Deliverable D

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1. Introduction

For this deliverable, three separate subsystems have been designated: the dust sensor, computer software, and the protective casing. Furthermore, from these, three functional solutions have been obtained using different categories of our three subsystems as outlined in the document. A final design has been determined and will be presented in section 5.2.

2. Initial Concepts

The initial concepts for subsystems were made as sketches by the group members and can be found below as figures 1–11. These concept sketches also include brief descriptions of the ideas and functionalities ideated by the group member.

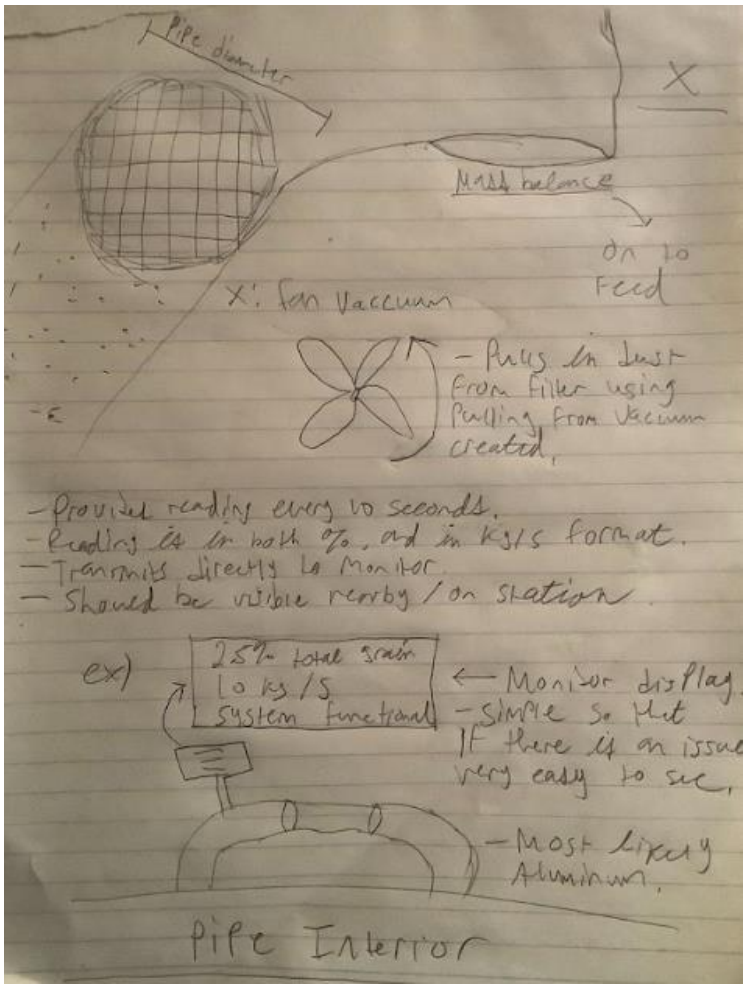

Figure 1. Dust Sensor Idea by Michael

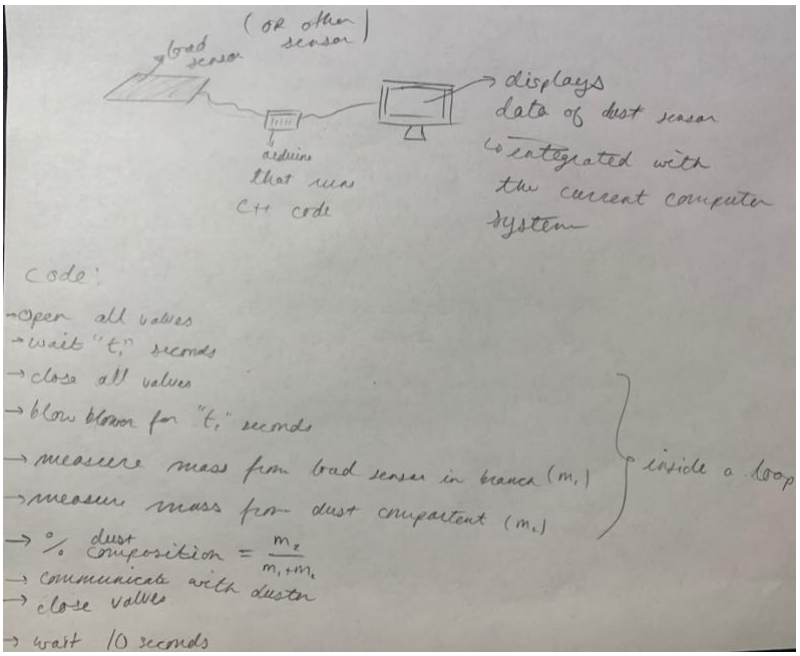

Figure 2. Software/Hardware Idea by Luke

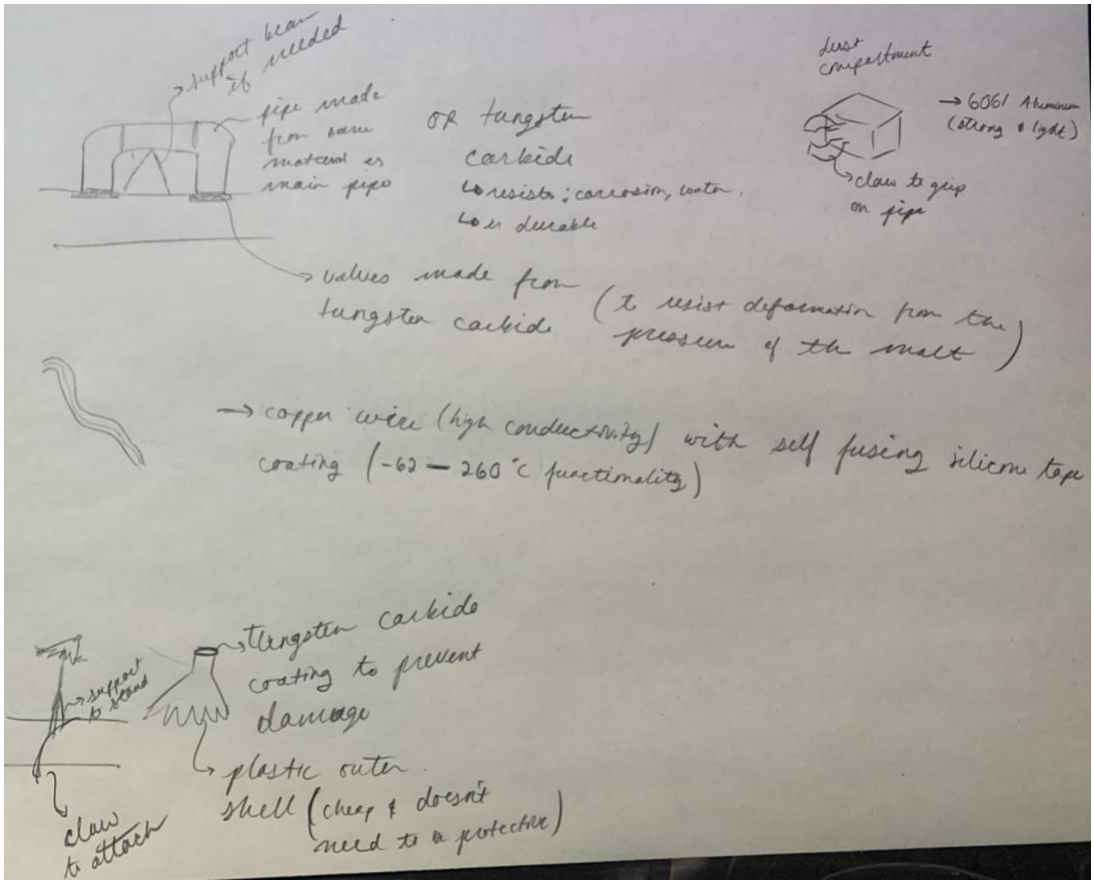

Figure 3. Protective Casing Idea by Luke - 1

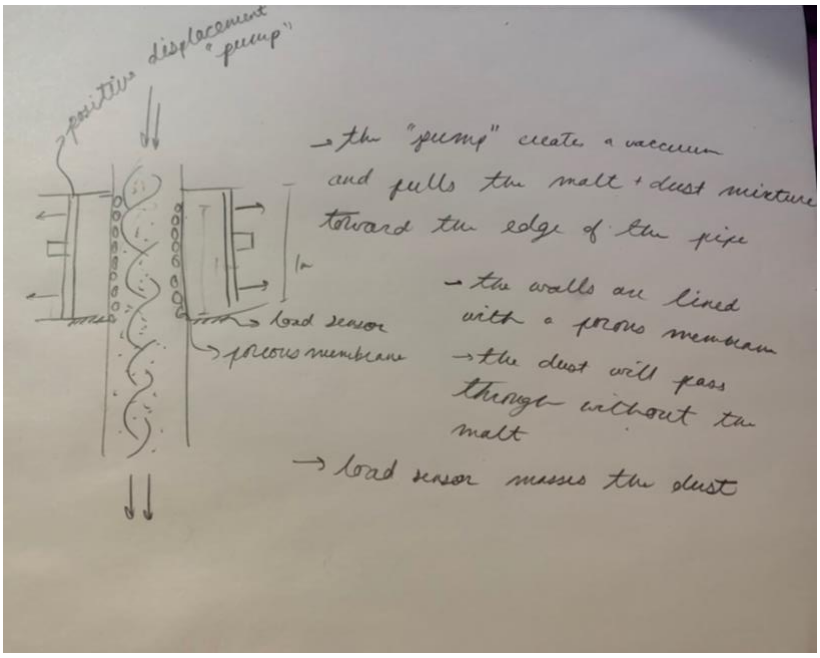

Figure 4. Dust Sensor Idea by Luke

