Deliverable H

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1. Introduction

The purpose of this deliverable to complete the last part of our prototype plan is testing the functionality of the load sensor with the conjunction with the code with various masses. The key information highlighted in this document is the design, the code and the results that have come with it. This deliverable will also include information such as client feedback, an updated design, task plan updates as well an updated bill of materials.

2. Prototype 3

2.1. Justifications and Reasonings

Prototypes 1 and 2 showed valuable information such as the usability of the vacuum's fan and motor and the needed materials for casing and insulation, respectively. The first prototype specifically showed that the vacuum could only suck 9.22% of the dust that passes by the porous sheet, meaning that the calculations for dust composition will need to incorporate this factor. However, the porous sheet was changed for prototype 3, and thus this value needed to be retested. Therefore, the dust-sucking portion of prototype 3 is, in essence, a higher fidelity version of prototype 1.

Prototype 2 gave needed information that led to galvanized steel and silicone rubber being chosen to use for the final design. However, since prototype 3 will not be retesting the strength and insulating abilities of the design, the chosen materials do not need to be used, they only need to be considered when building prototype 3. Therefore, we considered how to add insulation in the box that was built, and how to build a box that could be easily welded together. Thus, the casing of prototype 3 was a simple box with simple shaped roofs that would not be hard to create using galvanized steel for a final product. Furthermore, there was enough space left on the interior sides and the bottom of the boxes to allow for a silicone rubber layer to be added. Therefore, prototype 3, while not necessarily incorporating the results of prototype 2, was heavily modelled around the results that were obtained.

Finally, it should be noted that in prototype 2, it was mentioned that an interior heater would be needed to protect the load sensor. However, further research into load sensors showed that there are many industrial grade load sensors that can withstand temperatures beyond the minimum and maximum weather conditions that Toronto experiences. Therefore, this part of the design was disregarded as it is no longer necessary to consider.

2.2. Physical Design

The physical design was built as an almost-to-scale model of the final product. However, it uses wood and cardboard instead of galvanized steel for the outer casing to save money on building the prototype. This change should not be an issue for this prototype since the focus of it is not to test the strength, but to test if the load cell and vacuum can work in conjunction with a fully built design.

Figure 1 shows prototype 3. It should be mentioned that the front facing walls were not included in this prototype to allow the insides to be seen. This will be maintained for design day so the

judges can also see the insides. However, a final product of this design would include all walls, with no visible interiors.

Additionally, a tall carboard sheet can be seen in the top-center of figure 1. This is merely an emulation of the client's malt transfer pipe and is not actually part of our design. This was placed there just to show how the design would attach to the client's system.

Figure 1. Prototype 3

2.3. Code

The following code presented in figure 2 was developed to run the operate the system. It runs the fan for 5 seconds, then turns it off for 25. After those 25 seconds, it reads the mass of dust that was collected. Then, it calculates the dust composition using data of the mass flow rate, the detected dust mass, the multiplicity factor, and the run time of the vacuum. This composition is then displayed in the serial monitor. Then, the program loops infinitely to give a dust composition reading every 30 seconds.

This composition will be sent to the client's dust filtration system so it can know the needed intensity to operate at. Since the dust filtration system is not available for us to work with, we

cannot integrate our code with it. However, this integration would be very simple on their end because it would only need to pass one variable.

```
#include "HX711.h"

#define calibration_factor 1340.0 //makes the load sensor measure in grams

#define LOADCELL_DOUT_PIN  3
#define LOADCELL_SCK_PIN  2

float multiplicity_factor = 0.1963; //percentage of dust that is sucked through the vacuum
float flow_rate = 2000; //mass flow rate of malt (in kg/hr)
float run_time = 5; //vacuum run-time in one cycle (in seconds)
float off_time = 25; //time between vacuum run-times (in seconds)
float composition; //dust composition in malt flow stream (mass/mass %)

HX711 scale;

void setup() {
  pinMode(LED_BUILTIN, OUTPUT); //initialize the Arduino-relay connection
  Serial.begin(9600);
  scale.begin(LOADCELL_DOUT_PIN, LOADCELL_SCK_PIN);
  scale.set_scale(calibration_factor);
  scale.tare(); //set scale to 0
}

void loop() {
  digitalWrite(LED_BUILTIN, LOW); //turns fan on
  delay(run_time * 1000); //fan stays on for run_time
  digitalWrite(LED_BUILTIN, HIGH); //turns fan off
  delay(off_time * 1000); //fan stays off for off_time
  composition = ((scale.get_units(), 2) / multiplicity_factor) / (flow_rate * (1/36) * run_time); //calculate dust composition
  Serial.print(composition);
  scale.tare(); //set scale to 0
}
```

