Jonathan's Natural Juices Mechanical Juice Dispenser

Sponsor Contact: Lance Brookner

A Senior Project by:

Andrew Meyer	ameyer07@calpoly.edu
Jesus Gutierrez	jgutie33@calpoly.edu
Danielle Lauinger	dlauinge@calpoly.edu

Abstract

Team AJD was tasked with trying to create a juice dispenser that did not utilize pumps, but rather explore the venturi effect to see if it could be a suitable substitute. The venturi effect is when a fluid in a pipe goes through a gradual reduction in diameter in a pipe to increase the velocity and lower the pressure of a fluid. Utilizing this principle the team constructed a testing device to be able to run tests and verify the theory. The team was able to verify that the venturi effect was able to make juice at the correct mix ratios.

Statement of Confidentiality

The complete senior project report was submitted to the project advisor and sponsor. The results of this project are of a confidential nature and will not be published at this time. ME428/429/430 Senior Design Project 2014-2015

DISCLAIMER

Statement of Disclaimer Since this project is a result of a class assignment, it has been graded and accepted as fulfillment of the course requirements. Acceptance does not imply technical accuracy or reliability. Any use of information in this report is done at the risk of the user. These risks may include catastrophic failure of the device or infringement of patent or copyright laws. California Polytechnic State University at San Luis Obispo and its staff cannot be held liable for any use or misuse of the project.

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Introduction

Lance Brookner of Jonathan's Natural Juices contacted California Polytechnic State University, Cal Poly (Cal Poly) to design a new juice dispensing system that is more cost effective and reliable than other dispensing units in today's market. Today's juice dispensing machines utilize pumps to mix water and fruit concentrate to produce juice. Pumps are usually the most costly component and require upkeep in order to maintain proper function, leading to downtime and repair costs. Mr. Brookner proposed that the group chosen should design a system that does not employ the use of pumps. By reducing the amount of movable parts in the device, the machine would need less maintenance and servicing. Mr. Brookner has been working with Cal Poly since 2006 to develop a machine that does not use pumps. Mr. Brookner's findings with the last two senior project teams found that a venturi or jet pump could be effective as a substitute for a pump. The first group focused on verifying that a jet pump could theoretically produce the correct mix ratios within the allowable tolerances (Shollenberger, 2007). The second group worked to create the first prototype of the project (Owen, 2008). Building off the two teams' research, the task of this group is to build a fully operational prototype that will operate at a specified level and stay within the given parameters defined by the team.

Throughout the design process, the group will consider potential needs and wants of stakeholders which include: Jonathan's Natural Juices, manufacturers, suppliers, and the people who will drink the juice. Jonathan's Natural Juices is the main stakeholder and will be mainly concerned with the design and profitability of the final product. Manufacturers will require a design that can be made using commonly used processes that do not require specialized equipment. Suppliers will be mostly concerned with the distribution process for the product which will be directly related to the size of the final product design. Finally, the juice drinkers will expect a certain consistency and flavor that is found when the mixture is properly made.

Overall there are many aspects that the team will have to analyze and evaluate to create a working prototype within the project timeline. Customer considerations and design specifications will be incorporated into the formative decisions that will lead to the final design product. If successful, the group will have a functional mixing device and a trial setup that can be used to demonstrate how the device works and be a showcase to present to future clients of Jonathan’s Natural Juices.

Background

The first step in the engineering design process is to thoroughly research all aspects that may be useful in the design development. This includes preliminary research, previous design phases, modern machines and processes, as well as the current market and potential competitors. Understanding each of these is important in developing the best project possible that will not only satisfy our sponsor's requirements but potentially become a new competitive product in today's market.

Preliminary Research

After an initial discussion with the sponsor, the team believed it was important to understand the basic terminology of the juice making process as well as become familiar with any specialized methods or tools involved with the procedure. The key points that were focused on were: what defines juice concentrate, what was required for proper mixing, and what determined if proper mixing had occurred.

A concentrate is defined as a substance in which the majority of its base component is removed (for example the water in the fruit juice). Typically this is done to save weight while it is being shipped as well as increasing the life of the product. Additionally, when the concentrate is ready to be used it can be reconstituted by the addition of water. The first step in making juice concentrate is peeling away the skin of a ripened fruit and removing the core to expose the meat of the fruit. After this, the meat is then squeezed or pressed to extract the juice into a holding container. At this point in the process, the juice can be labeled as natural juice. Further treatment such as pasteurization and pulp removal can occur, or the juice can be further processed to achieve a concentrate state.

To obtain juice concentrate from a juice's natural state, the juice must first be subjected to a heat treatment. Heat treating the juice evaporates the bulk of the water, leaving behind the aromatic chemicals and flavor of the fruit. After heat treating the juice, chemicals are either added or extracted from the juice in order to produce a more condensed form of the fruit's natural juice. Finally, additives are used to maintain the juice's color and flavor, as well as elongate the shelf life of the juice concentrate (FitDay).

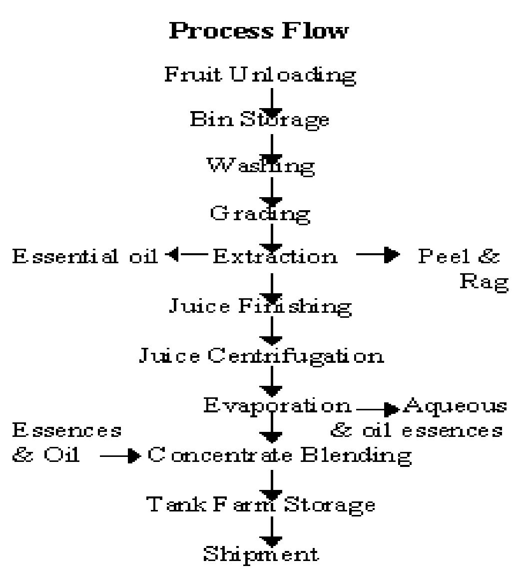


Figure 1: Process used to obtain concentrate (Johnson).

The next step was to find how the juice concentrate could be reconstituted into fruit juice be mixing the water back into the concentrate. Mixing in the beverage industries was usually accomplished with one of two methods, pre-mix and post-mix. Pre-mix is defined by the mixture being prepared before the operator activates the system, such as Slurpee/ICEE machines. Post-mix refers to a machine where the water and concentrate do not mix until an operator activates the system, such as soda machines. During the meeting with Mr. Brookner, the group acquired the Installation and Operating Guide to a JDF-2S and JDF-4S model dispenser, which are both post-mix machines. Mr. Brookner stated that this was the preferred method of mixing. With this information, the group was able to research the components used to create the mixing process. It was found that there are two types of pumps, centrifugal and peristaltic, that are currently utilized by juice machines today to mix the water and juice concentrate.

A centrifugal pump uses an impeller with curved fins which are in constant contact with the surrounding fluid. Once the impeller begins to rotate, the fins induce rotation within the surrounding water causing it to move out radially along the fins. By inducing radial flow along the vanes, the pressure at the pump outlet will rise while the pressure at the inlet will decrease. This decrease in pressure across the inlet allows fresh water to be suctioned into the pump, thereby continuing the flow of the water through the pump. In addition to creating a rise in water pressure, the fins also increase the area along the direction of the water flow which provides an increase in the static pressure within the impeller, reducing the flow velocity of the water (Learn Engineering).

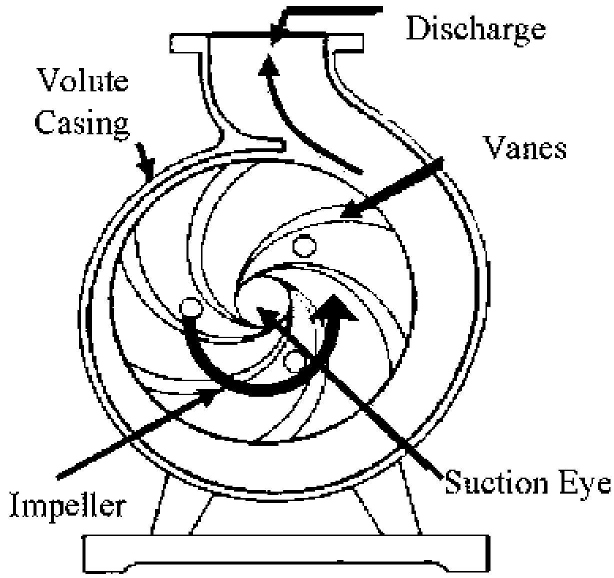


Figure 2: Components of a centrifugal pump (Coal Mining).

The other pump used to create the mixing process is a peristaltic pump. Within the circular housing of a peristaltic pump is a hose in which the desired fluid flows through. Located in the center of the housing is a component that consists of two rollers which rub up against the lining of the hose. As the component containing the rollers rotates, the rollers compress the hose in a way such that the fluid located before a roller is pushed forward through the hose while the fluid behind a roller is suctioned into the hose due to the vacuum created by the roller. This process allows for constant flow while also preventing backflow of the fluid within the hose (Wanner Engineering).

Figure 3: Different stages of a peristaltic pump cycle (Wanner Engineering).

After the mixing process occurs between the concentrate and water, the final juice product is dispensed into the customer's container. In order to ensure that the juice dispensers are correctly mixing the appropriate amount of water and concentrate, the industry checks the Brix number, also known as the Brix %. The Brix number refers to the amount of sugar found in an aqueous solution. A user can determine a juice's Brix number with a device called a refractometer.   With a refractometer, the user can place a couple drops of the solution on the daylight plane, where light then passes through the solution and into a prism located below. The refracted light then is viewable through the eyepiece. Here, the light fills part of the viewing area and illuminates a scale that tells the user the Brix number. A higher sugar content correlates to a higher Brix number on the scale. The industry standard Brix values for a variety of fruit juices can be found in Table 1. Ensuring proper mixing with a refractometer ensures that the juice will not taste too sweet or bland.

Figure 4: A refractometer used to determine the Brix number of a juice (ADMIN).

Table 1: Recommend Brix numbers for various juices (Installation).

Type of Juice	Brix %
Orange	11.8
Pineapple	12.8
Cranberry Fruit Cocktail	14
Grapefruit	10.6
Apple	12
Grape	13

Previous Phases

Once the group had a better understanding of the various technical concepts involved in the juice making process, the next step was to review the findings of the previous two senior projects that were completed with Mr. Brookner. The team was provided the formal reports of the projects the previous teams completed, which became the backbone of the team's research. The first document, called Phase II: Jet Pump Juice Mixer, comprised of only research and calculations based on jet pump/venturi selection. Their main goal focused upon developing a new mixer that decreased the overall cost of the machine while making the unit independent of any major electrical components (Shollenberger, 2007).

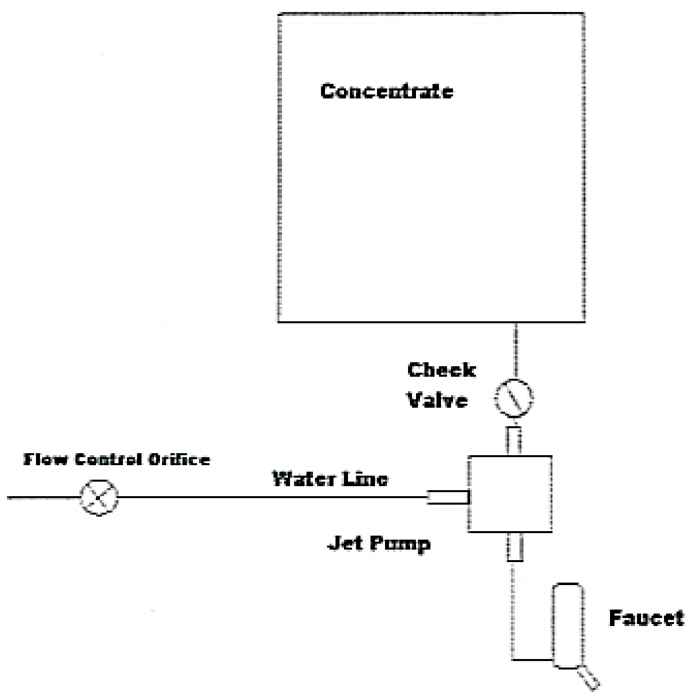


Figure 5: Initial configuration of the dispensing system designed in Phase II (Shollenberger, 2007).

Phase II focused on developing a valve that could correctly actuate and deliver the correct amount of concentrate to the mix. After consideration, a poppet valve was chosen that had screws to adjust the hole width allowing proper tuning to find the correct dispersal of concentration.

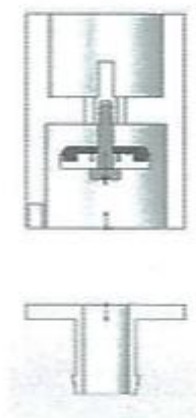


Figure 6: The final design of the poppet valve designed in Phase II (Shollenberger, 2007).

It was determined that it was very hard to maintain consistent results as temperature played a large role in the fluid properties. Recommendations for future projects included minimalizing vertical distances as it lead to incomplete mixing when heavier particles fell out of suspension, ensure that refrigeration stayed within 3 degrees of the accepted value, using solenoids to actuate the valves thereby eliminating the check valves, and threading the end cap to ease the assembly (Shollenberger, 2007).

The second document, Phase III, focused on producing a full-scale prototype by incorporating the design of the jet pump results acquired from Phase II. Phase III did not include the initial poppet value design because it would tend to have lean mix ratios, allow air in the water tank, and require large actuating forces. Additionally, the team wanted to place another valve above the jet pump which would diminish the static pressure that was required for the poppet valve to work. Finally the poppet valve allowed the mix to stagnate and was not replaceable, so a redesign was needed to make the system functional. It was concluded that the final design was successful in producing the correct mix ratio for orange juice but could not incorporate different juices using the same system set-up (Owen, 2008).

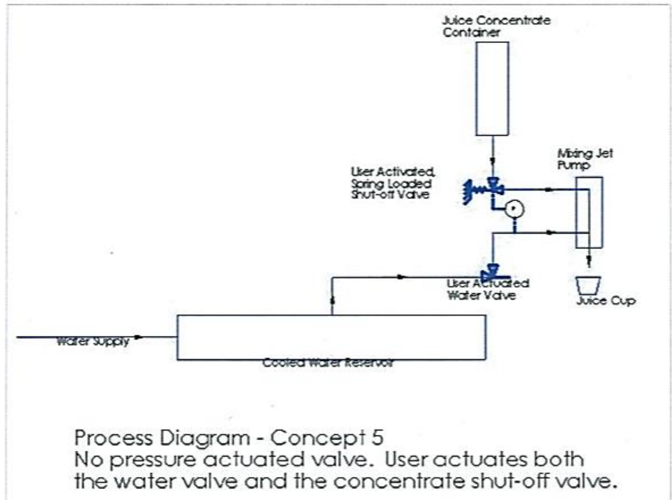


Figure 7: Configuration that was chosen after utilizing a Pugh Matrix (Owen, 2008).

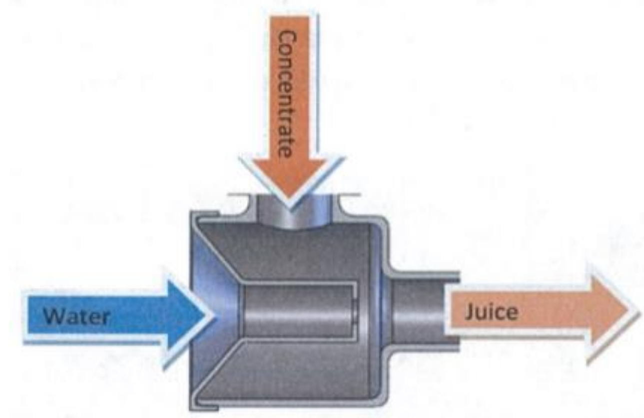


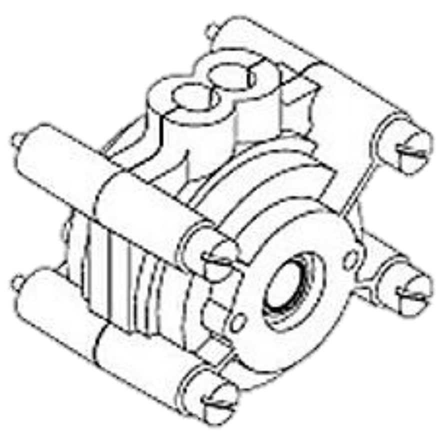
Figure 8: Jet pump valve design that was utilized in Phase III (Owen, 2008).

Current Machine

The next phase of research involved analyzing the juice dispensing machines that are currently being used in the industry today. The equipment depicted in Figure represent two types of dispensing machines manufactured by BUNN. Each model employs the use of a pump in order to deliver the water in the system at a high enough flow rate to induce mixing when it comes into contact with the juice concentrate.

Figure 9: The two models manufactured by BUNN. Located to the left is the JDF-2S model while the JDF-4S model is located to the right (BUNN).

For the initial set-up, the dispensers require a surface that can support at least 150 pounds and an outlet that uses an individual branch circuit rated at 120 volts AC and 15 amps. Plumbing for each model requires that it be connected to a cold water system which operates with pressures ranging from 20 to 100psi and produces a minimum flow rate of 3 oz. /sec. The main water inlet for both models is a 3/8" Male Flare Thread (MFL) connection meaning that the water line should be a Female Flare Thread (Installation). The pump that is used by both the 2S and 4S is a peristaltic pump pictured in Figure 10 (Pump).



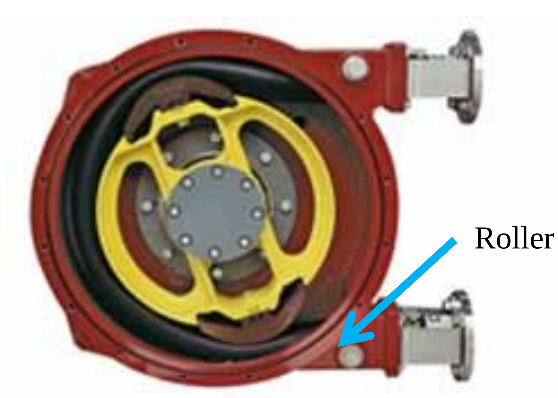


Figure 10: The peristaltic pump used in the JDF-2S and JDF-4S is located on the left (Installation). To the right is a Watson-Marlow tube pump which shows the components inside a peristaltic pump (Peristaltic).

Current Market and Competitors

In order to quantify how many juice dispensers could potentially be operated on a daily basis, the scope was tailored to the market of the United States lodging industry, 4-year universities, and hospitals. The restaurant industry was excluded because the heavy variance within the industry needing a juice machine was too difficult to calculate. Rough estimates showed that there were about 3,000 4-year universities (Fast Facts), 15,000 hospitals(Fast Facts on US Hospitals), and 53,000 lodging properties (AHLA). Assuming every university and hospital has a cafeteria, and every lodging property uses a machine the expected market can range from 18,000 to 71,000 units. Given this market size, the industry allows the customers to choose a product that has the ability to dispense two, four, or six different juices depending on the manufacturer and need. Two of the larger companies that produce juice dispensing machines are BUNN and Cornelius which both utilize the peristaltic pump machines that can dispense between 2-6 different types of juices.

Objectives

Currently Jonathan's Natural Juices only produces juice concentrate, however, hopes to introduce a new dispensing method that will create a more cost effective and reliable machine than its competitors, while still offering comparable dispensing properties. With the help of Cal Poly's Mechanical Engineering Senior Project team, the goal is to develop a new method to properly mix water and juice concentrate without the use of pumps and excessive electronics. If the project is successful, then Jonathan's Natural Juices hopes to expand its operations to include dispensing machinery.

The design goals for Phase IV will include every aspect that will be required to complete the build of a functioning prototype of a mechanical juice dispenser by June 5, 2015. The final design will be comprised of a water and concentrate delivery system, mixing chamber, and necessary support systems. The water and concentrate delivery systems will be based off prior research, which can be found under Appendix D and E in the Phase II report, while updating to include the current design requirements related to different mix ratios. Design of the mixing chamber will be based off Phase III Jet and Valve Assembly for initial design considerations to test and verify how the system will react to changes in geometry. Additional recommendations covered in either Phase II or III are not guaranteed to be considered in this project design due to new design requirements.

After reviewing the previous recommendations, the team began by determining a list of customer requirements that are vital to the final design unit that will be presented to Mr. Brookner. First, the team identified the most frequent customer that will be in contact with the final product, the people that will drink the juice. These customers are usually found in lodging, hospitals, or universities, although there are other locations that can be considered. The most important requirement for this customer was determined to be the consistency, or mix ratio, of the final juice product. In order to ensure customer satisfaction the juice produced must not be too sweet or bland, both of which depend on regulating the Brix level, or amount of sugar in the final product.

The next customer analyzed were the businesses who house the machines. As previously stated, the most prominent businesses that would use a juice dispensing machine would be lodgings, hospitals, and universities. The main personnel who would interact with the machine would be the employees responsible for replacing the concentrate packages, performing routine cleaning, and ensuring the maintenance of the machine. Replacement of the concentrate packages brought attention to three new customer requirements that needed to be addressed in the final design. The final designed unit must be able to fit within the current housing of a dispensing machine, use the current concentrate bags, and have the mixing apparatus be replaced when a new bag of concentrate is installed. Each of these three new customer requirements will ensure ease of use for the personnel replacing the concentrate packages. Additionally, the routine cleaning and maintenance of the machine identified four more customer requirements that would influence the final design. The final unit will be designed so that there is a limited amount of electronics, doesn't require the use of pumps, no leakage of fluids, and be able to adjust the water flow rate. All of these customer requirements will provide the customer easier and quicker ways to investigate the performance and state of the machine.

Finally, the third customer will be the sponsor of the project, Jonathan's Natural Juices. This company will be the primary distributer and manufacturer of the unit that is designed, which determined the last three customer requirements that the final design will incorporate. The unit must be made from materials that follow FDA/NSF Food Grade standards, have a moderately durable design, and a reduced cost compared to existing units. These final requirements will help ensure the integrity and safety of the beverages.

The final compilation of customer requirements, shown below in Table 2, quantifies the considerations that were found after identifying the three main potential customers. Using these customer requirements, the next step was to create a Quality Function Development (QFD), which allowed each individual customer requirement to be analyzed and assigned a rank of importance. The development of the QFD will provide the means to further develop the customer requirements into engineering specifications which will allow the team to determine the most important factors that will need to be incorporated into the final design.

Table 2: List of customer requirements.

	Requirement
1	Correct Water/Concentrate Ratio
2	FDA/NSF Grade Approved
3	Limited Electronics
4	No pumps
5	Moderately Durable Design
6	No leakage of concentrate or water
7	Constant Flow Rate Concentrate
8	Adjustable Flow Rate for Water
9	Use current juice concentrate bags
10	House in compatible unit used today
11	Valve replaced when new bag installed
12	Costs

The construction of the QFD, as seen in Appendix B, began by listing the three main customers who were identified along with a list of their customer requirements. Each customer requirement was then weighted according to its importance for a specific customer to gain a better understanding of which aspects of the project should receive extra consideration. For example, the weighted scores that were determined for the third customer requirement, limited electronics, varied between the three main customers. The customer represented as a drinker would most likely prefer a design that would require a small amount of interaction in order to operate the device. With this in mind, the customer represented as a drinker received a weighted score of importance of two due to the team's decision that the user interface will remain unchanged. In contrast, the customer represented as Jonathan's Natural Juices discussed with the team that the final design should limit the use of electronics so as not to raise the price of production of their current unit that would house the final design. To ensure that the team fulfills the requirement, the customer represented as Jonathan's Natural Juices received a weighted score of importance of nine.

After assigning each customer requirement a weighted score of importance, each customer requirement was further defined by specifying how each requirement will be achieved. Continuing with the example of the third customer requirement limited electronics, the team decided to break the requirement into two individual categories, electricity usage and electronics. The category of electricity usage is focused on the amount of electricity that the final design will require in order for the unit to function properly while the category of electronics is focused on the actual number of electrical components needed to control the final design.

These customer requirement definitions would become the basis for the engineering specifications, which are quantifiable ways in which to measure customer requirements. These engineering specifications will determine the final aspects that must be considered and achieved with the final design. In order to evaluate whether or not an engineering specification will be met at the end of the project, a target range, or value, was defined and will be discussed later in the report.

The completed list of engineering specifications, shown in Table 3below, includes the target range, risk factor, and the verification process for each individual specification. A risk factor was assigned to each specification in order to identify which specifications might prove to be hazardous when trying to incorporate them in the project's allotted time frame. The letters H, M, and L indicate a high, medium, or low risk respectively. Each specification was also given a process for the team to identify the method(s) to determine whether the target was reached within the given tolerances. Under the Process column an 'A' means that analysis, such as calculations or situational modeling, will be used to verify the given requirement. A 'T' will indicate that tests, such as taking several samples to determine the juice's Brix level, will be conducted for verification of a requirement. Inspection will be represented by the letter 'I', and will involve measuring and tabulation. Lastly, an 'S' will indicate that the specification will be verified based on its similarity to existing designs, such as the final volume size occupied by the new unit compared to the existing unit.

Table 3: The project list of engineering specifications obtained from using a QFD (Senior).

Spec. #	Parameter Description	Requirement or Target	Tolerance	Risk	Process
1	Sugar Levels	Specified Juice Brix Level	±0.8	H	A,T
2	Water Flow Rate	Calculate Depending on Juice	±10%	H	A,T
3	Juice Flow Rate	Calculate Depending on Juice	±10%	H	A,T
4	Electricity Use	1.8KW	Max.	M	T
5	Size of Unit	$10ft^3$	Max.	L	S
6	Cost of the Unit	$1,000	Max.	L	S,A
7	Life of Valves	Last for one bag of concentrate	Min.	M	A,T,I
8	Material	Meets FDA/NSF Standards	N/A	M	S,T
9	Pumps	No Pumps	N/A	L	I
10	Electronics	3 Components	±1	M	I

In some cases, the target range was based off prior information that was provided either by the sponsor or one of the previous phase's reports. For example, after talking with Mr. Brookner, the group learned about the various values and ranges for acceptable Brix percentages for each juice. A summary of for each juice's Brix values can be found in Table 1.

