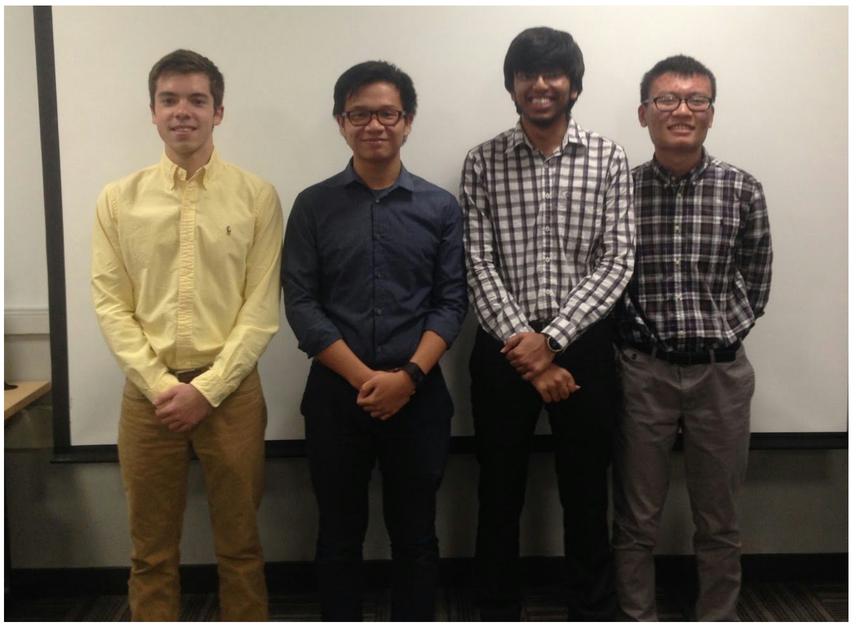
http://www.personal.psu.edu/fzg5058/EDSGN100/edsgn100_fa15_section10_team5_dp2.pdf

EDSGN 100: Introduction of Engineering Design

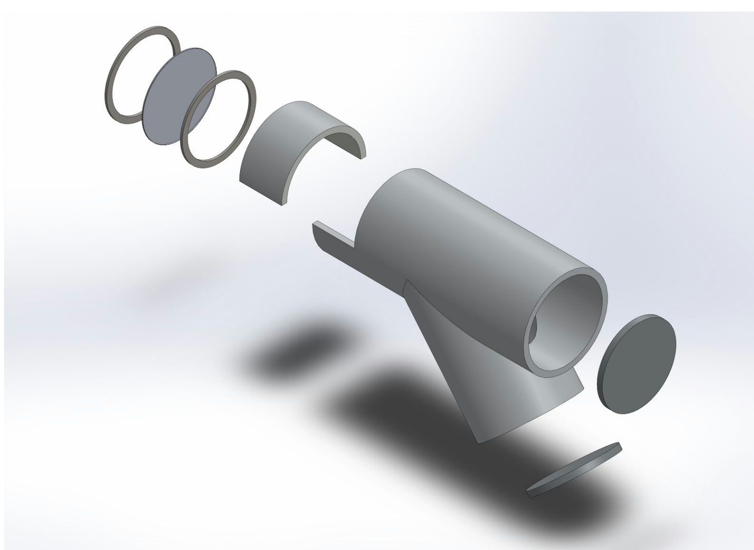
Section 10 Team 5



Submitted by Shunran Xu, Swapnil Dubey, Faris Ghazali, Kyle Moran

Submitted to Xinli Wu

Fall 2015



Abstract

Shunran Xu

Each year, the U.S Environmental Protection Agency (EPA) regulates locomotive emissions to reduce pollution. In Pittsadelphia, current locomotives do not meet the new EPA guidelines. Therefore, systematic upgrade to the current fleet is needed. This report documents the process of design for the air nano-filter that reduces locomotive emissions.

Table of Contents

Introduction

Shunran Xu

Problem Statement:

Everyday, approximately 165,000-tons of freight and minerals are transported in or out of Pittsadelphia via railroad. However, Tier 2 locomotives are approaching age for overhaul. Additionally, city residents complains about the smog from the locomotive emission. In order to meet the recent EPA emissions guidelines, major upgrade to the current locomotive fleet is necessary.

Mission Statement:

The mission of this project is to find a cost-effective solution to reduce locomotive emission while maintaining or increasing the current freight capacity.

Design Specification:

- The design should meet the EPA emission requirements, such as 70% NOx reduction.
- The design should maintain or increase the current fleet capacity of 7000 tons of freight per day.
- Depending on the customer analysis, return on investment (ROI) should be reasonably short (as low as 2 years).

