Deliverable F

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1. Introduction

The purpose of this deliverable was to complete a preliminary, simple prototype and to analyse its effects. This has been completed with the results shown. Also contained are the clients and user feedback sections, task updates and design modifications. All relative information regarding the prototype and updates as stated is included and has been thoroughly reviewed.

2. Client Feedback

The client meeting indicated that the general design concept is functional and should be continued with development.

However, the design was updated to accommodate the feedback. The client indicated that the arrangement of the silo was different than the group's previous understanding. The previous understanding was that the malt was extracted from the top of a cylindrical silo using a horizontal pipe. Currently, the understanding is that the malt is extracted from the bottom of a conical silo using a vertical pipe. This updated the product's design from being attached to the bottom of a horizontal pipe to being attached to the side of a vertical pipe.

Additionally, the meeting updated the idea of using cork for thermal insulation by supplementing it with the idea of using rubber or cork rubber. These three ideas will be tested and evaluated on their functionality with the product before a final selection is made.
Finally, the meeting provided guidance for using a Malt Sieve 60 as a porous plate. This product is relatively expensive compared to the budget of the project; however, one prototype will involve a laser cut porous plate that will mimic the qualities of the Malt Sieve 60 to test its viability.

3. Critical Analyses of Protype 1 Constituents

3.1. Porous Plate

The porous plate utilized in the prototype was a thin piece of cardboard cut out to fit the required size of the vacuum entryway. This was a means to filter out all materials that were unintended to be pulled into the vacuum. As per figure X, the porous plate held a simple disc shape with 28 x ⌀ 2 mm pores. These pores were punctured using a small screwdriver and made just big enough that the dust could be the only thing pulled out.

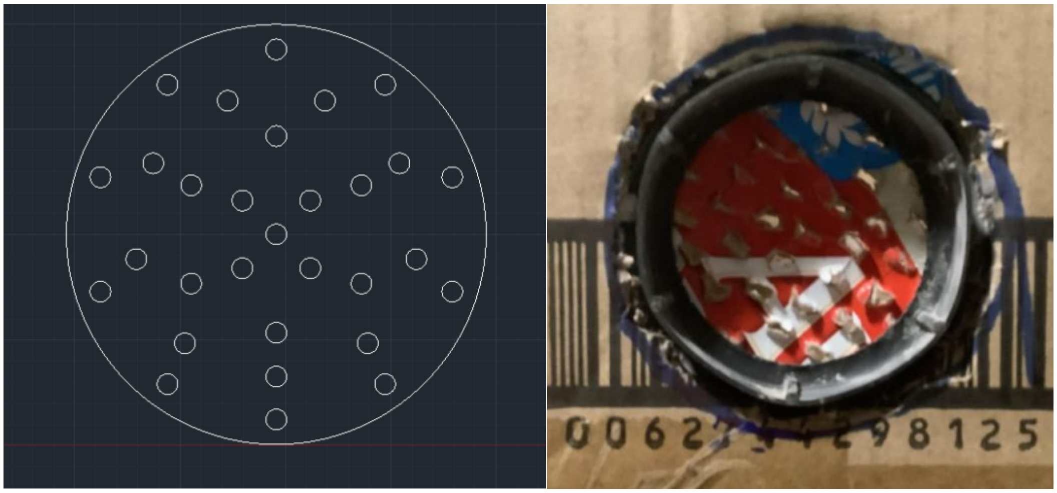


Figure 1. Porous Plate Diagram and Prototype Construction Comparison

We decided a diameter of 2mm would be sufficient as the average diameter of particles of flour (used to simulate malt dust) range typically from 0.2 - 0.6 mm.

While less evident on the diagram than the image, the decision of 28 pores came from the fact that that seemed to be the maximum amount that could be fit on the plate. The goal was to have as many pores as possible, as that would allow for the greatest amount of flour to be filtered through.

3.2. Fan and Motor

The fan and motor were extracted from a Hoover U4537-930 vacuum cleaner. The two pieces came assembled, as per figure 2, which has a clear entrance and exit. Therefore, the assembly was not taken apart since the motor and fan were already neatly assembled.

