coped to the dimensions of parts to which they will be mated to when welded. This will be done by the use of a tube notcher end mill. The best approach to this is to have an angle measurement tool and an angle vise which will hold the part at the appropriate angle for the end mill to cut material away from the tube to make the cope. In order to get the proper cut the mated piece will be used to outline the radius of the cut by periodically checking after every cut or by making a careful outline on the part. After all parts are coped then the telescoping tubes will have holes drilled for the pins. The only part left to be machined is the derailleur hangers which will be made out of solid aluminum round stock and will be turned and faced on a lathe, and then using a milling machine milled and drilled to be cut to make the hook. When finished the derailleur hanger will be placed in the end of the chain and seat stays and drill through both materials which will be riveted. There are a few parts that will be ordered through a distributor and will have no machining. These parts are the locking tube hinge and the hitch pin. The holes drilled in the tubes will be based on the size of the hitch pin and will receive a tolerance of +0.004 and -0.000 inches which is the value is given in chapter thirteen of the Machine Elements in Mechanical Design textbook. The locking tube hinges which were sold as a one inch inside diameter fitting was received and was made a little bigger than the manufactured one inch tubing. However, the locking tube hinge has an internal cone lock tightener which can be tightened using a small hex key. In order to fix this the tube ends will be located for where the tightener will be located and will be drilled and the cone will be used as a permanent countersink that will lock the tube in place relative to the hinge. The final step is welding. All welding will be outsourced by Jeff Colby. A jig will be made which will hold all the pieced in their proper locations and will be welded. Since welding on aluminum is difficult even with the best equipment this process will determine if the device will be done and working.

Discussion of Assembly

When the parts have been obtained the first process is to take all the tubes and turn all the telescoping tubes and fit them to size. This will be done using a lathe by turning the diameters to make sure that there is enough clearance for the tubes to fit inside one another comfortably but still be tight enough to have little movement between the tubes.

When all the diameters have been turned the next step in the process is to take the tubes that will be welded and mitering the tube ends to match the outer diameter of the tubes to which they will be welded and to the angles to which they will be sitting. This will be done by using a hacksaw and cutting away the material until the cut is near the desired shape which will then be filed down to size. In order to plan the perfect shapes, a computer program called TubeMiter.exe will be used to determine the desired shape which will print out a paper copy of the dimensions made on the program and can be used to wrap around the part to outline the shape of the cut.

The next step will be to take the telescoping tubes to a drill press and drill holes in the locations specified in the drawings. These drawing are shown in Appendix B. When the machining processes are complete the parts will be cleaned using a stainless steel wire brush. Using the jig the frame parts will then be placed in their corresponding locations which will be welded. The welding process that will be used is gas metal arc welding also known as MIG.

The last step is to take the remaining parts and fit them together using the pins and locking hinges.

TESTING METHOD

Introduction

The bicycle, when a load is applied, will deflect by bending, compression or tension. In order to test the safety of the frame it is important to keep track as to how much the frame deflects under the load to keep the frame from failing. The bicycle frame will be placed in a jig which will support the frame from the head tube location and another support at the derailleur hanger. If the frame appears to sink in the middle towards the crank tube when the load is applied it is because there is too much stress on the welded joints. Therefore, it is important to use a dial indicator or a measurement device to test the deflection. When deflection has been calculated for all of the tubing components by using the measurement device, a comparison can be tested for the calculated deflection from the tested deflection. It was calculated that the deflection will not exceed 1/32”. Other requirements of the frame include weighing no more than 15 lbs. Using SolidWorks, and the density of the materials used the calculated mass of the frame was approximately 14.6 lbs. The final test that will occur is a test of the volume when being collapsed. It is required that the bicycle frame when collapsed have the same dimensions or smaller which listed by American Airlines carry-on luggage as 22” length by 14” height by 9” width. Using the same SolidWorks model the frame should achieve a maximum of 22.03” in length by 15.67” in height by 6.44” in width. The schedule for each test is listed in the Gantt chart shown in Figure E-1.

Method

Several resources were used in the approach to testing the frames deflection. One idea given by Professor Charles Pringle had suggested the use of strain gages however after speaking with Professor Craig Johnson; the use of strain gages on this device would require the use of too many strain gages and would have been too complicated to analyze. It was Professor Craig Johnson that the best approach to testing the deflection of this device is by taking a video of the frame in a jig against a white wall and putting weight on the frame and measure the deflection with a ruler. The next step was to build a jig that would hold the frame in the front and back of the bicycle frame which would simulate the reaction force of the tires pushing back onto the frame when a load was applied. After planning on a jig design, Carl Pennington helped build the frame jig out of scrap material which was used for an old trailer lying around in his yard. The scrap was cut, welded and then painted. The materials for the jig that were given and all the welding work done were generously donated by Carl Pennington for free.

The tests done for the mass of the bicycle and the collapsing volume requires little documentation other than that they succeed the requirement constraints. However, for the loading and deflecting tests will both be done in a single test procedure and will be captured on video to document the maximum deflection under various loads. In order to do this a jig will be placed against a bright colored wall with the proper lighting in the room so that the camera can properly read the ruler which will read in 1/32". Both the camera and ruler will be placed at the base of the jig and view the bottom of the crank tube. The concept is that when a load is applied at the seat tube the camera will capture the deflection of the bicycle which will be shown at the crank tube as it moves downward. This test will be taken three times to eliminate any error that may occur. This test, being recorded by video is a visual based test to carefully observe the deflection in relation to the ruler. The ruler only reads 1/32" for an inch on both sides of the ruler so this test will need to take careful precaution as to the placement of the ruler and how it stands while the load is being applied.

Test Procedure

The first test is to take the bicycle frame and weigh it. This test only took several seconds. This was be done by holding the frame and weighing the frame as well as the person who is holding it. A second weight measurement was then taken of the person without the frame. Once both measurements were recorded the weight of the frame was determined by subtracting both weight measurements leaving just the mass of the bicycle.

In order to test the structural integrity of the device it was very important to place a heavy enough load on top of the frame but rather than risking injury the bike will be held up by placing the frame in a jig so that it will be held upright. This will be done by building a boxed frame structure which will be designed so that it will be free floating in the center of the bike and only supporting at the derailleur hanger bay and the head tube. While the frame stands upright a simulation of a weighted structure of approximately 180 lbs will sit on the seat of the frame. In this case a car jack was used, since the top of the jig frame was welded closed this was used to place the car jack between the top of the seat tube of the bicycle frame and the jig frame. So that a load measurement can be recorded a piece of 2" by 4" board was cut to size of the width of the jig and placed between the carjack and the top of the jig frame. A weight scale was then placed on top of the 2" by 4" to eliminate any point loading from the jack onto the scale. The idea is when the care jack is cranked to apply a force onto the bicycle frame the bicycle frame will also apply the same force back onto the carjack which will transfer over to the weight scale as it is being compressed between the carjack and the top of the jig frame. This will read how much pounds is being applied to the bicycle frame. If the frame does not fail under the load then a measurement of the deflection areas will be taken using a ruler to determine maximum deflection.

There will be a test to collapse the frame. This design does not include the tires, forks, handlebar, crank and chain assembly and will not be included in testing. The test will proceed by removing the pins for the telescoping tubes and collapsing the frame using the hinges placed at the chain and seat stays. When the frame assembly is completely collapsed a suitcase that has the maximum dimensions of 22 inches by 14 inches by 9 inches will be used to contain the frame and test if the frame is of sufficient size. This suitcase should be able to contain all the parts of the bicycle frame. The entire procedure will be as follows:

Procedure:

1. Acquire the bicycle frame, the testing jig, a socket wrench, two weight scales one digital and other dial, a hand crank car jack with handle, a 22 by 14 by 9 inch luggage case, a ruler that reads in 32nds of an inch, and a piece of 2 by 4 inch plank cut to fit into the jig.
2. Place the digital scale on floor then pick up the bicycle frame and step onto the scale and record weight
3. Put down the bicycle frame and step on the scale again and record weight
   Note: Subtracting the weight when holding the bicycle from the weight without the bicycle will calculate the bicycle mass
4. Place bicycle frame into the jig
5. Setup the jig by placing the car jack onto the seat tube, place the 2 by 4 inch plank onto of the car jack with the dial scale on top to be press fitted inside the jig
6. Turn the crank of the car jack so that scale fits just snug against the jig and still reads zero pounds on the scale
7. Take the ruler place it so that it stands from the floor to the free floating crank
8. Turn the crank of the car jack to and record deflection from the ruler from various loads that can be read from the dial scale
9. After recording numerous data from different loads remove bicycle frame from jig and begin removing pins and begin collapsing the bicycle frame
10. Place collapsed frame into the luggage to demonstrate that it meets the required dimensions

Discussion:

The deflection when fully loaded showed that the frame deflected more than what was required. However, this could be due to having components not having as tight of a fit between each telescoping tube. The telescoping tubes needed to have a tight fit but also have enough play so that sliding could occur. This could be due to not purchasing the tubes at a bigger size and then turning them down for a better fit but instead just purchasing the tubes to the size that was needed which left tolerance issues to occur giving more play between the tubes than what was desired.

Deliverables

The values that will be recorded for testing are the final mass of the entire device, the final dimensions of both the extended and the collapsed frame to ensure that is succeeds the required collapsible dimensions, and the deflection as each load occurs. Any calculations that will occur is only calculating the average deflection of all three tests for each load during the load/deflection testing. If the bicycle frame weighs less than 15 lbs, can fit into the required 22" by 14" by 9 " luggage, and also resist a deflection of 1/32" when a load is applied at the seat tube then this device will be successful.

BUDGET/SCHEDULE/PROJECT MANAGEMENT

In order to avoid the risk of not completing this project by the deadline there are three categories that have been used to gather necessary information. These categories are budget, schedule, and project management. The budget will include items such as tubes for the frame, hinges and the telescopic tubing used for the seat and down tubes for the frame.

Proposed Budget

Part Suppliers

The budget is located in Appendix E. The materials that will be purchased will be from multiple suppliers. The tubing will be bought by an online source called Metals Depot. Hardware is also needed for this project such as the hitch pins for the telescoping tubes, which will be purchased from MSCDirect.com and the tube hinges which will be purchased from ClothCanvas.com.

Labor/Outsource rates

In order to reduce the risk of time management and efficiency it is important to outsource whenever necessary. In order to maximize the projects project management the welding of the frame will be done by Carl Pennington who will be paid at a 30 dollar per hour rate.

Project Cost

The total cost based on the budget located in Appendix E shows that the total cost will be $409.79. Most of the tubing averaged about $8.72 for 9 different sized tubing whereas for 8 tube hinges it will cost $224.41. There will be about 10 pins purchased from MSCDirect.com which will have a total cost of $32.20. Finally, labor costs for outsourcing the welding of the frame was approximated at 30 dollars an hour.

Funding Source

The funding for the project will come out of pocket from money given by financial aid and money gained and saved over the summer when working at the Port Townsend Foundry as an intern.

Proposed Schedule

High Level Gantt Chart

The Gantt Chart is located in Appendix F which shows what tasks there are, the estimated time it will take to complete, the actual time it takes to complete, as well as the percentage done throughout the entire project. Each task is categorized by task identification. To the right of the times are weekly dates starting from the first week of the year to the last week of the school year with a total of 32 weeks for the year. A line for each category will symbolize the time per task that was worked. The first section of a total of three sections of the year most of the time and task will be related to analysis of the device. The second will focus on the build stage and the last section will be focused on testing and evaluation.

Tasks

The tasks listed in the Gantt Chart are listed by task identifiers. The tasks are split up into four different categories which are then split into sub categories. The four main categories are: Proposal, Analysis, Project Manufacturing, and Project Evaluation. The proposal covers all tasks related to engineer merit and project ideas. Analysis covers all tasks related to designing the parts to function as calculated. Project Manufacturing covers all tasks in the building phase of the project. Project evaluations are tasks related to testing the device. Each task will have a start and end week and will have an assumed hours working for that task, this will be followed by the tasks actual start and end week with an actual amount of hours worked.

Total Project Time

The total time to complete this project has been estimated at approximately 134 hours. The Proposal category is assumed to use about 71% of the total time worked on this project, followed by 14% for the Project Manufacturing task category and 15% for the Project Evaluation. The total number of worked hours on the entire project is at 185.1 hours. The Proposal category alone has reached 175 hours, which is almost doubled the time assumed. This was due to the additional time to make multiple corrections to the engineering analysis. A total of 10.1 hours has been worked on the manufacturing phase of the project which is assumed to reach 19 hours by the time manufacturing is complete.

Project Management

Human Resource

The lead engineer is responsible for all tasks in relation to this project; this includes the use of the machine shop during available lab times, obtaining material as well as budgeting and scheduling.

Resources

The machine shop located at Central Washington University will be used to do lathe and milling work. The CAD labs will be used to create drawings and 3D models with the use of SolidWorks. The financial sources from this project will be from the school's financial aid as well as money saved while working during the summer. Therefore the project manager of this project is fully responsible in making sure the budget is well within the affordable limit

DISCUSSION

Design Evolution

In the first week of starting this project, the first design for this project was to take the bicycle frame and to cut it down the middle. On one half of the cut frame was going to have beveling of the tubes so that they could be inserted inside the other half of the bike frame and connect it by canopy push pins. It was determined that there was not enough engineering merit for this design and it called for a more complex design. After spending an upwards of two hours looking for ideas and it became clear that there were no visible telescoping bicycle frame designs. There have been issues as to where to telescope as well as how the telescope tubes will be controlled so as to not collapse when in use. It was at this point that force and stress analysis and the start to a SolidWorks model was being developed. The first issue to solve was the telescoping tubes which took a couple of days to solve. The first design for the telescoping tubes was quite complex and would have involved in doing some machine work for inside cutting of the tubes to make grooves in the tubing to work as keyways. This idea was scrapped and was considered impossibility due to the lack of machining equipment that is capable to doing this task. To keep things simple, the decision was made to just make the telescoping tubes pinned. In order to collapse to the desired dimensions it was already determined that the top, down and seat tubes were to be telescoping.

The next issue was a design idea for the chain and seat stay. The first design implemented telescoping tubes for this as well but after having done a couple of SolidWorks designs it was determined that those tubes would be sticking too far out from the rest of the body and would not make the required collapsible dimensions. The second idea was to use hinges at the joints however, the bicycle frame tubing are round tubes and most of the hinges found were flat back hinges. While doing some more research on the internet, the third and final idea was to use tubular hinges. It was then that it was determined that using tubular hinges in the design allowed for the chain and seat stays to be folded multiple times which saves more needed space when it collapses.

The final design incorporated the issue which was to determine how long each telescoping tube was to be in reference with the last tube. Since it was decided to use pins it had to be considered what would happen when the pins were removed and then how could it be reassembled afterwards. It became clear that the tubes could not be each the same length or the tubes would be lost within each other making the reassembly process more difficult. It was then decided that each tube starting from the bottom end would get longer as the tubes moved up. It was this issue that made it crucial to make SolidWorks designs early on. It took seven weeks to come up with three different assembly designs to determine an allowable length for the tubes which would allow them to collapse to the desired dimensions needed to fit in the carry case.

Project Risk Analysis

This project is susceptible to having some major risks, such as time and cost. The risk dealing with time is that building this frame will consume the entire rest of the year and very little room for error. One mistake in calculation or the design could determine whether or not the project is done by the end of the year. Also being a college student with little funds, a single mistake in a part could result in a need to repurchase a part which will affect both time and cost.

CONCLUSION

This bicycle has many parts, but most of the parts will be bought through a supplier and will require little work. There is some machining that will take place but it has been determined that these tasks are minimal. Such machining tasks include cutting to lengths with a band saw, drilling holes for the pins, and possibly turning of some of the tubing so that they have the right tolerances to fit properly into position. Time will be taken to build a frame jig so that welding the components to the correct geometry will be possible. It was also determined that based on the design and analysis, the frame should have the strength to withstand the load applied to the seat and crank tube. The deflections that are caused by the load are calculated to be small enough to not affect the welded joints of the device. The device dimensions after collapsing have been determined from Figures D-1 to D-3 to be the approximate dimensions needed to fit in a carry-on bag for transport on a plane. The designed frame has been analyzed and designed to meet the requirements and the parts have been sourced and budgeted. Therefore, it is with this information that the device is ready to be created.

This project meets all the requirements for a successful senior project, including:

1. The device has been analyzed to be within the tolerance of sustaining the given load
2. The size of the frame after collapsing will be within the required dimensions
3. All parts and the build will be under the price of the benchmark
4. Device will be under the required mass

ACKNOWLEDGEMENTS

Thanks are due to the Professors Charles Pringle, Roger Beardsley and Dr. Craig Johnson for mentoring and advice pertaining to this project. Central Washington University has provided with the tools and resources to help in completing this project. Thanks are also due to Jeff Colby for offering his help with completing tasks for this project and Matt Burvee for his advice and mentoring in the use of equipment.

