FILTER SENSOR MOUNTING ADAPTOR

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ME450 - Section 3 - Team 18

Project Sponsor: *Donaldson Company*

Dec 16, 2024

ABSTRACT

This project focuses on designing and prototyping a solution to mount oil condition and differential pressure sensors onto a spin-on oil filter system. The goal is to enable *Donaldson*, the project sponsor, to collect real-time data for engineering development and customer diagnostics, improving diesel engine maintenance for Mack/Volvo fleets. By integrating sensors into existing filtration systems, this solution helps optimize oil and filter replacement timing, reducing waste and enhancing engine performance. The project considers space constraints, environmental conditions, and ease of installation to deliver a validated prototype and installation guide. The final product ultimately being put onto a diesel truck, contributes to sustainability and more efficient fleet management.

EXECUTIVE SUMMARY

This project tackles a critical operational challenge for Donaldson and its customers, including Mack/Volvo truck fleets, by developing a sensor mounting adapter for oil condition and differential pressure sensors. Without real-time data, fleet managers must estimate when to change oil filters, leading to unnecessary costs from premature replacements or the risk of engine damage from delayed changes. With each oil filter replacement for these trucks being costly and maintenance windows limited, the need for precise diagnostics is essential. The objective of this project is to design a solution that integrates seamlessly into Donaldson's existing spin-on oil filter systems, allowing fleet operators to optimize filter changes, improve engine performance, and minimize waste.

The team created the CAD models and drawings for a design that combined a double-mount sensor alignment system with a hook block locking mechanism. This design had been carefully developed to address several critical engineering challenges, including limited space within engine bays and the need for a non-permanent locking mechanism capable of withstanding high torque (200 ft-lbs) and harsh operating conditions. Additionally, the adapter was designed to meet IP69K standards for water and dust resistance, ensuring it could endure exposure to chemicals, extreme temperatures, and vibrations encountered during vehicle operation. This focus on environmental resilience ensured compatibility with Donaldson's quality standards and supported long-term durability.

By providing real-time data on oil and filter condition, this solution will enable Donaldson's customers to make informed maintenance decisions, reducing unnecessary filter replacements and extending engine life. This aligns with broader sustainability goals by minimizing waste and improving resource efficiency.

PROJECT INTRODUCTION & BACKGROUND

The sponsor of this project is *Donaldson Company, Inc.*, a global leader in the development of innovative filtration systems. *Donaldson's* solutions serve a wide range of industries, including construction, transportation, and manufacturing, with a specific focus on ensuring optimal engine performance through advanced air, oil, and liquid filtration technologies (*Donaldson* Filtration Systems). This project centers around Mack/Volvo truck fleets (MP7, MP8, D11, D13 engines), where there is a critical need for improved oil system diagnostics. The core objective of this project is to design and prototype an adapter that enables the seamless integration of oil condition and differential pressure sensors into an oil filter system. This adapter will allow the oil condition and differential pressure sensors to facilitate real-time data collection, essential for both engineering development at *Donaldson* and customer diagnostics for Mack/Volvo fleets.

Fleet managers often face challenges in determining the optimal times for oil filter replacement, which can lead to either premature or delayed oil changes. Oil filters on Mack/Volvo trucks are much more expensive than they are for the typical consumer vehicle, therefore oil filters are not changed every time the oil is replaced (McTaggart, heavydutykits.com). Premature changes increase unnecessary maintenance costs, while delayed changes risk engine damage and degraded performance. For Mack/Volvo truck fleets, the absence of real-time diagnostics compounds these challenges, potentially leading to additional costs of up to $120,000 for large fleets (*Donaldson* Connect Introduction). Additionally, the oil condition and differential pressure data will enable customers to pinpoint whether their vehicle's issue stems from the oil or oil filter, or if another component is causing the malfunction. This project aims to mitigate these issues by developing a system that allows customers to identify the precise time for oil filter replacement and assess oil condition in real time, reducing unnecessary maintenance and improving engine efficiency.

The primary objectives of the project include:

- Developing a sensor mounting adapter compatible with *Donaldson's* spin-on oil filter system.
- Ensuring the design can collect real-time oil condition and pressure data without disrupting normal vehicle operation or complicating the oil change process.
- Designing the system to withstand the harsh conditions found in automotive environments, including exposure to chemicals, extreme temperatures, and high vibration and shock levels.
- Meeting the sponsor's requirements for easy installation (less than 30 additional minutes for mechanics during oil changes) and non-permanent locking mechanisms that maintain sensor integrity and last 4+ oil changes and 4,000 hours of operation.

A successful project outcome will involve the completion of a fully functional CAD model, accompanied by a prototype that showcases proof of function. Additionally, the design must be validated through testing done by *Donaldson Company* with their internal standards, ensuring compliance with customer and engineering specifications. Although this testing may be completed after the semester is over, our design will be created with these standards in mind. Lastly, we will compile a thorough information guide on how to install and remove the system to be given to mechanics.

Donaldson has previously explored solutions for integrating sensors into oil filter systems. One notable concept involved a puck extension that would mount onto the oil filter housing, creating space for sensors. However, this solution encountered several challenges, including space constraints and the lack of a reliable non-permanent locking mechanism. The puck design, while functional in concept, required further development to address these critical issues and optimize the sensor mounting process.

The three most significant challenges of this project include:

1. Space Constraints: The design must accommodate a compact area while integrating sensors in a way that does not disrupt the vehicle's existing oil filtration system.
2. Non-Permanent Locking Mechanism: The solution must not rely on adhesives like *Loctite*, which can vary in application effectiveness and fail to meet reliability requirements for maintenance personnel.
3. Ease of Installation: The system must be easy to install and remove, adding no more than 30 minutes to the standard oil change process and requiring no specialized tools or training.

The IP69K standard is critical to this project , as it ensures that the system is resistant to water and dust ingress under high-pressure conditions, a necessity in the automotive environment (Avery Weigh-Tronix). Furthermore, the design must withstand temperatures ranging from -40°C to +125°C, endure vibration and shock per automotive standards, and maintain integrity under exposure to a variety of chemicals, such as kerosene, gasoline, and degreasers (*Donaldson* - Filter Sensor Mounting Adapter Requirements). The adapter must also meet burst pressure and operational pressure requirements, supporting up to 300 psi in certain conditions. In addition to the IP69K standard, the project will likely involve ISO standards for oil filtration systems and ASTM standards related to material durability and environmental resilience (example standards but not something we have discussed with *Donaldson* yet: ISO 4548, ASTM D6304, ISO 9001). *Donaldson* also has vibrational specifications and standards that our design has to account for. By adhering to these stringent standards and leveraging a diverse range of information sources, the project will ensure the development of a robust, reliable solution that meets both *Donaldson's* engineering goals and the operational needs of their end customers.

INFORMATION SOURCES

The development of this project has relied on a broad array of primary and secondary information sources. Stakeholder interviews with *Donaldson* engineers provided detailed insights into the specific challenges faced in oil system diagnostics, while benchmarking against current sensor mounting solutions in the automotive and industrial sectors highlighted potential avenues for innovation (J. Durand & M. Kalis). Additionally, a thorough literature review was conducted, focusing on relevant engineering principles and solutions implemented in similar applications, such as air flow sensors and spin-on filter systems (Li). Sources included automotive industry standards, technical documentation from *Donaldson's* filtration systems, and various academic papers on sensor integration in harsh environments (*Donaldson* Company - *Engine liquid filtration*, *Donaldson* Company - *Technical articles*). We used sources to verify our scientific and mathematical calculations when determining if our alpha solution was feasible. Another information source we have utilized is the mechanical engineering machine shop and the expertise of people there such as Don Wirkner. They have helped us identify possible manufacturing design problems which we have begun to address in our design. This helps ensure ease of manufacturing once the design is handed off to *Donaldson.*

DESIGN PROCESS

The selection of a design process that encapsulates the full project has been an integral part of this project. Due to our constraints of size and space within the engine bay, there has been, and will continue to be an immense amount of iteration on the design and continually analyzing the design problem. We believe that the design process that fits our project the best and allows for the most productivity related to our project is the French stage-based model referenced in *Figure 1* (Wynn D). Our design problem includes a multitude of challenges such as space constraints and functionality constraints. Therefore, as our team continues to iterate on designs, it will be instrumental to constantly check back to the analysis of the problem and improve based on that. As we continue to come up with designs and begin to select one or multiple to move forward with, the French model allows us to test these against our constraints and then reassess. While we initially worried about ensuring our design would fit the speed/ease of installation requirement, after solidifying our alpha design and building a prototype we are confident that this solution is able to be installed easily and in under 30 minutes. To be sure, upon manufacturing the prototype, we have timed ourselves installing the design to ensure that we can install it within specifications. We have sent a video of this to Donaldson, who can show it to their in-house maintenance team, to ensure that they agree that it aligns with the specifications.

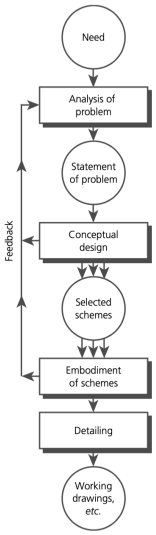


Figure 1: The design process by French in 1999,
Chosen by our group to guide our design process.

At the beginning of this project, after assessing the scope of our task, we analyzed the various methods in which we could tackle the problem. We considered various design processes such as those that fell in the category of either activity or stage based but not their counterpart. However, we found that solely stage-based methods would not suit our project due to being too linear. As we have gathered information from *Donaldson*, it has become apparent that reworking the solution for this project will be an almost every day thing. Reiteration is the premise of what we will be doing throughout the semester while working towards the best solution possible.

As we continue to follow the French stage-based model, it has become apparent that stage-based models that promote iteration upon evaluation of a potential solution are exactly what fit our project. The French stage-based model, the Pahl and Beitz model, and Cross' design model (Wynn D). The rotational constraint and space constraint force us to come up with a design, test it, and then rework because there are so many different factors we have to consider when trying to fit these sensors in such a small area. Therefore, through these design processes that promote iteration and exploring the design space as much as possible before landing on a final design are exactly what we need to follow to enhance our ability to supply *Donaldson* with our best work.

Our design process is very similar to the original framework outlined in the first ME450 class. The basic layout of this design process is the foundation that the French stage-based model follows after. The original design promotes iteration on designs and continually circling back to the design problem and making improvements through that. If there weren't options to iterate on the concepts that we design, the solution would not be as strong. Our design requirements force us to reassess at every step of the design process, which is outlined in the original design process that was introduced on the first day, as well as the design process that we chose to follow for the semester.

DESIGN CONTEXT

Stakeholders

The stakeholders are as outlined below in *Figure 2.* It is important to note the following: Primary stakeholders are those whose lives or work are directly impacted by the problem and/or the development of a solution. Secondary stakeholders are those who are part of the problem context but may not experience the problem themselves and/or may not be directly impacted by a solution. And, lastly, tertiary stakeholders are those who are outside of the immediate problem context but may have the ability to influence the success or failure of a potential solution.

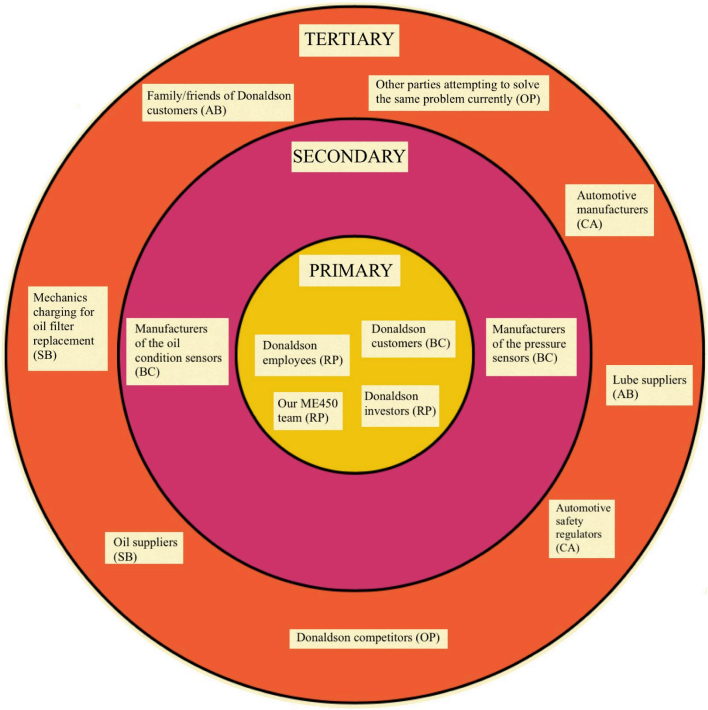


Figure 2: Stakeholder map where 'RP' stands for Resource Providers, 'SB' stands for Supporters & Beneficiaries of the Status Quo, 'CA' stands for Complementary Organizations and Allies, 'BC' stands for Beneficiaries and Customers, 'OP' stands for Opponents and Problem Makers, and 'AB' stands for Affected or Influential Bystanders.

This project will have a range of positive impacts on key stakeholders, particularly within *Donaldson Company* and its customers. *Donaldson* employees will benefit from the enhanced ability to collect real-time oil condition and differential pressure data, allowing for more effective product development and customer support. Fleet operators, who are primary customers, will experience cost savings by reducing unnecessary oil changes and improving vehicle performance. These real-time diagnostics will also enhance vehicle uptime and minimize maintenance costs. Additionally, sensor manufacturers involved in producing oil condition and pressure sensors will likely see increased demand as these components become integrated into *Donaldson's* solutions. Mechanics performing routine oil changes will benefit from a product designed for quick installation without disrupting the standard maintenance process.

There are also broader positive implications for *Donaldson* investors and automotive manufacturers like Volvo and Mack. Investors stand to gain from increased customer satisfaction and sales growth, while automotive manufacturers benefit from improved vehicle performance, leading to fewer customer complaints and a stronger brand reputation. The project also provides lube suppliers with the opportunity to deliver products that are used more effectively, ensuring optimal oil replacement intervals.

However, there may be some negative impacts. Although mechanics benefit from a product designed for quick installation, mechanics charging for oil filter replacements could see a reduction in service revenue as fewer oil filters may need replacing, thanks to the optimized diagnostics. Similarly, oil suppliers may experience a drop in demand due to less frequent oil changes, which could impact their sales. Additionally, *Donaldson's* competitors in the filtration market may struggle to keep up with this innovation, potentially losing market share if they do not develop comparable products.

Social and Societal Impacts

While the project aims to reduce environmental waste by minimizing unnecessary oil changes, the manufacturing and disposal processes for the new sensor mounts must be carefully considered. The production of these components could involve resource extraction, energy consumption, and waste, which may have an indirect negative environmental impact. If this project does not result in a successful solution, there could be significant environmental consequences. Inefficient filters can lead to increased emissions of carbon monoxide, hydrocarbons, and particulate matter, which contribute to air pollution. Moreover, clogged or incorrect filters reduce engine efficiency, resulting in higher fuel consumption and increased CO_2 emissions (Delaney Tire & Auto). Inadequate filtration can also cause oil leaks and spills, contaminating soil and water sources, which poses a serious threat to ecosystems. Without real-time diagnostics from sensors, mistimed oil changes may lead to the overuse of resources, including wasted oil and filter materials. Additionally, unfiltered oil laden with contaminants could cause increased engine wear, generating further waste through more frequent repairs. These broader environmental impacts underscore the importance of this project's success in improving filtration efficiency and diagnostic accuracy. Therefore, mitigating the environmental effects of both the manufacturing process and end-of-life disposal is a crucial consideration moving forward.

Beyond the immediate interests of the sponsor, this project addresses broader societal concerns related to sustainability, public health, and operational efficiency. One of the key societal drivers is the environmental impact of inefficient filtration systems. As was mentioned above, poorly maintained oil filters can lead to higher emissions of harmful pollutants, such as carbon monoxide, hydrocarbons, and particulate matter (rushtruckcenters.com). These emissions can

contribute to air pollution and can have significant adverse effects on public health, especially in urban areas where truck fleets are more concentrated (PWC). Additionally, resource conservation is a critical issue in today's world, where unnecessary oil changes result in wasted oil and materials, contributing to both environmental degradation and economic inefficiency. By improving diagnostic capabilities and reducing the number of mistimed oil changes, this project promotes resource efficiency and reduces the environmental footprint of truck fleets, aligning with societal goals for sustainable industry practices. Lastly, this work contributes to improving the operational reliability of essential transportation networks, which are vital to modern economies. By ensuring that truck fleets can optimize their maintenance schedules, the project helps reduce downtime, ensuring the continued delivery of goods and services. This efficiency contributes to the smooth functioning of supply chains, which ultimately benefits society by keeping transportation costs down and improving the availability of goods.