In order to achieve the correct Brix number for a given juice, both of the flow rates of the water and concentrate would have to fall within an acceptable range. Depending on the type of juice that is being produced, the specified ranges for the flow rates of the water and concentrate will vary. For example, the water to concentrate ratio for orange juice is 4 to 1. However, losses that occur due to changes in geometry and the nature of the fluids could possibly cause the flow rates to vary slightly. To account for this fluctuation in the flow rates, each fluid was given a tolerance that would still produce an acceptable mix ratio.

Unlike the flow rates of water and concentrate, some specifications had limitations rather than ranges. For example, the power consumption of the new design should not exceed the power consumption of the current design used on the market. Additional parameters that will be measured by limitations are size and cost of the unit, the life of the valves, and the number of electrical components used within the system.

For the two remaining specifications of materials and pumps, the target value was predefined and could not be changed by the group. In the case of materials, all components that come into contact with either the water or the concentrate must meet FDA/NSF standards. With this in mind, the actual material selection for the different components could vary depending on the application. For example, the material chosen to deliver the water should provide a relatively smooth inside surface and a rigid body structure, while the concentrate delivery material may need to be more flexible. Both cases would use materials that have been pre-approved by the FDA/NSF but the materials will differ because of their application.

After determining the target value and tolerances for each individual engineering specification, a process in which to test whether or not the final design meets the target value was defined. Based on the Process column in Table, each individual engineering specification was designated a test will verify whether it meets the final design requirements. Each engineering specification and its corresponding test are listed in Table 4below.

Table 4: The project list of engineering specifications and testing method.

Spec. #	Parameter Description	Test Description
1	Sugar Levels	Use refractometer to verify Brix level
2	Water Flow Rate	Hook the water line up to a flow meter, and adjust until appropriate flow rate is achieved
3	Juice Flow Rate	Directly dependent on the flow rate of water and will be adjusted in conjunction with water flow rate
4	Electricity Use	Attach a voltmeter to the electrical circuit to record the values of the current and voltage of the system to determine the power requirement
5	Size of Unit	Measure the final volume that the system will require
6	Cost of the Unit	Record each components value and determine the final cost of the system
7	Life of Valves	Hook up a new bag of concentrate to the system and test the integrity of the valves by draining the entire bag
8	Material	Research and use materials that are listed on the FDA/NSF approved materials list
9	Pumps	Visually inspect that there are no pumps that have been integrated into the system
10	Electronics	Count the number electronic components

Design Development

With the newfound knowledge of the juice industry and customer requirements the group felt ready to start design development. The four main subdivisions that comprised the design development were method of approach, management plan, ideation, and idea evaluation. Having a solid method of approach and management plan is critical to project success. It gives the group direction and keeps members on track in order to finish in a timely manner. Ideation and idea evaluation allows the group to fully explore all the options available and critique them to choose to the best possible solution to Mr. Brookner's problem.

Method of Approach

Having an organized plan of action is important to the success of a project, so the team decided to follow the path depicted in Figure 11which is a modified version of a design process discussed during the senior project lecture. This process will allow the team to produce the best solution that incorporates all of the engineering specifications that were defined through the QFD. Each step in the design process contains one to two major components that should be covered before moving onto the next step in the design process; however, iteration, or revisiting to a previous step, is almost always part of the design process. Only after a project has gone through all the steps is it considered complete with the current requirements.

Identification of need	• Sponsor Presentations
Problem Definition	• Plan for project • Understanding the problem
Design Review	• Project Proposal
Synthesis	• Generate/ Evaluate Concepts • Generate /Evaluate Designs
Design Review	• Preliminary Design Report
Analysis & Optimization	• Design Analysis
Design Review	• Final Design Report
Evaluation	• Prototype • Testing
Presentation	• Senior Design Expo • Final Project Report

Figure 11: Design Process Flow Chart.

Management Plan

The following is a summary of who is in charge of certain aspects of the project. Each lead will be in charge of making sure that his or her category remains on track with the overall timeline of the project. This includes scheduling times in which to meet, creating an agenda for each meeting, assigning specific details that need to be accomplished to each team member, and documenting the progress achieved during the meeting. Each lead is responsible for uploading the most updated versions to Google Docs for team member's reference.

Table 5: Summary list of team members and their lead responsibilities.

Job Title	Lead
Information Gatherer	Danielle
CAD Modeling	Danielle
Documentation of Project Process	Danielle
Documentation Editor	AJ
Prototype Fabrications	AJ
Prototype Testing Plans	AJ
Manufacturing Considerations	Jesus
Budget Management	Jesus
Communication	Jesus

In addition to assigning responsibilities during team meetings, a Gantt Chart (Appendix C) will be used to document the important milestones and their tentative completion dates. Under each of the main milestones will be additional material that will include specific tasks that should be completed during the allotted time period of that particular milestone. After creating a solid foundation of prescribed responsibilities and tentative completion dates, the next step was to begin the design development process in order to determine the aspects that will be incorporated into the final design. The design development process started with breaking down the juice dispenser into four subsystems which consisted of mixing, delivery, dispensing, and a pressurizing device. The mixing subsystem refers to the chamber, or the area, where the water and concentrate mix. The delivery system is in charge of getting the two fluids to the mixing chamber. The dispensing system handles getting the mixed product from the mixing area to the consumer's cup. The dispensing system also incorporates the user interfacing component of the dispensing unit. The pressurizing device is the part of the system that ensures that the concentrate pressure is maintained in order for the mixing to occur. Ideation and brainstorming sessions were held for each subsystem and were evaluated to select the best design in each category.

Ideation/Brainstorming

The team used a variety of methods for the ideation/brainstorming sessions that were held. It was important to try to exhaust all avenues of creativity to ensure that the maximum number of possible ideas were included in the evaluation process. Some of the methods that were used were brainstorming, SCAMPER, and brainwriting. Brainstorming is an ideation tool where the team tries to come up with as many ideas while talking with each other. There is no negative feedback, only positive to discourage fear to present ideas. This is an effective method to get the ideas started. Next the SCAMPER method, an acronym for Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, and Reverse, was utilized to look at previous ideas with a new light. This approach was less effective for the group so the third method, brainwriting, was heavily utilized to find more ideas. Brainwriting consists of each team member starting off the session by drawing an initial idea on a piece of paper. After an allotted amount of time, the team members exchange their papers with each other. Now with a different idea presented, an initial idea can be further explored or inspire a completely new idea. This process continues until all members of the team have contributed to each initial idea created by the team. This method produced the majority of the ideas that were utilized in our final decision matrices and proved to be the most effective method.

Mixing

The ideation session for mixing was done by the group splitting up individually and each member coming up with ideas to share with the rest of the group. The idea session produced several ideas; a funnel, pipe in a pipe, a venturi, jet pump, tesla valve for mixing, a fan, hand mixing, and spinning. The funnel concept relies on water and concentrate meeting on opposites at the top of the funnel and allowing the fluids to mix as they travel down the funnel.

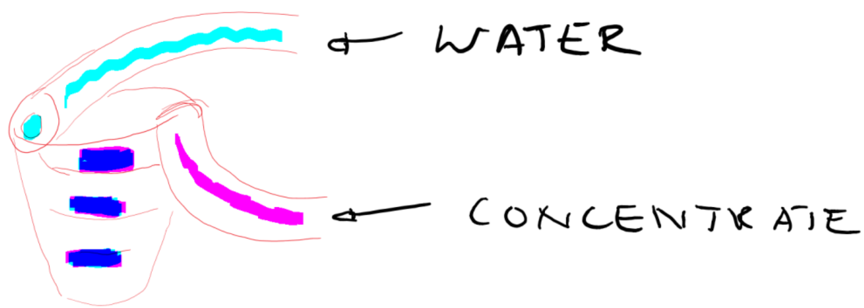


Figure 12: Drawing of funnel idea.

Another consideration was having two pipes that would simultaneous empty at the dispensing nozzle. The pipe in a pipe idea would use the turbulence in the glass to mix as the fluids filled the glass, similar to how a soda machine works. The pipes would be appropriately sized to ensure the right amount of water and concentrate was dispensed to get the right consistence.

The Tesla valve was developed by Nikola Tesla that would allow fluids to flow one way easily, but would have paths that would cause the flow to divert back to the original flow path if there was backflow. If flow was introduced in the other end it would be sent back by these paths. The idea was to use this to continuously inject a specific amount of fluid into the Tesla valve and it would repeatedly flow back on itself, mixing the fluid. After a certain amount of time the jet would stop and the mixed fluid could drain into the dispensing nozzle.

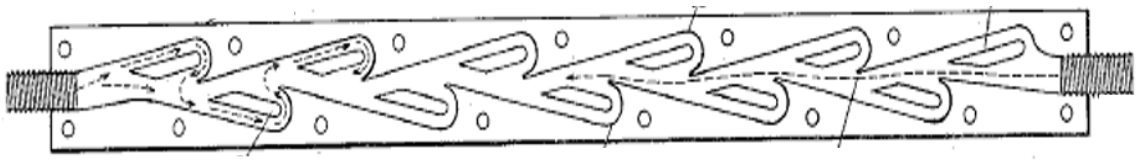


Figure 13: Tesla valve.

The fan idea is that the two fluids are inserted into a pipe and a fan will cause turbulence in the flow causing the two fluids to mix.

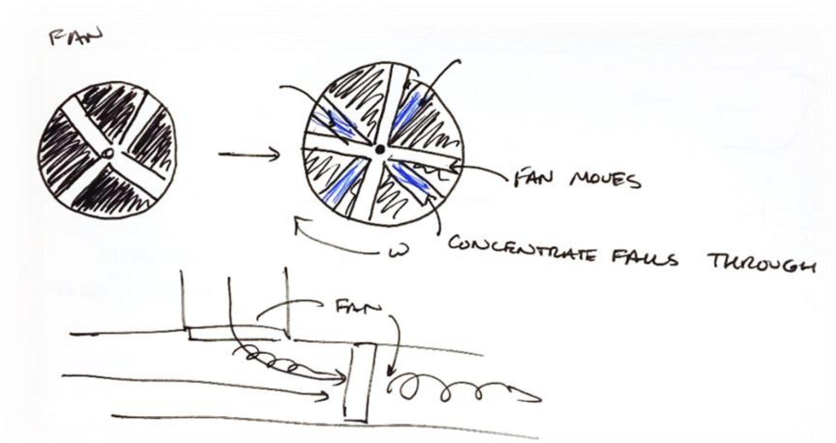


Figure 14: Drawing of fan idea.

Hand mixing is where you take the two fluids and mix them in a container by hand and then putting them in a storage container until ready to be poured. The spinning concept is similar to this where the fluids are mixed prior and put in a container where they are constantly stirred until ready to be poured.

A venturi's shape resembles that of an hourglass tilted on its side with the addition of a tube oriented perpendicular to its length and located at its midsection (as seen in Figure). Due to the constriction in pipe diameter, the fluid that flows within the venturi experiences an increase in velocity thus decreasing the pressure at the throat or midsection of the venturi. This decrease in pressure can be used as a suction to pull in a secondary fluid at a higher pressure into the primary stream. The fluids will mix in the expanding component of the venturi and become a singular fluid. (Henderson).

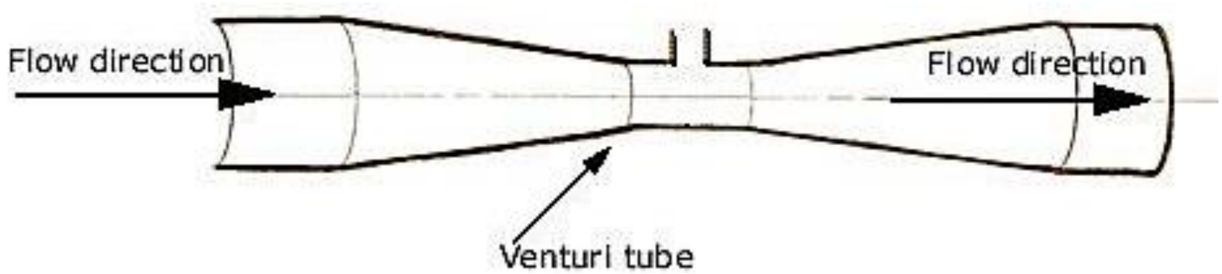


Figure 15: Configuration of a venturi (Henderson).

The design of a jet pump is simply a venturi with the addition of a nozzle located before the constriction occurs within the pipe as seen in Figure 16. In this application, the fluid passes through the motive fluid nozzle at an accelerated rate creating a pocket of lower pressure at the venturi's converging inlet nozzle. Once again, due to the lower pressure that is created by the motive fluid, the fluid contained within the reservoir is siphoned into the throat of the venturi.

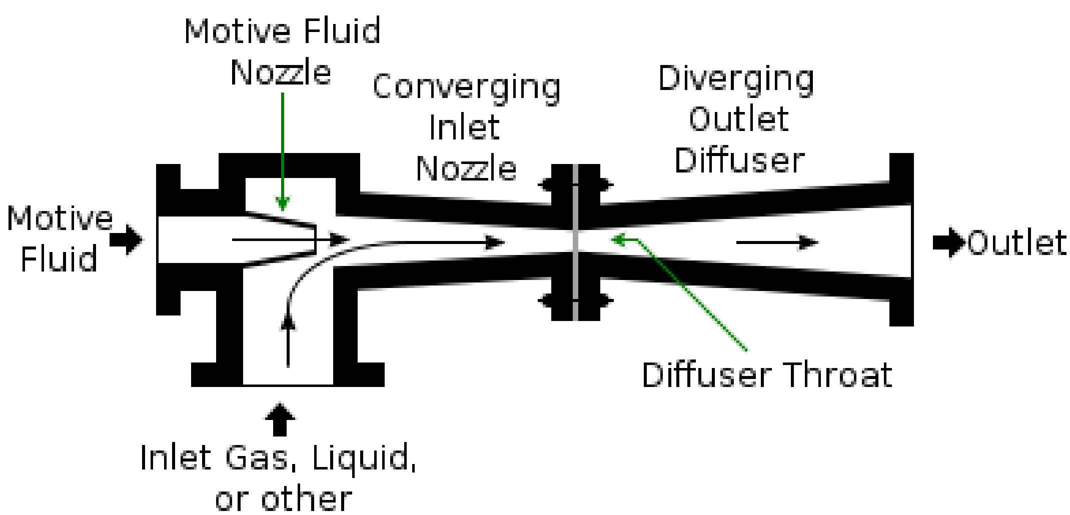


Figure 16: Jet pump diagram (GlobalSpec).

Delivery

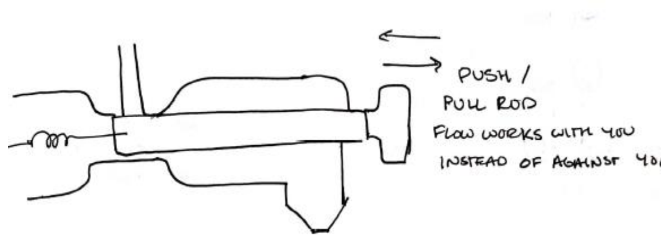
Several ideation sessions were held for the delivery subsystem. The first was performed as a group where individual ideas were put on a white board and explained to one another. It was determined that after this first session that the group lacked some knowledge about the different type of valves. The second session consisted of listing as many varieties of valves that the group could find. The list consisted of fifty-three different types of valves. The group then divided up the fifty-three valves and conducted research on how they worked and how they could be applied to deliver the fluids to the mixing chamber. The entire list can be found in Appendix D.

Dispensing

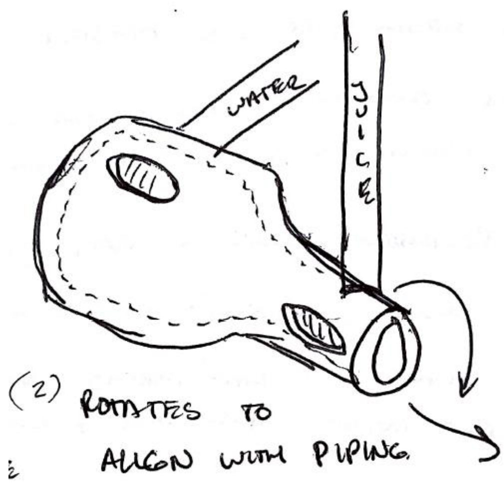
The dispensing ideation sessions were conducted using brainwriting. These sessions produced the ideas of a push button, push lever, push rod, pull rod, pressure plate, and a twisting motion for a dispensing mechanism. The push button utilizes a button that sends an electrical signal to the delivery unit when pressed, which is commonly used in drink dispensers today. The push lever can be compared to the apparatus used in soda dispensers, where the user pushes the cup against the lever that activates the delivery system. The push and pull rod are similar in design where a rod covers both the water and concentrate from entering the mixing chamber until the rod is either pushed or pulled out of the way to allow the two fluids to enter the mixing chamber. The pressure plate is similar to the push lever except that instead of pushing against the lever the user pushes the cup down on the plate to activate the delivery system. Lastly, a device that could be activated by twisting a lever would align the holes with the water and concentrate lines, flooding the device in the shape of a venturi and mixing the fluid within the device before it was dispensed.

Push Lever

Push/ Pull Rod



Twist Activation



Pressure Plate

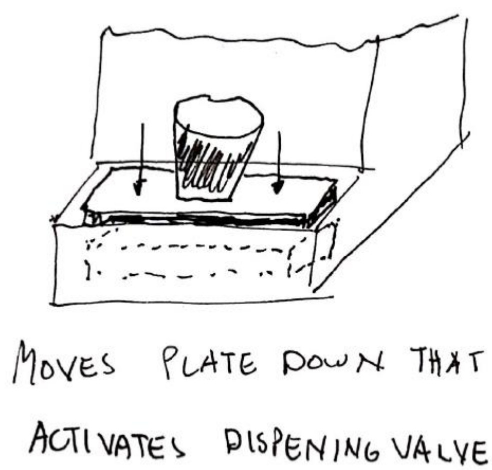


Figure 17: A variety of concept devices to use for dispensing.

Pressurizing Device

The pressurizing brainstorming session consisted of the group coming together and talking about ideas that could maintain the pressure of the concentrate. The concepts that needed more explanation were drawn in detail so that the group could efficiently communicate their concepts to the group. These ideas consisted of adding a compressor to pressurize the bag to a desired pressure. Another idea was to direct water flow over the concentrate bag to provide a constant weight on the bag to maintain pressure. Similarly, a weight or hydraulic press could be placed on top of the concentrate bag to provide constant pressure. Taking a different approach, another idea was to attach actuators to the concentrate delivery tube to pinch the pipe, which would act like a valve while simultaneously pressuring the fluid contained above the actuator. Finally, increasing the height of the concentrate would increase the pressure without needing to do so artificially.

Idea Evaluation

After the group's ideation/brainstorming sessions were concluded all of the concepts that were developed needed to be evaluated based on their feasibility and ability to function within the new system. There was a tiered system for determining components, which was Go/NoGo, Pugh Matrix, and Weighted Decision Matrix. If a decision could be made from a tier of the process the evaluation stopped, else it continued on to the next tier that focused on refining the criteria to ensure the proper component was selected. In the Go/NoGo matrix, the ideas were evaluated to see if they met the initial criteria. Ideas that passed the Go/NoGo matrix were then organized into a Pugh matrix, which compared each idea against a datum. A datum is the component that is being used in current machines to perform the action that satisfies the group's subsystem requirements. Finally a weighted decision matrix was created from all the ideas that passed the Pugh matrix in the given subsystem. In order to make a weighted decision matrix for each subsystem that required it, a pairwise comparison matrix had to be made. A pairwise comparison allows the designer to compare the customer requirements to one another to see which has a greater effect when choosing the design.

Table 6: Pairwise comparison.

	Correct Ratio	FDA/NSF Grade Approved	Limited Electronics	No pumps	Moderately Durable Design	No leakage	Constant Flow Rate Concentrate	Adjustable Flow Rate for Water	Use current concentrate bags	House in current unit	Valve replaced with new bag	Costs	Total	Total Plus 1	Weight Factor
Correct Ratio		0	1	1	1	1	0	0	1	1	1	1	8	9	11.5
FDA/NSF Grade Approved	1		1	1	1	1	1	1	1	1	1	1	11	12	15.4
Limited Electronics	0	0		0	1	0	0	1	0	0	1	1	4	5	6.4
No pumps	0	0	1		1	0	0	0	1	1	1	1	6	7	9.0
Moderately Durable Design	0	0	0	0		0	0	0	0	1	1	0	2	3	3.8
No leakage	0	0	1	1	1		1	1	1	1	1	1	9	10	12.8
Constant Flow Rate Concentrate	1	0	1	1	1	0		0	1	1	1	0	7	8	10.3
Adjustable Flow Rate for Water	1	0	0	1	1	0	1		1	1	1	0	7	8	10.3
Use current concentrate bags	0	0	1	0	1	0	0	0		1	0	0	3	4	5.1
House in current unit	0	0	1	0	0	0	0	0	0		0	0	1	2	2.6
Valve replaced with new bag	0	0	0	0	0	0	0	0	1	1		0	2	3	3.8
Costs	0	0	0	0	1	0	1	1	1	1	1		6	7	9.0
													Total	78	100

It was determined by the group that the two major subsystems that needed to be evaluated first should be pressurizing the device and the mixing component.

Pressurizing Device

The requirements for the Go/NoGo for a pressurizing device were that it did not use a pump and that it would fit in the unit. From the Go/NoGo matrix only the water flow over the concentrate bag, weight on top of the bag, and actuators were put into the Pugh matrix shown in Table 7. In the Pugh matrix it was clear that actuators were the best choice therefore the group did not need to create a weighted decision matrix for the pressurizing device subsystem.

Table 7: Pugh matrix for the pressurizing device.

	Water flow over bag	Weight on top of bag	Actuators	Peristaltic Pump
Limited Electronics	+	+	S	D
Reliability	-	-	S	
Cost	+	+	+	A
Adjustable	-	-	+	
No Pumps	+	+	+	T
No Fluid Leakage	-	-	+	
Use Current Juice Bags	-	-	+	U
∑+	3	3	5	
∑S	0	0	2	M
∑-	4	4	0	

Mixing

The initial criteria for the Go/NoGo matrix for the mixing subsystem were no pre-mix devices and that it was sanitary. In order for an idea to be selected it had to meet both criteria. The Go/NoGo matrix for mixing can be found in Appendix D. The Go/NoGo matrix eliminated three ideas that did not meet the initial criteria leaving the six that were used to construct the Pugh matrix below (Table 8). The group used the customer requirements that were relevant to the mixing subsystem as the attributes to compare to the datum. From the Pugh matrix the tesla valve and the fan mixing ideas were eliminated because they scored poorly compared to the datum. The four remaining ideas (venturi, jet pump, funnel, and pipe in a pipe) were put into a weighted decision matrix (Table 9). They were compared to the datum in each category of the customer requirements. The result from weighted decision matrix was that the venturi and jet pump were tied for the best solution for the mixing chamber.

Table 8: Pugh matrix for the mixing subsystem where tesla and fan were eliminated.

	Venturi	Funnel	Jet	Tesla	Pipe in pipe	Fan	Peristaltic pump
Correct Ratio	+	S	+	-	S	-	D
FDA/NSF Grade Approved	S	S	S	S	S	S	
Limited Electronics	+	+	+	+	+	+	A
No Pumps	+	+	+	+	+	+	
Moderately Durable Design	+	+	+	+	+	+	T
No Leakage	S	S	S	S	S	S	
Constant Flow Rate Concentrate	+	+	+	-	+	-	U
Adjustable Flow Rate For Water	-	-	-	-	-	-	
Use Current Concentrate Bags	S	S	S	S	S	S	M
House in current unit	+	+	+	S	+	+	
Costs	+	+	+	+	+	+	
∑+	7	6	7	4	6	5	
∑S	3	4	3	4	4	3	
∑-	1	1	1	3	1	3	

Table 9: Weighted decision matrix for mixing apparatus.

	Score				Weight Factor	Weighted Score			
	Venturi	Funnel	Jet	PIP		Venturi	Funnel	Jet	PIP
Correct Ratio	-1	-1	-1	-1	11.5	-11.5	-11.5	-11.5	-11.5
FDA/NSF Grade Approved	0	0	0	0	15.4	0.0	0.0	0.0	0.0
Limited Electronics	1	1	1	1	6.4	6.4	6.4	6.4	6.4
No Pumps	1	1	1	1	9.0	9.0	9.0	9.0	9.0
Moderately Durable Design	1	-1	1	-1	3.8	3.8	-3.8	3.8	-3.8
No Leakage	1	-1	1	-1	12.8	12.8	-12.8	12.8	-12.8
Constant Flow Rate Concentrate	-1	-1	-1	-1	10.3	-10.3	-10.3	-10.3	-10.3
Adjustable Flow Rate for Water	0	0	0	1	10.3	0.0	0.0	0.0	10.3
Use Current concentrate bags	0	0	0	0	5.1	0.0	0.0	0.0	0.0
House in current unit	1	-1	1	1	2.6	2.6	-2.6	2.6	2.6
Valve replaced with new bag	0	0	0	0	3.8	0.0	0.0	0.0	0.0
Costs	1	1	1	1	9.0	9.0	9.0	9.0	9.0
				Total	100.0	21.8	-16.7	21.8	-1.3

Delivery

The Go/NoGo matrix, which can be seen in Appendix D for the delivery subsystem reduced the selection from fifty three valves to six. The six valves left were the gate, solenoid, ball, needle, check, and double check valves. Since the actuators were chosen as the pressurizing device the concentrate no longer needed a delivery subsystem, so the decision would only affect how the water was delivered. This eliminated some of the valves such as the needle, check, and double check.

The ball valve is a full flow valve, comprised of a spherical ball that contains a through hole that is located on the centerline of the sphere. In a full flow valve, there is a direct unobstructed path for the fluid to flow however, depending on how much fluid a user wants to let through at a time, they can either have a reduced bore valve or adjust the amount the valve is turned to face the flow. Positioning the ball valve so that the hole is parallel to the fluid flow will allow the maximum flow though the valve. Alternatively, positioning the ball valve so that the hole is perpendicular to the direction of fluid flow will stop any fluid from continuing down the pipe. Another benefit of the ball valve is that it comes in both a manual and automated configurations depending on the application.