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APPENDIX A – Analyses

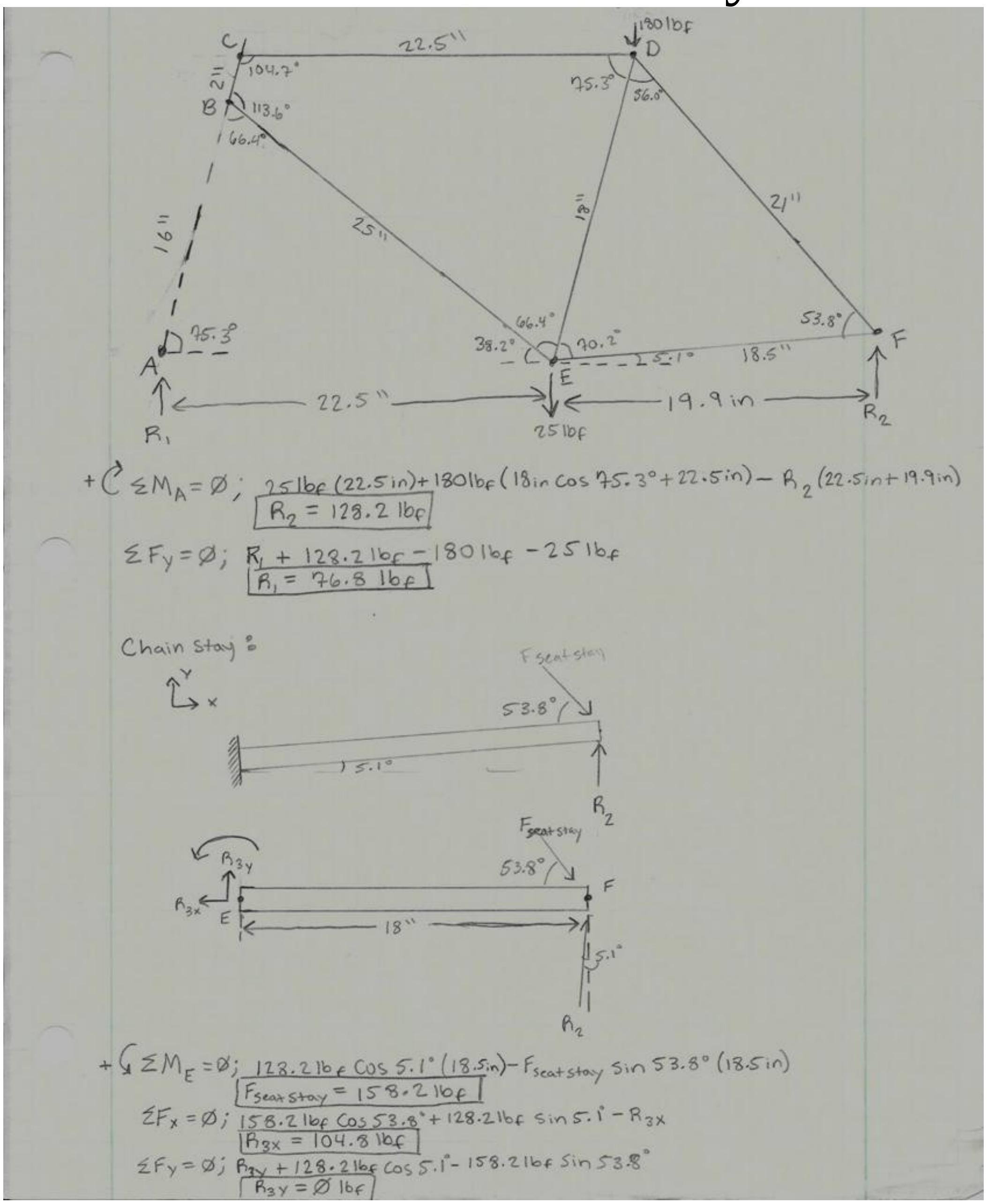


Figure A-1a: Free Body Diagram and Equilibrium Equations Page 1

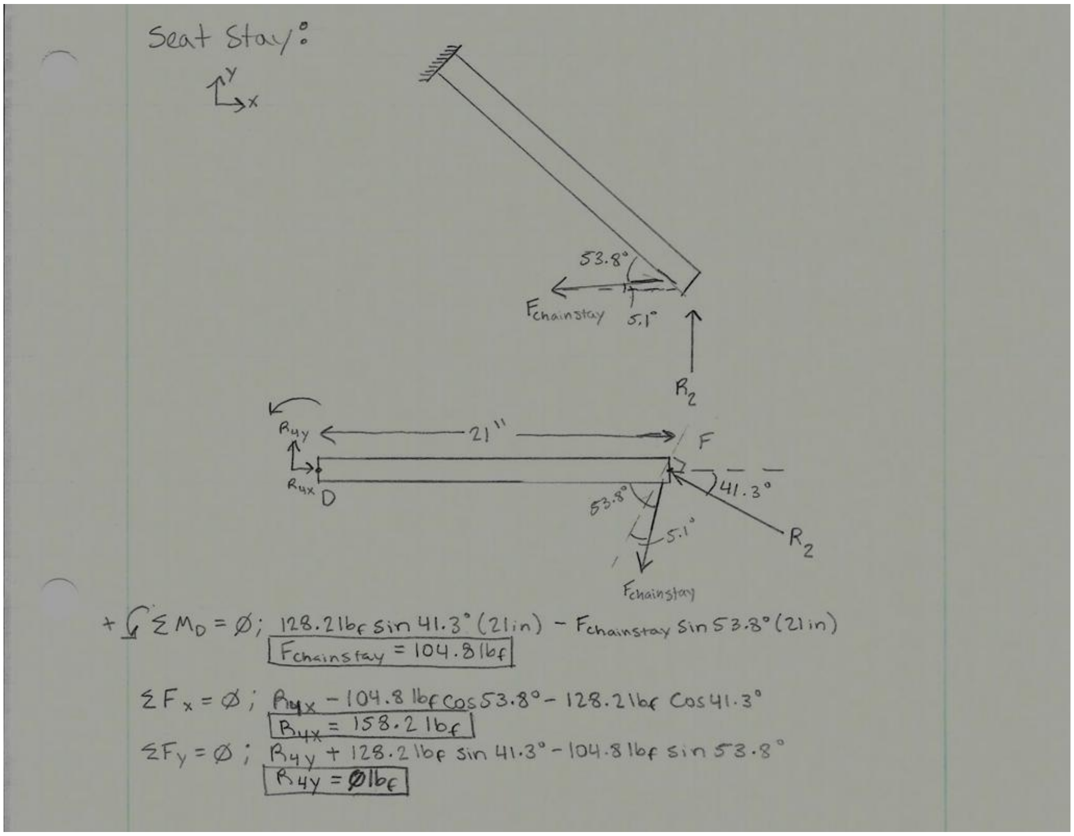


Figure A-1b: Free Body Diagram and Equilibrium Equations Page 2

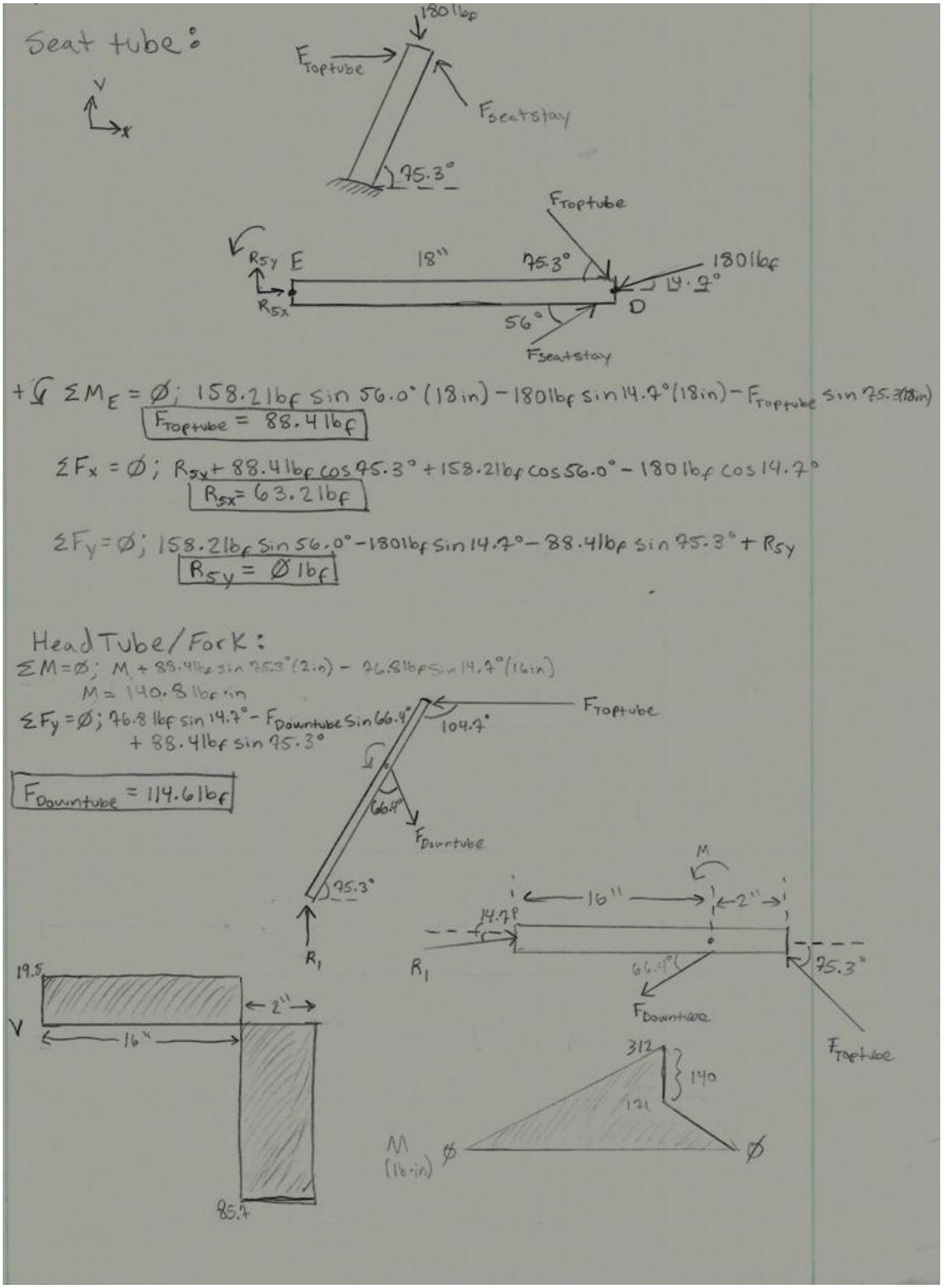


Figure A-1c: Free Body Diagram and Equilibrium Equations Page 3

Figure A–15–1

Bar in tension or simple compression with a transverse hole. $\sigma_0 = F/A$, where $A = (w - d)t$ and t is the thickness.

