Dryer Sensing Array

Final Report

Group: 18 –

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ECE 445 – Spring 2020

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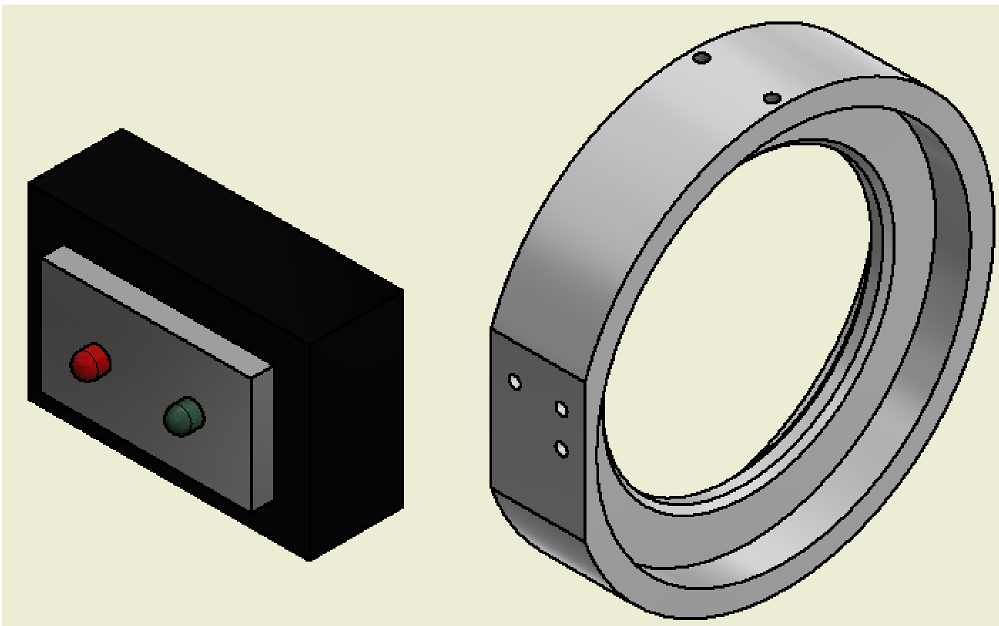
1 Abstract

Laundry dryers are common appliances used by millions of people across the world, and often for many years. When not maintained properly, dryers can manifest hazardous conditions, posing danger to the user and their belongings. This risk is particularly relevant for laundromats, which often have larger numbers of older machines. Our project aims to prevent such failures. The original solution relied on a single temperature sensor and relayed information via Bluetooth to the user's smartphone. Our solution utilizes an airflow sensor in addition to the temperature sensor, its collar mount mechanism ensures easy and robust installation, and offers a simplified interface for commercial applications.



2 Motivation and Background

2.1 Motivation

The design presented in this report deviates from previous iterations; namely, our algorithm for assessing the dryer's "health" accounts for its mounting relative to the dryer. Specifically, we assumed that placing the temperature probe at the exhaust rather than inside the lint trap would have minimal effects on our temperature deviations. However, this is incorrect, since the blockage occurs inside the trap and heat cannot escape to the vent. Our updated design uses real-world data to enable diagnostics beyond the dryer itself.

2.2 Problem Statement

Laundry dryers are used frequently by consumers around the world, often remaining in service for many years. Yet, they are not always perfectly made, and improper use or lack of maintenance can cause malfunction. Excess lint from clothing and fabric softener from dryer sheets can accumulate in various areas of the dryer. This can then lead to air vents becoming clogged, and eventually, this excess lint may even cause overheating. When air temperatures exceed 250°F, a fire hazard may occur since cotton and wool burn at those temperatures. This risk is particularly relevant for older machines, as they are more likely to have experienced improper use. Laundromats in particular often house large numbers of older machines susceptible to such hazards. Our goal is to monitor the state of the dryer, and alert the owner if potentially dangerous conditions arise. This will allow the owner to avoid danger, maintain peace of mind, save money, and make dryer maintenance easier. By doing this, fires and property damage may be avoided.

