Spring 2017

Composite Cold Expansion Tooling

Andrew Amos
amosa@cwu.edu

COMPOSITE COLD EXPANSION TOOL

Andrew Amos

Last revised on: May 31st, 2017

Created to fulfill the requirements of the Mechanical Engineering Technology Capstone Project

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INTRODUCTION

In the world of aircraft manufacturing, cold expansion products literally hold these aircraft together. The problem faced today is that the Little Brute Hydraulic Puller designed and built by Fatigue Technology Inc. is a handheld steel hydraulic cylinder that is heavy and expensive to produce. In a market that demands continuous improvement, there is a constant push to make the product cheaper, better and lighter. In order to accomplish this demand a composite tube will be substituted in the design as the primary pressure cylinder instead of the traditional steel pressure cylinder in order to create a lighter and cheaper design. Two separate designs we have been designed and built to withstand a given test pressure which will correlate to the sample provided by Polygon Composites. The first design is a single acting single cylinder that has caps at both end which extend past the outside diameter of the cylinder and will use bolts to hold the caps together. The second design will be similar however, the caps will thread onto an aluminum sleeve fitted outside the composite cylinder. The purpose of the aluminum sleeve will be to determine if the sample can meet the strength requirements with or without the extra layer. Each cylinder will be loaded until failure and the load will compared to a theoretical value established based on the dimensions of the sample. Both designs will be analyzed to determine their potential weight savings, cost of manufacturing and its potential improvement in machining and assembly time.

MOTIVATION:

The motivation for this project was to develop a lightweight composite solution to the Little Brute puller, FTI's handheld cold expansion tool. The current model for the Little Brute Puller Unit is made out of steel and is quite heavy. Considering the application of this tool is that a single worker uses it for hours at a time, it would be ergonomically advantageous to design a lighter tool. A heavier tool has a higher risk for repetitive motion injuries when operating the tool.

FUNCTION STATEMENT:

Evaluate using a composite material tube as an alternative to the current steel piston cylinder for an updated Little Brute Puller. The composite design must be able to withstand 7500 psi (internal) and deform elastically up to 10,000 psi. In addition to those performance requirements, the assembly should have a minimum of 50% weight reduction.

BACKGROUND INFORMATION

Cold expansion is the process of radially expanding a hole to either install a part and/or strengthen the area around the hole by adding residual compressive stresses. The compressive stresses that are left around the hole when it plastically deforms significantly improve the fatigue life of the hole and in effect remove the stress concentration that is created by the existing hole in the parent material.

DESIGN REQUIREMENTS:

- Must accommodate 7,500 psi hydraulic pressure
- Composite tubing must be ordered from a composite manufacturer.
- Piston diameters may be changed, but ultimate goal is reduced weight.
- Must be made with standard parts so that later models will be compatible with existing designs.

ENGINEERING MERIT

This project gets its merit from its thoughtful look into composite materials and structural analysis. Each part in the overall assembly has different challenges with how they are designed, constructed, and assembled without detracting from the overall structural integrity of the composite Little Brute.

In addition, each step of this project will be magnified due to the fact that it will require large scale manufacturing. Every manufacturing challenge will have to be accounted for in the project cost analysis and long term planning of future prototypes.

SCOPE OF EFFORT

Design and test a prototype cylinder concept that uses a composite liner or cylinder for a lightweight Cx puller. This first prototype will be a sort of proof of concept showcasing the composite tube ability to hold the maximum required load thus establishing the feasibility of future efforts.

SUCCESS CRITERIA

A success is defined as reaching 7500 psi with no observable failure. The second success criteria is that the composite tube stays in the elastic region during testing. It is important to note that composite materials generally do not behave in an elastic fashion like traditional metals would. The assumption for these tests is that the material is brittle and will behave as such. This will be determined by plotting the data on a stress-strain diagram.

DESIGN AND ANALYSES

See Appendix A for calculations. There it will outline the calculations for several different configurations of the composite housing.

The force being applied to the inside of the pressure vessel defines circumferential stress along with dimensions of the pressure vessel itself. Initial calculations for the composite pressure vessel show miscellaneous values that would be typical for the housing of the Little Brute. The second set of calculations are down with the actual specifications of a composite manufacturer.

Then, based on the manufacturers specifications of available composite tubing, the calculations for circumferential stress are compared to the yield strength of the composite material.

The ultimate strength of the composite tubing is not used directly because it is important that the stress on the material stays in the elastic region. Therefore, the ultimate strength will be combined with a safety factor to determine a safe operating limit. This operating limit is set at one-quarter of the composite's ultimate strength.

APPROACH: PROPOSED SOLUTION

The current model of Little Brute uses a steel housing for the hydraulic actuator. The proposed solution to the problem will be to construct a new housing out of a composite material while keeping the remainder of the puller unit the same. Just as previously stated, this project will focus on the first phase of prototyping, which will be a proof of concept static specimen.

This will be done in different phases to individually test different manufacturing obstacles. This project will be focused on analyzing structural strength and weight savings of using a composite tube instead of a steel tube.

DESIGN DESCRIPTION

The final design of the static specimen is designed in such a way that a minimal amount of machining will have to be done to the composite tube itself. Two end caps minor diameter will be fitted with o-rings and fit to the inside of the tube. The end caps major diameter will extend past the tube. The major diameter will have four holes in which nuts and bolts will tighten the caps together holding everything in place.

One of the end caps will be drilled and tapped to fit the hydraulic pump assembly that will be used for static testing. Before it is fitted to the pump, the now-sealed tube will be filled hydraulic fluid to evenly disperse the pressure to the inside of the tube, replicating a hydraulic piston.

See Appendix B for final part drawings and Methods and Construction section for images of the final assembly.

BENCHMARK

The benchmark used for this project will be the current model of little brute. For comparison purposes of weight, strength and analyses, a steel version of the composite assembly (built in SolidWorks) is acceptable.

PERFORMANCE PREDICTIONS

The composite puller will pass the minimum requirements of the static load test described by FTI mentor, James Ross. Failure during this test is defined as either weeping (hydraulic fluid seeping out of the pressure vessel) or structural failure of any kind.

A success is defined as reaching 7500 psi with no observable failure. The second success criteria is that the composite tube stays in the elastic region during testing. This will be determined by plotting the data on a stress-strain diagram.

Predicted values of performance state that failure will occur near or at 8000 psi.

DESCRIPTIONS OF ANALYSES

In a hydraulic system there is a conservative relationship that allows a pressure in one section of the device to yield a different pressure in a separate section and therefore a different force.

In order to determine weight savings, custom materials will be created in solidworks and the final assembly will be weighed using the mass properties. The aluminum end caps will be excluded from this analysis due to the fact they will not be in the final design.

The composite tube and cap will be treated as a single pressure vessel for pressure calculations as described in chapter 13 of Statics and Strengths of Materials Text.

SCOPE OF TESTING AND EVALUATIONS

All testing and evaluations will be done onsite at the FTI plant in Tukwila Washington. At the testing facility, a fixture will be constructed to model even pressure on the composite tube that would simulate the tube being pressurized.

ANALYSES

There are several important variables that make this project more difficult to analyze than with just a quick glance. The composite tube that is under pressure will be sealed at both ends with aluminum caps. This material decision is defined by FTI and was not chosen by some design choice made by the author.

Three different methods that could be used in attaching the caps to the pressure vessel would be create threads on the tube and caps, use an adhesive or use some sort of interference/press-fit. Each method has its advantages and disadvantages.

Using threads on the tube could weak the composite tube in a way that might accelerate failure. Another factor would be the difficulty in machining a composite piece. A treaded fit would allow the tolerances to be tight and provide for a strong hold as long as the composite tube is not compromised during the machining process.

If an adhesive were to be used in this application, it would have to be one that could operate after being under pressure, changes in temperature and elastic expansion of the composite tube.

A press fit would be difficult to machine but the only pieces that would need to be machined would be the aluminum ends. While installation would be quick and simple, it could damage the aluminum ends when pressing the other side or could alter the surface finish on the surface of contact and the support surface.

In an effort to create a more reliable design that does not hinder the performance of the composite tube, a capped and sealed design will be used because it will not affect the geometry of the tube during testing.

DEVICE PARTS, SHAPES AND CONFIGURATIONS

Parts lists:

a. Polygon Composite Fiberglass barrel
b. Aluminum end cap
c. Aluminum adapter to hydraulic press
d. Aluminum sleeve
e. ¼ inch bolts with matching nuts and washers
f. O-rings selected from design guide
g. Back-up O-rings

TOLERANCCES, KINEMATICS, ERGONOMICS, ETC.

One Tolerance to take into equation is the Polygon Fiberglass Tube. Each tube is identified by its inside diameter. However, each tube ID seems to be oversized with a tolerance that encompasses the actual standard size for which the tube is identified.

TECHNICAL RISK ANALYSIS, FAILURE MODE ANALYSIS, SAFETY FACTORS AND OPERATION LIMITS

Before testing, several failure modes were identified.

1. Weeping
2. Cracked
3. Catastrophic failure

Weeping is defined as hydraulic fluid escaping from the static specimen at any point across the apparatus. Due to the stark contrast between the color of the fluid and the device itself, it will be through simple visual inspection wether or not this error has occurred.

Depending on the dimensions of the tube itself will determine the circumferential stress on the inside of the tube. This pressure will compared with the yield strength of the material. If the circumferential stress in the fiberglass tube exceeds the yield strength of the fiberglass tube, this will constitute a failure.

Catastrophic failure will occur at the material’s Ultimate tensile strength. For the application of this device, it will be design in such a way that any force exerted on it in the field will occur in the elastic region of this specified fiberglass stress-strain curve.

METHODS AND CONSTRUCTION

CONSTRUCTION

The device in question that I would build is a prototype intended for testing and then after passing the testing requirements will be integrated with the remaining little brute parts including the handle assembly, trigger and hydraulic assembly.

The different parts that will be assembled will be the fiberglass barrel and aluminum end caps.

One manufacturing issue right away is finding a way to attach the aluminum ends to the fiberglass barrel. In the original steel design, the pieces are threaded together however that design was improved upon using a cap and seal method.

The following are pictures of the final construction of the testing apparatus.

TESTING

INTRODUCTION

The objective of this test was to assemble and test Assemble and test multiple designs for the composite hydraulic cylinder for the Little Brute Hydraulic puller and determine the actual strength of the tubing under an internal pressure. Each design was tested to a predetermined operating pressure (or to failure) and the resulting data will indicate if a more advanced prototype is feasible.

A success is defined as no observable failures at a pressure of 7500 psi. An observable failure is defined as little as weeping at the edges of the cylinder or as much as a physical defect appear such as a crack or total catastrophic failure.

According to the safety factors and pressure limits of the O-rings used in the test assembly, weeping failure was predicted at 6000 psi and structural failure at 8000 psi

METHOD/APPPROACH

The following procedures and resources were used to test the single acting composite tube.

Materials:

- PolySlide Composite Tubing courtesy of Polygon Composites
- Aluminum End caps fitted with O-rings and seals per the Parker Seal Guide
- Aluminum sleeve
- 4- ¼”Screws
- 4- ¼” Nuts
- Hydraulic press
- Hydraulic fluid
- Force gauge
- Blast Shield
- Camera

Process:

1. Assemble the aluminum end cap on the bottom side of the 6” specimen of composite tubing.
2. Fill the specimen with hydraulic fluid approximately half way up the cylinder. This amount is not critical.
3. Assemble the top end cap with single acting hydraulic plunger.
4. Place blast Shields in correct upright positions.
5. Turn on camera.
6. Align Force gauge so that is visible to the camera.
7. Apply a small load to the cylinder in order to align it.
8. Step behind the blast shield. Then engage the hydraulic press to slowly apply force to the plunger.
9. At increments of 100 psi, record the outer diameter of the tube at three locations along the tube.
10. Load the cylinder until failure or until 10,000 psi.
11. Record the values in the table below.
12. Repeat steps 1-10 with the second specimen.
13. Generate a critical design review for the test specimens.

TEST PROCEDURE

The test was deemed a success based on the previous criteria. A failure was detected at 8000 psi when weeping at the bottom end of the tube was observed. The test itself took approximately 57 minutes to complete and was loaded to 10,000 psi at which point the hydraulic press was at its maximum operating pressure. The test was performed on site at Fatigue Technology inc. in Tukwila, WA.

The resources and procedures used in the actual test followed the test plan almost exactly.

RESULTS AND CONCLUSION

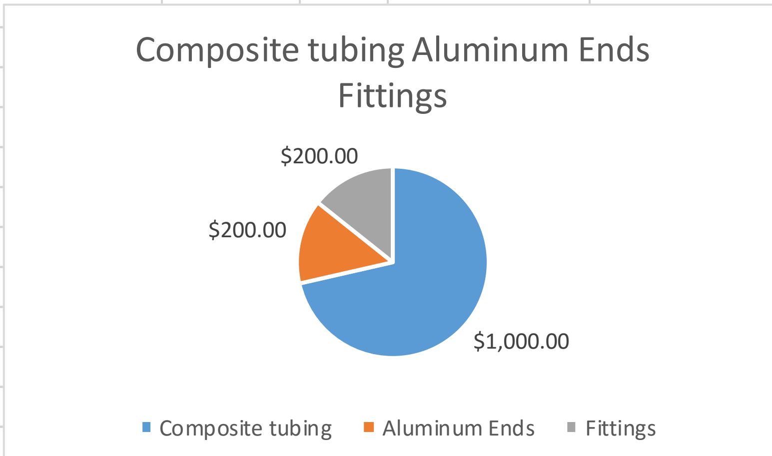
From observation, the test was a success and so much so that the composite tube with an additional aluminum sleeve did not need to be tested. It was assumed that if the unreinforced tube could sit at the maximum operating pressure with no structural failure that the stronger specimen would be as well.