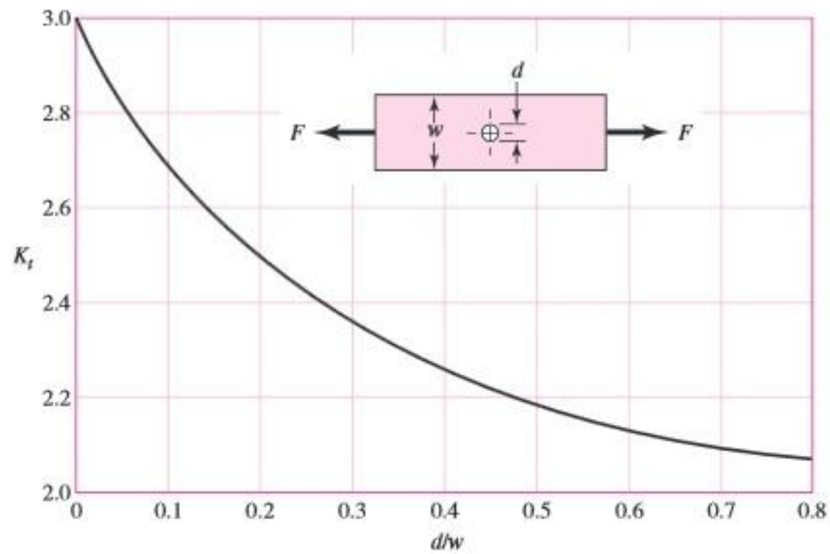


Figure A-2: Stress Concentration of tube with hole in compression/tension

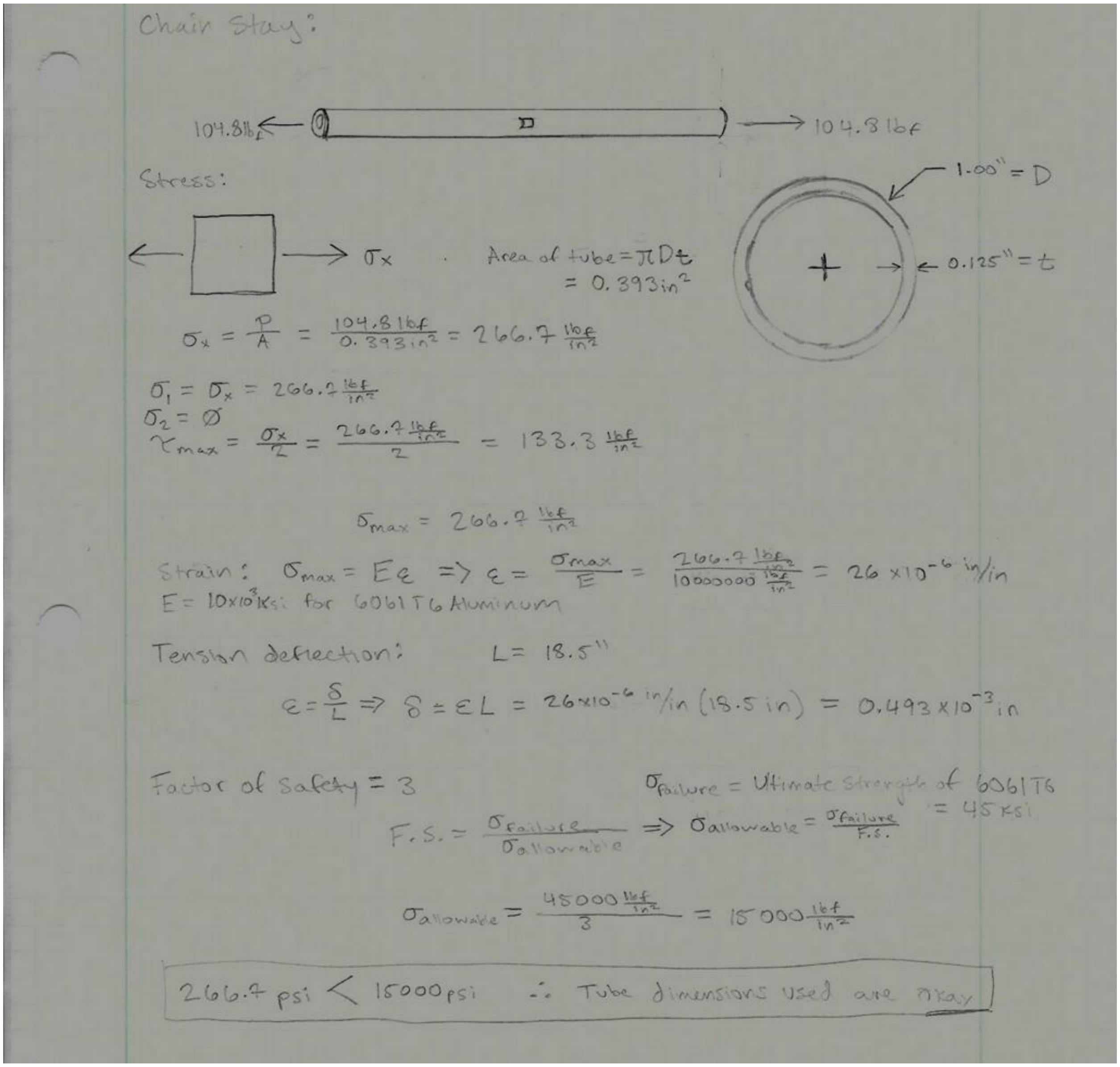


Figure A-3: Chain Stay Stress Analysis

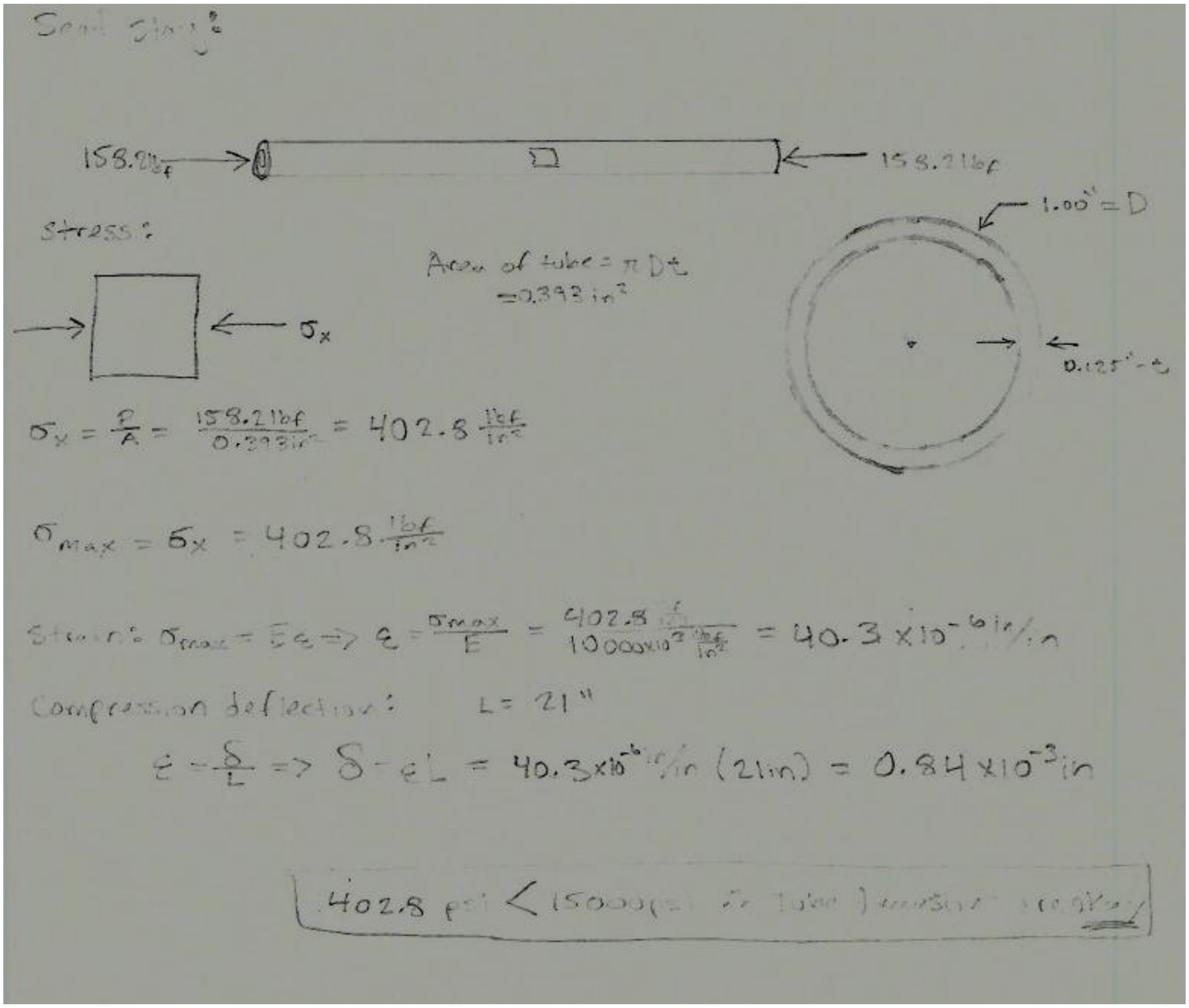


Figure A-4: Seat Stay Stress Analysis

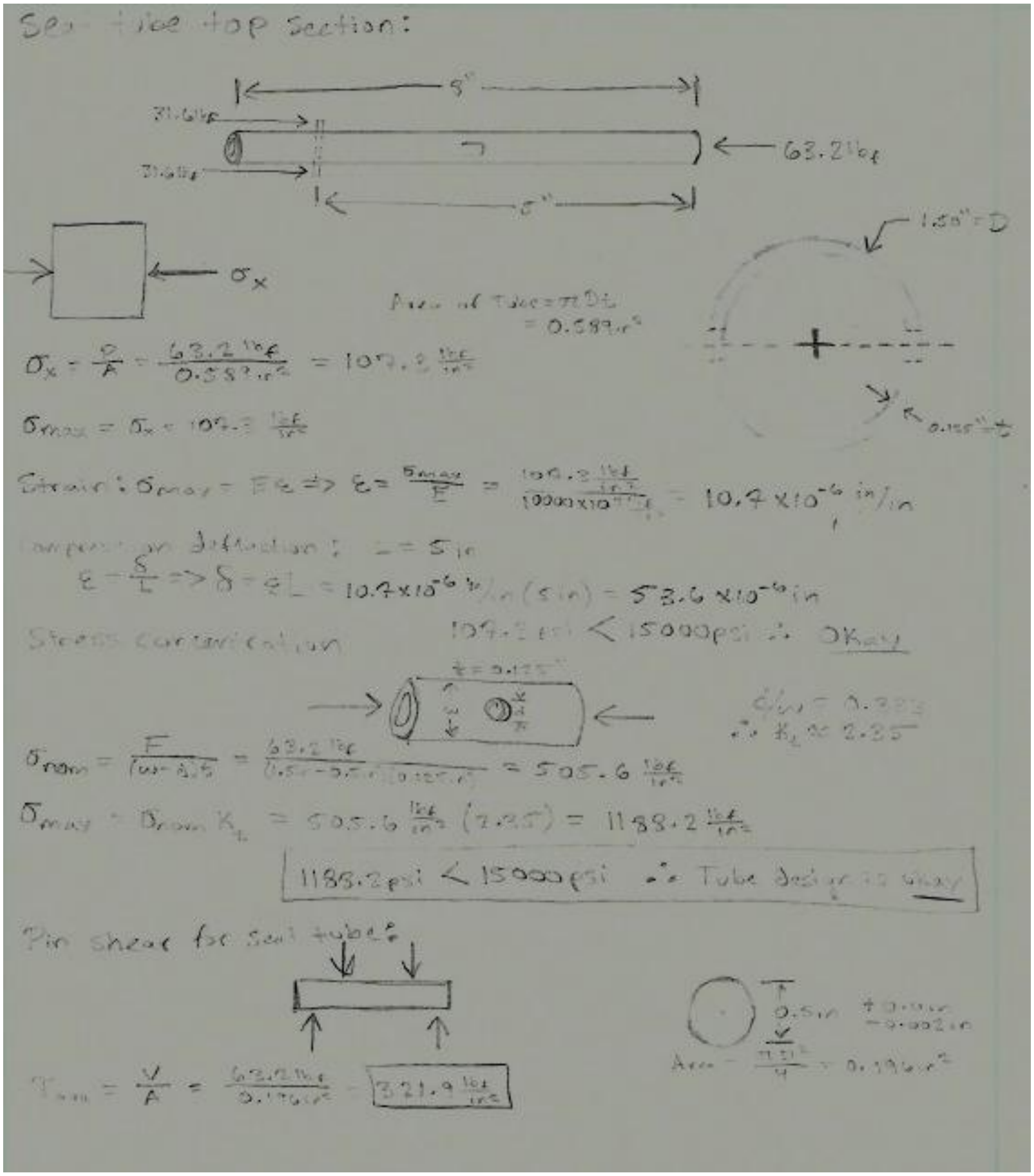


Figure A-5a: Seat Tube Stress Analysis 1

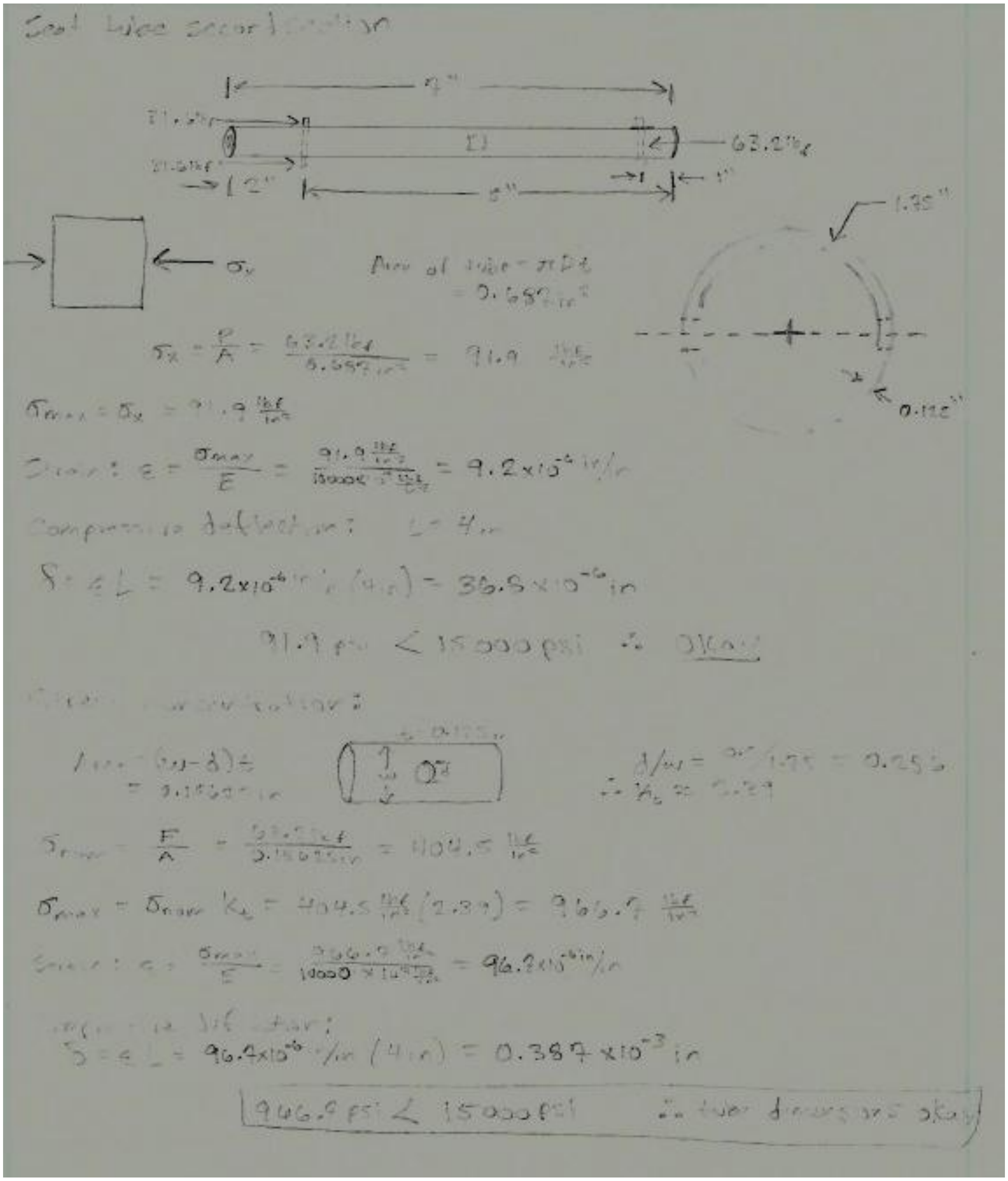


Figure A-5b: Seat Tube Stress Analysis 2

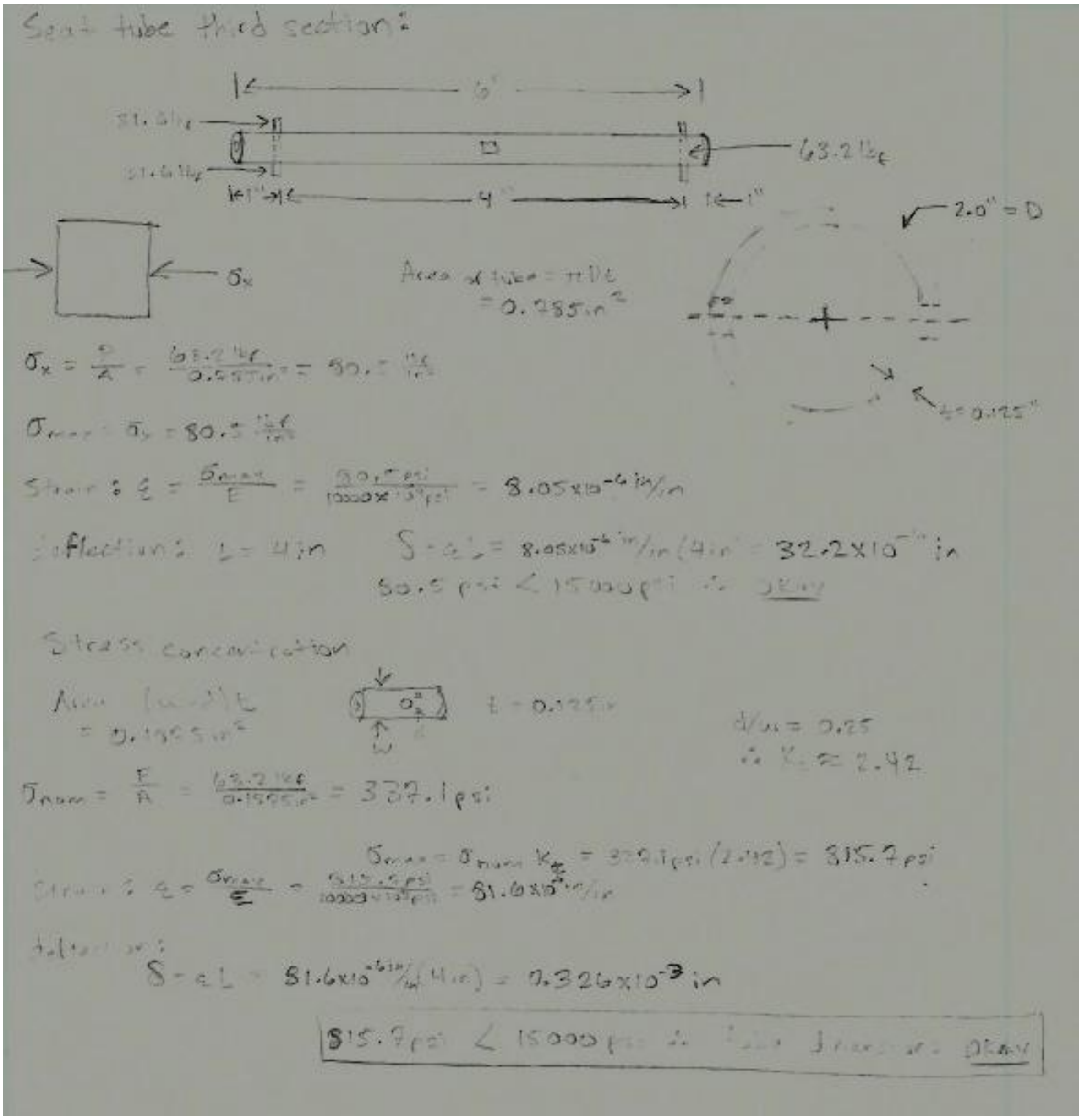


Figure A-5c: Seat Tube Stress Analysis 3

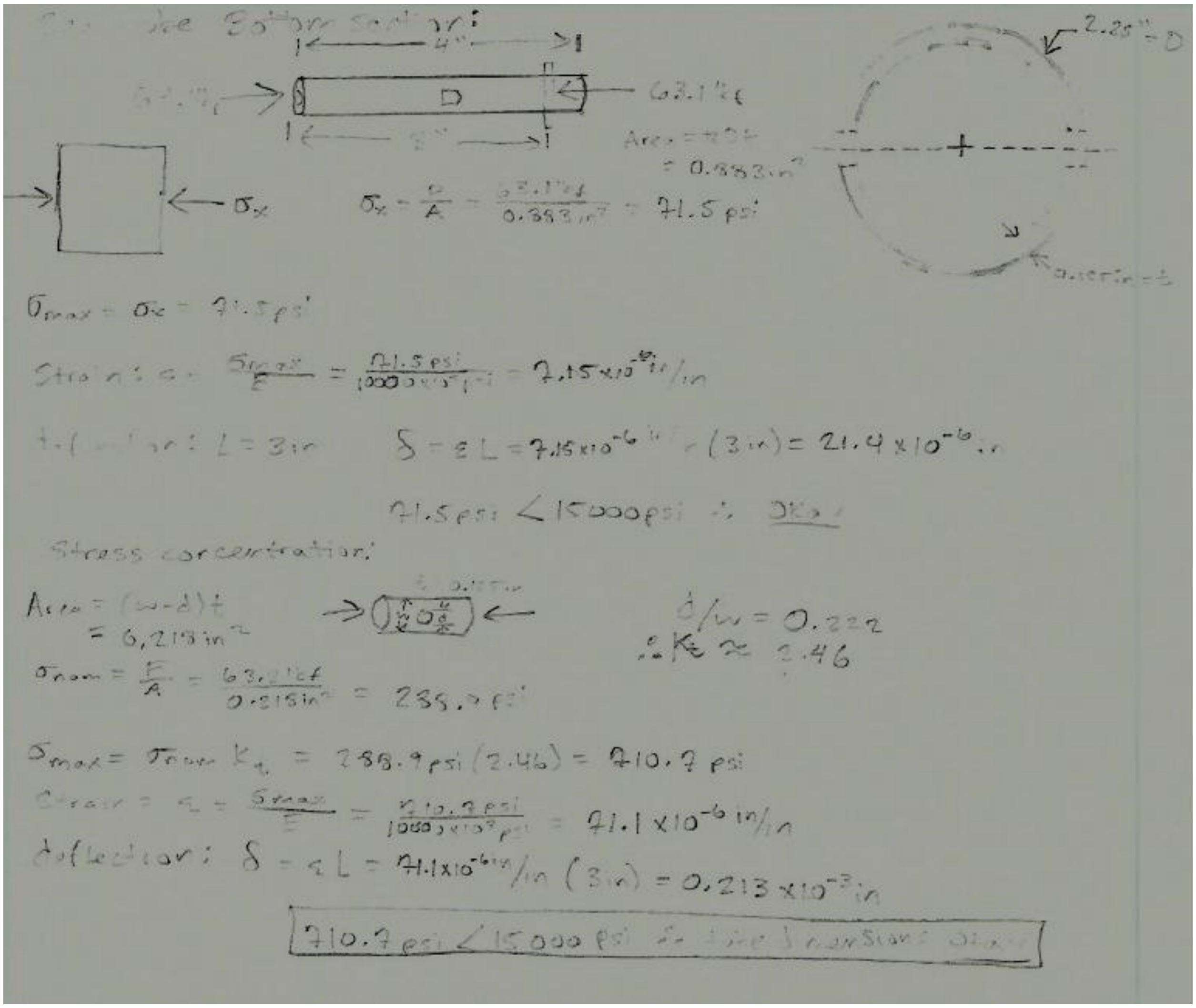


Figure A-5d: Seat Tube Stress Analysis 4

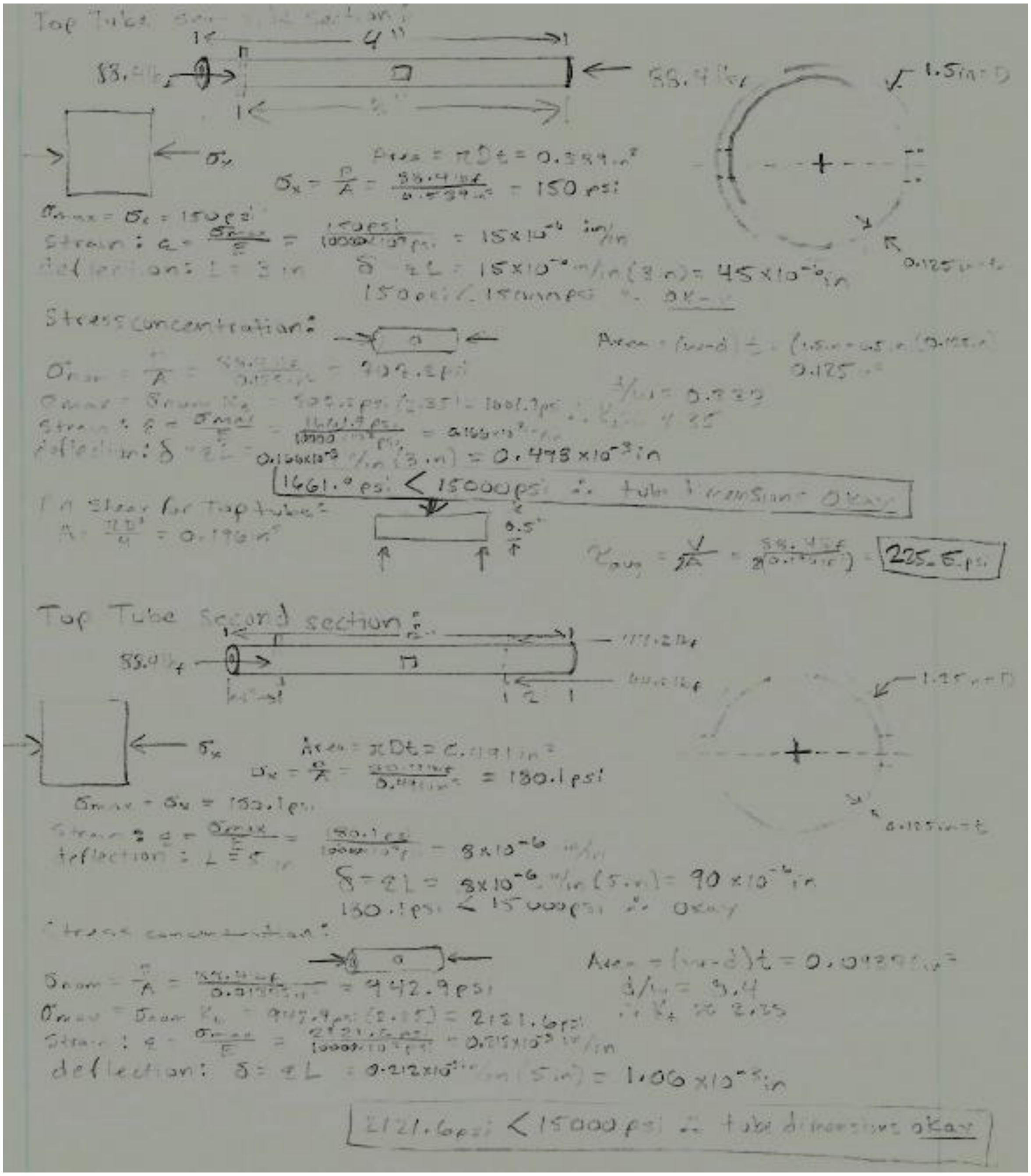


Figure A-6a: Top Tube Stress Analysis 1

