Determining the Effectiveness of Oleophobic Gaskets

Restated Project Definition and Scope/Project Plan

Team Number: 1

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ACKNOWLEDGEMENTS

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ABSTRACT

The goal of this Cummins Inc. sponsored project is to determine the effectiveness of oleophobic gaskets compared to standard nonoleophobic gaskets. This objective will be completed by utilizing on market oleophobic sealing solutions on current gasket materials, as well as non-traditional gasket materials and then testing these products in an experimental test rig, which will be designed and constructed by the team. The effectiveness of the oleophobic gaskets will be assessed by comparing the respective leak rates of each gasket type under several conditions, including two variable temperatures and variable clamping pressures, to that of baseline nonoleophobic gasket leak rates. The team has performed research on types of oleophobic solutions and have investigated which of these solutions are potential candidates to create an oleophobic gasket. The test rig has been designed and will be built by the team so that it can test gaskets with oil at room temperature and at an elevated engine-like temperature while under a constant low internal pressure of 2.5 psi with variable gasket clamping pressure. Some of these constraints have been updated from the initial values due to input from the Cummins Inc. liaison. Once the final concept was chosen, in-depth analysis was performed on various components in hopes of reducing and mitigating any sort of failure. Through this technique, several elements were added or modified such as a pressure relief valve, bolt size, and an active bolt load measurement procedure. Additionally, the team has updated the budget accordingly and continues to monitor it. The team has updated the Gantt chart to encompass the Spring semester and the numerous tasks that must be accomplished in order to complete the project on time and successfully.

1 Introduction

Cummins Inc. has proposed a project to determine the effectiveness of oleophobic gaskets to reduce the measured leak rate at low pressure, large joints on engines compared to the current gaskets used on engines. Oleophobic items are items which repel oil by having a lower surface energy than the oil. A gasket is an item which is placed between two flanges to form a seal, which is meant to prevent oils from leaking to the opposite side of the flange. The theory behind the project is that if the gasket can repel the oil, it is less likely that oil will be capable of leaking past the gasket.

In order to determine the effectiveness of oleophobic gaskets, the design team needs to determine what products on the market can be used to give a gasket oleophobic properties, create oleophobic gaskets using these products and nontraditional gasket materials, as well as design and build a test rig which measures the leak rate of a gasket at various temperatures and pressures. Once the design and construction of the project is complete, tests will be performed on oleophobic and standard gaskets using the test rig and results will be compared to determine the effectiveness. The test rig must be capable of testing oils that range from 22 to 120° Celsius and inducing a pressure on the oil ranging from 0 to 2.5 psi.

2 Project Definition

2.1 Background Research

Gaskets materials are used for different applications to prevent leakage of fluids at a joint, typically flanged bolted joints. These gaskets are usually metallic, polymeric, or paper materials, and they are expected to function effectively when subjected to various pressures and temperatures [1]. Gaskets are more likely to fail under adverse conditions, such as at higher pressures, higher temperatures, and poor flange surface conditions. The failure of gaskets can also be dependent on the size of the gasket, as larger gaskets have more potential leak paths. This project team is saddled with the task of determining if the use of an oleophobic gasket would prevent/reduce the effect of a gasket failure, while still having the reliability and durability of standard gaskets. The gasket performance will be tested with the use of a test rig, which is the second responsibility of the team.


Figure 1. Nonoleophobic (left) vs. oleophobic (right)

To have oleophobic properties means a material will have a tendency to repel oil from its surface which can be seen in Figure 1 [2]. Oleophobicity is reliant upon the concept of surface energy, which is the excess energy on the surface of a bulk material [3]. Therefore, oleophobic material must have a lower surface energy than oil.

This project is a first for FAMU/FSU senior design, meaning it is not a continuation of a previous project. Also, Cummins Inc. has not performed research or tests of their own, meaning that this senior design team is the first group to work on this project. Previous works related to this project involving oleophobic coatings are found on various items such as phones and clothing. Additionally, oleophobic impregnators are used as a tile and grout sealer. These sealants are not intended to prevent oil leakage. All of the aforementioned oleophobic solutions aim to simply repel oil from a surface, allowing the surface to maintain a clean finish. Currently, the design team has found no existing work involving the use of oleophobic sealing solutions on gaskets.

Lakshmi discusses how to lower the surface energy of a material through the application of a fluoropolymer [4]. This is relevant to the project as fluoropolymers are typically found in oleophobic sealing solutions, confirming the feasibility of on market sealing solutions.

There are four main types of gaskets used on engines to create seals: paper gaskets, FIPG gaskets, molded elastomer gaskets, and rubber coated metal gaskets. Paper gaskets are composed of 90% fibers and 10% elastomeric binder [1]. These gaskets are widely used because of how cost effective the production process is for them; however, they are subject to many failure modes such as weeping oil through the paper and bolt load relaxation. FIPG gaskets are gaskets that are applied to flanges in a liquid state and cure to create a seal. FIPG gaskets rely on adhesion to the flange surface to prevent leakage rather than pressure, as the other gaskets do. Rubber coated metal gaskets are composed of a metal core, which is coated with a thin layer of rubber, typically 25-75 μm thick [1]. Rubber coated gaskets are typically used in high temperature applications. The final type of gasket, molded elastomer gaskets, are gaskets which are composed of elastomers which were molded into a particular shape for usage. An example of a molded elastomer gasket is an o-ring. These gaskets typically display the best sealing characteristics of the four types of gaskets.

2.2 Need Statement

Cummins Inc., the largest diesel engine manufacturer in the world, would like to investigate if introducing an oleophobic substance to gaskets will decrease the amount of oil leakage experienced at various joints on their engines. Within the scope of the investigation is to research different types of oleophobic products, the different application procedures for these products, and which materials are compatible with these products. The contact joints that Cummins Inc. is most interested in are larger, low pressure flange joints. Examples of such a joint is the joint between the engine block and the oil pan. In such a joint, the oil is at a low pressure, but there is a large exposed gasket length for potential leaks to occur at. These leaks can lead to excessive engine wear and possible catastrophic failure. Currently gaskets prevent oil leakage solely through contact pressures between the gasket and the flange surfaces, which create a seal. The purpose of this project is to determine if using an oleophobic gasket would reduce the amount of oil leakage compared to current gaskets used by Cummins Inc.

Need Statement:

“Gaskets used at large joints where the oil is at low pressure leak more oil than desired.”

2.3 Goal Statement and Objectives

Goal Statement: “Determine the effectiveness of oleophobic gaskets through the use of a test rig designed by the team.”

Table 1. Project Objectives

Objective Number	Objective
1	Research what causes items to become oleophobic.
2	Create oleophobic gaskets using on market products.
3	Create oleophobic gaskets using non-conventional gasket materials
4	Design and build the test rig to be capable of varying clamping pressure and temperature
5	Test oleophobic gaskets and currently used gaskets for leak rate and compare results

3 Revised Constraints

3.1 Project Constraints

Multiple constraints associated with this project must be adhered to in order to determine the effectiveness of the gaskets. There are several categories for the constraints, and they are as follows:

Components/Gaskets

- An oleophobic gasket must be created using non-conventional gasket materials. This means that any form of rubber may not be used in the creation of this gasket.

Time Constraint

- The test rig construction must be completed within one month prior to the end of the semester, allowing time for gasket testing.
- The leak rate test results will be completed by the end of spring 2016 semester.

Testing Constraints

- Cummins Inc. requires that the design team use two types of standard gaskets as a baseline test to compare to the oleophobic gaskets. These two standard gasket types are paper gaskets and rubber coated metal gaskets.
- Cummins Inc. asks that the design team not test at internal pressures greater than 2.5 psi. The reasoning behind this is to accurately simulate the pressure present within an oil pan of an engine and to reduce the risk of injury during testing.

3.2 Design Specifications

Measurable design specifications important to this design include test rig dimensions, internal stress bearing capacity of the test rig, flange dimensions, clamping pressure needed for the bolts on the flanges, as well as flange surface roughness as shown in Table 2. Through preliminary research, some materials have been considered for the design. For example, the test rig can be made from an aluminum alloy or a steel alloy. The thickness of the test rig wall is not critical since the pressure difference between the inside and outside of the test rig is nearly negligible.

The minimum thickness of the bottom flange was determined to be 4.94 mm as calculated in Appendix A.

Table 2. Design Specifications

Design Specifications	Expected Value
Test Rig Dimensions	Inner Diameter (ID): < 55 mm
Test Rig Stress Capacity	Minimum thickness of bottom flange: 4.94 mm
Flange Dimensions	Inner Diameter (ID): < 55 mm Minimum Outer Diameter (OD): 140 mm
Clamping Pressure	Minimum of 0.5 MPa according to Cummins standards. Maximum of 10 MPa according to Cummins standards.
Flange Surface Roughness	Maximum 3.2 microns RA.