2.3 Solution

2.3.1 Original Solution

"A more cost-effective user-friendly dryer temperature probe can be created by utilizing three components. The temperature probe would be a k-type thermocouple that can withstand and measure temperatures of up to 350°F inside the dryer while it is running. The hardware unit would physically be placed on top of the dryer while it is running to read the data, convert it from analog to digital, and transmit the data via BlueTooth. A smartphone would then be used to view the temperature data in real-time and indicate whether or not the temperature is potentially dangerous. This interface would be more user-friendly compared to the LCD display commonly found on handheld thermocouple temperature sensors."

2.3.2 Our Solution

We propose a novel, easy-to-install system that can be attached to the exterior of the dryer. The add-on will have a temperature sensor, a pressure sensor to sense air-flow, and an inductance coil around the dryer's power wires to sense if it is in use. An ESP32 microcontroller would read the sensor data and alert the user if either the dryer is running and air-flow is below the baseline, the dryer is running and the temperature is increasing at a rate above baseline, or some combination of the two.

Finally, we propose simplifying the user interface by adding a second ESP module to the system. The sensing ESP will detect when the dryer begins running, make an assessment on the dryers cleanliness, and send the status signal to the second ESP. The second ESP, located on the top of the dryer, will then display the dryers status with a green or red LED. This will provide the user with an appropriate amount of information in an intuitive fashion. In this manner, our solution is designed to work out of the box, with no additional hardware or software to install by the end user. It allows the user to quickly determine the status of the dryer and address any problems in a timely fashion.

2.3.3 Comparison

Most people will not want to or be able to take apart their dryer to install a thermocouple into the lint trap. Additionally, the single sensor approach may lead to false positives because of ambient temperature changes; the lint trap of a dryer, gas or electric, should always connect to the outside through an air duct [1]. To combat the ambient temperature effects, we recognize that the heat removed from the dryer, by air, is directly proportional to the mass flow of the air through the dryer [2]. Hence, we are interested in the rate of temperature change in the dryer once it has started, or the airflow through the output.

2.4 High-Level Requirements

- Our system must be able to accurately detect hazardous conditions in the dryer, including dangerously high temperatures and insufficient airflow, and alert the owner when such conditions arise.
- Our system should be easy to install, while remaining durable and robust enough to function in the conditions required for dryer operation. It should be able to withstand the vibrations and heat produced well enough to last several years.
- Our system should communicate the status of the dryer to the user through a simple, intuitive interface designed to maximize the user's convenience.