Figure 2. Code to Operate the Design

2.4. Test Plan

Prototype 3 was a physical comprehensive model to determine the functionality our dust detection system. The testing was split into 2 parts: Functionality of the load cell, and functionality of the vacuum. These two sections were chosen for testing as they are the most important parts of the final system. It is crucial to ensure that the vacuum can successfully pull the dust from the breweries transfer pipe to measure, and that the measurement obtained is accurate before relaying that information to the client.

To test the functionality of the vacuum system, a test will be run similar to prototype 1's testing. A mixture of carefully measured popcorn kernels and flour dust will be mixed and then dropped through a constructed pipe that simulates that of the clients. We can then measure from the mass of flour collected by the vacuum the percentage of flour collected. That percentage of flour collected is crucial information as it allows us to accurately calculate the dust composition of the entire flow. This test will be run for 3 trials to prevent inaccuracy and the average dust percentage will be used.

Then, to test the functionality of the load sensor we can compare the mass of flour dust read from a high accuracy scale with the mass reading given from the load cell in our system. This will give us a percent error that if low enough can become a useable uncertainty value, and if too high will be an indication that the load cell is too inaccurate and requires changes. To carry out this experiment, a mass of flour dust will be measured by itself on a kitchen scale to determine its exact mass. Then, this mass of flour will be transferred to the vacuum bag of the system which rests on the load cell. The load cell will provide its best reading which can subsequently be compared with the actual value to give us a percent error. This test will additionally be done in multiple trials, all of which will have different mass values to ensure the load sensor also functions with different weights. The percent errors found can then be used to find an average percent error of the load cell which will allow us to determine our next steps.

2.5. Results

Table 1 shows the results of the vacuum functionality test. This was essentially a remake of the first prototype's test, but it yielded different results. This prototype showed that the vacuum and porous sheet extracts 19.63% of the flour that passes by it. Therefore, this value is the new multiplicity factor for the dust composition calculations, replacing the previous 9.22%.

Table 1. Vacuum System Test Results

Trial #	**Mixture Before Vacuuming**			**Mixture After Vacuuming**	**Flour Removed**	
	Kernels (g)	Flour (g)	Total (g)	Total Mass (g)	Mass (g)	% of Flour
1	130	10	140	138	2	20
2	130	9	139	136	2	22.22

3	128	6	134	133	1	16.67
Average						19.63

Table 2 shows the results of the load sensor's functionality test. The load sensor gives a mass reading that is more than 95% accurate, which is satisfactory for the design. Therefore, it is concluded that the load sensor is an adequate way to measure the dust composition for the final design.

Table 2. Load Sensor Test Results

Trial	Real Flour %	Measured Flour %	% Error
1	7.69	7.32	4.81
2	6.15	6.38	3.74
3	3.85	3.70	3.90
Average			4.15

3. Potential Client/User Feedback

For this deliverable, an additional potential client was found – Mitchel Vineyard. He is a high school shop/design teacher with an extensive knowledge of mechanics and construction. Mr. White (as referenced in previous deliverables) was also consulted. Both individuals agreed that our design was sound, effective, and logical. Given the alterations to our design, the team needed enhanced feedback on those alterations so as to be sure of their real-life incomparability. Hence, the following are the accounts of these two sources:

Mr. White:

Mr. White indicated it was a wise decision to further tweak the final design as improvements can always be made. He stated that in his HVAC career, he always double or triple checked his work to ensure accuracy for his clients. Making sure everything is in working order and calibrated prior to final delivery is also very important as there may not be an opportunity to do so later. So, since he had reviewed our previous designs, his advice was more general for this prototype so as to allow Mr. Vineyard to give directives for our design. His final declaration to us was ensure all non-essential elements were steady and working satisfactorily as these items can occasionally be forgotten. These include the casing, storage area, and chute attachment. We made sure to check these supports prior to final submission in keeping with Mr. White's guidance.

