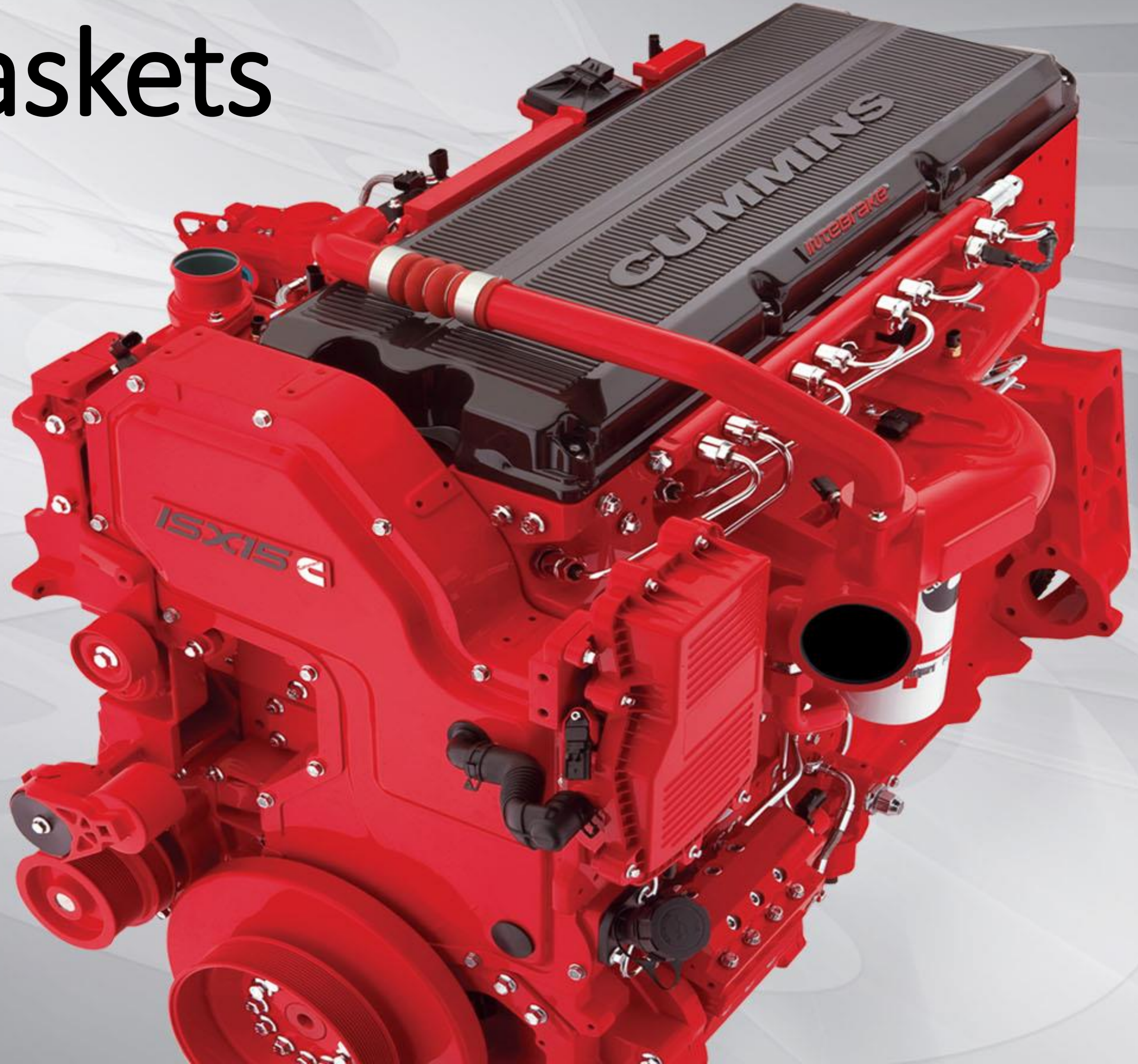
Determining the Effectiveness of Oleophobic Gaskets

Midterm 2 Presentation



Sponsor: Cummins Inc.

Advisor: Dr. William Oates

Instructors:

Dr. Nikhil Gupta

Dr. Chiang Shih

Team #1:

Heather Davidson
David Dawson
Aruoture Egoh
Daniel Elliott
Norris McMahon
Erik Spilling

Date: 11/17/2015

Agenda

- Project Background Recap
- Test Rig Design
- Gasket Testing
- Financial Prediction
- On Going Work
- Summary

Background Information

- Oleophobicity
  - Physical property of a molecule that causes it to repel oil
  - Must have lower surface energy than oil
- Gaskets
  - Mechanical seal created using a variety of materials and shapes
  - Placed in a space between two surfaces and will create a seal while under compression
- Four common gaskets types:
  - Paper
  - Rubber Coated Metal
  - Molded Elastomeric (O-rings)
  - Formed in Place Gasket

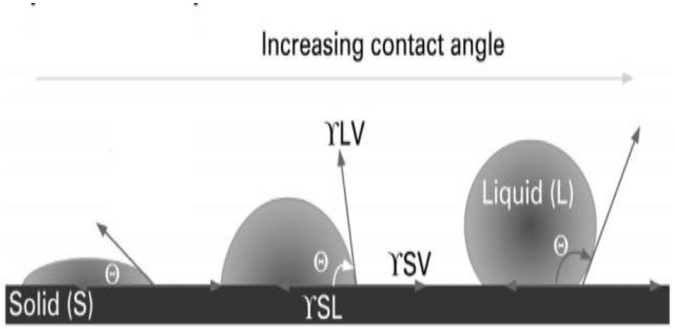


Figure 1. Substance beads up with a high contact angle[1]

Figure 2. Paper and a rubber coated metal gasket[2]

Project Needs and Goals

- Needs Statement:
  - Gaskets used at large joints where the oil is at low pressure leak more oil than desired.

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

Updated Objectives and Scope

Objective Number	Objective
1	Research what causes items to become oleophobic
2	Create oleophobic gaskets using current market products
3	Create oleophobic gaskets using non conventional gasket materials
4	Design and build the test rig to determine leak rate at different temperatures and clamping pressures at a stipulated pressure (2.5 psi)
5	Test new oleophobic gaskets and currently used gaskets for leak rate and compare results

- Revisions to the Project Scope:
  - Vary the clamping load instead of varying the internal pressure
  - Varying the surface roughness no longer a parameter.
    - Maintain a surface roughness less than 3.2 micron RA.