2.5 Block Diagram

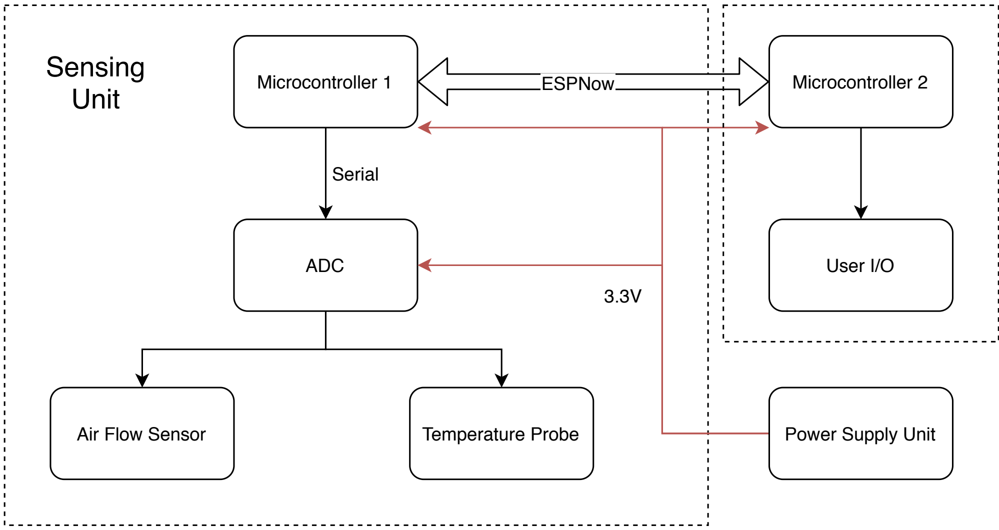


Figure 1. High-Level Block Diagram

2.6 Visual Aid

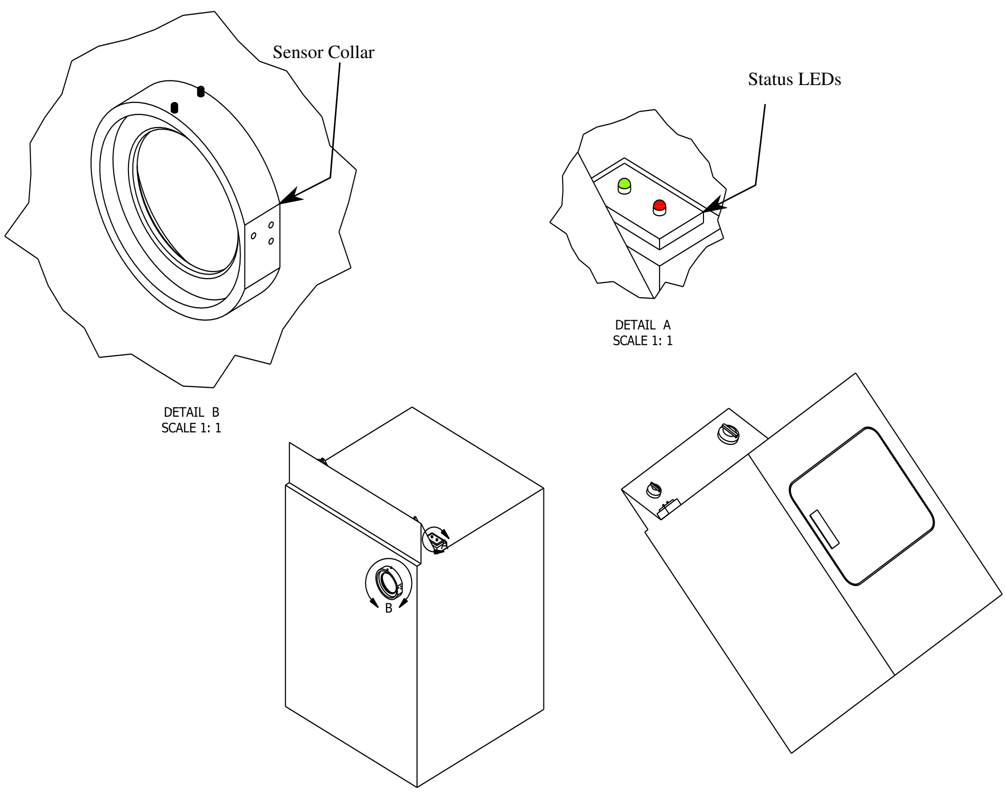


Figure 2. Sensors and status indicator mounted on the dryer. Detail A shows the indicator LED's, and Detail B shows the dryer collar.

3 Implementation

3.1 Relevant Design Data

Given the absence of numerical data for this project, we rely upon the findings of the US Consumer Product Safety Commission's report on the lint ignition characteristics of electric dryers [3]. As we predicted for our design review, Figure 4 shows how the dryer air-flow decreases with increasing amounts of blockage. Additionally, we also predicted that lower flow would manifest as a rising temperature at the exhaust; however, Figure 5 shows the opposite trend. Although we expected otherwise, as the blockage exceeds 50% the heat gets trapped in the tumbler and lint trap. Intuitively, the inability to exhaust heat is precisely why the blockage may lead to a fire.