3.3 Performance Specifications

The gasket will sit between the flanges of the test rig, providing adequate sealing and minimal leak rate during testing, thus simulating an actual bolted joint on an engine. The operational temperature of the test rig will be between 22 to 120°C with ± 2°C accuracy, and the internal oil pressure will range from 0 to 2.5 psi with ± 0.01 psi accuracy. The pressure sensor must be very precise as it will be used to measure the leak rate, which is expected to be a relatively small value. A very precise pressure sensor, such as a pressure transducer, will provide the necessary resolution. The test rig will be heated through an external source such as an electric hot plate, which will display the external temperature on its digital display. This heating arrangement will induce elevated temperature within the oil, which can be directly measured via an RTD (Resistance Temperature Detector) sensor within the test rig.

3.4 Constraint Changes from Original Project Plan

At the conceptual stage of this project, the design team planned on varying the oil pressure in the test rig between 0-50 psi, but later considered using a constant pressure of 2.5 psi during the testing. The reason behind this is to accurately simulate the pressure present within an engine and also reduce the risk of injury during testing. The operational temperature of the test rig was also changed from a temperature range of 22 to 150°C to 22 to 120°C. The sponsor changed this requirement in an effort to reduce any chance of injuries during testing. Additionally, varying the surface roughness is no longer a parameter to be considered in the final testing. The design team will just maintain a surface roughness less than a set amount of 3.2 microns RA, which is a Cummins Inc. standard for gasketed flanges on engines. This was changed to reduce the number of trials necessary during the testing process.

4 Project Updates

4.1 Clamping Load Measurement Technique

One of the test parameters that the team must be capable of varying is the clamping pressure on the gasket. In order to vary this pressure, the team must have a method of controlling the bolt load applied by the bolts used to clamp the two flanges together. One method to control the bolt load is to use a torque wrench with a predefined torque setting. Based on the coefficient of friction for the bolt, a theoretical torque value can be calculated to provide the desired bolt load. However, it is not possible to measure the exact coefficient of friction for each bolt. The standard friction coefficient for a steel bolt is 0.2, but this can vary by as much as 30% from bolt to bolt. Therefore, this method of controlling the bolt load would put the clamping pressure on the gasket in the approximate range desired, but it would not be a precise value. Because of this potential error, the team has decided to use an alternative method for controlling the bolt loads.

Figure 2. Modified bolt with strain gauge.

Load cells are devices that are capable of measuring the force being applied to them through the use of strain gauges within them. The team investigated purchasing load cells; however, the cost of just the load cells would equal the budget for the entire project. Cummins Inc. has offered to provide the team with strain gauges that can be placed on the bolts themselves. Cummins Inc. has the capabilities at their facilities to machine bolts and apply sheet resistive type strain gauges to the modified bolts. Figure 2 shows what the modified bolts look like with a strain gauges applied to them. Therefore, the senior design team has provided bolts to Cummins Inc., and Cummins Inc. will make the necessary modifications to the bolts and send them back to the senior design team. With strain gauges applied to the bolts, Cummins Inc. will create a calibration curve for each bolt. Using an MTS machine to apply a tensile load to each bolt, the output voltage of the strain gauges can be calibrated to the known applied load. Using this calibration, the team will be able to tighten these modified bolts on the test rig and be able to know the exact bolt load value based on the voltage output of the strain gauges. This method of measuring the bolt load is very precise as well as a cost effective solution to measuring the bolt load. Using these bolts, the clamping pressure on the gasket will be known and can be easily repeatable from test to test.

Because the use of modified bolts was not part of the original design for the test rig, changes needed to be made to the test rig design to accommodate the bolts. Based on information from Cummins Inc., the modified bolts provide the most accurate readings when the bolts are a minimum bolt size of M10 and have at least 2 inches of bolt length before thread engagement. Therefore, the design team specified new M10 bolts to be used on the test rig. In addition to increasing the bolt size from M8 to M10, the design team also purchased spacers to allow for the 2 inch length before thread engagement to be satisfied. Figure 3 shows the updated test rig design, which includes the new bolts and spacers. The updated CAD drawings can be found in Appendix A.

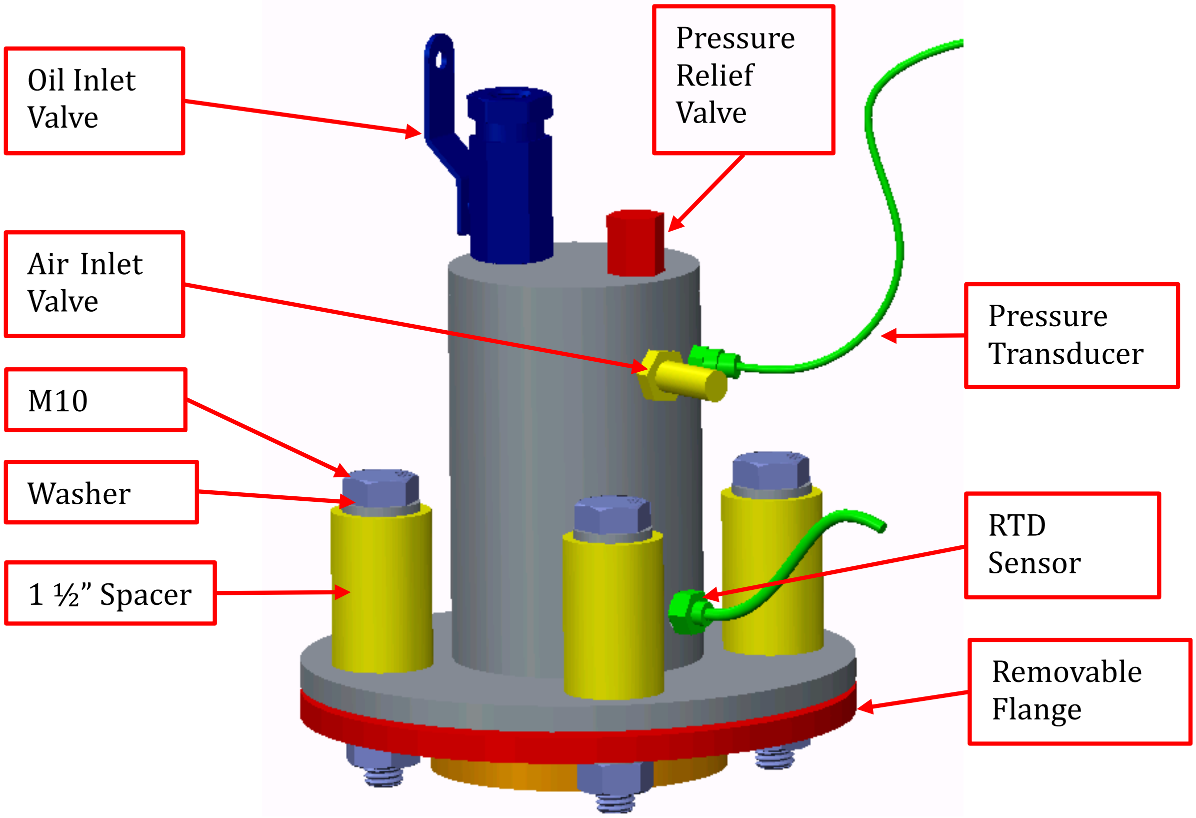


Figure 3. Updated Test Rig design.

4.2 Pressure Relief Valve

Another update to the previous test rig design was the addition of a pressure relief valve. A pressure relief valve was added for two purposes: as a method to control the initial 2.5 psi internal pressure, and to prevent the pressure transducer from being damaged from over-pressurizing it. Therefore, the design team specified a pressure relief valve, the Straval 1/8” Rva05-01T. Figure 4 is an image of the pressure relief valve ordered. The pressure relief valve is also shown in the revised design in Figure 3.

Figure 4. Straval 1/8” Rva05-01T pressure relief valve.

4.3 Gasket Update

The latest update to the gasket side of the project includes the arrival of the team's Polytetrafluoroethylene (PTFE) Teflon gaskets with a barium sulfate filler. Teflon gaskets are generally oleophobic by nature. These gaskets have a maximum temperature of 500°F and a maximum pressure of 1,200 psi. Therefore, these characteristics make this type of gasket suitable for the parameters of the experiment.

The team has also taken the rubber coated metal gasket sheet that was received by our sponsor to the COE Machine Shop. These will be cut into rings with an outer diameter of 75 mm and an inner diameter of 55 mm, making them uniform size and geometry in relation to the other gasket specimens. The team is still conceptualizing the best methods to ensure the size and stability of the nontraditional gasket materials throughout the entire length of the experiment. Currently, the team is investigating creating a metal template or die to cut the nontraditional materials into proper gasket size. The team is also working on the best technique to apply the oleophobic solutions to the traditional and nontraditional gaskets due to their different thicknesses and consistencies.

5 Updated Project Plan

5.1 Project Plan

In the Fall semester, many critical tasks were completed and the team was able to successfully stay on track with regards to the previous Gantt chart. Due to the success in the first semester, it was very easy to jump right into the project in the Spring semester.