Test Rig Product Specifications

- Design Specifications:

Design Specifications	Value
Test Rig Dimensions	Inner Diameter: ≤ 55 mm
Test Rig Stress Capacity	Minimum of bottom flange: 4.94 mm Vessel thickness not critical as pressure difference nearly negligible.
Flange Dimensions	Inner Diameter: ≤ 55 mm Outer Diameter: > 140 mm
Clamping Pressure	Minimum: 0.5 MPa Maximum: 10 MPa

- Performance Specifications:
  - Measure temperature: 22-120°C ± 2°C
  - Measure internal pressure: 0-5 psi ± 0.01 psi
  - Simulate actual seal

How to Measure Leak Rate

- Ideal Gas Law
  - PV = nRT
    - nRT will remain constant throughout test
    - Therefore $P_1V_1 = P_2V_2$
    - Solve for final volume V_2
    - Change in volume/time = leak rate
- Compressed air used to increase initial pressure
- Hot plate used to vary oil temperature

Figure 3. Pressure transducer[3]

Previously Chosen Concept

- RTD temperature sensor mounted to the side face
- Bottom flange (red) will be interchanged
- Four M8 bolts used to create a clamping load on the gasket
- Bottom spacer used to keep bolts off bottom face

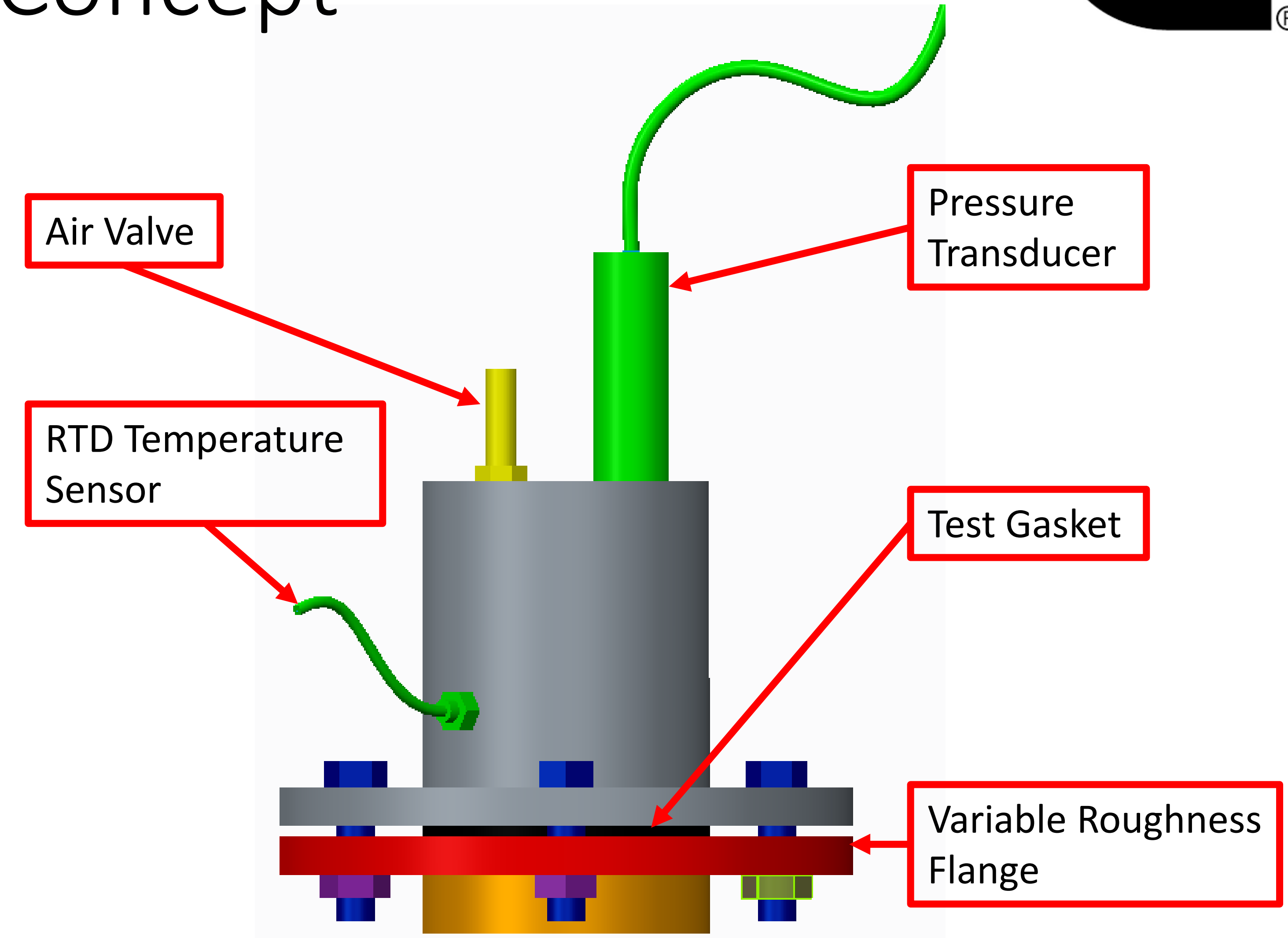


Figure 4. Previously Selected Test Rig Concept

FMEA Table

Component	Mode Of Failure	Cause	Probability	Effect	Severity	Recommended Action
Flanges	Bending	Torque	4	Increase in leak rate	2	Monitor torque wrench
	Surface Roughness	Machining Flaw	2			Follow machining standards
Gasket	Blowout	Material selection	1	Safety hazard	5	Material testing
	Oil leak	Improper materials	4	Increase in leak rate	4	Material testing
		Leak paths	6		2	Design selection
Pressure Vessel	Crack/break	Material selection	1	Blowout	6	Factor of Safety
		Tolerances	2			
Sensors	Overload	Improper selection	1	Inaccurate results	6	Consult sensor data sheet
	Accuracy					

Ranking Scale: 1-6; 1 = Low 6 = High

Gasket Pressure Distribution FEA

- Needed to confirm four bolts was suitable for design

Desired Gasket Clamping Pressure (MPa)	Calculated Required Bolt Load (kN)
0.5	0.255
2	1.020
10	5.100

- Results confirmed that the use of four bolts was sufficient
  - Gasket face never had a path of less than desired clamping pressure