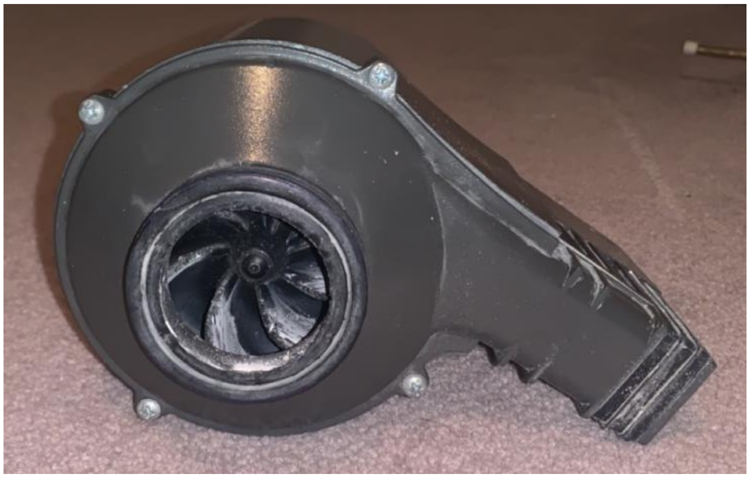


Figure 2. Fan and Motor Assembly of Hoover U4537-930

The power supplied to the motor came from an extension cord that plugged into a wall outlet. This extension cord came with the vacuum cleaner and was easily extracted from it. However, the power supplied from the wall is greater than the power that can be supplied from an Arduino, therefore, the original design idea will be updated to accommodate for this power difference when a solution is found.

The fan-motor assembly was placed along one face of the porous plate and then turned on. This allowed the pressure differential to be created inside the pseudo-pipe, thus mimicking the functionality of the real design.

The Hoover U4537-930 is a regular vacuum cleaner, and thus it can be assumed to operate at a rotational frequency of 30,000–35,000 rpm. This generates a sufficient pressure difference between the inlet and outlet, which will allow the malt dust to be sucked up.

The findings of prototype 1, as discussed in section 4.3 of this report, indicate that the fan-motor assembly used will be sufficient for the final prototyping design, and thus will be continued to be used.

4. Prototype 1

4.1. Test Plan

The plan for testing our prototype was to observe how well the vacuum could pull dust out of a greater amount of larger material. A mixture of popcorn and flour would be run through our container while the vacuum pulled as much flour as it could through the porous plate, simulating the malt flow process. The bag used to collect the vacuum's expulsion did not release air causing the prototype to be able to run for only 4 seconds. Due to this, we could not simulate the airborne quality that would happen in the actual silo with the material falling as it took far too long. We instead sat the material in our container, with one member mixing to mobilize the material as much as possible. Despite the mixing, the stillness would cause much less dust to have the opportunity to get sucked up, with most sitting on the bottom of the container. To account for this, a greater amount of flour was used, with flour being around 30% of the mass instead of the realistic 3% - 6%. With all issues seemingly accounted for, we ran 3 trials of this method, observing the quantity of flour that would be sucked out of thee greater material in 4 seconds of running.

4.2. Analysis

This model prototype was intended as a baseline physical example of the final product. The crudity is intentional as the model was meant to be completed with inexpensive and readily available materials simply as an indication of our direction. This prototype contains the vacuum fan for sucking in the dust through to a garbage bag representing the semi-permeable bag within the dust chute. Flour was used in place of dust (approximately same size) together with popcorn kernels representing the malt itself. Given the relative proximity of our results (within 4%) this model is a good example of the suction power of the fan. As for the porous membrane, it was constructed out of cardboard with diameter approximately 1/8 of a popcorn kernel to allow the flour (simulated dust) to pass through. The membrane was effective as it allowed dust to the flour to pass through. To simulate the mixing motion of the piping, a spatula with a turning motion was used to avoid static resources. Lastly, as the average amount of flour (dust) passed through was 9.22% of the total, the total dust can be assumed to be 10.8x the total dust collected in the collection receptacle above the sensor. Therefore, given the simplicity of this model, its results are certainly not wholly representative of the final system; However, did provide a considerable amount of useful data and applications.