While the past four months have been mainly devoted to background research, functional analysis, and purchasing materials, the next four months will primarily focus on the end result which is determining the effectiveness of oleophobic gaskets. This semester will focus on three main objectives: test rig fabrication, oleophobic gasket fabrication, and experimentation. The first objective entails submitting the completed CAD drawings of the test rig to the COE Machine Shop and continually monitoring its progress throughout the fabrication process. In the Gantt chart, one month is allotted for this very critical and potentially lengthy task.

While the test rig is being manufactured, the process of creating oleophobic gaskets will begin. Traditional gaskets such as rubber coated metal and paper gaskets will simply be both coated and impregnated with the selected oleophobic solutions. However, creating oleophobic gaskets out of nontraditional materials involves a much more in depth process. The nontraditional materials will need to be carefully shaped into the correct dimensions and shape before finally being coated and impregnated with the solutions. This process should not take longer than one month and will be completed concurrently with the test rig fabrication.

The final and last objective is to perform the actual experimentation and obtain results. The laboratory space will need to be prepped by setting up the DAQ (Data Acquisition) software, as well as hooking all of the sensors up to the correct output instruments. The experimentation will take place in several trials which will be conducted under the variable conditions for each gasket material. Once all of the data has been stored, the results of each material will need to be analyzed and conclusions must be drawn by the team. This last stage is expected to take a little over a month; however, this is the most unknown and unpredictable stage of the project.

5.2 Resource Allocation

The senior design team decided to divide into sub-teams in the previous semester so that the necessary effort could be applied to both the oleophobic gasket aspect of the project, as well as the design and fabrication of the test rig, simultaneously.

- Gasket Team:
  - This sub team consists of Norris McMahon, David Dawson, and Aruoture Egoh. This semester, the gasket team is responsible for obtaining the materials that will be used in the gasket testing, such as the gasket materials and oleophobic solutions. Also, the team is responsible for creating the non-traditional oleophobic gaskets. This will include creating a gasket template in order to cut out consistant gasket geometries, cutting the rubber coated metal gaskets, and applying oleopobic solutions.
- Test Rig Design Team:
  - The test rig design team consists of Erik Spilling, Heather Davidson, and Daniel Elliott. This semester, the test rig team is responsible for overseeing the fabrication of the test rig. Since the test rig was designed in the previous semester, the test rig team needs to communicate with the machine shop to have the test rig fabricated, as well as specify and order the correct hardware components for testing. This includes keeping updated CAD models, contacting suppliers, as well as working with Dr. Kumar to use the lab equipment in his Thermofluids Lab room.

The testing process will be performed by the entire team as well. Since a large number of tests are expected to be performed, the team plans to do one set of tests as a group. These initial tests will be done together to create a step by step testing process that the entire group understands. Then, testing will be broken into smaller groups so that the entire team does not need to be present for every single test run. The smaller groups will be groups of two or three.

The team web page was designed by Heather Davidson, and Heather will be responsible for the continued updating of the web site. This includes adding deliverables, adding pictures as they become available, and maintaining the clean look of the website.

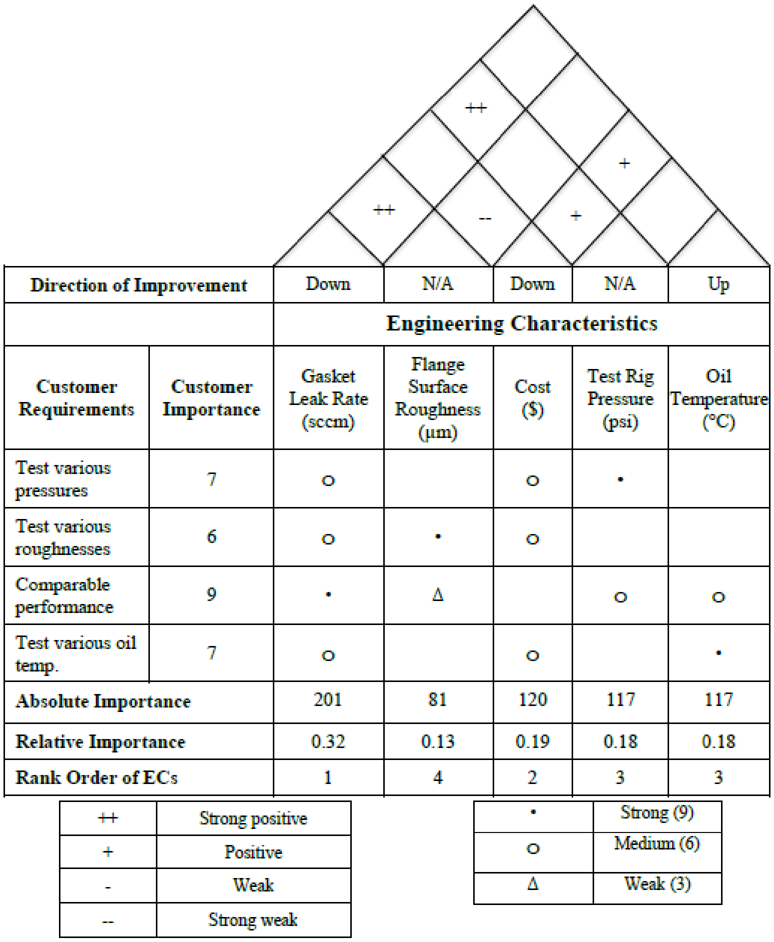
5.3 Schedule/Deliverables

A schedule of the design team's project plan for the Spring semester can be found in a Gantt chart (Appendix B). This Gantt chart entails a breakdown of when each task is scheduled to be completed. Additionally, critical tasks can be identified by their duration in the time schedule. For example, test rig fabrication is a very critical task as it is expected to take the longest, and the project cannot precede without the completion of it. A month was allotted to complete this task to ensure that the machine shop would have ample time to complete the machining of the parts in addition to other projects needing machining. Additionally, experimentation time overlaps with spring break and so several days of vacation time were taken into account for this task.

5.4 House of Quality

After first speaking with the sponsor and defining their requirements, a diagram known as a House of Quality (HOQ) was constructed (Figure 5). This diagram relates the sponsor's requirements with various engineering characteristics.

For instance, there is a strong correlation between the requirement of comparable performance and the characteristic gasket leak rate. Additionally, the diagram also depicts the relationship between any two engineering characteristics. This is illustrated in the top triangle of the "house."



Direction of Improvement		Down	N/A	Down	N/A	Up
		Engineering Characteristics				
Customer Requirements	**Customer Importance**	Gasket Leak Rate (sccm)	Flange Surface Roughness (µm)	Cost ($)	Test Rig Pressure (psi)	Oil Temperature (°C)
Test various pressures	7	○		○	•	
Test various roughnesses	6	○	•	○		
Comparable performance	9	•	Δ		○	○
Test various oil temp.	7	○		○		•
Absolute Importance		201	81	120	117	117
Relative Importance		0.32	0.13	0.19	0.18	0.18
Rank Order of ECs		1	4	2	3	3

++	Strong positive
+	Positive
-	Weak
--	Strong weak

•	Strong (9)
○	Medium (6)
Δ	Weak (3)

Figure 5. Constructed HOQ using sponsor information.

There is a strong positive correlation between the cost and the test rig pressure. To simulate higher pressures in the test rig a more complex design is required, and this will require money thus increasing the cost. Through this diagram, the number one engineering characteristic identified was the gasket leak rate. The HOQ was used by the team to divide tasks to ensure that the team’s tasks were focused on meeting the customer requirements through prioritizing the corresponding engineering characteristics.

6 Procurement and Budget

Parts ordering has mostly finished as the sub teams have reached their final designs. David Dawson has been responsible for maintaining the team budget, and thus has also be responsible for the parts ordering. The sub teams have been providing David with a list of the desired raw materials, and David checks to make sure that the parts or materials can be purchased within the team's budget, and makes the purchases.

The budget given for this project was $2,000 through the Aero Propulsion, Mechatronics and Energy Center. This budget will be used to acquire all of the materials that will be needed for application and testing for determining the effectiveness of oleophobic gaskets. The values shown in Table 3 are the maximum estimated values for each item needed and were calculated by researching into potential products. Even after calculating for the maximum prices, the total cost only comes out to $1,850, which leaves a remainder of $150 in case of an emergency.

Table 3. Budget

Item	**Maximum Estimated Amount**
Test Rig Raw Materials	$250.00
Test Rig Sensors	$900.00
Gasket Materials	$150.00
Oleophobic Solutions	$300.00
Oleophobic Material	$200.00
Oil Used for Testing	$50.00
Total	**$1,850.00**

In Table 4, all of the purchased items are shown with quantity and price. It is also organized by which category that item fits into within the budget. As it can be seen, the team is under the estimated cost for each of the budget sub groups. It should be noted that the team has received samples of gasket materials and oleophobic solutions, and finishing the initial testing to decide which materials and solutions will be used for the final experiments. The production of the nontraditional material gaskets has begun and any extra material or solutions will be purchased if needed.