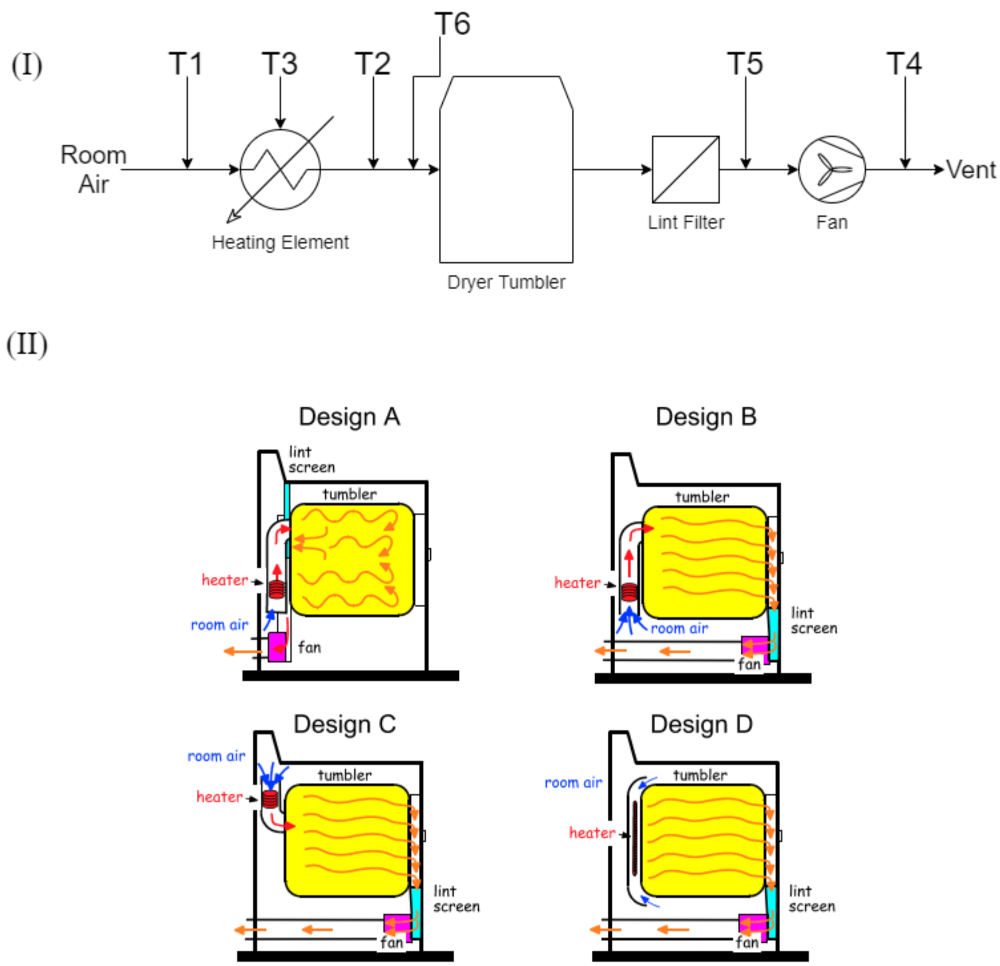


Figure 3. Diagram I shows the general dryer configuration with probe locations, while II displays tested configurations from [3].

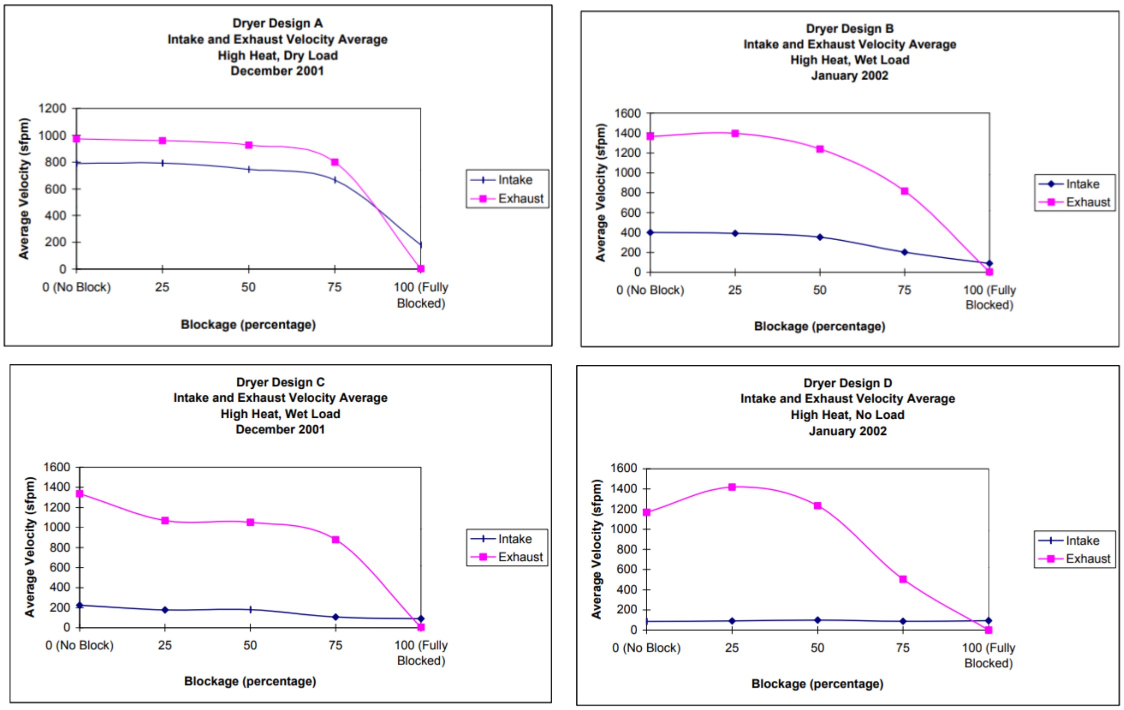


Figure 4. Vent Exhausts for each dryer type in Figure 3 [3].