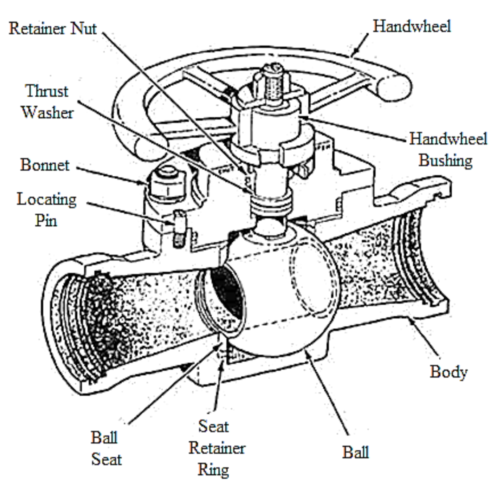


Figure 18: Components of a ball valve (Integrated Publishing).

Unlike the ball valve, a solenoid valve can only be activated electronically. There are two variations of a solenoid valve, normally closed and normally open. The "closed" and "open" refers to the state of the valve while the coil on top of the solenoid remains un-energized. For example, as soon as the oil is energized on a normally closed solenoid, the valve, usually represented by a diaphragm, is lifted to allow the given fluid to flow through. As soon as the coil becomes un-energized, the valve returns to its initial state.

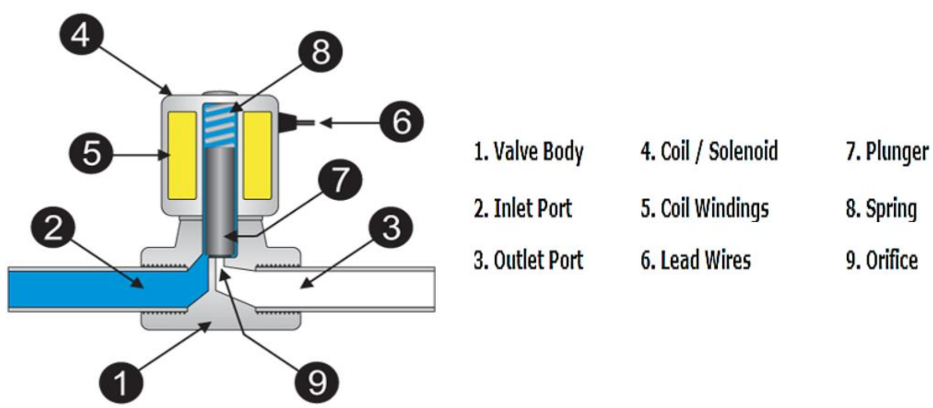


Figure 19: Components of a typical solenoid (Solenoid Valve Basics).

Even though the valves have pre-determined un-energized positions, the presence of a pressure differential across the valve itself is required to keep the valve in its un-energized rest state. To eliminate the effect that the presence of a pressure differential introduces, an engineer would apply one of the following three technologies: direct-acting, in-direct acting or, forced-lift. A direct-acting valve is designed so that if there is an absence of a pressure differential across the valve, the valve will still remain in its rest state. In contrast to the direct-acting valve, an in-direct acting valve requires a pressure differential across the inlet and outlet of the valve. With this type of technology, a significant change in pressure across either the inlet or outlet could cause the valve to change positions from its resting state. The last type of technology is implemented when the system is operating under high pressure conditions. Under these types of conditions, the material used for a diaphragm valve would prove to be too flimsy and therefore is replaced by simply using the piston as the means of blocking fluid flow (Process Industry Forum).

Just like the ball valve, a gate valve is classified as a full flow valve. Typically, a gate valve is manually activated through the action of turning a hand wheel that is connected to the stem, which is then connected to the gate. Due to it being manually activated, the only positions that could be accurately achieved are the open and closed orientations. If the gate was to be opened only partially, over time the fluid would cause wear along the surface of the gate and could possibly lead to failure. In order for a gate valve to be applicable for the apparatus that Jonathan's Natural Juices has requested, the group will have to either redesign the activation component so that it can be electrically activated or select an available actuator that would be applicable (Plumbing Valve Basics).

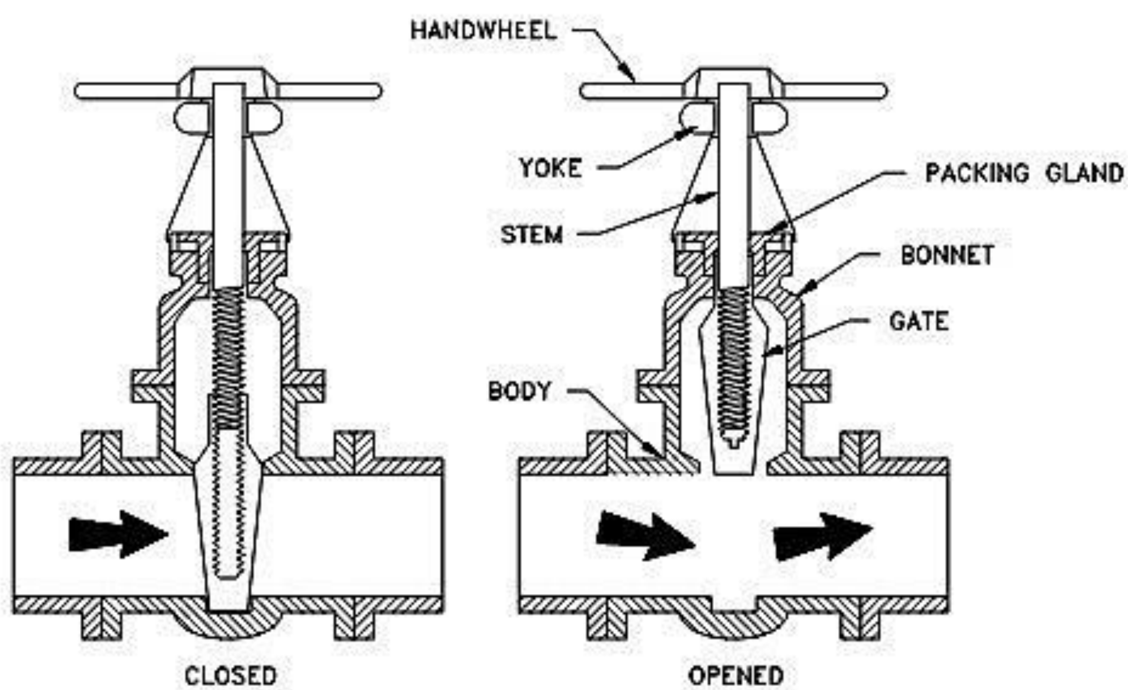


Figure 20: Components of an internally threaded gate valve (Marine Insight).

Using all the information a decision matrix was able to be made. The conclusion of the matrix was that the ball and solenoid valves were selected as potential solutions.

Table 10: Weighted decision matrix for delivery system.

	Score			Weight Factor	Weighted Score		
	Gate	Ball	Solenoid		Gate	Ball	Solenoid
Correct Water/Concentrate Ratio	0	0	0	11.5	0.0	0.0	0.0
FDA/NSF Grade Approved	0	0	0	15.4	0.0	0.0	0.0
Limited Electronics	1	1	1	6.4	6.4	6.4	6.4
No pumps	1	1	1	9.0	9.0	9.0	9.0
Moderately Durable Design	1	1	1	3.8	3.8	3.8	3.8
No leakage of concentrate or water	1	1	1	12.8	12.8	12.8	12.8
Constant Flow Rate Concentrate	0	0	0	10.3	0.0	0.0	0.0
Adjustable Flow Rate for Water	-1	0	0	10.3	-10.3	0.0	0.0
Use current juice concentrate bags	0	0	0	5.1	0.0	0.0	0.0
House in compatible unit used today	1	1	1	2.6	2.6	2.6	2.6
Valve replaced when new bag installed	0	0	0	3.8	0.0	0.0	0.0
Costs				9.0	0.0	0.0	0.0
			Total	100.0	24.4	34.6	34.6

Dispensing

From the Pugh matrix that was conducted on the dispensing subsystem, the group was left with five options, the push button, push lever, push rod, pull rod, and the pressure plate. Since the pressuring subsystem was left with only the actuators, the input needed to send an electric signal to activate the actuators. Out of the five options, only the push button, push lever, and pressure plate with a piezoelectric device are capable of delivering an electric signal, thereby excluding the other two options. It can be seen in the Pugh matrix that while the three options left all had the same positive scoring, the push button did not have any negative marks so it was chosen as the dispensing mechanism without needing to use a weighted matrix. Additionally, since it is commonly used today, it should be easily integrated into the system.

Table 11: Pugh matrix for the dispensing subsystem.

	Push Button	Push Lever	Push Rod	Pull Rod	Pressure Plate	Peristaltic pump
Limited Electronics	S	S	+	+	+	D
No pumps	+	+	+	+	+	A
Moderately Durable Design	S	-	-	-	-	T
No leakage	+	S	-	-	-	U
House in compatible unit used today	+	-	+	+	+	M
∑+	3	1	3	3	3	
∑S	2	2	0	0	0	
∑-	0	2	2	2	2	

Final Design Concept

After all the evaluation was done the group had to compile all the results to determine the final design concept, which are summarized in Table 12. While the pressurizing device and dispensing were only left with one option, the mixing and delivery options have to be analyzed and tested to determine which is the better selection.

Table 12: Final concept decisions made by team after ideation and evaluation.

Subsystem	Final Concepts/ Ideas	
Pressurizing Device	Actuators	
Mixing	Jet Pump	Venturi
Delivery	Ball	Solenoid
Dispensing	Push Button	

The proposed component configuration is shown in Figure 21 demonstrates how the components will be put together to form the complete juice dispensing system. The components that are selected for mixing and delivery subsystems will not affect this layout, outside of basic length adjustments as the diameters will still have to match the incoming water line. The current plan for choosing a jet pump/venturi and a ball/solenoid is to acquire each and test in a physical prototype to test response and accuracy in meeting the customer requirements.

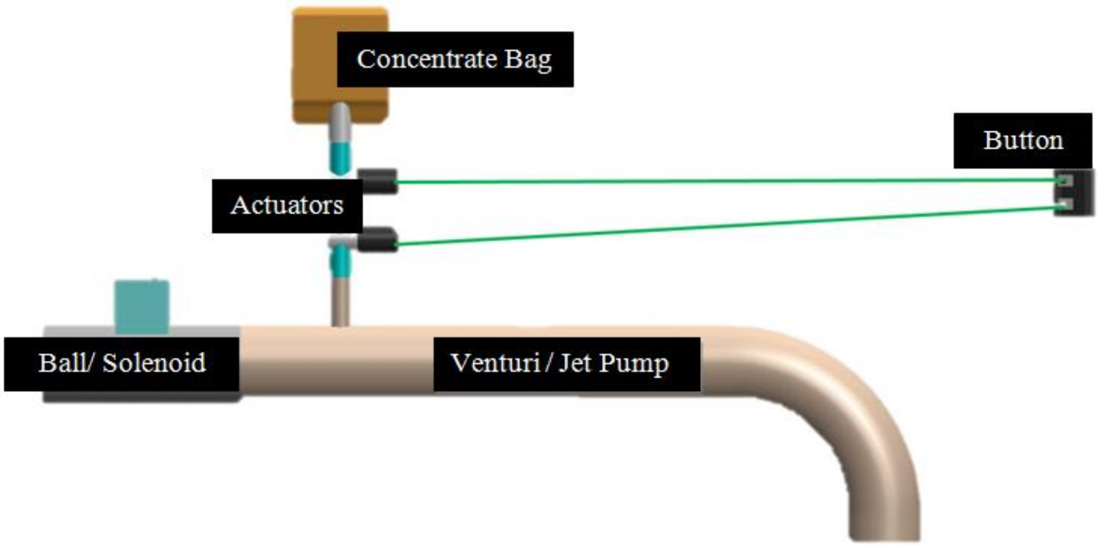


Figure 21: CAD Model demonstrating a basic configuration of the desired components

The venturi and jet pump will be 3D printed after the geometry has been finalized by the group, with the option to print ten percent bigger and smaller due to intricate nature of the components. This will allow the group to see which direction the geometry should change for better results.

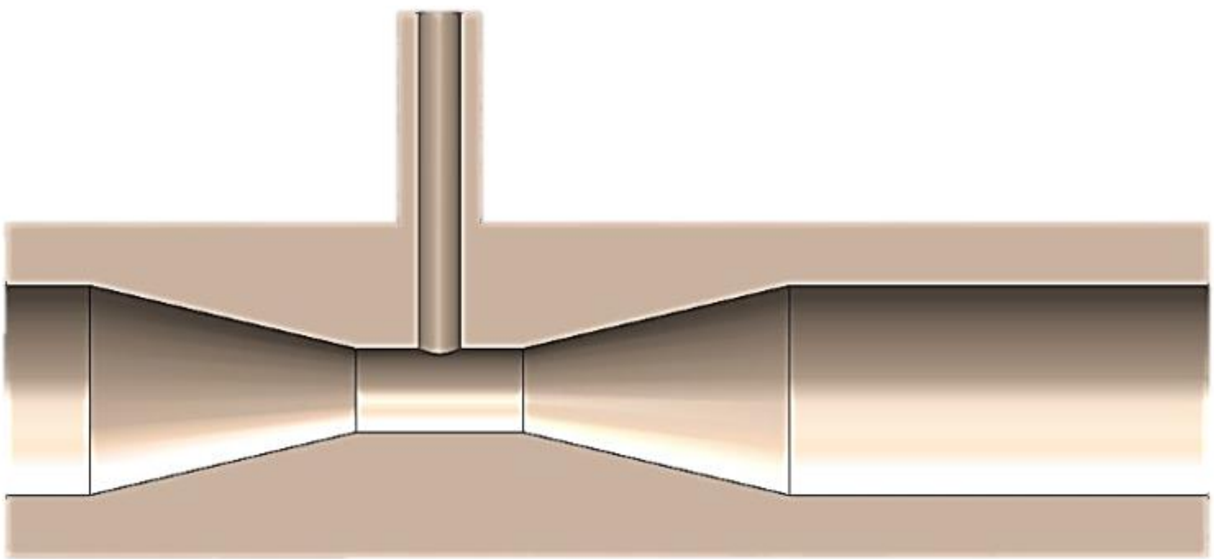


Figure 22: CAD model of proposed venturi design

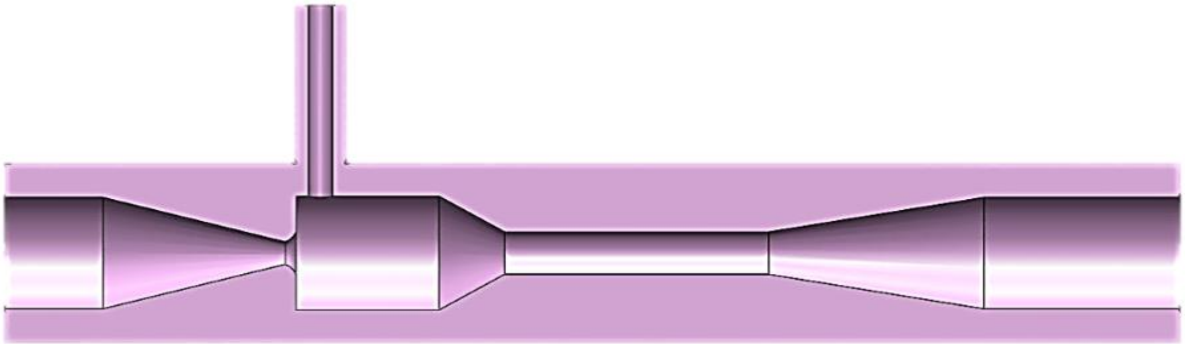


Figure 23: CAD Model of the proposed jet pump design

Design Analysis

In order to validate the final design concept the team had to analyze each component to verify that it could achieve the given target within the determined tolerances. The group first focused on studying the venturi effect so that the venturi/ jet pump could be properly sized to achieve the desired mix ratios. Upon analyzing the mixing chamber the team realized that the concentrate's viscosity had to be found to determine its effects on the system's flow. Likewise, selecting the proper valves was a key factor in maintaining proper adjustable flow within the system.

Mixing Chamber

Before the 3D printing models could be made the approximate geometry had to be found. After collecting the equations to evaluate the jet pump and venturi, the group decided to assess the venturi first as the equations were less complex than the jet pump. The jet pump equations that were found heavily relied on knowing the losses due to the geometry to find flow, so to use flow to find geometry was much more complicated as it was more of a guess and check process.

Initially, the plan to analyze the venturi was to define a desired pressure and velocity to determine the required geometry; however this proved difficult to calculate. The design was reevaluated so that instead the geometry was defined and the pressure necessary was back calculated. As long as the pressure was under the pressure from the water line, a pressure regulator could be added to drop the pressure to the desired amount. In addition to this being an easier process, it transformed the system from a rigid system that would need a new venturi with corrected dimensions, to a tunable system were the pressure could be adjusted to the right amount in order to achieve the correct flow rates.

The venturi was analyzed using Bernoulli's equations (Equation 1 and Equation 2). In order to properly study the venturi it had to be separated into three sections which is shown in Figure 24. From points 1 to 2 the water is entering the converging component where the decrease in area causes an increase in velocity which is possible from decreasing pressure due to the conservation of energy. To use Bernoulli's Equation the change in height (Z) was set to zero. The head loss is found from Equation 2 and using the friction factor (f), length of the pipe (L), average velocity (V), and diameter (D). Surface roughness is a function of the Reynolds Number (Re) found in Equation 3 which is dependent on density (ρ), dynamic viscosity (μ), velocity, and diameter as well and relative roughness (ε/D). The actually roughness of the pipe is given by ε; however the effects diminish as the diameter of the pipe increases. With relative roughness and the Reynolds number, friction factor can be found via a Moody Diagram. However, the pressure and velocity at the throat are unknown, so another Bernoulli's equation is applied for the juice concentration line. This is done because the initial values for state 3 are known and the values that are solved for define state 2.A concern for this section was the effect of the head loss due to the viscosity of the concentrate. After performing various experiments, which are discussed in detail in a later section, to find the viscosity, it was found that the effects were negligible compared to the other forces.

From state 2 to state3 the water has reached the throat, and if designed properly will be at a lower pressure than the concentrate. This difference in pressures will create suction pulling the concentrate into the water flow. The values found for state 2 are known and are used to calculate the initial pressure for state 1 which is what the pressure regulator will be set to.

$$\frac{P_A}{\rho} + \frac{V_A^2}{2} + Z_A g = \frac{P_B}{\rho} + \frac{V_B^2}{2} + Z_B g + h_L$$ **Equation 1**

$$h_L = \frac{fLV^2}{2D}$$ **Equation 2**

$$Re = \frac{\rho V D}{\mu}$$ **Equation 3**

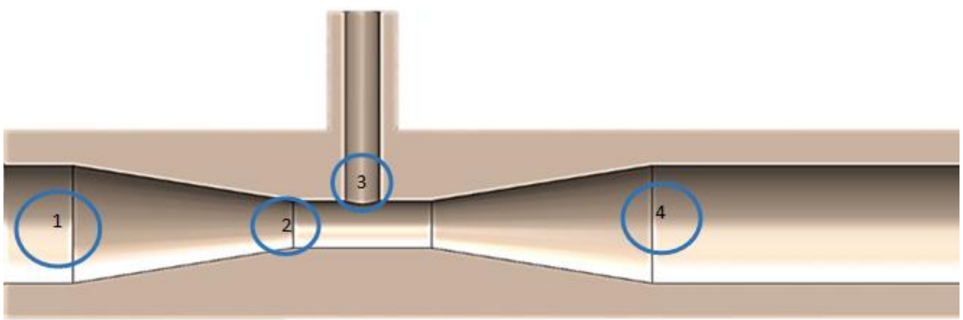


Figure 24: Venturi Figure showing the different sections used to analyze the flow

The values that were calculated from the MATLAB code (Appendix F) were reasonable for the prototyping application so the team decided to move forward with only a venturi model. Additionally, because of the new method of analysis only one prototype would need to be printed as the system could be tuned to adjust from any deviation from the original schematic.

Concentrate

To measure the viscosity of the concentrate and juice mixture the group employed the use of a Brookfield-type viscometer shown in Figure 25. With assistance from the Food Science department and Mr. Brandon Coleman, the team conducted a test using the viscometer, which works by using different size spindles and applying a torque to measure its viscosity in centipose (cp). After the first tests, the group notice that the data showed a couple abnormalities. In addition, the tests were conducted with concentrate that was warmer than the targeted operating point. This was a problem since viscosity is dependent on temperature, so the tests were run again with a cooler concentrate. These produced results that were more in line with expect values.

Figure 25: Brookfield type viscometer that was provided by the Food Science Department at Cal Poly

In addition to the tests that were run with the viscometer, it was recommended that the team use a rheometer, which is more accurate than a viscometer, to make sure the shear rates were consistent with the viscosity readings. With assistance from the Chemistry department and Dr. Raymond Fernando, the team was able to run a couple tests with a Discovery Hybrid

Rheometer shown in Figure 26 . A test for the concentrate confirmed three properties that were essential to understand how the fluid would respond in the system: the concentrate was a non-Newtonian fluid, it was a shear-thinning fluid, and the values were consistent with the Brookfield type viscometer. After talking to Professor Christopher Pascual, Professor Russell Westphal, and Professor Hans Mayer, the team was able to appropriately apply these to the model.

Figure 26 : Discovery Hybrid Rheometer that was provided by the Chemistry Department at Cal Poly

Dispensing nozzle

Initially the team was going to purchase a dispensing nozzle that was already manufactured and was appropriately sized for the prototype. However, Mr. Brookner decided that he wanted the dispensing nozzle attached to the venturi so that they were one solid piece. The nozzle will now be printed with the venturi. Bernoulli's equation was used to appropriately size the nozzle.

Valves

The ball and solenoid valves were the two valves selected from the weighted matrix for water delivery system. The team realized that valves would be a limiting factor for the total cost as the prices could range from a less than one hundred dollars to a few thousand dollars, so a limit of two hundred dollars was set to stay within the target budget. This severely limited the number of ball valves due to the fact that electronically controlled ball valves were often more than seven hundred dollars.

One additional factor that was not initially considered was response time. Out of all the ball valves that were reasonably priced for this project, the quickest response was five seconds, compared to the solenoids which on average responded in less than a second. Using a ball valve in the machine could create a problem as normal dispensing operations with current machines occur in under a second. If the machine was designed with the ball valve, the slow response time may cause primary customers to believe the machine is broken and alert management that their machine is not working. In order to have the designed machine assimilate smoothly into the environment a quick response time was deemed important, even though it was not an initial customer requirement. Due to this, the group decided to move on with a solenoid valve without testing either.

In addition, a 1/4inch pinch valve was selected as the actuator to control the concentrate flow into the venturi. The 1/4 inch valve was the largest available in the price range allowed. Selecting the largest valve allowed the most flow control with the smallest amount of vacuum pressure at the throat of the venturi.

Control System

The goal of the project was to create a machine that used a limited amount of electronics; however, there are a couple electronically controlled valves which will respond to a button input. The whole system will be controlled by an Arduino microcontroller, which when the button is pressed will activate the system and will open the valves to allow the fluids to flow and mix. The team decided to use an Arduino due to its reliability and simplicity.

Final Design

After the final components were selected, the last step was to find the actual components that could be purchased or manufactured so the prototype could be built. The most essential piece is the venturi, which is going to be 3D printed through the Mechanical Engineering Department. If necessary the venturi can be coated in a resin that will ensure that it is watertight which is vital a property for the component. The rest of the components will be off the shelf parts from various vendors. The schematic of the final design can be seen in Figure 27.

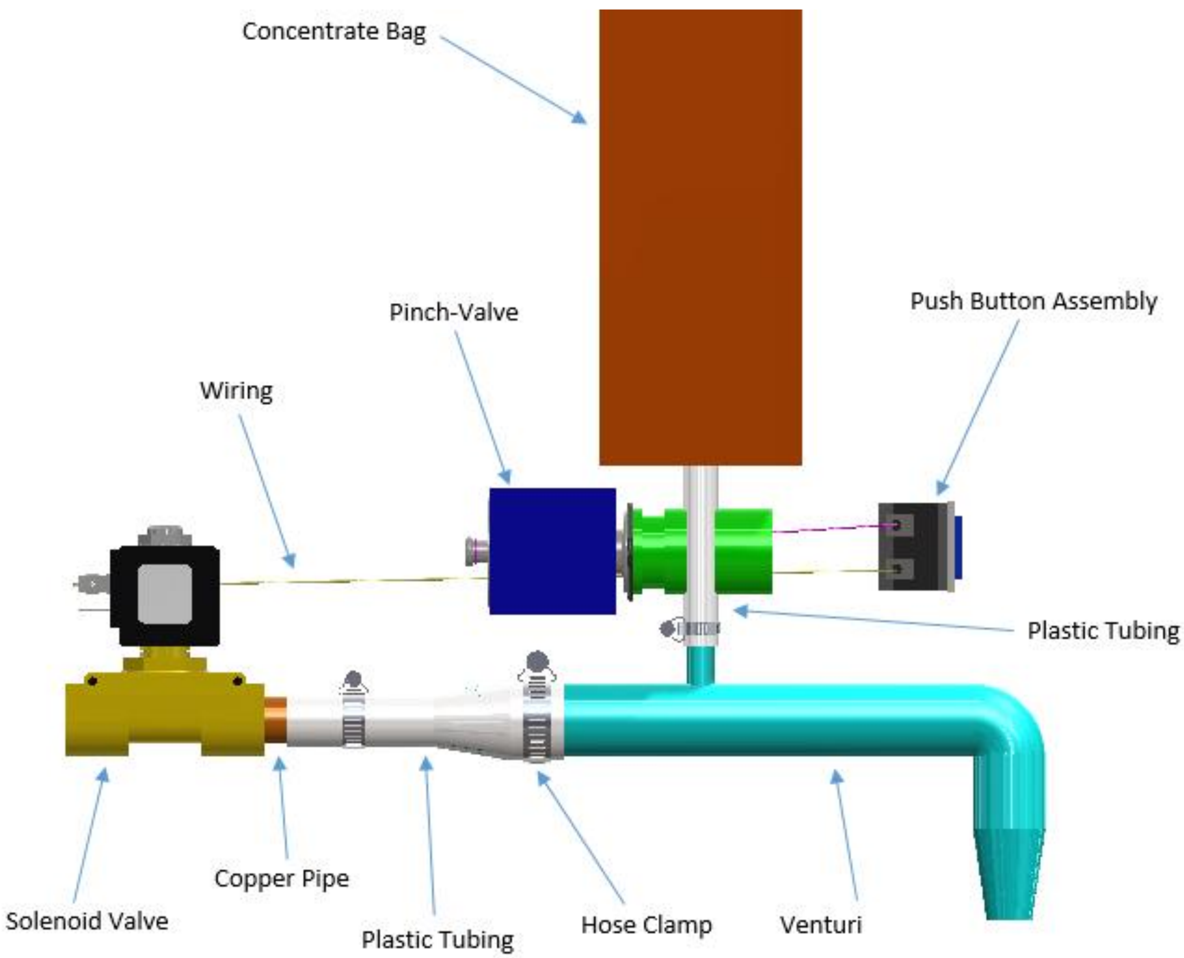


Figure 27: CAD model of completed final design with all components that were selected to move on to testing.