Design Process

Kyle Moran

Project Management

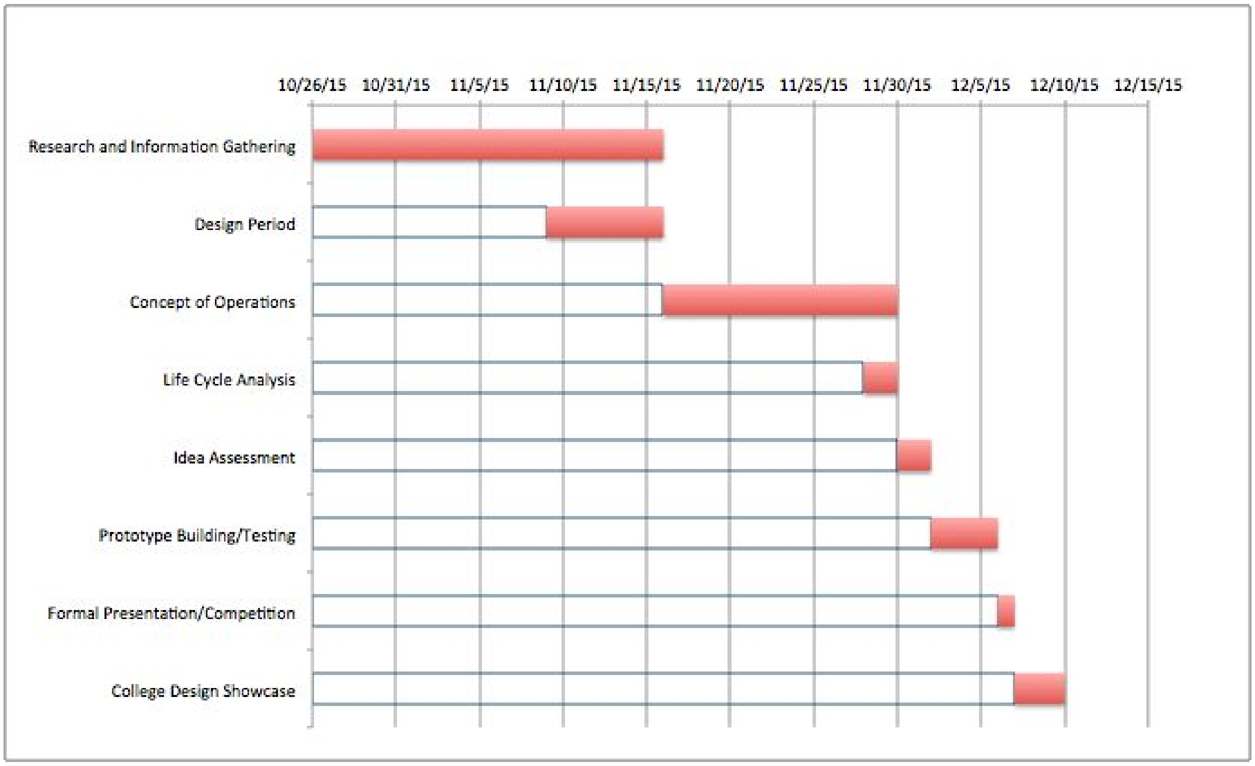


Table 1. Gantt Chart

Concept Generation

The first step in the design process was to gather information from General Electric and thoroughly study the figures and guidelines provided. After assessing the design specifications a new phase of brainstorming could begin based off of the following guidelines:

- The alternative must reduce emissions by at least 50% of Tier 2.
- The design should be reasonably priced and offer a return on investment after 2 years.
- Transition of design should be relatively efficient.

Initial Designs

Upgrade Approach(reference design): The Upgrade Approach is a design in which Tier 2 locomotives are upgraded to Tier 3 locomotives by removing a 4,000-pound catalytic converter and adding an after treatment in which reduces emissions. The new emissions will meet EPA standards but the upgrade is fairly costly at $750,000 per locomotive. Additional flaws in this design is that the lifetime of the system is shorter than that of a new locomotive as well as the fact that EPA standards could change in coming years to a point where Tier 3 may not satisfy.

<u>Solar Panel Approach</u>: The Solar Panel Approach was a brief consideration until the power output constraints were realized. The designed would've required solar panels covering a vast area or a secondary energy source in combination

<u>Electromagnet Design</u>: The Electromagnetic Railcar system involved renovations to the locomotive as well as the tracks themselves. 500 miles of electromagnetic track would be costly as well as time consuming to install.

<u>Buying Tier 4 Approach</u>: The idea to buy Tier 4 requires buying 50 locomotives at 4 million dollars each totaling to a 200 million dollar investment. Additionally, this idea also included the sale of existing Tier 2 locomotives at 1.5 million dollars each, cutting the investment to 125 million dollars total. Because of the upcoming EPA standards adjustment all Tier 4 locomotives would need to be bought right away.

<u>Aftertreatment Approach</u>: The design of the after treatment system includes 3 main components; a replaceable Polyacrylonitrile nano-filter, an air compressor pump and a pressurized holding tank. The idea is to tap into the end of the exhaust pipe and to allow pure air from the exhaust to filter out and to force harmful gases that are too large to permeate into a holding tank. After the completion of a trip, these emissions can be pumped out and sold or disposed of properly.