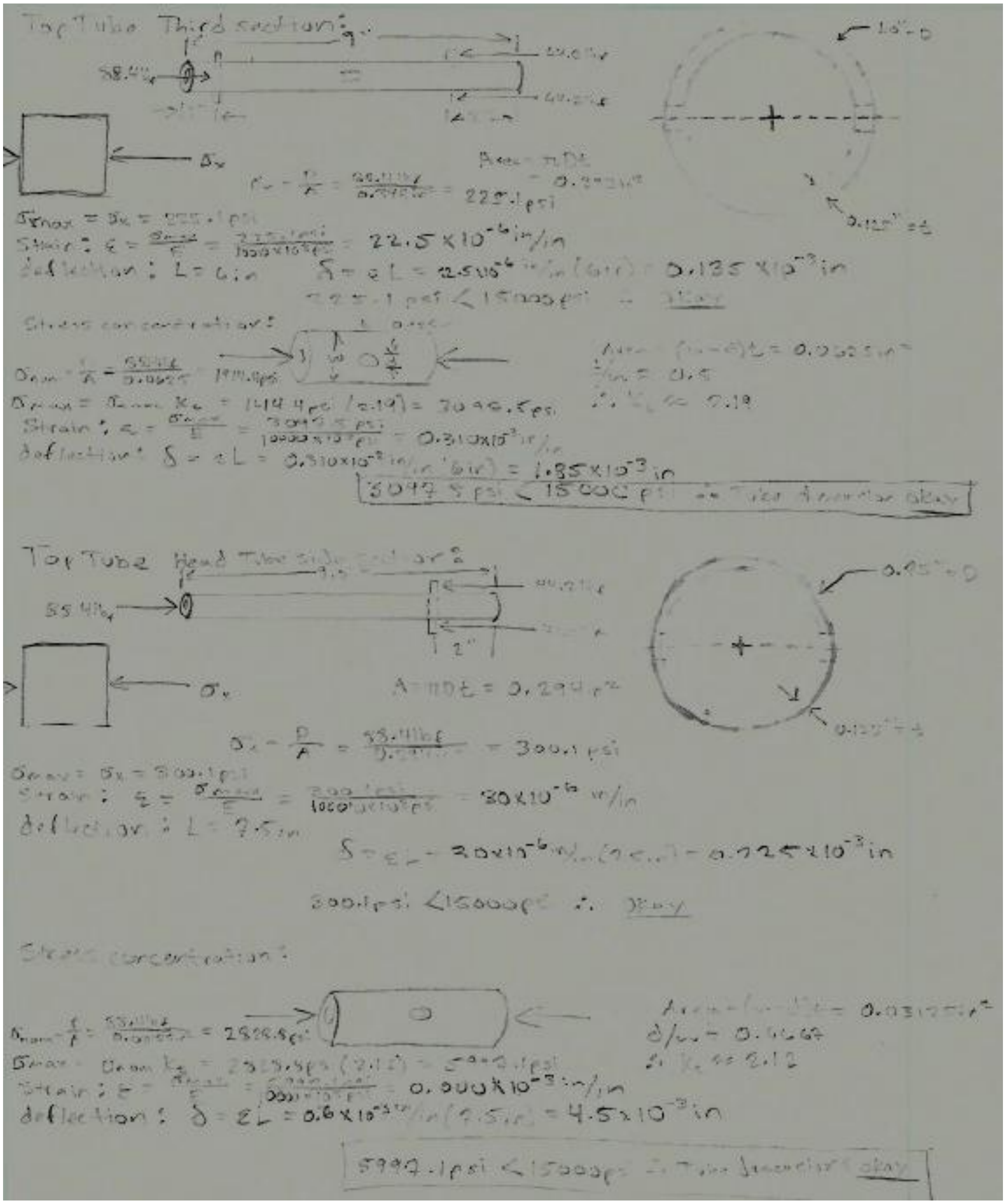


Figure A-6b: Top Tube Stress Analysis 2

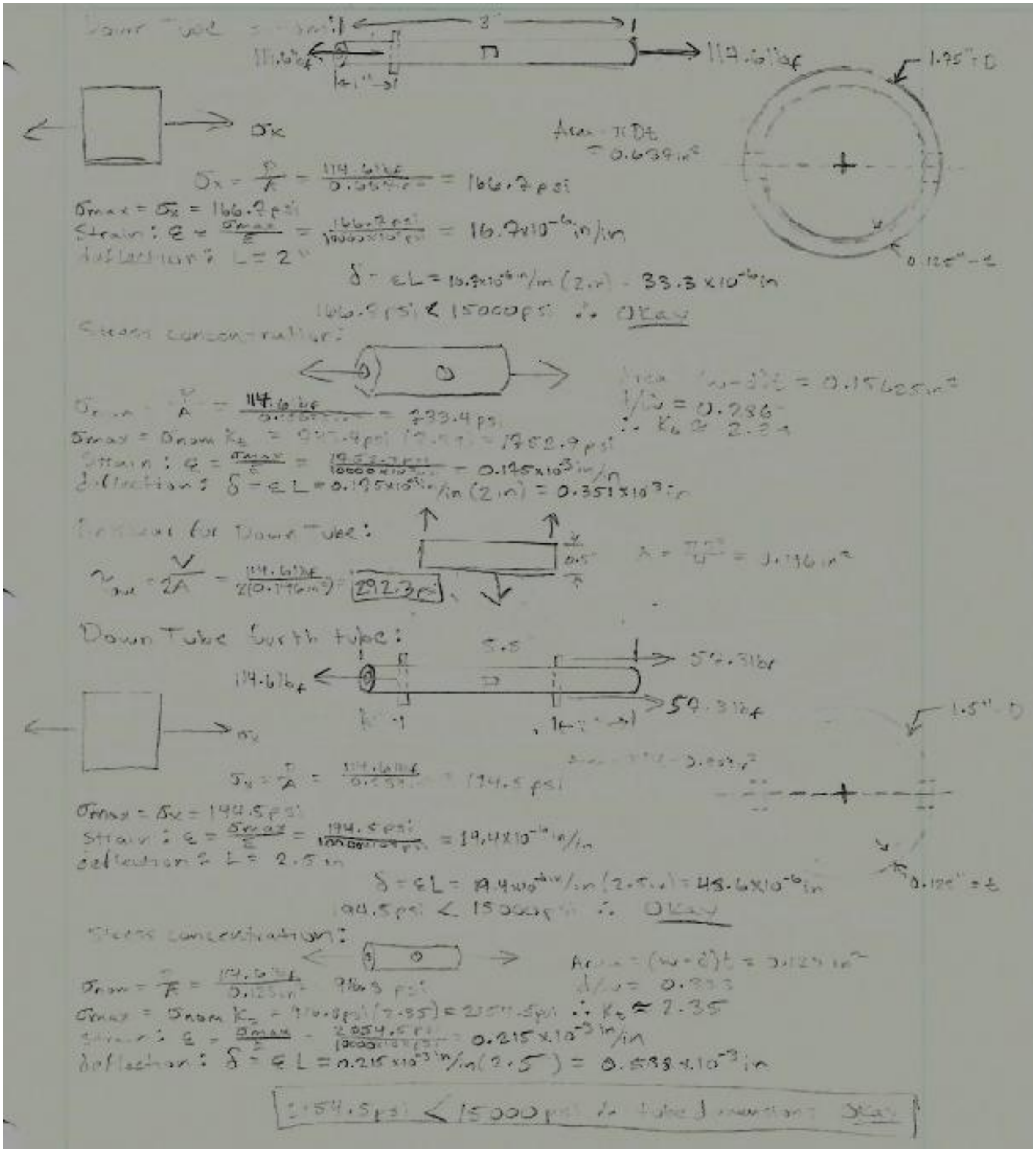


Figure A-7a: Down Tube Stress Analysis 1

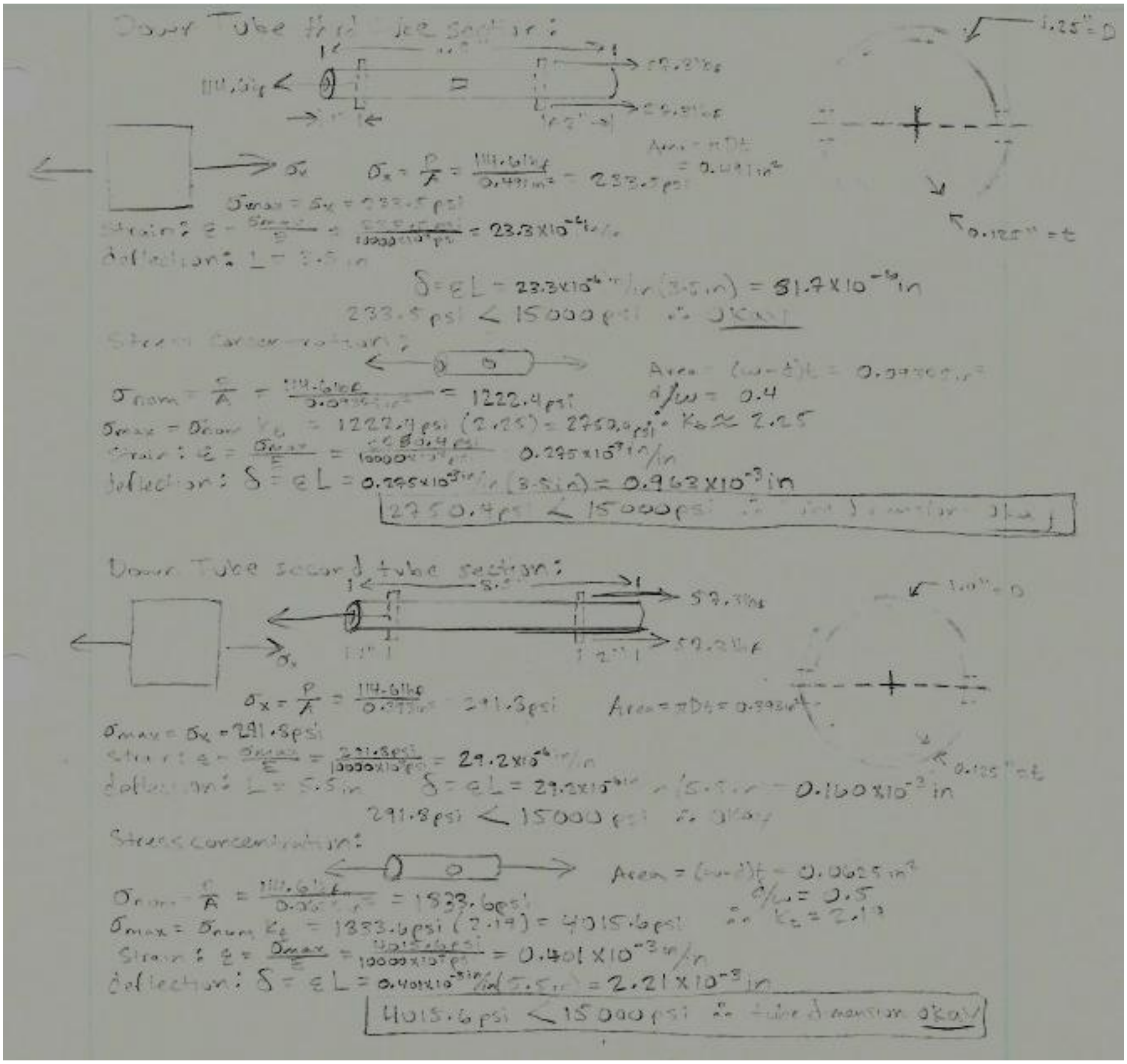


Figure A-7b: Down Tube Stress Analysis 2

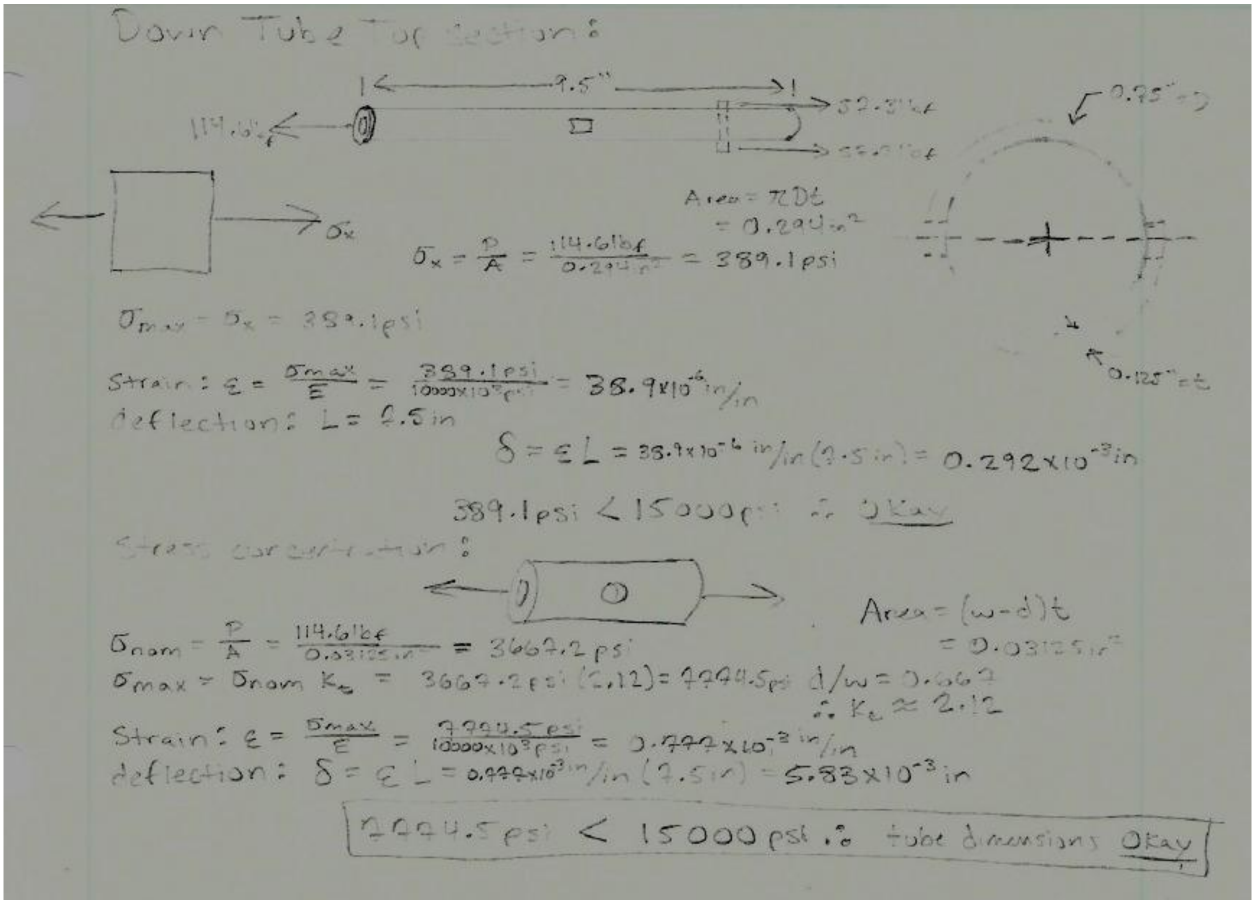


Figure A-7c: Down Tube Stress Analysis 3

APPENDIX B – Sketches, Assembly drawings, Sub-assembly drawings, Part drawings

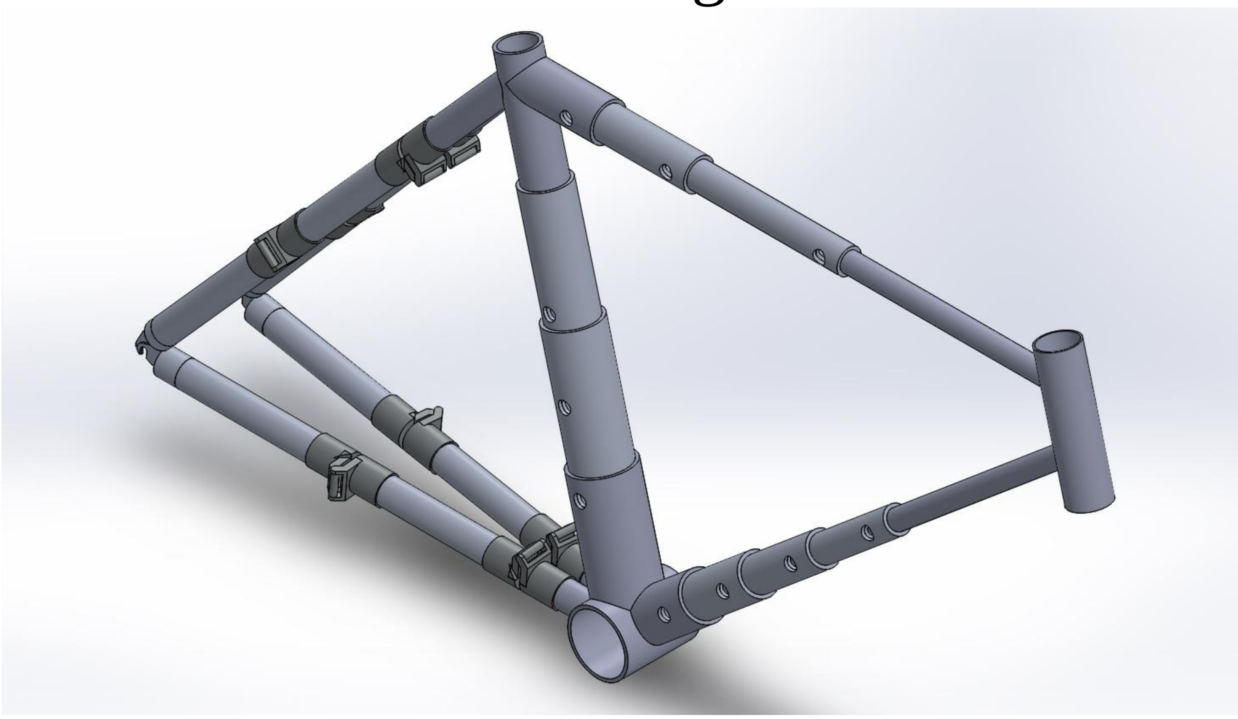


Figure B-1a: Isometric view of Bicycle Design

Figure B-1b: Right view of Bicycle Design

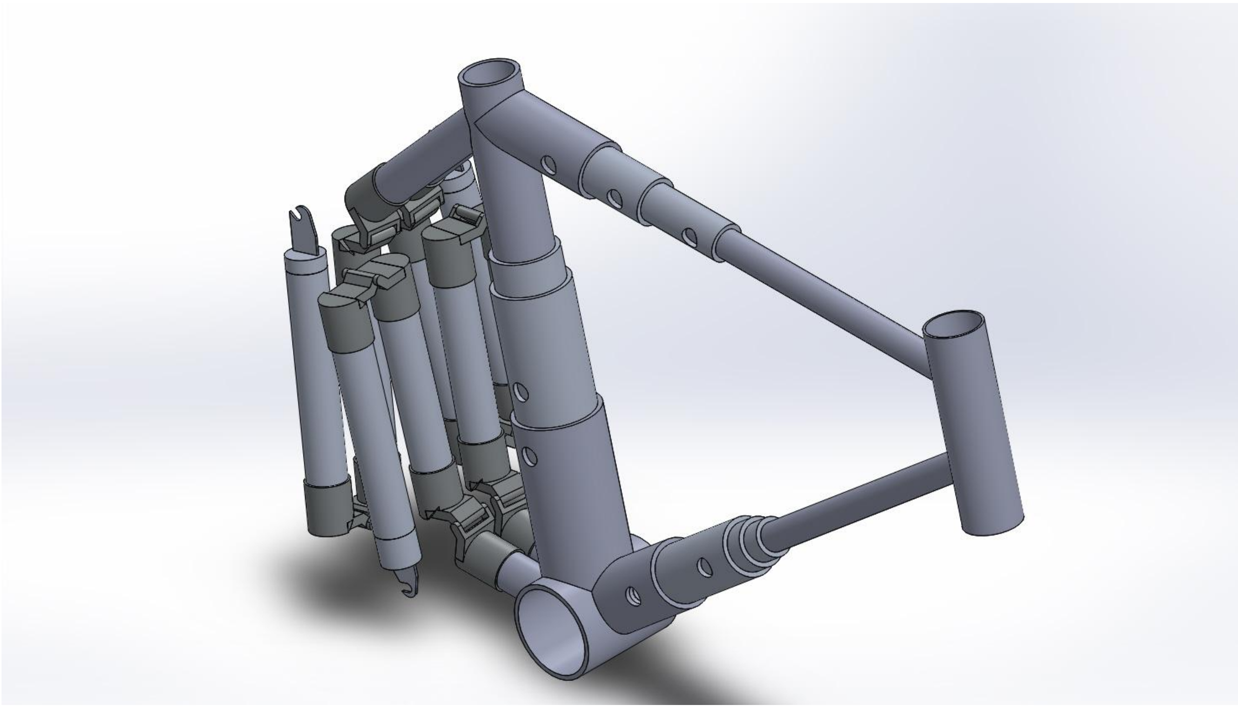


Figure B-1c: Isometric view of Collapsed Frame

Figure B-1d: Right view of Collapsed Frame

Figure B-2: 1” Tube Hinge

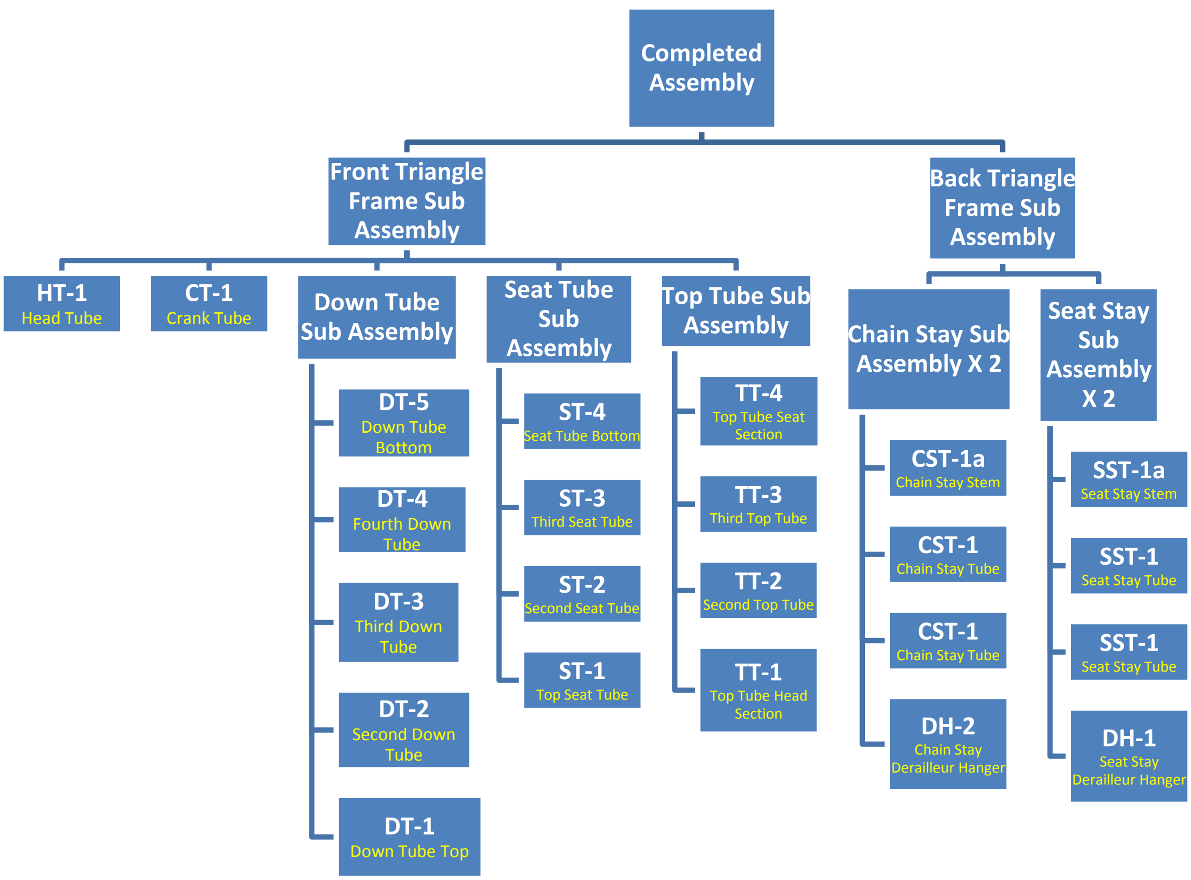