The venturi's final dimensions were designed to stay within the size requirement established by current machines. The inlet and outlet diameters were determined by the water valve and nozzle, but the converging and diverging angle was adjusted according to stay within the length requirements of 8.75 inches. A full engineering drawing can be found in Appendix H

The solenoid was a 1/2" 12V DC Electric Brass Solenoid Valve from Electric Solenoid Valves. The pressure limits were 0-145 psi and temperature limits were 15-265 °F, which are far from the operating point of the juice dispenser. Additionally the response time is under a second, which was important to the design. The valve is stated to work best with low viscous fluids such as water, which is the intended purpose of the valve. Overall, the valve should completely satisfy the requirements for the water line valve.

The pinch valve was the Pinch-Style Aluminum Solenoid Valve for Tubing, Normally Closed, for 3/8" Tube OD x 1/4" Tube ID, 12 VDC. The valve is rated for a max pressure of 15 psi and operates in temperatures between 14-140 °F, which both are satisfactory for the concentrate line design conditions. Furthermore the valve does not ever come in contact with the concentrate which was the most important property of the valve.

The controller system will involve the use of an Arduino Duemilanove, along with a breadboard, 10 kohm resistor, and some wires. The basic code and schematic to operate the button are provided by Arduino but may need to be modified.

The final component was a pressure regulator from Camping World. There were limited specifications but the price and gage attached to the pressure regulator in the picture lead the group to believe that the regulator would work for the application. Testing is required to see if the regulator is able to regulate at the pressures required, else a new regulator may need to be found.

Testing System

In order to test the prototype properly and accurately, it was important for the team to create an environment similar to the one the venturi will be operated in when put into production. To do so the team designed a controlled testing apparatus which can be seen in Figure 28. The team goal was to repurpose an old refrigerator to serve as a constant temperature area because the system is dependent on little to no temperature fluctuations. Water was brought into the fridge and chilled as it ran through the copper piping to the solenoid. When it reached the venturi it was approximately at the same temperature as the concentrate. The concentrate was controlled with a pinch valve. When a button was pressed, both valves opened to allow the water to follow into the venturi and pull the concentrate into the water. The mixture flowed through the venturi and came out the other side in the dispensing nozzle completing the process.

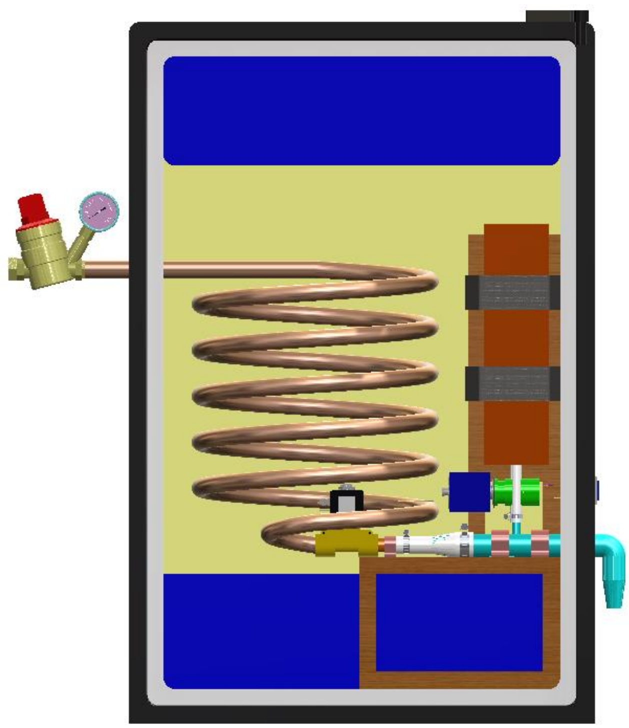


Figure 28: CAD Model of the complete prototype model that will be used for testing.

Cost Analysis

The total cost for the final design is shown in Table 13, which summarizes where the team will purchase the parts and a breakdown of the costs. This is repeated for the testing setup in Table 14.

Table 13: Cost analysis for the final design with total cost.

Unit Name	Source	Part Number	Unit Price	Qty	Tax	Shipping	Line Total
1/2" 12V DC Electric Brass Solenoid Valve	Electric Solenoid Valves	2W-160-15-12V	$39.95	1	$3.20	$4.95	$48.10
Pinch-Style Aluminum Solenoid Valve	McMaster Carr	5431T131	$195.15	1	$15.61	$10.00	$220.76
Arduino Duemilanove	Mini In the Box	#01240804	$16.31	1	$1.30	$5.00	$22.61
Breadboard	Mini In the Box	#00340903	$3.99	1	$0.32	$5.00	$9.31
Male to Male Breadboard Wires for Electronic	Mini In the Box	#00364598	$2.49	1	$0.20	$5.00	$7.69
Mini Pushbutton	Sparkfun	COM-00097 ROHS	$0.35	1	$0.03	$2.77	$3.15
10 kohm Resistor (20 pk)	Sparkfun	COM-11508 ROHS	$0.95	1	$0.08	$2.77	$3.80
Venturi	Cal Poly	N/A	$245.00	1	N/A	N/A	$245.00
Adjustable Pressure Regulator	Camping world.com	#49511	$52.14	1	$4.17	$16.00	$72.31
						Total	$632.73

Table 14: Cost analysis for the testing system with total cost.

Unit Name	Source	Part Number	Unit Price	Qty	Tax	Shipping	Line Total
20 Ft Copper Piping	Home Depot	PCLE-375L020	$43.21	2	$6.91	$0.00	$93.33
Refrigerator	Target	72010023	$159.99	1	$12.80	$0.00	$172.79
Shark Bites	Home Depot	U0008LFA	$6.94	5	$2.78	$0.00	$37.48
Hold Down Brackets	Home Depot	C624HD12	$2.30	1	$0.18	$0.00	$2.48
Bungee Cords	Home Depot	4T960N	$6.89	1	$0.55	$0.00	$7.44
Hose Clamps	Home Depot	626025E	$7.27	1	$0.58	$0.00	$7.85
2x4 Wood	Home Depot	20496UPPS	$3.00	5	$1.20	$0.00	$16.20
Refrigerator Thermometer	Walmart	Taylor 3507	$5.99	1	$0.48	$0.00	$6.47
Clear Tubing	Home Depot	SVNL10	$18.82	1	$1.51	$0.00	$20.33
						Total	$364.37

Safety

One risk that is still present is that it can be a tipping hazard if moved, for example by an untrained person or an earthquake. This was a problem with previous designs, as the machines are usually elevated for easier use. This risk is significantly decreased if the machine is placed on a sturdy surface with plenty of clearance from the edge of the surface. The group has evaluated possible risks associate with the product, and has recommended appropriate actions to mitigate the chance of personal injury. The group has evaluated the new design to see if the tipping could be reduced by moving the center of gravity in the machine, but due to the concentrate needing to be elevated, this was not possible.

The group performed a Failure Modes and Effects Analysis (FMEA) where the design is evaluated for all possible modes of failure and what could cause the failure. Each failure is given a severity from 1-10, with 1 being almost inconsequential to 10 which is worst case scenario with the product. Then each failure is given score based on the chance of occurrence. The two values are multiplied together and make the criticality of failure. Modes with the largest criticalities are given recommendations to mitigate effects on the final problem, and remedies if the failure happens. The full FMEA can be found in Appendix K. There were 48 potential causes of failure for the different modes, of which 15 were found to be of high enough criticality to warrant a recommended action that are discussed in the recommended actions column of the FMEA.

Manufacturing / Construction

With Mr. Brookner's approval of the final design the team was ready to start manufacturing the venturi and construction of the test system. The team decided to run some preliminary tests on each component before constructing the testing system to ensure that each component operated within the desired tolerances. The flowmeter, pressure regulator, and pressure gauges were all tested to verify their accuracy.

Prototype Manufacturing

The Venturi was manufactured using rapid prototyping. There were two types of 3-D printing options available to the team, the Eden 250 and the Stratasys 768. The primary concern with 3-D printing was layer separation, since the objective was to run fluids though the printed piece. The team evaluated the properties and abilities of each and found the Eden 250 to be the better machine for the application. The Eden 250 had the ability to print thinner layers which provide a part that was watertight. It also used gel-like support material that could be dissolved with a basic solution, which allowed a cleaner model unlike trying to remove the breakaway support material that the Stratasys 768 used.

Figure 29: The Eden 250 3-D printer that was used to make the prototype.

After the part was created in Solidworks it was converted into an STL file which the Eden 250 requires to be able to print the part. Due to the size of the venturi, it took approximately 7.5 hours to print. The printer uses an organic matter as a support material for printing, so after printing a pressure washer was used to remove it. Additional cleaning was required using a bottle bushes since the nozzle and throat made it difficult to clean the mixing chamber.

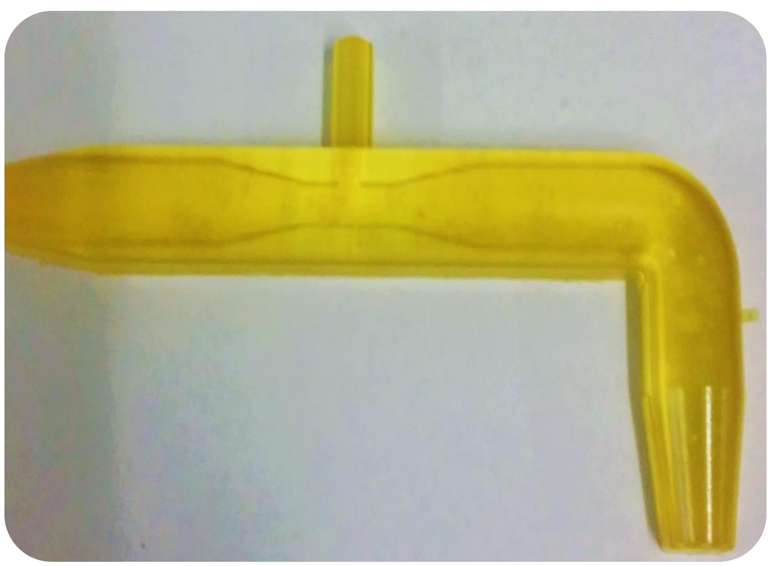


Figure 30: The prototype venturi that was printed.

Component Testing

The components were tested to verify their accuracy, and identify if a correction factor needed to be included when testing began. In order to test the flowmeter, water was sent through it for a measured amount of time. The water was collected in a bucket and measured with a hook scale to obtain the mass of water. With this information a flow rate could be calculated and compared against the flowmeter's reading. This was repeated at various flow rates to see if the trend was continuous over all flow rates. The testing concluded that the flowmeter read high, and a correction factor of 0.9 needed to be used.

The pressure gauges were not able to be tested, however, after talking to a professor, the team was told to trust the measurements. These were used in testing the pressure regulator to verify if the pressures that the team was trying to achieve were obtainable. Initially they were not, but again the team talked to a professor and was told that it was better to build the system and test in that environment as all the fluid resistances were difficult to reproduce with the team's simple test.

Test System Construction

The team used a mini refrigerator as the primary container for the testing unit, so that everything would be at a relatively constant temperature. The rest of the system was designed to be able to provide the appropriate pressure and flow rate for the water before reaching the venturi.

The first step was setting up the wooden framing that would support everything housed in the fridge. The venturi, solenoid, and pressure gauge were placed on a lower frame that stood about 10 inches above the ground, which was chosen so that a cup could fit underneath for testing. Additionally framing was built to hold the concentrate and pinch valve, and were placed appropriately so that they would line up with the concentrate line for the venturi.

Before the holes for the venturi and water line were cut, the team was alerted that the fridge was a newer model which tended to have the refrigerant coils along the side panels. The first plan to find the coils was utilizing a temperature gun to try and identify warmer area which would signify where the coils could be. This was unsuccessful as the refrigerator was built well and able to dissipate heat fairly even over the exterior. Unfortunately, this meant that they siding had to be removed so that the team did not cut through the refrigerant coils. After removing the paneling, the refrigerant coils were moved so that they would not be damaged, and the two holes were cut.

The next step was to set up the water piping for the system. This comprised of the system that would sit on top of the fridge, the 40 feet of coil, and the final piping that led to the venturi. The system on top of the fridge consisted of the ball valve to control flow, a flow meter, a pressure regulator, and pressure gauge, which would control the water before it entered the fridge. Unfortunately, due the positioning of the freezer tray, the layout had to change to accommodate the way the coils were installed. The piping components were fitted together using SharkBites, which is a mechanical gripping system to replace brazing. SharkBites are able to quickly connect the piping with a connector that can be removed if needed.

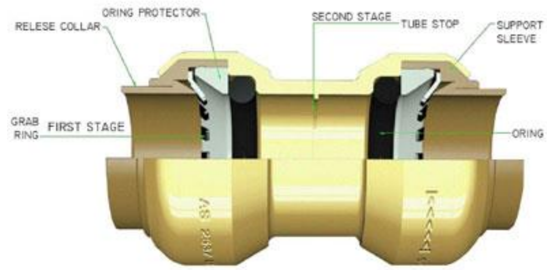


Figure 31: A SharkBite connector which allows the user to connect copper pipes with a non-permanent method.

Then a plastic sheath with tube clamps was used to attach the piping to the venturi. To connect the concentrate a nozzle had to be attached since the team was not able to get a hold of the proper device that will be used when the machine is put into production. A layout of the system that was built at this point can be seen below in Figure 32.

Figure 32: System layout.

The next step was to build a circuit to control the two valves. Both valves were 12 V and were able to be powered by a power source when in parallel. The system uses a push button that completes the circuit as long as the user is holding the button down. A circuit diagram can be seen below in Figure 33. All the electronics were housed in a box with only the button exposed so that everything else was grounded and covered.

The group could not use the refrigerator to power the system, so an external constant voltage power source was acquired. During the initial tests, both valves were not activating even though they were properly wired. After consulting an electrical engineering student, a possible issue was that the power source was not delivering the required current to open both valves. The team was able to acquire a variable power source which was able to power both valves at the voltage and amperage required, solving the problem.

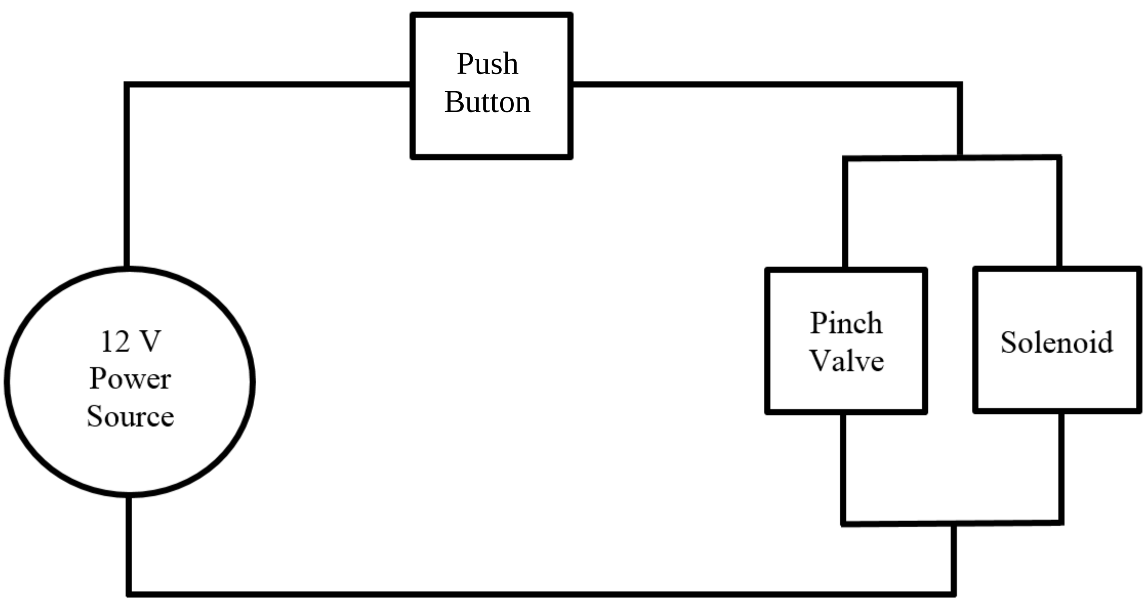


Figure 33: Circuit diagram.

Testing and Results

After the team assembled the prototype and testing environment, testing commenced in accordance to the Design Validate Plan and Report (DVPR) which can be found in Appendix J.

The DVPR is a systematic way of ensuring that the engineering specifications are met. It clearly mentions what the specification is, the method of testing, tolerance, and completion date. It also provides a section for test results and note area to annotate any adjustments that need to made to the system or engineering specification. The testing procedure that the team used can be found below:

Testing Procedure:

- Set pressure regulator
- Run system until test cup is almost full
- Measured Flow rate using a graduated cylinder
- Measured Brix level using refractometer
- If the level is acceptable, test again to verify values
- If level is not acceptable, adjust the pressure regulator accordingly and rerun

Initial Results

From tests performed by the group it was found that due to the low pressures of operation the pressure regulator had greater effect on the flow rate then desired and the ball valve worked solely as an isolation valve that had little to no effect on controlling flow. The data collected showed that the flow rate and Brix level had an inverse relationship. This can be seen in Figure 34 and the raw data can be found in Appendix M.

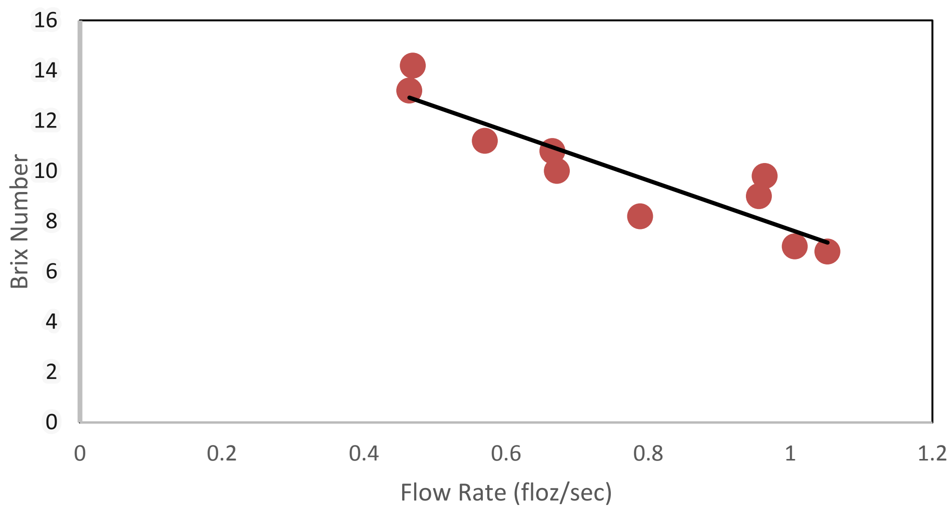


Figure 34: Brix Number vs. Flow Rate where the inverse relationship can be seen.

The group was able to achieve the desired Brix number, but during one of the verification tests, when the juice was retested, the Brix number was noticeably higher than before, even though none of the parameters had been altered. This led the team to investigate what could have caused the change in Brix number. It was discovered that if the juice was stirred, it usually resulted in a higher Brix number then before it was stirred. The group decided to add a step to the testing procedure: test the Brix number before stirring and after. This new step revealed that the venturi was capable of delivering concentrate and water but did a poor job at mixing the two fluids. The team attempted to adjust the pressure regulator in order to fix the mixing issues with no success.

Iteration

In order to fix the mixing issues the design was having, the team came up with some possible alterations for the venturi. These alterations consisted of: changing the geometry of the venturi, adding rifling similar to the ones found in guns, and adding baffles. The alteration options needed to be evaluated to verify if they were possible solutions to the mixing issues.

During the tests it was noticed that the juice was completely filling the pipe in the mixing chamber. The team needed to know if the flow was turbulent but in order to calculate that, the fluid level in the pipe needed to be known. Since there was no way to gather this information, the team decided that having a smaller diameter downstream of the throat would help full pipe flow and turbulence.

Research was conducted to see if adding rifling to the mixing chamber would improve mixing. The group found an article by Super Soaker where they were trying to improve the distance and speed of their water guns by adding rifling to the nozzles. They found that the rifling cause a reduction in the speed of the fluid and it to be more turbulent due to the centrifugal force caused by the rifling. While rifling did not work for Super Soaker's application, it would be a viable solution for the mixing problem.

Baffles were eliminated as a possible solution for mixing due to the difficulty of removing the support material that would be trapped by the baffles. With these ideas the team came up with three iterations to possibly fix the mixing issues.

Iteration 1

For the first iteration the group would keep the same size throat and inlet diameters as the original venturi. The downstream diameter would not go back up to its original size of a ½ inch but stay the same ¼ inch as the throat. The group would also add rifling to the downstream and nozzle areas of the venturi.

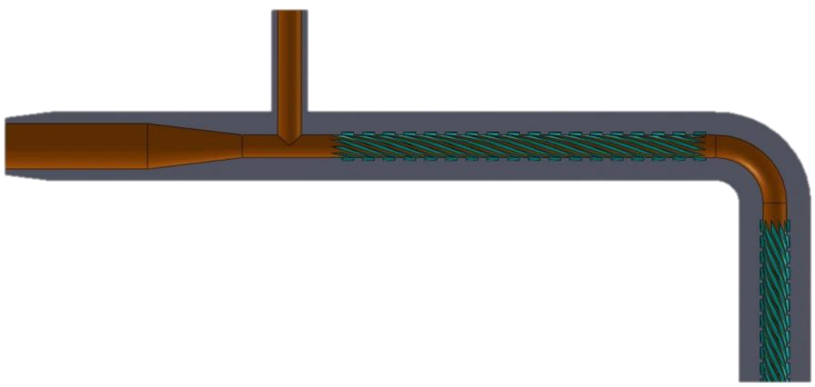


Figure 35: CAD model for Iteration 1.

Iteration 2

For the second iteration the group would reduce the throat diameter from a ¼ inch to an ⅛ inch but keep the ½ inch inlet diameter. For this iteration the downstream diameter would increase to a ¼ inch. No rifling would be added to this iteration.

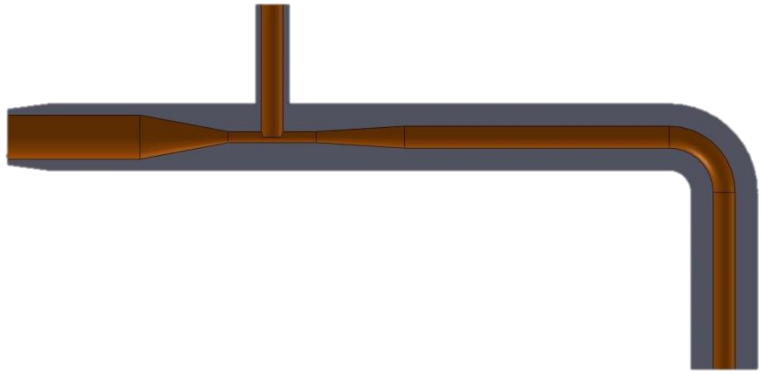


Figure 36: CAD model for Iteration 2.

Iteration 3

For the third iteration the group would add rifling to the downstream and nozzle areas of the second iteration. Full engineering drawings for all three iterations can be found in Appendix H.

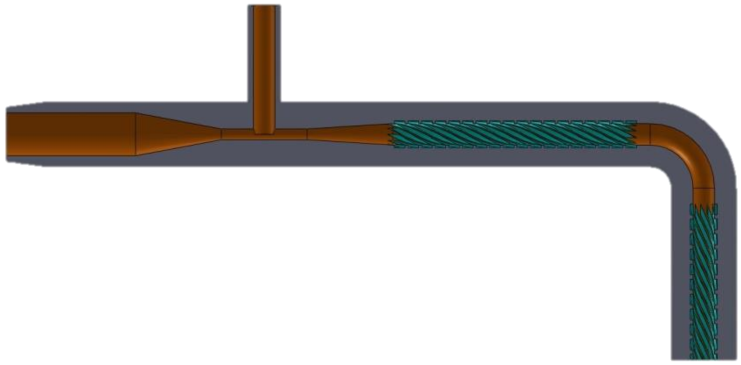


Figure 37: CAD model for Iteration 3.

Final Results

Mr. Brookner approved manufacturing on Iterations 1 and 3. The team alerted him that they would not be able to verify what would cause any improvement if all three were not printed; however, he insisted only the two be printed. The team used the same Eden 250 to manufacture the iterations. The team followed the new test procedure below to test the modified venturis.

Testing Procedure:

- Set pressure regulator
- Run
- Measured Flow rate using values with pressure regulator and timer
- Measured Brix level with refractometer
- Stir the mixture and re-measure the Brix level
- If the level is acceptable, test again to verify values
- If level is not acceptable, adjust the pressure regulator accordingly and rerun

Iteration 1 Results

From the data collected on Iteration 1 it was apparent that this venturi did a much better job at mixing the two fluids than the original prototype. This iteration consistently hit the same Brix number before and after mixing. The raw test data could be found in Appendix M. The main issue with this iteration was that the team was unable to reach the desired Brix level.

Iteration 3 Results

Iteration 3, like Iteration 1, was able to mix the two fluids, but the team was also unable to reach the appropriate Brix level. This iteration additionally had problems with flow into the concentrate due to the throat diameter being too small compared to the concentrate line, and large pressure build ups which caused burst of water into the glass that would spill over and dilute the juice.