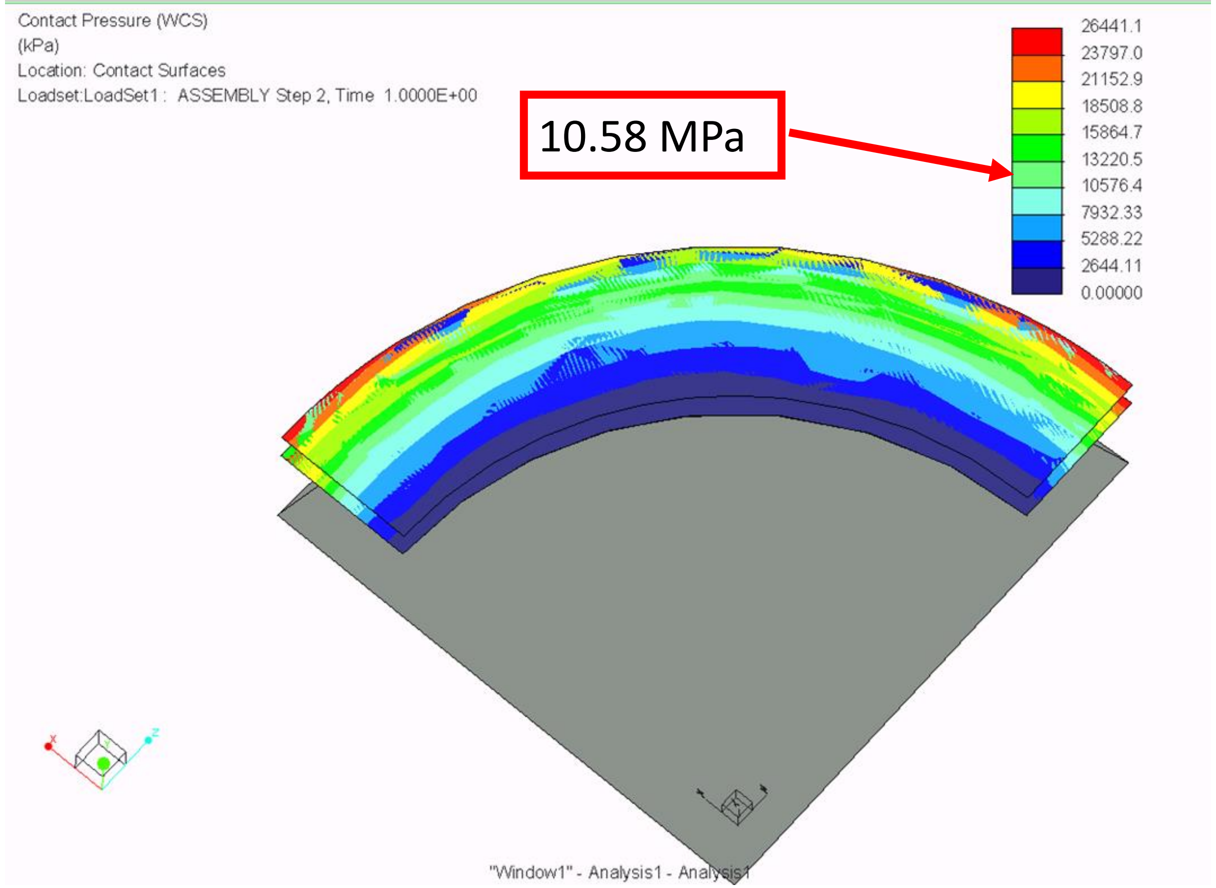


Figure 5. FEA of the pressure distribution along the gasket due to the bolt load of 5.1 kN (10 MPa clamping pressure)

Material Thickness Verification

- Minimum bottom flange thickness
  - Material chosen: A36 Steel
  - Green section: internal stress limited ($\sigma_{max\ internal}$ = 2.5 psi)
  - Blue section: clamping bolt pressure ($\sigma_{max\ bolt}$ = 10 MPa)

Section	Minimum Thickness (mm)
Internal	0.31
Bolt	4.94
Overall Bottom Flange	4.94

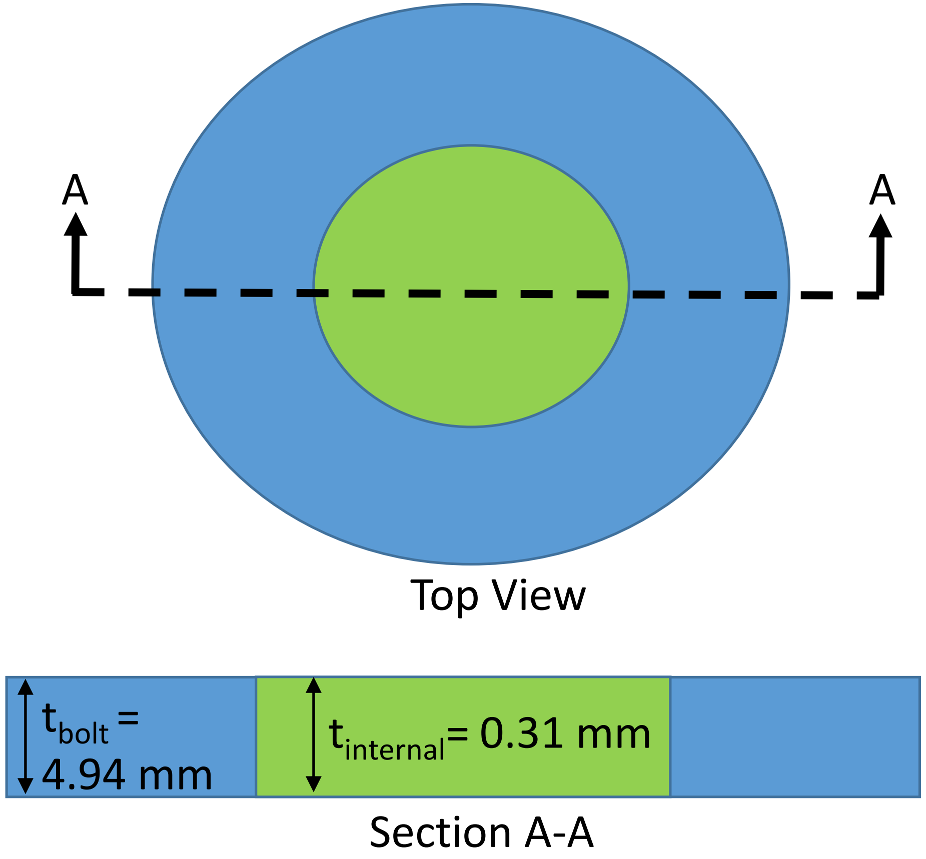


Figure 6. Bottom removable flange

Selected Sensors

- Omega Resistance Temperature Detector (RTD) Sensor
  - Required range: 22 – 120°C
  - Accuracy: ± 2°C
  - Length probe restriction (<55 mm)
  - Compression fitting
- Kulite Pressure Transducer
  - Required range : 0 – 5 psi
  - Accuracy: 0.005 psi
    - Used in further leak measurement calculations