Mr. Vineyard:

Mitchel Vineyard's feedback was much more material and physically based. This was the selected procedure as Mr. White had provided such commentary in the previous two deliverables. Mr. Vineyard outlined three areas of design importance: The detection system, the physical casing

and superstructure, and the vacuum. With respect to the detection system itself, he indicated simplicity is best. Hence, he agreed with the decision of a periodic load (mass) measurement so as to directly measure concentrations. He also stated this is likely the most direct method when compared to light receptors and sound-based detector systems. With the physical model, he stated it would likely be easier and more cost efficient for the sake of the prototype to NOT use galvanized steel, but instead to use wood. This is because wood itself is quite sturdy (especially compared to cardboard and other inexpensive materials) so would be a good substitute. He did suggest the roofing and more aesthetic portions could be simulated using thick cardboard to reduce expense and workload. Finally, the vacuum is a suitable dust-sucking, professional grade vacuum and is extremely effective at dust collection. He was a little surprised we managed to extract it and make it workable, so was all the more impressed with the design. He said the only thing to be concerned about was the noise level, but if it was insulated outside, as planned, it should not be a significant hurdle.

Therefore, a final potential user feedback session was conducted with Mr. White and Mr. Vineyard to determine the efficacy of the team's dust detection system. Both agreed it was efficient, straightforward, and when final testing was complete, would be ready for use.