Final Costs

Supplier	Quote Cost	Actual Cost	Difference
McMaster Carr	220.76	247.01	26.25
Target	172.79	172.79	0.00
Home Depot	164.79	223.33	58.54
Industrial Zone	0.00	236.37	236.37
Electric Solenoid Valves	48.10	44.90	-3.20
Mini in the box	39.61	34.60	-5.01
Camping World	72.31	0.00	-72.31
Cal Poly	245.00	351.66	106.66
Walmart	6.47	0.00	-6.47
Spark Fun	6.95	5.31	-1.64
Installation Parts Supply	0.00	132.66	132.66
Total	976.78	1448.63	471.85

Although the team was over the target budget, it was approved by Mr. Brookner. The primary reason for going over budget was the inclusion of the two pressure gauges that were not in the initial cost analysis, and the printing of two more venturis for the iteration testing.

Recommendations

Due to time constraints, the team was unable to complete additional iterations to correct the issues that were experienced during testing. If time permitted, the following would have been the next steps the team would have taken in order to improve the performance of the juice dispenser. As an alternative to printing more venturis, the goal was to see what could be done to improve the existing configurations.

The first venturi had issues with consistency and mixing, and while new iterations of the venturi were made, the team came up with some ideas to possibly improve the design. Two cost effective and quick solutions that were adding an aerator, such as a screen mesh, or an additionally mixing chamber at the dispenser that can be found on higher end epoxies. If the mixing could be improved, the consistency may follow suit.

After testing the first iteration, the team found that while it was consistent it was not able reach the Brix level required. A couple solutions that could be easily added to the system would be purchasing a more precise pressure regulator or flow control valve. A metal regulator would be desirable, however, the team could not find a cost effective one that would operate at the pressures needed. Therefore, a plastic regulator is likely to be required, but they are not as sturdy which caused problems during testing when trying to create watertight connections. Additionally, a flow control valve like a globe valve could be added in place of the ball valve, which is an isolation valve. The ball valve can be used for flow control; however, it has a limited range of effectiveness. Another inclusion would be adding a control system that could time and govern the solenoid to open incrementally to prevent the initial bursts of flow by allowing flow to develop gradually, and better synchronize with the pinch valve to have better mix ratios.

The second iteration was not printed, however, it is recommended that it modified to the mirror iteration 1 without rifling, in order to see if the rifling has a significant effect on the consistency the first iteration experienced. If the rifling did not need to be included, it could make the manufacturing of the component significantly easier and less expensive. The last iteration has flow problems and high pressure bursts, and it is suggested that the design not be pursued.

Conclusion

The team was able to verify that a venturi is able to pull in the correct amount of concentrate to make juice at the desired Brix, however, improvements need to be made in order to ensure mixing and consistency. If these issues can be solved then the venturi may be a viable option to replace pumps in the juice dispenser, however, any costs that are saved by switching to the venturi could very easily be lost to the control system that may be required to make the machine work properly. This exchange is seen in industry, but the company is willing to accept the higher capital costs, as the venturis can last longer than pumps. Overall, the benefits of using a venturi juice machine would be savings in the operational and servicing costs.

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Appendix A: Refractometer Diagram

Figure 38: An example of how to use a refractometer. Place the drop of the desired juice onto the daylight pane and look into the viewing piece (Aquarium Line).

Figure 39: The Brix number is determined after reading this scale which can be seen through the eyepiece (Grapestompers).

Appendix B: QFD

Project:
Revision:
Date:

Correlations	
Positive	+
Negative	−
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

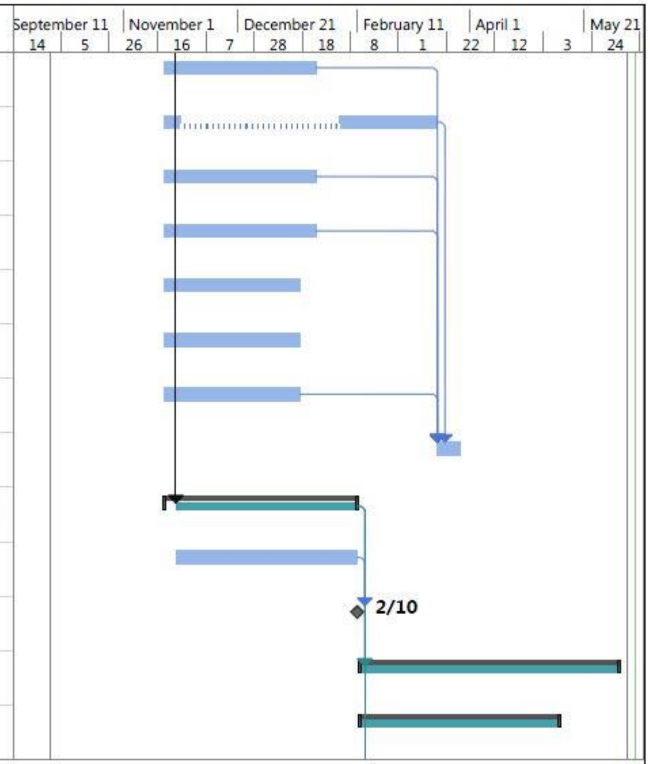
Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼

Row #	Weight Chart	Relative Weight	WHO: Customers – Businesses	WHO: Customers – Jonathan's Natural Juices	WHO: Customers – Drinkers		Maximum Relationship	WHAT: Customer Requirements (explicit & implicit) / HOW: Engineering Specifications	1 Sugar Levels	2 Water Flow Rate	3 Juice Flow Rate	4 Electricity Usage	5 Size of Machine	6 Costs of the Machine	7 Life of Valve	8 Material	9 Pumps	10 Electronics	11	12	13	14	15	16
								Direction of Improvement	▲	▼	◇													
1		14%	7	7	8		9	Correct Water/Concentrate Ratio	●	○	○				▽			▽						
2		18%	10	10	10		9	FDA/NSF Grade Approved								●								
3		7%	5	8	2		9	Limited Electronics		○	○	●	○					●						
4		7%	4	9	2		9	No pumps		○	○		○				●							
5		6%	3	8	2		9	Moderately Durable Design						○	●	○								
6		8%	6	7	3		9	No leakage of concentrate or water		○	○				○	●								
7		5%	3	7	1		9	Constant Flow Rate Concentrate			●					○								
8		5%	3	7	1		9	Adjustable Flow Rate for Water	○	●						○								
9		8%	8	8	1		3	Use current juice concentate bags					○	○										
10		7%	7	8	1		9	House in compatible unit used today					●	○										
11		6%	3	9	1		9	Valve replaced when new bag installed						○	●									
12		9%	8	8	2		9	Costs					▽	●	○	▽								
13		0%																						
14		0%																						
15		0%																						
16		0%																						

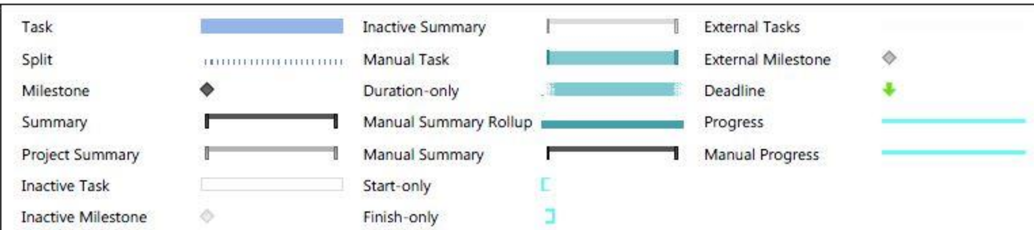
Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
HOW MUCH: Target	±0.8 of Juice's Brix Level	±10% of acceptable levels	±10% of acceptable levels	1.8KW Maximum	10 ft^3 Maximum	$1,000 Maximum	Lasts for a 1 Gallon Bag of Concentrate	FDA/NSF Approved	No Pumps	3 Electronics Components ± 1 Component						
Max Relationship	9	9	9	9	9	9	9	9	9	9						
Technical Importance Rating	138.517	153.376	153.376	65.0351	140.006	158.892	171.444	296.306	63.6825	78.7914						
Relative Weight	10%	11%	11%	5%	10%	11%	12%	21%	4%	6%						
Weight Chart																

Appendix C: Gantt Chart

ID	Task Name	Duration	Start	Finish
14	Obtain & Analyze concentrate	31 days	Wed 11/19/14	Fri 1/23/15
15	Pressure drop Calculations	36 days	Wed 11/19/14	Tue 3/17/15
16	Calculate desired flow rate	31 days	Wed 11/19/14	Fri 1/23/15
17	Geometry	31 days	Wed 11/19/14	Fri 1/23/15
18	Research different valve manufactures	26 days	Wed 11/19/14	Fri 1/16/15
19	Build model for Arduino	26 days	Wed 11/19/14	Fri 1/16/15
20	Dipensing nozzle	26 days	Wed 11/19/14	Fri 1/16/15
21	CAD Modeling	8 days	Wed 3/18/15	Fri 3/27/15
22	**CDR**	**43 days**	**Wed 11/19/14**	**Tue 2/10/15**
23	Final Design Report (CDR)	40 days	Mon 11/24/14	Tue 2/10/15
24	CDR Presentation	0 days	Tue 2/10/15	Tue 2/10/15
25	**Prototype and testing**	**81 days**	**Thu 2/12/15**	**Thu 6/4/15**
26	**Prototype Construction**	**63 days**	**Thu 2/12/15**	**Sat 5/9/15**

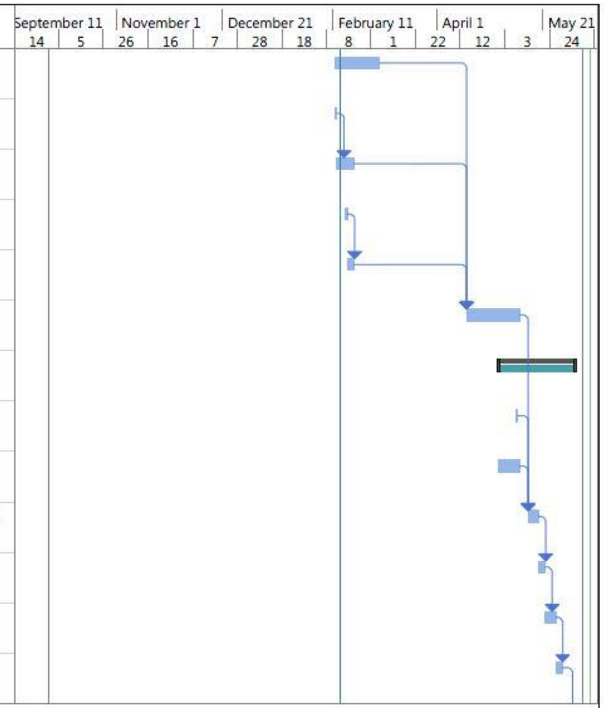


Project: AJD Gantt
Date: Fri 6/12/15



Page 2

ID	Task Name	Duration	Start	Finish
27	Order parts	15 days	Thu 2/12/15	Wed 3/4/15
28	Home Depot Run	1 day	Thu 2/12/15	Thu 2/12/15
29	Construct testing system	6 days	Fri 2/13/15	Fri 2/20/15
30	Meet with Larry	1 day	Tue 2/17/15	Tue 2/17/15
31	3D Print Venturi	3 days	Wed 2/18/15	Fri 2/20/15
32	Assemble Prototype	18 days	Wed 4/15/15	Sat 5/9/15
33	**Prototype Testing**	**26 days**	**Thu 4/30/15**	**Thu 6/4/15**
34	Pump	1 day	Fri 5/8/15	Fri 5/8/15
35	Electronics	7 days	Thu 4/30/15	Sat 5/9/15
36	Water Flow Rate	3 days	Thu 5/14/15	Mon 5/18/15
37	Juice Flow Rate	3 days	Tue 5/19/15	Thu 5/21/15
38	Sugar Level	3 days	Fri 5/22/15	Tue 5/26/15
39	Life of Valves	3 days	Wed 5/27/15	Fri 5/29/15

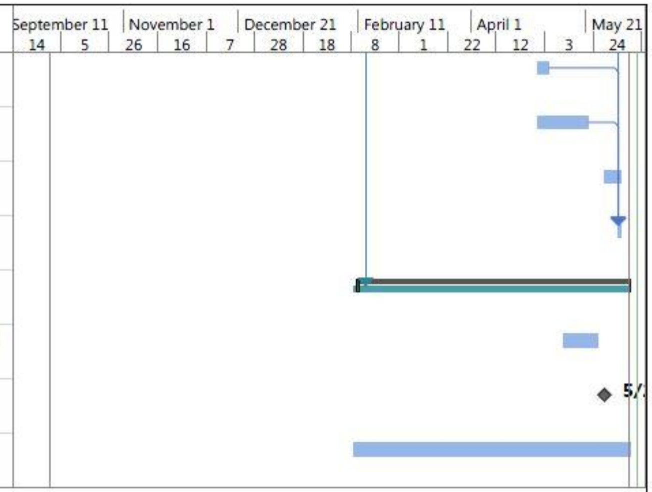


Project: AJD Gantt
Date: Fri 6/12/15

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

Page 3

ID	Task Name	Duration	Start	Finish
40	Electricity Use	3 days	Thu 4/30/15	Mon 5/4/15
41	Size of Unit	16 days	Thu 4/30/15	Thu 5/21/15
42	Iteration	5 days	Fri 5/29/15	Thu 6/4/15
43	Cost of Unit	1 day	Thu 6/4/15	Thu 6/4/15
44	**Final Report**	**84 days**	**Wed 2/11/15**	**Mon 6/8/15**
45	Prepare For Expo	11 days	Mon 5/11/15	Mon 5/25/15
46	Expo	0 days	Fri 5/29/15	Fri 5/29/15
47	Final Project Report	86 days	Mon 2/9/15	Mon 6/8/15



Project: AJD Gantt
Date: Fri 6/12/15

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

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Appendix D: Idea Evaluation Matrices

Table 15: Go/No-Go for pressurizing device subsystem.

	No pumps	Fits in Housing	GO/NO
Compressor		X	No
Water flow over bag	x	X	Go
Weight on top of bag	x	X	Go
Actuators	x	X	Go
Hydraulic system			No
Additional Height	x		No

Table 16: Go/No-Go matrix for mixing subsystem.

	No Pre-Mix	Sanitary	GO/NO
Funnel	X	X	GO
Pipe in a Pipe (PIP)	X	X	GO
Venturi	X	X	GO
Jet	X	X	GO
Tesla	X	X	GO
Fan	X	X	GO
Spinning		X	NO
Swish and Spit			NO
Hand mix			NO

Table 17: Go/No-Go matrix for the delivery subsystem.

	Relevant	Control Flowrate	User Input ON/OFF	Prevent Backflow	GO/NO
Solenoid	X	X	X	X	GO
Tesla	X			X	NO
Check	X	X	X	X	GO
Needle	X	X	X	X	GO
Gate	X	X	X	X	GO
Double-Check	X	X	X	X	GO
Duckbill	X			X	NO
Choke					NO
Thermostatic					NO
Thermostatic Radiator					NO
Trap-Primer					NO
Vaccuum Breaker					NO
Sleeve					NO
Pressure Sustain					NO
Preston/Shrader					NO
Reed					NO
Rocker					NO
Roto-lock					NO
Rotory					NO
Rupture Disc					NO
Saddle					NO
Stop-Cock					NO
Swirl					NO
Faucet					NO
Plunner					NO
Butterfly					NO
Ceramic Disc					NO
Globe					NO
Knife					NO
Pinch					NO
Piston					NO
Poppet					NO
Spool					NO
Pressure Reducer					NO
Safety					NO
Aspin					NO
Ball-Cock					NO
Bib-cock					NO
Blast					NO
Cock					NO
Demand					NO
Double-Beat					NO
Flipper					NO
Heimlich					NO
Foot					NO
Fourway					NO
Freeze Seal					NO
Gas Pressure Regulator					NO
Heart					NO
Johnson					NO
Leaflet					NO
Pilot					NO

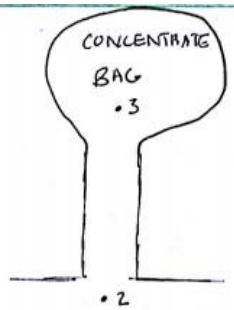
Table 18: Pugh matrix for delivery subsystem.

	Gate	Ball	Solenoid	Needle	Check	Double Check	Peristaltic Pump
Correct Ratio	-	-	S	-	-	-	D
FDA/NSF Grade Approved	S	S	S	S	S	S	
Limited Electronics	+	+	S	+	+	+	A
No pumps	+	+	+	+	+	+	
Moderately Durable Design	+	+	+	+	+	+	T
No leakage	-	-	S	-	-	S	
Constant Flow Rate Concentrate	+	S	-	+	S	S	U
Adjustable Flow Rate for Water	+	+	+	+	+	+	
House in compatible unit used today	+	+	+	+	+	+	M
Costs	+	+	+	+	+	+	
∑+	7	6	5	7	6	6	
∑-	2	2	1	2	2	1	
∑S	1	2	4	1	2	3	

Table 19: Go/No-Go matrix for dispensing subsystem.

	Quick Response	Reliable	GO/NO
Push button	X	X	GO
Push lever	X	X	GO
Pneumatic	X		NO
Push rod	X	X	GO
Pull rod	X	X	GO
Pressure Plate	X	X	GO
Twisting		X	NO

Appendix E: Hand Calculations



POINT 3	POINT 2
$P_3 = 0$	$P_2 = ?$
$V_3 = 0$	$V_2 = Q/A_2$
$z_3 = 0$	$z_2 = 3in$

$Q = 0.6\ oz/s = 6.267 \times 10^{-4}\ ft^3/s$

$$\frac{P_3}{\rho} + \frac{V_3^2}{2} + z_3 g = \frac{P_2}{\rho} + \frac{V_2^2}{2} + z_2 g + h_L \quad \therefore \text{ SOLVE FOR } P_2$$

$$P_2 = -\rho\left(\frac{V_2^2}{2} + z_2 g + h_L\right) \quad \therefore \quad h_L = \frac{fLV^2}{2D}$$

FIRST TRY IDEAL CASE WHERE $h_L = 0$

$$P_2 = -\rho\left(\frac{V_2^2}{2} + z_2 g\right)$$

$$= -2.407\ \frac{slug}{ft^3}\left[\frac{(1.839\ ft/s)^2}{2} + \left(\frac{3}{12}ft\right)\left(32.174\ \frac{ft}{s^2}\right)\right]$$

$$= -23.43\ lbf/ft^2$$

$$\boxed{P_2 = -0.163\ psi}$$

$$\rho_c = 10.3523\ \frac{lbm}{gal} \rightarrow 2.407\ \frac{slug}{ft^3}$$

$$V_1 = \frac{Q}{A} = \frac{4Q}{\pi D^2}$$

$$= \frac{4\ (6.267 \times 10^{-4}\ ft^3/s)}{\pi\ (0.25/12)^2}$$

$$V_1 = 1.839\ ft/s$$

NOW TRY NON-IDEAL CASE WITH h_L INCLUDED

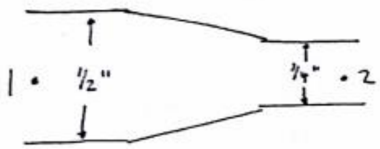
1ST CASE: $$Re = \frac{\rho V D}{\mu} = \frac{\left(2.407\ \frac{slug}{ft^3}\right)\left(\frac{1.839}{2}\right)\left(0.25/12\right)}{(1\ Pa\,s)\left(\frac{1\,psi}{6894.76\,Pa}\right)\left(\frac{144\,in^2}{ft^2}\right)} = 2.2$$

2nd CASE: $$Re = \frac{\rho V D}{\mu} = \frac{(2.407)(1.839/2)(0.25/12)}{(0.2\ Pa\,s)\left(\frac{1\,psi}{6894.76\,Pa}\right)\left(\frac{144\,in^2}{ft^2}\right)} = 11.04$$

DUE TO SUCH LOW REYNOLDS NUMBERS, THE MOODY DIAGRAM WAS INSUFFICIENT AND THE FRICTION FACTOR WAS FOUND TO BE NEGLIGIBLE. THIS MEANS THAT THE IDEAL CALCULATION IS THE ONLY VIABLE ANSWER.

POINT 1 | POINT 2

$P_1 = ?$ | $P_2 = -23.43\ lbf/ft^2$



$z_1 = 0$ | $z_2 = 0$

$V_1 = Q/A_1$ | $V_2 = Q/A_2$

$Q = 2.4\ oz/s = 0.02507\ ft^3/s$

$$\frac{P_1}{\rho} + \frac{V_1^2}{2} + z_1 g = \frac{P_2}{\rho} + \frac{V_2^2}{2} + z_2 g + h_L \quad \therefore \text{ SOLVE FOR } P_1$$

$$P_1 = \rho\left(\frac{V_2^2 - V_1^2}{2} + h_L\right) + P_2 \quad \therefore\ h_L = \frac{fLV^2}{2D}$$

FIRST TRY IDEAL CASE WHERE $h_L = 0$

$$P_1 = \rho\left(\frac{V_2^2 - V_1^2}{2}\right) + P_2$$

$$= \left(1.94\ \frac{slug}{ft^3}\right)\left[\frac{7.354^2 - 1.839^2}{2}\right] - 23.43$$

$$= 49.178 - 23.43$$

$$= 25.75\ lbf/ft^2$$

$$\boxed{P_1 = 0.179\ psi}$$

$$V_1 = \frac{4Q}{\pi D_1^2} = \frac{4(2.507\times10^{-3}\ ft^3/s)}{\pi\ (0.5/12)^2} = 1.839\ ft/s$$

$$V_2 = \frac{4Q}{\pi D_2^2} = \frac{4\ (2.507\times10^{-3}\ ft^3/s)}{\pi\ (0.25/12)^2}$$

$$V_2 = 7.354\ ft/s$$

NOW TRY NON-IDEAL CASE WITH h_L INCLUDED

$$Re = \frac{\rho VD}{\mu} = \frac{(1.94)\left(\frac{7.354 + 1.839}{2}\right)(0.5/12)}{(8.94\times10^{-4}\ Pa\cdot s)\left(\frac{1\ psi}{6894.76\ Pa}\right)\left(\frac{144\ in^2}{ft^2}\right)} = 19900$$

$$f = 0.026 \qquad V_{avg} = 7.354 + 1.839/2 = 4.5965$$

$$h_L = \frac{(0.026)(5\ in/12)(4.5965)^2}{2\ (0.5/12)} = 2.747$$

$$P_1 = 31.08\ lbf/ft^2$$

$$P_1 = 0.216\ psi$$

Appendix F: Matlab Code

AJD: Venturi Code

Contents


```
clc;
clear;
```

Given

```
rhoc       = 2.402 ;                 % Density of the concentrate
f          =.024   ;                 % Friction fator
PartCon    = 1;                      % Part of concentrte
PartWater  = 4;                      % Part of water
ToatlPart = PartCon + PartWater;     % Total Part

D1    = .5/12;                       % Diameter of the inlet pipe (water)(ft)
D2    = .25/12;                      % Diameter of throat of the Venturi (ft)
D3    = .25/12;                      % Diameter of the inlet pipe (concentrate)(ft)
L     =  3/12;                       % Lenght of pipe from Venturi to concentrate bag (ft
)
rhow =  1.94;                        % Density of the water (slug/ft^3)
g     = 32.174;                      % Gravity
```

Flow rates

```
Qt = 0.00313313802;                  % Total flow rate (ft^3/s)
Qw = (PartWater/ToatlPart) * Qt;     % Flow rate of water (ft^3/s)
Qc = (PartCon/ToatlPart) * Qt;       % Flow rate of concentrate (ft^3/s)
Vc     = Qc/(pi*D3^2/4);             % Velocity of concentrate in pipe at point 3 (ft/s)
```

Reynolds number

```
mu1= 0.0208854342332;                % Viscosity of concentrate (slug/(ft-s))
mu2= 0.00417708684664;               % Viscosity of concentrate (slug/(ft-s))
mu3= 0.009147820194142;              % Viscosity of concentrate (slug/(ft-s))
mu4= 0.00417708684664;               % Viscosity of concentrate (slug/(ft-s))

Re1 = (rhoc * Vc/2 * D3) / mu1;      % Reynolds number
Re2 = (rhoc * Vc/2 * D3) / mu2;      % Reynolds number
```

```
Re3 = (rhoc * Vc/2 * D3) / mu3;      % Reynolds number
Re4 = (rhoc * Vc/2 * D3) / mu4;      % Reynolds number
```

Finding P2

```
Vbag   = 0;                                    % Velocity at concentrate bag (lbd/ft^2)
Pbag   = 0;                                    % Pressure of concentrate bag (lbf/ft^2)
Vap2   = ((Vc+Vbag)/2);                        % Average pressue (ft/s)
hL     = (f * Vap2^2 * L) / (2*D3);            % Major head loss
P21    = (((-L*g) - (Vc^2/2) - hL) * rhoc);    % Pressure 2 with head loss (lbd/ft^2)
P22    = (((-L*g) - (Vc^2/2)) * rhoc);         % Pressure 2 without head loss (lbd/ft^2)
P21psi = P21/144                               % Pressure 2 with head loss (psi)
P22psi = P22/144                               % Pressure 2 without head loss (psi)
```

```
P21psi =

   -0.1644


P22psi =

   -0.1624
```

Finding P1

```
V1 = Qw/(pi*D1^2/4);                            % Veloctiy of water at piont 1
V2 = Qw/(pi*D2^2/4);                            % Veloctiy of water at piont 2
P11 = (((P21/rhow)+(V2^2/2)-(V1^2/2))*rhow)/144 % Pressure 1 with head loss (psi)
P12 = (((P21/rhow)+(V2^2/2)-(V1^2/2))*rhow)/144 % Pressure 1 without head loss (psi)
```

```
P11 =

    0.1771


P12 =

    0.1771
```

Appendix G: Concentrate Viscosity Results

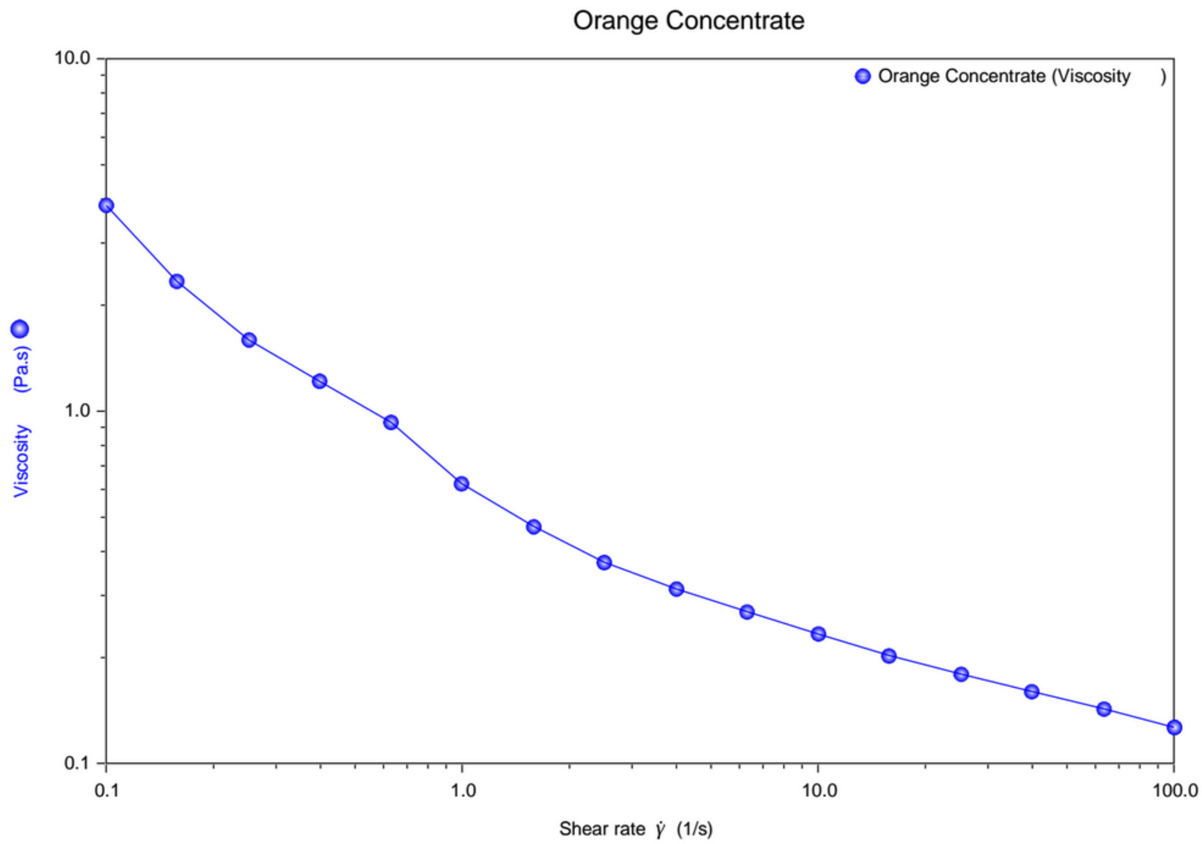


Figure 40: Results from Discovery Hybrid Rheometer

Table 20: Data from Brookfield Viscometer of spindle 2at room temperature.