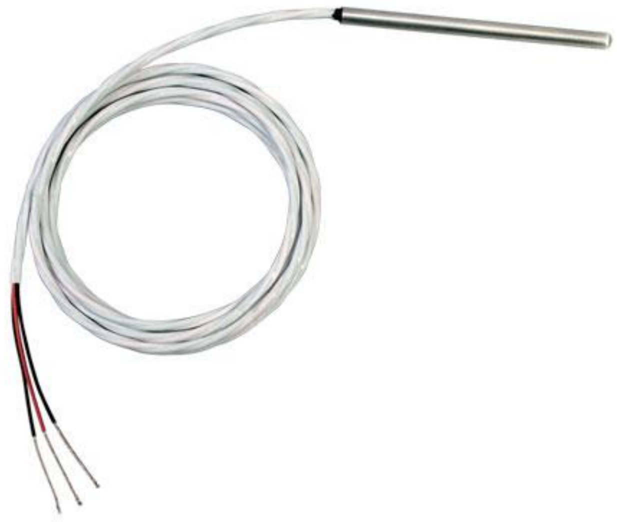


Figure 7. Short RTD probe (PR-20-2-100-3/16-2-E-T)[4]

Figure 8. Pressure Transducer (XT-123B-190-5G)[5]

Final CAD Model of Test Rig

- Oil inlet valve on top surface, offset from the center of the test rig
- RTD temperature sensor, pressure transducer, and air valve are mounted to the side face
- Bottom flange (red) will be interchanged
- Four M8 bolts used to create a clamping load on the gasket

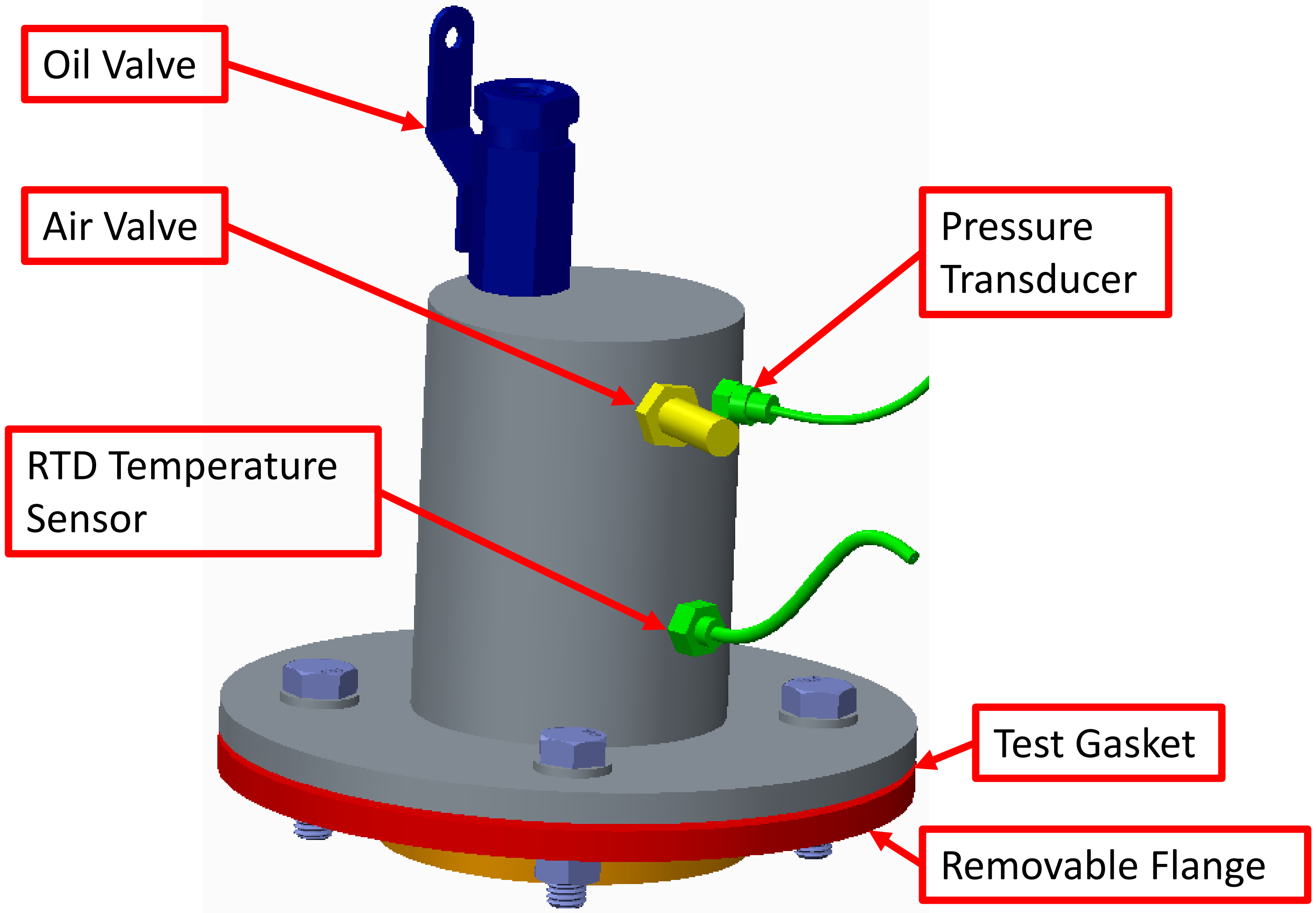


Figure 9. Final Test Rig Concept

Internal Features of Test Rig

- RTD sensor completely submerged in oil
- Pressure transducer and air valve open to air cavity
- Oil valve near the interior edge to allow for easy draining
- All material is 6.34 mm (0.25 in)