In addition to our testing success, the data showed that when it was plotted on a stress-strain diagram to be linear. This is one of the most important outcomes of the test because it suggests that the material deformed elastically. Plastic deformation would have meant that the second phase of development for the double acting hydraulic cylinder would not be able to continue.

BUDGET/SCHEDULE/PROJECCT MANAGEMENT

PROPOSED BUDGET

Item	amount	total	Over/under	comment
Composite tubing	$1,000.00	$0.00	-$1,000.00	Donated by Polygon
Aluminum Ends	$200.00	$0.00	-$200.00	Donated by FTI
Fittings	$200.00	$0.00	-$200.00	Donated by FTI



PROPOSED SCHEDULE

First Quarter Goals include designing a tentative testing appartatus, identifying and setting performance goals, making a schedule, budget and testing plan.

Second Quarter Goals include procuring the composite specimen and designing the testing apparatus using the geometry of the part we are given.

Third Quarter Goals were to have a functioning assembly that is readty to be tested at the beginning of the quarter. The rest of the quarter will be spent fulfilling the requirements of the capstone program.

See Appendix E for Gantt chart.

PROJECT MANAGEMENT

1. Human Resources:
    a. James Ross, Project mentor
2. Physical Resources: Machines, Processes, etc.
    a. Engine lathe
    b. Hydraulic press
    c. Bridgeport mill
    d. FTI testing facility
3. Soft Resources: Software, Web support, etc.

    a. Solidworks

4. Financial Resources: Sponsors, Grants, Donations
    a. The Primary financial resource for the project will be Fatigue Technology who have approved the sponsorship of this design, construction and testing of the composite Little Brute Puller.

DISCUSSION

INTERPETING OUR RESULTS

From observation, the test was a success and so much so that the composite tube with an additional aluminum sleeve did not need to be tested. It was assumed that if the unreinforced tube could sit at the maximum operating pressure with no structural failure that the stronger specimen would be as well.

PROJECT RISK ANALYSIS

Due to the fact that the tube itself was difficult to machine, this will create a large manufacturing hurtle that will require a solution if eventual production is going to happen.

SUCCESS

In addition to our testing success, the data showed that when it was plotted on a stress-strain diagram to be linear. This is one of the most important outcomes of the test because it suggests that the material deformed elastically. Plastic deformation would have meant that the second phase of development for the double acting hydraulic cylinder would not be able to continue.

FUTURE PROTYPING

Procurement, assembly and static testing was just phase one of the prototyping. Phase two will involve project cost analysis, critical design review and extensive fatigue testing.

CONCLUSION

In the world of aircraft manufacturing, cold expansion products literally hold these aircraft together. The problem faced today is that the Little Brute Hydraulic Puller designed and built by Fatigue Technology Inc. is a handheld steel hydraulic cylinder that is heavy and expensive to produce. In a market that demands continuous improvement, there is a constant push to make the product cheaper, better and lighter. In order to accomplish this demand a composite tube will be substituted in the design as the primary pressure cylinder instead of the traditional steel pressure cylinder in order to create a lighter and cheaper design.

Two separate designs we have been designed and built to withstand a given test pressure which will correlate to the sample provided by Polygon Composites. The first design is a single acting single cylinder that has caps at both end which extend past the outside diameter of the cylinder and will use bolts to hold the caps together. The second design will be similar however, the caps will thread onto an aluminum sleeve fitted outside the composite cylinder. The purpose of the aluminum sleeve will be to determine if the sample can meet the strength requirements with or without the extra layer.

Each cylinder will be loaded until failure and the load will compared to a theoretical value established based on the dimensions of the sample. Both designs will be analyzed to determine their potential weight savings, cost of manufacturing and its potential improvement in machining and assembly time.

The original predicted values for this test was that it would experience weeping failure at 7500 psi.

The test was deemed a success based on the previous criteria. A failure was detected at 8000 psi when weeping at the bottom end of the tube was observed. The test itself took approximately 57 minutes to complete and was loaded to 10,000 psi at which point the hydraulic press was at its maximum operating pressure. The test was performed on site at Fatigue Technology inc. in Tukwila, WA.

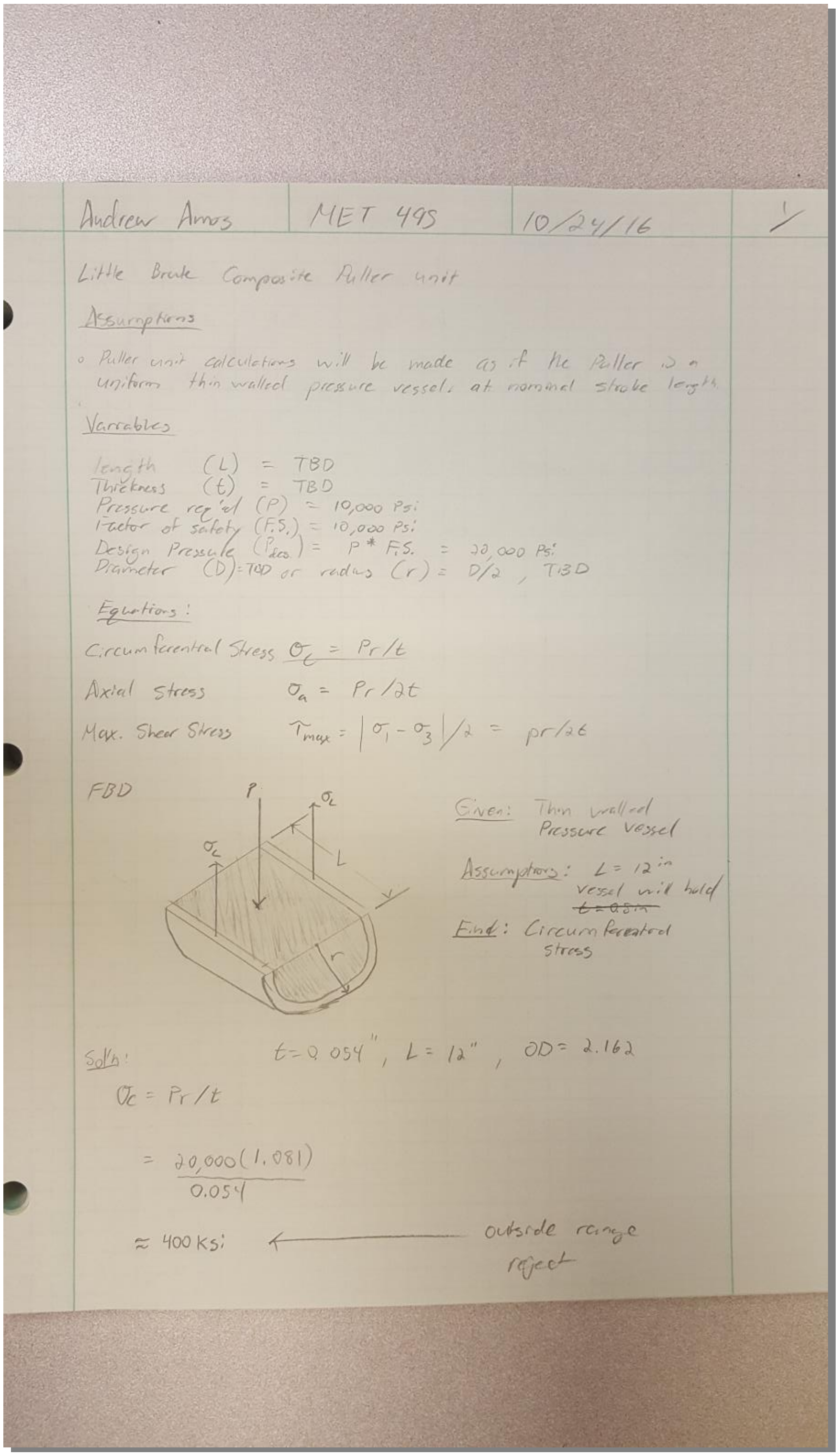
From observation, the test was a success and so much so that the composite tube with an additional aluminum sleeve did not need to be tested. It was assumed that if the unreinforced tube could sit at the maximum operating pressure with no structural failure that the stronger specimen would be as well.

In addition to the pressure performance success, the material also succeeded in passing the weight requirements. The weight savings goal was at least 25%. Both designs exceeded this goal at 29% reduction for the sleeved model and 72% reduction with the plain fiberglass tube.

In addition to our testing success, the data showed that when it was plotted on a stress-strain diagram to be linear. This is one of the most important outcomes of the test because it suggests that the material deformed elastically. Plastic deformation would have meant that the second phase of development for the double acting hydraulic cylinder would not be able to continue.

APPENDICES

APPENDIX A: ANALYSES



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Little Brute Composite Puller unit

Assumptions

- Puller unit calculations will be made as if the Puller is a uniform thin walled pressure vessel, at nominal stroke length

Variables

Length (L) = TBD
Thickness (t) = TBD
Pressure req'ed (P) = 10,000 Psi
Factor of safety (F.S.) = 10,000 Psi
Design Pressure (P_{des}) = P * F.S. = 20,000 Psi
Diameter (D) = TBD or radius (r) = D/2, TBD

Equations:

Circumferential Stress $\sigma_c = Pr/t$

Axial Stress $\sigma_a = Pr/2t$

Max. Shear Stress $\tau_{max} = |\sigma_1 - \sigma_3|/2 = pr/2t$

FBD

Given: Thin walled Pressure vessel

Assumptions: L = 12 in, vessel will hold, ~~t = 0.05 in~~

Find: Circumferential stress

Sol'n: t = 0.054", L = 12", OD = 2.162

$\sigma_c = Pr/t$

$= \frac{20,000(1.081)}{0.054}$

$\approx$ 400 ksi ← outside range reject

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rework problem w/ new varicbles

$t = 0.081\text{in}$, $L = 12.00\text{in}$, $OD = 2.00$

$$\sigma_c = \frac{20{,}000\,\text{psi}\,(1.000\,\text{in})}{0.081\,\text{in}}$$

$= 246{,}913.58 \approx$ 247 ksi unacceptable, reject.

Composite Resources may be unavailable as a supplier.

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<u>Composite Resources Carbon tubing</u>

ID Range: .625 - 2.00
OD Range: .679 - 2.162
Thickness: 0.027, 0.054, 0.081
Standard Length: 72.00" +/- .125in

Fiber Type: Standard Modulus
Matrix type: Epoxy
Fiber orientation: 0°/90°
Fiber tensile strength: 512 - 660 ksi
Fiber Modulus: 32-34 msi
Fiber Density: 0.063 lb/in³
Laminate density: 0.057 lb./in³

Finish: Tape wrapped OD

composite-resources.com/stock-tubes.

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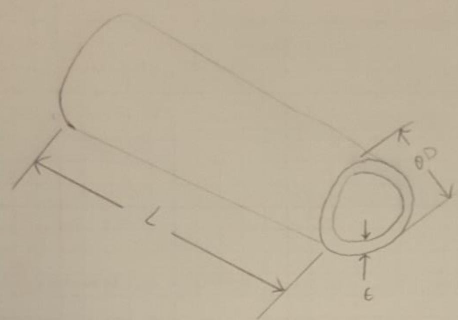
List of ~~acceptable~~ possible dimensions



Force = 8000 lbs
F.S. = 3
Max force = 24,000 lbs

$$\sigma = \frac{F}{tL}$$

$$\sigma = \frac{24{,}000}{(.125)(1.25)} = 153600$$

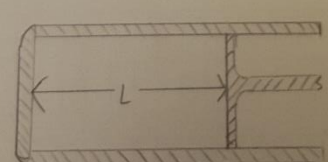
L (in)	t (in)	σ_{max} (ksi) (hoop)
1.25	.125	153.60
1.25	.250	76.80
1.50	.125	128.00
1.50	.250	64.00
1.75	.125	109.72
1.75	.250	54.86
2.00	.125	96.00
2.00	.250	48.00
2.25	.125	85.34
2.25	.250	42.67

(1.25 rows) disregared (min stroke = 1.5")

(1.50–2.25 rows) Values rounded up to be conservative and avoid rupture due to rounding error.

L is defined as the distance between the head of the cylinder and the piston. ~~Max st~~ Stroke length is a min. of 1.5.

side view



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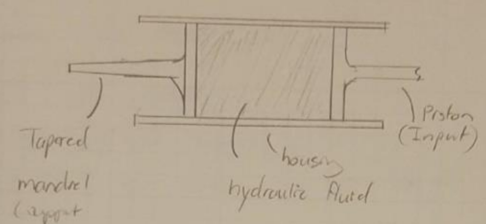
Preliminary drawings of hydraulic tube.



→ Dimensons on tapered mandrel and piston are fixed based on specified parts on FTI specifications.

→ Mandrel is steel, piston is steel

→ Objectives:

- identify common yield strength for carbon fiber
- specify composite manufacturer
- Right at budget specified by James Ross
- Create Solidworks drawings of parts
  - housing
  - Piston
  - Mandrel
- Update Schedule

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Objective: determine whether or not Dragon Plate composite tubing is a suitable material for the hydraulic chamber in the new Little Brute™

Equations: Hoop stress = $\sigma_c = \frac{Pr}{t}$

P = 24,000 lbs
r = radius to OD
t = wall thickness

Given: ID ; Wall thickness and tensile strength

Find: Stress in walls of tubing.