While profit and economic efficiency are certainly significant drivers for *Donaldson*, social impact ranks highly in this project's goals. The focus on developing a sensor system to diagnose oil and filter issues for fleets of trucks has clear social implications, particularly in terms of environmental sustainability and public health. By improving oil filtration systems, the project contributes to reducing emissions, optimizing resource use, and preventing leaks or spills that could harm the environment. These factors align with growing societal and regulatory pressures to minimize the environmental footprint of large transportation fleets. Although this project is not aimed at mass manufacturing, its implementation has the potential to create positive ripple effects across *Donaldson's* customers by promoting more sustainable practices in fleet management. Additionally, the educational aspect of developing new technology and engineering solutions also supports the company's commitment to innovation. However, the ultimate economic benefits - both for *Donaldson* and its customers - remain a critical factor, as the project promises cost savings, improved vehicle uptime, and optimized maintenance schedules. In summary, while economic considerations are important, social and environmental impacts are prioritized highly, reflecting the project's broad benefits beyond just profit.

The priorities of the design that our group along with *Donaldson* have with this project will instrumentally affect the design of the product. Through careful analysis of how the design is intended to be tackled, we have determined that the social impact of this project is incredibly significant for how we look at the design problem. Since the design is heavily social impact based, due to the benefits being more intended for the user as opposed to profits for a company, we aim to produce something that positively impacts society. As stated above, it is essential to state that *Donaldson* is a business that will always have to keep monetary motives in mind when exploring solutions such as this. However this product is not intended to be a mass produced item. Therefore the social impact is driving the project.

Intellectual Property

Intellectual property became a prominent point of concern or emphasis in the latter half of the class. At the beginning, we were just in possession of *Donaldson* property and had information about the project that could not be shared with anyone outside of the project. However, moving forward throughout our semester, as we designed and prototyped for the project, it became of more emphasis. This is because it is a solution to a problem that has been needed to be addressed, and no other company has figured out a way to do it within the constraints that *Donaldson* has.

At the beginning of this project, we signed intellectual property agreements with *Donaldson* which essentially did not allow our team to share the information and designs that we came up with, along with the information that *Donaldson* provided us with. Intellectual property protections such as patents and trade secrets became applicable to our project. Since our team designed something that is worth being patented, if it is patented, our names would be on the patent, but *Donaldson* would own said patent. Trade secrets will be kept confidential to our group which ensures that our group can gain all the information that our sponsors have, facilitating the best design that we can come up with.

Sustainability

The sustainability of our design can be reduced to the materials that we utilize to meet our end goals. These materials must be resistant to a multitude of harsh chemicals, pollutants, and engine bay environments that most recyclable options would not be able to survive. The manufacture of our design however is not intended for mass production which reduces the environmental impact that the finished product will have. The most important aspect of our design's sustainability is the use. Our design aims at enabling trucking companies to monitor the health of their oil filter, along with ensuring that companies are utilizing the proper oil filters for their applications. These uses are important because an oil filter that is discarded too soon before its end of life is a waste of product. Over the course of a large truck fleet, this can add up to an immense amount of unnecessary waste. Secondly, the use of an improper oil filter, or leaving it on well past the end of life, can lead to poor engine performance which in turn promotes additional pollutants to be put into the atmosphere (HT Saves). Along with this, poor engine performance burns excess fuel and oil, exhausting more non-renewable resources unnecessarily (Mospart).

In addressing the less sustainable aspects of our sensor mounting device, several changes could be implemented to enhance sustainability. For example, substituting non-recyclable materials with biodegradable or recycled options would reduce environmental impact. However, this could come at the cost of decreased durability or increased expense, potentially leading to more frequent replacements. Another approach would involve designing the product for easier disassembly and recycling at the end of its life, a move that could increase design complexity and production costs but would reduce environmental waste in the long term. These changes are

all out of the current scope of the class but could be looked at by *Donaldson* prior to implementation.

Ethics

Several ethical dilemmas could arise during the design of the oil filter monitoring device. One example is in balancing the sometimes conflicting interests of stakeholders, such as project sponsors, technicians, and customers, might present ethical conflicts, especially if financial pressures clash with product use intentions. For example, our product gives data into how long an oil filter can be used before needing to be replaced. We are working on behalf of the filter manufacturing company who may not mind selling more filters whereas their customers want to ensure they are buying as few filters as possible to save the most money. Although true, competition in the oil filter market is very high which means a company like *Donaldson* is also highly incentivized by customer satisfaction. Managing these dilemmas would involve adhering to established engineering codes of ethics (National Society of Professional Engineers), particularly around maintaining open, transparent communication with all parties involved to ensure decisions are both responsible and equitable. This illuminates the difference between personal and professional ethics where personal ethics can be dependent mainly on context whereas professional ethics largely depends on established codes of ethics and who you are working on behalf of.

Power Dynamics

Power dynamics in this project exist primarily between the project sponsor *Donaldson*, their representatives, and our team members. Project sponsors hold financial authority and guide the project direction. They also are the subject matter experts which puts them in a position of authority in terms of decision making. To resolve any consequences of these dynamics, open communication is key. Fostering an inclusive environment where everyone's ideas are respected ensures more balanced and effective outcomes.

Inclusivity

To address inclusivity, the team encouraged diverse perspectives and actively tackled implicit biases in decision-making. Regular reflection on team dynamics, alongside anonymous feedback channels, helped identify inclusivity issues early. The team has sourced information from a variety of places - such as manufacturing experts, industry experts, and scholarly books and articles - to ensure that diverse perspectives are considered. Moreover, we recently submitted a CATME team survey in which each team member anonymously rated various components of how well the team functioned. After discussing these results, the team is confident that we have worked well together.

USER REQUIREMENTS AND ENGINEERING SPECIFICATIONS

The requirements and specifications for this project were primarily obtained by interviewing the primary stakeholder and project sponsor, *Donaldson*. Due to having a clear understanding of the problem as well as company and industry standards, the list of requirements and specifications is comprehensive. The requirements and specifications related to environment and vibrational resilience come directly from *Donaldson's* company standards for design. Some are arbitrary based on the needs of the application but others are well defined industry standards such as adhering to the IP69K dust and water ingression standard. The list of requirements and specifications for this project are outlined in Table 1.1 below.

Table 1: Requirements and Associated Specification (*Donaldson* - Filter sensor mounting adapter requirements)

Requirement:	**Specification:**
Must withstand harsh system environment conditions: Adapter, Sensors, and associated components must withstand exposure to the following conditions without compromising the integrity of any seals, insulation, etc.	Resist chemical deterioration to all chemicals listed in **Table 1.2** [1]
	Must operate in a temperature range of -40°C to +125°C. [1]
	Must withstand a 48 hour salt spray with no visual corrosion. [1]
	Must prohibit dust and water ingression per IP69K standard. [1]
	Must withstand a burst pressure of at least 300psi and standard operating pressure of 25psi to 100psi. [1]
Must withstand system vibration and shock: Adapter will be attached directly to the engine oil head and will need to withstand all engine related vibrations and shock as noted without damage or leaking.	Sinusoidal Vibration: Must withstand the following test conditions for 8 hours/axis [1] - Frequency: Logarithmic Sweep from 10Hz to 2000 Hz to 10 Hz [1] - Sweep Period: 20 minutes in each axis (X, Y, and Z in mounted orientation) [1] - Displacement Limits: 1.5m from 10 Hz to 91 Hz. [1] - Acceleration Limits: 173 m/sec 2 RMS (25g peak) from 91 Hz to 2000 Hz. [1]
	Random Vibration: Must withstand the following test conditions for 8 hours/axis [1] - Frequency: 5 Hz to 2000 Hz [1] - Overall Grms: 15.82 Grms [1] - Acceleration (squared) Spectral Density (ASD): [1] - 5Hz: 0.055 G 2 /Hz, 100 Hz: 0.15 G 2 /Hz, 1000 Hz:

	0.15 G 2 /Hz, 2000 Hz: 0.075 G 2 /Hz [1]
	Shock: Must withstand the following tests [1] - Type of Pulse: Half-Sine Pulse [1] - Peak Pulse Amplitude: 500m/sec 2 [1] - Pulse Duration: 11 ms [1] - Number of Axes: 3 (X, Y, Z in mounted orientation) [1]
Minimal Reduced Pressure Drop: A filter is considered to have a terminal (end of life) pressure drop (PD) of 20psi between the clean and dirty side of the filter.	The adapter must not add more than a 2psi pressure drop across the filter at a flow rate of 80 l/min. [1]
Must be durable	Adapter will need to survive at least 4,000 hours of operation. [1]
Must not interfere with standard oil change process	Technicians unaware of sensor mount being installed must be able to carry out oil change without specialized training. [1]
Easy Installation	Must not take more than 30 minutes and must be adequately described by instruction manual so no formal training for technicians are needed. [1]
	Must be able to be installed using zero custom tools. [1]
Must fit system size constraint	Must not have a diameter greater than 4.23 inches. [2]
	Must not have sensors extrude from the filter more than 3 inches in 110 degrees of rotation. [3]
Filter must be able to be changed	Must be able to stay locked in through 4 oil changes. [1]
Must not be destructive of existing parts	Design must require zero modifications of existing mounting parts and the filter. [1]
	No visible damage after one use (install and removal). [1]
Must Lock	Must be able to withstand 50 ft-lbs of force while installing the filter and 200 ft-lbs when removing the filter. [1]

Ease of Manufacturing	Corners must be fillet to a radii no smaller than 0.5” $_{5}$[1]

Table 2: Full Chemical List	
Alcohol	Gasoline
Anti-freeze	Kerosene
Automatic Transmission Fluid	Mass Flow Sensor Cleaner
Brake Fluid	Muriatic Acid
Degreasers	Penetrating Oils
Diesel Exhaust Fluid (DEF)	Power Steering Fluid
Diesel Fuel #2 ULSD	Soap and Detergent
Diesel Fuel B20	Spray Paint
Diesel Fuel Additive	Sulfuric Acid
Electrical Contact Cleaner	Undercoating Material
Electronics Cleaner	UREA
Engine Oil	Vinyl Plasticizers
Ether	Windshield Washer Fluid

The relative importance of requirements and specifications is determined by what stakeholder the requirement is created for. At the beginning of our collaboration with *Donaldson* a comprehensive list of what they needed our adapter to do was provided. All of which related directly to what the intentions for what the adaptor could provide to them, the primary stakeholder. In further interviews with the *Donaldson* representatives, we arrived at a few additional requirements and specifications related to the needs of a tertiary stakeholder such as the technician (J. Durand & M. Kalis). An example of such a requirement is the ease of installation. Although important and *Donaldson* was pleased with us considering said perspective in design, this requirement does not directly impact the performance and utility of the product for our sponsor. As a result this requirement can be seen to be less important than other requirements and specifications which have a direct impact on whether the design will satisfy our

[1] Given by Donaldson
[2] Diameter of existing Donaldson filter, due to how close the sensors are to each other we have no additional space
[3] Degrees of rotation given by Donaldson, extrude length in that direction based on inferred size from picture given
[5] Advice given from Don Wirkner for ease of manufacturing. Based on the end mill that will be used.

stakeholder's needs. Additionally, *Donaldson* is less concerned with these tertiary stakeholder requirements as the final product is intended to be utilized on a much smaller scale compared to their actual fuel filters. As a result, additional time to install this adaptor is not of the utmost concern for the company and is just a wish. On the other hand, the requirements and specifications related to performance and system conditions must be met or else the design will be deemed a failure.

All requirements and specifications with the ability to be quantified have been. This is important for the verification of these requirements in order to ensure the success of the design. Some specifications however have not been quantified. Examples of these are the chemicals that the design must be able to withstand. Due to physical testing of our design's resistance to these chemicals being outside of the scope of this project, quantification of a duration to which our design can withstand these chemicals is not relevant. Rather, materials will be chosen based on research into whether certain materials are known to have adverse reactions to these chemicals or not. The rest of the requirements and specifications have been quantified and therefore can be verified.

One requirement that could have been included is the cost of the adaptor. Although possible to define, our sponsor made it clear to us that because they do not intend to have our design mass manufactured they are not concerned with how much each unit costs.

CONCEPT GENERATION

There are two separate design problems within this project that need to be addressed: the locking mechanism and sensor mounting. The first, and more intricate, design problem that will be discussed is the locking mechanism. Based on the requirements and specifications we were given, namely the space constraints, the basic concept of our design was set in stone. The idea was a cylindrical adapter that utilized basic design similar to oil filter extenders on the market today. However, there are no current solutions for a locking mechanism.

Our first approach for the generation of locking mechanism ideas was to develop a concept tree, as seen in *Figure 3*. The first logical division for our application was determining if the solution was going to be partially disposable or reusable. Partially disposable solutions for this application are determined as a piece of the assembly that needs to be replaced each time, as it is deformed in some way. Reusable solutions will not have to have anything replaced between removal and installation on a separate oil head.

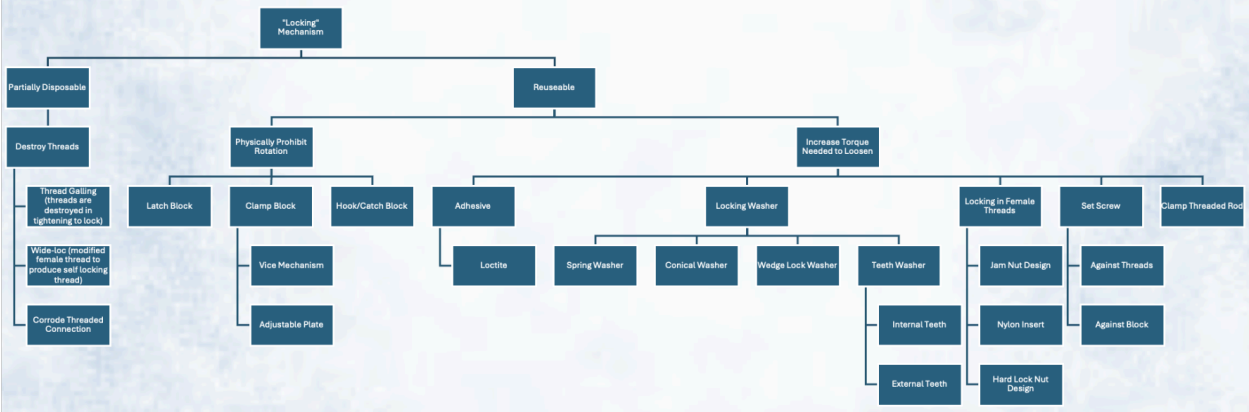


Figure 3: Concept tree outlining the locking mechanism potential designs

The partially disposable branch of the tree can be simplified by discussing destructive thread locking nuts. These work through deformations in the nut, which can be creases, pinches or uneven threads that deform around the male thread, making it more difficult to unscrew than when it is being installed. The nut would be made out of a softer metal than the threads on the oil head, ensuring that there would be no damage to the permanent part of the engine block. As shown in *Figure 4*, there would be an insert for the destructive nut to be removed and replaced upon needed for another application.