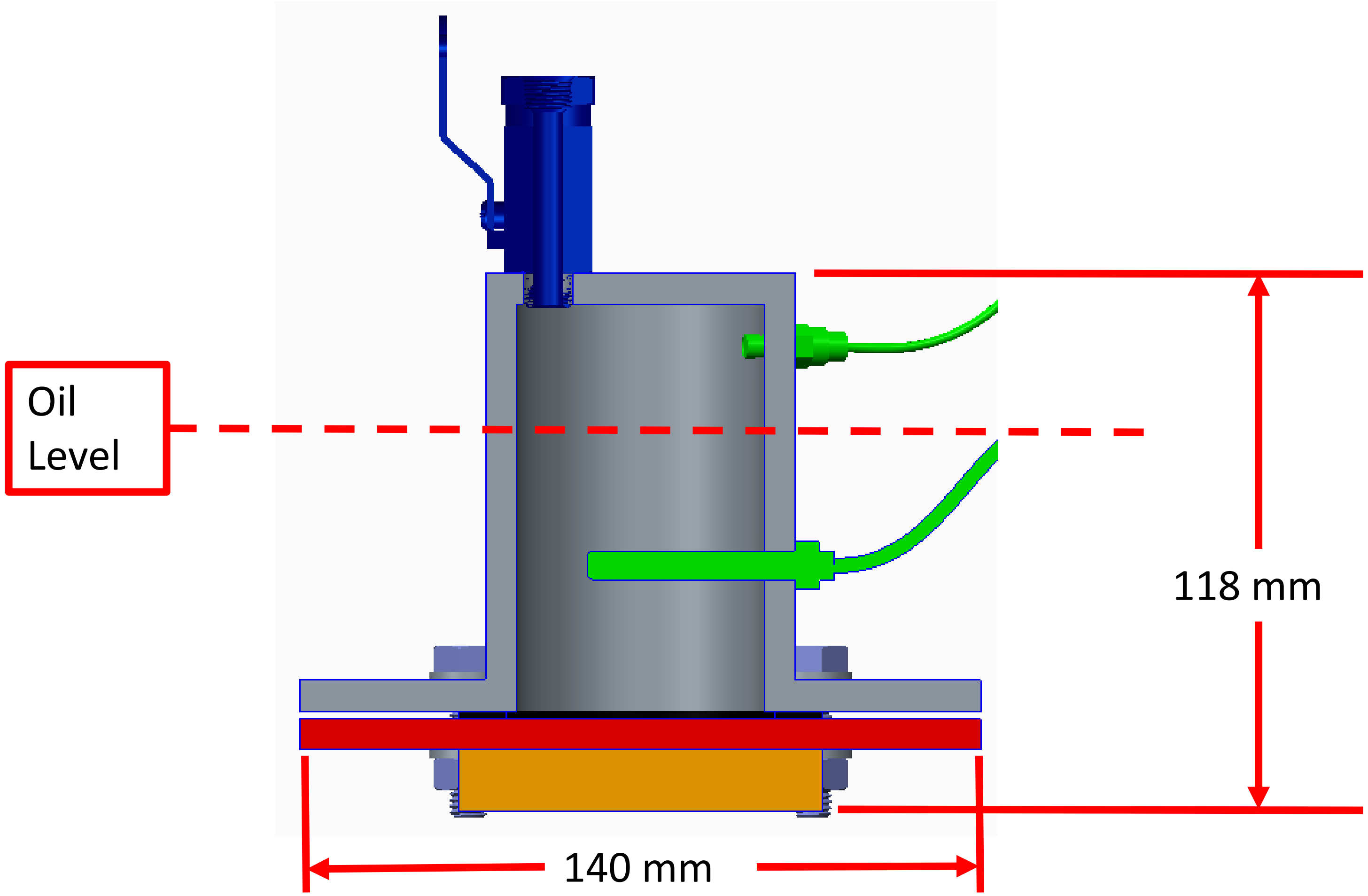


Figure 10. Internal Configuration of the Test Rig

Making Oleophobic Gaskets

- Standard methods of making oleophobic surfaces
  - Spray
    - Using a sprayer such as an air brush or paint gun to apply a consistent and constant spray
  - Impregnator solution
    - Sealer that penetrates the surface to allow for protecting from dense liquids such as oil
- Non-traditional gaskets
  - Teflon gaskets
    - Naturally has oil repellent properties
  - Coat a high density fabric or other material with an oleophobic solution to create a unique oleophobic gasket

Baseline Gasket Material Testing

- Preliminary testing has been conducted to see if the gasket materials and oleophobic solutions would be viable for this experiment

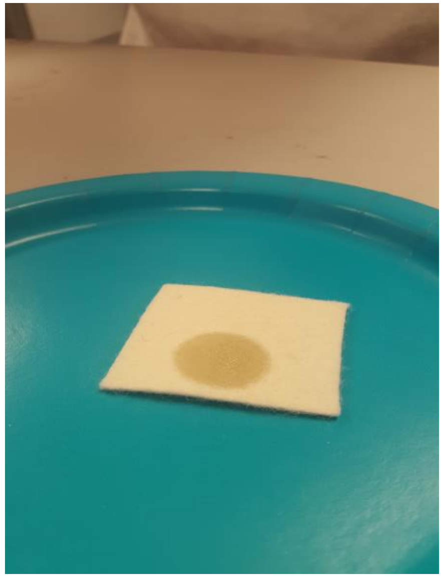


Figure 11. Top view of fiber felt without any solution.

Figure 12. Bottom view of fiber felt without any solution.

Figure 13. Rubber coated metal gasket without any solution.

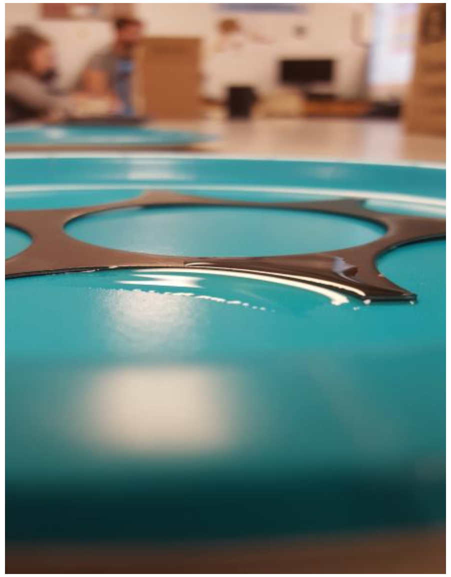


Figure 14. RCM gasket after attempted oil removal.

Baseline Gasket Material Testing

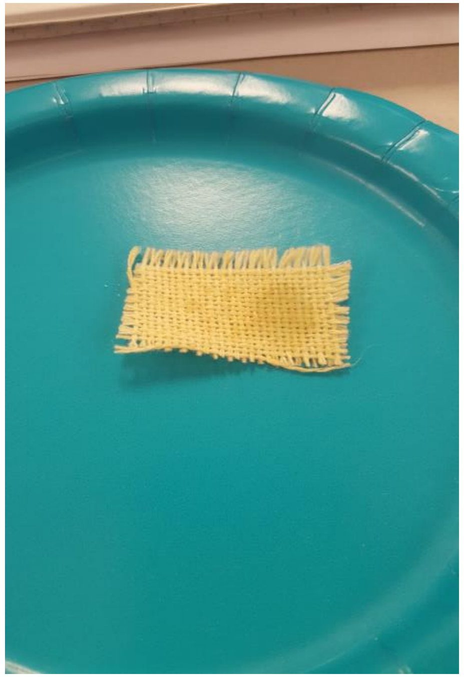


Figure 15. Top view of fiber cloth without solution.