Design Sketches

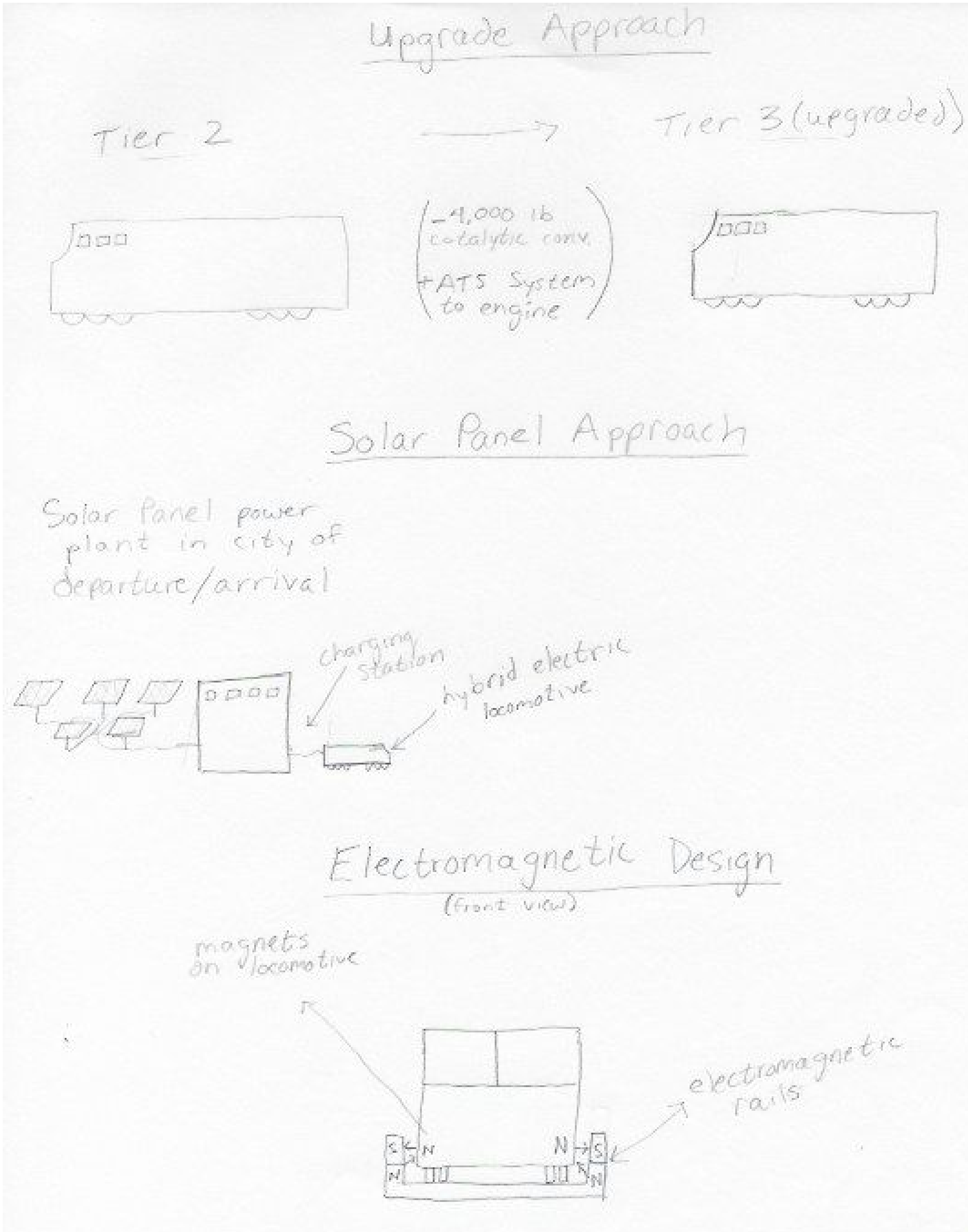


FIG 1. Sketches 1-3

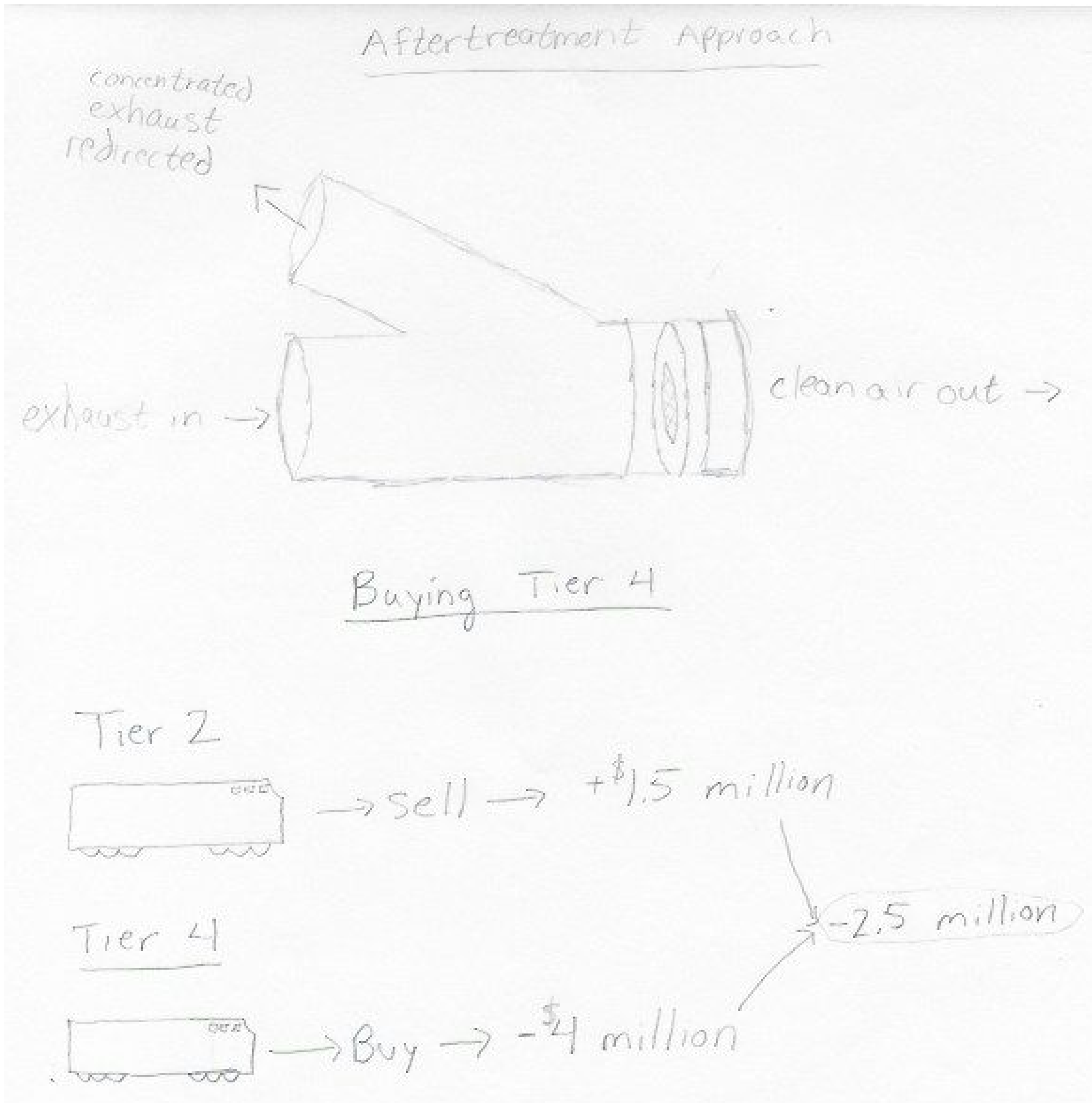


FIG 2. Sketches 4-5

Design Matrix

Approach	Upgrade approach (reference)	Solar Panel approach	Electromagnet design	Buying Tier 4	Aftertreatment Filter
Cost of Approach	0	-	-	-	+
Fuel Costs	0	+	+	+	0
Running Costs	0	+	+	0	0
Time	0	-	-	+	0
Certainty of Functionability	0	-	-	0	-
Emissions	0	+	+	+	+
Ease of Transition	0	-	-	+	+
Sum of +'s	0	3	3	4	3
Sum of 0's	7	0	0	2	0
Sum of -'s	0	4	4	1	1
Net Score	0	-1	-1	3	2
Rank	2	3	3	Combine	Combine

Table 2. Selection Matrices

Final Design Selection: The combination of both the After Treatment Design and Buying Tier 4 provide a temporary solution for a gradual development of the total plan. First, an after treatment system will allow clean air from the locomotive exhaust system via a polyacrylonitrile filter. Harmful gases that cannot permeate the filter will then be directed into a compressed holding tank. This system will contain gases; rather than release them into the atmosphere. Because the gases are still initially produced with the after treatment system; the need for a long term alternative is necessary. The solution will allow the customer to buy tier 4 gradually and make a plan to upgrade the whole fleet based on an initial wiling investment. Once the difference is made up in fuel savings the customer can reinvest as they please.