Figure B-3: ½” Hitch Pin with 2.5” usable length

Figure B-4: Drawing Tree

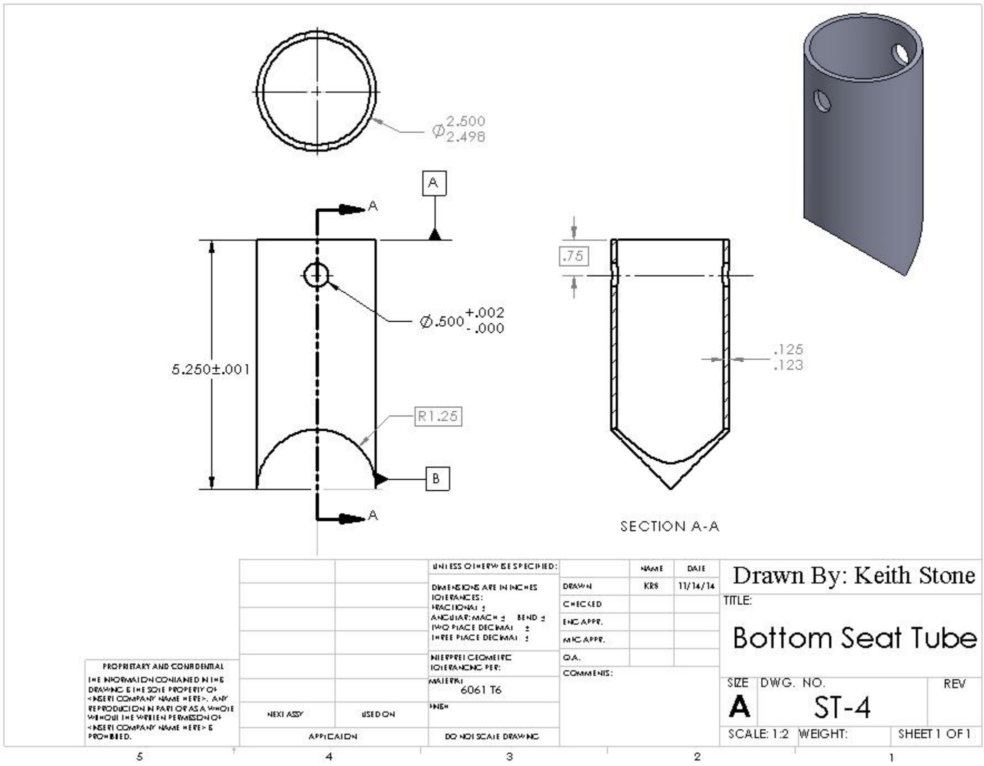


Figure C-1: ST-4 bottom of the seat tube

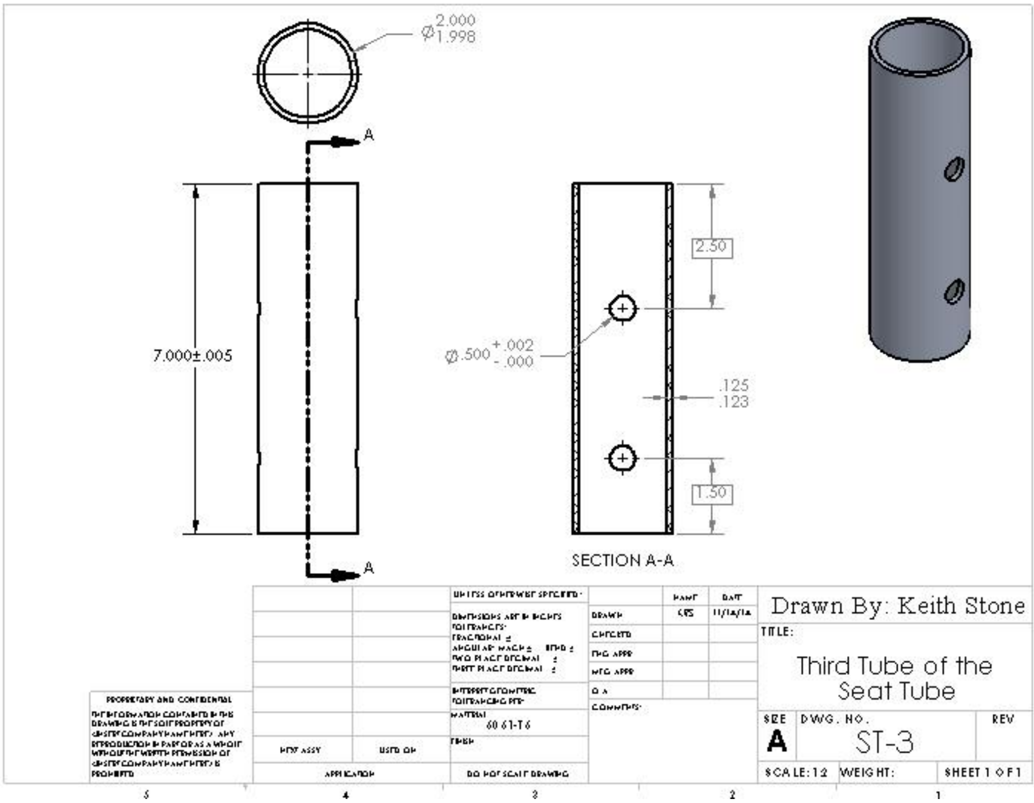


Figure C-2: ST-3, third section of seat tube

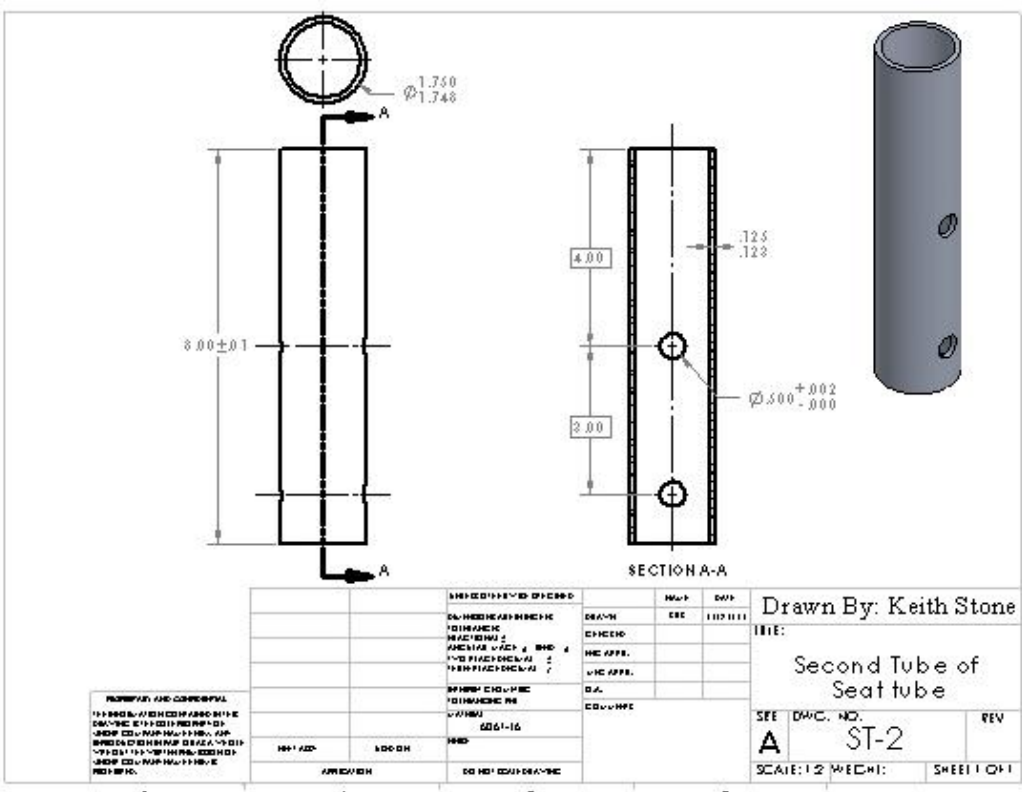


Figure C-3: ST-2, Second section of seat tube

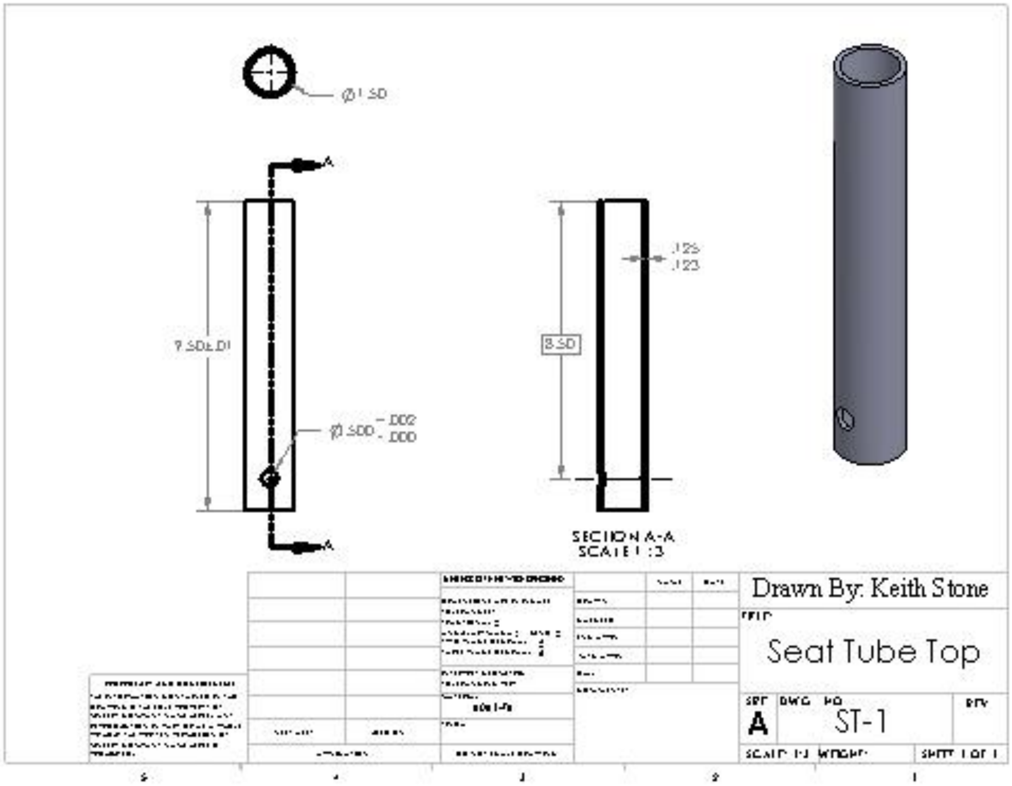


Figure C-4: ST-1, first section of seat tube

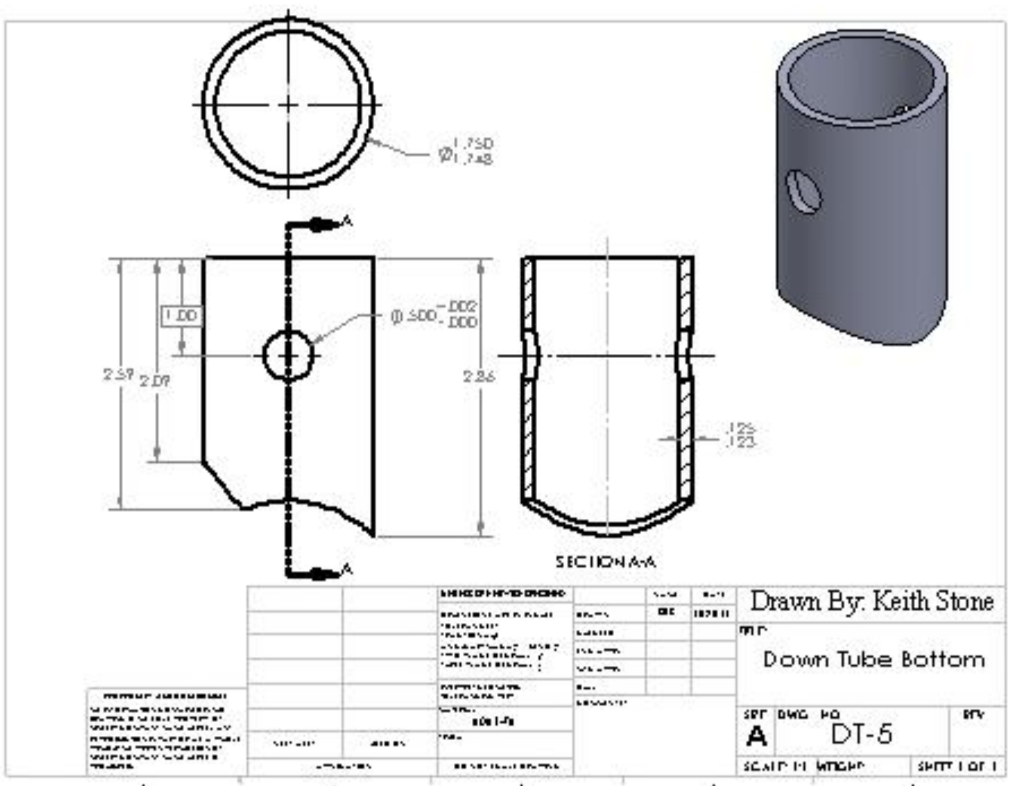


Figure C-5: DT-5, Bottom section of down tube

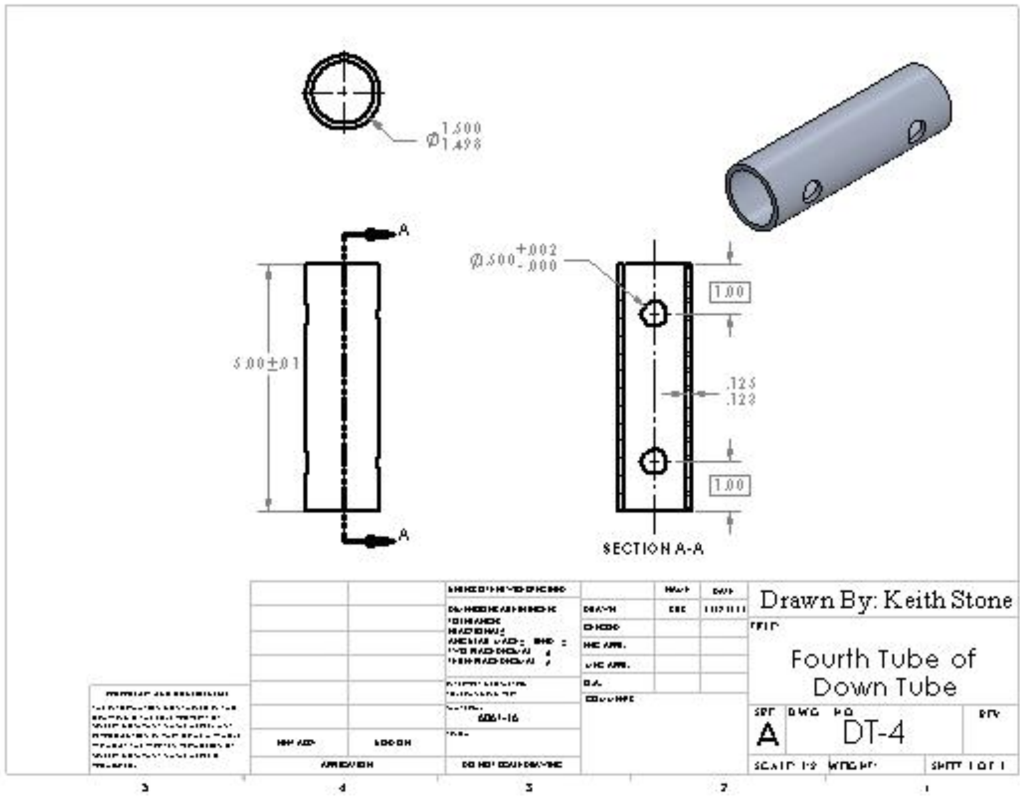


Figure C-6: DT-4, fourth section of down tube

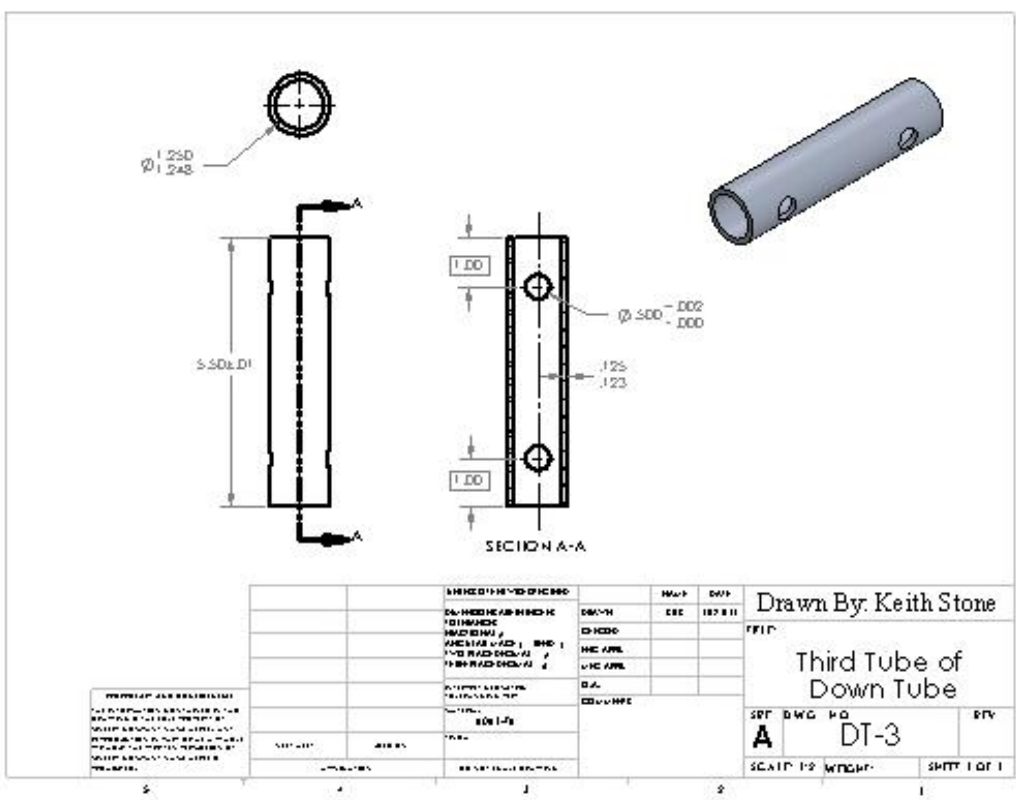


Figure C-7: DT-3, third section of down tube