Figure 16. Bottom view of fiber cloth without solution.

Figure 17. Paper gasket without solution.

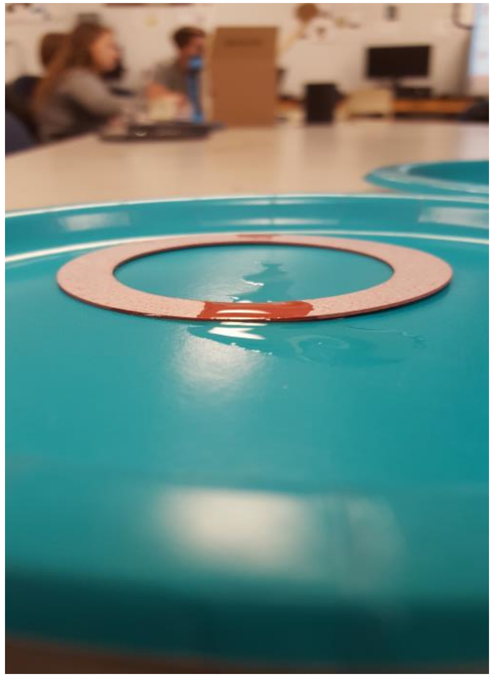


Figure 18. Paper gasket after attempted oil removal.

Oleophobic Gasket Material Testing

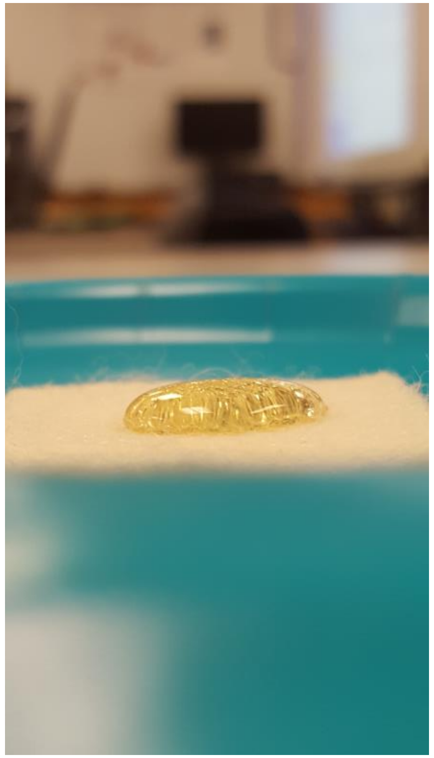


Figure 19. Fiber felt after impregnation and oil droplet dispersed

Figure 20. Fiber felt after impregnation and oil has run off

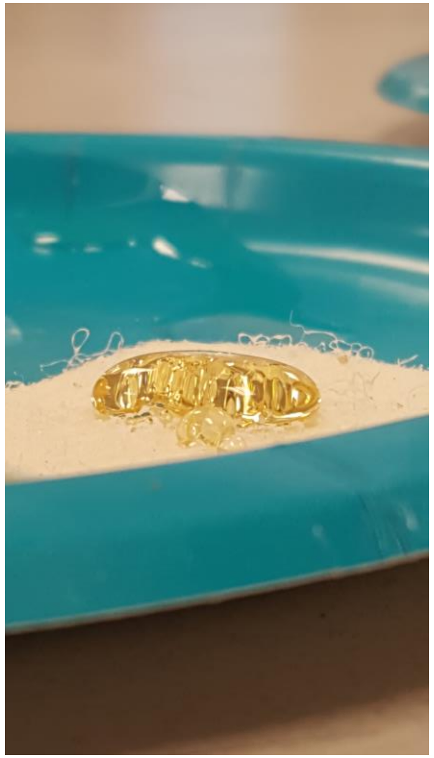


Figure 21. Fiber felt after spray application and oil droplet dispersed

Figure 22. Fiber felt after spray application and oil has run off

Oleophobic Gasket Material Testing

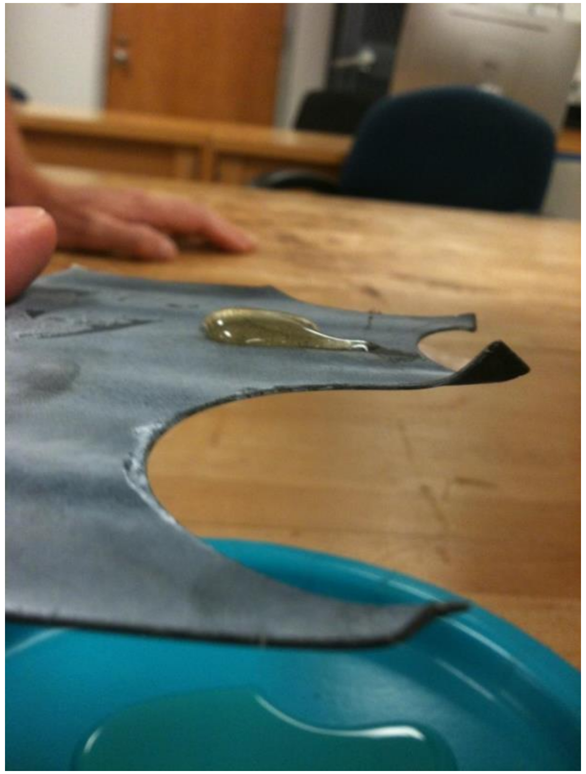


Figure 23. RCM gasket after spray and oil droplet dispersed.

Figure 24. Fiber cloth material after impregnation and oil droplet dispersed.