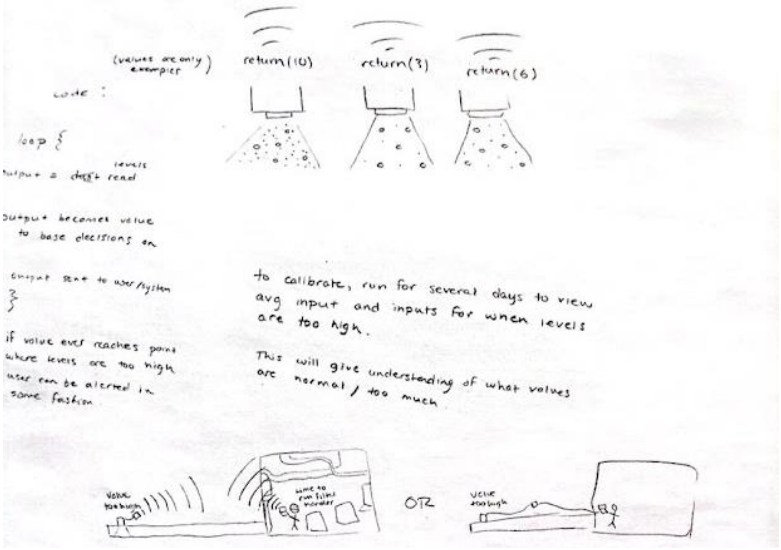

Figure 5. Dust Sensor Idea by Harrison

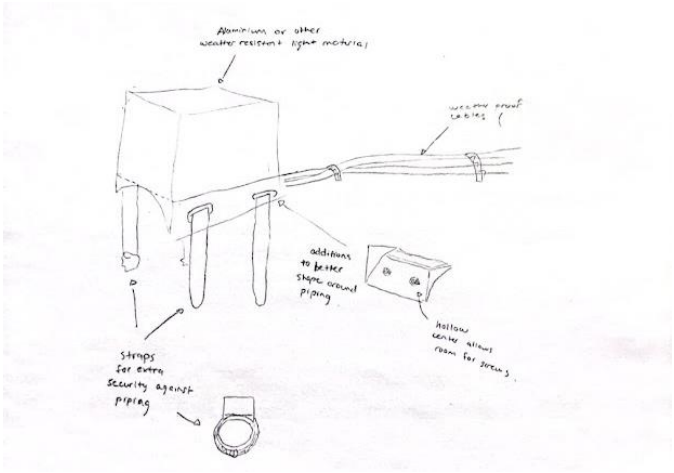

Figure 6. Protective Casing Idea by Harrison - 1

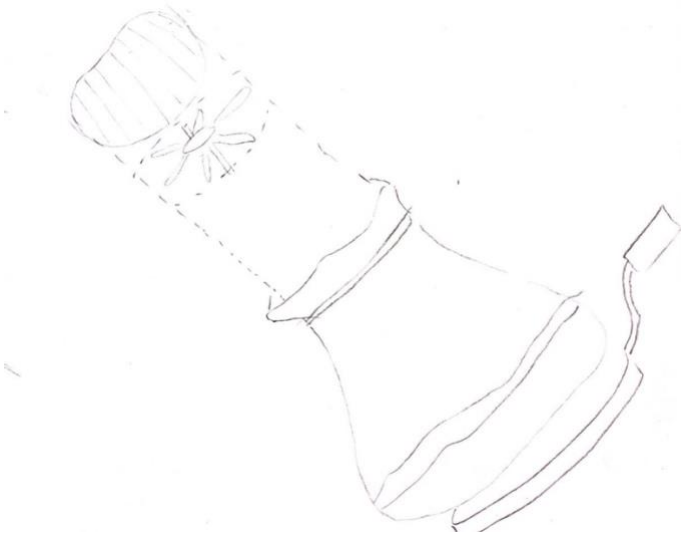

Figure 7. Protective Casing Idea by Harrison – 2

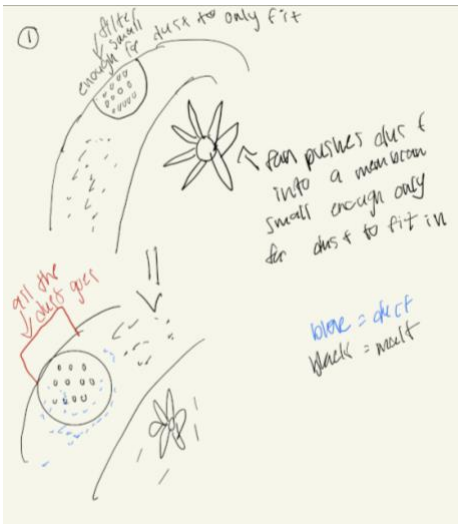

Figure 8. Dust Sensor Idea by Nicholas

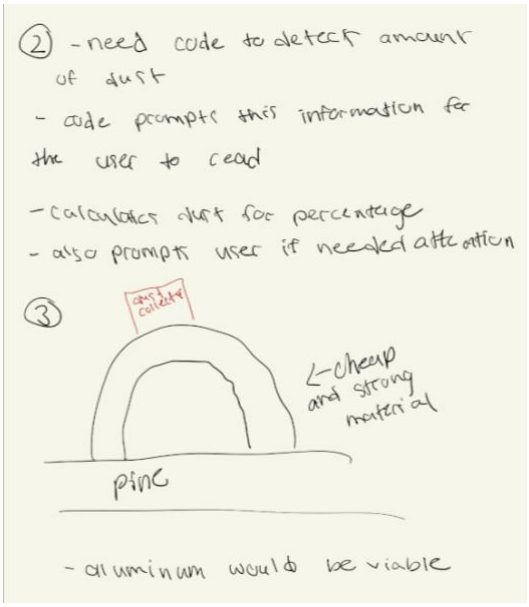

Figure 9. Protective Casing Idea by Nicholas

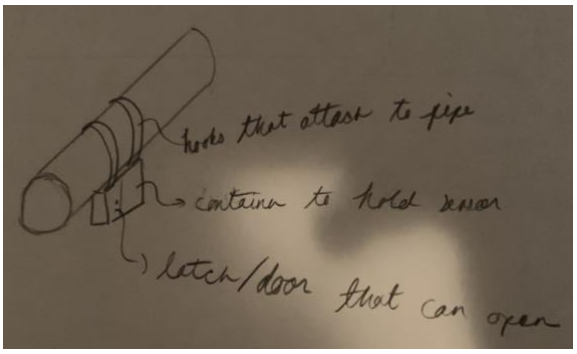

Figure 10. Protective Casing Idea by Luke - 2

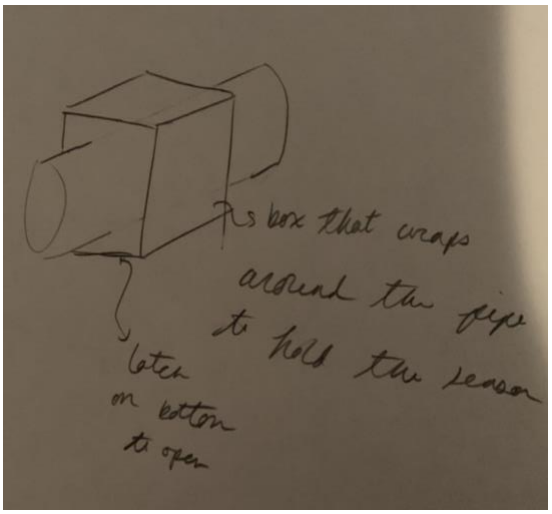

Figure 11. Protective Casing Idea by Luke - 3

3. Refined Subsystems

There are three subsystems for this deliverable, the load sensor, the software, and the protective casing. Each subsystem has four further subsystems to ensure diverse ideas within the criteria. For the dust sensor these are load sensor, audio sensor, light sensor, and a charge sensor. For the software, C++, C, VBA, and Thunkable are the sub-subsystems. Lastly, for the casing, welded, hook attached, riveted, and a wrap-around system were selected. Further information on these subsystems is found below:

3.1. Dust Sensor

The first defined subsystem is the dust sensor. Its function is to detect the amount of dust within the malt flow stream.

3.1.1. Load Sensor

The first discussed option for a dust sensor is a load sensor. It converts a force, the weight of dust for this project's purpose, into an electrical signal. This sensor can be used through the accompanying of a porous membrane and a centrifugal fan.

As per figure 12, the porous membrane lines the wall of the pipe with pores small enough to allow dust to pass through but not malt. When the fan is turned on, it will create a pressure differential between its front and back, thus creating a partial vacuum. When this vacuum is created, the malt flow stream will be sucked toward the porous membrane, where the dust will be passed through. Then, the load sensor can find the mass of the dust, which will be used to calculate the flow stream composition.