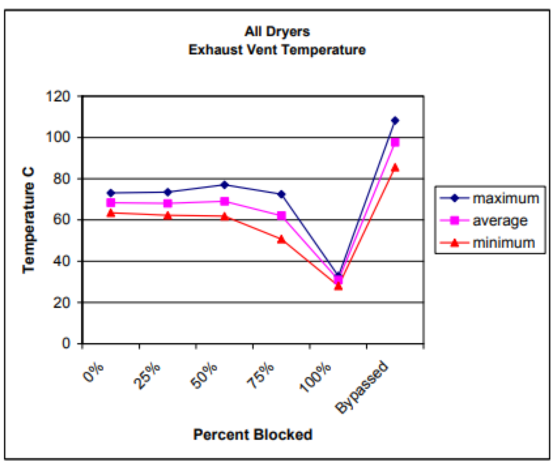


Figure 5. Aggregate exhausts temperatures for all dryer types in Figure 3 [3].

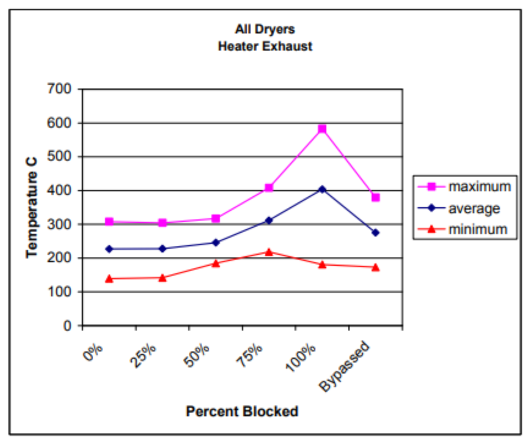


Figure 6. Heater exhausts temperatures, note that temperature increases.

3.2 Details and Analysis

The two-sensor design offers several advantages, by allowing for the system to determine the location of the airflow obstruction, and operation over a wider range of conditions. Regardless of the dryer's design, Figure 3, we observe a drop in the exhaust airflow in Figure 4.

Naturally, to quantify the airflow restriction, the device must be calibrated at its maximum operation condition. Ideally, by running a calibration with an empty, clean dryer the device can determine the 0% blockage point. This point should be held in the microcontroller's EEPROM, so that if the system loses power the calibration data is retained. From Figure 4, regardless of the dryer design at 50% blocked the flow has dropped by approximately 20%. Therefore, we may choose our threshold value for "insufficient airflow" at a 15% decrease from the baseline.

Although monitoring the airflow through the system is sufficient for determining if there is an obstruction, it cannot tell us if the blockage is in the vent or dryer. If the obstruction is in the vent, the blockage creates a temperature gradient; additionally, the obstructions surface along with the gradient means that water may begin to condense on the cooler side. On the other hand, if the blockage is in the lint trap then there is a fire-hazard. However, by also monitoring the exhaust temperature the relative location of the obstruction may be inferred, see Figure 7.