Final Design and Prototype

Faris Ghazali

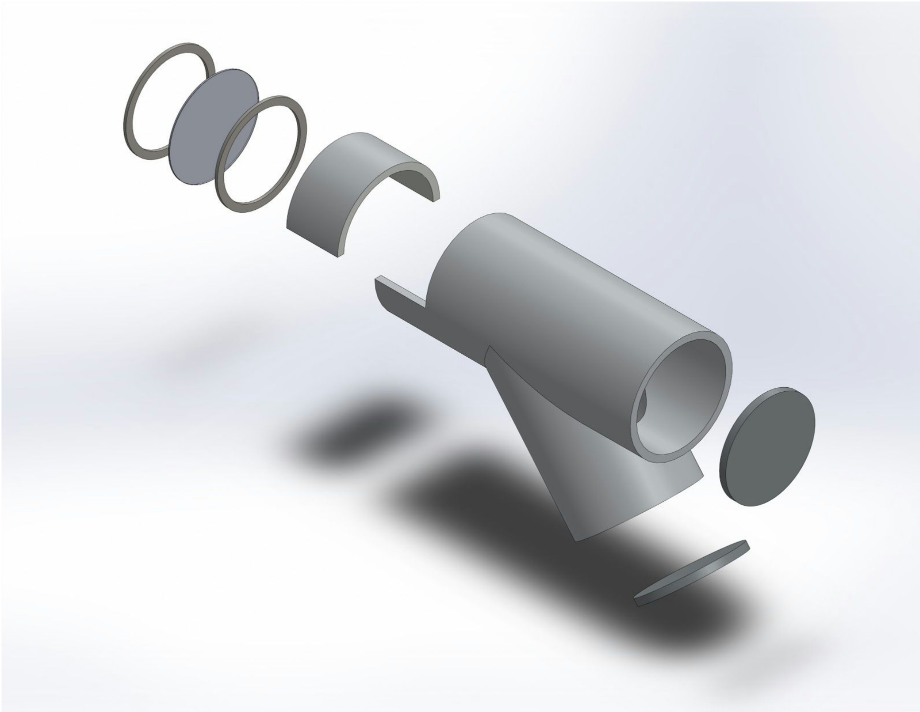


FIG 3. P.A.N. Filter Exploded View

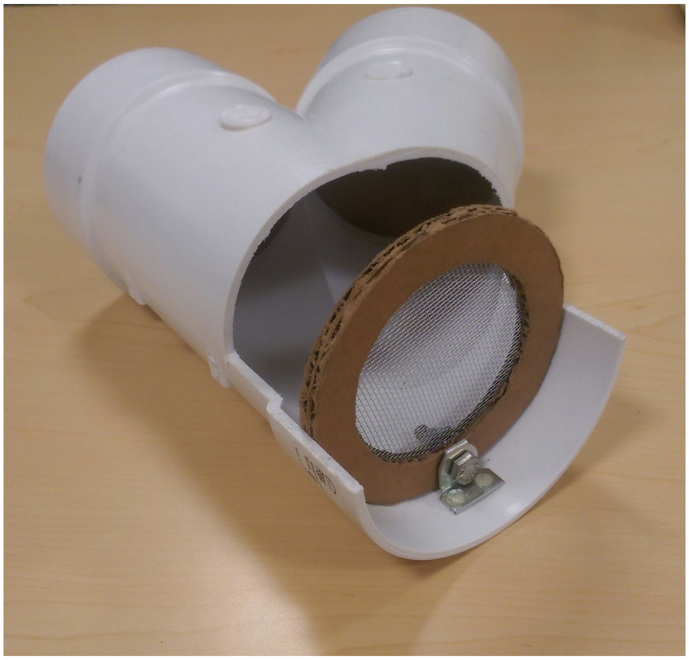


FIG 4. P.A.N. Filter Prototype
(Scale 2:1)