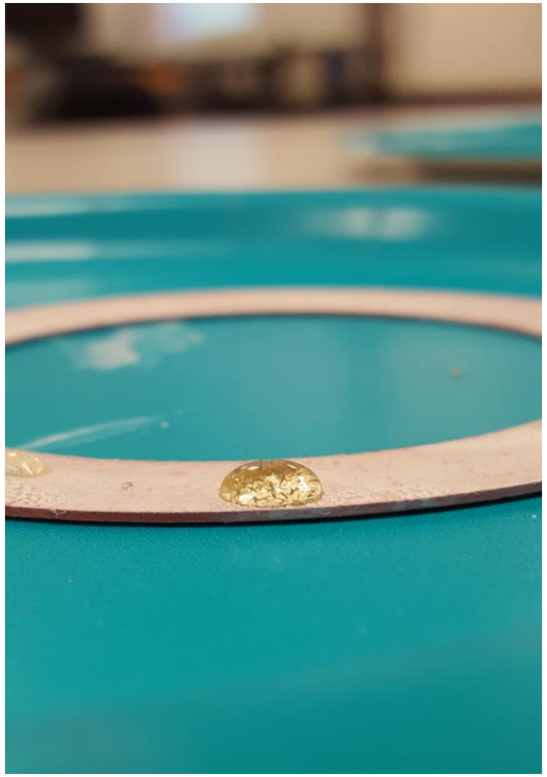
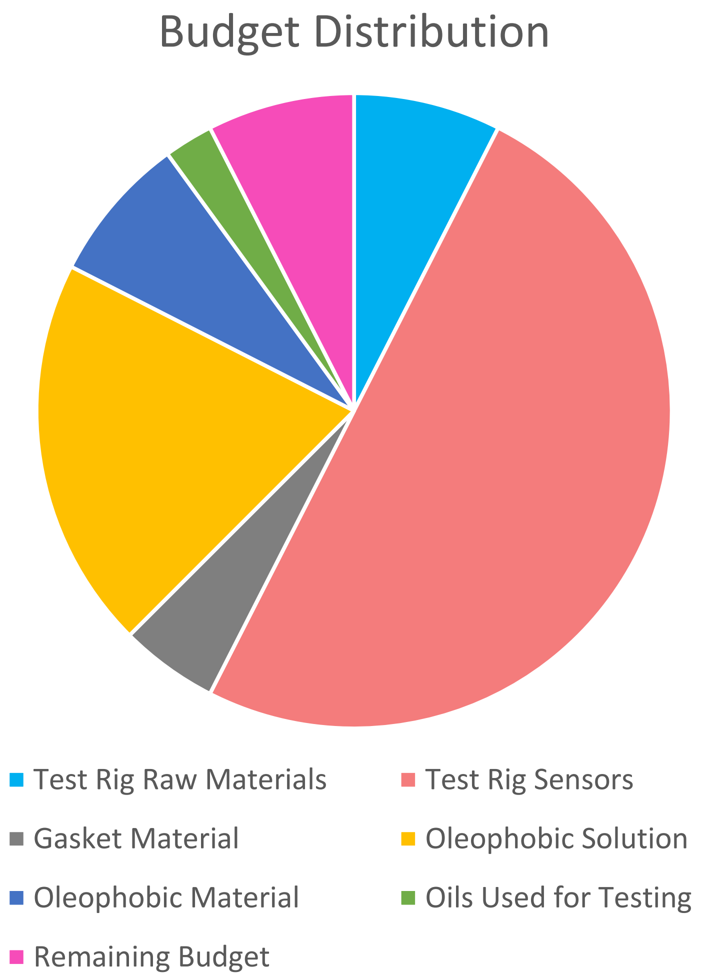


Figure 25. Paper gasket after impregnation and oil droplet dispersed.

Budget Forecast

- Budget provided: $2,000
- Total estimated cost: $1,850

Item	Maximum Estimated Cost
Test Rig Raw Materials	$150.00
Test Rig Sensors	$1,000.00
Gasket Materials	$100.00
Oleophobic Solutions	$400.00
Oleophobic Material	$150.00
Oils Used for Testing	$50.00
Remaining Budget	$150.00



Purchased Items

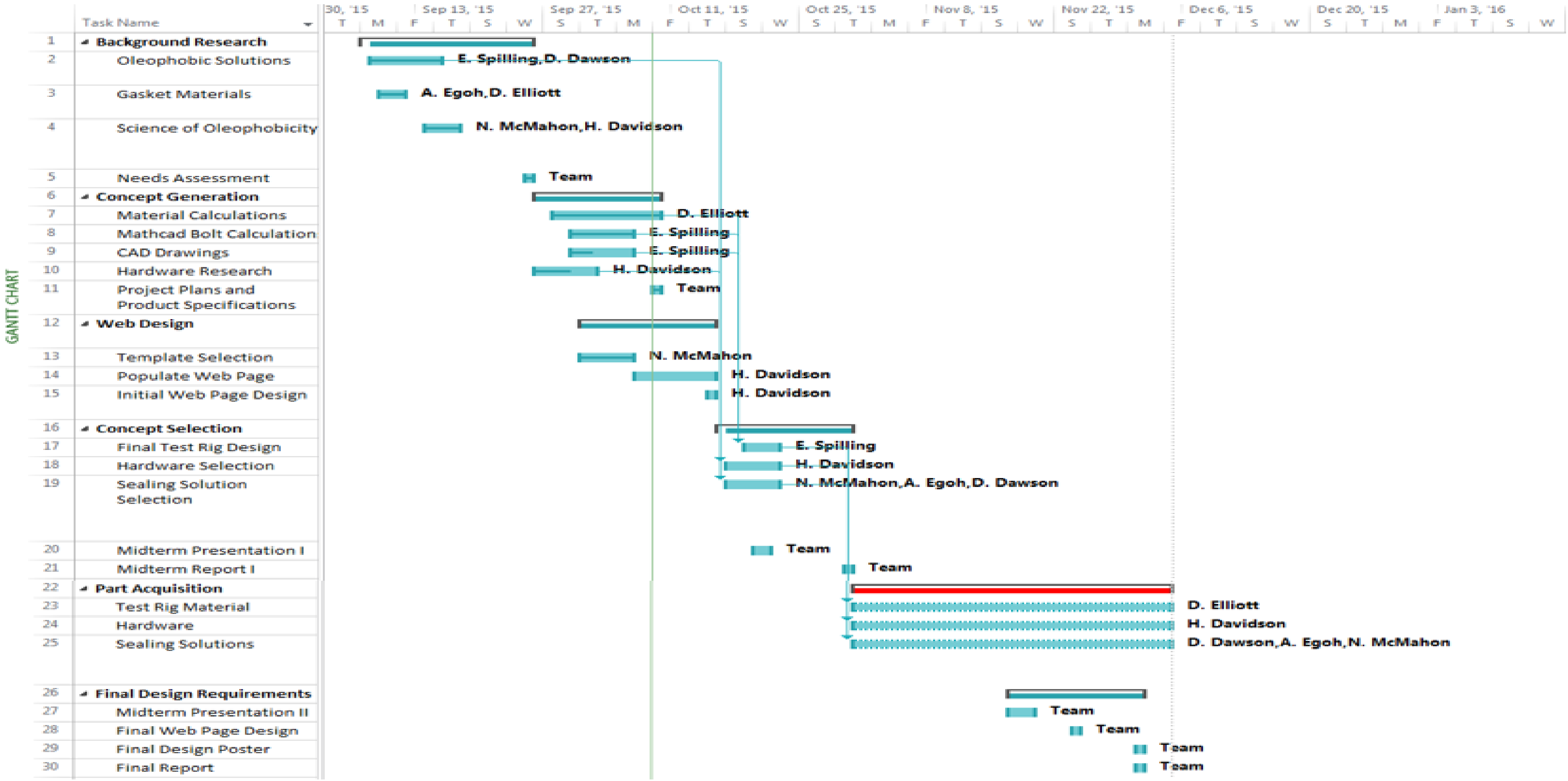
Budget Category	Item	Quantity	Cost
Test Rig Material	M8 Class 10.9 Cap Screw	1 (Pack of 25)	$7.91
Test Rig Material	M8 General Purpose Steel Washer	1 (Pack of 100)	$6.09
Test Rig Material	M8 Class 10 Steel Nut	1 (Pack of 100)	$10.48
Test Rig Material	Compact High-Pressure Brass Ball Valve	1	$11.34
Test 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	1 ft Long 2-1/2 OD x 2 ID Round Steel Tube	1	$36.04
Test Rig Sensors	Short RTD Probe	1	$66.00
Test Rig Sensors	Compression Fitting	1	$20.00
Oils Used for Testing	T Triple Protection CJ-4 15W-40 Motor Oil	1 (Gallon)	$13.44
	Total		**$191.11**