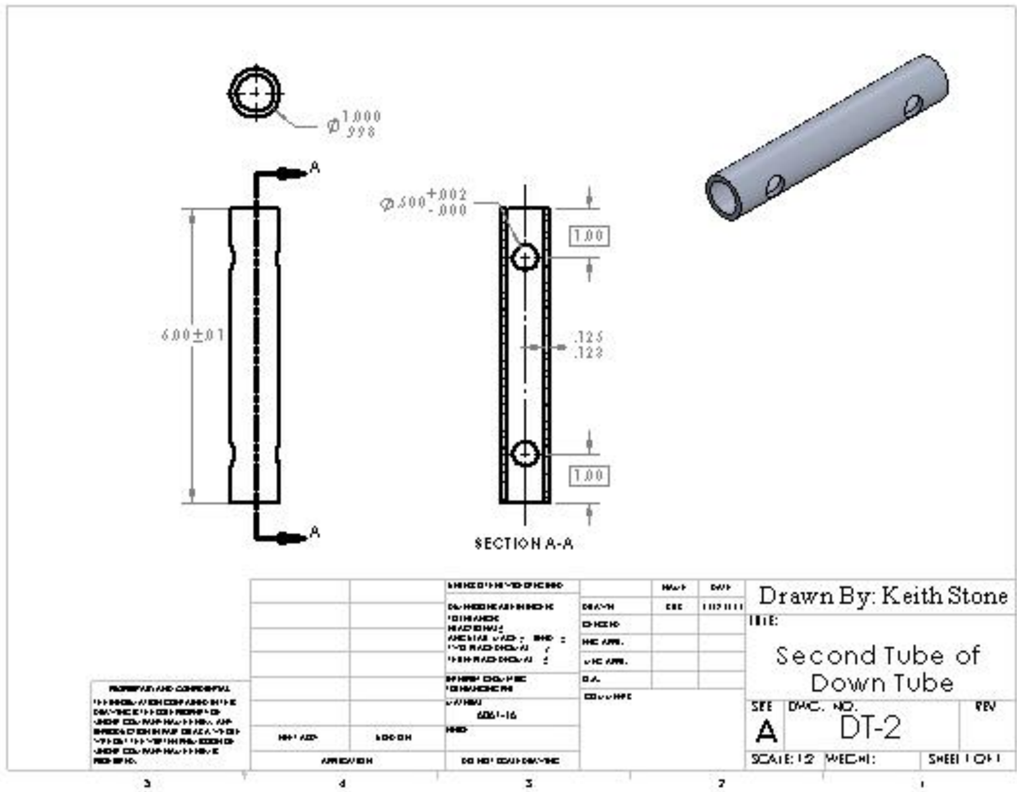


Figure C-8: DT-2, Second section of down tube

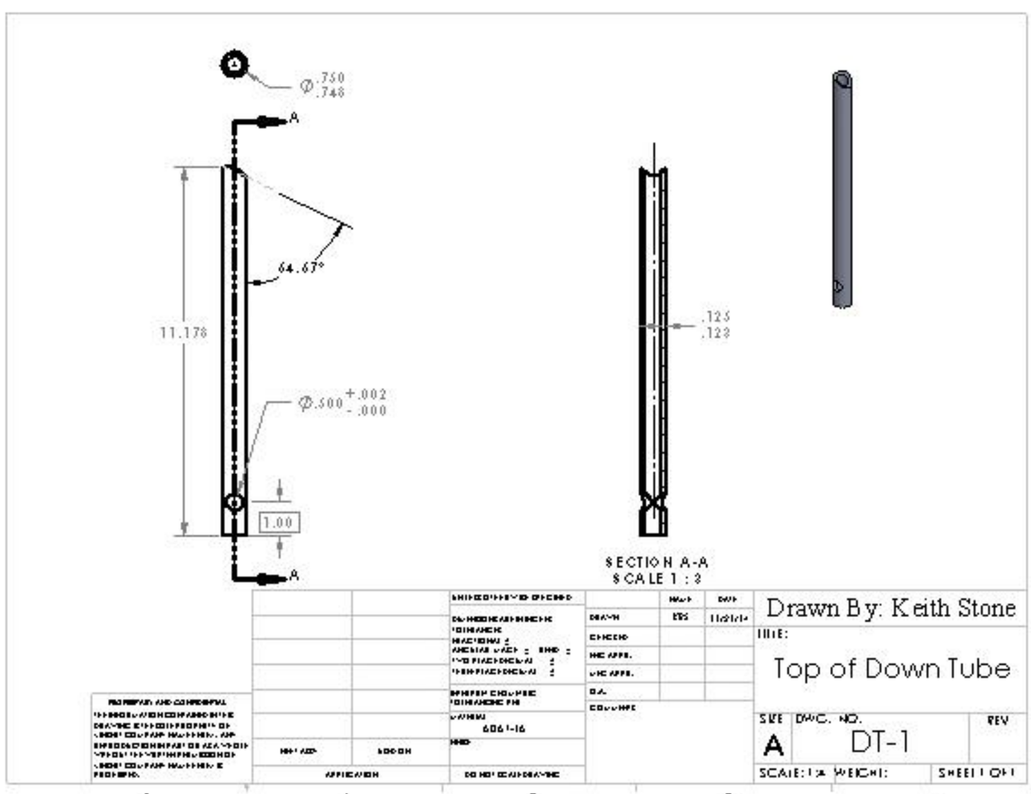


Figure C-9: DT-1, Top section of down tube

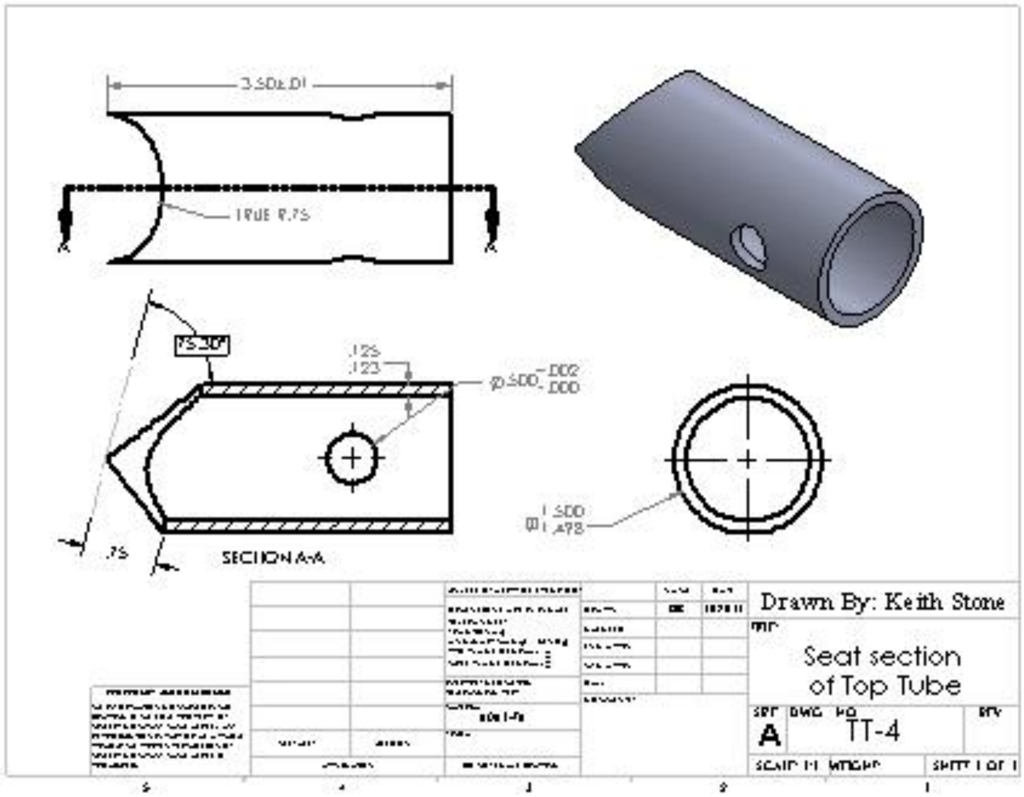


Figure C-10: TT-4, Top tube section that is welded to top seat tube.

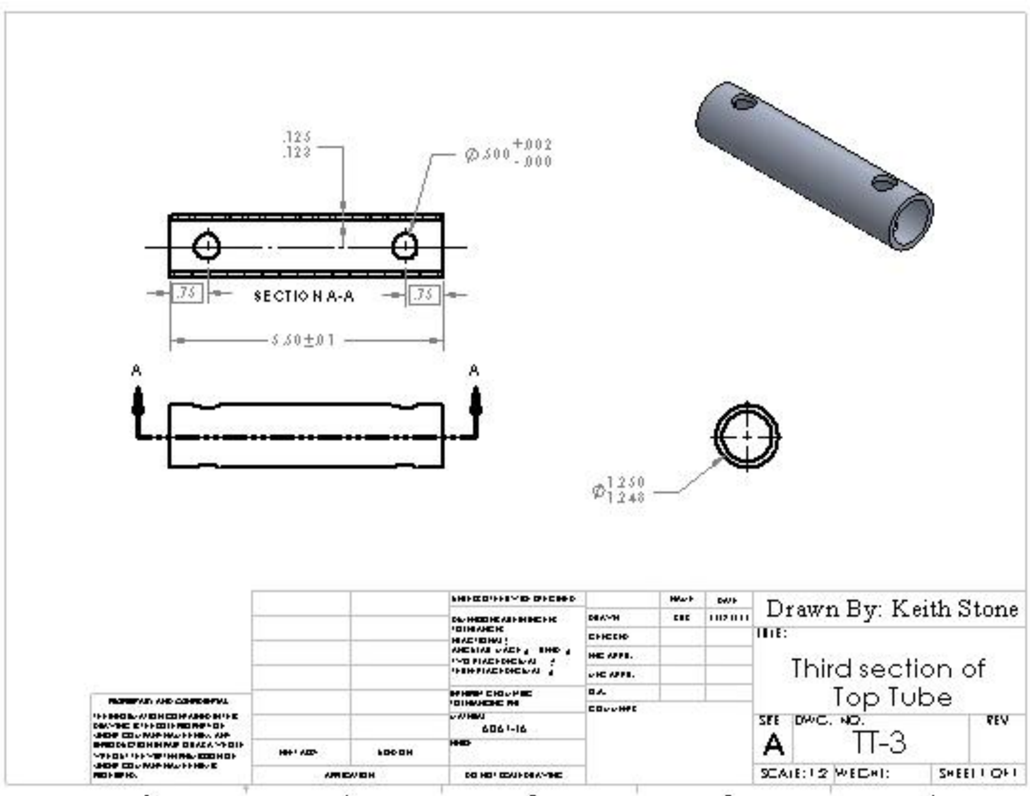


Figure C-11: TT-3, Second section top tube from the welded seat tube

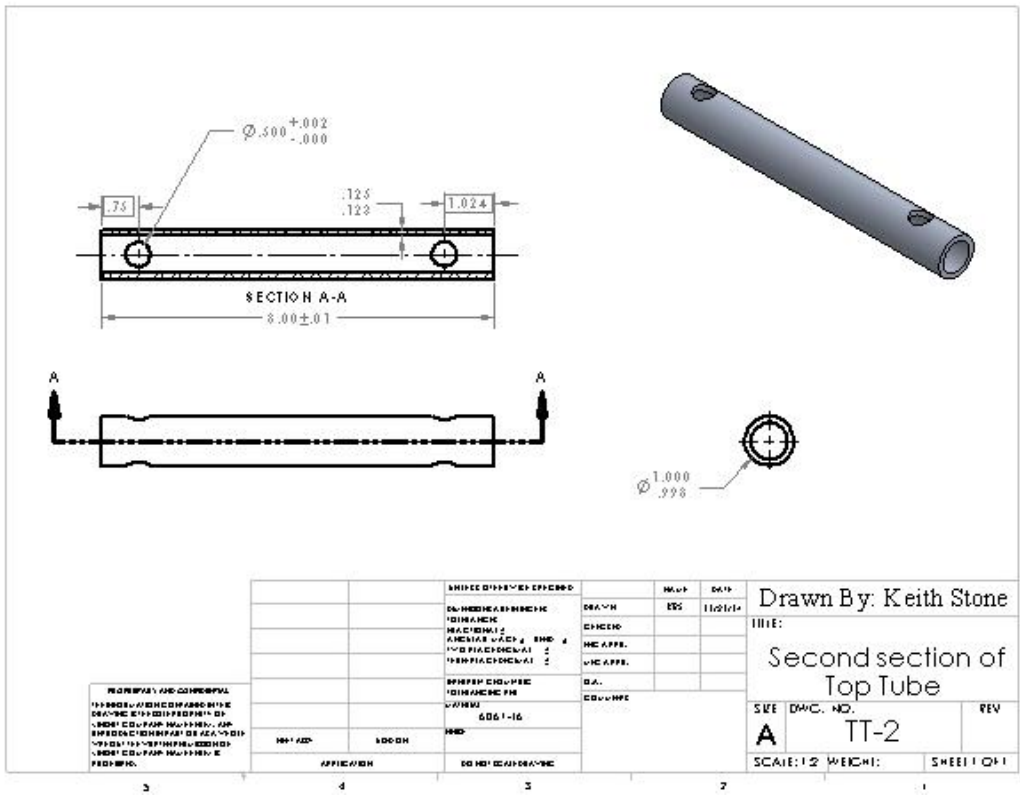


Figure C-12: TT-2, Second section top tube from the welded head tube

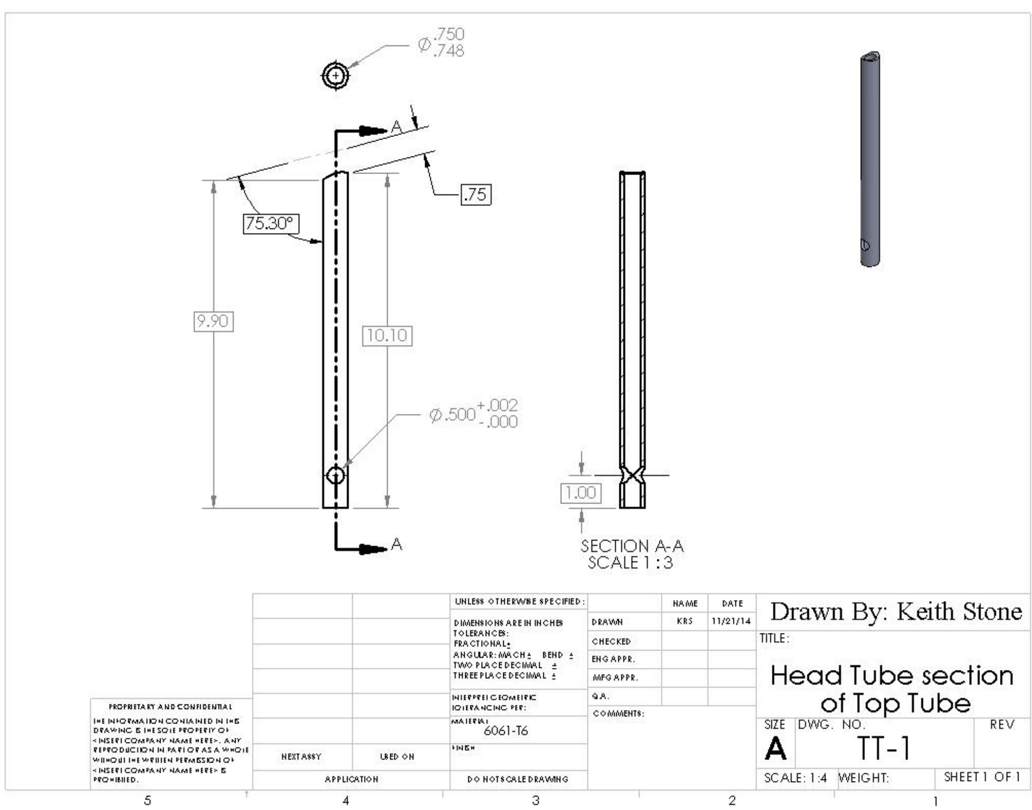


Figure C-13: TT-1, Top tube section that is welded to head tube

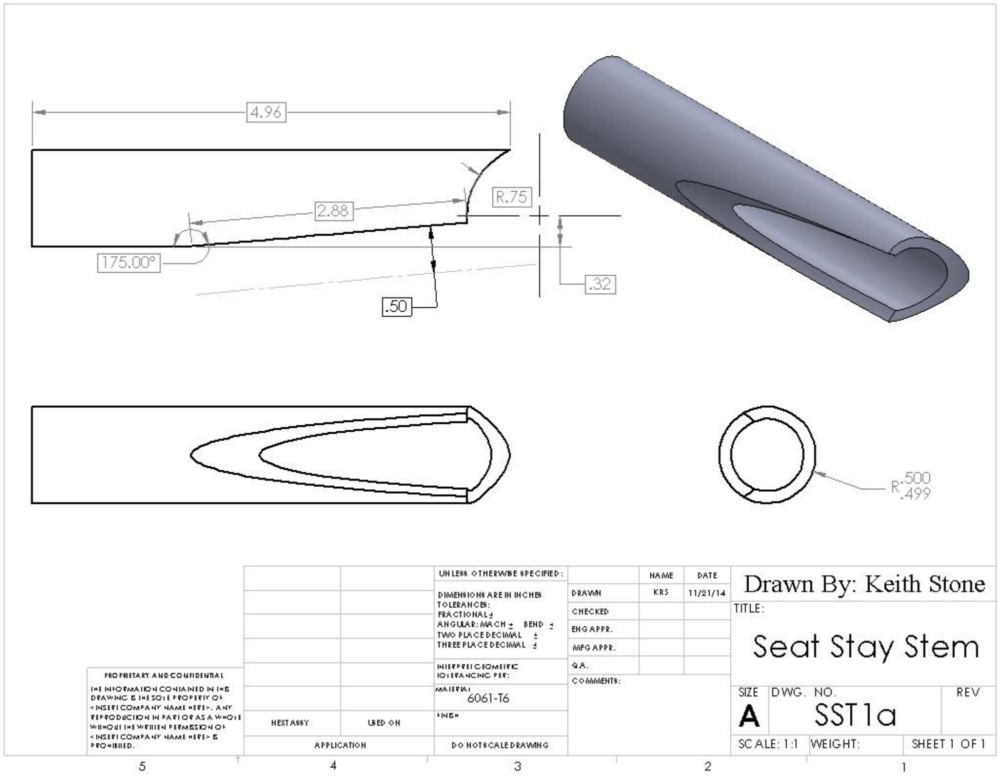


Figure C-14: SST-1a: Seat Stay Stem (There are two of these)