4.3. Results

The three trials performed each indicated a different amount of flour removed from the mixture, as per table 1. It is important to note that, because of the porous plate used, no popcorn was removed from the mixtures in any of the three trials. Therefore, all the removed mass is attributed to removal of flour.

Table 1. Amount of Flour Removed from the Popcorn-Flour Mixture

	Mixture Before Vacuuming			**Mixture After Vacuuming**	**Flour Removed**	
Trial #	Popcorn (g)	Flour (g)	Total (g)	Total Mass (g)	Mass (g)	% of Flour
1	156	70	226	221	5	7.14
2	153	70	223	217	6	8.57
3	152	67	219	211	8	11.94
Average						9.22

As seen in Table 1, the results of the first prototyping test show that the fan and motor used were able to remove 9.22% of flour from the popcorn-flour mixture. Therefore, when creating the final design, it will be known that the fan can remove approximately 9.22% of malt dust it encounters. Thus, when the final design takes a dust mass reading, it must adjust the calculations to incorporate the fact that is only reading 9.22% of the total dust in the malt flow stream.

Furthermore, this test may be repeated and/or updated when a more accurate piping system is prototyped or when actual malt and malt dust are purchased. However, this prototype still gives a good baseline for what can be expected of the performance of the fan. Additionally, it also shows that the current design will be functional, as the dust will actually be able to be detected from the flow stream.

5. Potential Client/User Feedback

We were able to obtain useful feedback on our design from a user of vacuuming products – an HVAC self-employed individual named Steven White. He routinely works with air conditioning, heating, and vacuuming systems so is in a good position to give advice. He said that our device was sound and reminiscent of many products that he has seen. In terms of the intricacy, he indicated that in most cases, simplicity is best and using a load sensor (by mass) does just that. The only thing he said to make sure of is to ensure proper spacing for the system within the confines of the brewery. Therefore, for our final design we must have the total system spacing acceptable with respect to the area allotted by the auger. Also, by ensuring there isn't an undo burden on the piping system already associated with the factory, the dust collection piping should not remove or separate any existing infrastructure as this could cause spacing issues when reassembly would begin. Hence, as identified by a regular user of such devices, our design is sound and compatible with modern thought on suctioning devices.