Presenter: David Dawson

Future Challenges

- Determine consistent methods of application for the oleophobic solutions
- Accurately measure the clamping pressure
- Creating gaskets from unconventional materials, such as woven fabric

Projected Schedule



Future Work

- Complete preliminary testing of gasket materials
- Final ordering of materials/hardware
- Fabrication of the test rig
- Actual testing preparations
- Set standard procedure for leak rate measurement
- Collection, manipulation and analysis of data using standard methods
- Final experimental comparison/deduction

Summary

- Goal:
  - Determine the effectiveness of oleophobic gaskets through the use of a designed test rig
- Completed Tasks:
  - Material selection analysis
  - Clamping pressure analysis
  - Final design of test rig
  - Sensor selection
- Key next steps:
  - Complete the purchasing of materials
  - Start the machining process

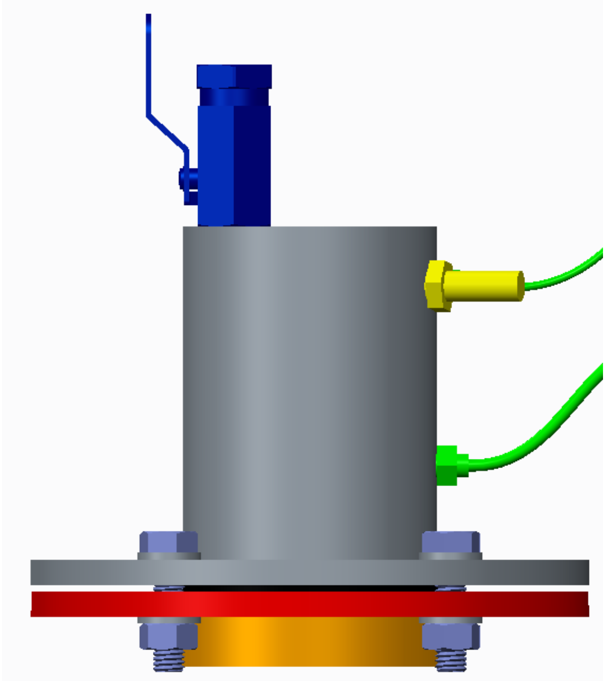


Figure 26. Test Rig Design

Reference

[1] http://pubs.rsc.org/en/content/articlehtml/2014/cs/c3cs60415b

[2] http://store.jamesgaskets.com/product_info.php?products_id=742&osCsid=4s6r9tgqtdt3s1tfi5q7puf9t2

[3] https://www.omega.com/subsection/voltage-output-pressure-transducers.html

[4] http://www.omega.com/pptst/PR-20.html

[5] http://www.kulite.com/products.asp?p=4-1

Appendix

$\sigma_{clamping} := 10MPa$

$\sigma_{vessel} := 2.5psi = 0.017 \cdot MPa$

$ID := 50mm$

$OD := 150mm$

$D_{gasket} := 75mm$

$A_{vessel} := \pi \cdot \left(\frac{ID}{2}\right)^2 = 2.376 \times 10^{-3} \cdot m^2$

A36 Steel

$nu_{steel} := 0.26$

$A_{flange} := \pi \cdot \left[\left(\frac{OD}{2}\right)^2 - \left(\frac{ID}{2}\right)^2\right] = 0.015\,m^2$

$\sigma_{failuresteel} := 322.5MPa$

$density_{steel} := 7.85 \cdot 10^6 \frac{gm}{m^3}$

$P_{atm} := 14.696psi = 0.101 \cdot MPa$

$\Delta P_{vessel} := P_{atm} - \sigma_{vessel} = 0.084 \cdot MPa$

$\Delta P_{flange} := \sigma_{clamping} - (P_{atm}) = 9.899 \cdot MPa$

A36 Steel

$$m_{vesselsteel} := \left[\frac{3 \cdot (1 + nu_{steel}) \cdot \Delta P_{vessel} \cdot \left(\frac{ID}{2}\right)^6 \cdot \pi^2}{8}\right]^{\frac{1}{2}} \cdot \left(\frac{density_{steel}}{\sigma_{failuresteel}^{\frac{1}{2}}}\right) = 5.693 \times 10^{-3}\,kg$$

$m_{vesselsteel} = 5.693 \times 10^{-3}\,kg$

$$t_{vesselsteel} := \frac{m_{vesselsteel}}{density_{steel} \cdot A_{vessel}}$$

$t_{vesselsteel} = 0.305 \cdot mm$

$$\sigma_{failuresteel} = \frac{3 \cdot (3 + nu_{steel}) \cdot \Delta P_{flange}}{8 \cdot t_{flange}^2}$$

$m_{flangesteel} = density_{steel} \cdot A_{flange} \cdot t_{flangesteel}$

$$m_{flangesteel} := \left[\frac{3 \cdot (3 + nu_{steel}) \cdot \Delta P_{flange} \cdot \left[\left(\frac{D_{gasket}}{2}\right)^2 - \left(\frac{ID}{2}\right)^2\right] \cdot \pi^2}{8}\right]^{\frac{1}{2}} \cdot \left[\frac{density_{steel}}{(\sigma_{failuresteel})^{\frac{1}{2}}}\right] \cdot \left[\left(\frac{OD}{2}\right)^2 - \left(\frac{ID}{2}\right)^2\right] = 0.593\,kg$$

$m_{flangesteel} = 0.593\,kg$

$$t_{flangesteel} := \frac{m_{flangesteel}}{density_{steel} \cdot A_{flange}}$$

$t_{flangesteel} = 4.939 \cdot mm$