3.2.1 Diagnostic Algorithm

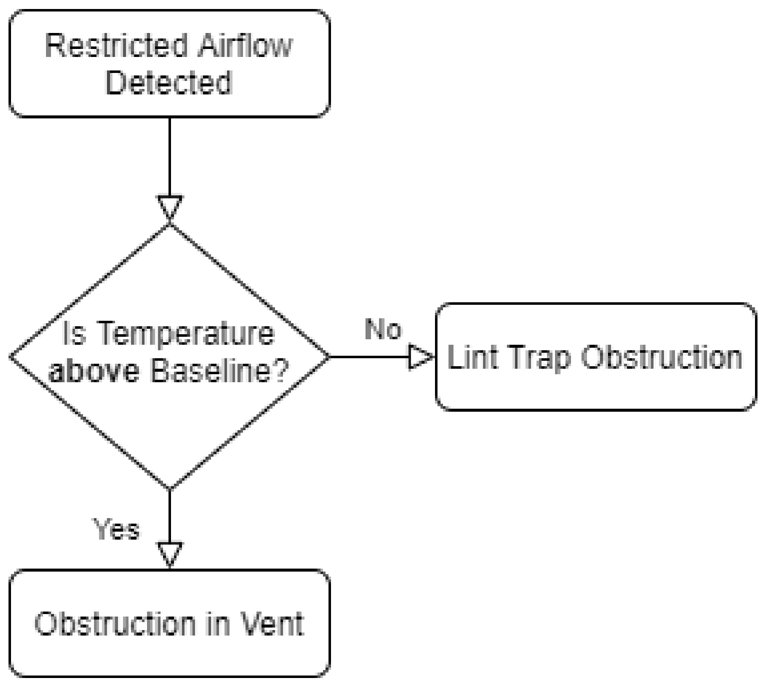


Figure 7. Diagnostic algorithm, note that this process is executed only if the airflow is below baseline.

The position of the air blockage may be determined using Figure 7. Figures 5 and 6 are the basis of this design; if the blockage is upstream of the sensors the temperature drops, and if there is downstream blockage the temperature increases. Additional temperature monitoring may be enabled by taking the Fourier transform of the heat, which should show frequency spikes from the PID controller in the dryer. However, the report's data is not sufficient to verify this process.

3.2.2 Control Algorithm

Figure 8. Sensor Controller algorithm, it is assumed that the device has been properly calibrated.

3.2.3 Sensor Collar

Our physical design serves as a convenient sensor mount, and as a critical component to the airflow sensing. The chamfered central spine serves to restrict airflow, allowing for us to measure the pressure drop caused by the dilation, and therefore the flow. The third mounting point samples the inlet temperature.

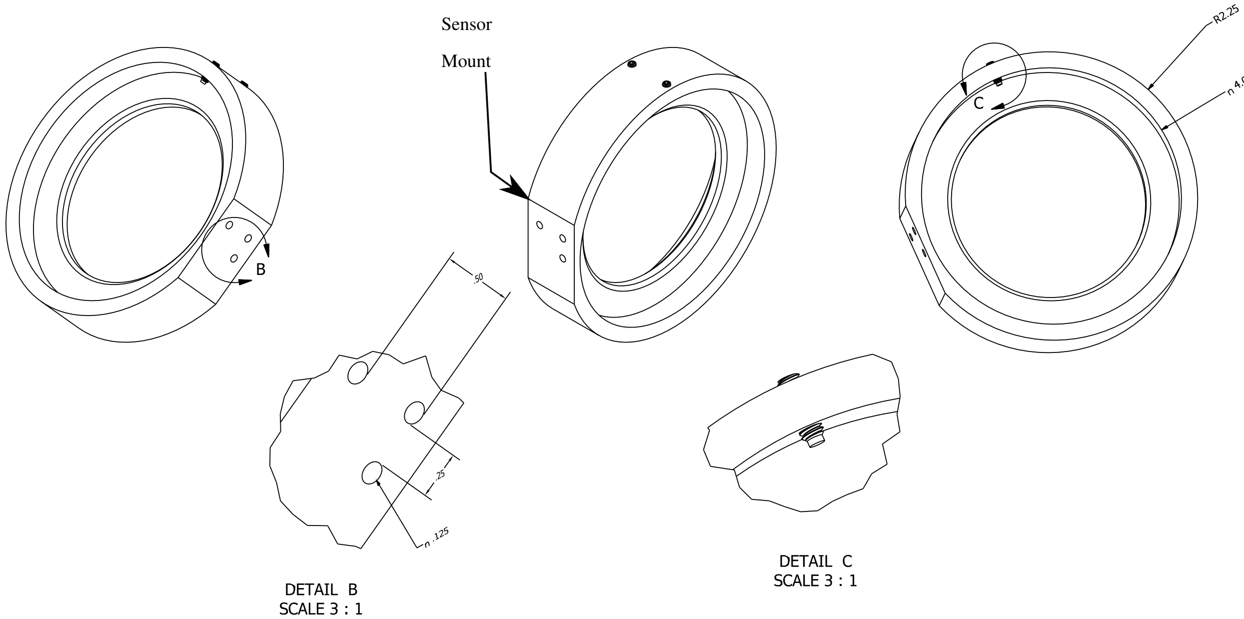


Figure 9. Standard dryer collar with sensor mount. Detail B shows the three sensor mounting holes, and Detail C shows the set screw mechanism.