ID	thickness	OD	Radius	σ_c	Pass/Fail
0.75	.040	0.83	0.415	249 ksi	
1.00	.040	1.08	0.540	324 ksi	
1.50	.040	1.58	0.790	474 ksi	
2.00	.045	2.09	1.045	558 ksi *	
3.00	.085	3.17	1.585	448 ksi	
4.00	.080	4.16	2.080	624 ksi	
6.00	.080	6.16	3.080	924 ksi	

Sample calculation

$OD = ID + (2t)$

$= .750 + (2 * .040)$

$= 0.83$

$r = OD/2$

$= 0.83/2$

$= .415$

$\sigma_c = \frac{24{,}000(.415)}{.040}$

$= 249{,}000$ Psi

$= 249$ ksi

* All Answers rounded up

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Design
- Composite tube
- Steel liner/sleeve outside of tube

Determine weight savings

Weight from solidworks model (W_{st}): 4.14 pounds

Weight of Carbon fiber (W_{CF}): 0.075 lb

Remaining weight from Solidworks model. (W_{Al}): 0.89 + 0.40

Composite puller weight (W_c) = $W_{CF} + W_{Al}$ =

$$\text{Weight savings} = \frac{W_c}{W_{st}} \times 100$$

$$= \left(\frac{[(0.89 + 0.40) + 0.075]}{4.14}\right) \text{lbs}$$

$$= \boxed{32.97\ \%}$$

The composite assembly is 32.97 % of the same assembly made out A36 steel. The composite assembly uses dragonplate carbon fiber tubing at a Ø = 2.00 and 2024-T36 Aluminum ends / sleeve.

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Find: a tube size that internal pressure is less 10,000 psi, factor of safety = 4 and generates 9000 lbf

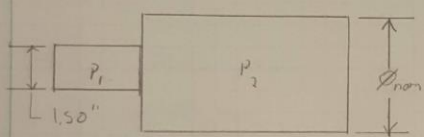
Sol'n: effective max pressure = $P_{max} * N$

$= 10{,}000 * 4$

$= 40{,}000$ Psi

Pull load = 9000 lb_f

Mandrel diameter: 1.5"



Using a conservation equation, Choose a std. size

size = 2.00 in ID

$P_1 = P_2$

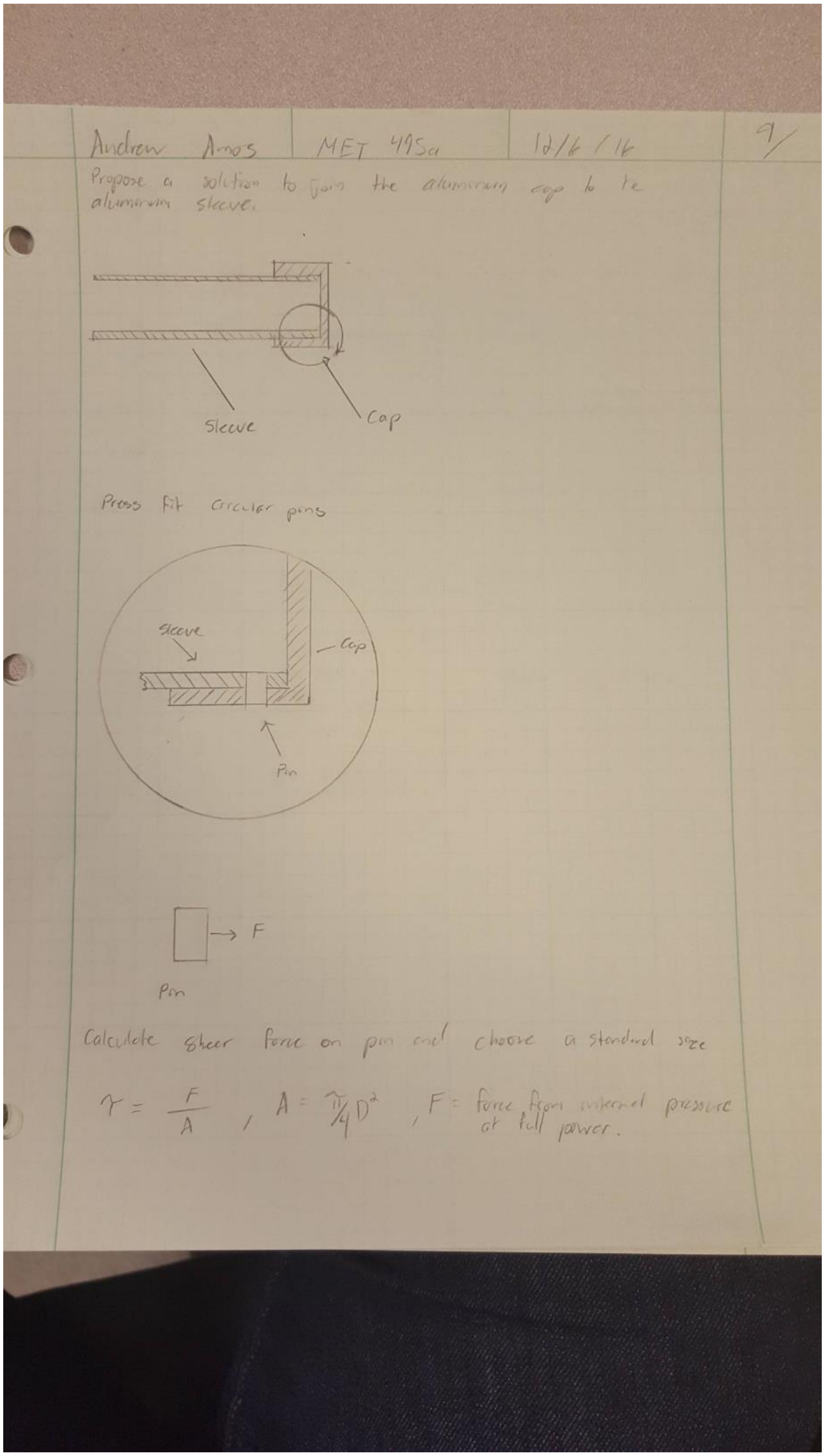
$$\frac{9000 \text{ lbs}}{\frac{\pi}{4}(1.5^2)} =$$

$$5092.96 = \frac{lb_f}{\frac{\pi}{4}(2.00^2)}$$

$5092.96\pi = lb_f$

Force in Carbon fiber chamber = 16,000 lb_f →

Choose 2.00 standard size



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Propose a solution to join the aluminum cap to the aluminum sleeve.

Sleeve

Cap

Press fit circular pins

Sleeve

Cap

Pin

F

Pin

Calculate shear force on pin and choose a standard size

$\tau = \frac{F}{A}$, $A = \frac{\pi}{4}D^2$, F = force from internal pressure at full power.

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$\tau = \frac{F}{A}$, $A = \frac{\pi}{D^2}$

F = 16,000 lbs acting across the ~~diameter~~ cross-section of the pin.

Since the design factor, the cap will have 4 pins

Material: ~~2024 Al (T361)~~ 6061 Al – T6, Shearing Strength: ~~42 ksi~~ 30 ksi (Table A-4)

Goal: $\tau <$ ~~42ksi~~ 30ksi

$\tau = \frac{16,000}{\frac{\pi}{4} D^2} \Rightarrow$ Choose arbitrary Diameter value.

$= \frac{16000}{\frac{\pi}{4}(.25)^2} = 325,949$ Psi $\approx$ 326 ksi. Choose larger size

$= \frac{16,000}{\frac{\pi}{4}(.75)^2} = 36$ ksi   choose larger size

$= \frac{16,000}{\frac{\pi}{4}(1^2)} = 20.4$ ksi   ✓

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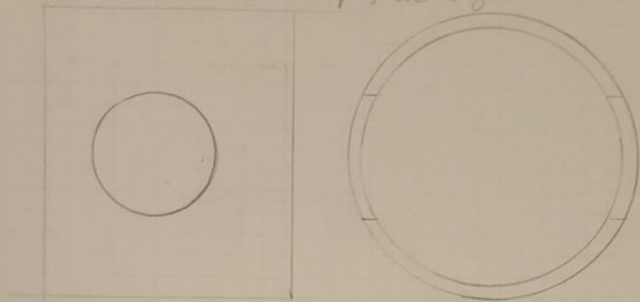
Scale drawing 1:1 of cap and pins.

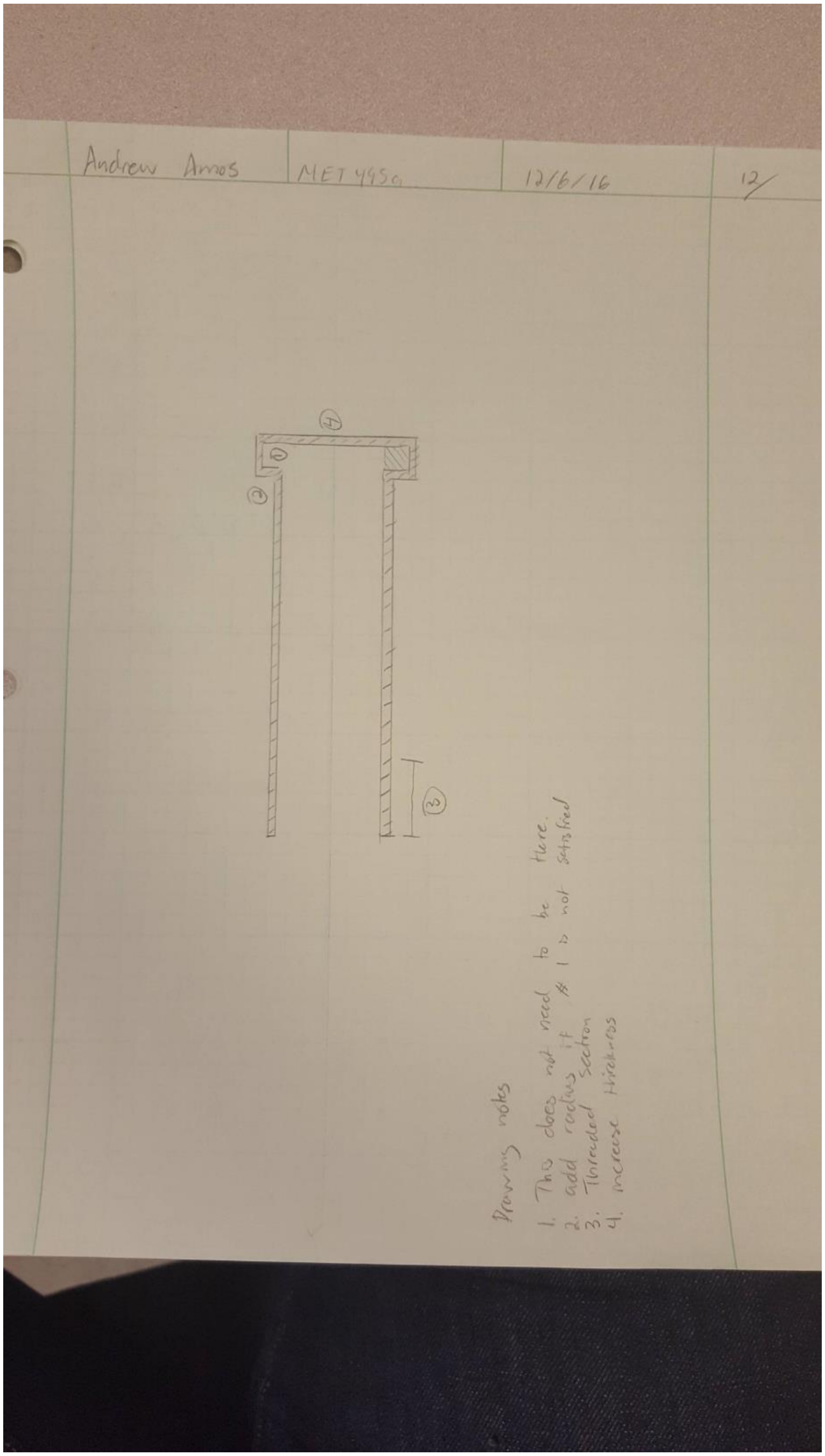
Determine wether or not the pins are a good idea



This solution eliminates to much material and introduces large stress concentrations.