Temperature (°C)	Spindle Speed (Rpm)	% Torque	Viscosity μ , (cP)
20.9	5	12.5	259
20.9	6	14.6	245
20.9	10	19.4	198
20.9	12	22.0	187
20.9	20	31.6	158
20.9	30	42.9	143
20.9	50	66.3	132
20.9	60	80.0	131

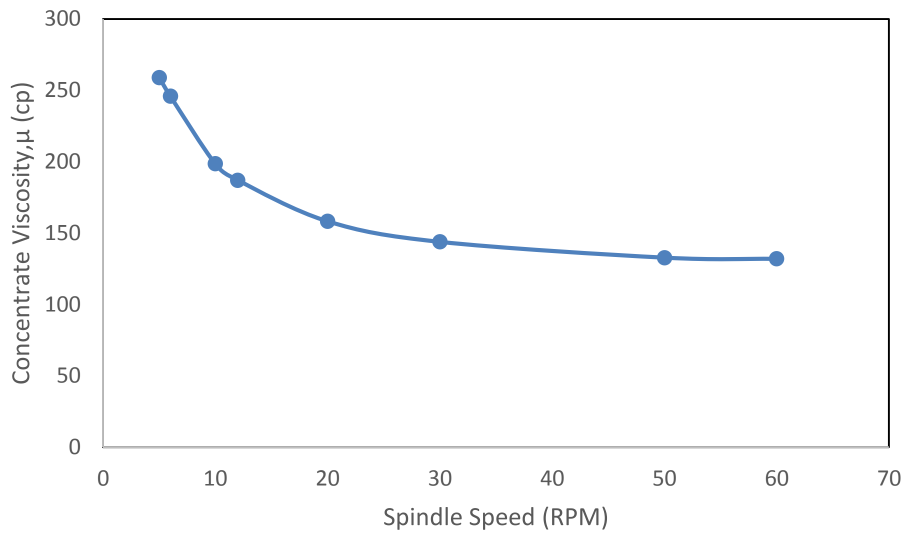


Figure 41: Concentrate Viscosity vs. Spindle Speed for spindle 1 at 20.7°C.

Table 21: Data from Brookfield Viscometer of spindle 2 at room temperature.

Temperature (°C)	Spindle Speed (Rpm)	% Torque	Viscosity μ , (cP)
20.8	30	12.3	163
20.7	50	18.5	147
20.9	60	22.5	151
20.7	100	38.1	155

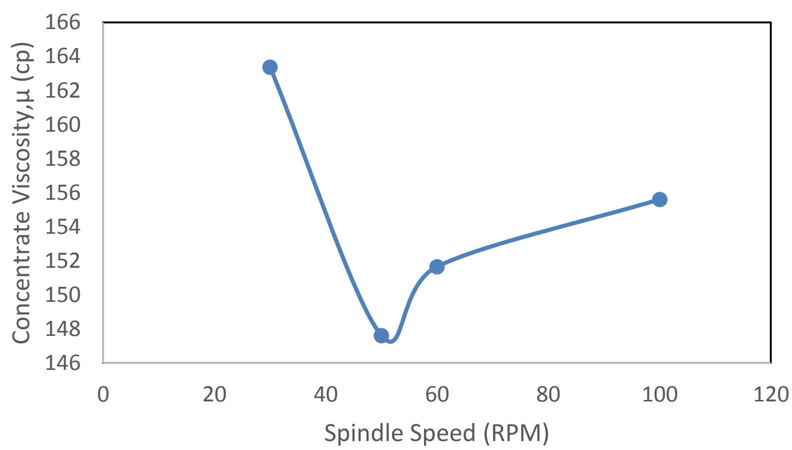


Figure 42: Concentrate Viscosity vs. Spindle Speed for spindle 2 at 20.7°C.

Table 22: Data from Brookfield Viscometer of spindle 1 for a chilled concentrate.

Temperature (°C)	Spindle Speed (Rpm)	% Torque	Viscosity μ , (cP)
12.3	3	12.8	438
11.8	4	16.1	390
12.2	5	19.1	383
12.0	6	20.0	335
12.3	10	30.5	306
12.0	12	32.5	272
12.4	20	50.2	249
12.2	30	65.6	218

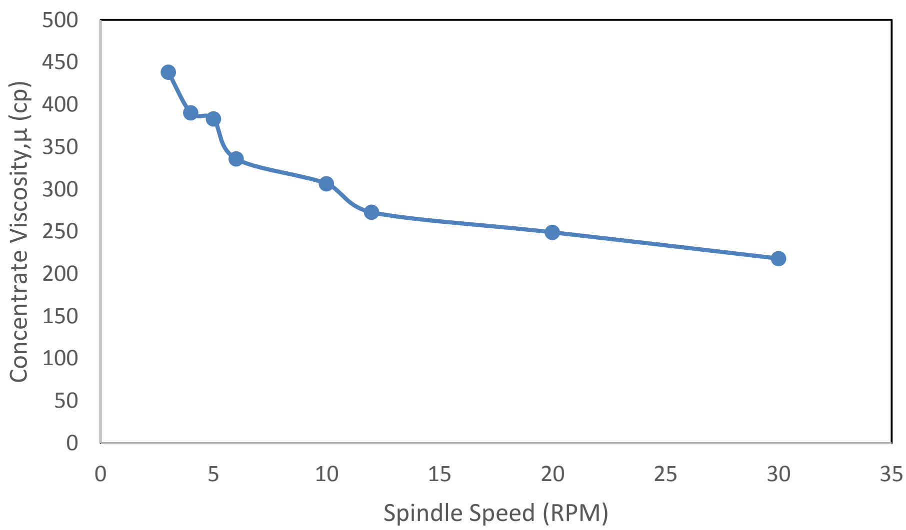


Figure 43: Concentrate Viscosity vs. Spindle Speed for spindle 1 at 12°C.

Table 23: Data from Brookfield Viscometer of spindle 2 for a chilled concentrate

Temperature (°C)	Spindle Speed (Rpm)	% Torque	Viscosity μ , (cP)
13.1	20	12.5	250
13.3	30	17.6	234
13.1	50	26	208
13.2	60	31.4	205.65
13.2	100	50.1	199.2

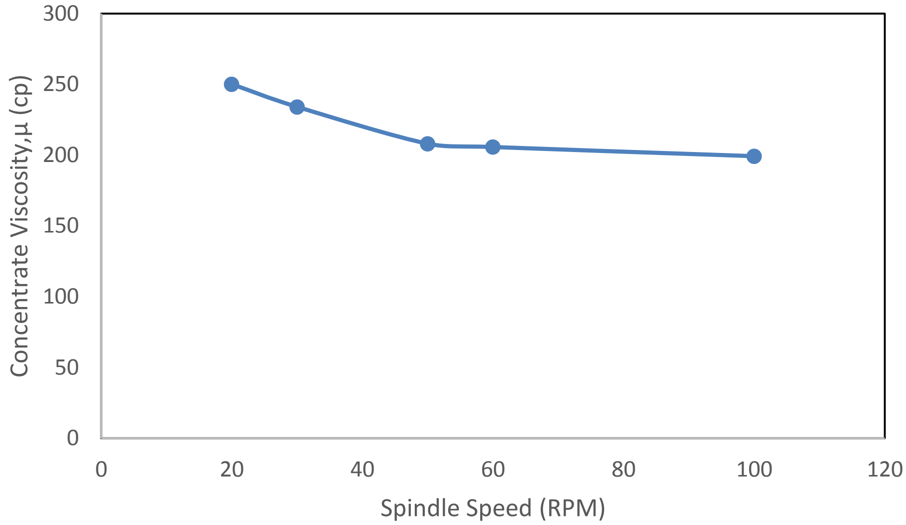
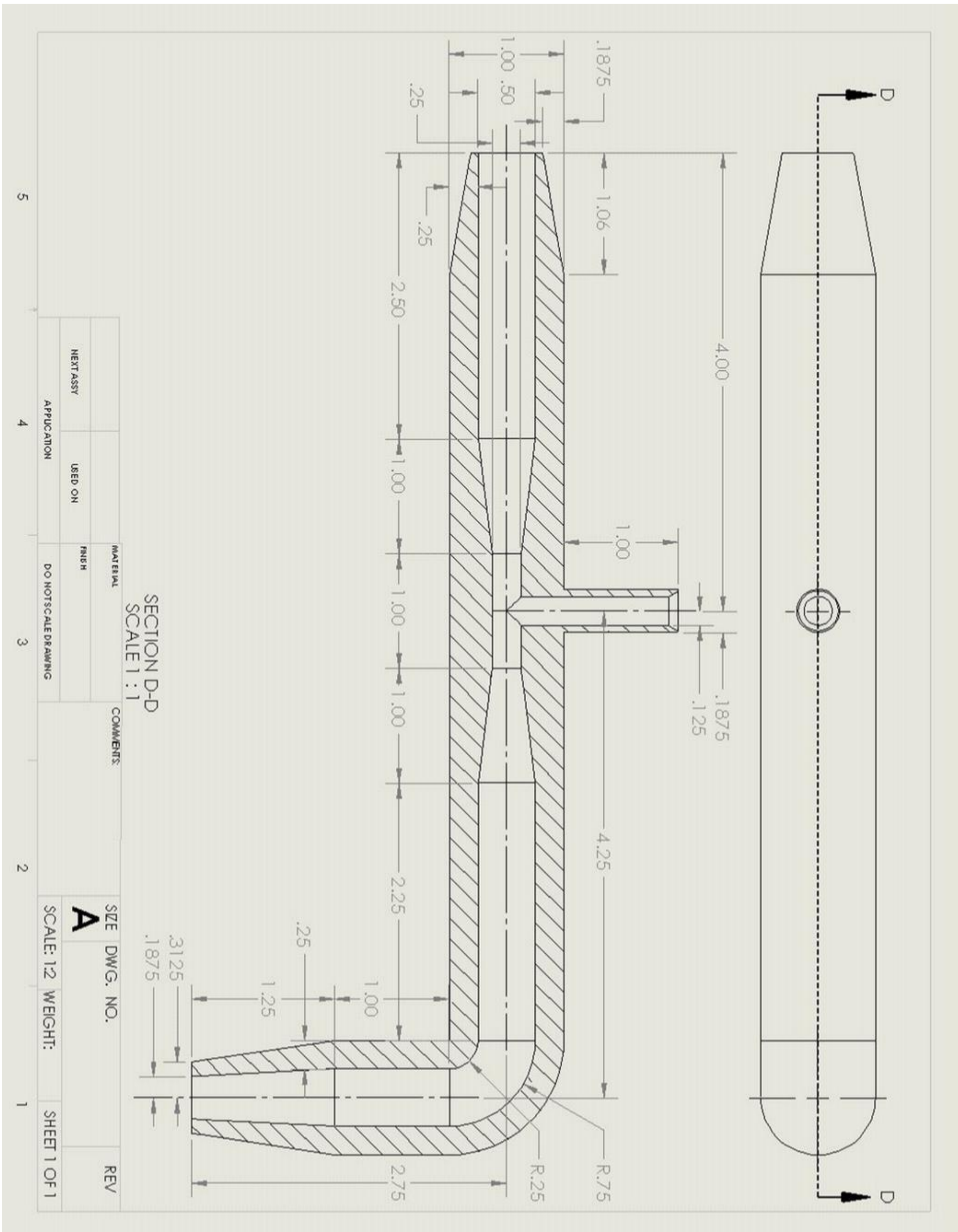
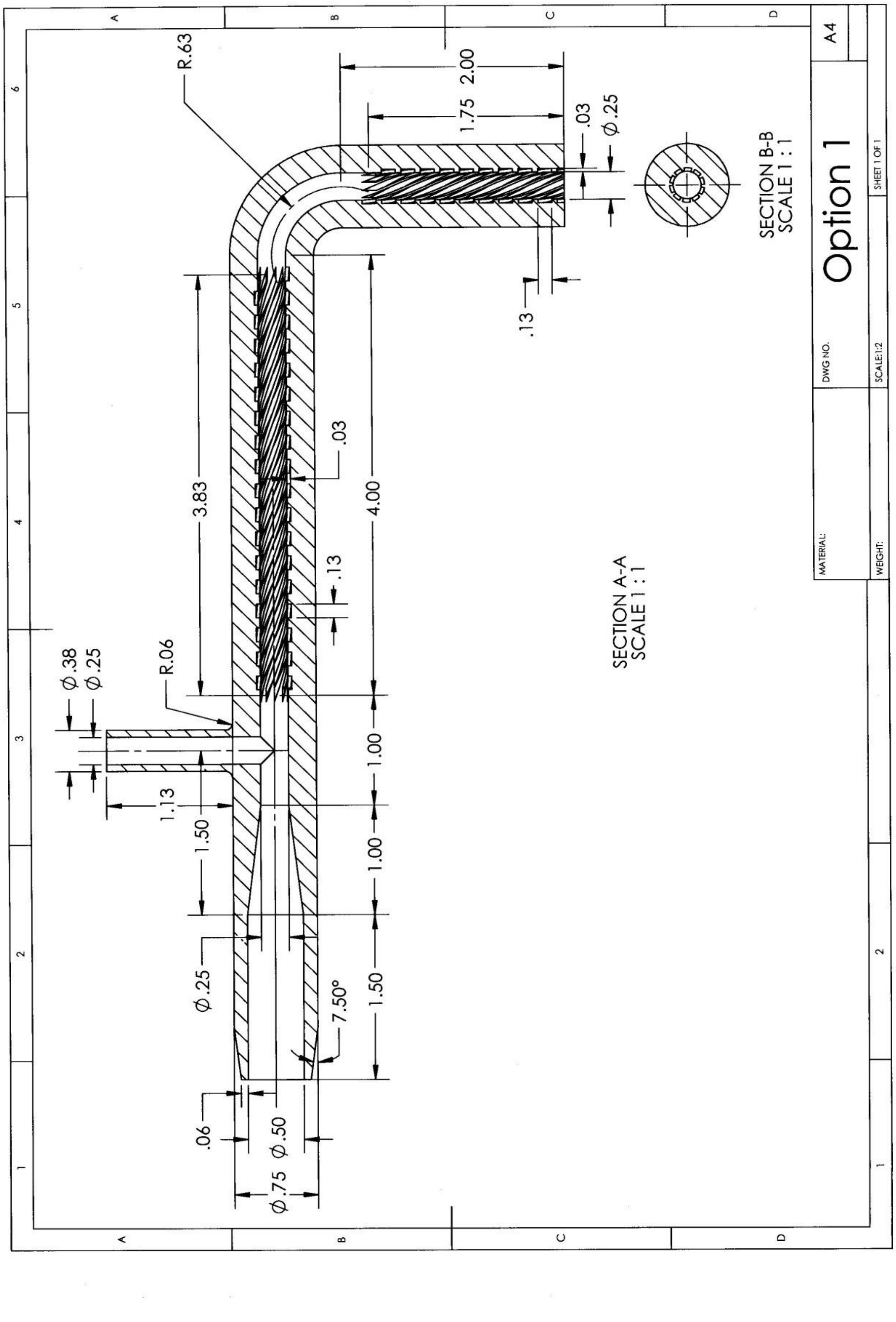


Figure 44:Concentrate Viscosity vs. Spindle Speed for spindle 2 at 13°C.

Appendix H: Engineering Drawing for Final Venturi

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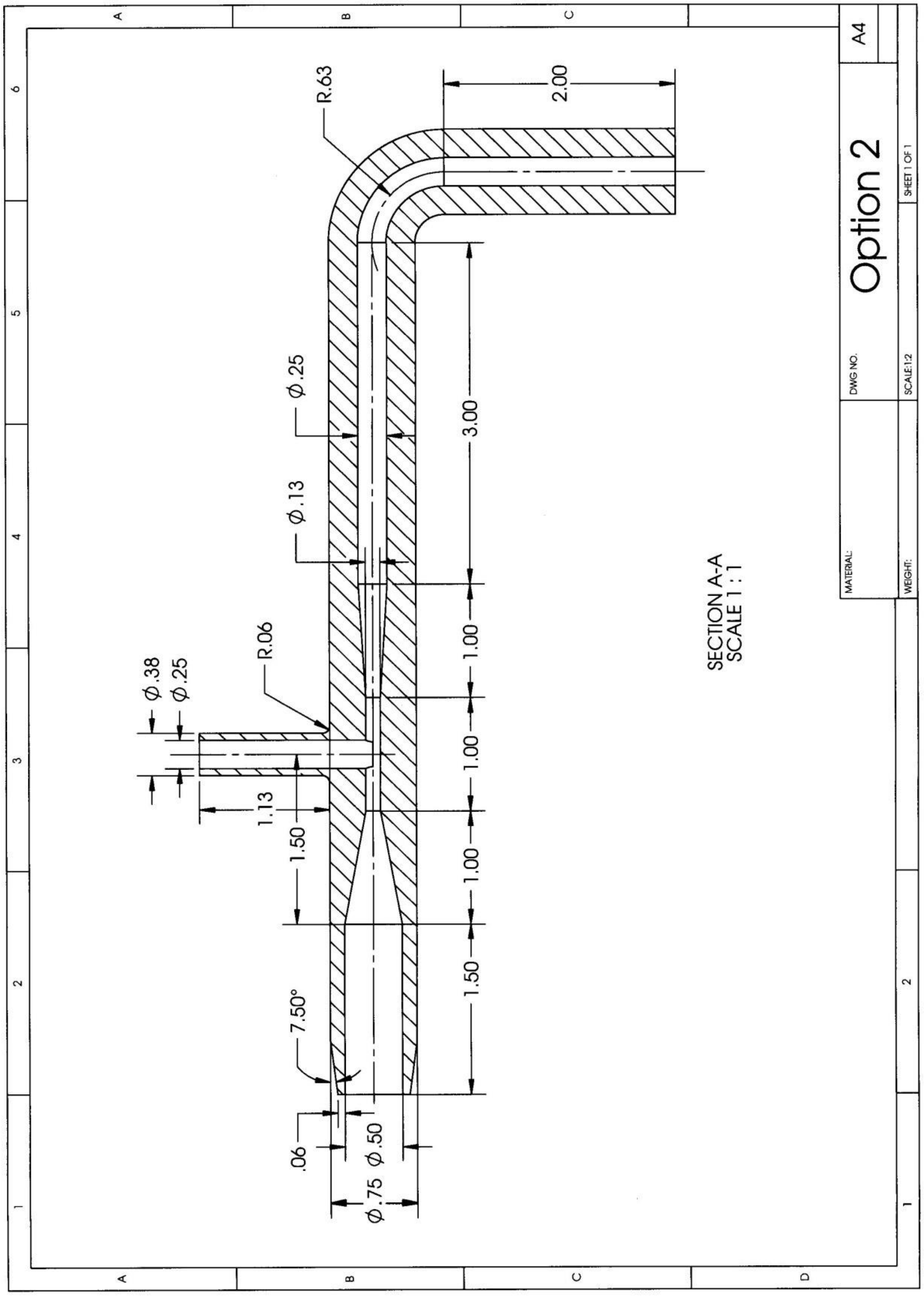
SECTION B-B
SCALE 1 : 1
Option 1
A4
DWG NO.
MATERIAL:
WEIGHT:
SCALE:1:2
SHEET 1 OF 1
R.63
R.06
2.00
1.75
.03
Ø.25
.13
3.83
4.00
1.00
1.50
1.13
Ø.38
Ø.25
7.50°
.06
Ø.50
Ø.75


SECTION A-A
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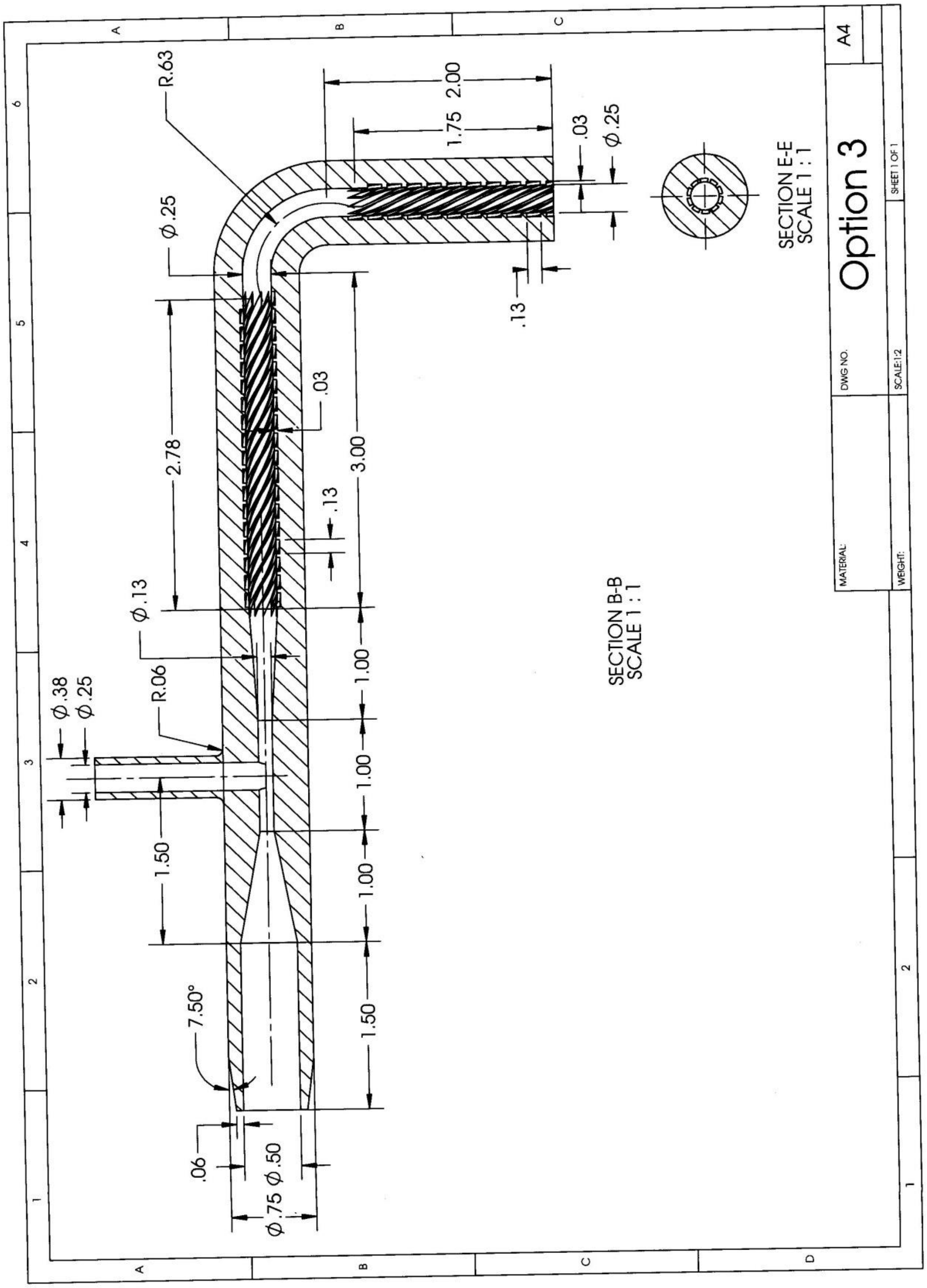
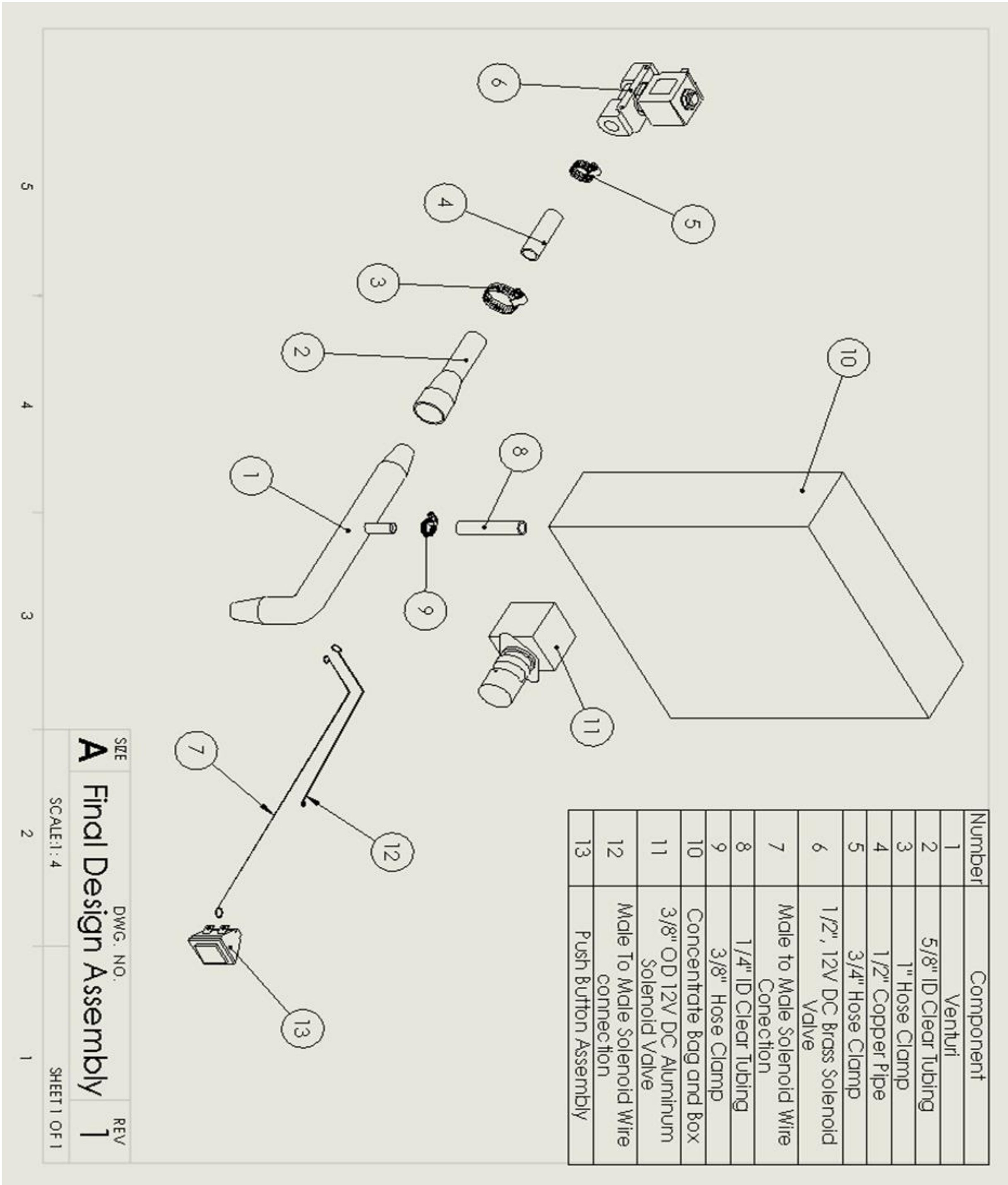
R.63
2.00
3.00
Ø.25
Ø.13
R.06
Ø.38
Ø.25
1.13
1.50
1.00
1.00
1.00
1.50
7.50°
.06
Ø.50
Ø.75
MATERIAL:
WEIGHT:
DWG NO.
SCALE:1:2
Option 2
SHEET 1 OF 1
A4