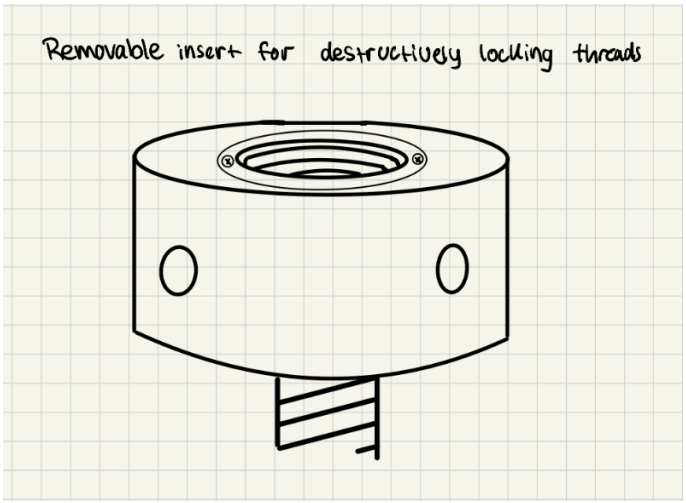


Figure 4: Partially disposable destructive locking nut design

The reusable section of the tree can be divided into two categories: increasing the torque through the threads and physically prohibiting rotation by utilizing the actual oil head. Increasing the torque through the threads includes *Loctite*, different types of washers such as nylon or locking washers, and reusable locking nuts. The physically prohibiting rotation branch exhibits a stopper that is attached to the cylindrical adapter design and contacts the oil head which prohibits the rotation.

Increasing the torque required to remove the adapter through the threads satisfies our space constraints. The goal was to find a solution that would resist the torque without adding anything to the outside of the part. Applying *Loctite* to the threads would increase the torque needed to remove the piece, as it is essentially glue. Another solution related to this would be utilizing the different types of washers including nylon rings, spring locking washers, wedge locking washers, and wave locking washers. These are all depicted in *Figure 5* below.

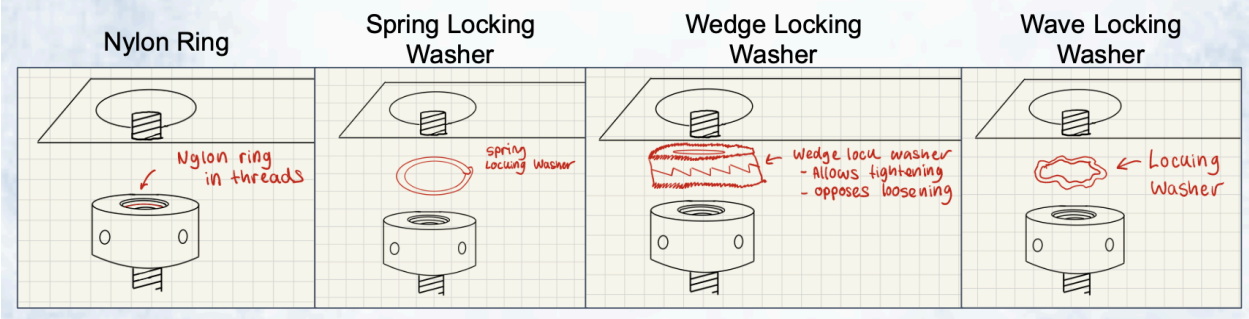


Figure 5: Types of rings and washers to increase torque required to remove adapter

Physically prohibiting the rotation through the use of a piece that contacts the oil head is the other reusable solution that shows the most promise for being able to counteract the torque of removing the oil filter. This is done through an external piece being screwed into the adapter once it is set in place. The main distinguishing factor between the designs listed in *Figure 6* is where the external piece can be installed from. The two designs on the left are fastened from the side, which can prove to be slightly difficult due to space constraints, and the design on the right is fastened from the bottom.

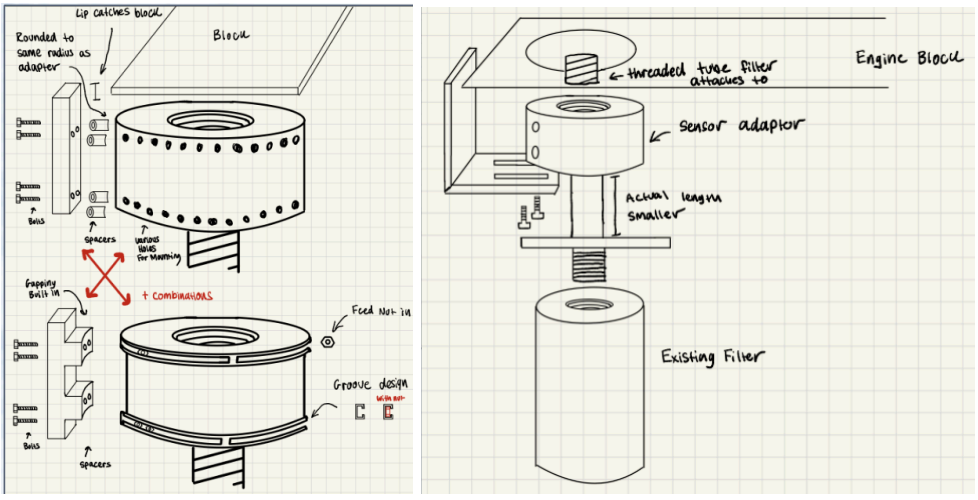


Figure 6: Designs for physically prohibiting rotation externally

The second portion of the design that needs to be addressed is the sensor mounting strategy. Contrary to the locking mechanism, there are not very many ways to do this. In order to come up with a design, our group started with a concept tree, outlined in *Figure 7*.

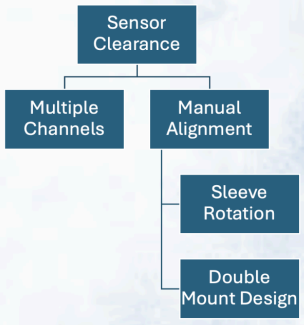


Figure 7: Concept tree outlining the sensor mounting potential designs

The only major division that is encountered in this concept tree is the distinction between having multiple channels, where one is used and the others are plugged, versus using rotation to manually align where the sensors are needed to be. Since the spatial constraints allow for a 110 degree space where sensors can protrude from the cylindrical adapter, four separate pluggable holes at 90 degree increments will guarantee that one of them will be within the 110 degree opening. The diagram of the multiple channel sensor mount is shown in *Figure 8*.

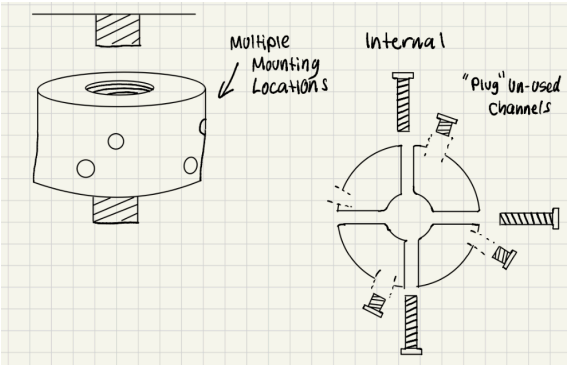


Figure 8: Multiple channel sensor mounting concept

Following the right side of the design tree yields the manual alignment concept. The premise involved having a rotating cylinder that is manually aligned by the technician and then secured in place. The two designs that come from this are the sleeve rotation, *Figure 9*, and the double mount design, *Figure 10*.

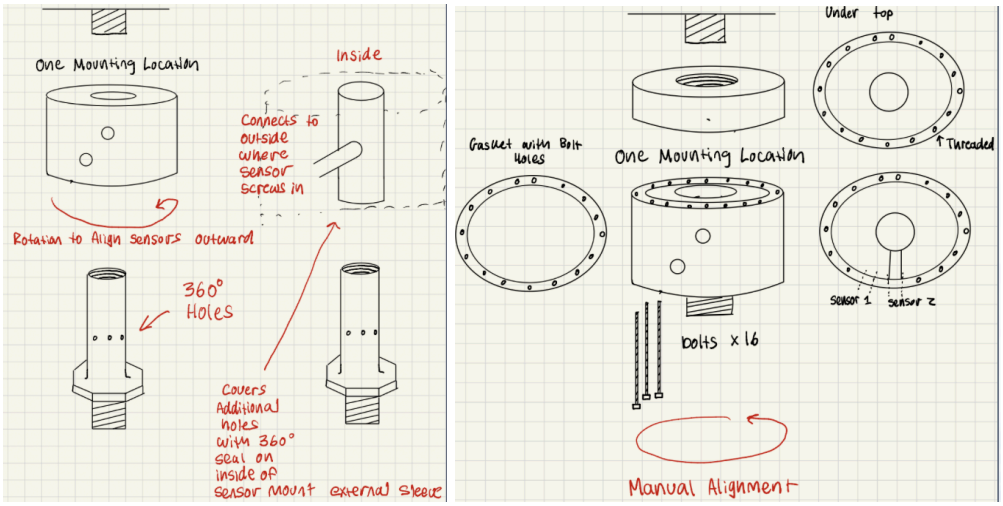


Figure 9 (left), Figure 10 (right): Rotating sleeve and double mount design, respectively

In *Figure 9*, the rotating sleeve relies on the concept of the threaded port sliding through the cylindrical adapter, and once the adapter is rotated to its desired position, the threaded part secures the entire assembly. There are holes from the outlet 360 degrees around the threaded piece in order to measure the differential pressure from the clean oil outlet. The sleeve has a channel that will align with one of the holes, and a gasket will seal the others so that there are no leaks of pressure or oil.

In *Figure 10*, the double mount design calls for a two piece approach. The first piece is secured to the threads on the oil head, and then the second is secured through bolts from the bottom. The technician will be able to rotate the bottom piece to its desired position, and then secure it with bolts that are secured from the bottom. The benefits of this design are that the technician has ease of access from below, decreasing the time it takes to install the adapter. The sensors will be able to be installed prior so that there will not be a need for any work from the side.

More generated concepts are detailed in the appendix, although many of these were deemed infeasible from the start and thus were not included.

CONCEPT SELECTION

The first step of concept selection involved creating a Pugh chart to evaluate the 12 locking mechanism ideas created by the design tree described earlier. In this Pugh chart each of our requirements were ranked from 1-7 in terms of relative importance with ‘Torque’ meaning the ability to withstand the 200 ft-lbs of torque being the most important, and ease of installation being the least important. This Pugh chart can be seen below in *Figure 11*.

	Requirement:	Pressure	Temperature	Chemicals	Vibration	Shock	Torque	Ease of Instillation	
	Mechanism:	6	5	4	3	2	7	1	Weight of Requirement
Partially Disposable	**Destroy Threads**	1	1	1	1	1	0	1	Sum of Weighted Totals:
		6	5	4	3	2	0	1	21
Physically Prohibit Rotation	**Clamp Block**	1	1	1	0	1	1	-1	
		6	5	4	0	2	7	-1	23
	Hook Block	1	1	1	1	1	1	-1	
		6	5	4	3	2	7	-1	26
Locking Washer	**Spring Washer**	-1	1	1	0	0	0	1	
		-6	5	4	0	0	0	1	4
	Wave Locking Washer	-1	1	1	0	0	0	1	
		-6	5	4	0	0	0	1	4
	Conical Washer	0	1	1	0	0	0	1	
		0	5	4	0	0	0	1	10
	Wedge Locking Washe	-1	1	1	0	0	0	1	
		-6	5	4	0	0	0	1	4
	Teeth Washer	-1	1	1	0	0	0	1	
		-6	5	4	0	0	0	1	4
Locking in Threads	**Jam Nut**	1	1	1	0	0	0	1	
		6	5	4	0	0	0	1	16
	Nylon Insert	1	-1	1	1	1	0	1	
		6	-5	4	3	2	0	1	11
Set Screw	**Set Screw**	1	1	1	-1	-1	0	0	
		6	5	4	-3	-2	0	0	10
Clamp	**Clamp Rod**	-1	1	1	1	0	1	0	
		-6	5	4	3	0	7	0	13

Figure 11: Pugh Chart for Design Selection

From this Pugh chart it can be concluded that our top 3 locking mechanism designs are (1) Hook Block, (2) Clamp Block, and (3) Destroy Threads. Due to these findings these will be the locking mechanism designs we continue to evaluate in our down selection process. Due to grouping the type of locking mechanisms by the branch of the concept generation tree they came from, it can also be concluded which branches score poorly as a whole and why. For example, locking washer designs score poorly because of poor ability to seal for pressure which is the second most important requirement. This ensures we do not continue to pursue ideas down this branch. We can also draw conclusions about our top 3 ideas based on the components of their scores. Thread destruction does not score poorly in any categories (-1) whereas the physically prohibiting designs do in ease of installation. However, ease of installation is the least important requirement and thread destruction scores 0 in the most important category, locking.

After arriving at our top 3 locking mechanism designs and having our 3 sensor mounting designs, we created a morphological chart which gives 9 combinations of the solutions to these two design problems. This morphological chart is shown below in *Table 3*.

Table 3: Morphological Chart for Design Compatibility

Locking Designs	Sensor Designs: Multiple Channels	Double Mount Design	Threaded Sleeve
Hook Block	Compatible	Compatible	Not Compatible
Clamp Block	Compatible	Compatible	Not Compatible
Destroy Threads	Compatible	Compatible	Compatible

It is important to mention that the Threaded Sleeve design is not compatible with the Hook Block or the Clamp Block design. This is due to these two locking mechanisms relying on no movement between the side of the sensor mount and the side of the filter block. Due to the threaded sleeve design allowing rotation of the sensor mount these combinations would not be subtable.

Next, for the down selection process we eliminated the column consisting of the multiple channel sensor mounting designs. This is because these designs violate the ease of installation and space constraint requirements. These requirements are violated due to the technician installing the filter mount needing to install the plugs for the filter channels not being used, many of which would be in the direction there is little to no clearance. This would make it difficult if not impossible to tighten these plugs with the required tools.

Furthermore, we eliminated the row consisting of destroying the threads as a locking mechanism design. We did so because we could not find any evidence to show that thread destroying mechanisms could withstand such a high torque as required for this application (200 ft-lbs). Additionally should our threads be able to withstand the torque requirements specified, these threads would also need to be destroyed by applying the same torque. This would be difficult for the technician installing the filter to ensure, and thus also violates the ease of installation requirement.

Now we are left with our final two designs. Both designs utilize the double mount sensor design however one utilizes hooking the block and the other uses clamping the block. We eliminated clamping the block due to all of the clamp block designs requiring the use of space at the bottom of the filter for the clamp to move in or out relative to. For this to be possible, the sensor mount diameter must be reduced in order to allow for this space to be used for the mount. As a result the flow would be reduced immensely which could negate any data our sensors collect. As a result our alpha design is the combination of the double mount sensor design and hook block locking mechanism.

The first solution concepts that occurred to our team when the project was assigned were very basic in the sense that we did not fully consider or understand the extent to which the requirements and specifications would affect our final design. Furthermore, we were not aware of the torque requirement at the beginning of the class. However, upon receiving this specification after our talks with Donaldson, it became an important driver in our locking mechanism selection. Our first solution concepts look very similar to our current design in the sense that they are all cylindrical extensions of the oil filter, however their locking mechanisms and sensor mounting solutions are much more complex. We do not see evidence of fixation on an early idea or existing idea in the market because there are no solutions that fully encompass our

requirements. While we definitely drew on existing sensor mounting solutions, even these had to be adapted to fit our design.

SELECTED CONCEPT/ALPHA DESIGN

As outlined in the concept selection section of this report, the alpha design chosen was a combination of the best solution to each design problem. That is, the hook block design for our anti-rotation mechanism was chosen along with the double mount design for sensor alignment. This preliminary alpha design is pictured below in *Figure 12*.