Consider making the sleeve and cup one piece

→ Practical to machine ✓
→ W/in my skill level ✓
→ Solve the joining issue
→ easier to adapt to the Mandrel piece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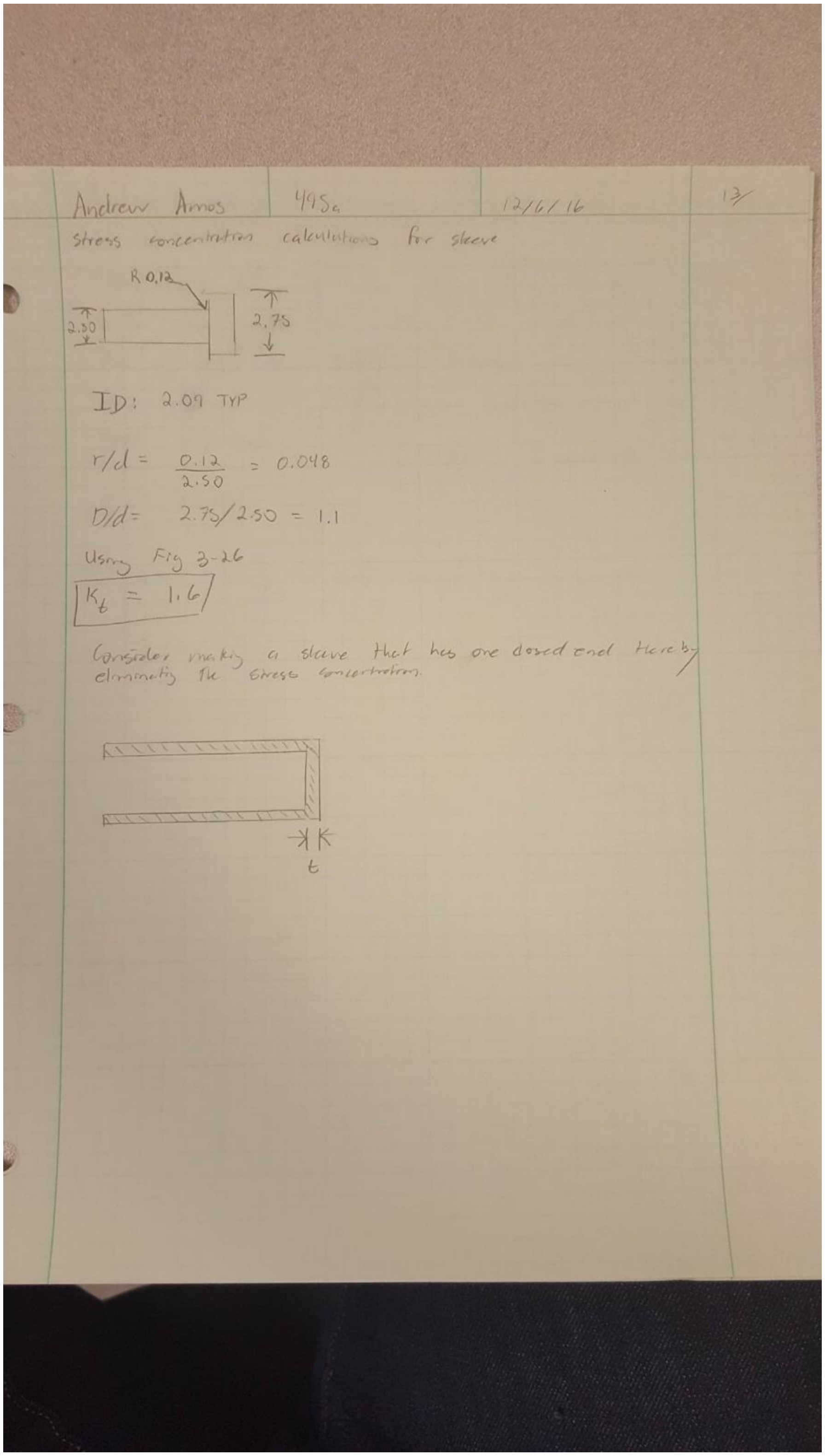
MET 495a
12/6/16
12/
Drawing notes
1. This does not need to be here.
2. add radius if #1 is not satisfied
3. Threaded Section
4. increase thickness



Andrew Amos | 495a | 12/6/16 | 13

Stress concentration calculations for sleeve

ID: 2.09 TYP

$r/d = \frac{0.12}{2.50} = 0.048$

$D/d = 2.75/2.50 = 1.1$

Using Fig 3-26

$K_t = 1.6$

Consider making a sleeve that has one closed end thereby eliminating the stress concentration.

Andrew Amas | MET 495c | 12/6/16 | 14

Weight calculations for Sleeve 2.0

Sleeve weight: W_{S1} : 0.99 lbs

Carbon fiber tube W_{CF}: 0.075 lbs

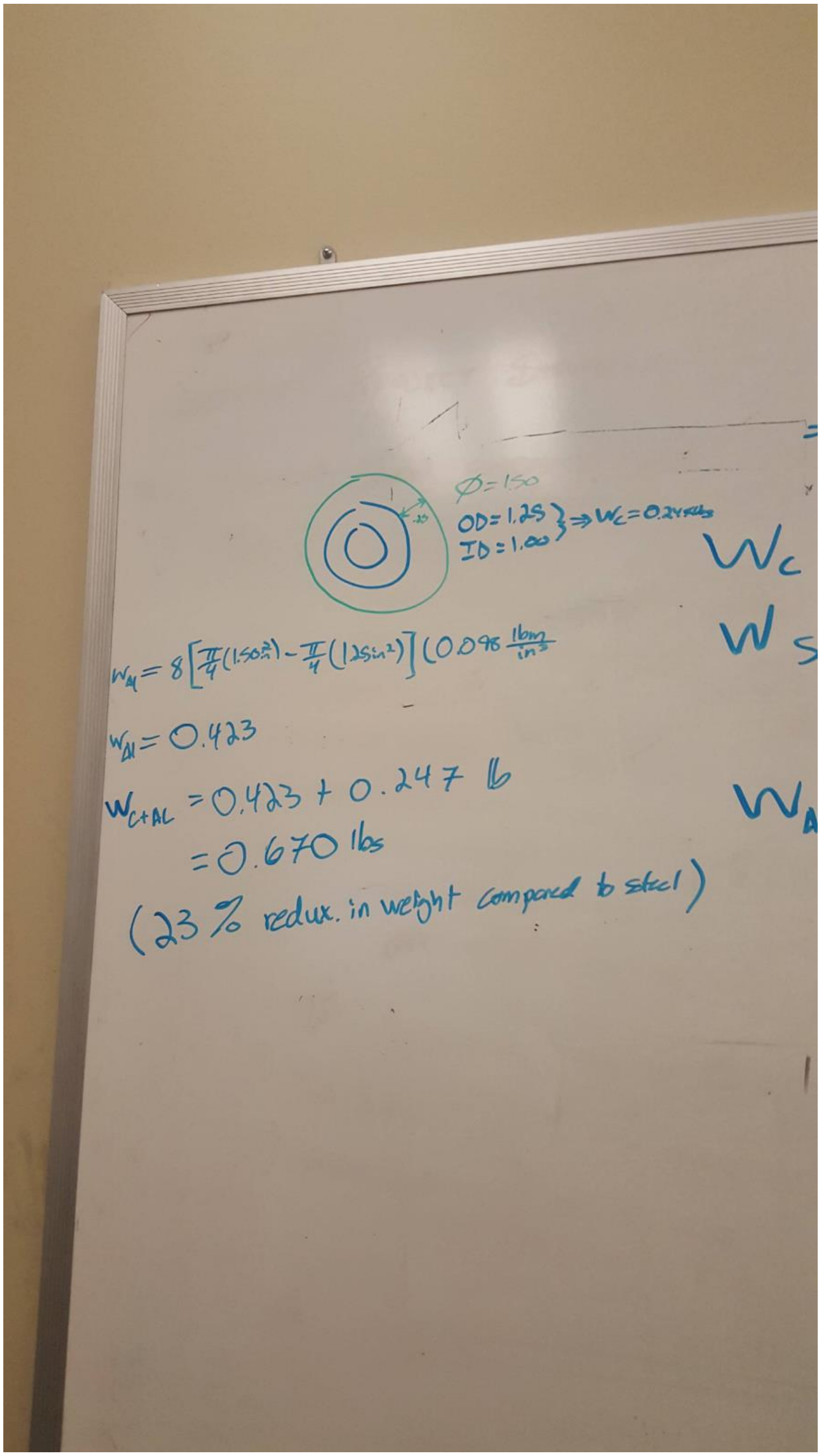
Assembly weight W_A : ~~[illegible]~~ 1.065 lbs

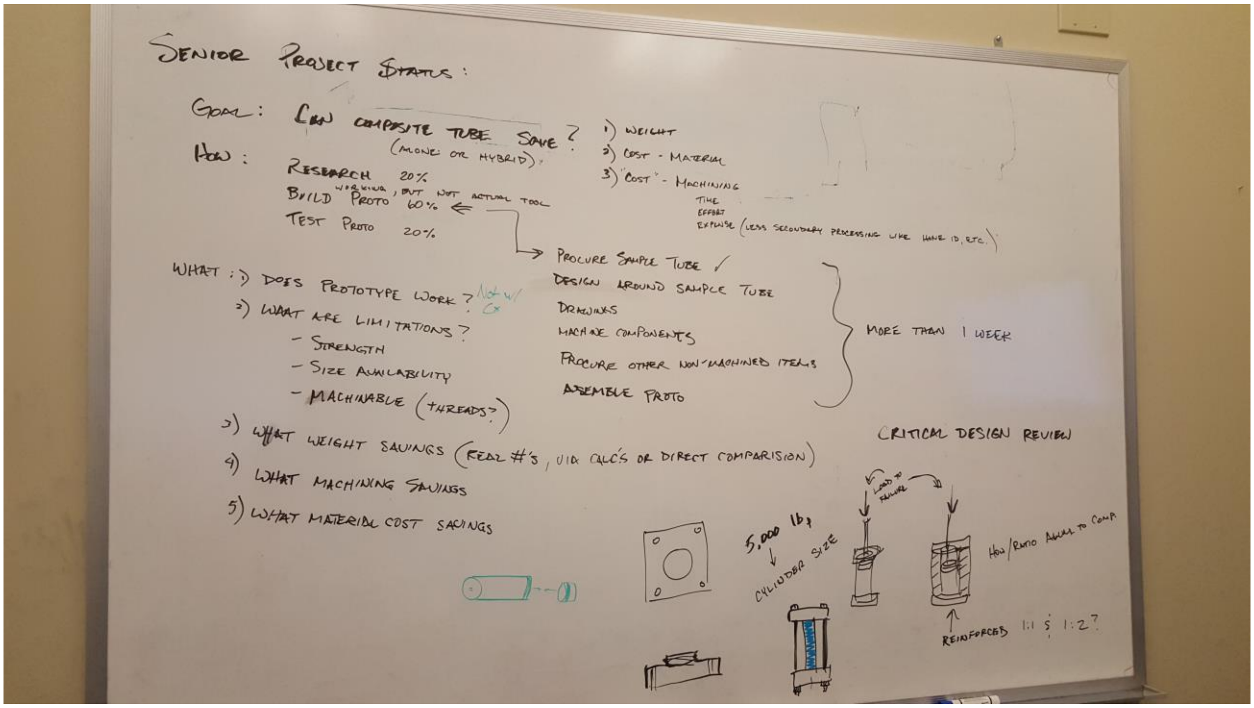
Steel version W_{St} : 2.80 + 0.49 = 3.29 lbs

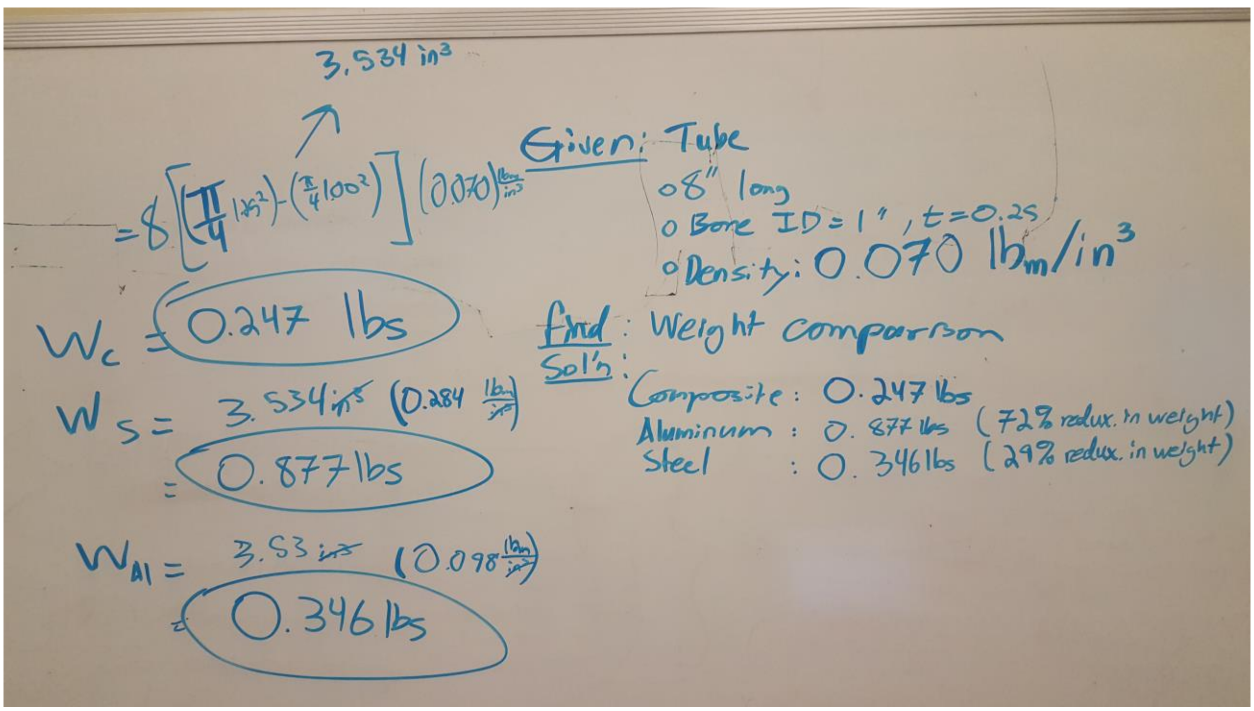
Weight comparison $\frac{W_{CF} + W_{S1}}{W_{St}} \Rightarrow \frac{W_A}{W_{St}} \times 100\%$

$100\% * \left(\frac{1.065 \text{ lbs}}{3.29 \text{ lbs}}\right) = 32.37\%$

No significant change in weight savings. still acceptable.