Table 4. Purchased Items

Budget Category	Item	Quantity	Cost
Test Rig Material	M8 Class 10.9 Cap Screw	1(Pack of 25)	$7.91
Test Rig Material	M8 General Purpose Steel Washer	1 (Pack of 100)	$6.09
Test Rig Material	M8 Class 10 Steel Nut	1 (Pack of 100)	$10.48
Test Rig Material	M10 General Purpose zinc plated steel washer	1 (Pack of 100)	$4.36
Test Rig Material	M10 Class 8 Zinc Plated Steel Hex Nut	1 (Pack of 100)	$10.48
Test Rig Material	Zinc-Plated Steel Unthreaded Spacer	4	$55.32
Test Rig Material	M10x1.5 70mm long class 8.8 cap screw	1 (Pack of 10)	$8.58
Test Rig Material	Pressure Relief Valve	1	$48.00
Test Rig Material	Compact High-Pressure Brass Ball Valve	1	$11.34
Test Rig Material	Brass Air Fill Valve Straight	1	$4.40
Test Rig Material	1ft x 1ft x ¼ in Thick A36 Steel Plate	1	$15.41
Test Rig Material	1ftLong 2-1/2 OD x 2 ID Round Steel Tube	1	$36.04
Test Rig Material	**Total**		**$218.41**
Test Rig Sensors	Short RTD Probe	1	$66.00
Test Rig Sensors	Compression Fitting	1	$20.00
Test Rig Sensor	Pressure Transducer	1	$618.00
Test Rig Sensor	**Total**		**$704.00**
Oleophobic Material	Teflon Gaskets	20	$170.00
Oil Used for Testing	T Triple Protection CJ-4 15W-40 Motor Oil	1 (Gallon)	$13.44
Purchased	**Total**		**$1,105.85**

7 Conclusion

The purpose of this project is to determine if the development and implementation of oleophobic gaskets would be useful in practical applications. These oleophobic gaskets will be compared to baseline model tests using engine oil at a constant pressure of 2.5 psi. The goal of the test rig is to be capable of operating with oil temperatures of 22 to 120°C. Tests will be performed with a gasket at variable clamping pressure to change the compression on the gasket. The clamping pressure will be measured via strain gauges that will be added to the bolts by Cummins Inc. The results from this experiment will provide a better understanding of oleophobic gasket solutions and if they are effective in terms of practicality, performance, and applicability.

The team has already compiled all necessary drawings and sent them to the COE Machine Shop for the machining process to be completed. The team will continue to hold informal and formal bi-weekly meetings to provide regular updates on the progress of the project. A schedule in the form of a Gantt chart has been put in place to allow the team to have a visualized timeline of major and minor tasks throughout the completion of this project. The team was on schedule and met all of the goals set for the previous semester and aims to continue this into the Spring semester.

The goal for the next deliverable is to be further along in the machining process or hopefully it will be complete so the team can begin test preparation. All oleophobic solutions and nontraditional oleophobic gasket materials should be on site and ready to use when it comes time to begin experimenting barring no unforeseen errors or issues. Once the testing process has begun, the design aspects of the project are completed. The project scope will shift to focusing on obtaining data which either supports or rejects the theory that oleophobicity is a desirable property for a gasket to contain.

References

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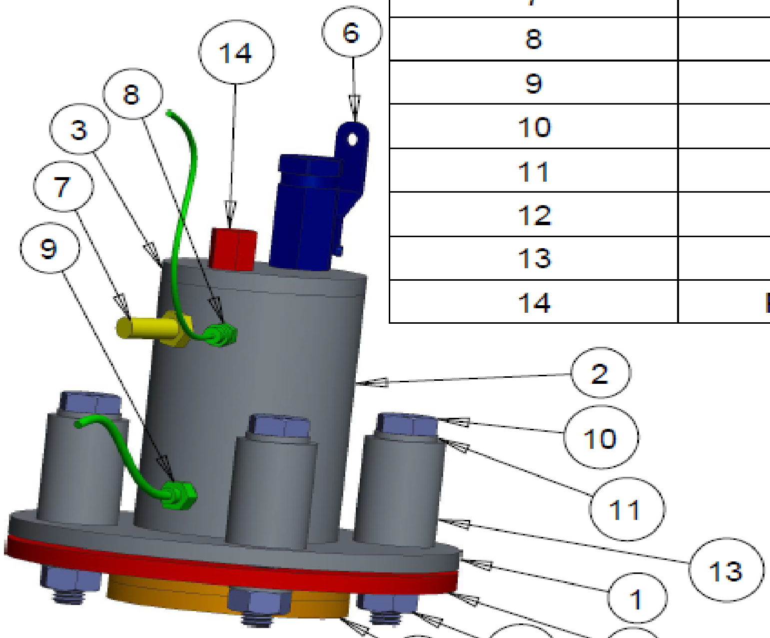
Appendix A



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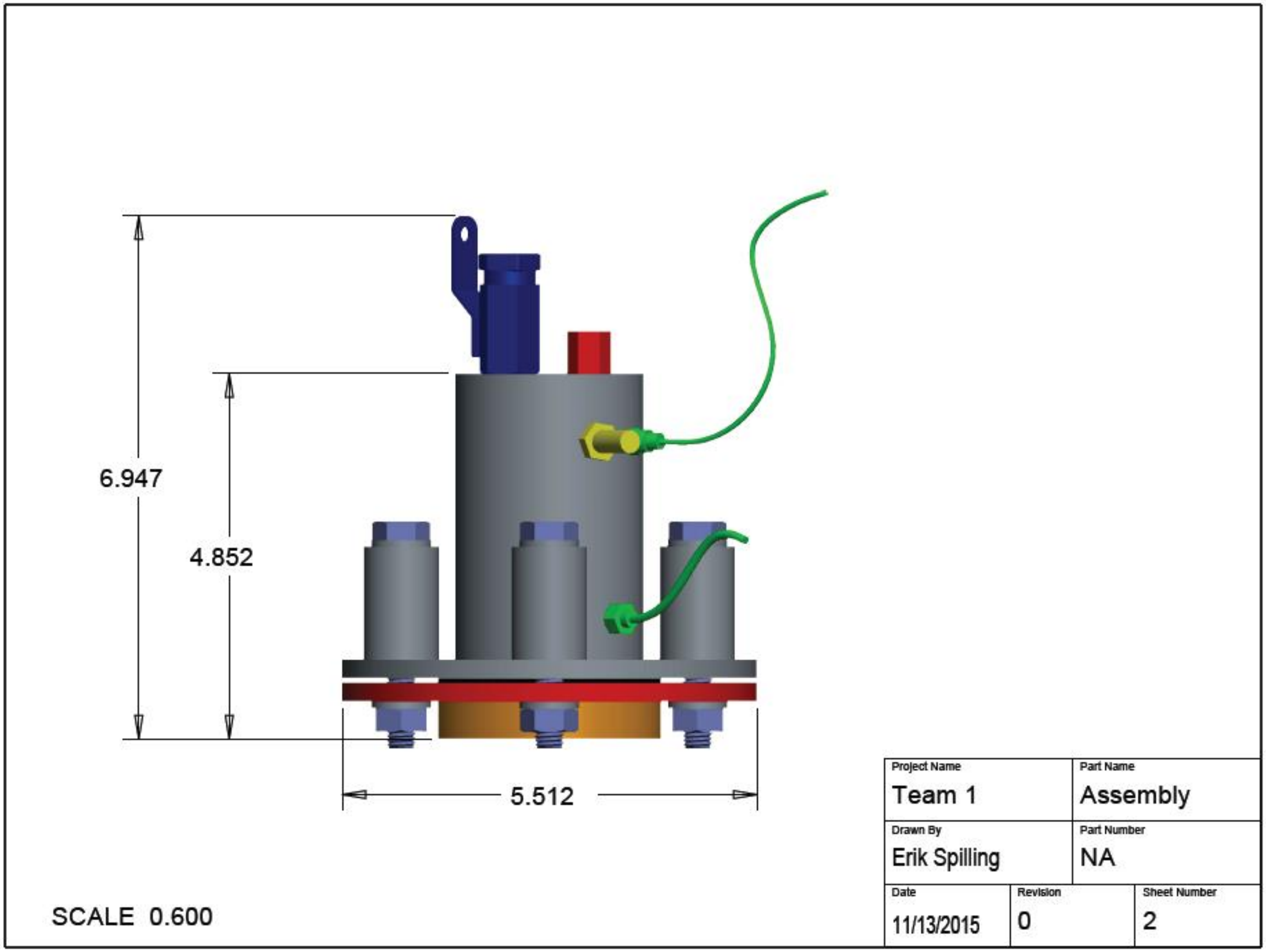
Part Number	Part Name	Quantity	Material
1	Top Flange	1	A36 Steel
2	Top Tube	1	A36 Steel
3	Top Cap	1	A36 Steel
4	Bottom Flange	1	A36 Steel
5	Spacer	2	A36 Steel
6	Oil Valve	1	Bronze
7	Air Valve	1	Bronze
8	Pressure Transducer	1	Steel
9	RTD Sensor	1	Steel
10	M10x1.5 70mm Bolt	4	Steel
11	M10 Washer	8	Steel
12	M10x1.5 Nut	4	Steel
13	Bolt Spacer	4	Steel
14	Pressure Relief Valve	1	Brass