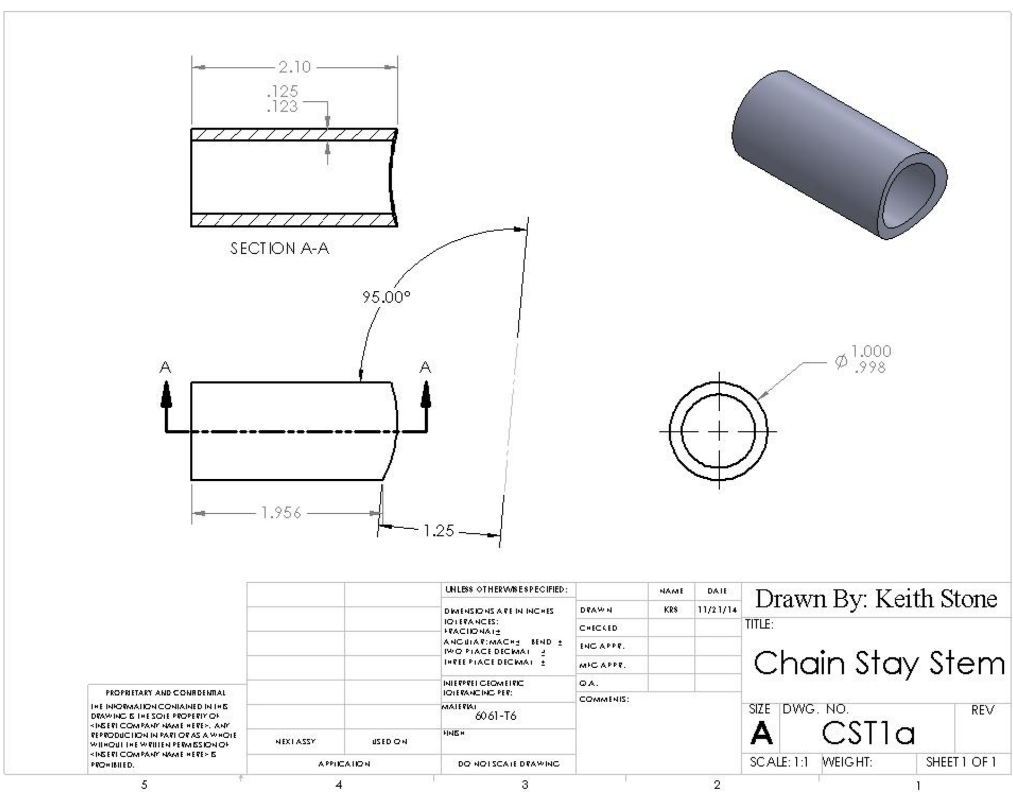


Figure C-15: CST-1a, Chain stay stem (There are two)

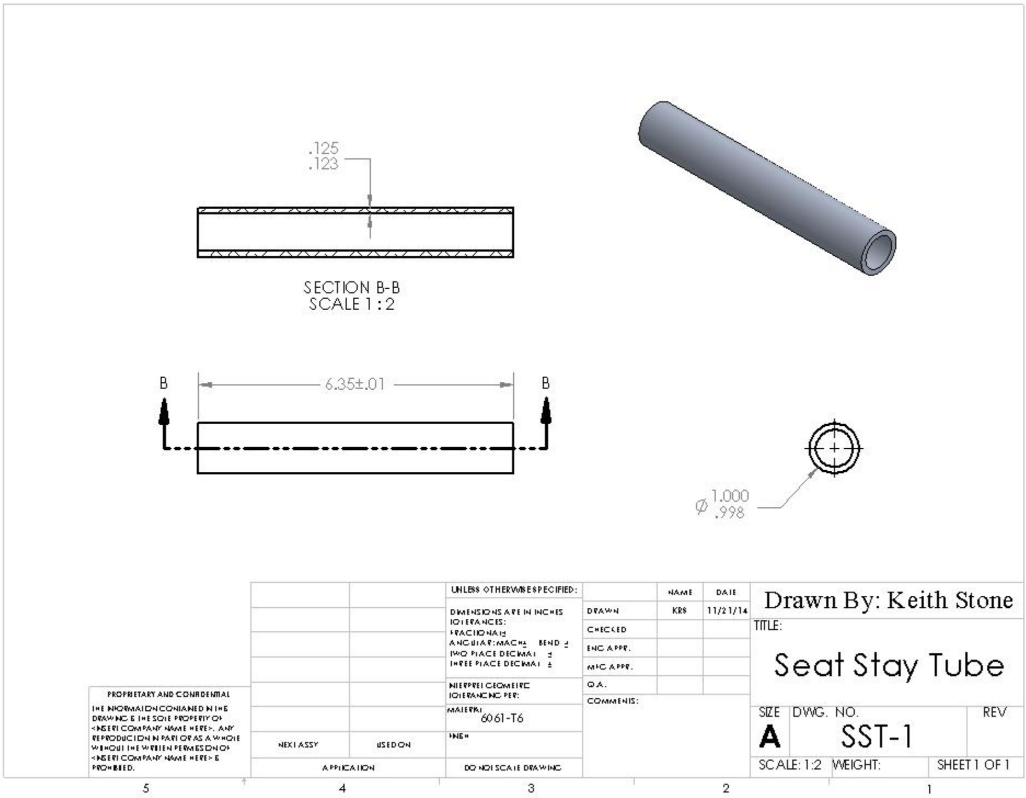


Figure C-16: SST-1, Seat Stay Tube (There are four total, two on each side)

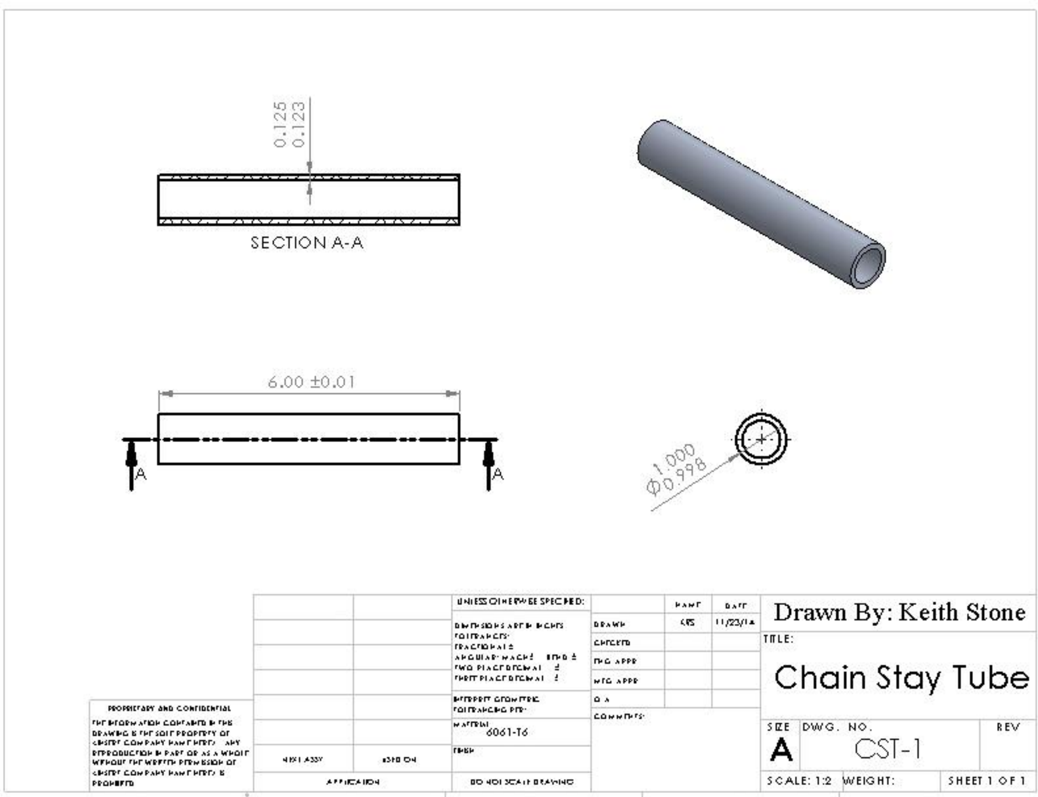


Figure C-17: Chain Stay Tube (there are four total, two on each side)

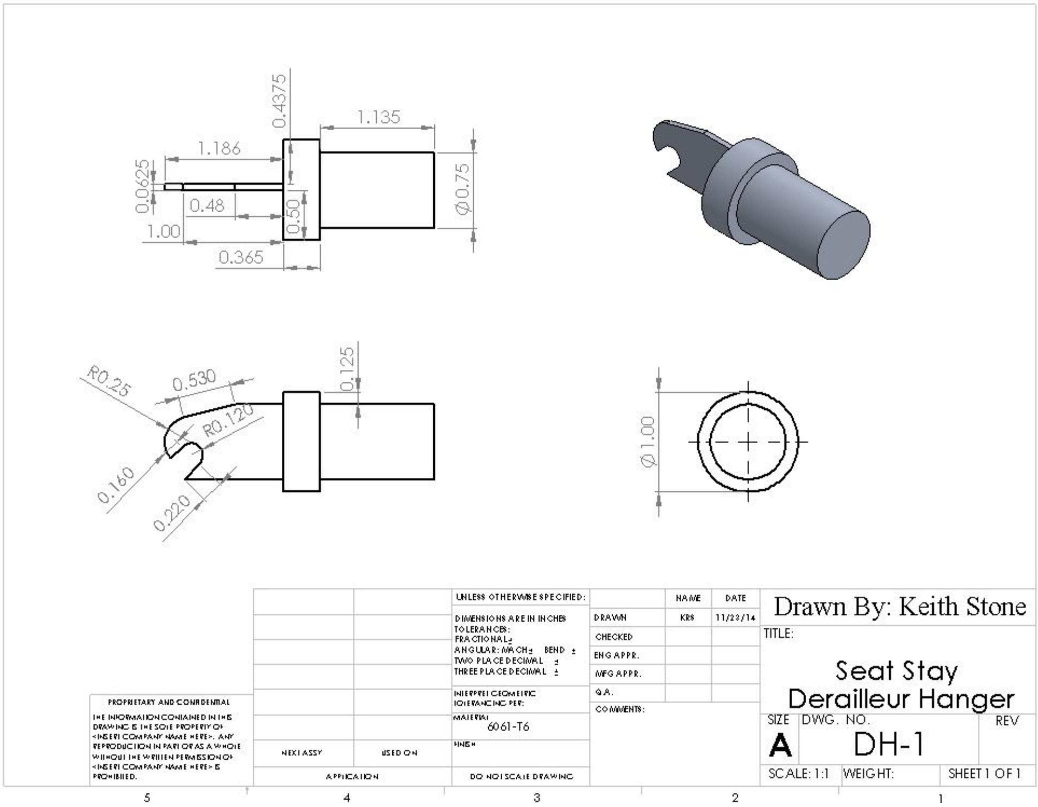


Figure C-18: Seat Stay Derailleur Hanger (There are two)

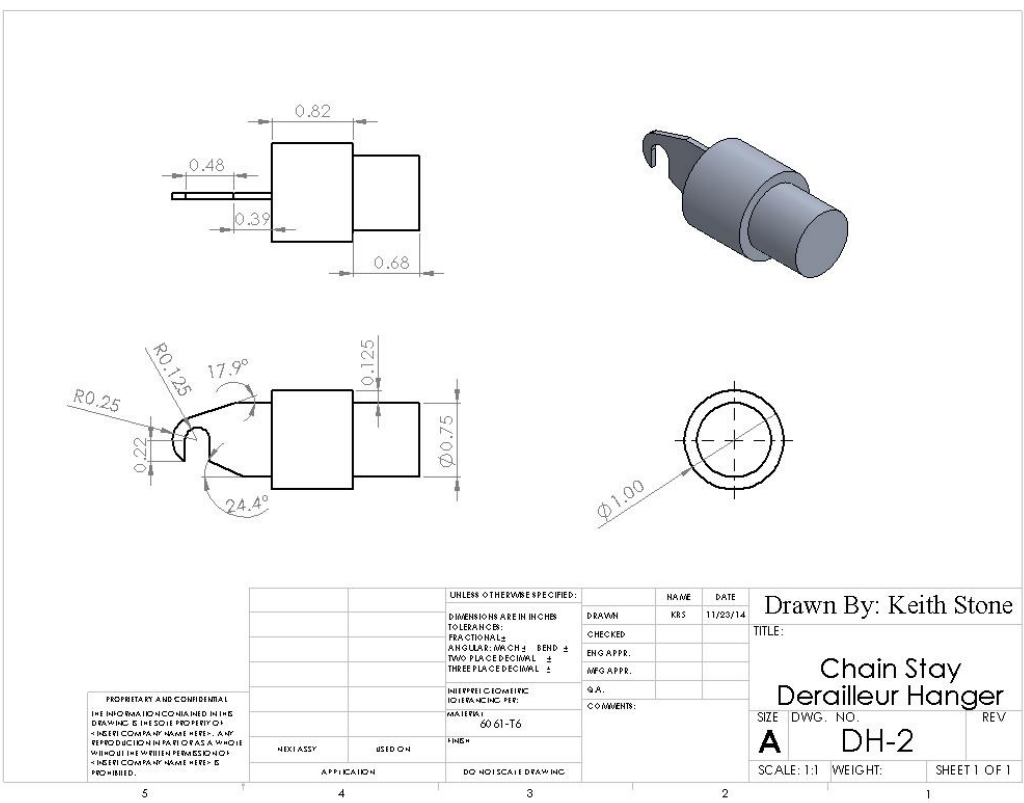


Figure C-19: Chain Stay Derailleur Hanger (There are two)

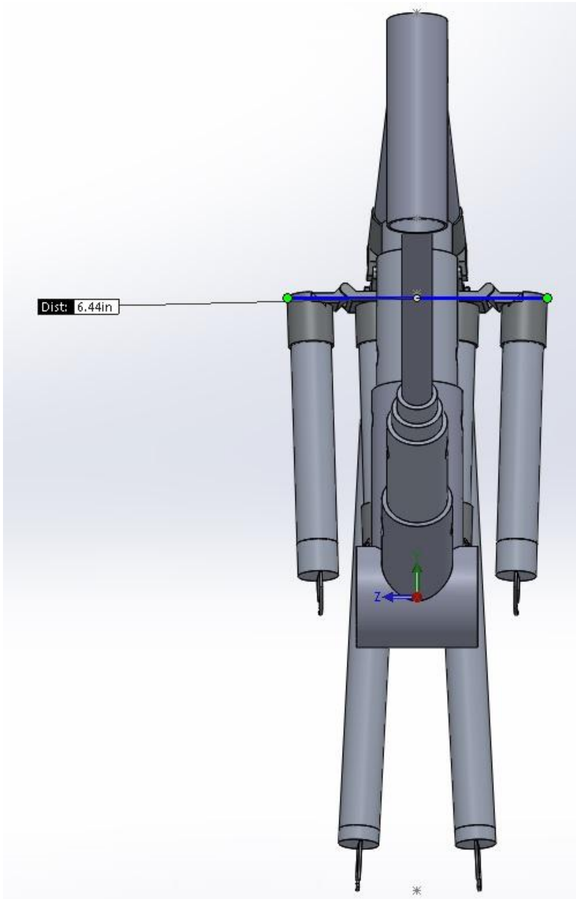


Figure D-1: Front bicycle frame profile with approximate depth after collapse

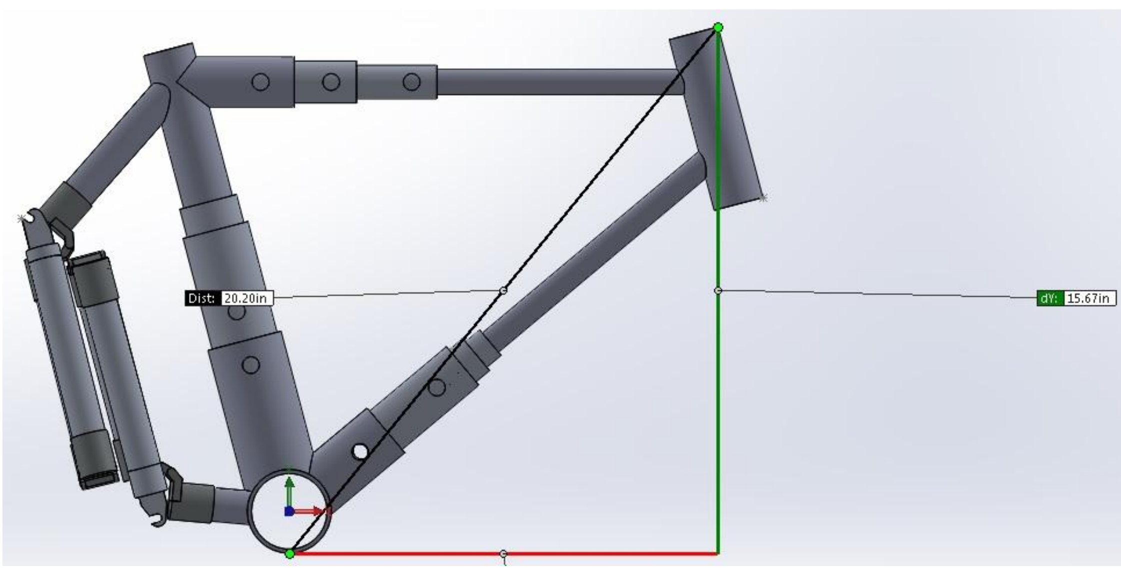


Figure D-2: Side bicycle frame profile with approximate height after collapse

Figure D-3: Side bicycle frame profile with approximate length after collapse

APPENDIX C – Parts List

Item ID	Part #	SolidWorks Model Part ID	Part Description ODxWallxID	Quantity/Lengths needed
To be machined from item 1a		TT-1	Top tube (welded at head tube section)	10.25"
		DT-1	Down tube top section	12"
1a	**T3R-34125**		**0.75"x0.125"x0.5" Tube**	**22.25"**
To be machined from item 1b		TT-2	Top tube second section	7"
		DT-2	Down tube second section	6"
		SST-1	Seat stay left side	18"
		SST-2	Seat stay right side	18"
		CST-1	Chain stay left side	8"
		CST-2	Chain stay right side	8"
1b	**T3R-1125**		**1"x0.125"x0.75"**	**5' 4.5"**
To be machined from item 1c		TT-3	Top tube third section	4.5"
		DT-3	Down tube third section	5.5"
1c	**T3R-114125**		**1.25"x0.125"x1"**	**10"**
To be machined from item 1d		HT-1	Head tube	5.5"
1d	**T3R-112065**		**1.5"x0.065"x1.37"**	**5.5"**
To be machined from item 1e		ST-1	Seat tube top section	9.5"
		TT-4	Top tube (welded at seat tube section)	3.5"
		DT-4	Down tube bottom middle section	5"