Ø=1.50
OD=1.25
ID=1.00
W_AL = 0.423
W_C+AL = 0.423 + 0.247 lb
= 0.670 lbs
(23 % redux. in weight compared to steel)


SENIOR PROJECT STATUS:
GOAL: CAN COMPOSITE TUBE SAVE? (ALONE OR HYBRID)
1) WEIGHT
2) COST - MATERIAL
3) "COST" - MACHINING
TIME
EFFORT
EXPENSE (LESS SECONDARY PROCESSING LIKE HONE ID, ETC.)
HOW: RESEARCH 20%
BUILD "PROTO" 60%
WORKING, BUT NOT ACTUAL TOOL
TEST PROTO 20%
PROCURE SAMPLE TUBE
DESIGN AROUND SAMPLE TUBE
DRAWINGS
MACHINE COMPONENTS
PROCURE OTHER NON-MACHINED ITEMS
ASSEMBLE PROTO
MORE THAN 1 WEEK
WHAT: 1) DOES PROTOTYPE WORK?
2) WHAT ARE LIMITATIONS?
- STRENGTH
- SIZE AVAILABILITY
- MACHINABLE (THREADS?)
3) WHAT WEIGHT SAVINGS (REAL #'S, VIA CALC'S OR DIRECT COMPARISION)
4) WHAT MACHINING SAVINGS
5) WHAT MATERIAL COST SAVINGS
CRITICAL DESIGN REVIEW
5,000 lbf
CYLINDER SIZE
REINFORCED


3.534 in³
= 8 [(π/4 1.5²) - (π/4 1.00²)] (0.070) lbm/in³
Given: Tube
o 8" long
o Bore ID = 1", t = 0.25
o Density: 0.070 lbm/in³
W_c = 0.247 lbs
Find: Weight comparison
Sol'n:
Composite: 0.247 lbs
Aluminum: 0.877 lbs (72% redux. in weight)
Steel: 0.346 lbs (29% redux. in weight)
W_s = 3.534 in³ (0.284 lbm/in³)
= 0.877 lbs
W_Al = 3.53 in³ (0.098 lbm/in³)
= 0.346 lbs

APPENDIX B: DRAWINGS

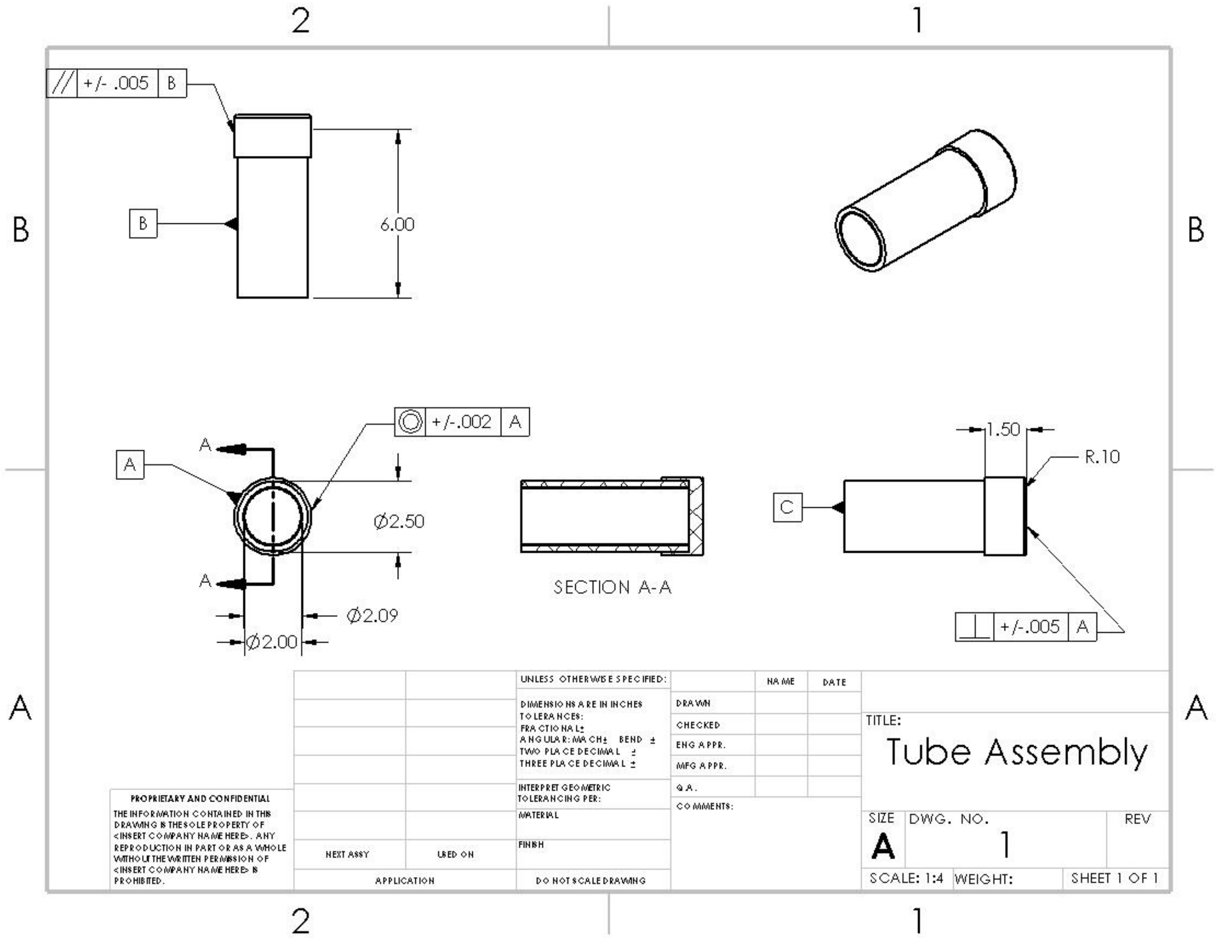


Figure 1: Tube Assembly 1.0

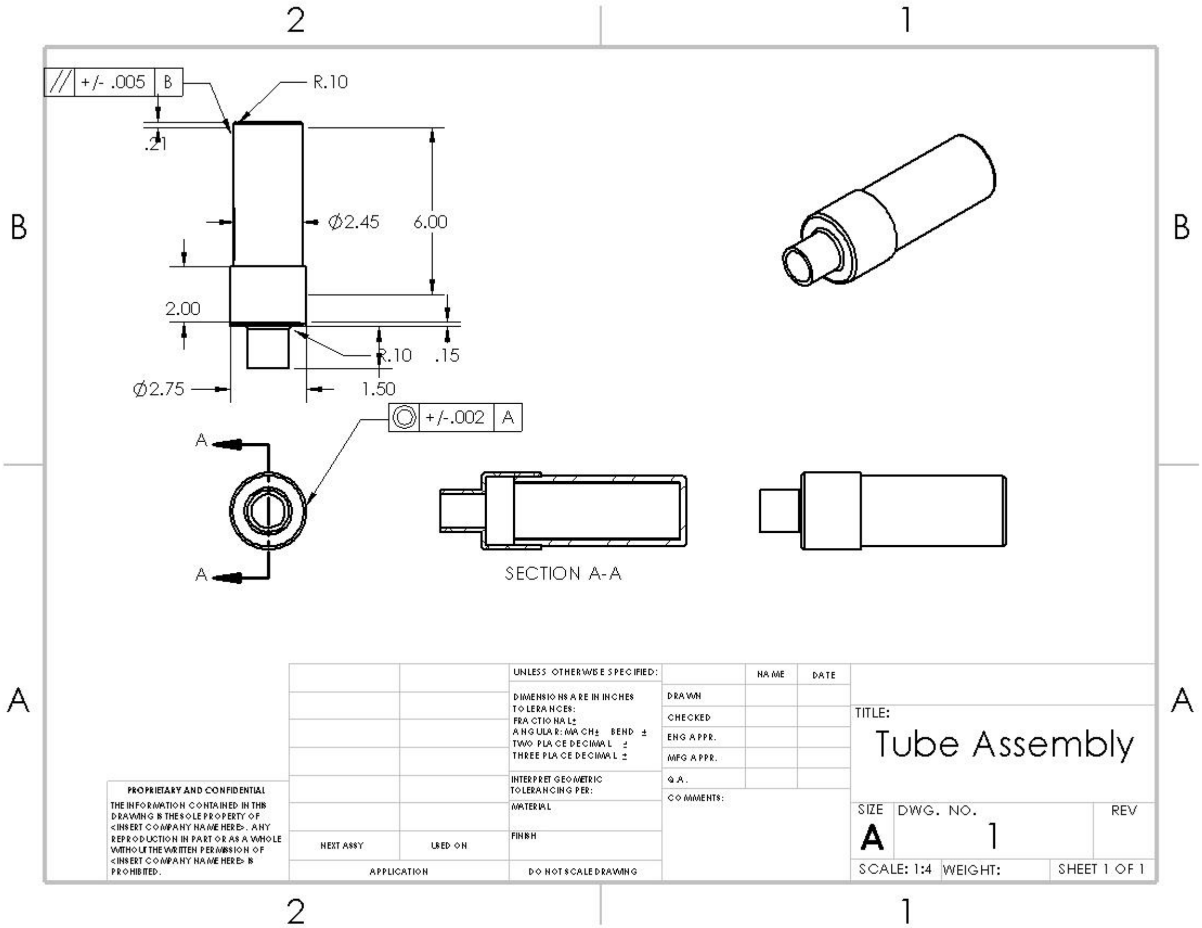
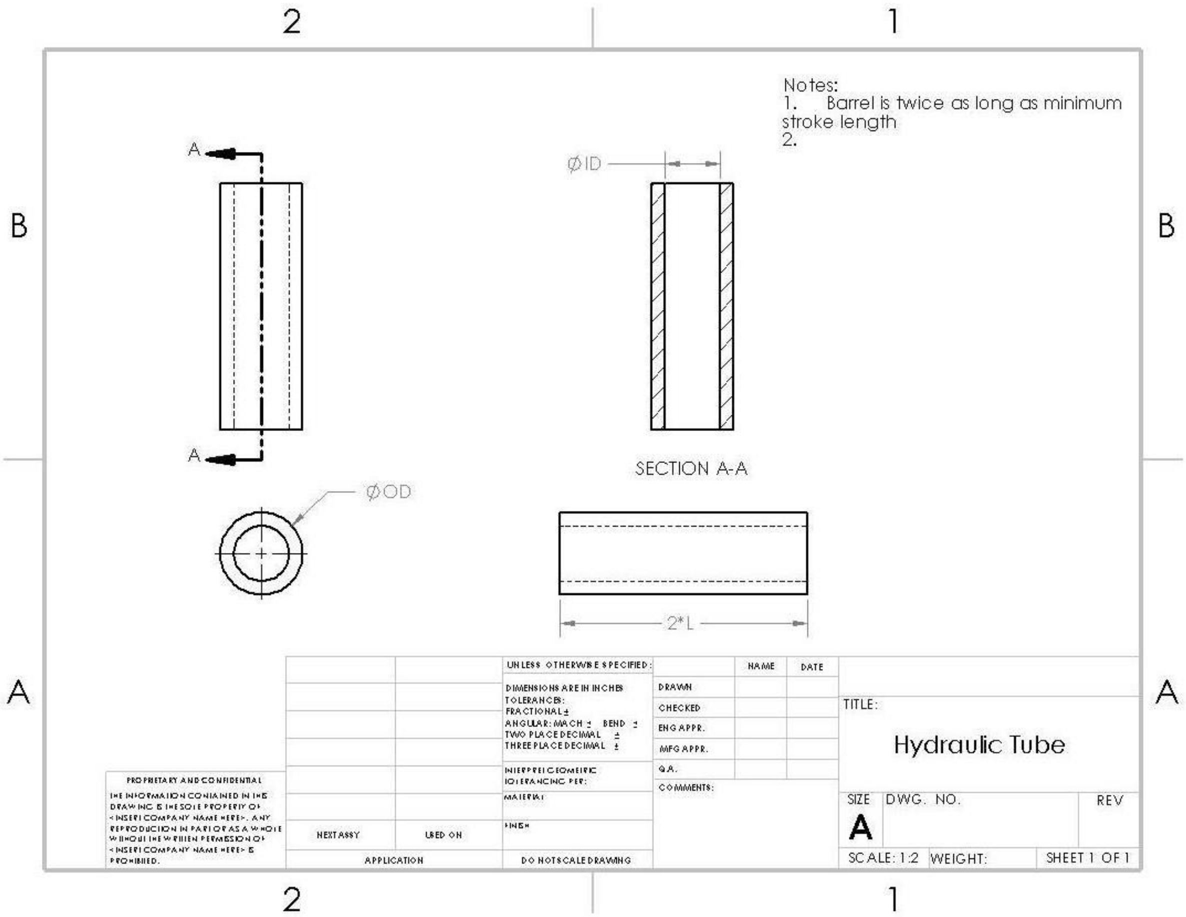
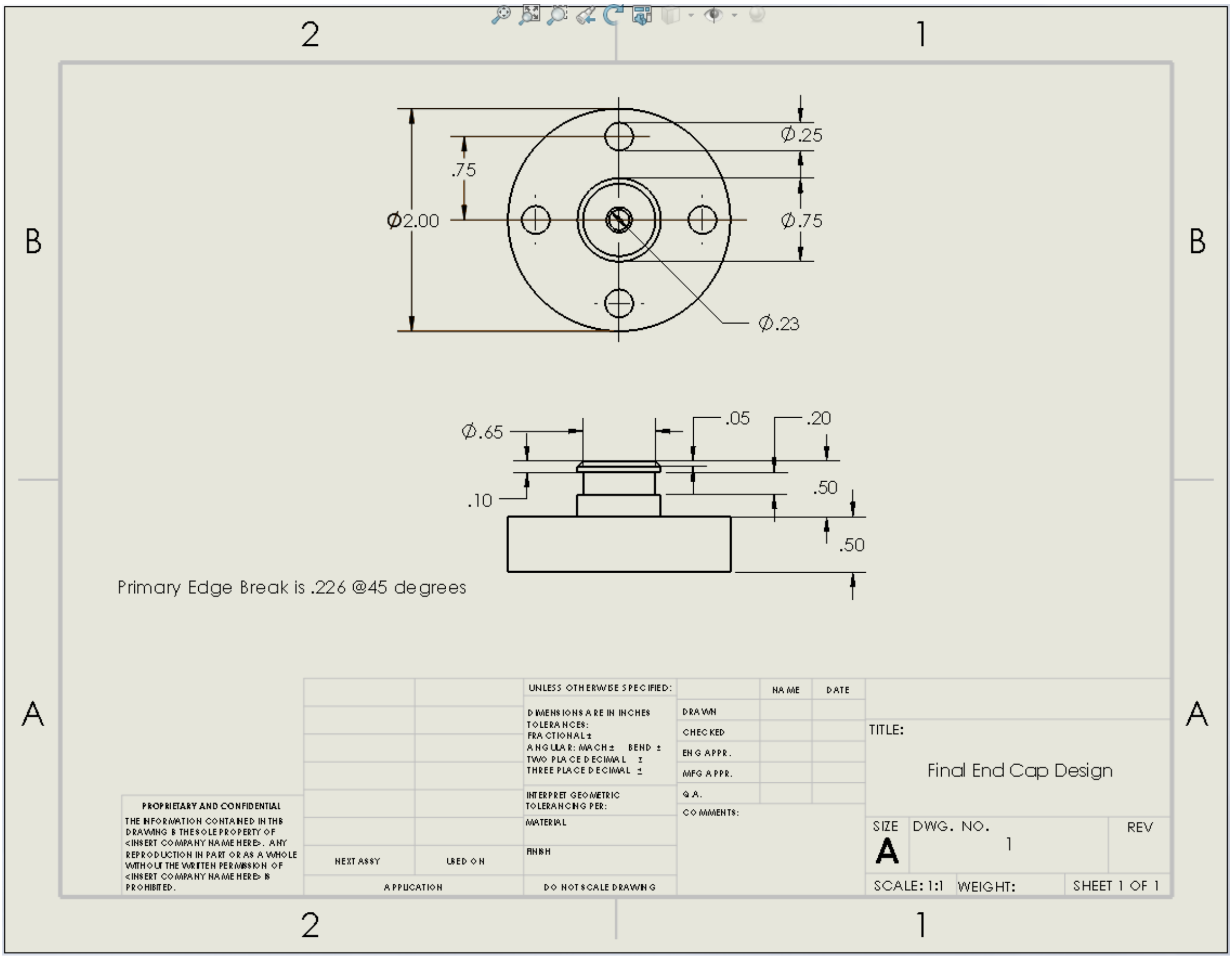
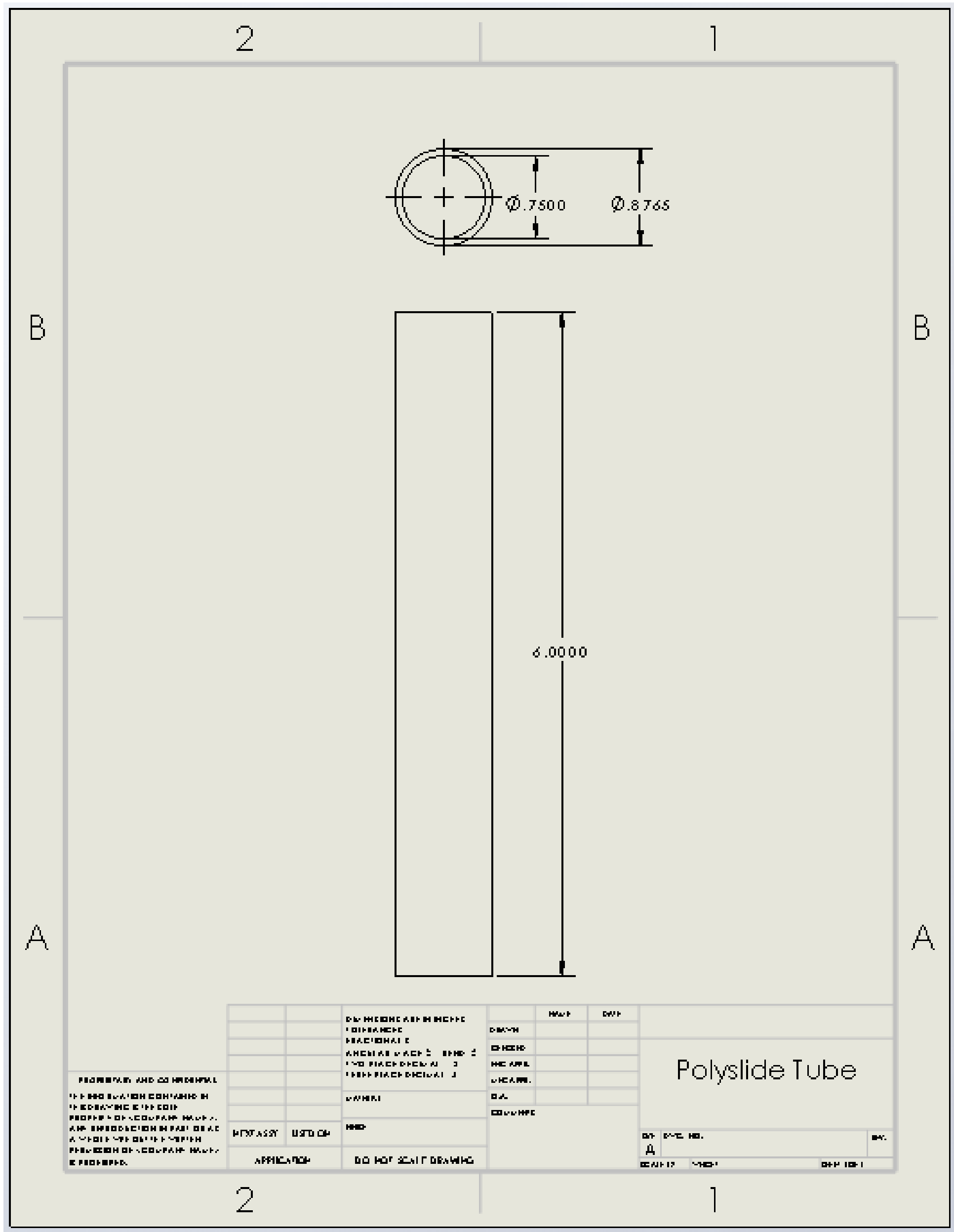