Project Name Team 1	Part Name BOM	
Drawn By Erik Spilling	Part Number NA	
Date 11/13/2015	Revision 0	Sheet Number 1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4.852
5.512
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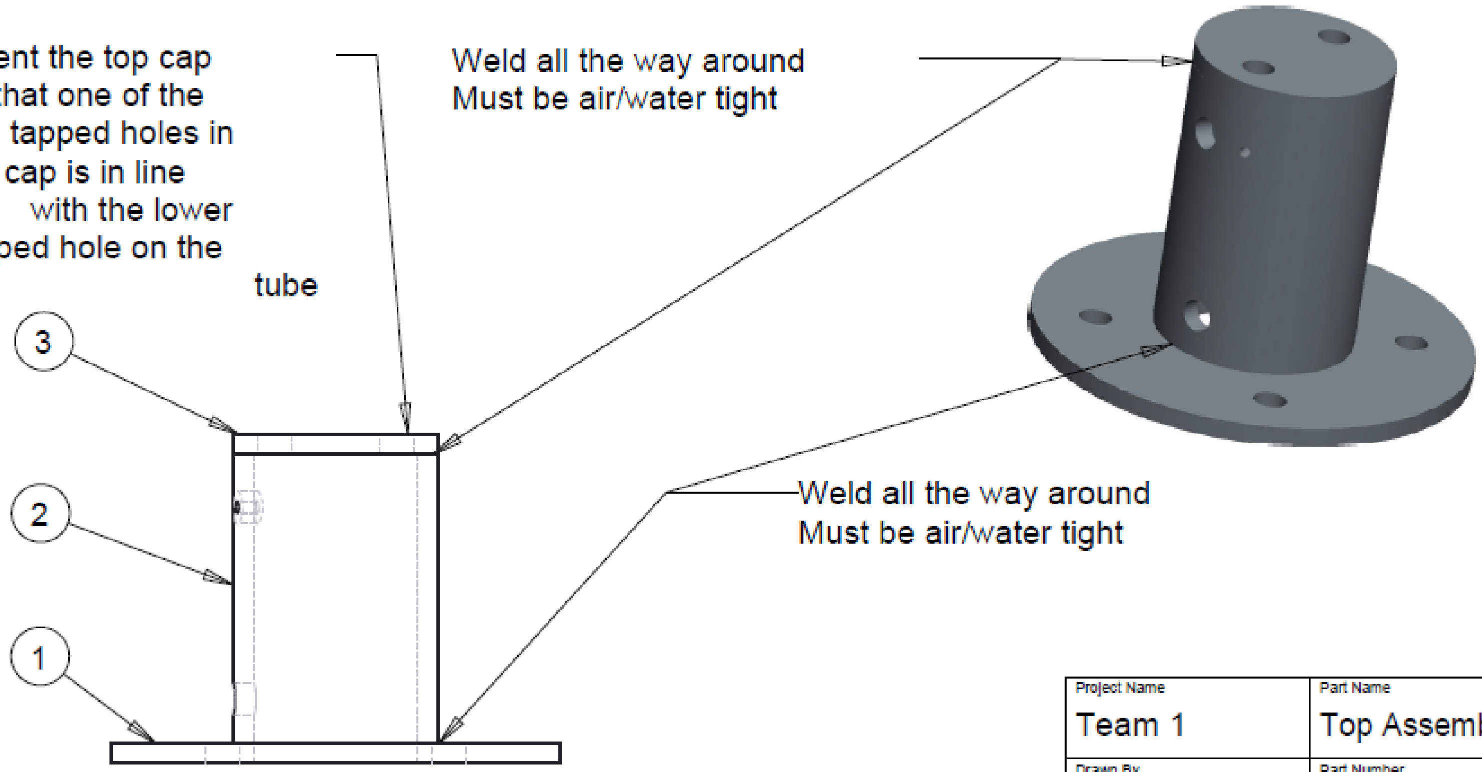
Project Name
Team 1
Part Name
Assembly
Drawn By
Erik Spilling
Part Number
NA
Date
11/13/2015
Revision
0
Sheet Number
2

Part Number	Part Name	Quantity	Material
1	Top Flange	1	A36 Steel
2	Top Tube	1	A36 Steel
3	Top Cap	1	A36 Steel



Orient the top cap so that one of the tapped holes in the cap is in line with the lower tapped hole on the tube

Weld all the way around
Must be air/water tight

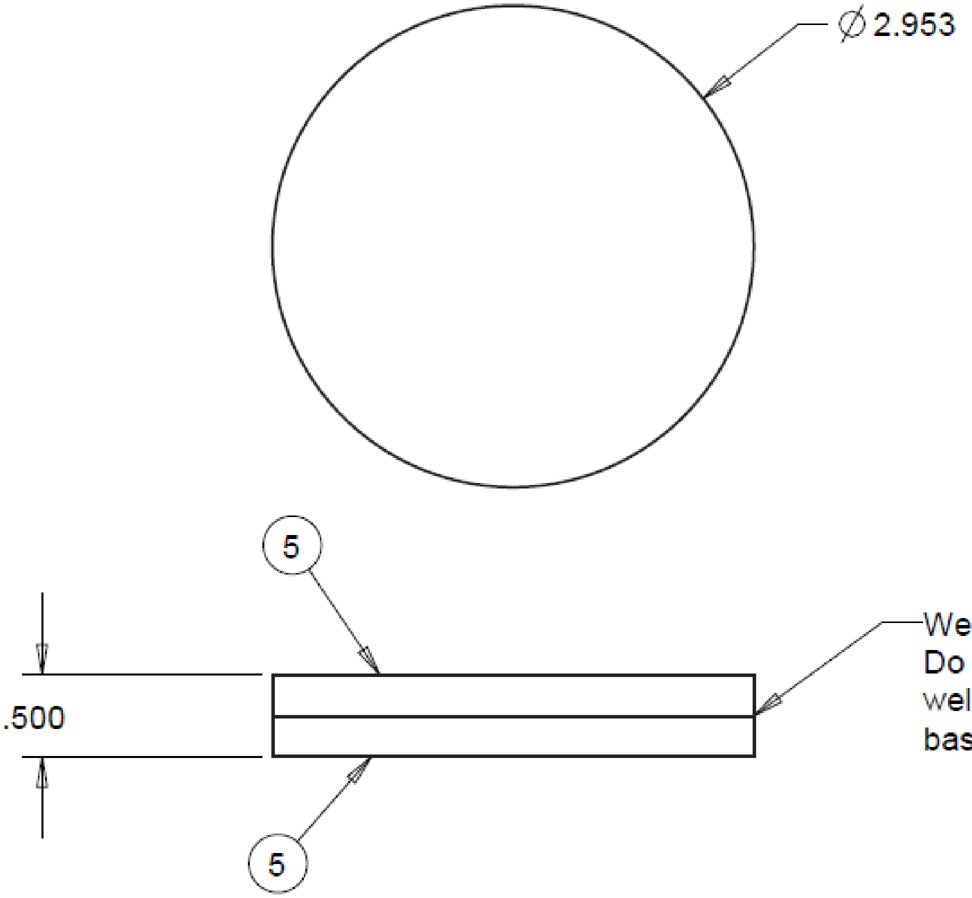
Weld all the way around
Must be air/water tight