1e	**T3R-112125**		**1.5”x0.125”x1.25”**	**18”**
To be machined from item 1f		ST-2	Seat tube second section	8”
		DT-5	Down tube bottom section	3.75”
1f	**T3R-134125**		**1.75”x0.125”x1.5”**	**11.75”**
To be machined from item 1g		ST-3	Seat tube third section	7”
1g	**T3R-2125**		**2”x0.125”x1.75”**	**7”**
To be machined from item 1h		ST-4	Seat tube bottom section	5.25”
1h	**T3R-214125**		**2.25”x0.125”x2”**	**5.25”**
To be machined from item 1i		CT-1	Crank tube	3”
1i	**T3R-212125**		**2.5”x0.125”x2.25”**	**3”**
2	**A-1**		**Stainless Tube Hinge (1” OD Tubing)**	**8**
3	**B-1**		**0.5”x 3” Hitch Pin with Clip**	**10**

Table 3: Part list

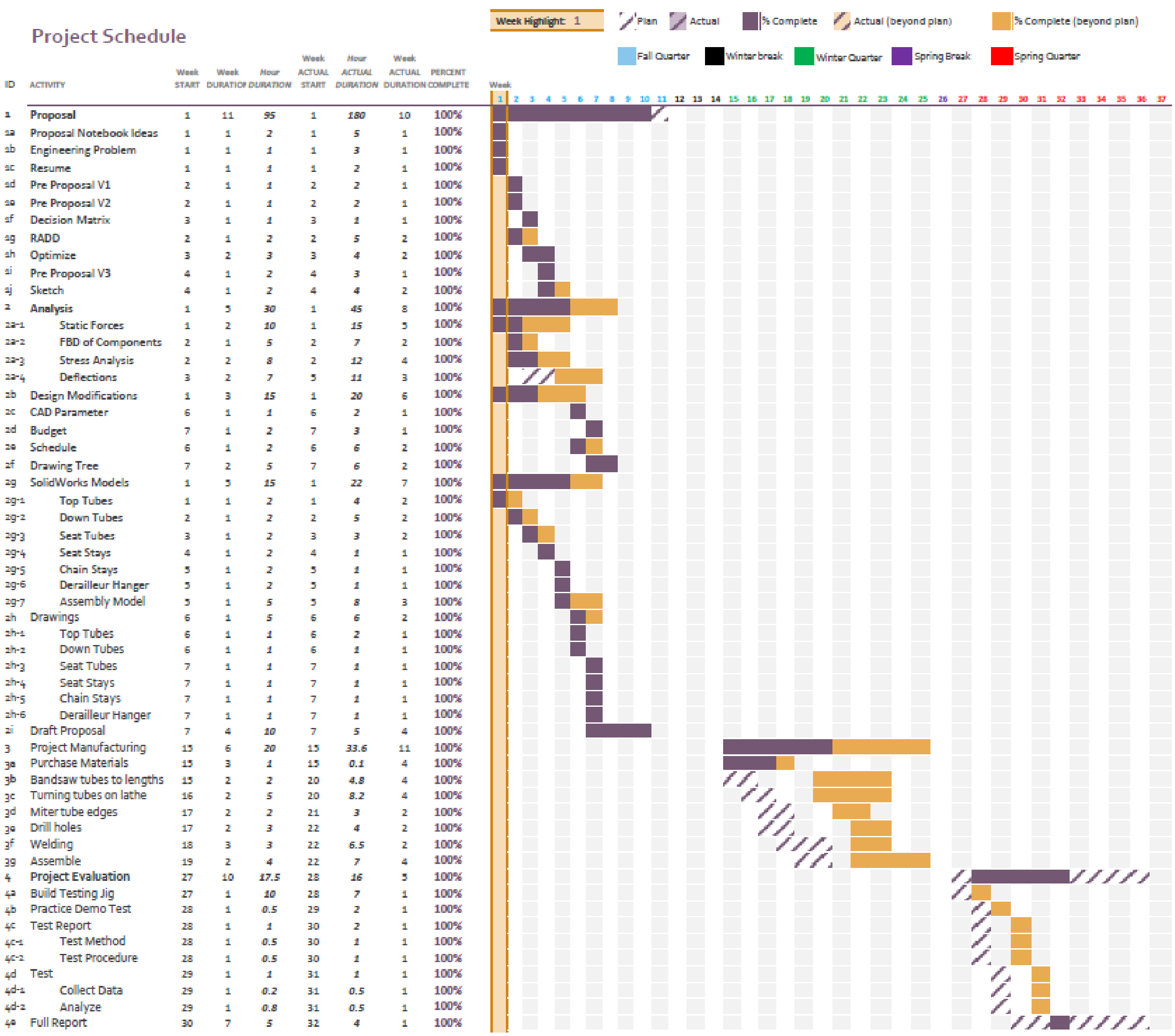
APPENDIX D – Budget

Item ID	Part Number	Description (ODxWallxID)	Material	Cost of Raw Material	Quantity to purchase	Location of Purchase	Total Cost
1a	T3R-34125	0.75”x0.125”x0.5” Tube	Aluminum 6061 T6	$7.20/2 ft	2 ft	Metalsdepot.com	$7.20
1b	T3R-1125	1”x0.125”x0.75” Tube	Aluminum 6061 T6	$6.66/2 ft	5.5 ft	Metalsdepot.com	$20.32
1c	T3R-114125	1.25”x0.125”x1” Tube	Aluminum 6061 T6	$7.80/2 ft	2 ft	Metalsdepot.com	$7.80
1d	T3R-112065	1.5”x0.65”x1.37” Tube	Aluminum 6061 T6	$6.32/2 ft	0.5 ft	Metalsdepot.com	$3.58
1e	T3R-112125	1.5”x0.125”x1.25” Tube	Aluminum 6061 T-6	$9.52/2 ft	1.5 ft	Metalsdepot.com	$9.56
1f	T3R-134125	1.75”x0.125”x1.5” Tube	Aluminum 6061 T6	$11.92/2 ft	1 ft	Metalsdepot.com	$7.96
1g	T3R-2125	2”x0.125”x1.75” Tube	Aluminum 6061 T6	$13.50/2 ft	7 inches	Metalsdepot.com	$5.94
1h	T3R-214125	2.25”x0.125”x2” Tube	Aluminum 6061 T6	$19.50/2 ft	0.5 ft	Metalsdepot.com	$6.88
1i	T3R-212125	2.5”x0.125”x2.25” Tube	Aluminum 6061 T6	$79.20/4 ft	0.5 ft	Metalsdepot.com	$11.90
2	A-1	Tube Hinge	316 Stainless Steel	$25.99	8	Clothcanvas.com	$224.41
3	B-1	Hitch Pin	Steel	$3.22	10	MSCDirect.com	$32.20

1a.1	CWU-MACH	Machining Cost	Time	$0/hr	32 hours	CWU Machine Shop	$0
1a.2	OUT-Welding	Welding Cost	Time	$30/hr	2 hours	Outsource to Jeff Colby	$60
						Total:	$397.33

Table 4: Budget list

APPENDIX E – Schedule; use a spreadsheet or software (MS Project), for the year.



ID	ACTIVITY	Week START	Week DURATION	Hour DURATION	Week ACTUAL START	Hour ACTUAL DURATION	Week ACTUAL DURATION	PERCENT COMPLETE
1	Proposal	1	11	95	1	180	10	100%
1a	Proposal Notebook Ideas	1	1	2	1	5	1	100%
1b	Engineering Problem	1	1	1	1	3	1	100%
1c	Resume	1	1	1	1	2	1	100%
1d	Pre Proposal V1	2	1	1	2	2	1	100%
1e	Pre Proposal V2	2	1	1	2	2	1	100%
1f	Decision Matrix	3	1	1	3	1	1	100%
1g	RADD	2	1	2	2	5	2	100%
1h	Optimize	3	2	3	3	4	2	100%
1i	Pre Proposal V3	4	1	2	4	3	1	100%
1j	Sketch	4	1	2	4	4	2	100%
2	Analysis	1	5	30	1	45	8	100%
2a-1	Static Forces	1	2	10	1	15	5	100%
2a-2	FBD of Components	2	1	5	2	7	2	100%
2a-3	Stress Analysis	2	2	8	2	12	4	100%
2a-4	Deflections	3	2	7	5	11	3	100%
2b	Design Modifications	1	3	15	1	20	6	100%
2c	CAD Parameter	6	1	1	6	2	1	100%
2d	Budget	7	1	2	7	3	1	100%
2e	Schedule	6	1	2	6	6	2	100%
2f	Drawing Tree	7	2	5	7	6	2	100%
2g	SolidWorks Models	1	5	15	1	22	7	100%
2g-1	Top Tubes	1	1	2	1	4	2	100%
2g-2	Down Tubes	2	1	2	2	5	2	100%
2g-3	Seat Tubes	3	1	2	3	3	2	100%
2g-4	Seat Stays	4	1	2	4	1	1	100%
2g-5	Chain Stays	5	1	2	5	1	1	100%
2g-6	Derailleur Hanger	5	1	2	5	1	1	100%
2g-7	Assembly Model	5	1	5	5	8	3	100%
2h	Drawings	6	1	5	6	6	2	100%
2h-1	Top Tubes	6	1	1	6	2	1	100%
2h-2	Down Tubes	6	1	1	6	1	1	100%
2h-3	Seat Tubes	7	1	1	7	1	1	100%
2h-4	Seat Stays	7	1	1	7	1	1	100%
2h-5	Chain Stays	7	1	1	7	1	1	100%
2h-6	Derailleur Hanger	7	1	1	7	1	1	100%
2i	Draft Proposal	7	4	10	7	5	4	100%
3	Project Manufacturing	15	6	20	15	33.6	11	100%
3a	Purchase Materials	15	3	1	15	0.1	4	100%
3b	Bandsaw tubes to lengths	15	2	2	20	4.8	4	100%
3c	Turning tubes on lathe	16	2	5	20	8.2	4	100%
3d	Miter tube edges	17	2	2	21	3	2	100%
3e	Drill holes	17	2	3	22	4	2	100%
3f	Welding	18	3	3	22	6.5	2	100%
3g	Assemble	19	2	4	22	7	4	100%
4	Project Evaluation	27	10	17.5	28	16	5	100%
4a	Build Testing Jig	27	1	10	28	7	1	100%
4b	Practice Demo Test	28	1	0.5	29	2	1	100%
4c	Test Report	28	1	1	30	2	1	100%
4c-1	Test Method	28	1	0.5	30	1	1	100%
4c-2	Test Procedure	28	1	0.5	30	1	1	100%
4d	Test	29	1	1	31	1	1	100%
4d-1	Collect Data	29	1	0.2	31	0.5	1	100%
4d-2	Analyze	29	1	0.8	31	0.5	1	100%
4e	Full Report	30	7	5	32	4	1	100%

Figure E-1: Gaant Chart

APPENDIX F – Evaluation sheet (Testing)

Bicycle Mass Test			
Name:			
Date:			
Trial	Me+Bike (lbs)	Me (lbs)	Bike(lbs)
1			
2			
3			
4			
5			
	Average Total Mass		

Table 5-1: Bicycle Mass Test Sheet

Bicycle Frame Loading Test		
Name:		
Date:		
Trail	Load (lbs)	Deflection at Crank (in)
1	20	
2	40	
3	60	
4	80	
5	100	
6	120	
7	140	
8	160	
9	180	

Table 5-2: Load Testing Sheet

Dimension Testing		
Name:		
Date:		
Expanded		
Length (in)	Height (in)	Width (in)
Collapsed		
Length (in)	Height (in)	Width (in)

Table 5-3: Dimension Test Sheet

APPENDIX G – Testing Report

Collapsible Frame Report

Introduction:

For this lab a test will be done for the testing the static strength of the frame. A frame jig will hold the frame in place as a load is applied to the seat which will be measured by a bathroom scale. A ruler will be used to measure the deflection as the load is applied and will be viewed and analyzed by recording the deflection by capturing the deflection data by video recording. The frame will also be tested by collapsing the frame into a bag of specific dimensions to confirm that the frames size is within the required dimensions.

Procedure**:**

1. Acquire the bicycle frame, the testing jig, a socket wrench, two weight scales one digital and other dial, a hand crank car jack with handle, a 22 by 14 by 9 inch luggage case, a ruler that reads in 32nds of an inch, and a piece of 2 by 4 inch plank cut to fit into the jig.
2. Place the digital scale on floor then pick up the bicycle frame and step onto the scale and record weight
3. Put down the bicycle frame and step on the scale again and record weight
4. Place bicycle frame into the jig
5. Setup the jig by placing the car jack onto the seat tube, place the 2 by 4 inch plank onto of the car jack with the dial scale on top to be press fitted inside the jig
6. Turn the crank of the car jack so that scale fits just snug against the jig and still reads zero pounds on the scale
7. Take the ruler place it so that it stands from the floor to the free floating crank
8. Turn the crank of the car jack to and record deflection from the ruler from various loads that can be read from the dial scale
9. After recording numerous data from different loads remove bicycle frame from jig and begin removing pins and begin collapsing the bicycle frame
10. Place collapsed frame into the luggage to demonstrate that it meets the required dimensions

Data:

The following tables display the bicycle frame weight, load and deflection, and dimensions.

Bicycle Mass Test			
Trial	Me+Bike (lbs)	Me (lbs)	Bike(lbs)
1	163.9	151.4	12.5
2	163.7	151.4	12.3
3	163.8	151.3	12.5
4	163.7	151.2	12.5
5	163.8	151.5	12.3

	Average Total Mass	12.42

Table 6-1: Bicycle Mass test data

Bicycle Frame Loading Test		
Trail	Load (lbs)	Deflection at seat to Crank (in)
1	20	0.03125
2	40	0.0625
3	60	0.0625
4	80	0.0625
5	100	0.0625
6	120	0.0625
7	140	0.0625
8	160	0.0625
9	180	0.0625

Table 6-2: Bicycle Loading Test Data

Dimension Testing		
Expanded		
Length (in)	Height (in)	Width (in)
33	23	5.5
Collapsed		
Length (in)	Height (in)	Width (in)
22	14	5

Table 6-3: Final Dimensions Data

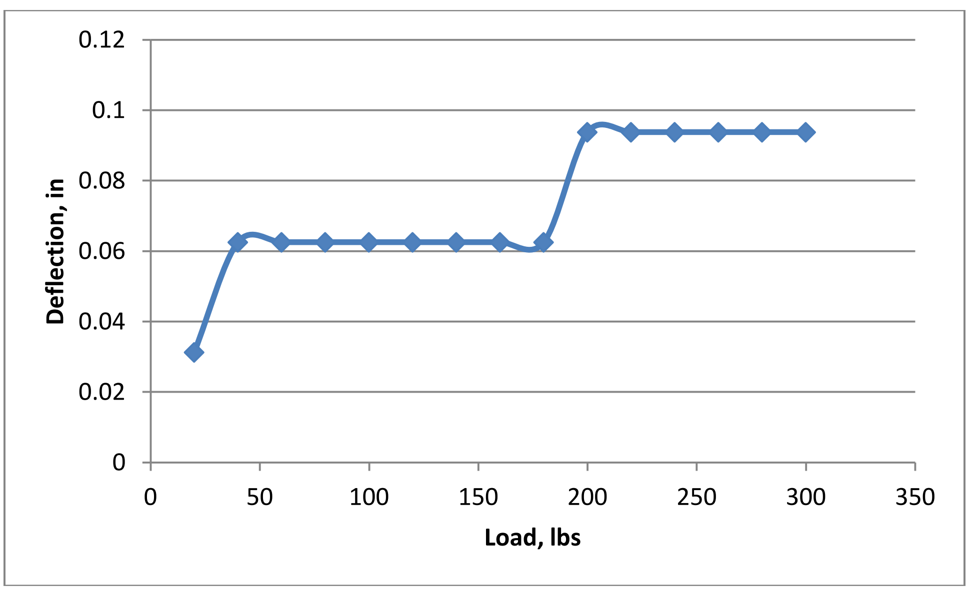


Figure G-1: Loading vs Deflection Graph

Results:

The collapsible frame was measured at approximately 12.5 lbs in total mass. This is smaller than the maximum weight of 15 lbs and lies within the required parameters. The frame also collapses into the 22” x 14” x 9” bag although other considerations will have to be met for the additional parts of the bicycle frame which include the forks, handle bars, tires and the gear assembly, or a redesign of the frame will be required to allow for the entire frame and parts to fit inside the luggage. The frame had a maximum deflection of 1/16th of an inch which is a larger deflection than the calculated 1/32nd of an inch. This is largely due to the amount of allowable play that is caused from the telescoping tubes being out of tolerance which allows the tubes to have more room and be less rigid.

Conclusion:

The purpose of this lab was to simulate the static load of this designed bicycle frame prototype in regards to the required functions of the bicycle. In this test the frame succeeded in static loading, deflection due to static loading, and being able to collapse to the required size. By analyzing the frames strength and stresses throughout the frame it would be determined if the prototype bicycle succeeded the requirements and should move on to the next phase of testing which would be dynamic testing.

APPENDIX H – Testing Data

Bicycle Mass Test			
Name: Keith Stone			
Date: April 18, 2015			
Trial	Me+Bike (lbs)	Me (lbs)	Bike(lbs)
1	163.9	151.4	12.5
2	163.7	151.4	12.3
3	163.8	151.3	12.5
4	163.7	151.2	12.5
5	163.8	151.5	12.3
	Average Total Mass		**12.42**

Bicycle Frame Loading Test		
Name: Keith Stone		
Date: April 18, 2015		
Trail	Load (lbs)	Deflection at Crank (in)
1	20	0.03125
2	40	0.0625
3	60	0.0625
4	80	0.0625
5	100	0.0625
6	120	0.0625
7	140	0.0625
8	160	0.0625
9	180	0.0625

Dimension Testing		
Name: Keith Stone		
Date: April 18, 2015		
Expanded		
Length (in)	Height (in)	Width (in)
39	23	5.5
Collapsed		
Length (in)	Height (in)	Width (in)
22	14	5

APPENDIX I – Resume

Keith Stone (253) 241-3213
504 E Country Side Avenue, Ellensburg, WA 98926 keithstone23@hotmail.com

OBJECTIVE Mechanical engineering career

SUMMARY OF QUALIFICATIONS

- Completing last year of four year mechanical engineering degree, completion date June of 2015.
- Strong communications skills
- Ability to work accurately in a fast paced work environment.
- Works well in a team and individually

EXPERIENCE

Port Townsend Foundry, Port Townsend, WA June 2014 to Present
Responsibilities:

- Cleaning the parts, such as necessary grinding and machining
- Participating in safety meetings
- Helping with metal pours

Mechanical Engineering Degree Program, Central Washington University, Ellensburg, WA September 2011 to present.
Featuring classes in:

- CAD, Rhino, SolidWorks, including national certification in SolidWorks.
- Welding/Fabrication, Machining and Casting
- Currently on Dean’s list

Jack’s Liquidation, Port Orchard, WA November 2010 to August 2011
Responsibilities:

- Cashier
- Stock merchandise
- Manage and organize back stock
- Maintain a clean and well organized sales floor, using lean manufacturing methods.
- Unloading of freight from distribution center.

Target, Gig Harbor, WA May 2006 to December 2009
Responsibilities:

- Trainer of new Target employees
- Stock merchandise
- Manage and organize back stock
- Keep the receiving area and stockroom clean and safe using lean manufacturing methods.
- Operation of electronic forklift, W.A.V.E, pallet jack, and cardboard baler

EDUCATION

Central Washington University, Ellensburg, WA
Mechanical Engineering with Specializations Bachelor's Degree, completion date: June 2015

Olympic Community College, Bremerton, WA
Associates in Arts and Sciences, June 2008

South Kitsap High School, Port Orchard, WA
Graduation: June 2005

ACTIVITIES/CLUBS

American Foundry Society (AFS), Central Washington University June 2014 to Present

- **Secretary**

Central Technology Education Association (CTEA), Central Washington University January 2013 to June 2014

- **Secretary**
- **Participated in club activities**
  - **Judge for Washington State Vex Robotics Tournaments**