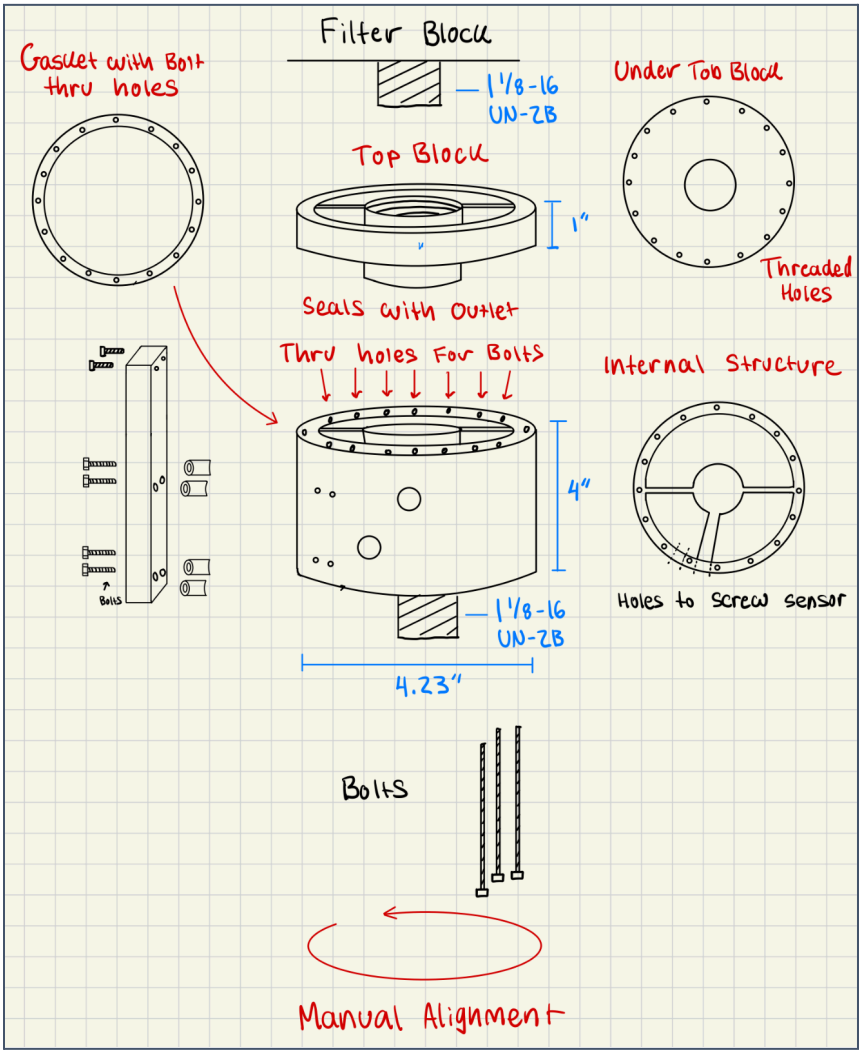


Figure 12: Preliminary Alpha Design Drawing

In this design, the primary engineering challenge of having a non permanent locking mechanism is addressed through the plate shown on the left which will hook to the flat side of the engine block prohibiting rotation. This design allows for multiple spacer configurations to ensure compatibility with the desired Mack/Volvo truck fleets (MP7, MP8, D11, D13 engines). Not only does this ensure compatibility with the filter blocks in the scope of this project, but it also allows

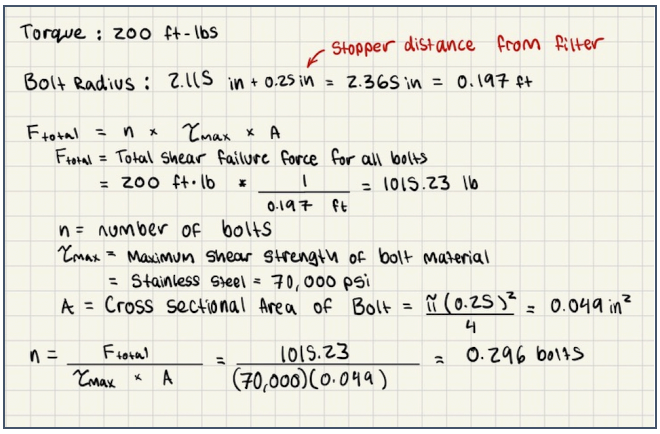
Donaldson to easily configure our design to other applications should they desire to in the future. In this design, the plate is screwed into the side of the sensor mount and the set screws shown at the top of the plate will allow for finite adjustment ensuring a tight lock with the side of the filter block.

Furthermore, the sensor alignment problem is addressed with the two part sensor mount design. In this design, the top cylinder is screwed on in the same way a typical *Donaldson* filter screws into the filter block. Next, the bottom cylinder can be aligned so that the sensors protrude in the direction of clearance and be screwed into the top cylinder from the bottom. This is important as the bottom is the only direction with ample room making the installation and tightening of these bolts possible. The numerous tapped holes in the top cylinder and associated thru holes in the bottom cylinder allows for ample adjustment ensuring alignment of not only the sensors outwards but also the hook plate which is mounted to the bottom cylinder. There is a gasket between the two cylinders with holes for the thru bolts. This design also only requires one channel to the outlet of the filter as the sensors can be manually aligned maximizing the oil flow through the adapter. Another benefit to screwing the bottom cylinder onto the top is that the locking mechanism can be installed prior to installing the sensor mounting cylinder as it does not need to be able to rotate and is simply tightened into place.

Overall, arriving at this design followed an objective concept selection process and was influenced by our sponsor to a very small degree. Throughout our weekly meetings *Donaldson* has always been very open to ideas we come forward with and are interested to see the ideas we can come up with given a blank slate. This concept that we have come up with is well defined enough to be analyzed.

PROBLEM ANALYSIS AND ITERATION

In order to determine the feasibility of our alpha design we conducted a first principle analysis of the primary point of failure for each design. For the locking mechanism, this is the bolts used to fasten the plate to the side of the sensor mount as this resists the 200 ft-lbs of torque specified by our project sponsor, Donaldson. These calculations are shown in *Figure 13* to the left below. The primary failure mechanism for the sensor mounting design is the thru bolts that run through the bottom cylinder, fastening into the top cylinder. These bolts must also withstand the 200 ft-lbs of torque. These calculations are shown in *Figure 14* to the right below.



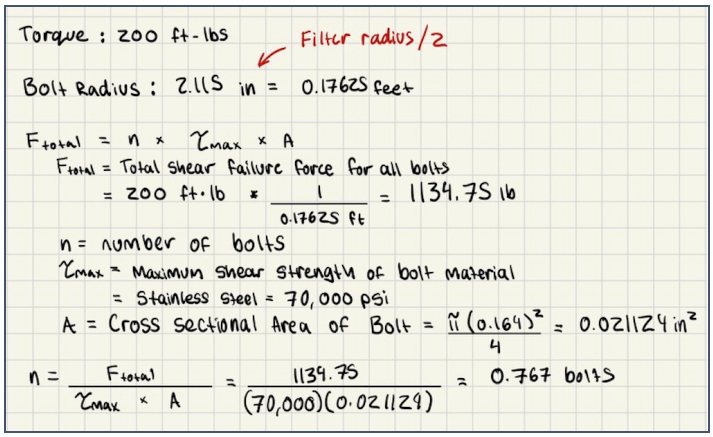


Figure 13 (left), Figure 14 (right): Shear Calculations for Bolts used in Alpha Design

Both of the first principle analysis above follow a similar process. First, the distance from the center of rotation to the place the respective bolt needs to resist the torque was determined in feet. The actual force that the bolt needs to withstand was calculated by dividing the torque by that distance. With this force, the shear strength of the bolt, and the cross sectional area of the bolt, the number of bolts needed to resist the torque could be calculated. As shown above, the number of bolts needed to resist the 200 ft-lbs of torque for both points of failure is less than one meaning that we have design freedom to choose how many bolts to use and they withstand the torque.

Our design involves multiple scientific disciplines. Solid mechanics is critical to the stress and shear calculations for the bolts. Fluid dynamics plays a role in minimizing pressure drop across the filter, which ensures that the adapter does not hinder engine performance. Dynamics is also relevant, as the design must endure vibration and shock during vehicle operation. Materials science will help guide the selection of components that can withstand exposure to harsh chemicals, high temperatures, and environmental conditions to meet IP69K standards.

To validate our concept, we will conduct torque testing with an impact drill to confirm the bolts can handle 200 ft-lbs. Shop air testing will validate that the adapter does not introduce excessive pressure drop across the filter. These empirical tests will provide early evidence that our design meets key engineering specifications.

After arriving at and verifying our alpha design idea we met with both our project sponsor and the Mechanical Engineering Machine Shop in order to identify any further design problems. After meeting with *Donaldson*, they urged us not to put holes in the gasket as they did not know how that would affect the sealing ability which would violate our pressure and IP69K requirements. We then met with Don Wirkner from the Mechanical Engineering Machine Shop to determine any potential issues with our design from a manufacturing perspective as we will

have to manufacture our chosen design. In this meeting we were told to decrease the height of the bottom cylinder to no more than 3.33” due to the maximum drilling depth of the bit needed for the thru holes. He also urged us not to have any radii smaller than 0.5” for the internal geometry due to the end mill we would use to hollow the cylinder out. Below in *Figure 15* is the iterated design to accommodate this feedback from Donalson and Don Wirkner.

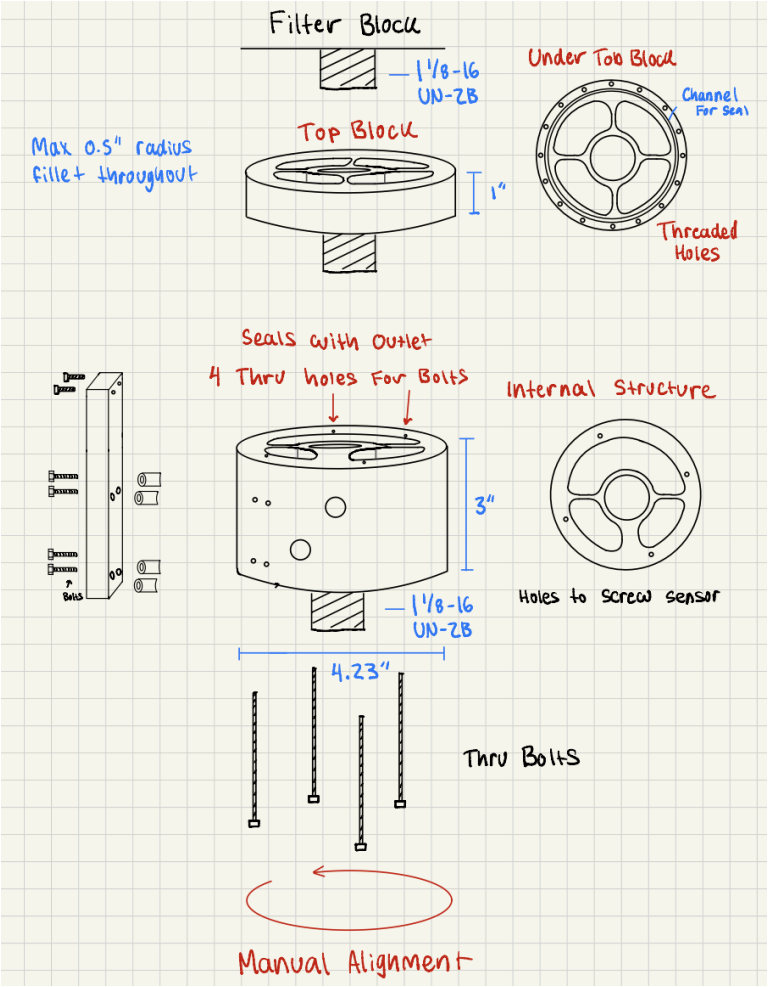


Figure 15: Final Alpha Design Drawing

Additionally, due to the first principles analysis conducted previously we can reduce the amount of thru bolts to 4 which helps with the ease of installation requirement. Due to still having 16 threaded holes in the top cylinder the adjustability would remain the same.

Upon completion of the final CAD design. It was also necessary to do a flow analysis to verify that the change in internal geometry between our design and the existing Donaldson filter does not result in excessive pressure change. This is necessary as one of the sensors used in our adaptor monitors pressure and in order to obtain relevant data this pressure must be similar to that of the existing filter without our adaptor installed. As outlined in our requirements and

specifications, our design must not contribute more than 2psi at an initial flow rate through the filter or 80 liters/min.

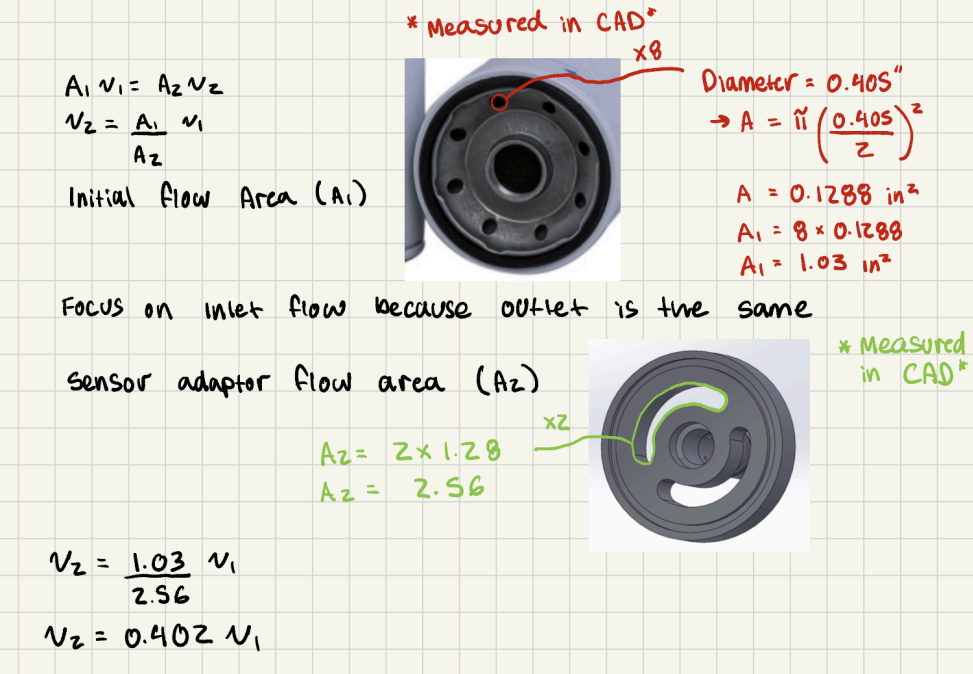


Figure 16: Velocity change through filter adaptor design.

Figure 16 above calculates the velocity through our adaptor as a function of the initial velocity. This can be done knowing the initial area of the Donaldson filter in which the oil can flow through and the area in which oil can flow through our filter design. This ratio is determined based on the fact that the same fluid must flow through each area thus $A_1 \cdot v_1 = A_2 \cdot v_2$. These calculations result in v_1 being 0.402 times v_2.

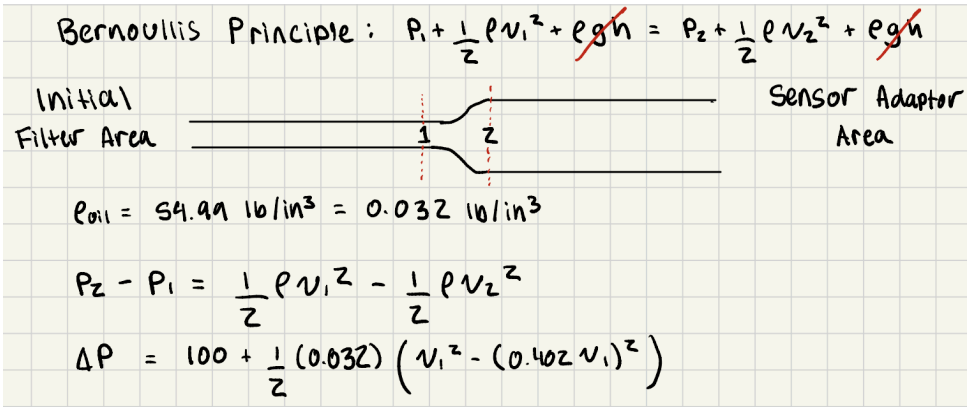


Figure 17: Bernoulli's Equation to determine change in pressure as a function of initial velocity.

Using this ratio and Bernoulli's Principle, the pressure increase as a result of our adaptor design can be calculated which is shown above in *Figure 16*. For the purpose of these calculations

position 1 is defined to be flow through the Donaldson filter and position 2 is defined to be the flow through our sensor mount design. Plugging in the constant density of oil into Bernoulli's Equation and isolating P_2 - P_1 we are able to find an expression for ΔP, the change in pressure as a result of our sensor adaptor. Knowing the relationship between v_1 and v_2, as calculated previously, we are able to write this expression in terms of one unknown, v_1.