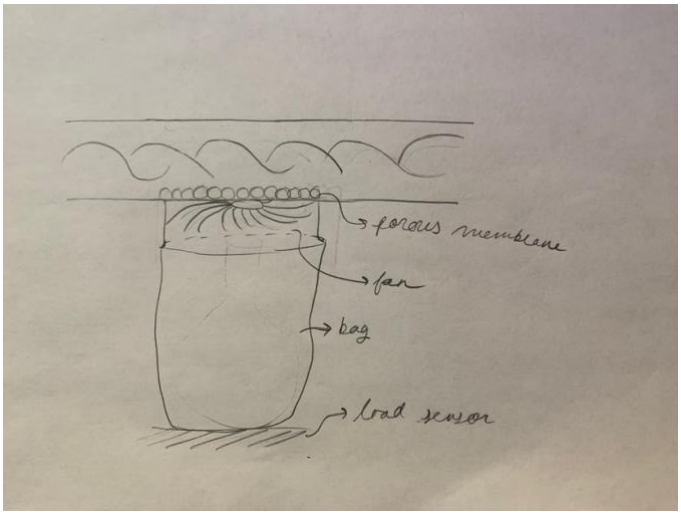

Figure 12. Refined Load Sensor Idea

The load sensor's main benefits are the accuracy of the reading and the ease of operation. Since the porous membrane allows only dust to pass through, there is no risk of detecting malt instead of dust. Moreover, since the flow rate is always 2000 kg/hr, the dust composition can be

accurately calculated from a dust mass reading. Additionally, since the load sensor can be placed on the ground instead of inside the pipe, cleaning or inspecting it can be very easily performed by one person. Furthermore, the ground placement has less risk of incurring damage from the auger or other unpredictable occurrences, making the dust sensor less likely to malfunction or be replaced.

The load sensor's main drawback is the speed of measurement. Since it cannot continuously weigh the dust, it must operate in a batch process. Therefore, the dust composition information can only be given in intervals.

3.1.2. Audio Sensor

The audio sensor works by incorporating sound waves into the piping system to determine dust concentration. Dust particles produce a lower frequency than the larger and heavier malt and hence the sound is different. The frequency of a dust particle is approximately 0.1 Hz, whereas that of a malt particle is about 100 Hz. Two sensors therefore attuned to the relative frequencies would be able to "pick up" such frequency data and transmit to a software system where it would be analyzed to determine a concentration of dust in the system.

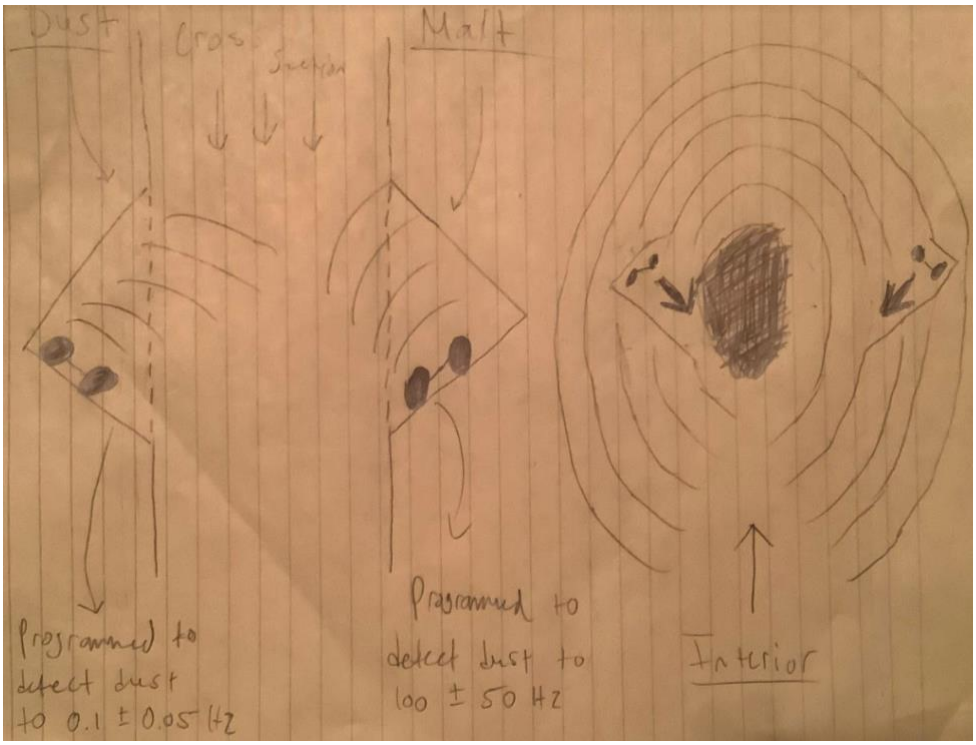

Figure 13. Refined Audio Sensor Idea

This sensor does not require extensive reconstruction of the tubing used in the transportation mechanism. Two small alcoves are constructed on the exterior of the pipe to house the two sensors. As in figure 13, these mounts extend only to a sufficient length and width of the detectors – again maintaining minimal alteration. Also, this device does not interfere at all with the flow of malt. The transmitters are protected by a wired mesh that stops malt from becoming

clogged by the sensors. This is a great asset as it allows the malt flow from one compartment to another maintaining the current functionality.

One of the main drawbacks here is the relative uncertainty in composition. On occasion, dust particles may vary in size and so a safety factor of +/- 0.05 Hz is applied to sensor 1, and +/- 50 Hz is applied to sensor 2. This ensures that ALL material data will be collected. Furthermore, the mesh protecting the sensors from malt will not impact results as it will be constructed from high grade plastic, not impacting the echo of sound.

3.1.3. Light Sensor

An additional discussed option is the light sensor. This sensor would create an electric signal based on the concentration of particles calculated by an LED light and photodiode sensor.

As seen in figure 14, the sensor would emit an LED light on the interior of the piping. This light would then bounce off any particles of dust and malt flowing through the pipe. The photodiode sensor would then capture how much light is reflected, turning the amount picked up into a charge that can be used to measure the concentration.