SECTION B-B
SCALE 1 : 1
SECTION E-E
SCALE 1 : 1
Option 3
A4
DWG NO.
MATERIAL:
WEIGHT:
SCALE:1:2
SHEET 1 OF 1
R.63
2.00
1.75
.03
Ø.25
.13
2.78
3.00
Ø.13
R.06
Ø.38
1.50
1.00
7.50°
.06
Ø.75
Ø.50

Appendix I: Assembly of Prototype



Appendix J: DVPR

ME428 DVP&R Format

Report Date		Sponsor							Component/Assembly		REPORTING ENGINEER:		
TEST PLAN										**TEST REPORT**			
Item No	Specification or Clause Reference	Test Description	Acceptance Criteria	Test Responsibility	Test Stage	SAMPLES		TIMING		TEST RESULTS			NOTES
						Quantity	Type	Start date	Finish date	Test Result	Quantity Pass	Quantity Fail	
1	Sugar Levels	Place a drop of juice on the daylight plane and read the Brix level through the eyepiece	±0.8%	AJ	DV	6	B	5/22/2015	5/26/2015		X	X	First iteration was able to reach Brix, second iterations were not
2	Water Flow Rate	Hook the water line up to a flow meter and measure the volumetric flow rate and adjust until the desired flow rate is obtained	±10%	JESUS	DV	6	B	5/14/2015	5/18/2015	2.4 oz/s	X		Flow Meter
3	Juice Flow Rate	Hook the concentrate line up to a flow meter and measure the volumetric flow rate and adjust until the desired flow rate is obtained	±10%	DANIELLE	DV	6	B	5/19/2015	5/21/2015			X	Not a value that could be calculated, meter did not fit
4	Electricity Use	Attach a voltmeter to the electrical circuit to record the values of the current and voltage of the system to determine the power recquirement	1.8KW Max.	AJ	DV	2	B	4/30/2015	5/9/2015	1.036	X		36 Watts were required for the valves
5	Size of Unit	Measure the final volume that the system will require	$10ft^3$	JESUS	PV	1	C	4/20/2015	5/11/2015	$3.55\ ft^3$	X		
6	Cost of the Unit	Record each components value and determine the final cost of the system	$1,000	DANIELLE	DV	1	B	5/11/2015	5/11/2015	$1,242.77		X	Mr. Brookner is ok with this value
7	Life of Valves	Hook up a new bag of concentrate to the system and test the integrity of the valves by draining the entire bag	Last for one bag of concentrate	AJ	DV	1	B	4/29/2015	5/1/2015		X		
8	Material	Research and use materials that are listed on the FDA/NSF Approved materials list	Meets FDA/NSF standards	JESUS	PV	1	C	4/20/2015	4/20/2015			X	For testing purposes FDA/NSF materials weren't used, but in recommended materials found
9	Pumps	Visual inspect that there are no pumps that have been integrated into the system	No Pumps	DANIELLE	DV	1	B	4/20/2015	4/20/2015	No Pumps	X		
10	Electronics	Count the number of valves, controllers and push buttons that are incorporated into the system	3 Components	AJ	DV	1	B	4/20/2015	5/9/2015	3	X		2 valves, 1 button

Appendix K: FMEA

Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Crit	Recommended Action(s)	Responsibility & Target Completion Date	Actions Taken	Sev	Occur	Crit
Too much water in the juice	Brix level will be lower than the target value, juice will be a bland taste	3	The water delivery valve is open too much	4	12	Adjust the valve until desired flow rate is achieved	5/14/2015 (J)	Close the valve	3	1	3
			Concentrate valve could possibly be closed	4	12	Physically inspect that the valve is functioning properly	5/14/15 (J)	Check for pinching	3	1	3
			The concentrate tube contains a blockage	1	3	Not critical enough for action					
			Too much pressure in the water line	1	3	Not critical enough for action					
			Venturi/Jet Pump has incorrect geometry	1	3	Not critical enough for action					
Not enough water in the juice	Brix level will be lower than the target value, juice will be too sweet	3	The water delivery valve is not open enough	4	12	Adjust the valve until desired flow rate is achieved	5/14/2015 (J)	Open the valve	3	1	3
			There is a blockage within the water line	1	3	Not critical enough for action					
			Loss of water pressure	4	12	Adjust the pressure regulator to achieve the correct water line pressure unless an exterior problem	5/14/2015 (J)	Adjust the valve and see if pressure changes	3	1	3
			Venturi/Jet Pump has incorrect geometry	1	3	Not critical enough for action					
			There is a blockage within the water line	1	3	Not critical enough for action					

Too much concentrate in the juice	Brix level will be higher than the target value, juice will be too sweet	3	The water valve is closed	4	12	Visually inspect that the solenoid is functioning properly	5/14/2015 (J)	Check for activation noise	3	1	3
			There is a loss in water pressure	4	12	Adjust the pressure regulator to achieve the correct water line	5/14/2015 (J)	Adjust the valve and see if pressure changes	3	1	3
			Venturi/Jet Pump has incorrect geometry	1	3	Not critical enough for action					
Not enough concentrate in the juice	Brix level will be higher than the target value, juice will be a bland taste	3	The concentrate delivery valve is not open enough	4	12	Reprogram the Arduino to achieve the desired flow rate	5/14/2015 (A)	Check for pinching and replace if needed	3	1	3
			There is a blockage in the concentrate line	1	3	Not critical enough for action					
			The water pressure has increased	1	3	Not critical enough for action					
			The water delivery valve is open too much	4	12	Adjust the valve until desired flow rate is achieved	5/14/2015 (J)	Close the valve	3	1	3
			Venturi/Jet Pump has incorrect geometry	1	3	Not critical enough for action					
Juice is not mixed properly even with the correct water to concentrate ratio	The juice will have an incorrect consistency	5	Improper geometry of the Venturi/Jet Pump	1	5	Not critical enough for action					
			Improper geometry of George (dispensing tubing)	1	5	Not critical enough for action					
Too much water in the juice	The mixing of the juice will be affected	1	The solenoid valve is set incorrectly	4	4	Not critical enough for action					
			The controller is set incorrectly	1	1	Not critical enough for action					
			The pressure is too high before the solenoid valve	1	1	Not critical enough for action					

Not enough water in the juice	The mixing of the juice will be affected	1	The delivery valve is set incorrectly	4	4	Not critical enough for action					
			The controller is set incorrectly	4	4	Not critical enough for action					
			The pressure is too low before the solenoid valve	4	4	Not critical enough for action					
Leakage occurs where the water line meets the valve	The system loses water, pressure, flow rate, and makes a mess	9	The pressure regulator is malfunctioning	1	9	Not critical enough for action					
			Improper fitting between the water line and valve	4	36	Verify that the installation was done correctly	5/14/2015 (D)	Adjust clamps, replace if needed	9	1	9
Too much concentrate in the juice	The mixing of the juice will be affected	1	The delivery valve is set incorrectly	4	4	Not critical enough for action					
			The controller is set incorrectly	1	1	Not critical enough for action					
			The pressure differential in the throat of the Venturi/Jet Pump is	1	1	Not critical enough for action					
Not enough concentrate in the juice	The mixing of the juice will be affected	1	The delivery valve is set incorrectly	4	4	Not critical enough for action					
			The controller is set incorrectly	1	1	Not critical enough for action					
			The pressure differential in the throat of the Venturi/Jet Pump is	4	4	Not critical enough for action					
Leakage occurs where the concentrate line meets the Venturi/Jet Pump	The system loses concentrate, pressure, flow rate, and makes a mess	9	Improper fitting between the concentrate line and the Venturi/Jet	4	36	Verify that the installation was done correctly	5/14/2015 (D)	Adjust tube	1	9	
			The hose clamp is not secure	6	54	Ensure the fitting is tight enough	5/14/2015 (D)	Tighten clamp	4	36	
			Tubing connecting the concentrate bag to the venturi has to big of an inner diameter	4	36	Ensure that the correct part was ordered for installation	5/14/2015 (D)	Verify the part	1	9	

Leakage occurs where the actuator punctures the concentrate line	The system loses concentrate, pressure, flow rate, and makes a mess	9	Improper sizing of the actuator	1	9	Not critical enough for action				
The aparatus does not dispense the juice	The user doesn't receive any juice	6	Short within the circuit	4	24	Perform a current test with the use of a voltmeter	5/14/2015 (A)	Check circuit for short	1	6
			Machine could be unplugged	2	12	Plug in machine	5/14/2015 (A)	Check if machine is plugged in	1	6
			Off-mode	4	24	Verify that the power switch is on	5/14/2015 (A)	No power switch, push button was	1	6
			Controller or push button malfunction	4	24	Verify connections and current supply	5/14/2015 (A)	Replace button	1	6
			Gearge is clogged	1	6	Not critical enough for action				
The aparatus does not stop dispensing the juice	Requires clean up due to making a mess, causes safety hazards	9	Push button could get stuck	1	9	Not critical enough for action				
			Either valves could be stuck open	4	36	Conduct preventitive maintanance	5/14/2015 (J)	Check if valve is open and pinch off if concentrate or shut ball valve	2	18
			Circuit/controller malfunction	4	36	Verify connections and current supply	5/14/2015 (A)	Check circuit for short	2	18
The outlet is spraying juice	Requires clean up due to making a mess, causes safety hazards	9	The nozzle has been broken off	1	9	Not critical enough for action				
			The nozzle contains a crack	1	9	Not critical enough for action				
Juice dispensed does not correspond to the desired juice	The user recieves the undesired juice	1	Label is incorrect	4	4	Not critical enough for action				
			Incorrect concentrate bag is	1	1	Not critical enough for action				
			The controller circuit is wired	4	4	Not critical enough for action				

Appendix L: Safety Checklist

Table 24: Potential hazards and their corresponding potential solutions.

Description of Hazard	Corrective Actions to Be Taken	Planned Completion Date	Actual Completion Date
Tipping	Warning Sticker	5/11/14	TBD
Electric Hazard	Ground the machine Cover exposed wires All electronics within unit	5/11/14	TBD
Slippage	Prevent as much leakage as possible Have a drip tray to catch any leakage or overflow	5/11/14	TBD

Appendix M: Testing Results

Table 25: Testing Results of Iteration 1

Time (s)	Volume (ml)	Volume (fl oz)	Flowrate (floz/s)	Brix before mixing	Brix after mixing
3.19	112	3.79	1.2	4.2	4.2
5.23	149	5.04	1.0	3.0	3.0
4.49	138	4.67	1.0	2.6	2.6
5.19	159	5.38	1.0	3.6	3.6
5.04	140	4.73	0.9	2.8	2.8
4.18	135	4.56	1.1	3.0	3.0

Table 26: Testing Results of Iteration 3

Time (s)	Volume (ml)	Volume (fl oz)	Flowrate (floz/s)	Brix before mixing	Brix after mixing
2.07	151	5.1	2.5	4.2	4.0
2.33	154	5.2	2.2	1.6	1.6
1.86	138	4.7	2.5	3.2	3.2
2.35	155	5.2	2.2	4.0	4.0
1.99	136	4.6	2.3	3.2	3.2
2.34	157	5.3	2.3	3.8	3.8
2.67	191	6.5	2.4	4.8	4.8
5.56	172	5.8	1.0	5.0	5.0
3.27	137	4.6	1.4	4.8	4.8
3.8	141	4.8	1.3	4.2	4.2
4.01	144	4.9	1.2	4.2	4.4

Appendix N: Manufacturer's Manual

Purpose

To provide a step-by-step walkthrough for a safe setup, assembly and operation of the Mechanical Juice Dispenser Testing System.

Responsibility

Assemblers are responsible for complying with all the specifics and requirements of this procedure.

Health, Safety, and Environmental Precautions

Potential hazards include the possibility of pinch points created when connecting equipment together and sharp edges of specific tools and cut material.

It is required that all male ends of pipe fittings to be coated with Teflon in order to ensure a water tight system and to prevent a potential slipping hazard during operation.

When modifying the integrity of the refrigerator walls, remove the outer plastic lining to locate the internal piping and cooling equipment so as not to puncture/damage the equipment or inflict harm upon oneself.

Required Parts/Special Materials

Part Name	Qty	Figure
1/2 in. Brass Push-to-Connect x Female Pipe Thread Adapter	2	
1/2 in. Brass Push-to-Connect x Male Pipe Thread Adapter	5	
1/2 in. Brass Push-to-Connect Tee	2	
1/2 in. Brass Push-to-Connect 90-Degree Elbow	3	
1/2 in. Brass Push-to-Connect Coupling	1	
1/2 in. x 3/8 in. Brass MIP x FIP Hex Bushing	2	
1/2 in. x 1/4 in. Lead-Free Brass FPT x FPT Coupling	2	

1/4 in. Lead-Free Brass Pipe Nipple	2	
1/2 in. Brass Push-to-Connect x Female Pipe Thread Ball Valve	1	
1 in. O.D. x 3/4 in. I.D. x 10 ft. PVC Clear Tubing	1	
1/2-1-1/4 in. Hose Repair Clamp	2	
2 in. x 4 in. x 8 ft. Premium Standard & Better Douglas Fir Lumber	1	
1/2 in. x 10 ft. Copper Type M Copper	1	
1/2 in. ID x 20 ft. Copper Soft Type L Coil (5/8 in. OD)	2	
1/2 in. x 520 in. Thread Seal Tape	1	

#8 2-1/2 in. Philips Square Flat-Head Multi-Material Screws (20-per Pack)	1	

Tools: Junior tube cutter, 1/2 in. disconnect clip, power drill, crescent wrench, power saw, and a ratchet socket set.

Procedure

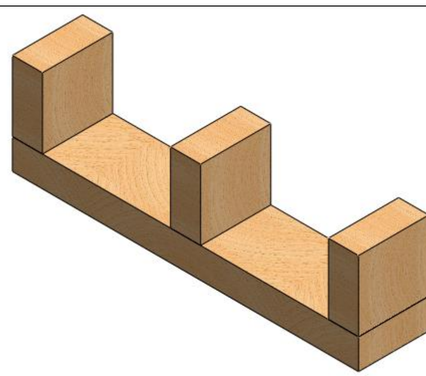
Venturi Support Base

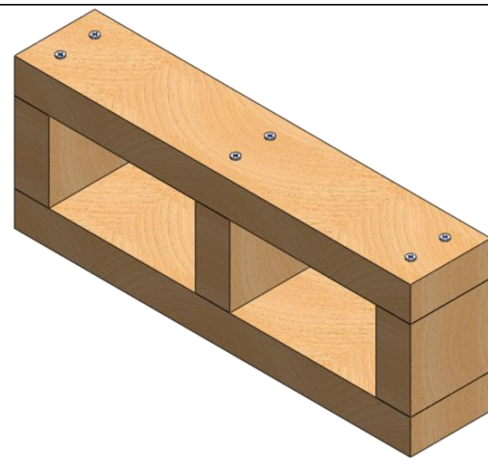
Step 1: Take the 2x4 eight foot beam and cut it to lengths listed in the table below.

Table 27: Venturi support base part dimensions.

Dimensions, in	Quantity
2x4x17.25	2
2x4x3.5	3

Step 2: Assemble the Venturi Support Base.

Evenly space the three shorter length planks along one of two longer planks with the cut faces of the shorter length planks coincident with the top face of the long plank.	

Attach the planks in their respective places by using 2 wood screws for each.	
Attach the remaining long plank to the top faces of the three shorter planks with 2 wood screws each.	

Concentrate Support Base

Step 1: Take the remaining length of the 2x4 eight foot beam and cut it to lengths listed in the table below.

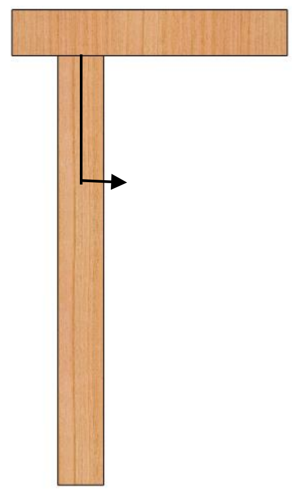
Table 28: Concentrate support base part dimensions.

Dimensions, in	Quantity
2x4x14	1
2x4x9	1
2x4x7.75	1

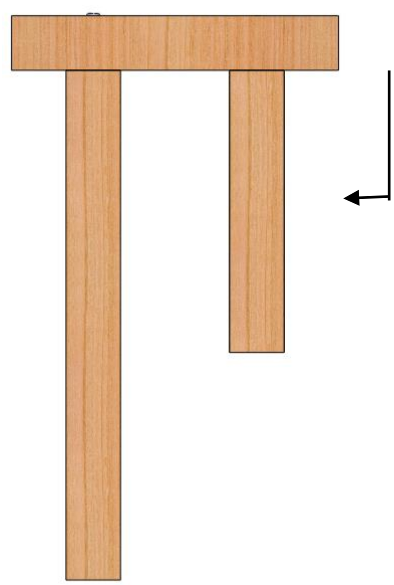
Step 2: From the plywood sheet, cut a 9x6 sized piece.

Step 3: Assemble the Concentrate Support Base.

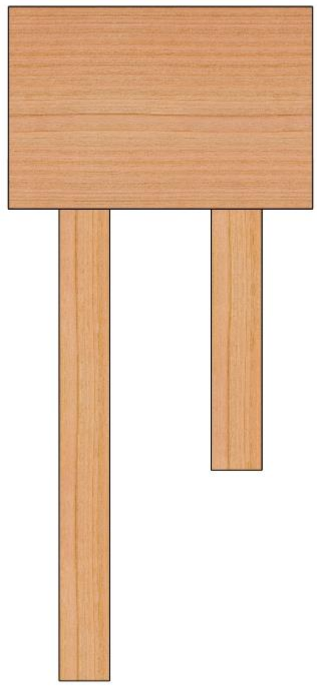
Align the 14” plank so that the front face is 1.5” to the right of the front face of the 9” plank. Attach together with 2 wood screws.



Align the 7.75” plank so that the back face is 1.5” to the left of the back face of the 9” plank. Attach together with 2 wood screws.



Align the 9x6 plywood piece to the 9" plank so that both front, back, and bottom faces are aligned. Attach together with 3 wood screws.



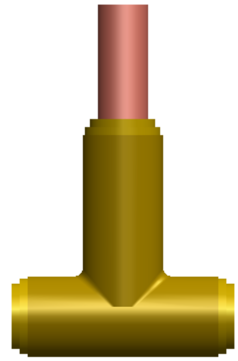
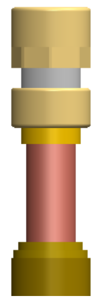
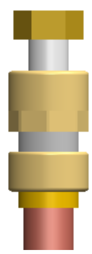
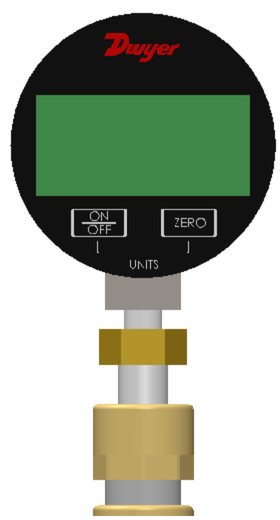
Top Fridge Assembly

Step 1: Cut the copper tubing to the specific lengths listed in the table below.

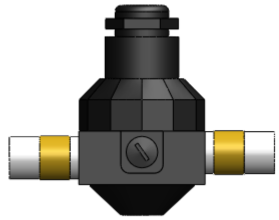
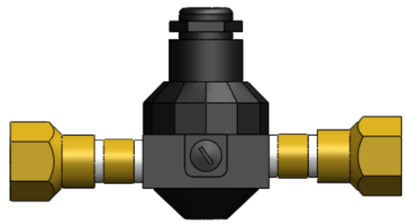
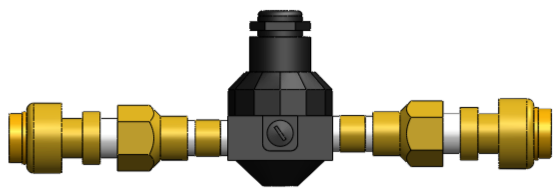
Table 29: Fridge top assembly cut to length copper tubing parts.

Length, in	Quantity
2.0	2
10.25	1
3.0	1

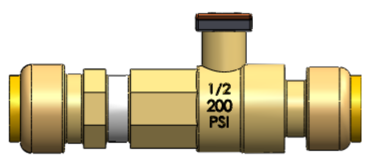
Step 2: Assemble the Dwyer Attachment.

Grab a ½" brass push-to-connect tee and connect 1 of the 2" long copper pipe to the vertical outlet	
Connect the sharkbite side of a ½" push-to-connect female pipe thread adapter to the 2" long copper pipe.	
Connect a 1/2"x3/8" brass hex bushing to the ½" push-to-connect female pipe thread adapter.	
Connect the Dwyer pressure gauge to the 1/2"x 3/8" brass hex bushing.	

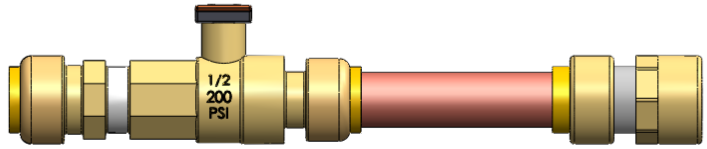
Step 3: Assemble the Pressure Gauge attachment.

Grab the plastic pressure regulator and screw in a ¼" brass pipe nipple into each port.	
Attach a ½"x ¼" brass coupler to each ¼" brass pipe nipple.	
Attach a ½" brass push-to-connect male pipe thread adapter to each ½"x ¼" brass coupler.	

Step 4: Assemble the Ball Valve attachment.

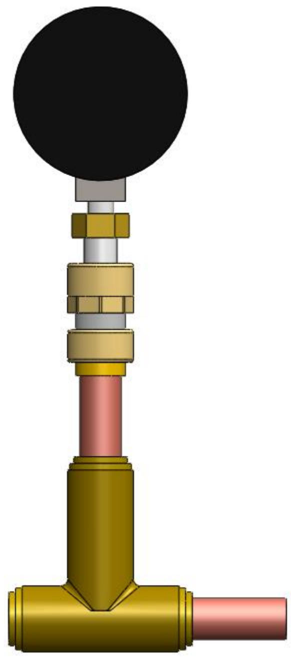
Grab the ½" brass push-to-connect female pipe thread ball valve and attach a ½" brass push-to-connect male pipe thread adapter.	
Attach a 3" long copper pipe to the sharkbite side of the ½" brass push-to-connect female pipe thread ball valve.	

Connect the sharkbite side of a ½” push-to-connect female pipe thread adapter to the 3” long copper pipe.