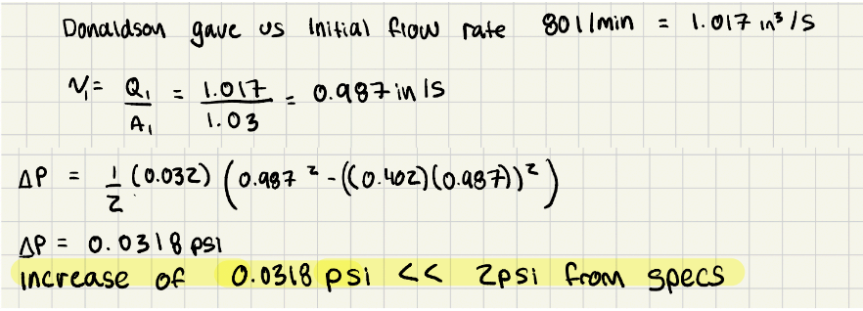


Figure 18: Bernoulli's Equation to determine change in pressure.

Knowing the initial flow rate provided by Donaldson and the initial area of the Donaldson filter, the initial velocity, v_1 can be calculated. Using this value and plunging into the equation found in *Figure 17,* the increase in pressure as a result of our sensor adaptor design was calculated in *Figure 18.* Due to the increase in pressure being much less, 0.03818 psi, than the 2psi allowed by our specifications the design can be verified from a fluid flow perspective. Additionally, *Donaldson* is concerned about whether the addition of our adaptor will prohibit the flow from the perspective of the pump being able to push the oil throughout the unit. We do not see this as a concern due to the fact that the area the fluid is pumped through is smaller than that of the oil filter inlet and the additional length that it would need to be pumped through is small in comparison to the various filters *Donaldson* installs on this oil head. For these reasons we do not see this as a concern as it relates to our sensor adaptor design.

Throughout our project, our design has undergone numerous changes and iterations based on recommendations from peers and our sponsor. Initially, we conducted primary research and analysis, which allowed us to create a rough sketch of our alpha design, shown in *Figure 15*. This design featured two stainless steel cylinders: one screwed into the oil header, and the other used for sensor placement and the locking mechanism. The initial CAD model of this alpha design is depicted in *Figure 19.*

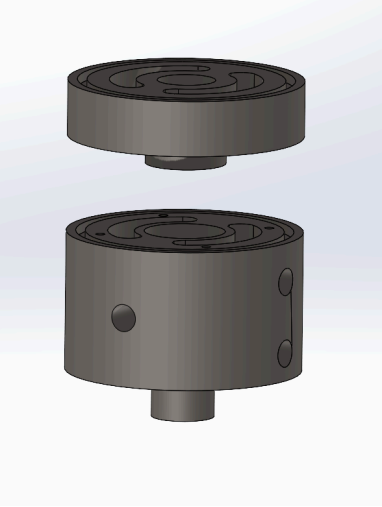


Figure 19: Initial CAD model of alpha design.

However, significant changes were necessary after our sponsors raised concerns about the product's weight. The heavy steel block could potentially damage the oil header, violating one of our requirements. To reduce weight, we decided to use a less dense material. We chose aluminum for its chemical resistance and lower density. Nevertheless, a fully aluminum product would result in weak male and female threads, unable to meet the torque specifications. Additionally, peers highlighted concerns about thermal expansion between the threads, which could weaken the seal. To address these issues while reducing weight, we developed a final design featuring an inner steel part for the threads and an outer aluminum part for the sensors and locking mechanism. The full design and description are detailed in the section below. The weight changes are illustrated in *Figures 19, 20, 21, and 22.*

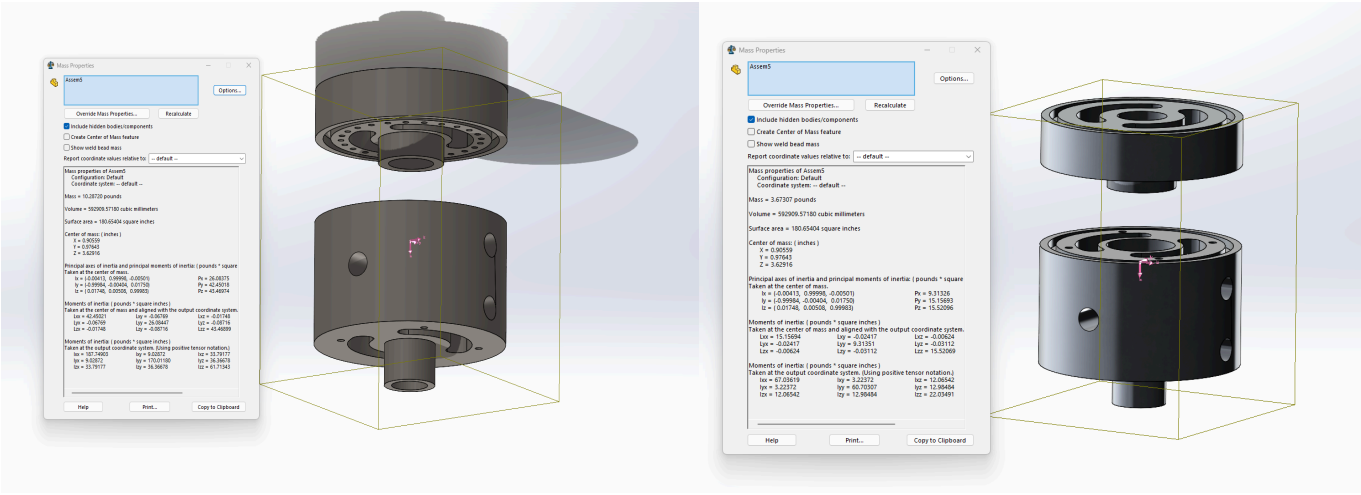


Figure 19 (left) 20 (right): Initial CAD design weight in Steel (left) and aluminum (right)

Shown above our initial design weighed 10.29 lbs in steel and 3.67 pounds in aluminum. The new design is shown below.

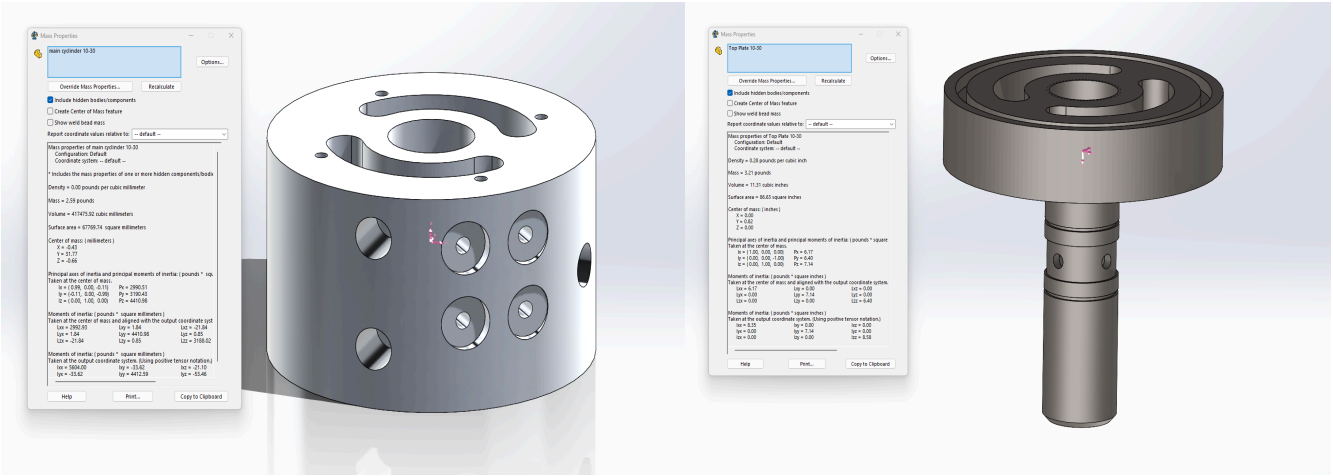


Figure 21 (left) 22 (right): Final CAD design of bottom aluminum part (left) and top steel part (right)

With the new design incorporating both aluminum and steel components, the final weight is 5.8 lbs, reducing the weight by approximately 50%. With this new weight, we and Donaldson believe that our product will not damage the oil headers and will meet the torque specifications.

From our work on the oil filter project, we learned several key lessons. Firstly, the complexity of locking mechanisms and sensor mounting solutions required us to innovate beyond existing market solutions, adapting and improving upon them to meet our specific needs. This process highlighted the importance of flexibility and iterative design, as we had to continuously refine our concepts based on feedback and testing. Additionally, the integration of multiple scientific disciplines, such as solid mechanics, fluid dynamics, and materials science, was crucial in addressing the engineering challenges we faced. Finally, collaboration with our sponsor and manufacturing experts was essential in identifying and resolving potential issues early, ensuring our design was both feasible and effective.

BUILD DESIGN/FINAL DESIGN DESCRIPTION

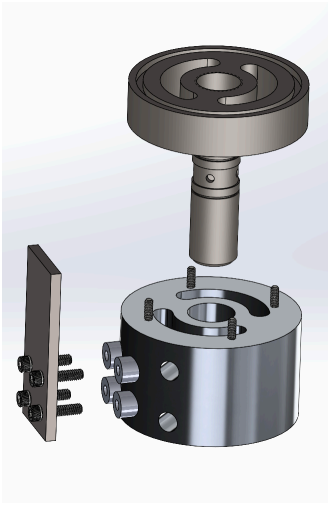


Figure 23: Final Design Solution featuring a three part assembly

The final design solution displayed in *Figure 23* is a culmination of multiple solutions to separate problems needing to be packed in a small environment. The design is divided into three sections. The top plate, shown in *Figure 24*, which is fastened to the oil head in the same place that an oil filter normally would, mimics the bottom of an oil filter, utilizing the same seal as Donaldson. On the shaft that is a part of the top plate, there are two notches that sandwich a recessed area with holes to the outlet. The notches are designed for HNBR O-Rings to seal the inner chamber that will ultimately be used to measure the outlet pressure. The bottom of the top plate, where the cylindrical adapter seals, is a mirror image of the side that seals to the oil header. There are 24 tapped holes that allow for adjustability, and the same seal that is used in Donaldson's oil filters. On the bottom of the shaft, it is tapped with the 1⅛-16 UN-2B threads exhibited on the oil head where the oil filter will be screwed into.

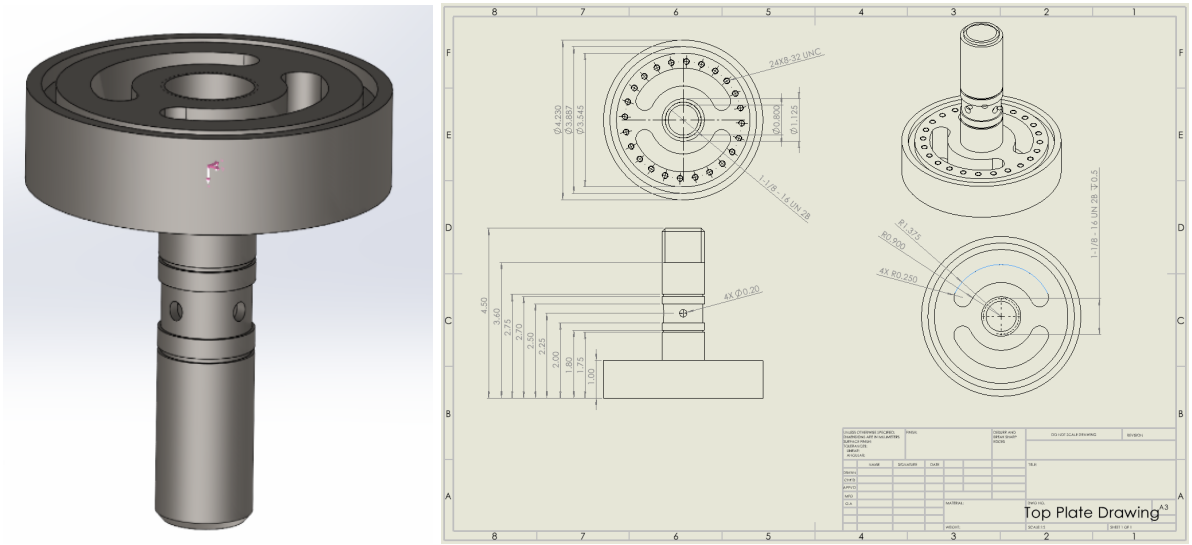


Figure 24: Top Plate and Engineering Drawing

The part shown above in *Figure 24* is made of A1018 Steel. This was selected due to it sharing the same coefficient of expansion as the threads on the oil head, as well as the fact that this grade of steel is machinable in the ME450 Machine Shop (all of our threaded interfaces are steel, ensuring their strength and compatibility). The ability to withstand pressure and seal the outlet from the inlet oil chambers is one of the most vital constraints of our design, meaning seal selection is extremely important. The seals used on the bottom of the Donaldson oil filter are tested and known to work with all of our constraints, therefore we utilized those where we could. The second seal that is as important is sealing the pressure chamber which separates the inlet and outlet oil. For this seal selection, we utilized the same seal catalog that Donaldson uses, which outlines every best use for O-Rings and what their capabilities are. Using a table describing various metrics of an O-ring seal material, we selected the four that relate to our design. As outlined in *table 4*, HNBR performs the best according to our specifications. We selected an HNBR O-Ring that fits in the two channels and will seal the inlet and outlet oil chambers.

	Cold Resistance	Heat Resistance	Oil Resistance	Tensile Strength
HNBR	Good	Excellent	Excellent	Excellent
NBR	Good	Good	Excellent	GE
Silicon	Excellent	Excellent	FG	Poor

Table 4: Condensed Table of O-Ring materials and their suitability

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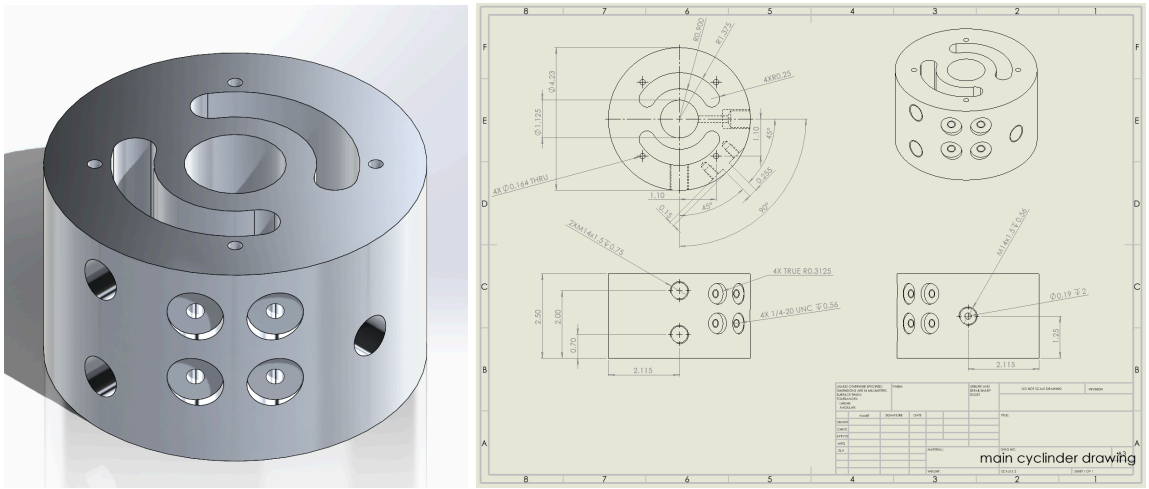


Figure 25: Main Cylinder and Engineering Drawing

The second part to the assembly, shown in *Figure 25* is the cylinder that will be used to measure the differential pressure and oil health, along with securing the locking mechanism to keep the adapter in place during an oil change. This piece is made of 7075 Aluminum, which was recommended to us by Donaldson for its strength, price, light weight, and ease of

manufacturability. The design features three access points for the sensors to screw into, with the port on the right side of the picture extending through the support and into the inner circle where the outlet oil travels. When installed, the inside diameter of the cylinder seals around the O-Rings on the shaft of the top plate. This creates a pressure chamber which allows for the measurement of the outlet pressure. Four through holes on the cylinder improve adjustability along with dispersing even pressure on the seal to the top plate. There are four recessed holes that are guides for the spacers between the main cylinder and the locking mechanism, which are concentrically aligned on the tapped holes for fastening.