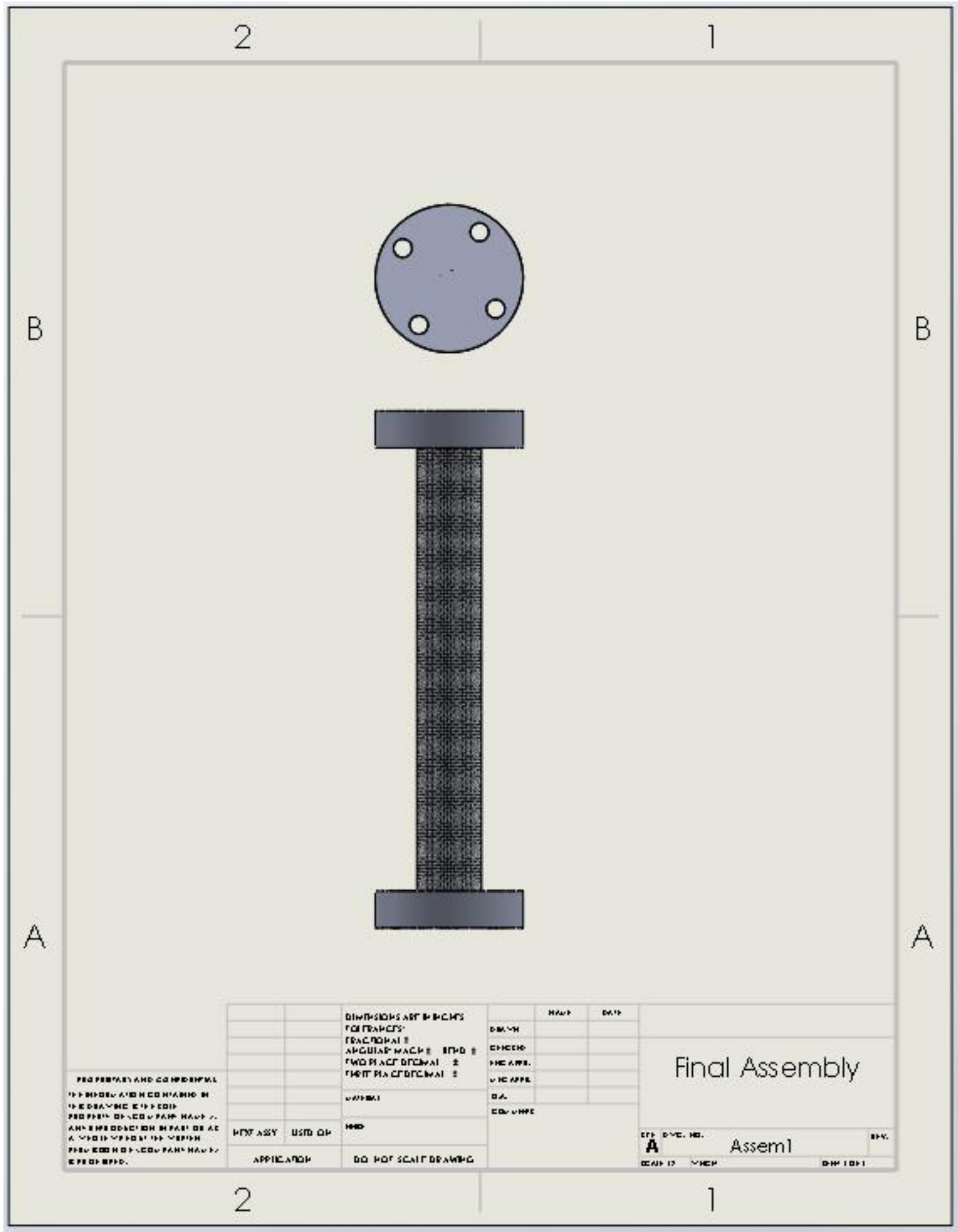
Figure 2: Tube Assembly 2.0, See Figure 1 for GDT notes


Notes:
1. Barrel is twice as long as minimum stroke length
2.
ØID
ØOD
SECTION A-A
2*L
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
MATERIAL
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
TITLE:
Hydraulic Tube
SIZE
A
DWG. NO.
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1



Ø.25
.75
Ø2.00
Ø.75
Ø.23
Ø.65
.05
.20
.10
.50
.50
Primary Edge Break is .226 @45 degrees
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Final End Cap Design
SIZE
A
DWG. NO.
1
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL


Ø.7500
Ø.8765
6.0000
Polyslide Tube
DO NOT SCALE DRAWING
APPLICATION
A



Final Assembly
Assem1

APPENDIX C: PARTS LIST

Materials:

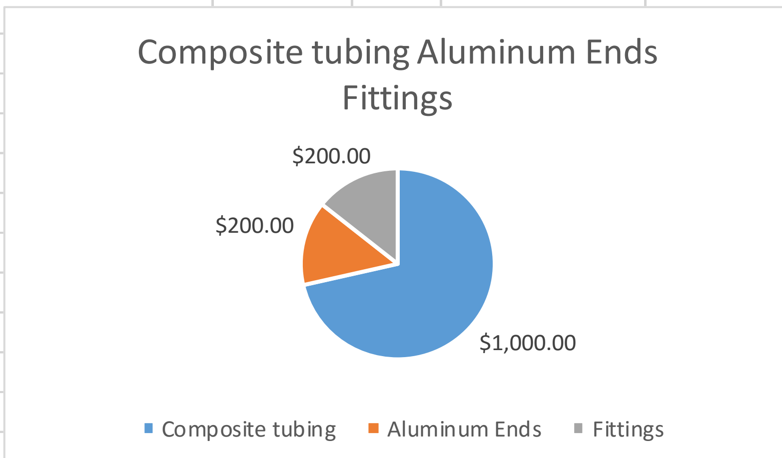
- PolySlide Composite Tubing courtesy of Polygon Composites
- Aluminum End caps fitted with O-rings and seals per the Parker Seal Guide
- Aluminum sleeve
- 4- ¼”Screws
- 4- ¼” Nuts
- Hydraulic press
- Hydraulic fluid
- Force gauge
- Blast Shield
- Camera

APPENDIX D: BUDGET

Total Budget spent: $0.00

All materials were either recycled from Fatigue Technology or donated by Polygon.

Item	amount	total	Over/under	comment
Composite tubing	$1,000.00	$0.00	-$1,000.00	Max.
Aluminum Ends	$200.00	$0.00	-$200.00	
Fittings	$200.00	$0.00	-$200.00	

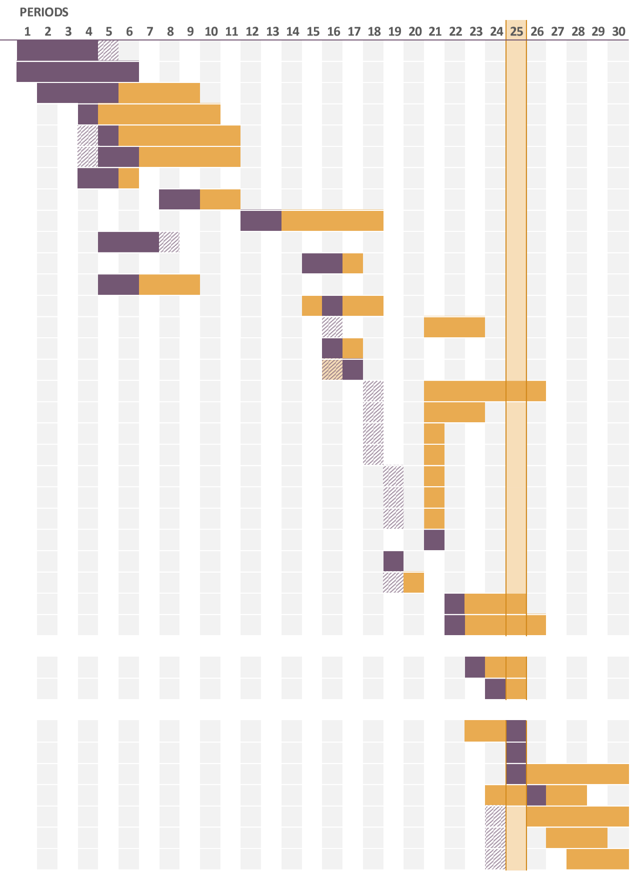


APPENDIX E: SCHEDULE

Senior Project Planner

Select a period to highlight at right. A legend describing the charting follows.