SCALE 0.500

Project Name Team 1	Part Name Top Assembly
Drawn By Erik Spilling	Part Number NA

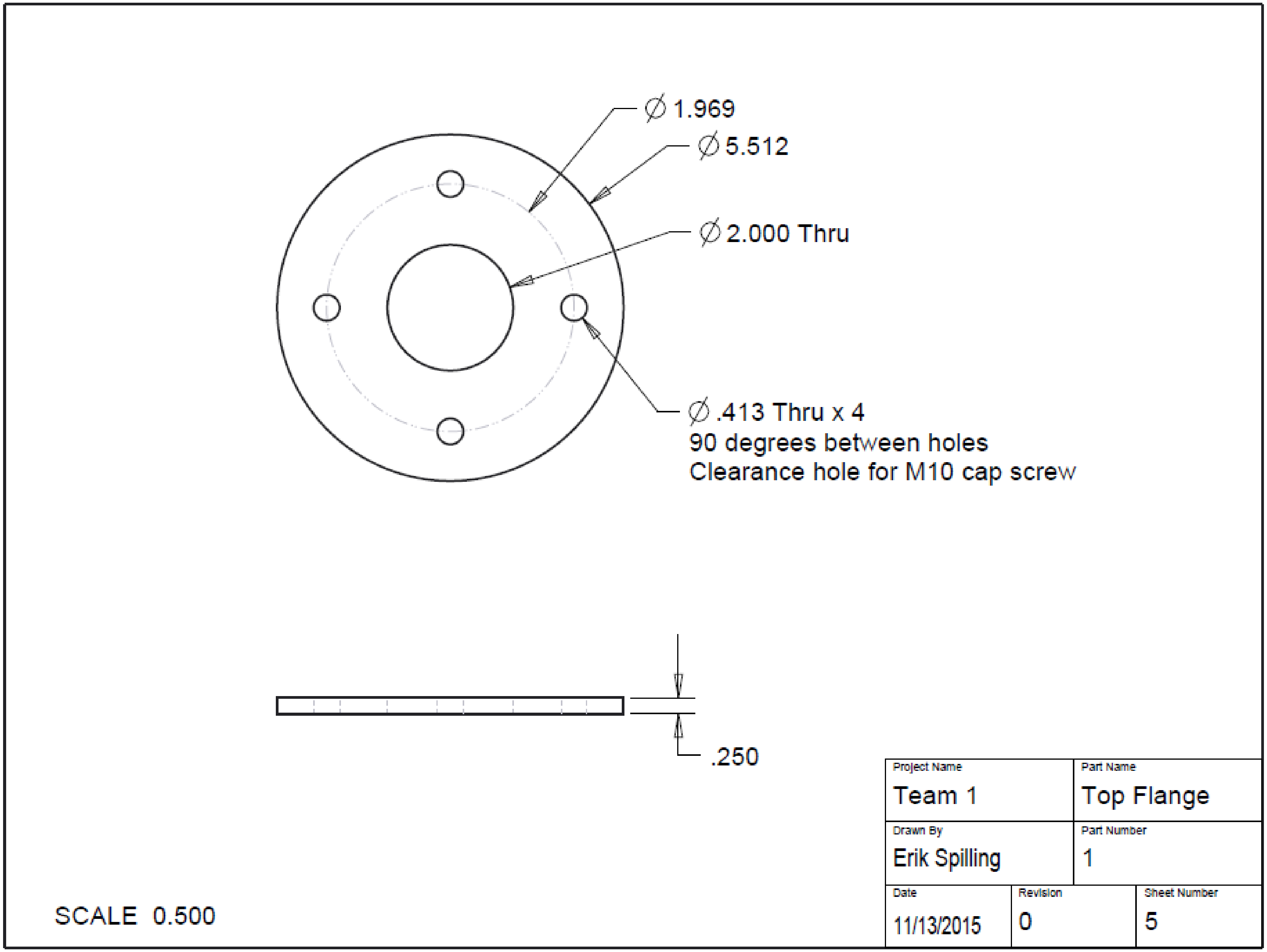
Date	Revision	Sheet Number
11/13/2015	0	3

Part Number	Part Name	Quantity	Material
5	Spacer	2	A36 Steel

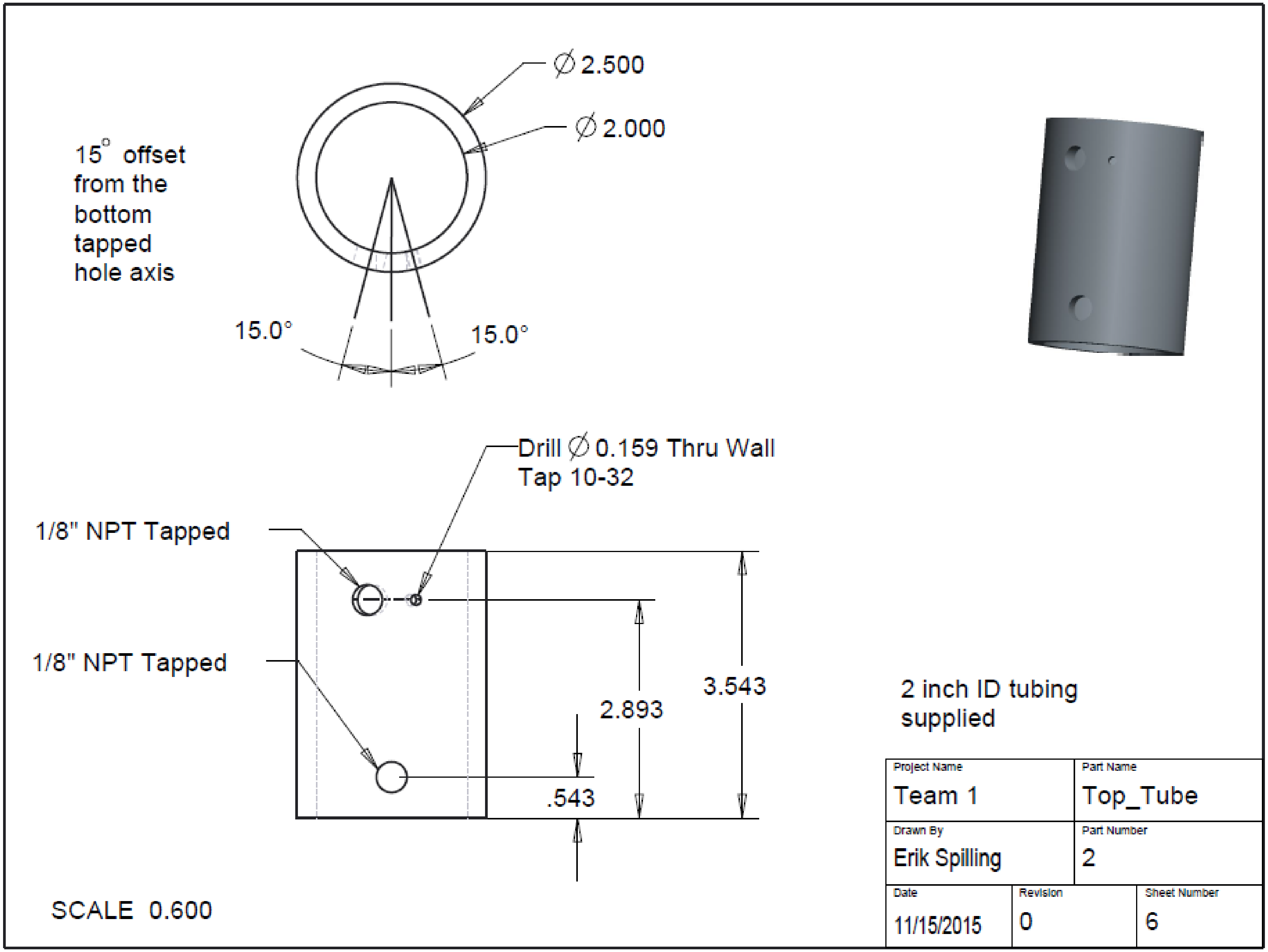


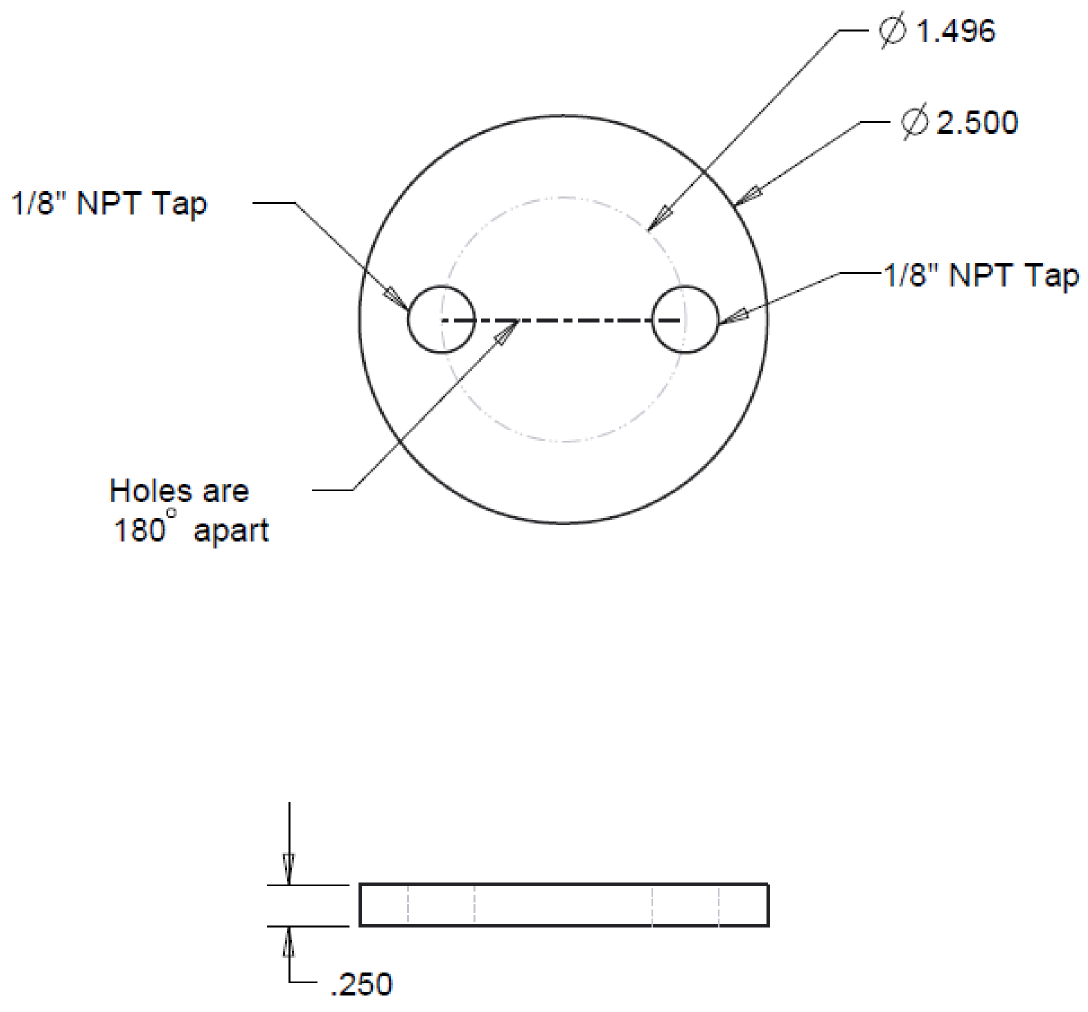
Weld Together
Do not need to be full
welds. Part is used as a
base platform