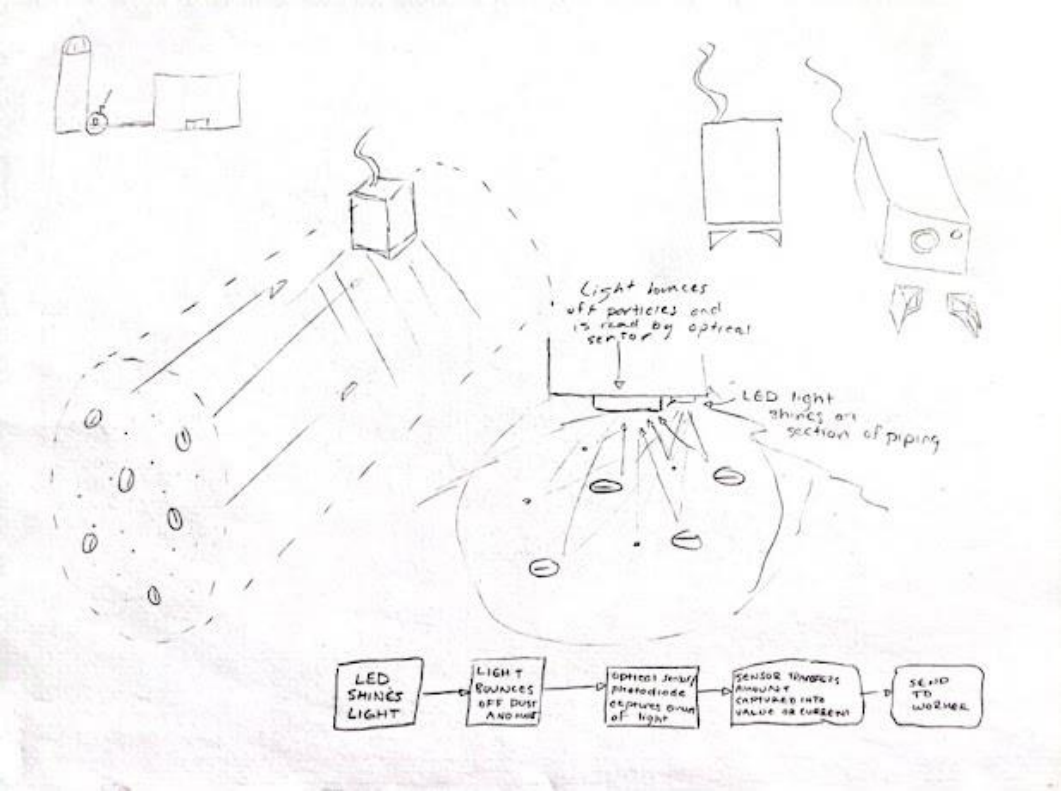

Figure 14. Refined Light Sensor Idea

Many of the benefits of the light sensor lie in the simplicity of the system. The light sensor utilizes a simple photodiode sensor with an LED attachment. Sensors like this are very easy to

find, and quite cheap relative to other methods. Most similar sensors are very compact due to their lack of complexity, allowing for a lightweight and compact build that can easily be fitted onto the piping without the need for reinforcement with the ground. Also, the method of detecting concentration is done purely observationally, meaning no aspects of the sensor will obstruct malt flow or effect flow rates in any fashion.

This systems simplicity also brings its drawbacks. Due to the method of capturing light reflection, it is unrealistic for such a system to be able to differentiate malt and dust. While overall levels will still be readable, this severely impacts the accuracy of the system. Additionally, the light sensor is most effective when objects are airborne. Further testing would have to be done to see if such a method could properly function alongside the auger system that causes malt flow.

3.1.4 Charge Sensor

A charge sensor is used as an electronic electroscope. The charge sensor can do quantitative measurements. Numerical measurements improve the electrostatic experiments. It can measure the charge by induction, friction and as well contact. The charge sensor can also be used to measure the charge of polarity.

As seen in figure 15, the electric charge sensor would be constructed to the bottom of the pipe, allowing the sensor to determine the charge of the malt and dust passing through the pipe causing the malt and dust to have friction. With this information, we would be able to determine how much dust composition there is since the malt and dust would have different charges.

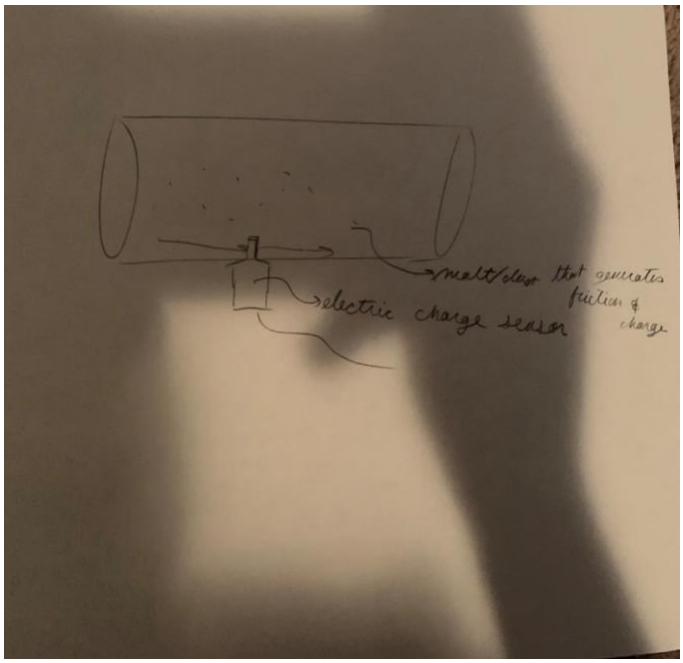

Figure 15. Refined Charge Sensor Idea

The advantage of this sensor is that it is a simple sensor to use. It is a compact design as well due to its simplicity, not much management would be required for this sensor.

There are a few disadvantages of this sensor. One of the disadvantages include the price. This sensor is on the expensive side and other sensors that could do the same function of determining the dust composition could do it at a cheaper price. Another disadvantage is that it will not be as reliable of a sensor. Determining dust composition using charges could be difficult and hard to implement into the system.

3.2. Computer Software/Hardware

The computer software/hardware subsystems function in a similar manner, the major difference between them being the language of choice. Therefore, figure 16 shows the general process that any of the coding languages would follow.