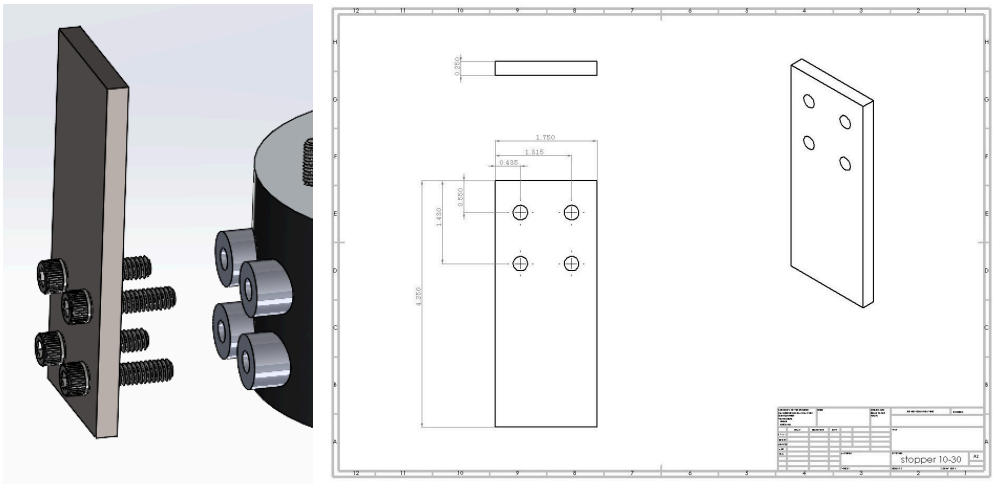


Figure 26: Locking Mechanism and Engineering Drawing

The locking mechanism, along with the screws and spacers, is displayed in *Figure 26*. This piece is also made of A1018 Steel, as it must withstand the 200 ft-lb torque requirement. The space constraint of our design restricts the ability for a technician to install the locking mechanism when the main cylinder is fastened into the truck. Therefore, the design allows the installation to happen prior to the main cylinder being fastened to the top plate, and then adjusted as needed. Once it is clamped down and installed, the top part of the block rests against the oil head and resists the rotation.

Upon installation and engine ignition, the oil will flow through the outer chambers of the adapter. The two sensors, one inlet pressure sensor and the oil health sensor, will measure their respective data. The oil will then flow through the oil filter, and out through the outlet chamber of the adapter. When this happens, the oil will fill the pressure chamber which will be read on the outlet pressure sensor. The flow of oil will be continuous and not be restricted by the adapter as analyzed prior. Once the oil filter needs to be changed, a mechanic will proceed with the oil change as they normally would, as the adapter is designed to not interfere with the standard process. The locking mechanism will ensure that when the 200 ft-lbs of torque that the adapter could experience from the removal of the oil filter is applied, the adapter will not move. Similarly, the product will not move when the oil filter is installed.

The manufacturing process for the sensor mounting adaptor involves several machining operations. Initially, the steel cylindrical stock is turned down to the required outer and inner diameters. This step needs to be done prior to working on the aluminum part because it is easier to precisely bore a hole in the aluminum piece so that the steel piece fits in snugly. Grooves are precisely cut into the reduced-diameter section of the steel cylinder on the lathe to fit O-rings, ensuring effective sealing. An additional groove is machined into the base of the assembly, either on a lathe. Then, additional slots are cut into this piece with a ½" end mill, and precise screw holes are drilled and tapped on the milling machine. Separately, the aluminum cylindrical stock is turned on a lathe to achieve the specified outer diameter. A boring operation on the lathe is then performed to remove the central material, creating a cavity to accommodate the steel insert. Slots are milled using an extra long ½" end mill to specified dimensions, and additional features, such as spacer holes, sensor mounting holes, and threaded holes for screws, are drilled and tapped on a milling machine for accurate alignment. These steps ensure accurate dimensional tolerances, fit, and functionality for secure sensor mounting and sealing.

BILL OF MATERIALS

Part No	Part Title	Material	Dimensions	Supplier	Quantity	Price
1	Round Aluminum Stock	7075 Aluminum	4.5" D x 3" L	OnlineMetals	1	$119.65
2	Round Steel Stock	A1018 Steel	4.25" D x 6" L	OnlineMetals	1	$222.47
3	Long Thru Bolts	316 Stainless Steel	8-32 Thread 4" L	McMaster	4	$13.56
4	Stopper Plate	7075 Aluminum	1/4" T x 2" W x 7" L	OnlineMetals	1	$32.30
5	Stopper Bolts	316 Stainless Steel	1/4-20 Thread 2" L	McMaster	4	$4.11
6	Donaldson Gasket	Hydrogenated Nitrile Rubber	4.35 OD x 3.545" ID	Donaldson	2	Provided
7	Concentric O-ring	HNBR	2 1/16" OD x 1 1/4" ID	The O-Ring Store	2	$5.70

Figure 27: Bill of materials for sensor mount design

The bill of materials pictured in *Figure 27* above includes seven items sourced from OnlineMetals, McMaster, Donaldson, and The O-Ring Store. Key components are the Round Aluminum Stock and Round Steel Stock, both from OnlineMetals, costing $119.65 and $222.47, respectively. The steel selected to use is A1018 and the aluminum is 7075 both materials were chosen due to being used by Donaldson and thus can withstand the harsh environmental conditions. Additional parts include Long Thru Bolts and Stopper Bolts from McMaster, a Stopper Plate also from OnlineMetals, and two types of gaskets: a Donaldson Gasket provided by Donaldson and a Concentric O-ring from The O-Ring Store. The total cost of materials, fasteners, and gaskets listed above is $397.79 just below the $400 budget for this project. With that being said certain tools for manufacturing will need to be purchased on top of these materials however Donaldson has expressed to our team the costs associated with these should not be deducted from our overall budget. These required tools are listed below.

Additional Tools Required for Manufacturing:

- Extra long end mill (1/2" width, 4.5" length)

- 1 1/8 - 16 MSC tap
- Aircraft length #10 drill bit

VERIFICATION AND VALIDATION PLANS

Verification Plans

Specification	Verification Plan	Limitations	Contingencies	Justification
Dust & water ingression (IP69K Standard)	Passes IP69K rating test using pressure washer and sand bath to verify	Water temperature (80°C) limitations	Send to IP69K rating body and let them perform designed tests	Pressure washers are able to easily get up to 1600 psi. We believe the pressure and sand are more important than temperature.
Torque (200 ft-lbs)	Use an impact wrench to apply torque to design and observe if fails	We will need to figure out a fixture to attach an impact wrench to our design	We could deliver 200 ft-lbs given a lever of known length and mass	Some impact wrenches can deliver up to 500 ft-lbs
PSI (100psi & 300psi bursts)	Pressurize design using shop air	How to attached and seal ports sealed by oil filter	Submerge in water 231’ deep and check for water ingression	Air will leak before oil, and pressures are higher than what will be faced while in use
Must be compact	Find a Volvo/Mack truck to ensure that our design fits within the space available.	We might not be able to find a local truck that would allow us to install our design.	Create a cardboard mock of space available to ensure it fits.	Our design will have to fit into the constraints of the engine. We have been designing with these constraints in mind however verifying would ensure nothing was overlooked.

Table 5: Engineering Verification Plans

Table 5 above outlines the most critical validations plans necessary for this project that we can test if the scope of our project included manufacturing the final product. Unfortunately, we were unable to manufacture a prototype, and had to settle for a 3D printed model. The full table with all verification plans is in the appendix. To justify the verification methods chosen for each specification in Table 5, each was selected to balance practical feasibility with alignment to the relevant performance requirements. For dust and water ingress (IP69K standard), the best method identified was a pressure washer and sand bath test, as this replicates the high-pressure, abrasive conditions the design will face in the field. We assume that IP69K testing at lower temperatures (around 80°C rather than the standard’s upper limit) would still validate the design,

as the pressure and sand exposure are considered more critical. The main limitation is that we cannot fully replicate the exact IP69K conditions in-house, so sending the design to an IP69K rating body was considered as a contingency. Our preliminary results suggest that the design should be capable of meeting the IP69K requirement due to the robust construction and materials selected.

For torque testing, we initially planned to use an impact wrench that can deliver the required 200 ft-lbs, simulating real-world force application during filter removal. However, the limitation here is the need to devise a custom fixture to secure the impact wrench properly. Therefore, our contingency plan is much less involved, and simply requires us to deliver torque with a lever of known mass and length. This test would provide a reliable simulation, and, coupled with the fact that initial tests show that the design is resistant to the required torque levels, gives us great confidence that if our design passes this test it will perform properly when in-use.

To verify the design's ability to withstand pressures up to 100 psi, and 300 psi bursts, we plan to pressurize the design using shop air, which is readily available and safe for initial testing. Since the ports are sealed by the oil filter, we will ensure a tight seal under pressurized conditions. Submerging the design in water at a depth of 231 feet served as a contingency to check for water ingress (231' deep = 100 psi). This approach assumes that air leaks will appear before oil leaks, which is a valid assumption due to oil's higher viscosity and lower volatility. The results from these tests will indicate that the design exceeds typical operational pressures, confirming its robustness for real-world use.

For the compact requirement, we plan to use a mockup with a foam model to verify space compliance within a Volvo/Mack truck engine bay, simulating the adapter's fit and alignment with space constraints. While it would be ideal to use an actual truck, logistical challenges make this challenging, so the mockup will provide a reasonable approximation. We expect that the design's dimensions fit within the acceptable range, giving confidence that it will integrate seamlessly with the engine components.We also plan to bring this mockup to the Design Expo to show functionally how little space we were given to work with.

For specifications not tested directly by us - such as extreme temperature resistance, salt spray corrosion, vibration, shock, pressure drop, and long-term durability - we relied on engineering analysis and material selection. The adapter uses materials that meet industry standards for these conditions, as validated by similar applications in Donaldson's other products. For example, the selected materials are known for their high-temperature resistance, corrosion resistance, and mechanical stability, which suggests they will perform reliably under specified conditions. Experience with similar designs by Donaldson reinforces our confidence that the design will meet these requirements. Donaldson's planned in-house testing for these specifications further assures stakeholders that the adapter will meet the needed durability and resilience standards.

In summary, the verification processes will confirm whether the adapter meets most critical requirements, giving us high confidence in its overall compliance with the project specifications. While certain tests (e.g., for vibration, extreme temperature, and long-term durability) remain to be completed by Donaldson, initial mathematical analysis demonstrates that the adapter is robust, with each tested component meeting or exceeding performance expectations. Stakeholders can be confident in this approach, as the adapter leverages proven engineering standards and practices and will undergo further validation with Donaldson's in-depth testing to confirm any untested specifications. Moreover, almost all of our specifications will be verified by a combination of material selection, engineering analysis, proven designs in industry, and/or a verification test, and thus stakeholders have 2+ sets of proof that our design will work.

Validation Plans

Question	Validation Method	Testing Plan	Testing Metric	Justification
Will the adapter be able to be installed within 30 minutes?	Usability Testing	Deliver sensor mount and instructions to a technician and have them install it	Is the installation time less than or equal to 30 minutes?	The technician will not have prior knowledge of how to install our design
Does the data obtained through the sensors help customers?	Financial Analysis	Compare the amount a customer was spending on filters before having proper filter fitting using out sensor mount to what they spend after.	Look through historical financial records and compare to what they spend over the period of a month.	The main benefit to our design is being able to extend the life of filters for customers which would validate why this design was helpful
Will the design be able to handle below average road conditions?	In-use Testing	Install adapter and drive truck on poor road conditions	Does the device function properly?	Driving on roads with large potholes and bumps will provide below average road conditions

Table 6: Engineering Validation Plans

Table 6 above outlines the validations plans necessary for this project. Validation plans are important to ensure that once the product is in use, it satisfies the design issue, doing what it was designed to do. First, to determine if the adapter can be installed within 30 minutes, a usability test will be conducted by providing a technician with the sensor mount and instructions to install it. The success metric is whether the installation takes 30 minutes or less. This method is justified by the fact the technician lacks prior experience with this design, if this technician can install the sensor adaptor in the required timeframe it can be assumed a Donaldson technician would also easily be able to do so. For our scope of the project, we were able to test the installation time of the product, utilizing the installation guide and moving slower than the average person to add additional time as a safety factor. The installation time was just over 3 minutes, which is well below our requirement of under 30 minutes additional time to the standard oil change process. Second, to assess whether the data gathered from the sensors benefits customers, a financial analysis will compare customers' spending on filters before and after using the adapter, based on historical financial records. This validates that the adapter helps extend filter life. Lastly, to

ensure the design's durability under poor road conditions, an in-use test will involve driving a truck equipped with the adapter on rough roads for the intended use period of the sensor adaptor. The success metric is the adapter's continued functionality, with the justification that harsh road conditions simulate below-average scenarios.

DISCUSSION

Problem Definition

If we had more time and resources, we would have been able to create a functional final product manufactured out of steel and aluminum. With a toleranced final product, we could test all our requirements and specifications to ensure that our product performs as intended. These testing processes require significant time and specialized equipment, which we do not currently have access to, so the manufacturing and testing will be completed by Donaldson. We would also study the long-term durability and performance of the adapter under real-world conditions through extended field testing and accelerated life testing. Furthermore, we would work more closely with other stakeholders, particularly truck operators, to gather insights and identify any additional features they would like included in the product. By addressing these questions and using these methods, we could develop a more robust, efficient, and user-friendly oil filter adapter that passes all tests and meets customer needs.

Design Critique

Our design has several strengths and weaknesses. One of the primary strengths is the effective use of multiple materials to achieve lower weight while maintaining thread strength. We also had successful iterations that demonstrated progress through various challenges and new information. Additionally, our design is highly durable and passes all stress and shear calculations with flying colors. However, there were some weaknesses. We did not have a specific target number, which limited our weight reduction efforts. The manufacturing process also generates a significant amount of waste with our inner shaft. In hindsight, we could have improved our design by setting more precise targets and exploring alternative manufacturing methods to reduce waste. In the future, weight could be further reduced by removing excess material from the product's walls. We could also redesign the top plate into two parts to minimize waste and lathe time. This could be achieved by welding two separate cylinders together to ensure a strong connection.

Risks

During our design process, we encountered several challenges. The weight of our product was a concern because it would be installed on a moving vehicle and would experience vibrations and shocks, which could cause dislodging or damage to the thread. Finding a suitable locking

mechanism that met our torque requirements was difficult, and ultimately we had to use a mechanical stop, which increased the weight and added an additional part. Adjustability was also an issue, as the thread did not always end up in the same place, and we needed it to fit within a 110-degree radius due to space constraints. We addressed these challenges by carefully selecting materials, optimizing the design to minimize weight, testing various locking mechanisms, and ensuring that we had enough threaded holes to provide a lot of adjustability. The risks associated with our final design include potential oil leaks, damage to the oil header, the filter or adaptor falling off, and unreliable sensor data.

REFLECTION

Relevant Factors

The project significantly impacts public health, safety, and welfare by ensuring diesel engines operate efficiently and reliably. Introducing a new product into a diesel engine requires careful consideration to avoid oil leaks or engine damage, which could pose a danger to the public. Additionally, providing real-time data on oil condition and differential pressure helps prevent engine failures and reduces the risk of accidents caused by oil overuse. On a global scale, the design benefits the marketplace by offering a modular solution adaptable to various truck fleets worldwide. Improved diagnostics can lead to reduced operational costs and enhanced environmental sustainability, aligning with global environmental standards. The manufacture, use, and disposal of the design have several social impacts. Manufacturing the adapters creates jobs and supports local economies. The product improves fleet efficiency by reducing the number of filters needed, demonstrating Donaldson’s commitment to customer care over maximizing oil filter sales. Although our product will not be mass-manufactured, proper disposal of the sensors and adapters remains important to minimize environmental impact. Economically, the project reduces maintenance costs for fleet operators by optimizing oil and filter replacement schedules. This leads to cost savings and extends the lifespan of engines, providing significant economic benefits to companies operating large fleets. To characterize the potential societal impacts, we used stakeholder maps to identify key stakeholders and their relationship to our product. Life cycle costing on large fleets was conducted by our sponsors to evaluate the savings our stakeholders might achieve by using the product.