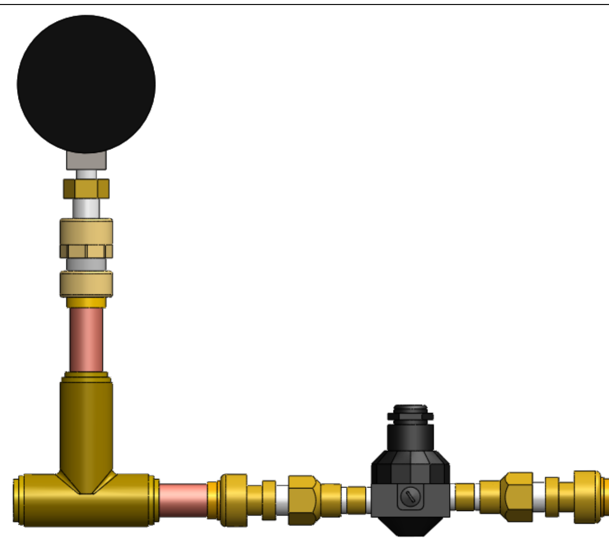


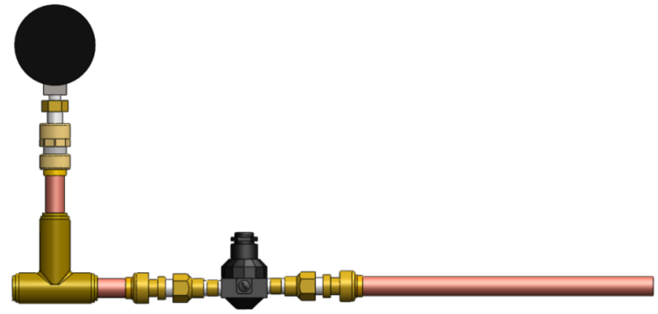
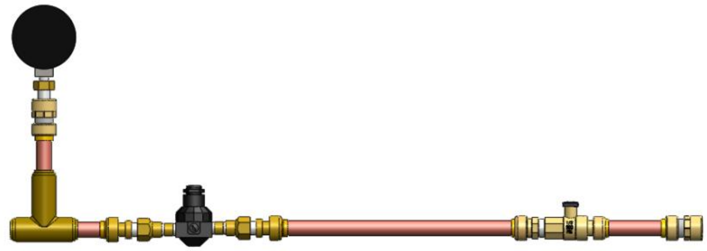
Step 5: Build the complete Top Fridge assembly.

Connect the remaining 2” long copper pipe to the ½” brass push-to-connect tee right hand port of the Dwyer Attachment assembly.



Connect the Pressure Gauge attachment assembly to the open end of the 2” long copper pipe.



Connect the 10.25" long copper pipe to the right end of the Pressure Gauge attachment assembly.	
Connect the Ball Valve attachment assembly to the open end of the 10.25" long copper pipe.	

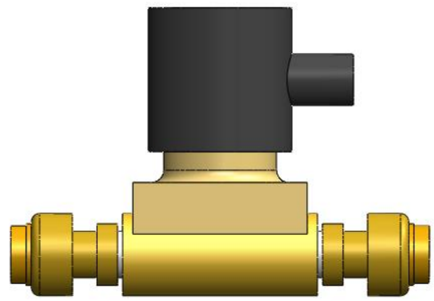
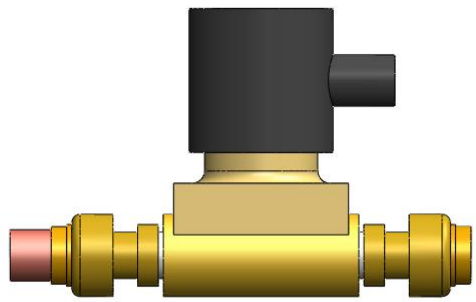
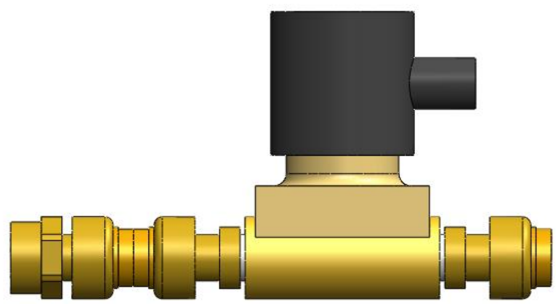
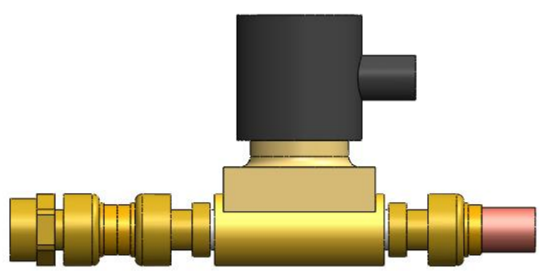
Venturi Connection Assembly

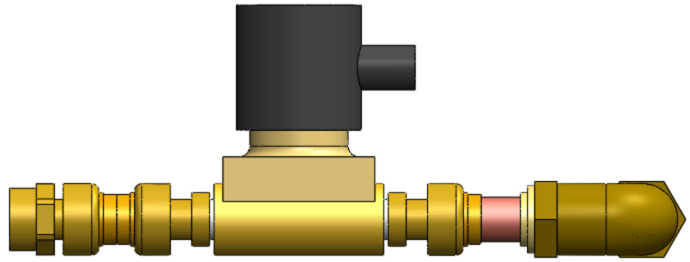
Step 1: Cut the copper tubing to the specific lengths listed in the table below.

Length, in	Quantity
1.25	1
1.375	1
1.5	1
2.0	1
2.125	1
2.375	1

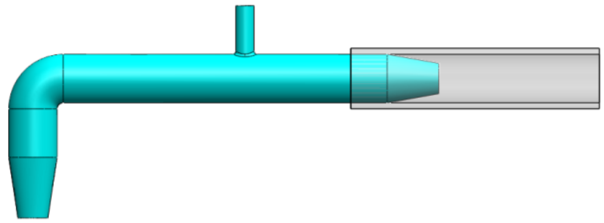
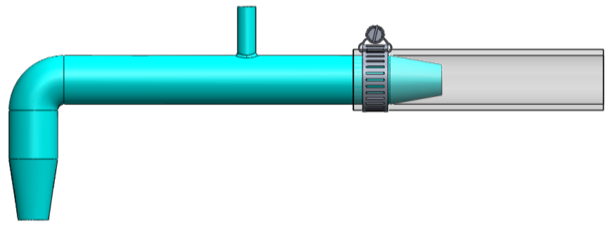
Step2: Cut the 1"OD x 3/4"ID clear tubing to a length of 5.25".

Step 3: Assemble the Solenoid Valve Attachment.

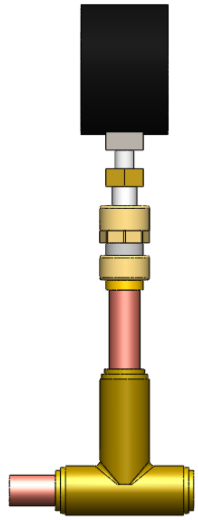
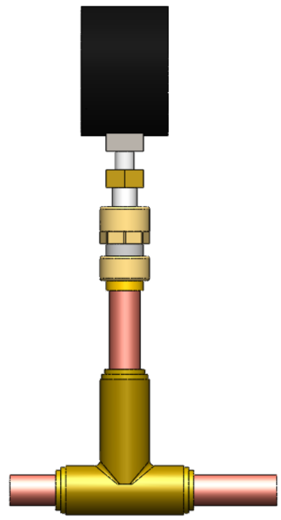
Grab the ½" electric brass solenoid valve and attach a ½" brass push-to-connect male pipe thread adapter to each side.	
Connect the 1.25" long copper pipe to the left ½" brass push-to-connect male pipe thread adapter.	
Connect a ½" brass push-to-connect female pipe thread adapter to the 1.25" long copper pipe.	
Connect a 1.5" long copper pipe to the right ½" brass push-to-connect male pipe thread adapter.	

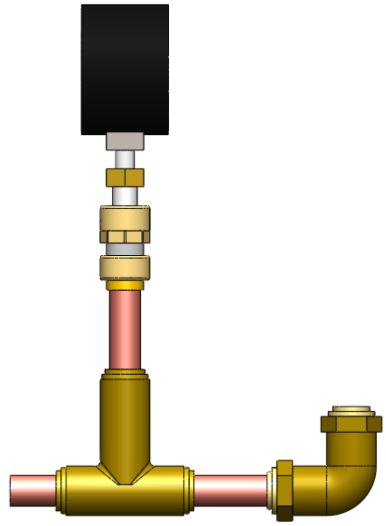
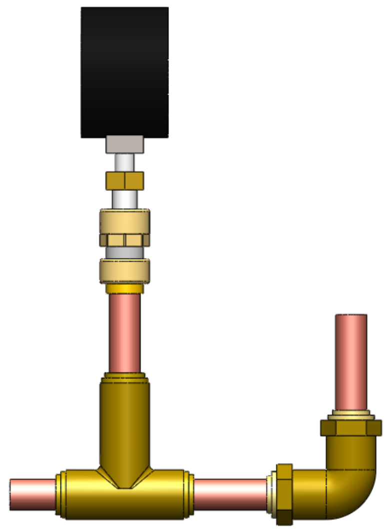
Connect a ½” brass push-to-connect 90-deg elbow to the 1.5” long copper pipe.	

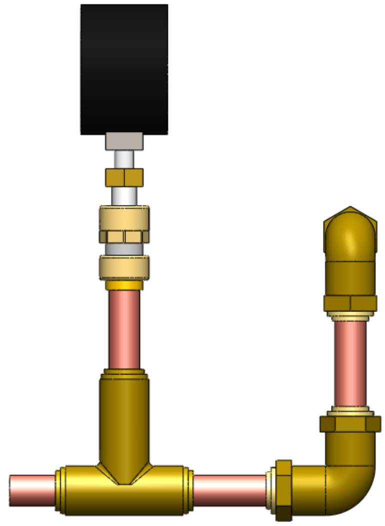
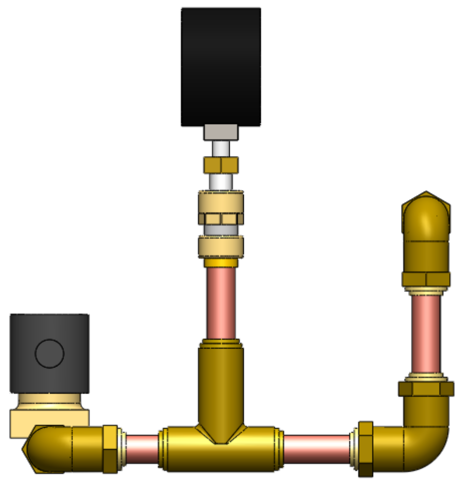
Step 4: Assemble the Venturi Attachment.

Grab the Venturi configuration you wish to use. Pull the 1”OD x 3/4”ID clear tubing over the water inlet side of the venture until about ¾” of the tube is past the chamfer.	
Attach and tighten down a ½”-1 ¼” hose repair clamp on the outside of the clear tubing until it is a snug fit.	

Step 5: Assemble the complete Piping Connection.

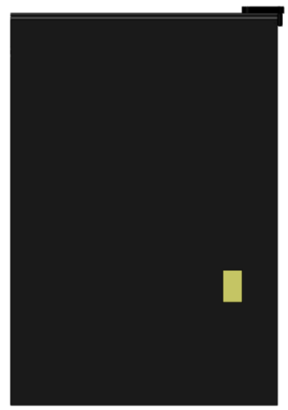
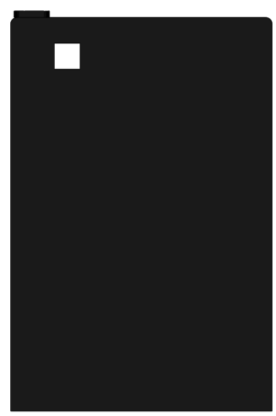
Replicate the Dwyer Attachment assembly discussed in the Top Fridge Assembly. After that, attach the 1.375" long copper pipe to the ½" brass push-to-connect tee left hand port.	
Connect the 2.125" long copper pipe to the ½" brass push-to-connect tee right hand port.	

Connect a ½” brass push-to-connect 90-deg elbow to the 2.125” long copper pipe.	
Connect the 2.375” long copper pipe to the ½” brass push-to-connect 90-deg elbow.	

Connect a ½” brass push-to-connect 90-deg elbow to the 2.375” long copper pipe.	
Connect the ½” brass push-to-connect 90-deg elbow of the Solenoid Valve Attachment assembly to the 1.375” long copper pipe.	

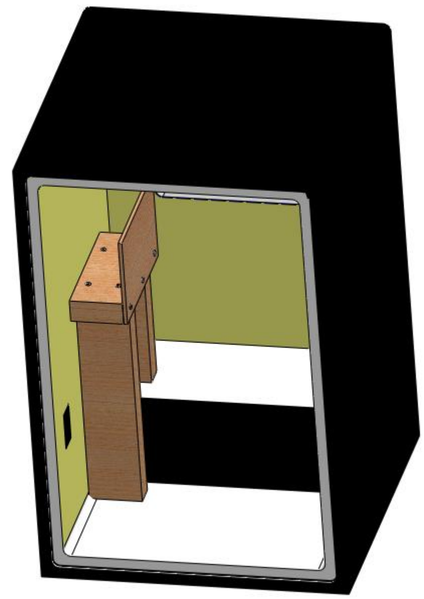
Inside the Fridge Assembly

Step 1: Cut the needed holes within the refrigerator.

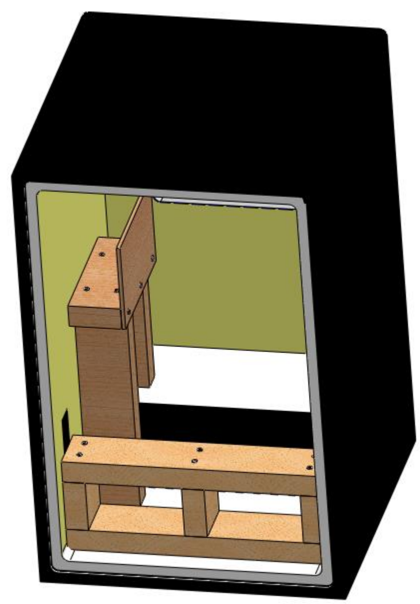
Cut a slot 2.5” tall and 1.5” wide into the left hand side of the refrigerator. The bottom of the slot should be 8” above the bottom of the refrigerator.	
Cut a square slot of 2” into the back of the refrigerator located 2” from the top and 3.375” from the left side of the refrigerator.	

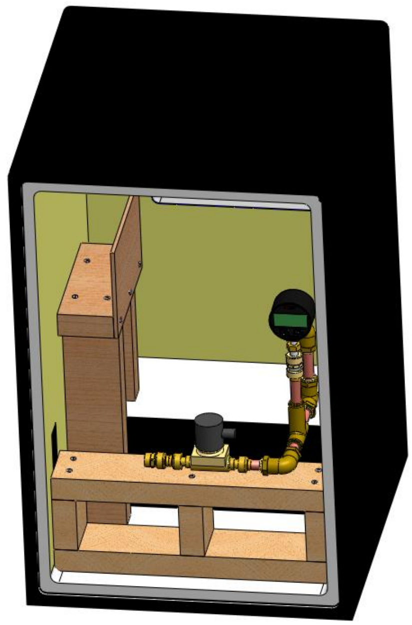
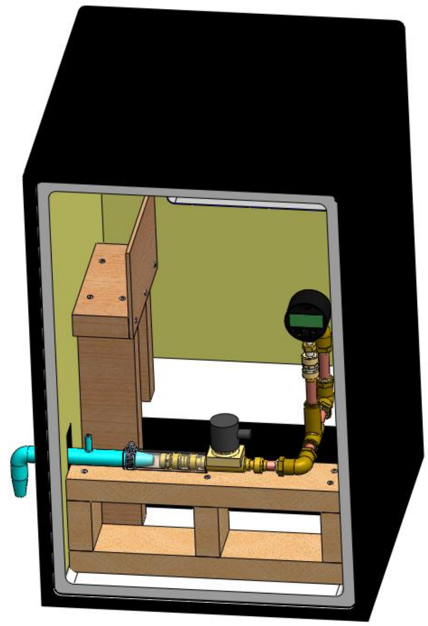
Step 2: Place the wood base supports and the Pipe Connection assembly into the fridge.

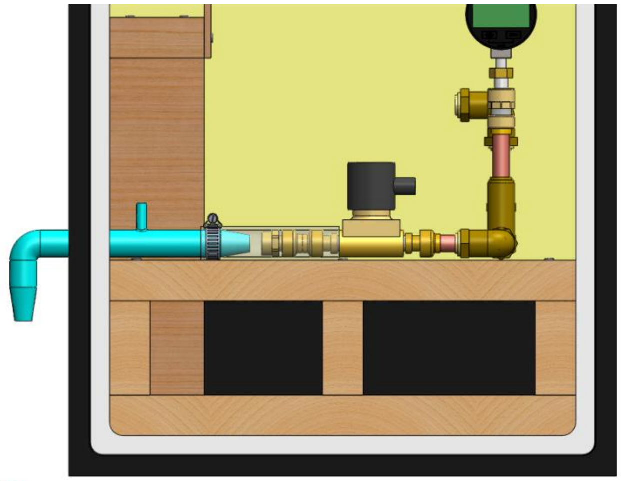
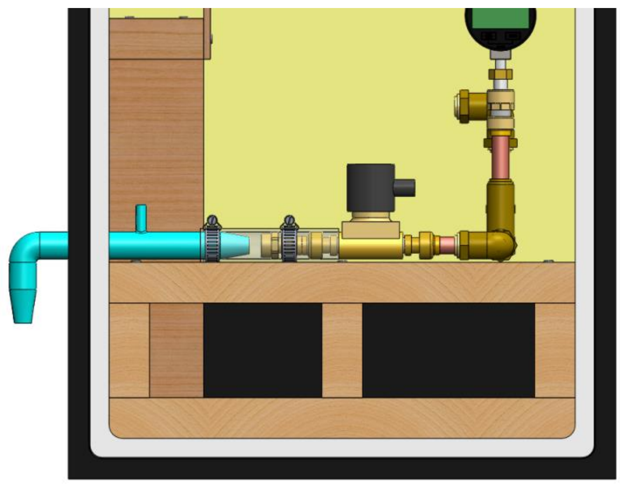
Place the Concentrate Support Base assembly into the refrigerator so that the front face of the 14"wood plank is 7.75" from the front of the refrigerator. Make sure the left hand side of the support base is flush with the left wall of the refrigerator.



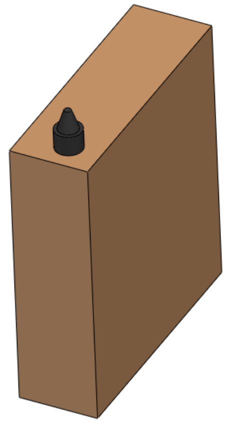
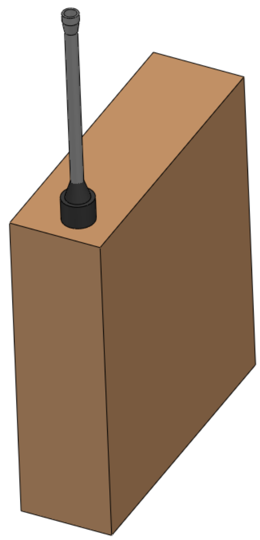
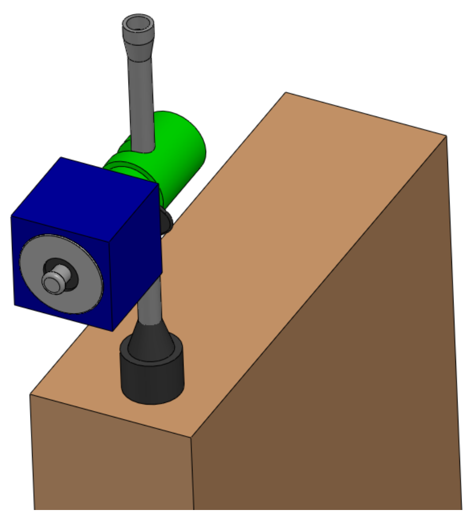
Place the Venturi Support Base assembly into the refrigerator so that it is centered on the slot located on the left wall of the refrigerator.



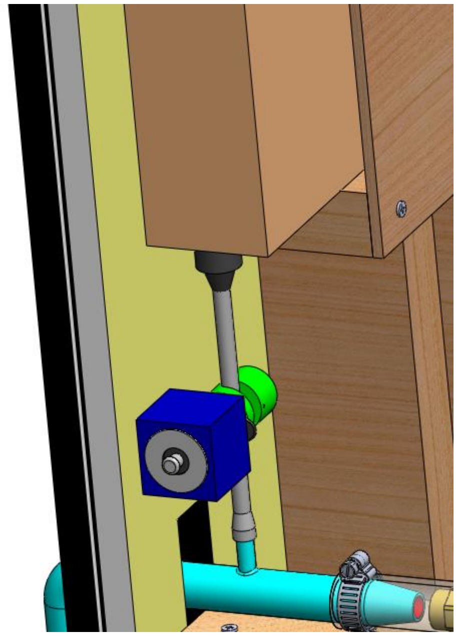
Place the Pipe Connection assembly into the refrigerator so that the ½” electric brass solenoid valve is centered along the venturi support base.	
Bring the Venturi Attachment assembly through the slot located in the left wall of the refrigerator.	

Pull the 1"OD x 3/4"ID clear tubing of the Venturi Attachment assembly over the left hand side of the Solenoid Valve Attachment assembly until the end of the clear tubing touches the solenoid valve.	
Attach and tighten down a ½"-1 ¼" hose repair clamp on the outside of the clear tubing until it is a snug fit.	

Step 3: Assemble the Concentrate Connection.

Turn the concentrate box upside down and place it on a flat surface.	
Connect the 3/8” OD food grade tubing to the nozzle of the concentrate bag. (Modifications to the outlet nozzle of the concentrate bag were needed to make this plausible).	
Attach the pinch valve to the 3/8” OD food grade tube in order to keep the concentrate from exiting.	

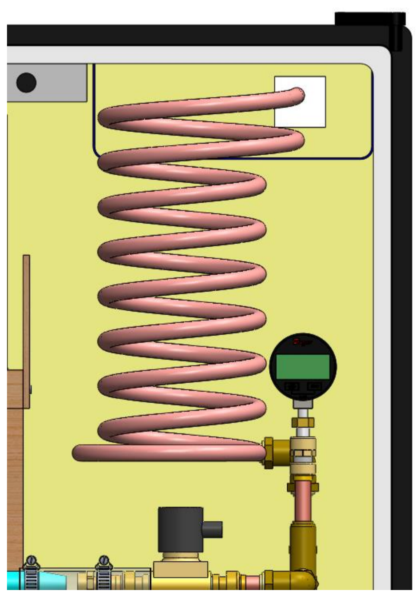
Pull the 3/8" OD food grade tube over the concentrate "tower" of the venturi. When the ¼" ID of the food grade tube is stretched over the concentrate "tower," it will be a snug enough fit so no additional components are needed.

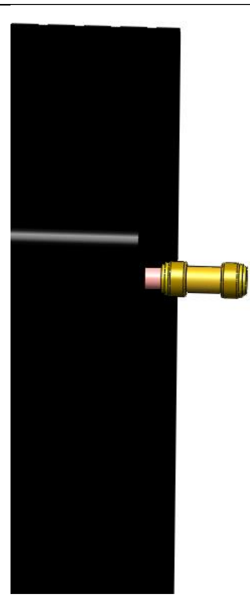
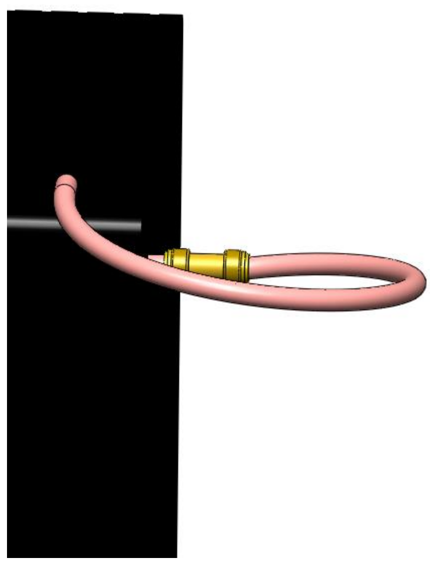


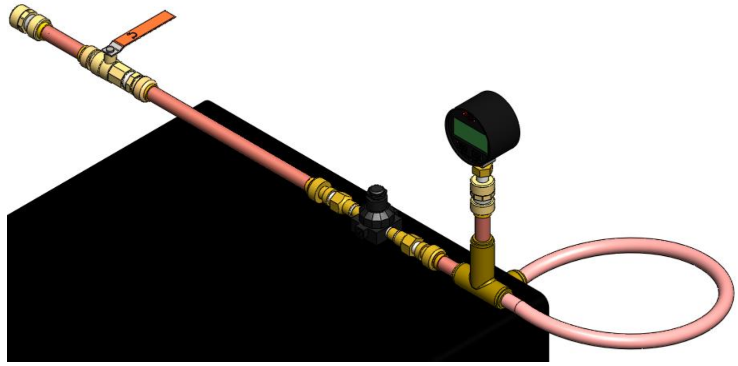
Outside the Fridge Assembly

Step 1: Attach the Top Fridge assembly.

Insert enough of the ½" ID copper coils into the refrigerator where the end exits out the slot located on the back wall. Connect the bottom of the coils to the ½" brass push-to-connect 90-deg elbow of the Piping Connection assembly.



Connect a ½” brass push-to-connect coupling to the ½” ID copper coils that exit the slot on the back wall of the refrigerator.	
Connect another set of ½” ID copper coils that reach above the top of the refrigerator.	

Attach the ½” brass push-to-connect tee of the Top Fridge assembly to the end of the ½” ID copper coil.	

Trouble-Shooting

Leaking during operation

-Occurs between fittings, check that Teflon was applied correctly to the male fitting.

-Occurs along the 1”OD x 3/4”ID clear tubing, check that the location of the 1/2-1-1/4 in. hose repair clamp is sitting upon a flat surface and is securely tightened.

Piping is moving during operation

-Occurs along the Venturi Support Base, add properly sized pipe clamps along the line and secure to the wooden base.

-Occurs along the copper coils, construct a support base and secure the coils to the support base with properly sized pipe clamps.

-Occurs along the Top Fridge assembly, add brackets to the outer lining of the refrigerator and attach the assembly.

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