Project Name	Part Name	
Team 1	Spacer Welded	
Drawn By	Part Number	
Erik Spilling	NA	
Date	Revision	Sheet Number
11/13/2015	0	4

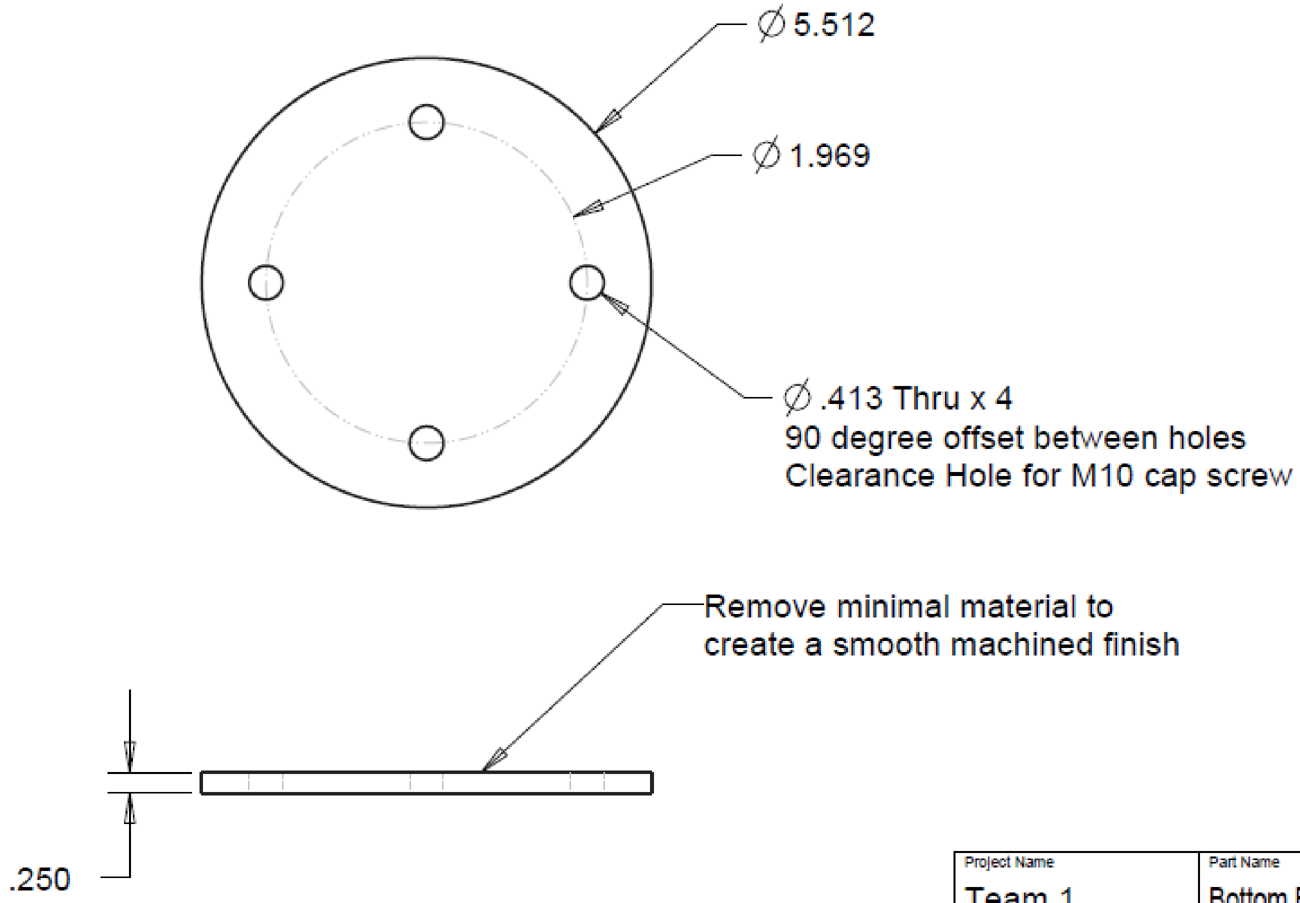


Project Name Team 1		Part Name Top Flange
Drawn By Erik Spilling		Part Number 1
Date 11/13/2015	Revision 0	Sheet Number 5


Ø 2.500
Ø 2.000
15° offset from the bottom tapped hole axis
15.0°
15.0°
Drill Ø 0.159 Thru Wall
Tap 10-32
1/8" NPT Tapped
1/8" NPT Tapped
3.543
2.893
.543
2 inch ID tubing supplied
SCALE 0.600
Project Name
Team 1
Part Name
Top_Tube
Drawn By
Erik Spilling
Part Number
2
Date
11/15/2015
Revision
0
Sheet Number
6

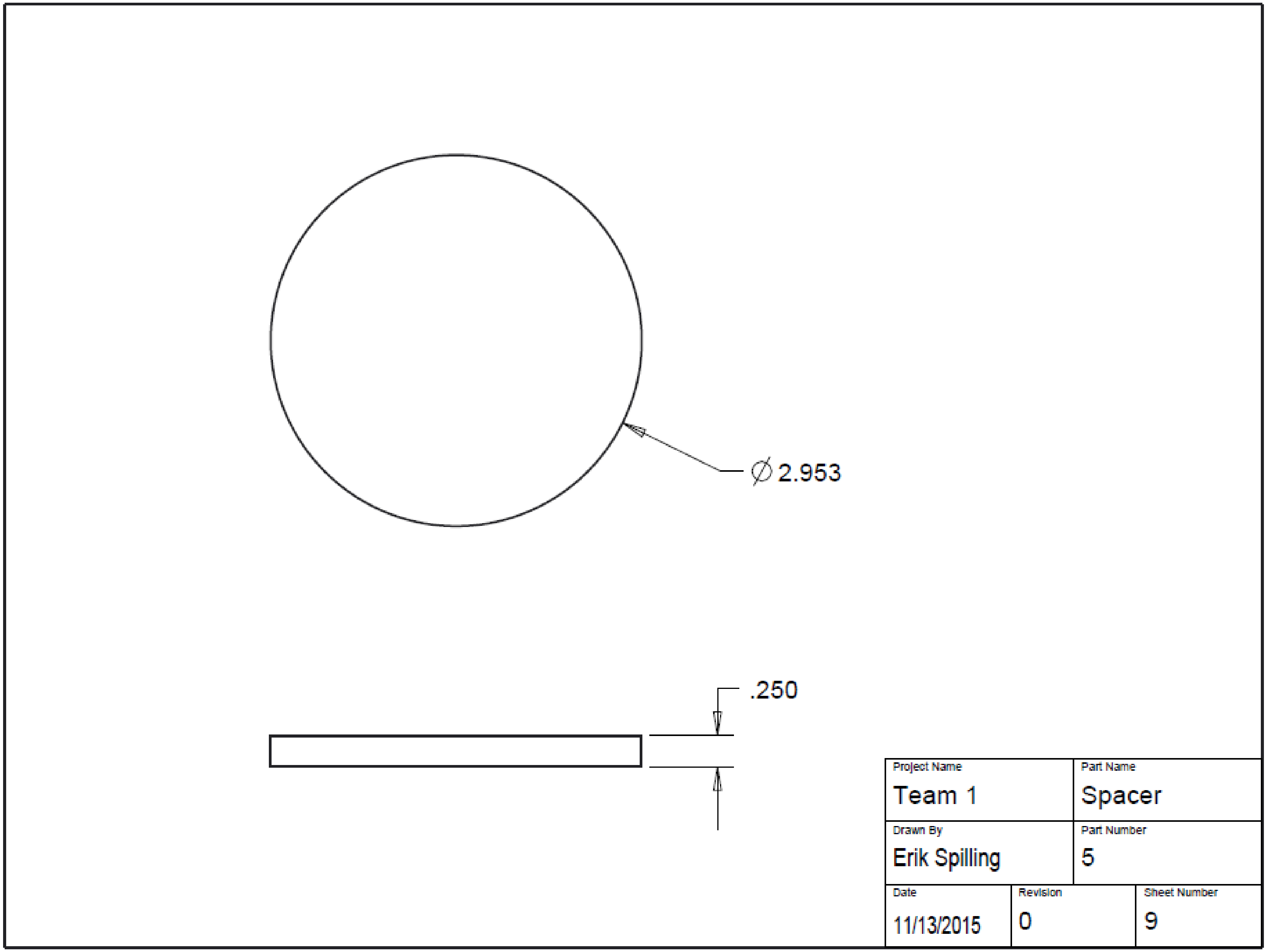


Project Name Team 1	Part Name Top_Cap	
Drawn By Erik Spilling	Part Number 3	
Date 11/13/2015	Revision 0	Sheet Number 7