Period Highlight: 25 | Plan Duration | Actual Start | % Complete | Actual (beyond plan) | % Complete (beyond plan)



	ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE	Planned Hours	Actual Hours	Over/Under Hours
1	Introduction	1	5.00	1	4.00	100%	5	4	1
2	Design and Analysis	1	6.00	1	6.00	100%	6	6	0
3	Calculations	2	4.00	2	8.00	100%	4	8	-4
4	Materials study	4	1.00	4	7.00	100%	1	7	-6
5	Drawings	4	2.00	5	7.00	100%	2	7	-5
6	Budget	4	3.00	5	7.00	100%	3	7	-4
7	Redesign 1	4	2.00	4	3.00	100%	2	3	-1
8	Redesign 2	8	2.00	8	4.00	100%	2	4	-2
9	Redesign 3	12	2.00	12	7.00	100%	2	7	-5
10	Performance predictions	5	4.00	5	3.00	100%	4	3	1
11	Choose Cylinder System from Supplier	15	2.00	15	3.00	100%	2	3	-1
12	Order Parts	5	2.00	5	5.00	100%	2	5	-3
13	Modeling	16	1.00	15	4.00	100%	1	4	-3
14	Finalize Solidworks drawings	16	1.00	21	3.00	100%	1	3	-2
15	Construct FEA model	16	1.00	16	2.00	100%	1	2	-1
16	Develop CNC program	17	1.00	17	0.00	100%	1	0	1
17	Aluminum Sleeve Construction	18	1.00	21	6.00	100%	1	6	-5
18	Turn OD	18	1.00	21	3.00	100%	1	3	-2
19	Bore ID	18	1.00	21	1.50	100%	1	1.5	-0.5
20	Drill and Tap bottom Pad	18	1.00	21	0.75	100%	1	0.75	0.25
21	Assembly	19	1.00	21	1.25	100%	1	1.25	-0.25
22	Sleeve and piston	19	1.00	21	1.00	100%	1	1	0
23	Piston and hydraulic system	19	1.00	21	1.00	100%	1	1	0
24	Device configurations	21	1.00	21	0.75	100%	1	0.75	0.25
25	Tolerances, Kinematics	19	1.00	19	1.75	100%	1	1.75	-0.75
26	Technical risk	19	1.00	20	1.25	100%	1	1.25	-0.25
27	Testing Specimen 1	22	1.00	22	4.00	100%	1	4	-1
28	Testing Specimen 2	22	1.00	22	5.00	100%	1	5	-4
29	Testing Presentation 1	23	3.00	23	4.00	100%	3	4	-3
30	Post-testing Analysis	23	1.00	23	3.00	100%	1	3	-2
31	Revisions	24	1.00	24	2.00	100%	1	2	-1
32	Testing Presentation 2	25	1.00	23	1.00	100%	1	1	0
33	Post-testing Analysis	25	1.00	23	3.00	100%	1	3	61
34	Revisions	25	1.00	25	1.00	100%	1	1	-1
35	Website Edits	25	1.00	25	6.00	100%	1	6	-6
36	Finalize Proposal	26	1.00	24	5.00	100%	1	5	-5
37	Final Report and presentation	24	1.00	26	5.00	100%	1	5	-5
38	Source Poster Work	24	1.00	27	3.00	100%	1	3	-3
39	Source	24	1.00	28	3.00	100%	1	3	-3
							64	136.3	-15.25

APPENDIX F: TESTING DATA

Attached is the testing data.

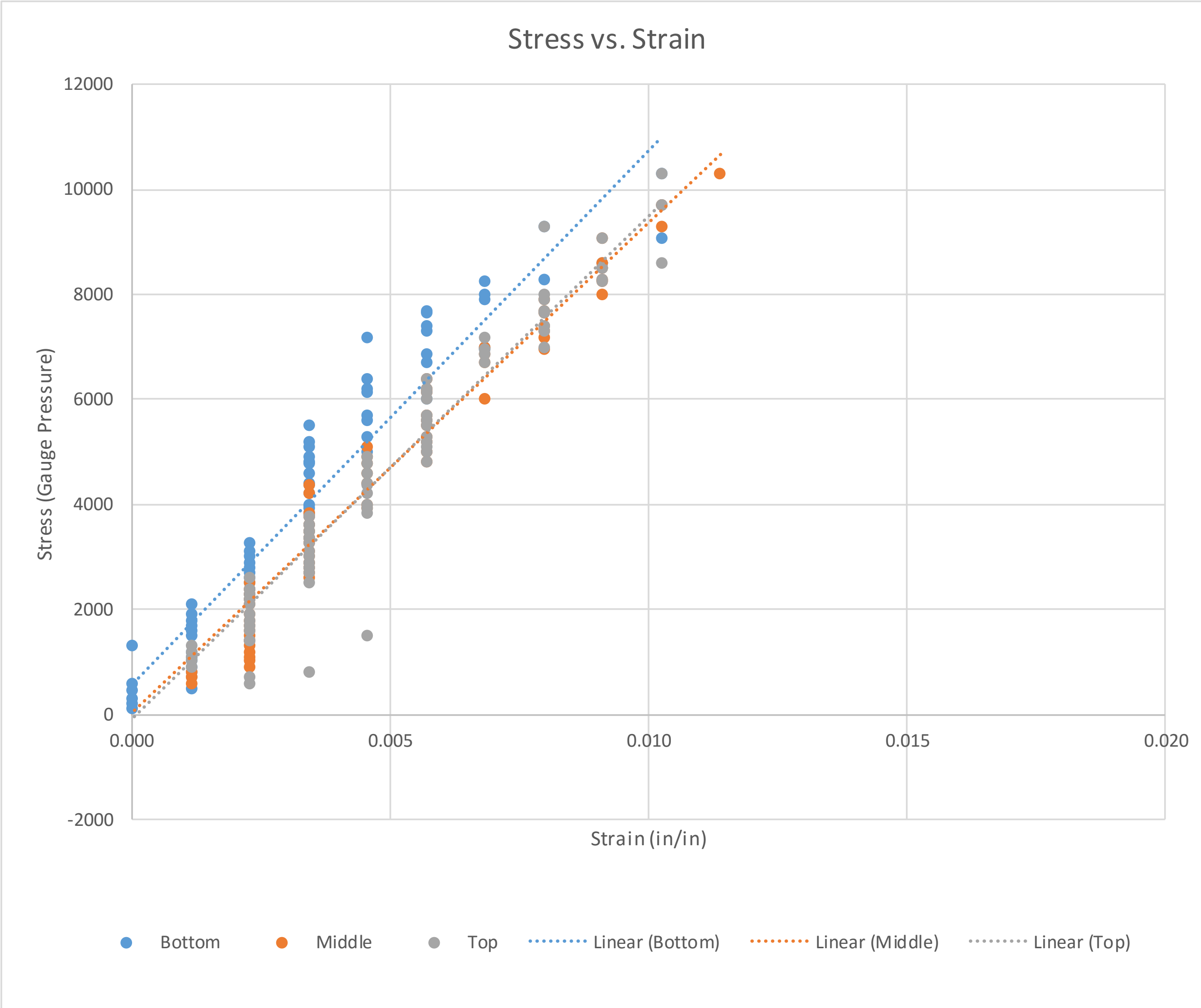
Specimen 1				
Load (PSI)	Deformation			Comments
Enerpac Hydraulic pump	Mitutoyo 0-1" Digital Caliper			
	Bottom	Middle	Top	
0	0.878	0.878	0.878	No load being applied (baseline)
100	0.878	0.878	0.878	
207	0.878	0.878	0.878	
309	0.878	0.878	0.878	No Change
454	0.878	0.878	0.878	
500	0.879	0.878	0.878	
600	0.878	0.879	0.880	
700	0.879	0.879	0.880	
800	0.879	0.879	0.881	
900	0.879	0.880	0.879	
1030	0.879	0.880	0.879	
1100	0.879	0.880	0.879	
1200	0.879	0.880	0.879	
1300	0.878	0.880	0.879	
1400	0.880	0.880	0.880	Difficult to maintain pressure at this
1500	0.879	0.880	0.882	
1600	0.879	0.880	0.880	
1700	0.879	0.880	0.880	
1800	0.879	0.880	0.880	
1900	0.879	0.880	0.880	
2100	0.879	0.880	0.880	
2200	0.880	0.880	0.880	
2300	0.880	0.880	0.880	
2400	0.880	0.880	0.880	
2500	0.880	0.880	0.881	
2600	0.880	0.881	0.880	
2700	0.880	0.881	0.881	
2800	0.880	0.881	0.881	
2900	0.880	0.881	0.881	
3000	0.880	0.881	0.881	Pressure is continually harder to to

PSI	Bottom	Middle	Top
Max	0.887	0.888	0.887
Min	0.878	0.878	0.878
Range	0.009	0.010	0.009

3100	0.880	0.881	0.881	
3260	0.880	0.881	0.881	Pressure settles at a value.
3375	0.881	0.881	0.881	
3480	0.881	0.881	0.881	
3600	0.881	0.881	0.881	
3780	0.881	0.881	0.881	
3840	0.881	0.881	0.882	
3930	0.881	0.882	0.882	
4000	0.881	0.882	0.882	
4200	0.881	0.881	0.882	
4370	0.881	0.881	0.882	
4400	0.881	0.882	0.882	
4600	0.881	0.882	0.882	
4770	0.881	0.882	0.882	
4815	0.881	0.883	0.883	
4900	0.881	0.882	0.882	
5000	0.882	0.883	0.883	
5100	0.881	0.882	0.883	
5200	0.881	0.883	0.883	
5300	0.882	0.883	0.883	
5500	0.881	0.883	0.883	
5600	0.882	0.883	0.883	
5700	0.882	0.883	0.883	
6000	0.883	0.884	0.883	
6150	0.882	0.883	0.883	
6200	0.882	0.883	0.883	
6400	0.882	0.883	0.883	
6700	0.883	0.884	0.884	
6860	0.883	0.884	0.884	
6950	0.884	0.885	0.884	
7000	0.884	0.884	0.885	
7170	0.882	0.885	0.884	
7300	0.883	0.885	0.885	
7400	0.883	0.885	0.885	
7650	0.883	0.885	0.885	
7700	0.883	0.885	0.885	
7900	0.884	0.885	0.885	
8000	0.884	0.886	0.885	
8250	0.884	0.886	0.886	
8300	0.885	0.886	0.886	
8500	0.886	0.886	0.886	Weeping observed on the specimen
8600	0.886	0.886	0.887	
9080	0.887	0.886	0.886	Small drop formed
9300	0.885	0.887	0.885	
9700	0.887	0.887	0.887	Holding pressure for several minutes
10300	0.887	0.888	0.887	before we released

Nominal Value		0.878				
Deformation			Strain			Load (PSI)
Mitutoyo 0-1" Digital Caliper			$\Delta L/L_O$			Enerpac Hydraulic pump
Bottom	Middle	Top	Bottom	Middle	Top	
0.878	0.878	0.878	0.000	0.000	0.000	0
0.878	0.878	0.878	0.000	0.000	0.000	100
0.878	0.878	0.878	0.000	0.000	0.000	207
0.878	0.878	0.878	0.000	0.000	0.000	309
0.878	0.878	0.878	0.000	0.000	0.000	454
0.879	0.878	0.878	0.001	0.000	0.000	500
0.878	0.879	0.880	0.000	0.001	0.002	600
0.879	0.879	0.880	0.001	0.001	0.002	700
0.879	0.879	0.881	0.001	0.001	0.003	800
0.879	0.880	0.879	0.001	0.002	0.001	900
0.879	0.880	0.879	0.001	0.002	0.001	1030
0.879	0.880	0.879	0.001	0.002	0.001	1100
0.879	0.880	0.879	0.001	0.002	0.001	1200
0.878	0.880	0.879	0.000	0.002	0.001	1300
0.880	0.880	0.880	0.002	0.002	0.002	1400
0.879	0.880	0.882	0.001	0.002	0.005	1500
0.879	0.880	0.880	0.001	0.002	0.002	1600
0.879	0.880	0.880	0.001	0.002	0.002	1700
0.879	0.880	0.880	0.001	0.002	0.002	1800
0.879	0.880	0.880	0.001	0.002	0.002	1900
0.879	0.880	0.880	0.001	0.002	0.002	2100
0.880	0.880	0.880	0.002	0.002	0.002	2200
0.880	0.880	0.880	0.002	0.002	0.002	2300
0.880	0.880	0.880	0.002	0.002	0.002	2400
0.880	0.880	0.881	0.002	0.002	0.003	2500
0.880	0.881	0.880	0.002	0.003	0.002	2600
0.880	0.881	0.881	0.002	0.003	0.003	2700
0.880	0.881	0.881	0.002	0.003	0.003	2800
0.880	0.881	0.881	0.002	0.003	0.003	2900
0.880	0.881	0.881	0.002	0.003	0.003	3000
0.880	0.881	0.881	0.002	0.003	0.003	3100
0.880	0.881	0.881	0.002	0.003	0.003	3260
0.881	0.881	0.881	0.003	0.003	0.003	3375
0.881	0.881	0.881	0.003	0.003	0.003	3480
0.881	0.881	0.881	0.003	0.003	0.003	3600
0.881	0.881	0.881	0.003	0.003	0.003	3780
0.881	0.881	0.882	0.003	0.003	0.005	3840
0.881	0.882	0.882	0.003	0.005	0.005	3930