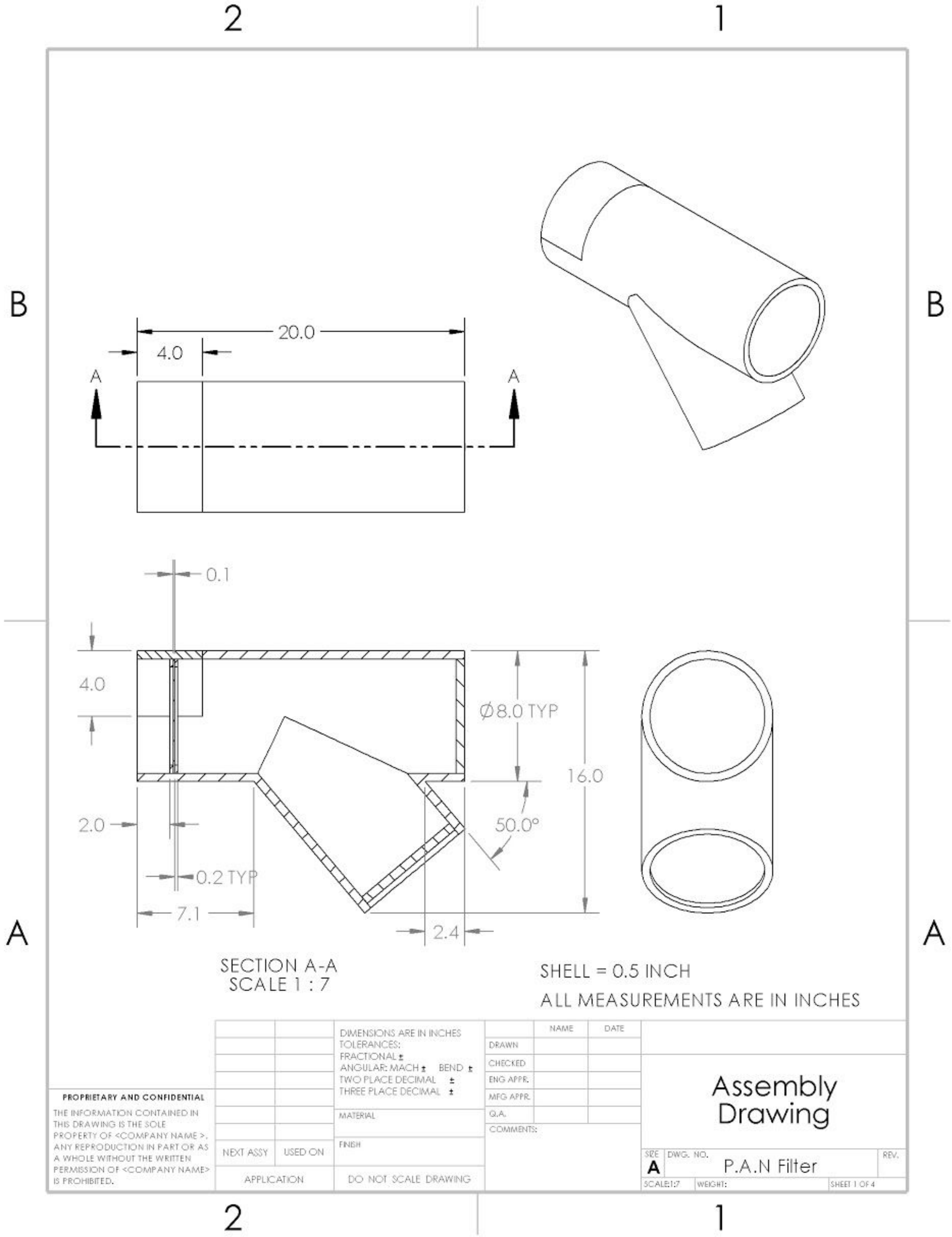


FIG 5. P.A.N. Filter Assembly Drawing

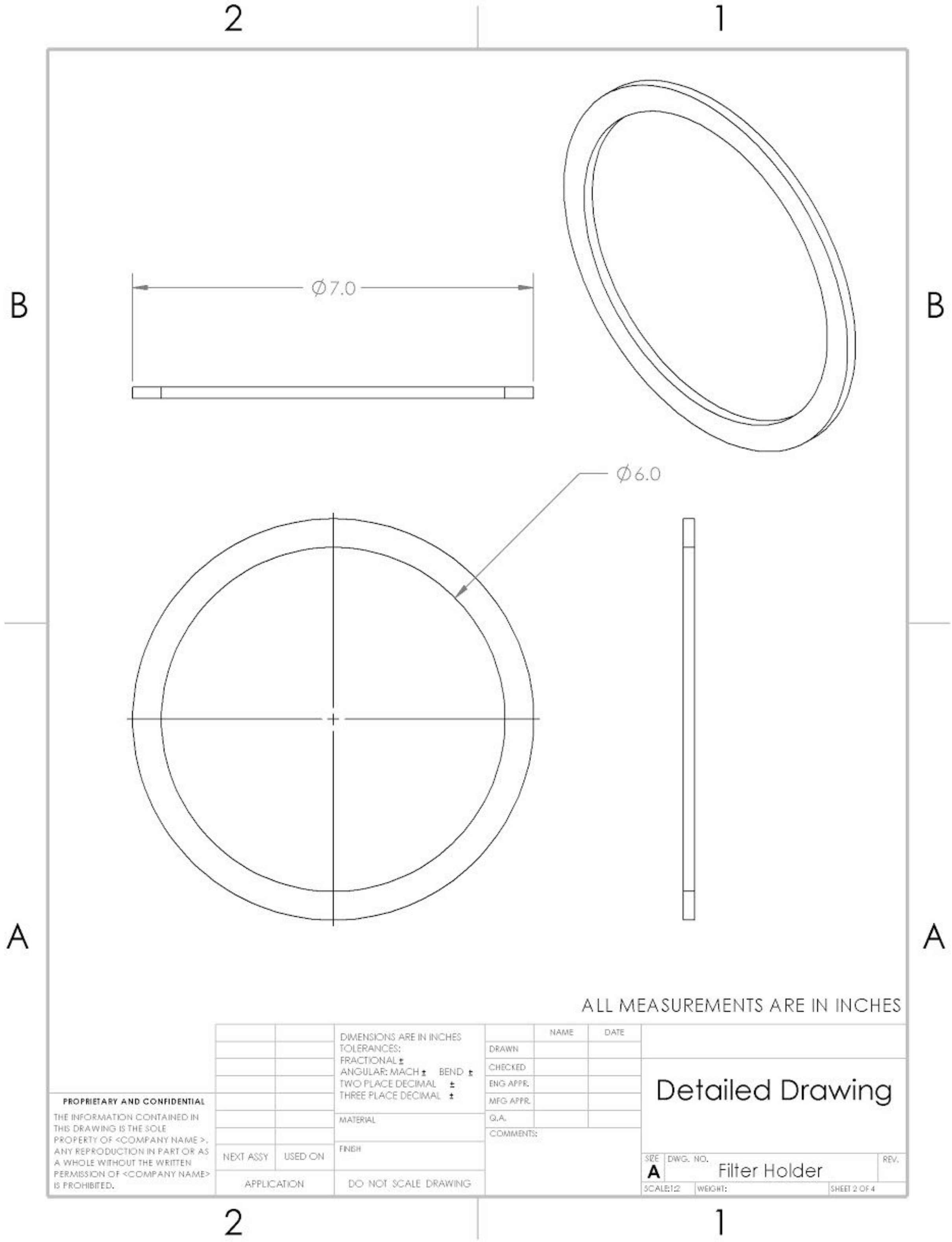


FIG 6. Filter Holder Detailed Drawing

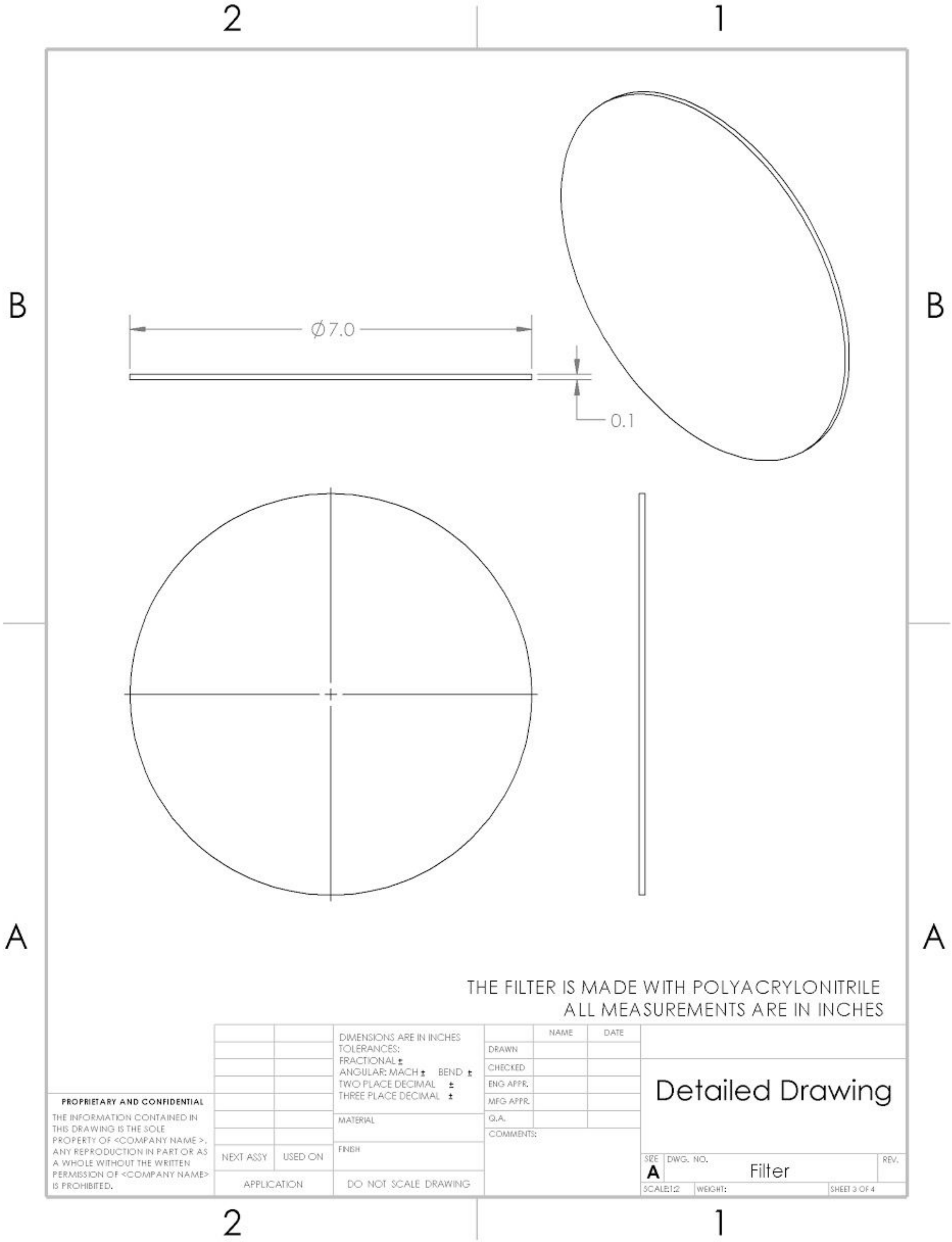


FIG 7. Filter Detailed Drawing

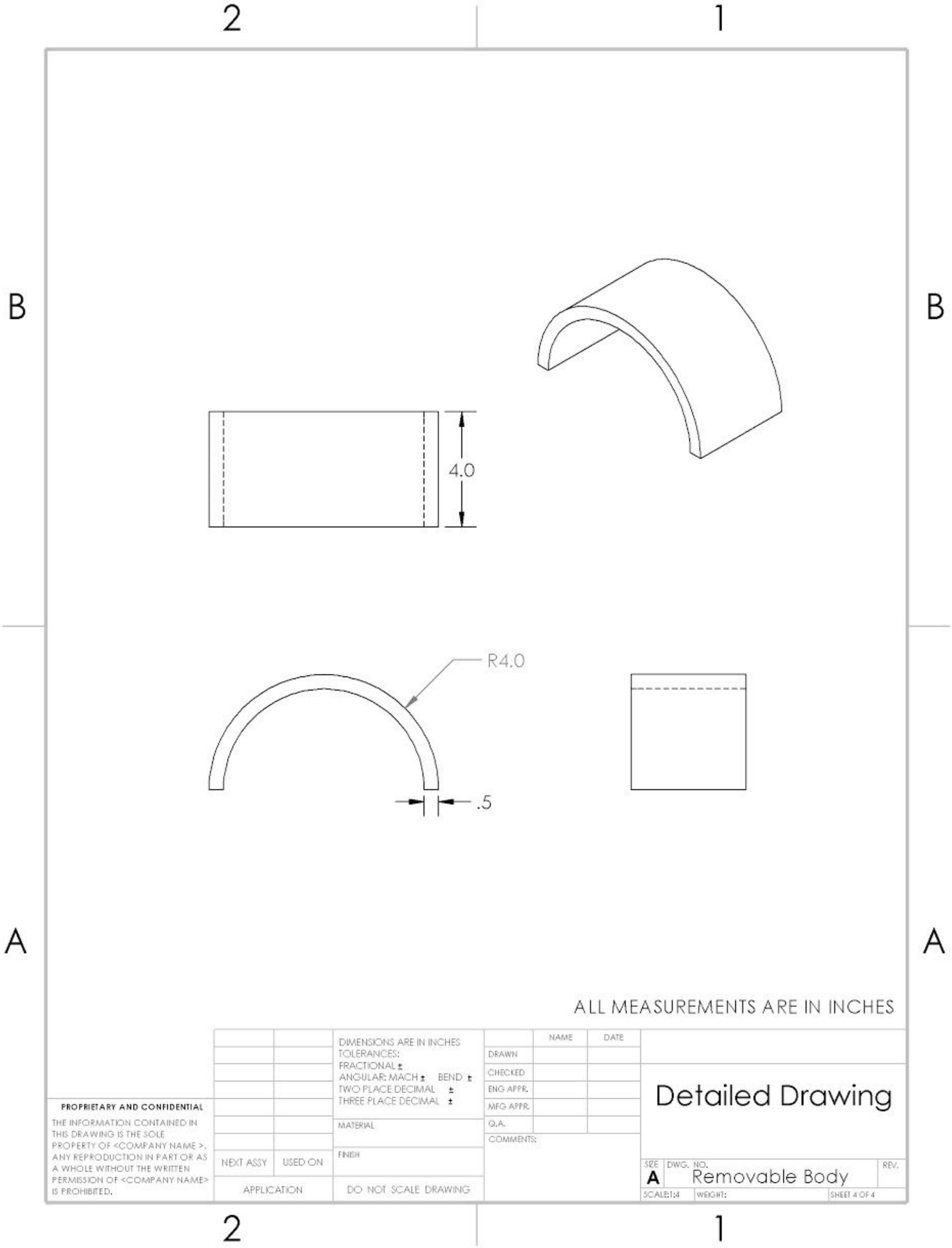


FIG 8. Removable Body Detailed Drawing

Design Features

The P.A.N filter consists of 5 parts. The main part is the filter itself that is made up of PolyAcryloNitrile and has a thickness of 0.1 inch. The filter is hold by a steel filter holder on both side and is attached to the aluminium main body by a screw which can be referred on FIG 2. The other two end of the P.A.N filter has a valve that opens and closes according to the airflow. One end is attached to the train's muffler and one end is attached to a tank that that has an air compressor attached to it. When there is fumes from the train's muffler, the valve that is attached to the storage tank is closed to accumulate harmful gases inside the filter body while letting clean air to flow through the filter. When the muffler is producing least amount of fume, the valve attached to the muffler is closed while the other valve opens to allow harmful gases to enter the storage tank and the gases will be compressed. There is a section of the main body that can be removed by unscrewing a screw to change the filter.

The filter cost approximately $100 dollars while the industrial price for a big holding tank is $200 dollar and air compressor is $1000

Analysis

Swapnil Dubey