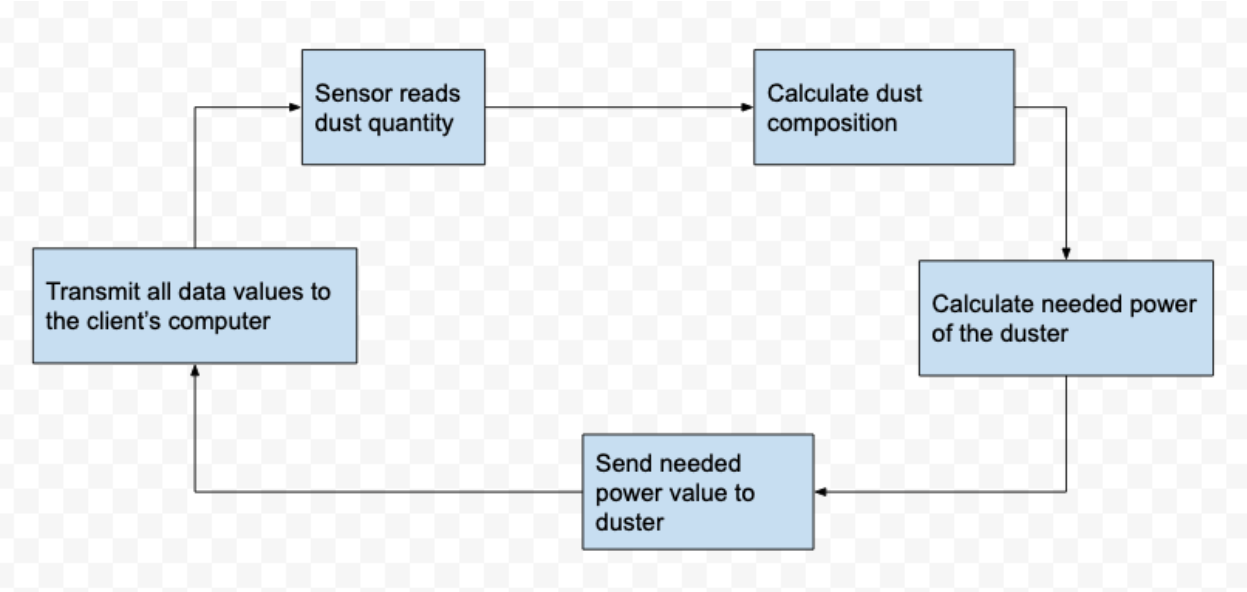

Figure 16. Computer Software Flowchart

3.2.1. C++

A refined idea for the computer software subsystem is a C++ code. This will run in conjunction with the sensor and receive an input of dust quantity. Then, depending on which sensor is used, the code will perform calculations to determine the composition of dust in the flow stream and convey that information to the client's computer.

The main benefit of using C++ is its functionality with Arduino. This allows easy prototyping and testing of the sensor and code since the group has experience with both C++ and Arduino. Additionally, C++ has more functionality than C, making it the preferred programming language.

The main drawback of C++ is the lack of expertise in coding amid the group. Since no group member has a strong background in coding C++, it will pose a challenge to develop efficient code in comparison to easier programming methods, like Thunkable. However, the code that must run is not expected to be overly complicated, and thus it will be able to be done.

3.2.2. C

Another functional software that could be used is coding in C. Similar to C++, This code would be used to receive inputs of the dust quantity based on one of the several sensor ideas, and then proceed to calculate the concentration of dust to relay to a nearby computer.

Like C++, a great benefit to coding in C is its functionality with Arduino. This allows for more familiarity in the group when it comes time to create and test the program. Additionally, our group includes multiple members that have experience coding in this language. Not only will this accelerate the coding process by having familiarity, but group members with experience will be able to work together to make efficient code.

A considerable drawback to coding in C is its simplicity. Especially in contrast to its similar counterpart C++, C is very simple, allowing for much less complexity in the code. It is yet to be seen if the code required will reach these limits of complexity.

3.2.3. Thunkable

Thunkable is a program used to be able to make apps. Using thunkable, it would be used to design an app where it is easy for the user to see all the data that the sensor is performing. Using this program would allow the users to easily access the information that the sensor would be providing allowing the user to be able to respond to such data and acting on it if needed attention.

Thunkable is a good and simple software to use and learn which allows it to viable in this situation. This is good due to us not having much experience with this program, we would be able to learn the functions of it with not much effort needed.

The disadvantage of Thunkable is figuring out how to connect the sensor and displaying the data that the sensor is retrieving. Due to not having a lot of experience to the program, it would take a lot of time figuring out how to connect the sensor with the app.

3.2.4 VBA

VBA is a method for coding that runs in conjunction with Microsoft systems. It is used in Academia mostly and it is generally used for inputting commands into excel or word. This code would receive the inputs from any sensor (audio, load etc…) and follow them through to an excel spreadsheet. This would be a well-organized method as all data would be in tabular form without the need for cross-referencing.

This coding method is extremely consistent meaning whatever data is being uploaded, the way in which it is done so is the same each time. This provides for more certainty in data recognition as the method of delivery is constant so there is little area for misinterpretation. Excel, the main program to which VBA transmits, is extremely versatile. It can be used for computing averages, percents, deviations, and enormous amounts of raw data that can be used for analysis. Hence it allows for going above and beyond the necessary program requirements.

A disadvantage of VBA is the necessity of knowing how to program in it – which can be a challenge. VBA is fairly complex in its coding capabilities and therefore can seem a daunting challenge by a newcomer. Also, this software is ONLY available to Microsoft users so it lacks diversity in terms of the usable devices that can run it. This is only an issue; However, if there is no Microsoft-device capability.

3.3. Protective Casing

3.3.1. Welded

The welded design is a sort of structure that sits below the pipe giving any one of the sensors access to room below for any needed accessories, parts, or appliances. There will be a door to give the client access to the room below. The case and door will be made of stainless steel as it is relatively inexpensive and durable, and other materials such as aluminum would require a unique method of welding that the group lacks experience in.

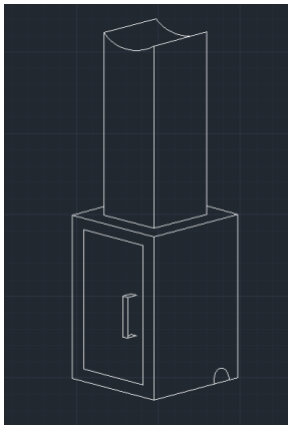

Figure 17. Welded Protective Case

The benefit of having a case such as this is its sturdiness and size. Having the case on the ground is more secure and doesn't have the risk of anything falling and breaking the system. Additionally, the large area inside with a door, allows the client to have quick access to the sensor and system and fit any additional systems inside.

A drawback to having a case that sits on the ground is the higher material requirement and susceptibility to weather. A larger case unsurprisingly leads to more material required for the case's construction which increases price and time that will be required. Also, with the case sitting on the ground, the system becomes more susceptible to weather damage. Harsh

weathers such as snow and rain could possibly affect the system, requiring additional weather proofing to avoid any damages.