Team and Sponsor Dynamics

The cultural, privilege, identity, and stylistic similarities and differences among our team members shaped our approaches by bringing diverse perspectives and innovative solutions. Drawing from our previous internship and project experiences, we were able to consider various viewpoints and leverage each other's strengths and weaknesses, ensuring efficient teamwork. Our design processes were influenced by cultural and power differences with our sponsor, requiring

us to align our solutions with their expectations and standards. We had to ensure our design met their technical requirements while considering our class constraints. This also provided a fresh perspective on the project, allowing us to avoid decisions based solely on past solutions.

Inclusion and Equity

Power dynamics existed between our team, sponsor, and class, forming a triangle where each had influence over the others. The sponsor set the requirements and specifications, the class determined the calendar and deliverables, and we made the design decisions. Our identities and experiences shaped our perspective, making us more aware of the practical challenges faced by end users. We included diverse viewpoints by actively seeking feedback from all stakeholders and classmates, ensuring everyone's ideas were considered. We balanced different viewpoints by discussing and evaluating each idea's feasibility and impact. This collaborative approach ensured that the best solutions were selected to inform the project. Cultural similarities and differences among team members influenced our approaches by bringing in varied problem-solving techniques and perspectives. These differences enriched our design processes and final product by incorporating a broader range of ideas and problem-solving methods.

Ethics

We faced ethical dilemmas related to ensuring the accuracy and reliability of our product, which we managed by adhering to Donaldson’s strict testing protocols and quality standards. If the product were to enter the marketplace, we do not foresee any ethical issues, as our product aims to reduce waste. Our personal ethics align with the professional ethics upheld by the University of Michigan and future employers, emphasizing integrity, responsibility, and respect for all stakeholders. Maintaining these ethical standards was crucial throughout the project to ensure a certain level of trust between the University, the team, and Donaldson.

RECOMMENDATIONS

Based on our experiences in the project, we have several recommendations for our sponsor to address system-level and detailed-level issues, as well as to mitigate the risks identified in the discussion section. System-level recommendations revolve around material selection and stakeholder engagement. Exploring the use of aluminum or other lightweight materials for the entire product would allow for a simpler and lighter design. Engaging more with other stakeholders would provide insights and recommendations that the sponsor and school could not offer. Detailed-level recommendations include weight reduction, optimizing the manufacturing process, and improving the locking mechanism. In the future, weight could be further reduced by removing excess material from the product's walls. The manufacturing process generates a

significant amount of waste with our inner shaft. We recommend exploring alternative manufacturing methods to reduce waste, such as redesigning the top plate into two parts to minimize waste and lathe time. This could be achieved by welding two separate cylinders together to ensure a strong connection. Finding a suitable locking mechanism that met our torque requirements was difficult, and ultimately we had to use a mechanical stop, which increased the weight and added an additional part. We recommend continuing to explore and test various locking mechanisms to find a more efficient solution that meets the torque requirements.. For risk mitigation, we need to address potential oil leaks, faulty sensor data, and the risk of the device falling off. By implementing these recommendations, we can develop a more robust, efficient, and user-friendly oil filter adapter that meets all requirements and specifications.

CONCLUSION

The purpose of this project was to design a robust and effective adapter to integrate oil condition and differential pressure sensors into Donaldson's existing spin-on oil filter systems. The primary challenge stemmed from balancing engineering constraints - such as space limitations, torque requirements, and environmental resilience - with the need for real-time data to optimize diesel engine maintenance. By addressing these challenges, the solution enables Donaldson's customers, particularly Mack/Volvo fleets, to reduce unnecessary maintenance costs, extend engine life, and improve fleet sustainability.

Our solution incorporates a double-mount sensor alignment system paired with a hook block locking mechanism. This design ensures ease of installation while meeting stringent torque requirements of up to 200 ft-lbs during oil filter changes. The adapter was engineered to withstand harsh environmental conditions, including exposure to extreme temperatures, chemicals, and vibrations, while adhering to IP69K standards for dust and water resistance. The final design features a combination of A1018 steel and 7075 aluminum, reducing weight by 50% (from a previous design iteration in which it was fully made of steel) without compromising strength or durability.

Verification analyses demonstrated the solution's effectiveness. Stress and shear calculations confirmed the adapter's ability to resist torque forces, and fluid flow analysis showed minimal pressure drop - well below the 2 psi specification - ensuring compatibility with Donaldson's filtration systems. Iterative feedback from Donaldson and manufacturing experts further refined the design, enhancing its feasibility and ease of production.

While the prototype was not fully manufactured within the project's scope, the design has been validated through rigorous engineering analysis and partially tested installation procedures, which demonstrated that installation can be completed in under 30 minutes. Additionally, the

product's modular design allows for adaptability across different truck engine models, positioning it as a flexible and scalable solution for Donaldson's customers.

In conclusion, this project successfully addresses the need for precise oil diagnostics in diesel engines while delivering a high-quality, durable solution. By enabling optimized maintenance schedules, the adapter promotes cost savings, resource efficiency, and environmental sustainability, aligning with both Donaldson's and their customers' operational goals. Future testing and field validation by Donaldson will confirm the full potential of this design as a critical innovation in fleet maintenance systems.

ACKNOWLEDGEMENTS

Team 18, the Filter Sensor Oil Adaptor team, extends our gratitude to the University of Michigan College of Engineering for providing us with the opportunity and resources to work on this project. We are especially thankful to the Mechanical Engineering department and Dr. Jonathan Luntz for their guidance and support throughout the project. Additionally, we would like to express our appreciation to our sponsor, Donaldson, with special thanks to our points of contact, Josh Durand and Matt Kalis, for their continuous assistance and encouragement.

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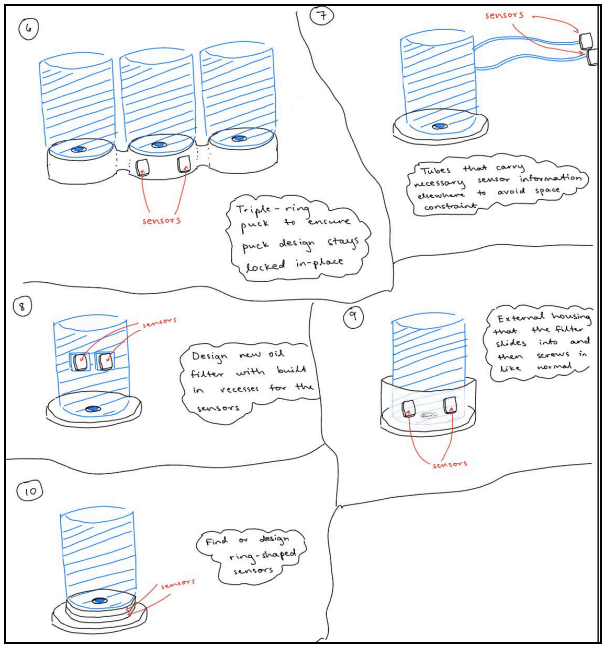
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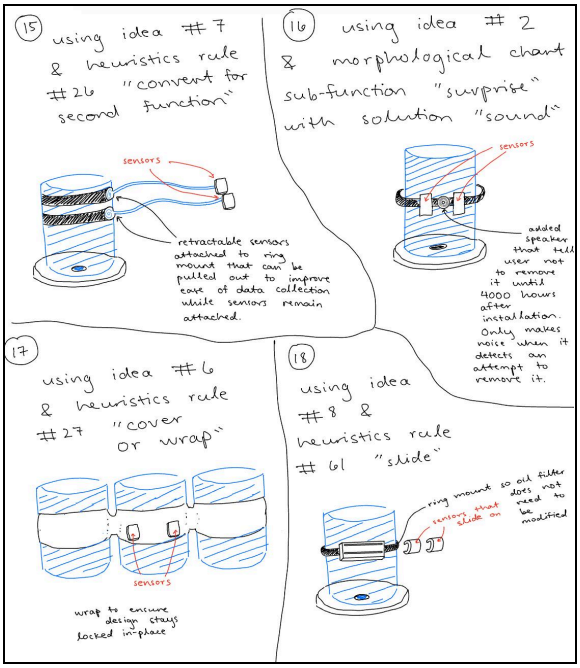
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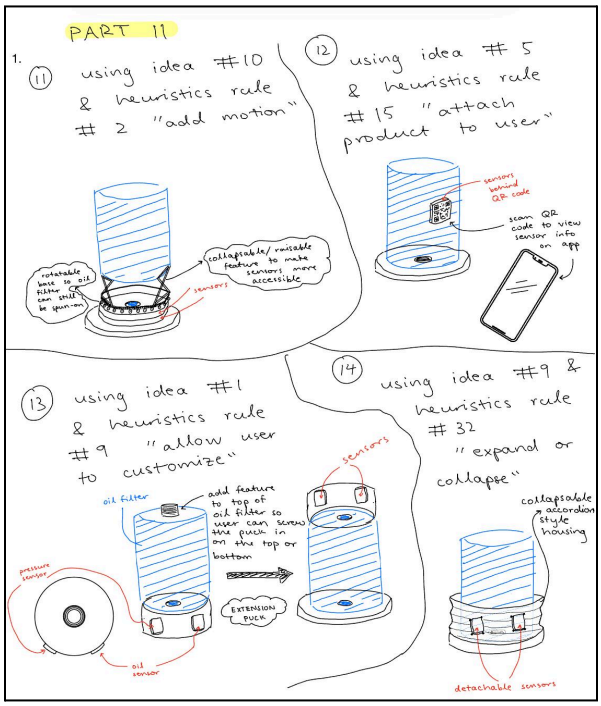
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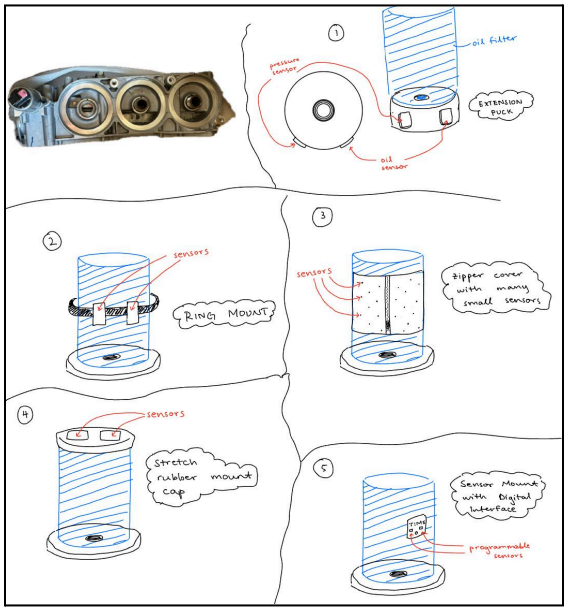
Verification Plans

Specification	Verification Plan	Limitations	Contingencies	Justification
Must withstand temperature range of -40°C to +125°C	Expose our prototype to temperatures within this range (freezer and oven) for 30 minutes	Time range may not be long enough, one of our freezers cannot get to -40°C	Expose our prototype to temperatures that we have access to for a 48 hour period using cold chamber and heat oven	We believe that freezer and oven temperatures will get us to a close enough range to feel comfortable with our design, given that our material selection also took this into account
Must withstand a 48 hour salt spray with no visual corrosion	Put prototype in sea salt bath for 48 hours	Sea salt bath does not have air or continuous added salt as a spray would	Send to Minneapolis so Donaldson can test it in their salt spray chamber	A sea salt bath presents a cost effective way to identify corrosion from water and salt
Must withstand system vibration and shock	Send to Donaldson to perform the vibration testing to company standards	This may occur outside the scope of the class	Attach to oil header given to us by Donaldson and perform various controlled vibrations available to us.	Donaldson will be able to perform a better vibration test than we will due to not having the proper machinery.
Minimal Reduced Pressure Drop	Calculate using fluid dynamics analysis	Theoretical analysis does not always correlate to real world use	Test differential pressure with and without sensor mounting adapter	Using first principles analysis with a factor of safety will lead to positive results
Must be durable	Utilizing same materials that Donaldson does in their Oil Filters	Theoretical analysis does not always correlate to a different use	Donaldson's lab will simulate 4,000 hours of use	Utilizing the same materials that Donaldson does that have been extensively tested will yield positive results


6
sensors
Triple-ring puck to ensure puck design stays locked in-place
7
sensors
Tubes that carry necessary sensor information elsewhere to avoid space constraint
8
sensors
Design new oil filter with build in recesses for the sensors
9
External housing that the filter slides into and then screws in like normal
sensors
10
sensors
Find or design ring-shaped sensors


15
using idea #7 & heuristics rule #26 "convert for second function"
sensors
retractable sensors attached to ring mount that can be pulled out to improve ease of data collection while sensors remain attached.
16
using idea #2 & morphological chart sub-function "surprise" with solution "sound"
sensors
added speaker that tell user not to remove it until 4000 hours after installation. Only makes noise when it detects an attempt to remove it.
17
using idea #6 & heuristics rule #27 "cover or wrap"
sensors
wrap to ensure design stays locked in-place
18
using idea #8 & heuristics rule #61 "slide"
ring mount so oil filter does not need to be modified
sensors that slide on


PART II
1.
11
using idea #10 & heuristics rule #2 "add motion"
rotatable base so oil filter can still be screwed
collapsable/raisable feature to make sensors more accessible
sensors
12
using idea #5 & heuristics rule #15 "attach product to user"
sensors behind QR code
scan QR code to view sensor info on app
13
using idea #1 & heuristics rule #9 "allow user to customize"
oil filter
add feature to top of oil filter so user can screw the puck in on the top or bottom
sensors
pressure sensor
oil sensor
EXTENSION PUCK
14
using idea #9 & heuristics rule #32 "expand or collapse"
collapsable accordion style housing
detachable sensors


1
oil filter
pressure sensor
EXTENSION PUCK
oil sensor
2
sensors
RING MOUNT
3
sensors
zipper cover with many small sensors
4
sensors
stretch rubber mount cap
5
Sensor Mount with Digital Interface
programmable sensors

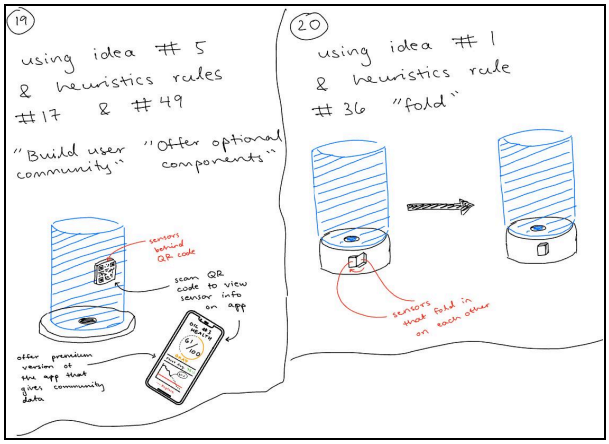
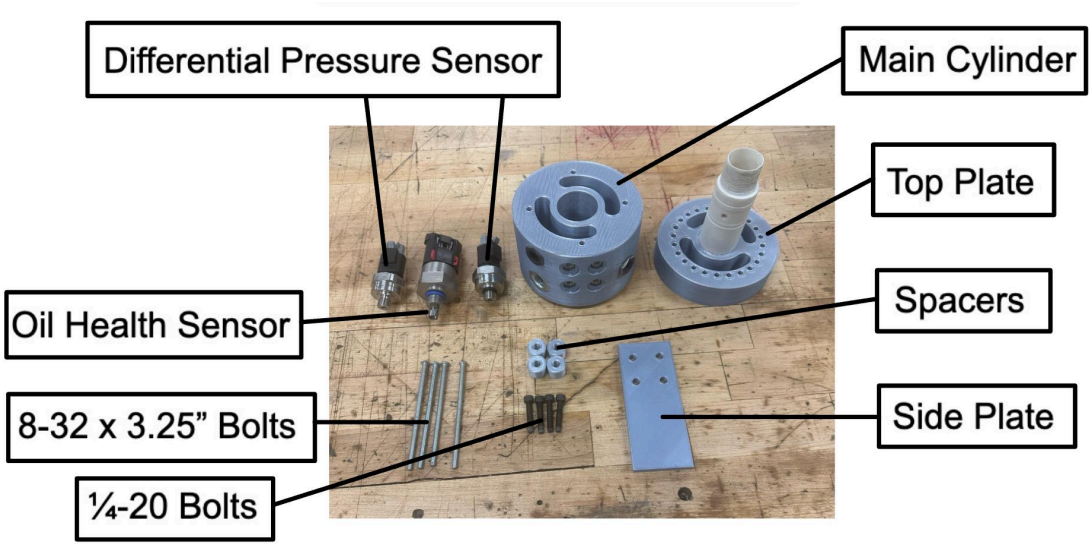


Figure 28: Concept generation from Learning Block

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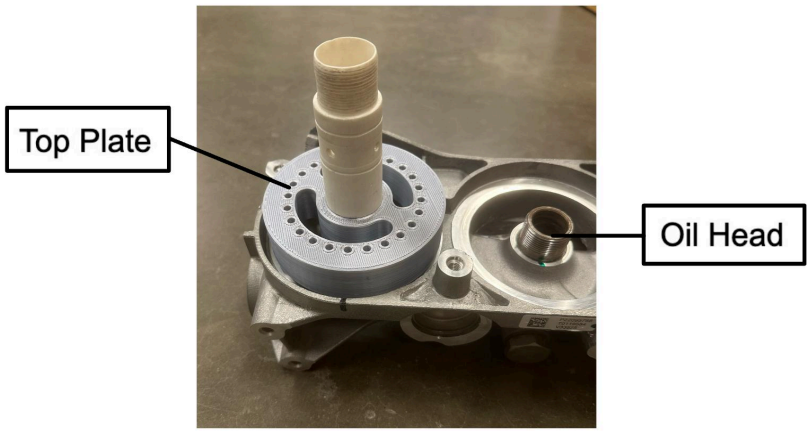
INSTALLATION GUIDE

The oil filter sensor adapter kit comes with a top plate, main cylinder, four spacers, side plate, and the necessary hardware components. Along with this, the two differential pressure sensors and one oil health sensor is included. Installation should take less than 30 minutes additionally to the standard oil change process.