It was deduced that buying Tier 4 trains that has been worked on and extensively tested by professional engineers was the most practical way of to solve our problem. The concept of using a nano-filter to completely filter out harmful gases, although possible, is too good to be true and with the current technology and advancements in the product it is only viable as a temporary solution that can help reduce costs. Adding the filter a light weight filter is cheap, to maintain and to install on the train compared to all the alternatives.

CONOP

The filter is a thin woven sheet of made out of PolyAcryloNitrile (PAN) with holes thin enough to stop particles from the harmful gases produced and only let out simple non harmful gases like air particles. These blocked particles get collected in the exhaust pipes and since there is no other place for them to go, the follow the only route available to them, that is, inside the gas containment unit. These stored gases can then be sold off to people who may find them useful. The only human intervention needed is to periodically change the filters and empty the gas containers.

Life-Cycle Analysis

The material being used in the filter right now is PolyAcryloNitrile (PAN) which is the same material used in surgical gloves, which means that it is easy and cheap to buy. Research for stronger and cheaper material still continues in the labs of Stanford. After use, the metals from the filter can be reused for new filters while the old ones can be disposed of without causing much damage to the environment since they are so small to begin with

Feasibility

It is cheap and the only maintenance required is to replace them. As of now, with current technology it can last about a week before the filter needs to be replaced. Since the train already has many routine checks and work done on it, this isn't a big addition and could be done while incurring least amount of cost. The installation of the system is also easy enough since we are permanently replacing about 20 inches of the exhaust pipe where we can fit the filter and add a route leading to the containment unit.