3.3.2. Hook attachment

The hook attachment is designed to rest atop the malt pipe and contain the needed sensor, as per Figure 18. The hooks and box would be made of stainless steel because it is relatively inexpensive and durable.

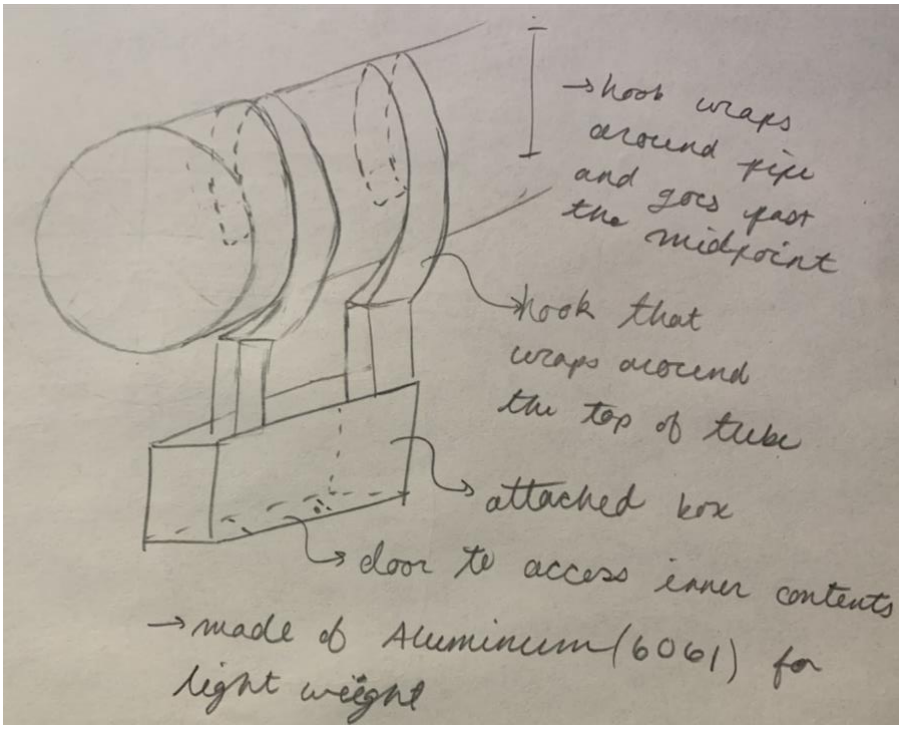

Figure 18. Hook Attachment Protective Casing

The main benefit of the hook attachment is the compactness of the design. It involves little material used, which reduces cost, and it does not impede on other components of the malting process.

The main drawback of the hook attachment is its instability. The hooks would apply pressure to the parts of the pipe atop which they rest, causing a risk of damage or breakage to the pipe. Furthermore, the hooks are not physically attached to the pipe, they merely rest on it. Therefore, the attachment is not secure and could easily fall off due to an unpredictable external force.

3.3.3. Riveted Chute

The riveted chute is designed in a very similar fashion to the welded chute except it is riveted (bolted) together rather than welded. As mentioned, this is a chute that leads directly down from the transport pipe allowing dust (from the filter) to fall with gravity down to the sensor. The sensor is enclosed by a small “room” configuration with a door for ease of access.

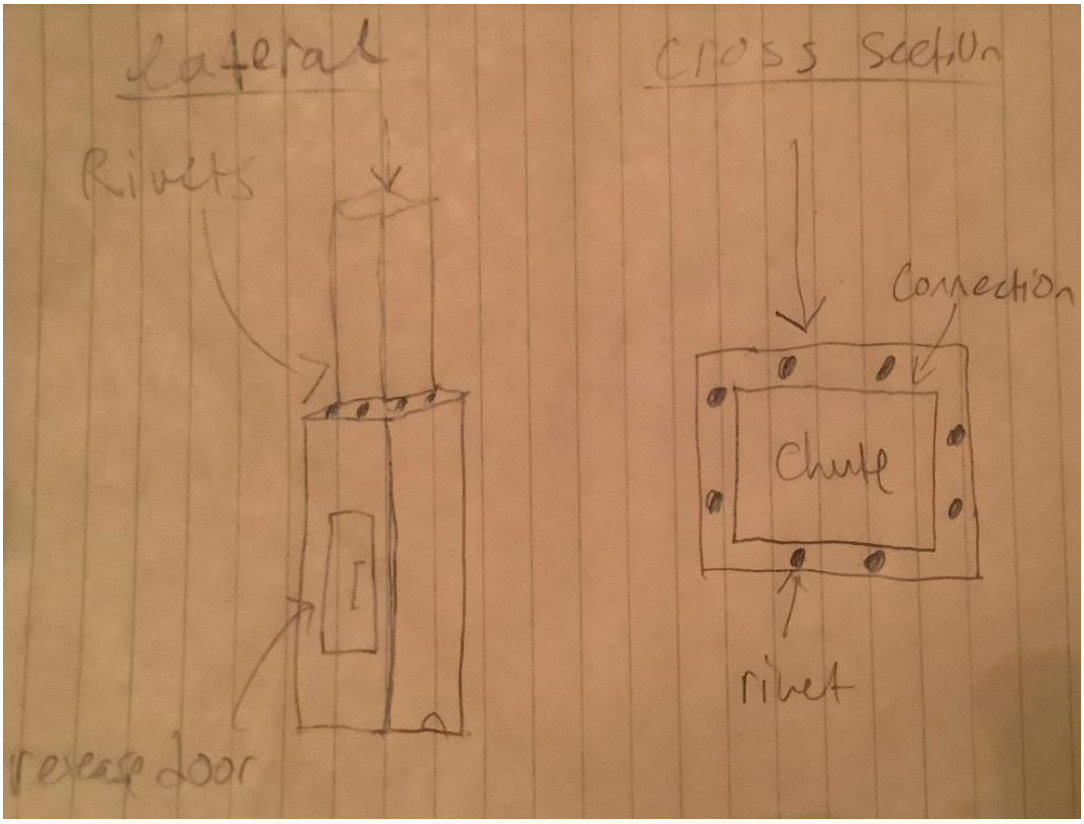

Figure 19. Riveted Chute Protective Casing

This design allows for clean, easy maintenance of the sensor and the dust contained within it. The door in the receiving compartment greatly assists with this process as the dust is contained to that one area and can then be easily scooped out by staff. Furthermore, this greatly prevents clogging as there are no bends/turns in the chute, so passage of dust is unaffected.