6. Updated Design

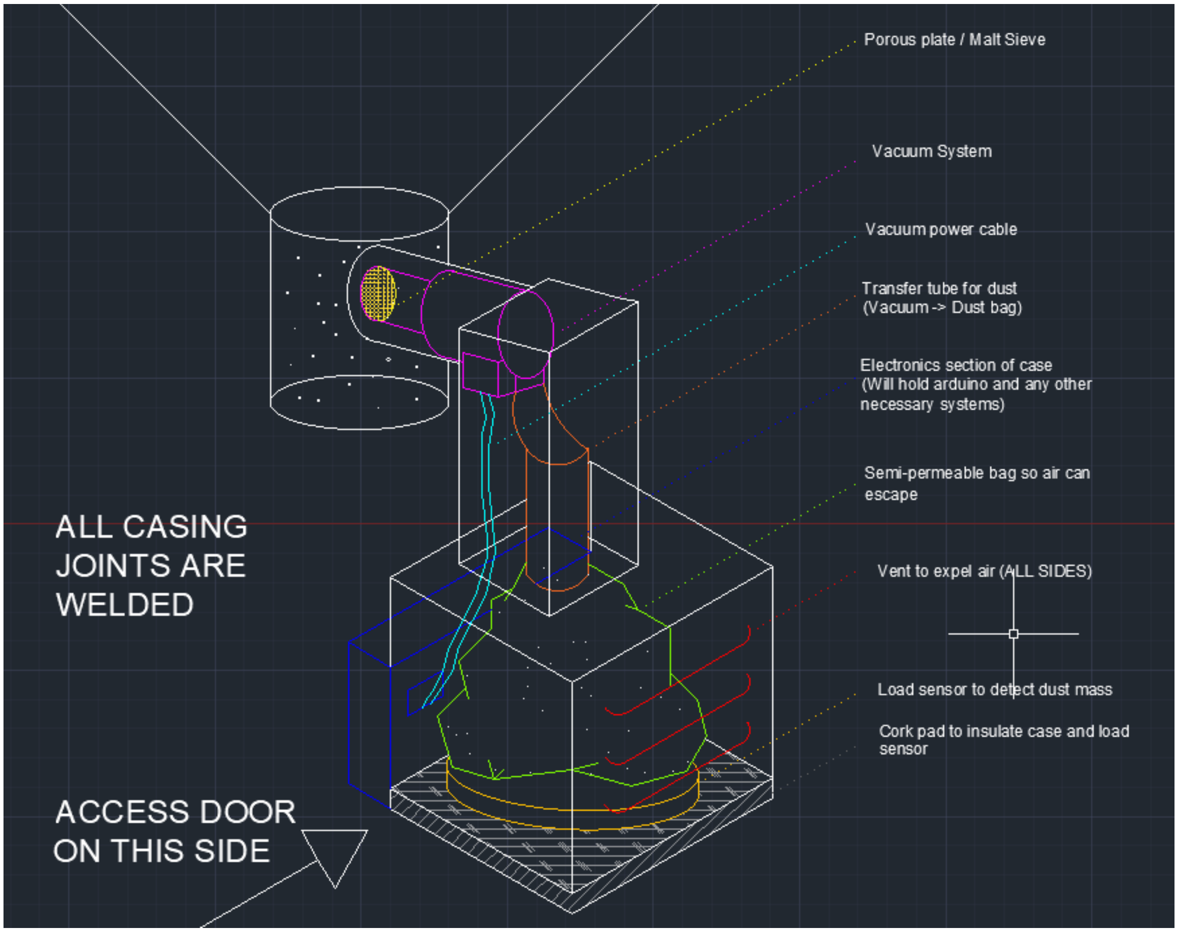

Porous plate / Malt Sieve
Vacuum System
Vacuum power cable
Transfer tube for dust (Vacuum -> Dust bag)
Electronics section of case (Will hold arduino and any other necessary systems)
Semi-permeable bag so air can escape
Vent to expel air (ALL SIDES)
Load sensor to detect dust mass
Cork pad to insulate case and load sensor
ALL CASING JOINTS ARE WELDED
ACCESS DOOR ON THIS SIDE