Buying Tier 4, was deduced to be the most efficient method of directly reducing the production of such harmful gases and since it's a technology that been in development for years and is now ready for use, it is also the most reliable.

Economic Viability

Buying a full fleet at once would have hurt the profits severely so the team came up with a plan to smoothly transition into tier 4. It was proposed that half the fleet could be bought first while the other trains use filters until the company breaks even on their investment, approximately in 6.6 years. These plans could be modified depending on how many installments the company wants to invest in. The P.A.N filter only costs $65000 for the whole fleet and the maintenance cost is only for changing the filter every week. It is a viable option for temporary reduction of pollution.

Summary and Conclusion

Faris Ghazali

The final approach of the team is to gradually buy new Tier 4 locomotives and sell the old Tier 2 locomotives while installing a temporary filter system that can effectively filter harmful gases to achieve Tier 4 requirements of the EPA. Buying Tier 4 locomotives permanently avoids the cost of maintaining aftertreatment solutions or the cost of upgrading locomotives and fueling station to support liquefied natural gas. The inexpensive P.A.N. filter can effectively filter harmful gases temporarily while waiting for the whole fleet to change to Tier 4 locomotives. The R.O.I of the company is expected at 3.3 years after investment are made and is the most economically viable option.

The team is proud to present the approach as the team worked hard for 6 weeks to gather all the required informations and come up with a creative idea to reduce the harmful gases polluting the environment of Pittsadelphia.

Acknowledgement

Faris Ghazali / Swapnil Dubey

The team are very thankful to everyone who contributed and helped us complete our project effectively and more importantly, on time.

We are thankful of our Professor, Xinli Wu. He was always there to help us and has supported us and guided us in our project. We are also grateful to our TAs, Nick A. Petrunyak and William A. Haunstein. They were always ready to help whenever we found ourselves in a fix.

Last but not least, we would like to thank our sponsor, General Electric for giving us the opportunity to work on this project that can possibly be materialized to help with their own problem of deciding whether to upgrade to Tier 4 for their locomotives.

Attachments

Kyle Moran

The link to the design project presentation can be found here Design Project II Presentation

Reference

Faris Ghazali

http://sedtapp.psu.edu/design/design_projects/edsgn100/fa15/

http://news.stanford.edu/news/2015/february/filter-air-pollution-021815.html

http://web.stanford.edu/group/cui_group/papers/Chong_Cui_NCOMMS_2015.pdf

http://www.industrytap.com/ges-hybrid-locomotive-moves-a-ton-of-freight-500-miles-on-a-gallon-of-fuel/

GE Logos: https://commons.wikimedia.org/wiki/File:General_Electric_logo.svg

Penn State Logos:
http://onwardstate.com/2015/08/04/penn-state-refreshes-its-brand-identity-with-new-shield/