4. Updated Design

Figure 3. Final Design

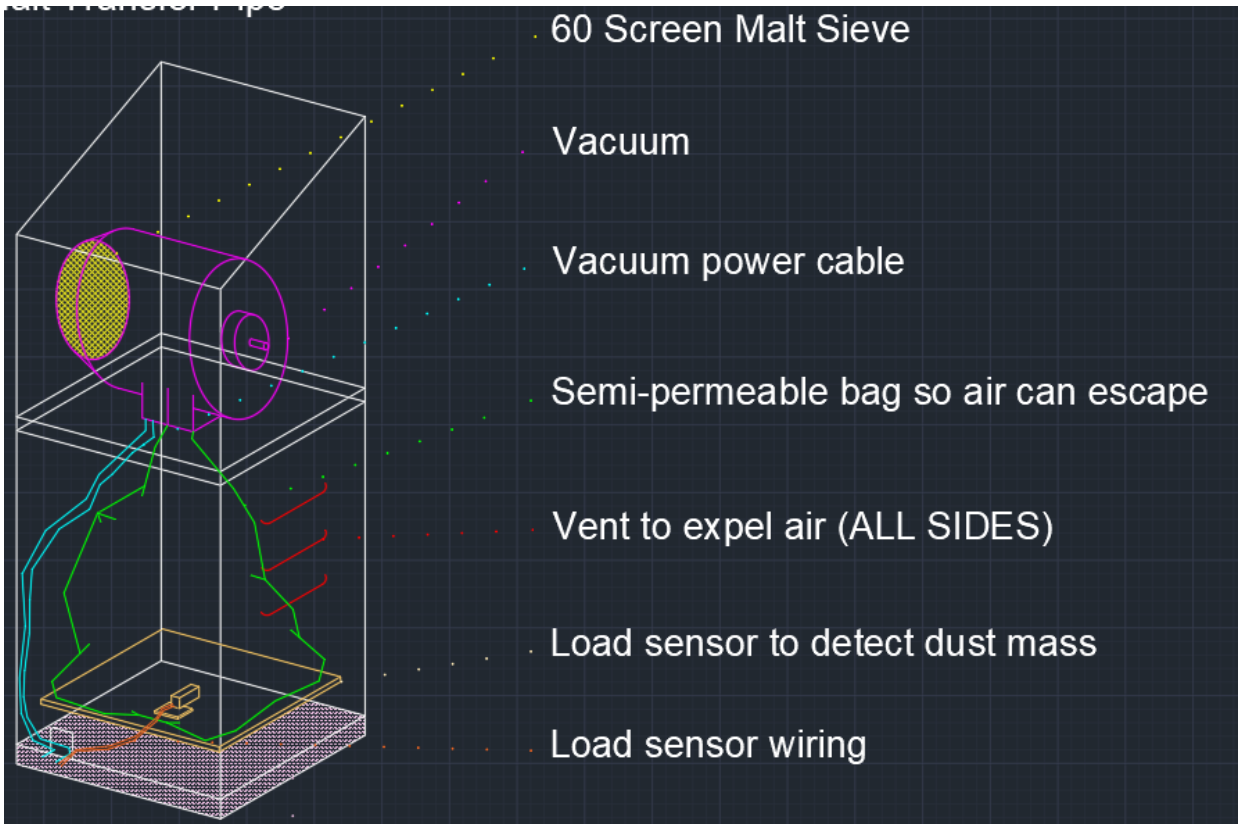

Figure 4. Final Design – Load Sensor Box

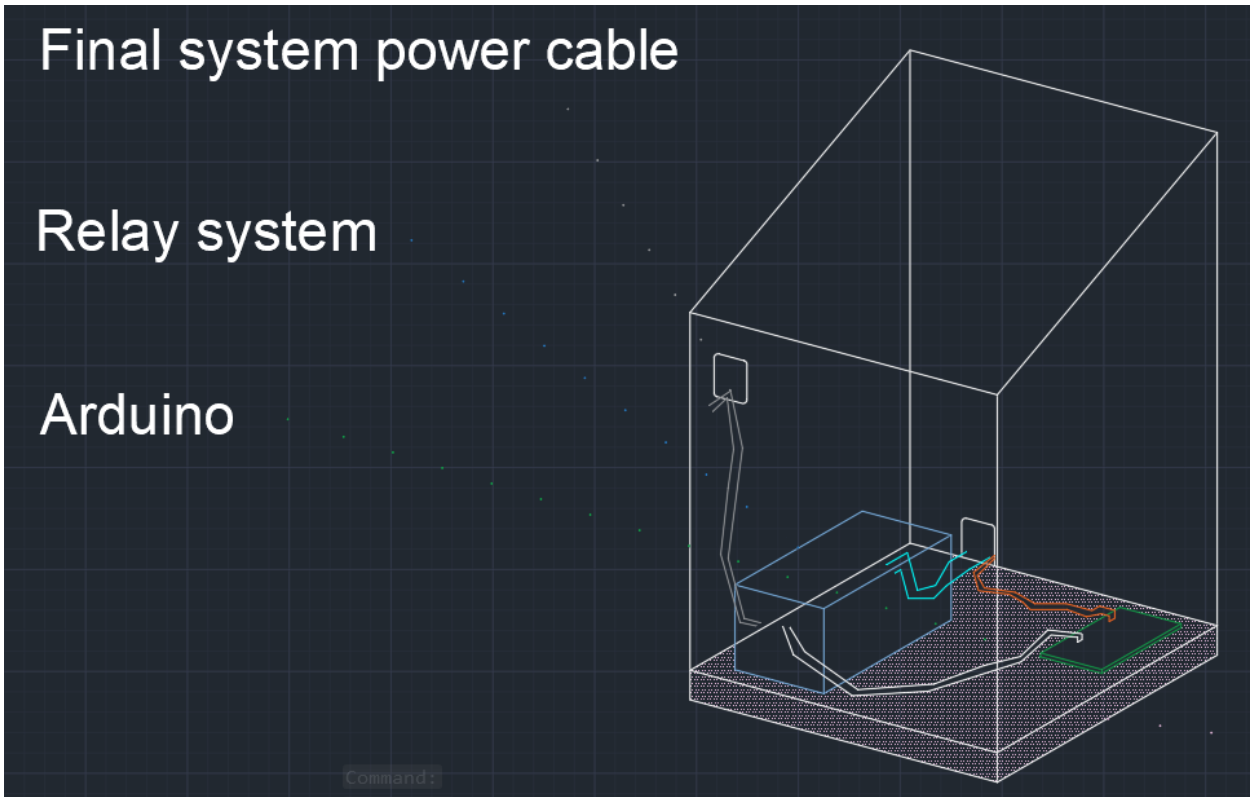

Figure 5. Final Design – Electronics Box

5. Updated Bill of Materials

Table 3 shows the most updated bill of materials. It is currently tentative and will be updated when new items are needed.

Table 3. Bill of Materials

Material/equipment	Quantity	Cost ($)	Purpose	Obtained From
Centrifugal Fan	1		Create partial vacuum	
-----Vacuum Cleaner	1	$ 10.00	Obtain fan	https://www.facebook.com/marketplace
Fan Motor	1		To run the fan	
-----Vacuum Cleaner	1	$ -	Obtain fan motor	https://www.facebook.com/marketplace
Cardboard			Construct fake pipe for testing	
-----old boxes	10	$ -	Obtain cardboard	Garbage
Duct Tape	1 roll	$ -	Fasten Cardboard	House
Old Popcorn	1 Bag	$ -	To emulate malt in first prototype	House
Flour	150 g	$ -	To emulate malt dust in first prototype	House
Garbage Bag	1	$ -	Capture dust in testing	House
Arduino Box	1	$ 13.39	Contain Arduino and relay	Home Depot
Power			Power motor of fan	
-----Wired		$ -	Power motor of fan	Wall outlet
Screwdriver	1 case	$ -	Deconstruct vacuum cleaner/general construction	House
Dirt Bag	1	$ -	Collect dust in final product	comes with vacuum cleaner
Arduino Uno Clone	1	$ 17.00	Send code to load sensor for testing	MakerStore
Wires	1 pack	$ 15.81	Wire Arduino	Amazon
Load Sensor	1	$ 16.94	Measure dust mass in final product	Amazon
Kitchen Scale	1	$ -	Measure dust mass in testing	House
Arduino Uno IDE	1	$ -	Write code for arduino	https://wiki-content.arduino.cc/en/software