4 Conclusion

4.1 Implementation Summary

Our chapter two was very successful. While we unfortunately didn't have the time or manufacturing abilities to actually build it, we were able to establish the problem and came up with a valid solution. We all put in a significant effort to pull this project together, of note; Lukas modeled the sensor collar, Steve worked on the control algorithm, and Andrew researched and put together the effects of hot air and air velocity sensor data within the exhaust pipe.

4.2 Unknowns, Uncertainties, and Required Testing

We were unable to have the device collar manufactured. The ECE machine shop is closed down due to coronavirus safety reasons. If we had access to a machine shop elsewhere for a cheap price, we could have it manufactured. Unfortunately, most other machine shops are closed down as well. Even if one wasn't closed down, our part would be very expensive to have manufactured in low quantities.

We also need access to the lab to carry out testing on our sensors. Once we have the collar built, it would be very useful to have the lab equipment to accurately evaluate and calibrate our sensors.

4.3 Ethics and Safety

4.3.1 Ethics

The primary goal of improving a product design is to enhance people's lives as seen in section 3.1 of the ACM Code of Conduct [4]. We will accomplish this by adding a safety device to any dryer which will notify the user if the dryer malfunctions. It will also alert the user if the lint trap needs to be cleaned.

This project is also going to be designed to prevent harm to others which is a large component to the ACM Code of Conduct section 1.2. [4] Fires caused by dryers overheating or getting clogged cause 2900 house fires in the US every year [5] with 34% of those caused by not cleaning the lint trap. Our sensor array will be designed to minimize the risk of dryer caused house fires.

We recognize that owners will rely on our product for the safety of their possessions and of themselves. We must be sure that our product is dependable in order to meet this responsibility.

4.3.2 Safety

The idea of this design is to improve safety, however there are a few things that could still be hazards. The sensors could break or stop functioning, resulting in a potential overheating situation that goes unnoticed. Our code will ensure that the error light flashes red if a sensor fails. The connection between Microcontroller 1 and 2 could fail. We will ensure the light flashes red to notify the user there is an error.

4.4 Project Improvements

Assuming COVID-19 clears up quickly, we would start with physical design and manufacturing. Once the machine shop opens up, we could get a physical model of our device made, install sensors and continue to the second stage.

The software portion would come next. We could theoretically start it without a complete model built if we had the sensors and boards on hand. This project is not extremely software heavy, but it would still take some time and effort to come up with a solution that works properly.

The last stage would involve testing... lots of testing. We need to ensure without a doubt that our sensor package is capable of doing what we would like. To do that, we would have to test with various amounts of lint and moisture in the exhaust air. Then we would have to vary the temperature as well. On top of that, we would need to add blockages into the exhaust pipe before the sensor package(at the lint trap) and after the sensors (simulating a blocked pipe). The testing data would then need to be compared to our theoretical and models built.

5 First Project Progress

Significant progress was made on our first project. We designed breakout PCB boards for the required sensors. Many hours were spent hashing out the diffraction gratings for the optics.