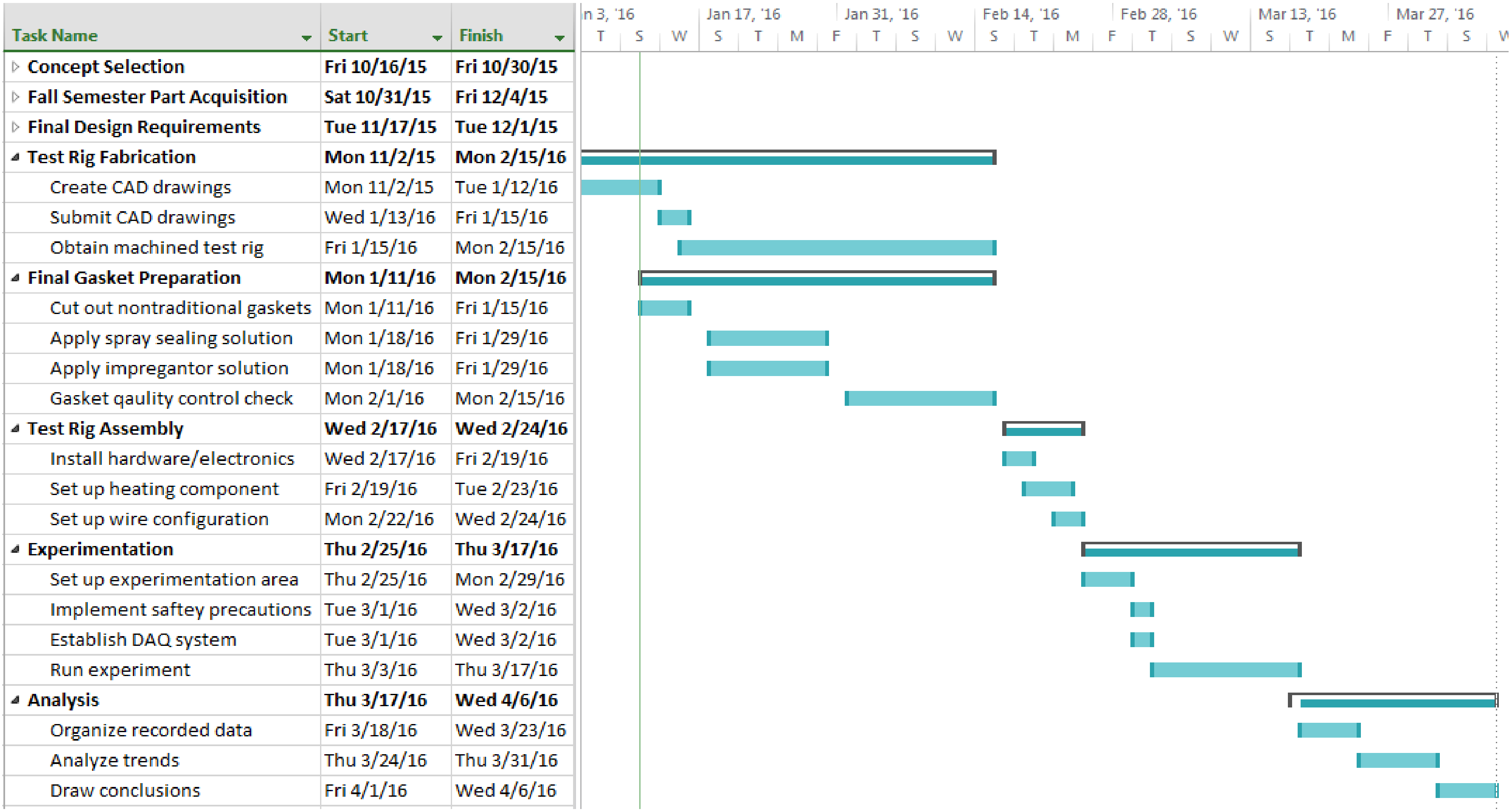
SCALE 0.500

Project Name Team 1		Part Name Bottom Flange
Drawn By Erik Spilling		Part Number 4
Date 11/13/15	Revision 0	Sheet Number 8



Project Name Team 1	Part Name Spacer	
Drawn By Erik Spilling	Part Number 5	
Date 11/13/2015	Revision 0	Sheet Number 9

Appendix B



Task Name	Start	Finish
Concept Selection	**Fri 10/16/15**	**Fri 10/30/15**
Fall Semester Part Acquisition	**Sat 10/31/15**	**Fri 12/4/15**
Final Design Requirements	**Tue 11/17/15**	**Tue 12/1/15**
Test Rig Fabrication	**Mon 11/2/15**	**Mon 2/15/16**
Create CAD drawings	Mon 11/2/15	Tue 1/12/16
Submit CAD drawings	Wed 1/13/16	Fri 1/15/16
Obtain machined test rig	Fri 1/15/16	Mon 2/15/16
Final Gasket Preparation	**Mon 1/11/16**	**Mon 2/15/16**
Cut out nontraditional gaskets	Mon 1/11/16	Fri 1/15/16
Apply spray sealing solution	Mon 1/18/16	Fri 1/29/16
Apply impregantor solution	Mon 1/18/16	Fri 1/29/16
Gasket qaulity control check	Mon 2/1/16	Mon 2/15/16
Test Rig Assembly	**Wed 2/17/16**	**Wed 2/24/16**
Install hardware/electronics	Wed 2/17/16	Fri 2/19/16
Set up heating component	Fri 2/19/16	Tue 2/23/16
Set up wire configuration	Mon 2/22/16	Wed 2/24/16
Experimentation	**Thu 2/25/16**	**Thu 3/17/16**
Set up experimentation area	Thu 2/25/16	Mon 2/29/16
Implement saftey precautions	Tue 3/1/16	Wed 3/2/16
Establish DAQ system	Tue 3/1/16	Wed 3/2/16
Run experiment	Thu 3/3/16	Thu 3/17/16
Analysis	**Thu 3/17/16**	**Wed 4/6/16**
Organize recorded data	Fri 3/18/16	Wed 3/23/16
Analyze trends	Thu 3/24/16	Thu 3/31/16
Draw conclusions	Fri 4/1/16	Wed 4/6/16

Gantt chart displaying the projected schedule for the Spring semester

Biography

Erik Spilling: Project Leader

Erik is a Florida State University Mechanical Engineering student from Saint Augustine, Florida. Erik has completed three internships at Cummins Inc., with two of those internships having been spent in High Horse Power Design Engineering. After graduation, Erik will join Cummins Inc. full time as a High Horse Power Design Engineer.

Heather Davidson: Lead ME and Web Designer

Heather is a Florida State University Mechanical Engineering student graduating in May of 2016. Heather was born in Deland, Florida. She has completed two summer internships with ExxonMobil at an oil refinery in Torrance, California. After graduation, she will be working at Southern Company in Birmingham, Alabama.

David Dawson: Financial Advisor

David is a Florida State University mechanical engineering student with a focus on Thermal Fluids and Energy. David was born in South Africa and raised in Jacksonville, Florida. Following graduation, David plans to pursue a job in either energy satiability or work for the armed forces as a mechanical engineering officer.

Aruoture Egoh: Lead Materials Engineer

Aruoture is an exchange student of Florida Agricultural and Mechanical University from Federal University of Technology, Akure, Ondo state, Nigeria. He plans to complete his bachelor’s degree in Materials Engineering, attend graduate school to pursue a master’s degree and PhD in materials engineering focusing on Polymeric Materials.

Daniel Elliott: Research Coordinator

Daniel is a Senior Mechanical Engineering student with a minor in Psychology and a mixed focus in Materials and Energy Systems. After graduation, he plans to move to Austin, Texas as his first step in his professional career and in order to be closer to his family.

Norris McMahon: Chronicler

Norris is a student at Florida State University originally from Pensacola, Florida. His area of focus is Mechanics and Materials. He has experienced an internship with Blattner Energy Inc. Following graduation, Norris plans to pursue a Masters in Sports Engineering and would like to end up in the Research and Development of sports products field.