Outlet Power Strip	1	$ 27.11	Create Arduino Controller	Amazon
NM/SE Clamp Type Connector	1	$ 14.14	Create Arduino Controller	Amazon
Leviton T5320-W	1	$ 2.98	Create Arduino Controller	Amazon
Arduino Relay	1	$ 3.50	Connect vacuum with arduino	MakerStore
Sieve	1	$ 14.66	Filter out malt from dust vacuumed by system	Walmart
Load Cell Platform				
-----1/8" MDF Sheet	1	$ 3.00	Build Platform for Load cell	Makerstore
Popcorn Kernels	130 g	$ -	Emulate malt in testing	House
Wood	4 sq.ft	$ -	Build Casing	House
Screws	11	$ -	Connect wood	House
Aluminum Foil Tape	1 roll	$ 6.47	Connect pieces when duct tape was not strong enough	Home Depot
Flex Tape	1 Roll	$ 20.31	Connect pieces when Al Foil Tape wasn't strong enough	Walmart
Hand Saw	1	$ -	Cut wood	House
Electric drill	1	$ -	Create screw holes	House
Total		$ 165.31		

6. Task Plan Update

https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=xNiCuCKfHX8Qdw0oy6Ud2wNPhVfZm0Fl%7CIE2DSNZVHA2DELSTGIYA

7. Conclusion

To conclude, we have completed every component of our prototype test plan. These three components were the functionality of the partial vacuum and porous plate, finding the best material and insulation for the casing, and finally testing the load sensor in conjunction with the code. With all of this being successful, we will now be focusing on design day.

8. References

DegrawSt. (2020, October 22). *Arduino scale with 5kg load cell and HX711 amplifier*. Instructables. Retrieved March 22, 2023, from https://www.instructables.com/Arduino-Scale-With-5kg-Load-Cell-and-HX711-Amplifi/