The main disadvantage of this concept is strength. Riveting is not as strong as welding and is more likely to fail due to structural pressures. Because welding fully encases the edge of the compartment whereas welding simply bolts in sections, the structural integrity is diminished in the riveted design. Also, riveting adds extra weight and cost to the system where welding would not.

3.3.4. Wrap-around attachment

The wrap around attachment is a box that wraps around the pipe which would hold the sensor inside of it. The way this box would be open to access the sensor is that there would be a latch at the bottom to open it.

The advantage of this design is that it would be allow easy access to the sensor and allowing the sensor to be protected from the outside.

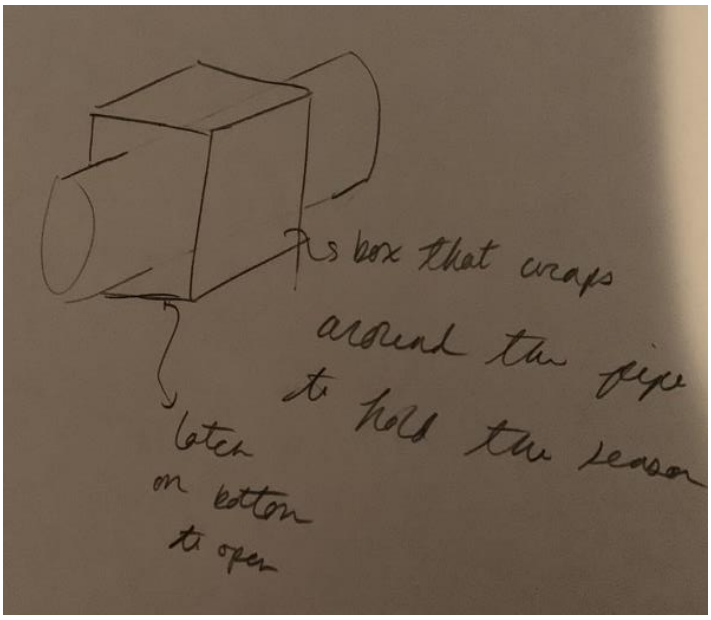

Figure 20. Wrap-around Protective Casing

The disadvantage of this casing is that it would be hard to implement in the system. This would be quite expensive due to the how the piping design is. There would have to be moving around for this to work.

4. Functional Solutions

The refined subsystems were combined a way that allowed the dust composition to be read in three ways by three different functional solutions. These solutions are combinations of subsystems that were deemed to be most effective.

4.1. First Solution

The first functional solution that the group created is the combination of the load sensor, the C++ code, and the welded chute.

The welded chute allows the sensor to be placed on the ground, which thus allows the load sensor to hold large masses of dust without imposing damage to the pipe. Furthermore, the welded chute, made of stainless steel, provides a safe place for an Arduino or another needed motherboard to be placed, which thus allows C++ code to be run. Therefore, this combination of subsystems allows each one to work optimally together

4.2. Second Solution

The second functional solution that the group came up with was the combination of the audio sensor, VBA, and the hook attachment casing.

Ideally, the audio sensor will be two sensors on each side of the piping, so they can determine the frequency of dust and malt individually. The hook attachment casing works perfectly with

this method as it is a secure method designed for the sides of the piping. The sensors on each side are relatively compact, this would benefit the hook attachment casing as it limits the size and weight, negating any worry of too much pressure on the piping. VBA will work quite well with the audio sensor, as the audio sensor will be sending out very large amounts of raw data that will need to go through several stages of calculation to obtain the concentration of dust. VBA functions quite well with this as it transmits to Excel, which is very good at holding immense amounts of data and easily putting it through calculations to store the results.

4.3. Third Solution

The third functional solution that the group created was the combination of the charge sensor, using C for the coding and as well the wrap around attachment.

The box wrapped around the pipe would allow the sensor to connected onto the pipe allowing the sensor to be protected. A latch would be put onto the bottom the box allowing access to the sensor if needed. The charge sensor would be used to determine the charge of malt and dust by using friction than which would allow the C code to be run for finding out the dust composition.

5. Evaluation of Ideas

The three functional solutions are analyzed for the purpose of determining the best solution to proceed with during the rest of the design process. The method of evaluation used is a selection matrix. This method allows each design criteria to be weighted according to its importance, and it allows each solution to be measured against those design criteria.

5.1. Selection Matrix

Using a selection matrix, each design criteria was ranked on a scale of 1–6, with 6 being the highest, or most important. Additionally, the three solutions were evaluated on a scale of 1–3, with 3 being the highest, or best, evaluation.

Table 1. Selection Matrix for the Three Solutions

Design Criteria	Priority	First Solution	Second Solution	Third Solution
Pre-emptive dust reading	6	2	3	1
Ease of operation	5	3	2	2
Reasonable Cost	4	2	3	1
Handleability of all dust qualities	3	3	1	1
Safety	2	3	2	2
Applicability to current process	1	2	3	1
Total Score	-	**52**	**50**	**28**

5.2. Selected Functional Solution

After weighing the many options, the group concluded that the first solution was the best design to move forward with. In the end, this design held the most strengths, and had the least weaknesses.

The issue with the third solution (Charge sensor, C, Wrap-Around casing) was it completed the task but less effectively than each other solution. This method would be both slower and much more difficult to implement into the current system, all for a higher cost.

The second solution (Audio sensor, VBA, Hook attachment casing) held many positive traits, it detected the concentration fast, was cheaper than alternatives, and could be very easily implemented. However, its uncertainty with composition was a major drawback. It also didn't help that in comparison to the first solution it wasn't the easiest to setup and operate for the client.

The first solution (Load sensor, C++, Welded casing) was the decided best solution. This method was considered far more accurate in determining concentration by physically measuring the weight instead of attempting to read it. It was also found to be the most client-friendly, being very easy to use and read, as well as being perfectly safe for all parties. These strong features along with the distinct lack of strong weaknesses are what caused the group to select the first option.

6. Conclusion

In conclusion, the best-determined design was the load sensor, with the C++ code – Arduino combination, and the welded sensor chute. This was solved by using a selection matrix and by general group discussion. The process will likely be refined after our group client meeting to incorporate feedback obtained from that discourse. Finally, this design is the best of the three final solutions and therefore will be our baseline moving forward.