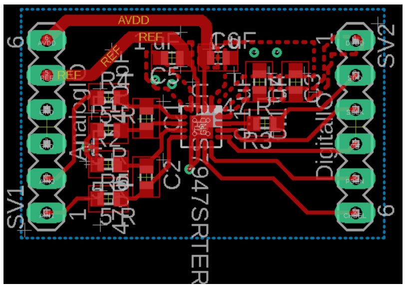


Figure 10. ADC breakout board

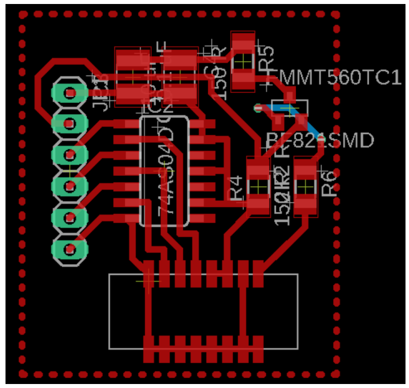


Figure 11. CCD breakout board

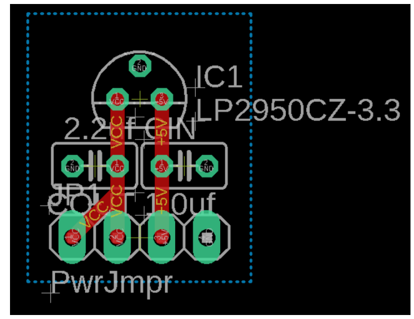


Figure 12. vReg breakout board

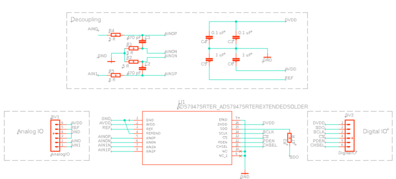


Figure 13. ADC schematic

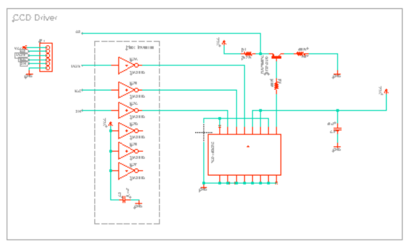


Figure 14. CCD schematic

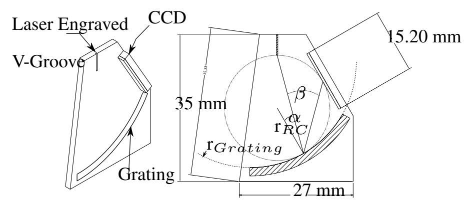


Figure 15. Photonics Schematic.

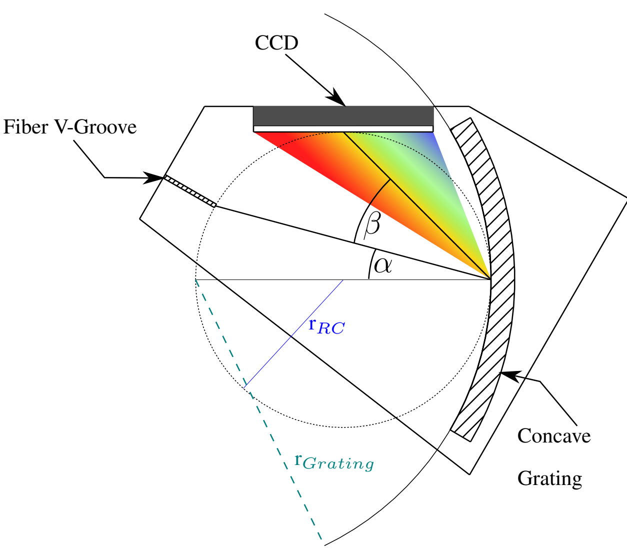


Figure 16. Rowland circle mounting for an external CCD.

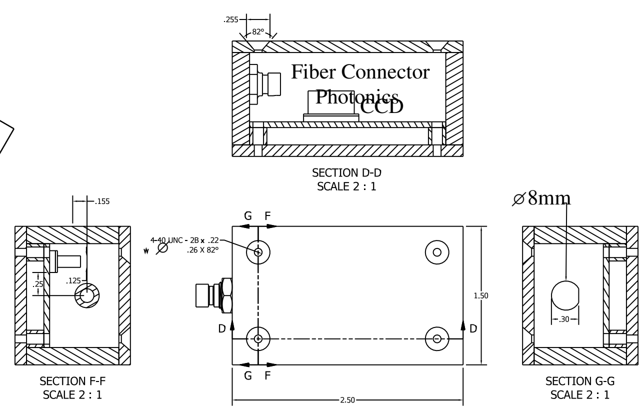


Figure 17. Spectrometer housing.

References

[1] "What Is the Danger of Running a Dryer Not Vented Outside? — Hunker." [Online]. Available: https://www.hunker.com/13410484/what-is-the-danger-of-running-a-dryer-not-vented-outside

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[4] "ACM Code of Ethics and Professional Conduct." [Online]. Available: https://www.acm.org/code-of-ethics

[5] "Clothes Dryer Fires in Residential Buildings (2008–2010)," Tech. Rep., 2012. [Online]. Available: https://www.usfa.fema.gov/downloads/pdf/statistics/v13i7.pdf