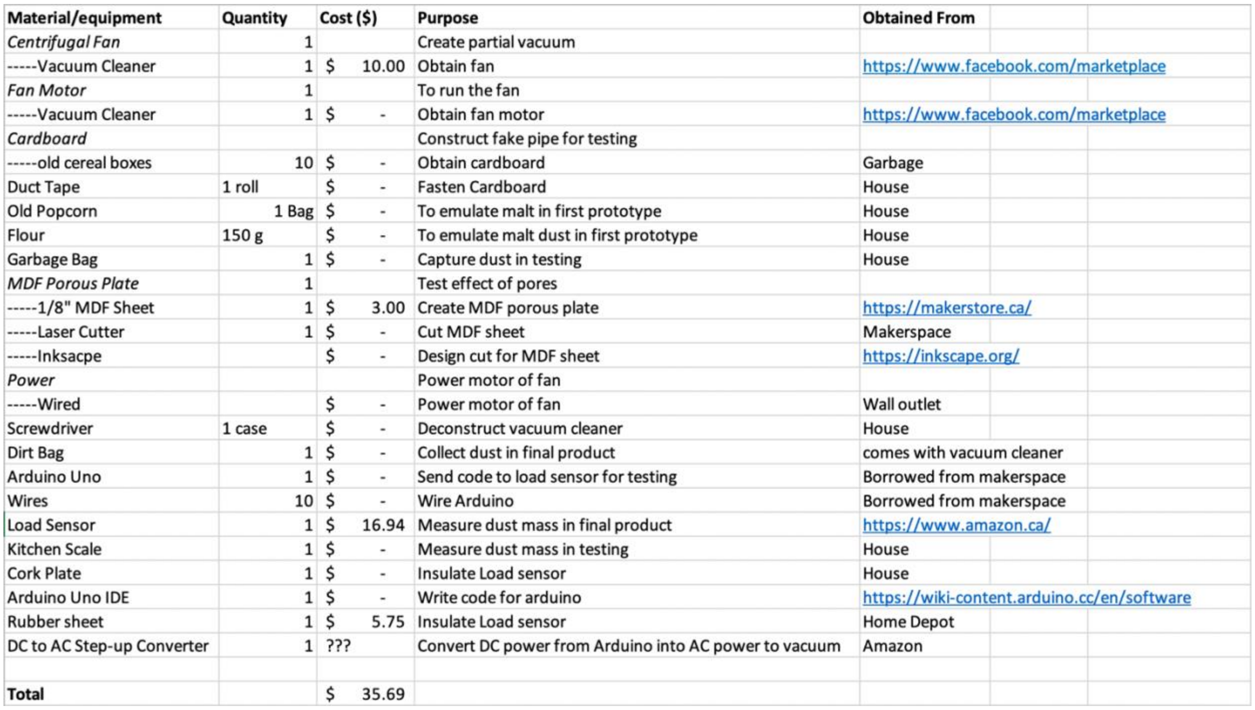
Figure 3. Updated Design

7. Updated Bill of Materials

After discussion with project manager and the first prototype testing, the bill of materials has been updated to accommodate the current requirements of the design, as per table 2. This list is still tentative and will be updated as any new requirements are understood.

It should be mentioned that the DC to AC step-up converter is not yet known how it will work, and thus it also unknown what product should be purchased. Therefore, there is currently no listed price, but there will be one after group discussion and further discussion with the project manager.

Table 2. 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 cereal 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
MDF Porous Plate	1		Test effect of pores	
-----1/8" MDF Sheet	1	$ 3.00	Create MDF porous plate	https://makerstore.ca/
-----Laser Cutter	1	$ -	Cut MDF sheet	Makerspace
-----Inksacpe		$ -	Design cut for MDF sheet	https://inkscape.org/
Power			Power motor of fan	
-----Wired		$ -	Power motor of fan	Wall outlet
Screwdriver	1 case	$ -	Deconstruct vacuum cleaner	House
Dirt Bag	1	$ -	Collect dust in final product	comes with vacuum cleaner
Arduino Uno	1	$ -	Send code to load sensor for testing	Borrowed from makerspace
Wires	10	$ -	Wire Arduino	Borrowed from makerspace
Load Sensor	1	$ 16.94	Measure dust mass in final product	https://www.amazon.ca/
Kitchen Scale	1	$ -	Measure dust mass in testing	House
Cork Plate	1	$ -	Insulate Load sensor	House
Arduino Uno IDE	1	$ -	Write code for arduino	https://wiki-content.arduino.cc/en/software
Rubber sheet	1	$ 5.75	Insulate Load sensor	Home Depot
DC to AC Step-up Converter	1	???	Convert DC power from Arduino into AC power to vacuum	Amazon
Total		$ 35.69		

8. Second Prototype Test Plan

After completing the first step of the prototype test plan, which was test the functionality of the partial vacuum with the porous plate. We can move onto the second step which is now testing the functionality of the load sensor in conjunction with the code in C++.

This plan will be successful if the load sensor will be connected to an Arduino which will be run a C++ code into an Arduino IDE, which will be able to the display the load sensor is performing and the values. Also, when giving the dust composition, we will determine how long it takes the load sensor to give to the values. We will record the time it takes to retrieve the value.

We will need to make sure while developing this code, that everything runs smoothly and that we do not encounter any errors. If done correctly, we will be given the dust composition in reasonable time. We will be doing several tests making sure that our code is functional and that we are running into no issues. Also making sure that the value we are retrieving from the code is like what we expect from our first test.

9. Task Plan Update

https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=k4HzxMjDPms4ou9ZIuCcnOmyBWODW9HD%7CIE2DSNZVHA2DELSTGIYA

10. Conclusion

Therefore, this prototype was a simplistic mechanistic example designed to provide physicality and basic data to allow us to continue this project. The main objective was to test the efficacy of the vent fan and its approximate proportionality and appropriate positioning. This has been accomplished and will be re-examined in later models.