0.881	0.882	0.882	0.003	0.005	0.005	4000
0.881	0.881	0.882	0.003	0.003	0.005	4200
0.881	0.881	0.882	0.003	0.003	0.005	4370
0.881	0.882	0.882	0.003	0.005	0.005	4400
0.881	0.882	0.882	0.003	0.005	0.005	4600
0.881	0.882	0.882	0.003	0.005	0.005	4770
0.881	0.883	0.883	0.003	0.006	0.006	4815
0.881	0.882	0.882	0.003	0.005	0.005	4900
0.882	0.883	0.883	0.005	0.006	0.006	5000
0.881	0.882	0.883	0.003	0.005	0.006	5100
0.881	0.883	0.883	0.003	0.006	0.006	5200
0.882	0.883	0.883	0.005	0.006	0.006	5300
0.881	0.883	0.883	0.003	0.006	0.006	5500
0.882	0.883	0.883	0.005	0.006	0.006	5600
0.882	0.883	0.883	0.005	0.006	0.006	5700
0.883	0.884	0.883	0.006	0.007	0.006	6000
0.882	0.883	0.883	0.005	0.006	0.006	6150
0.882	0.883	0.883	0.005	0.006	0.006	6200
0.882	0.883	0.883	0.005	0.006	0.006	6400
0.883	0.884	0.884	0.006	0.007	0.007	6700
0.883	0.884	0.884	0.006	0.007	0.007	6860
0.884	0.885	0.884	0.007	0.008	0.007	6950
0.884	0.884	0.885	0.007	0.007	0.008	7000
0.882	0.885	0.884	0.005	0.008	0.007	7170
0.883	0.885	0.885	0.006	0.008	0.008	7300
0.883	0.885	0.885	0.006	0.008	0.008	7400
0.883	0.885	0.885	0.006	0.008	0.008	7650
0.883	0.885	0.885	0.006	0.008	0.008	7700
0.884	0.885	0.885	0.007	0.008	0.008	7900
0.884	0.886	0.885	0.007	0.009	0.008	8000
0.884	0.886	0.886	0.007	0.009	0.009	8250
0.885	0.886	0.886	0.008	0.009	0.009	8300
0.886	0.886	0.886	0.009	0.009	0.009	8500
0.886	0.886	0.887	0.009	0.009	0.010	8600
0.887	0.886	0.886	0.010	0.009	0.009	9080
0.885	0.887	0.885	0.008	0.010	0.008	9300
0.887	0.887	0.887	0.010	0.010	0.010	9700
0.887	0.888	0.887	0.010	0.011	0.010	10300



Stress vs. Strain
12000
10000
8000
6000
4000
2000
0
-2000
0.000
0.005
0.010
0.015
0.020
Stress (Gauge Pressure)
Strain (in/in)
Bottom
Middle
Top
Linear (Bottom)
Linear (Middle)
Linear (Top)

CRITICAL DESIGN REVIEW OR: NAMES

NAME: Andrew Amos DATE: 5/3/17*

PROJECT: Little Brute Composite Hydraulic Prototype Score: please use percentages
Metric: 0: none, .5 partial, 1 complete (or %)

NOTE: 'Business Casual' dress is appropriate
(Refer to the student presenting)

QUESTION #1 Outcome 3i (professional with social/ethical responsibilities)
Does the principal engineer demonstrate 'professional' aspects of our discipline?
Note: Use the Engineering Code of Ethics (www.nspe.org) for guidance.

- Eng. Methods: Professional appearance, speech, ethics, and social character.
  COMMENTS: ______100____%

(Refer to Requirements slide in student presentation)

QUESTION #2 Outcome 3j (respect for diversity, societal, global issues)
Do the Requirements support 'Appropriate Diverse Input' into a solution?
Note: Engineering Requirements should be inclusive for all uses to avoid failures.

- Engineering **Requirements**: Diverse Input
  OMISSIONS? ______100____%

(Refer to an Analysis slide in student presentation)

QUESTION #3 Outcome 3k (continuous improvement)
Do the req's and analyses support 'Continuous Improvement' of an engineering solution.
Note: Engineering Analyses should result in 'Dimensions' that are used in a 'Drawing'.

- Eng. Process: **2+ Analyses, Design Opt., Perf. Prediction, Test Methods**
  OMISSIONS? ______100____%

(Refer to an example Drawing slide in student presentation)

QUESTION #4 Outcome 3a (modern tools), 3b (eng. applications), 3g (comm.)
Does the drawings represent a usable device in a standard and effective medium?
Note: Use ANSI Y14.5 for guidance.

- Engineering **Drawings**: Completeness and compliance.
  OMISSIONS? _____100_____%

(Refer to Parts List slide in student presentation)
QUESTION #5 Outcome 3d (design components)
Does the Part List show enough detail to acquire the necessary materials?

* Eng. Proj. **Parts List, Budget**, Part ID, Sources and TOTAL $ EST [____$10___]
OMISSIONS?

_____100_____%

(Refer to <u>Schedule</u> slide in student presentation)
QUESTION #6 Outcome 3k (timeliness)
Does the Schedule detail necessary ‘Tasks’ with appropriate ‘Duration’ estimates and ‘Timeliness’ to get the project done?

* Eng. **Proj.Schedule**: Task IDs, Seq., Milestones, TOTAL HR EST [75 hours]

Test Design for Composite Cold Expansion Tooling

Author: Andrew Amos

Created to satisfy the requirements of the Mechanical Engineering Technology Capstone Project.

Introduction:

The objective of this test was to assemble and test Assemble and test multiple designs for the composite hydraulic cylinder for the Little Brute Hydraulic puller and determine the actual strength of the tubing under an internal pressure. Each design was tested to a predetermined operating pressure (or to failure) and the resulting data will indicate if a more advanced prototype is feasible.

A success is defined as no observable failures at a pressure of 7500 psi. An observable failure is defined as little as weeping at the edges of the cylinder or as much as a physical defect appear such as a crack or total catastrophic failure.

According to the safety factors and pressure limits of the O-rings used in the test assembly, weeping failure was predicted at 6000 psi and structural failure at 8000 psi

Methods:

The following procedures and resources were used to test the single acting composite tube.

Materials:

- PolySlide Composite Tubing courtesy of Polygon Composites
- Aluminum End caps fitted with O-rings and seals per the Parker Seal Guide
- Aluminum sleeve
- 4- ¼"Screws
- 4- ¼" Nuts
- Hydraulic press
- Hydraulic fluid
- Force gauge
- Blast Shield
- Camera

Process:

14. Assemble the aluminum end cap on the bottom side of the 6" specimen of composite tubing.
15. Fill the specimen with hydraulic fluid approximately half way up the cylinder. This amount is not critical.
16. Assemble the top end cap with single acting hydraulic plunger.
17. Place blast Shields in correct upright positions.

18. Turn on camera.
19. Align Force gauge so that is visible to the camera.
20. Apply a small load to the cylinder in order to align it.
21. Step behind the blast shield. Then engage the hydraulic press to slowly apply force to the plunger.
22. At increments of 100 psi, record the outer diameter of the tube at three locations along the tube.
23. Load the cylinder until failure or until 10,000 psi.
24. Record the values in the table below.
25. Repeat steps 1-10 with the second specimen.
26. Generate a critical design review for the test specimens.

Test Procedure

The test was deemed a success based on the previous criteria. A failure was detected at 8000 psi when weeping at the bottom end of the tube was observed. The test itself took approximately 57 minutes to complete and was loaded to 10,000 psi at which point the hydraulic press was at its maximum operating pressure. The test was performed on site at Fatigue Technology inc. in Tukwila, WA.

The resources and procedures used in the actual test followed the test plan almost exactly.

Conclusion

From observation, the test was a success and so much so that the composite tube with an additional aluminum sleeve did not need to be tested. It was assumed that if the unreinforced tube could sit at the maximum operating pressure with no structural failure that the stronger specimen would be as well.

In addition to our testing success, the data showed that when it was plotted on a stress-strain diagram to be linear. This is one of the most important outcomes of the test because it suggests that the material deformed elastically. Plastic deformation would have meant that the second phase of development for the double acting hydraulic cylinder would not be able to continue.

APPENDIX I: RESUME AND COVER LETTER

See next page.

ANDREW AMOS

604 N. Sprague St. #4 Ellensburg, WA 98926
Andrew.j.amos@gmail.com | 253-370-3589

OBJECTIVE

To fill a position in the field of engineering in which I can learn more about my field, the company and become a well-rounded individual.

SKILLS & ABILITIES

CSWA Certification

Lean Bronze Certification (IN PROGRESS),

Experience in machining, CNC programming, internal auditing, mechanical design, and employee management.

EXPERIENCE

ENGINEERING INTERN FATIGUE TECHNOLOGY INC.
JUNE 2016- SEPTEMBER 2016

Experience working in Quality Assurance specifically to maintain current ISO 9001 / AS9100 QMS standard requirements. I also participated in several external audits and conducted an internal audit at FTI.

Experience working in Research and Development as a lab technician and design assistant.

STUDENT LAB TECH AND OFFICE ASSISTANT CENTRAL WASHINGTON UNIVERSITY
SEPTEMBER 2015 - PRESENT

Experience in managing fellow student employees including scheduling, hiring and daily computer lab maintenance.

STUDENT CUSTODIAN AND CREW LEAD CENTRAL WASHINGTON UNIVERSITY
JUNE 2014-DECEMBER 2014, JUNE 2015-SEPTEMBER 2015

Experience in managing fellow students, cleaning and sanitizing residence halls.

CHECKER SAFEWAY
MARCH 2014-JUNE 2014

Experience in handling currency, troubleshooting customer concerns and in customer relations.

SUMMER HIRE PIERCE COUNTY SURFACE WATER MANAGEMENT
JUNE 2013 – SEPTEMBER 2013

Experience in landscaping and pest control. This job required me to work long days in the summer heat. This job was on opportunity to work cohesively in a small team.

SERVER/DISHWASHER WILLOW GARDENS RETIREMENT COMMUNITY
JANUARY 2013- MAY 2013

Experience in waiting, busing and resetting tables at a fast pace on a strict schedule.

EDUCATION

CENTRAL WASHINGTON UNIVERSITY, ELLENSBURG, WA
MECHANICAL ENGINEERING TECHNOLOGY, BS

Emphasis in Mechanical Design. GPA: 2.99

EMERALD RIDGE HIGH SCHOOL, SOUTH HILL WASHINGTON
HIGH SCHOOL DIPLOMA

GPA: 3.25

COMMUNICATION

I am a natural born leader. I have plenty of experience communicating and speaking in groups both large and small. My extra-curricular activities give me ample opportunities to communicate on a relational level and mentor other men.

LEADERSHIP

My leadership experience includes, 3 varsity letters in football, 2 varsity letters in community service through United Way, High School club officer and Chi Alpha Christian Fellowship student leadership.

REFERENCES

JAMES ROSS, R&D ENGINEER
FATIGUE TECHNOLOGY

Email: jross@fatiguetech.com Phone: (206) 701-7238

JEFF WATSON, QUALITY ENGINEER
FATIGUE TECHNOLOGY

Email: Jeffrey.w.watson@gmail.com Phone: (509) 385-3254

SANDY SPERLINE, INFORMATION TECHNOLOGY SUPERVISOR
CENTRAL WASHINGTON UNIVERSITY INFORMATION SERVICES

Email: Sandra.Sperline@cwu.edu Phone: (509) 963-2989

TIM POLLOCK, CUSTODIAN 5
CENTRAL WASHINGTON UNIVERSITY CUSTODIAL SERVICES

Email: Timothy.Pollock@cwu.edu Phone: (509) 963-1140

Andrew Amos

604 N Sprague Apt. 4, Ellensburg, WA 98926 | (253) 370-3589 | Andrew.j.amos@gmail.com

June 2nd, 2017

Astronics AES

12950 Willows Road N.E.

Kirkland, WA 98034

ATTN: Human Resources

To whom it may concern,

Thank you for taking the time to look at my resume and considering me for the position of Quality Engineer. I hope you see at first glance that I would be an excellent addition to your team. I am currently studying Mechanical Engineering Technology at Central Washington University and plan to relocate to the Seattle area when I graduate this June.

A quick summary of skills include mechanical design, CAD experience, machining, lean manufacturing, internal auditing, quality control, and data analysis. I also excel working in teams, working independently and reviving criticism. I am a great team member and constantly strive to improve my workplace. I have completed my CSWA certification and am working towards a LEED Gold certification as well.

As a portion of my engineering experience, I was employed by Fatigue Technology as a quality engineer intern. During this time, I conducted an internal audit for a manufacturing process, assisted on external audits in compliance with AS9100 and ISO 9001 requirements and updated manufacturing processes and corresponding work instructions within the company.

Thank you again for taking the time to consider me for Quality Engineer. I appreciate the opportunity to interview with you and I look forward to learning more about the mission of Astronics.

Sincerely,
Andrew Amos