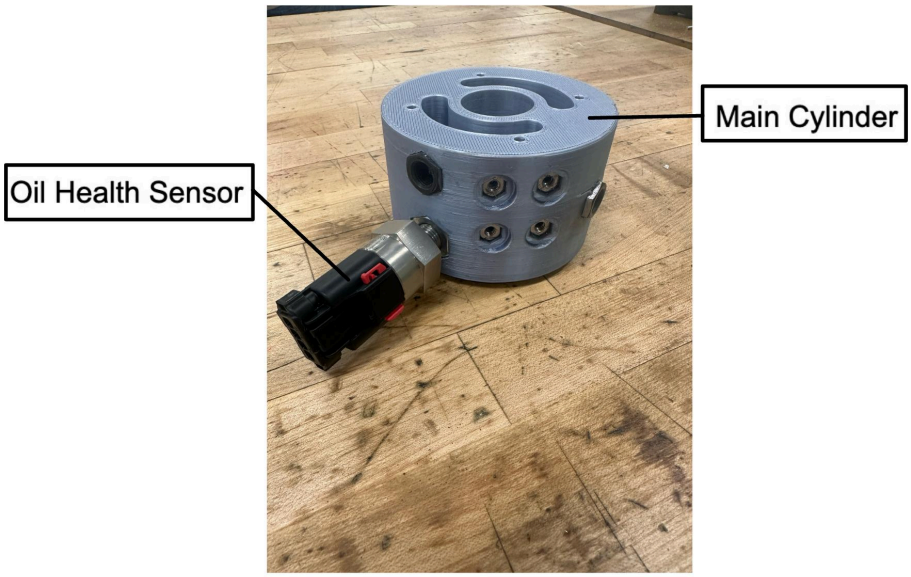
Installing the Top Plate

1. Locate the desired oil filter male thread that the adapter will be installed on.
2. Thread the Top Plate onto the oil header with the same amount of force as a standard oil filter.

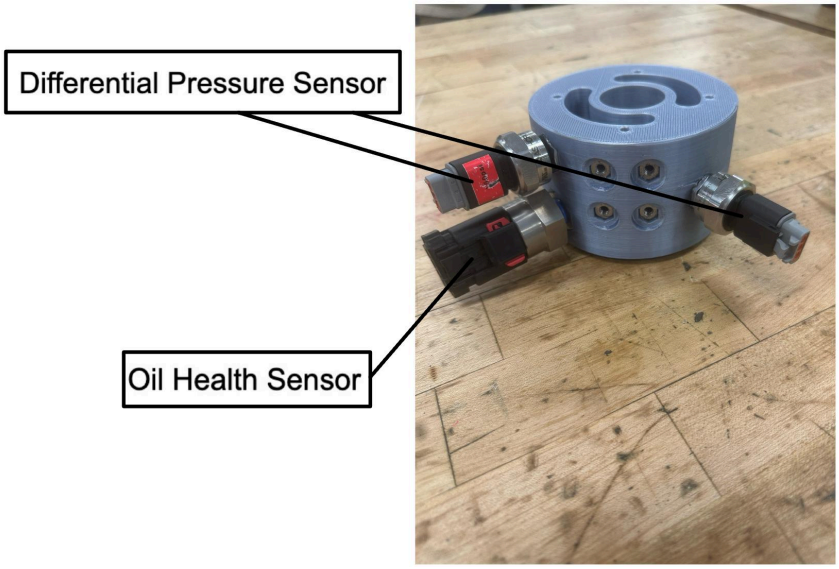


Installing the (3) Sensors and Side Plate to the Main Cylinder

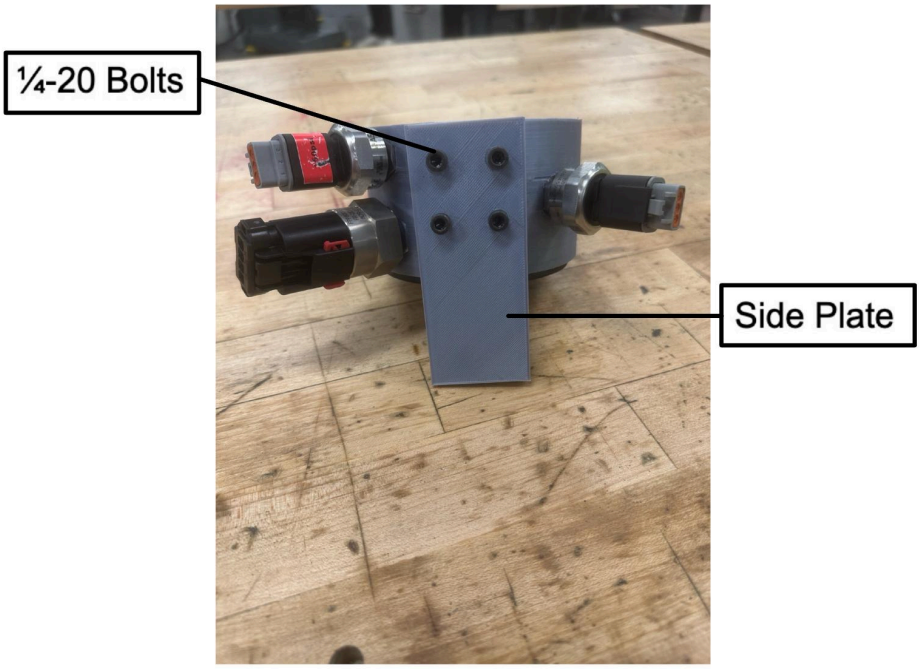
3. Locate the Oil Health Sensor (larger of the two types of sensors) and thread into the side of the main cylinder as shown below.

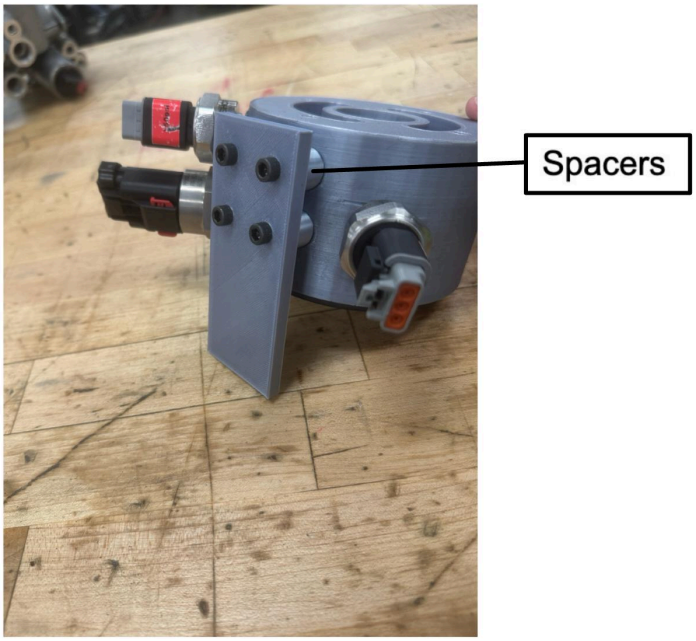


4. Locate the (2) Differential Pressure Sensors and thread them into the side of the main cylinder as shown below. The two sensors can be interchangeable, as one does not need to be specifically located at the inlet or outlet reading port.



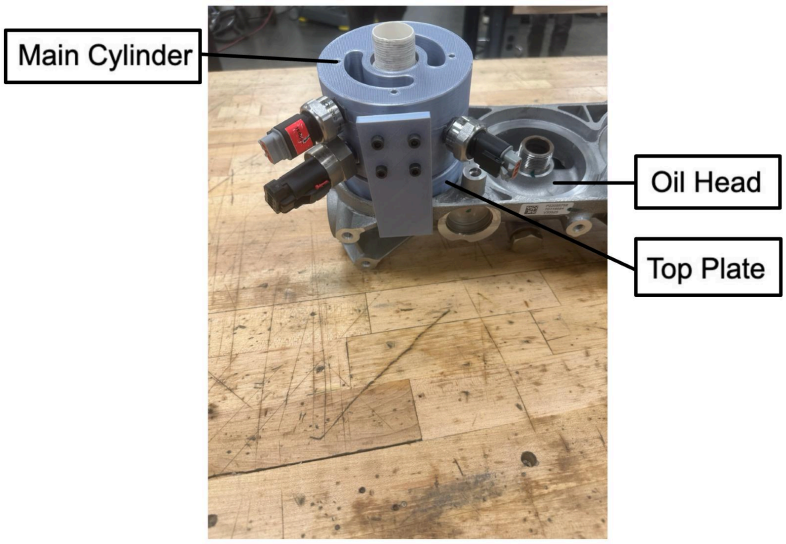
5. Locate the four ¼-20 bolts, in bag A, and insert them through the four holes of the side plate.
6. Slide a spacer over each bolt, and orient the side plate to extend over the side of the main cylinder that has the gasket on the bottom. Tighten the screws snug, securing the side plate to the main cylinder.



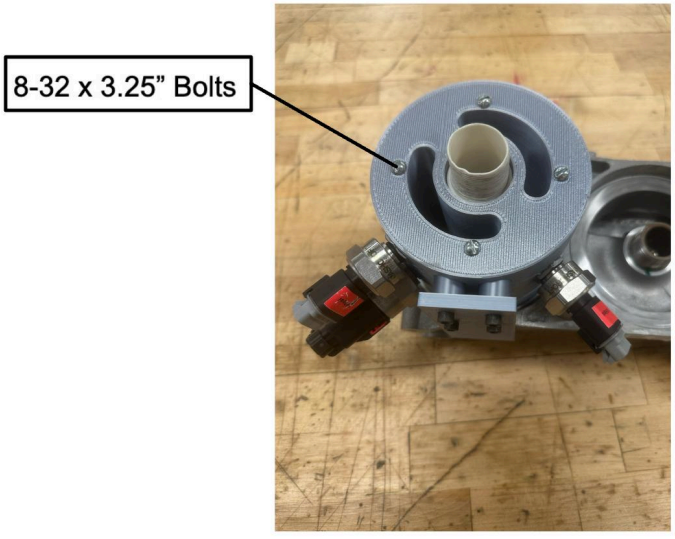


Install the Main Cylinder to the Top Plate

7. Slide the main cylinder over the shaft of the top plate, with the gasket contacting the top plate and the side plate facing outwards, towards the open area in front of the oil header.



8. Insert the four 8-32 x 3.25” bolts into the four holes on the bottom side of the main cylinder and rotate the main cylinder slightly until the holes on the top plate and main cylinder line up. Thread and tighten the four bolts with even pressure.
    a. **Note: The side plate must be flush with the oil header, therefore it may be necessary to tighten the top plate, compressing the gasket, in order to achieve this.**



9. Once installed, attempt to rotate the entire assembly clockwise (loosening) in order to determine if the side plate was installed correctly.

If:

a. Unit does not move, it is installed correctly.
b. Unit unscrews, repeat steps 7 through 9.

10. Start engine and run for five minutes to determine if there are any leaks.

If:

c. Unit does not leak, it is installed correctly.
d. Unit leaks, repeat steps 1 through 10.



BIOS

Jayden Mannisto:

My name is Jayden Mannisto and I am originally from Grand Cayman in the Cayman Islands. Outside of my professional and academic life, I enjoy fishing, diving, and playing golf. I am currently studying Mechanical Engineering at the University of Michigan, with an expected graduation in May of 2025. My interest in mechanical engineering is driven by my fascination with how systems operate and my desire to apply engineering principles to tackle real-world challenges. Throughout my academic journey, I've gained valuable hands-on experience through various internships and projects. For instance, last summer I worked as a technology consulting intern at *Ernst & Young*, where I played a role in a large-scale SAP implementation for a Fortune 500 power and utilities client. I also have collaborated on renewable energy research at *Technische Universität Berlin*, deepening my understanding of efficient energy systems. Looking ahead, I aspire to leverage my unique background and skills from mechanical engineering within the financial services sector helping drive innovation through technological solutions.

William Postma:

My name is William Postma and I am from Rochester Hills, MI. I am currently studying Mechanical Engineering at the University of Michigan and I am expected to graduate in the spring. My interest in Mechanical Engineering stems from my fascination with complex and technical problem solving. Thus far, I have interned in the automotive industry, focusing on mechanical design and electric vehicles, and the oil & gas industry, where I worked on multiple large scale facility projects. With my work and project experience I hope to apply these skills to go into project or product management where I can utilize my technical background as well as my communication skills. Outside of work and school I am an aspiring home chef as well as an advanced downhill skier. I also enjoy hiking outdoors and hope to move to the mountains one day.

Oscar Roden:

My name is Oscar Roden and I am from Sugar Land, TX. I am currently studying Mechanical Engineering at the University of Michigan and I am expected to graduate in the spring of 2025. I have always been fascinated by how things work, and growing up near Houston, surrounded by the energy industry and a strong culture of innovation, I naturally gravitated towards mechanical engineering. After my sophomore year, I interned in the civil engineering sector for a company called *Wade Trim*, where I assisted in the preparation of computer-drafted natural gas pipeline designs for DTE Energy and utilized Autodesk Civil 3D software to reproduce historic pipeline drawings. This past summer, I interned at *Kellanova*, where I was a process engineer specifically working on the *PopTarts*, *Rice Krispie Treats*, and *Pastry Crisps*. These experiences have led me to an interest in the consulting sector as I have realized I enjoy projects with a quick turn-around

and get bored easily working on one thing. Outside of school I enjoy playing a variety of sports including soccer and football, and I am currently working to walk-on to the Michigan football team as a kicker. I am also awaiting responses from several schools about kicking somewhere else for graduate school.

Ethan VanderRoest:

My name is Ethan VanderRoest and I am from Traverse City, MI. I am currently studying Mechanical Engineering at the University of Michigan, with an expected graduation in May of 2025. I am an avid backpacker and love to collect vinyl records. Throughout my life, my father and I have indulged in many different projects in our personal lives that have led me to be fascinated with the design and manufacturing process. This has led me to fall in love with mechanical engineering. Upon graduation, I aspire to move to the Pacific Northwest or Alaska to design backpacking gear including ultralight tents, backpacks, and cookware for some of the largest backcountry brands in the world. Throughout my academic career, I have interned at two companies: Cone Drive Inc. in Traverse City and Davco Technologies in Saline. Through these two internships, I have gained extremely valuable knowledge on research and design methods along with working in a lab.