2018

DEFENDER AUTOMATEDMEDIA FEEDER SYSTEM

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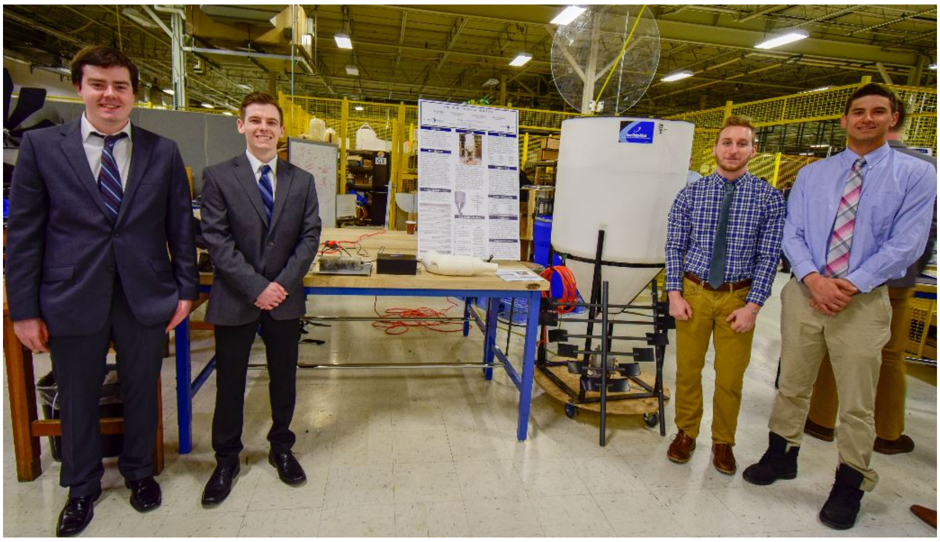
Capstone Final Design Report

DEFENDER AUTOMATED MEDIA FEEDER SYSTEM



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Abstract

Team Defender was tasked under the sponsorship of Neptune Benson to design a device capable of automating the transfer of their filtration media of choice, perlite, from the packaging into their varying Defender ®Regenerative Filtration system models. The current process used for this media transfer is time consuming, inefficient, labor intensive, and leads to overexposure to the perlite media.

There were a multitude of parameters that needed to be considered during the concept generation of this particular design in order to properly solve the task at hand. In addition to the aforementioned automation of the feed process and inherent compatibility with the existing Defender design, the product needed to be cost efficient, compact, mobile, and have complimentary safety features. After consultation with the project sponsor, it was determined that the principal issue that would be encountered during the design process would be flow stagnation brought on by the jagged interlocked structure of perlite media.

Due to the properties of the perlite media, it was concluded that a mixer would be the most viable, and cost efficient solution as a primary option for ensuring continuous flow. In the first generation prototype, the team weighed the options for mixer designs, and led to the design of a mixer that used arms of various lengths to create a contact with the edge of the conical section of the hopper. This mixer was attached to a rotational motor that was fed through the outlet assembly and into the bottom of the container. After testing at the Neptune Benson facility, it was determined that this stir design was incomplete in its functionality, and that some sort of other contacts would have to be added to the arms in order to produce a viable design. The final design implemented a larger hopper with a steeper cone angle. The new mixer was also added to this design, which included extra rubber flanges to the ends of the stir arms for added contact points on the edge of the container. This setup was placed on a mobile rig, allowing for easy maneuverability. While the final redesign has not yet been field tested, the initial prototype design yielded extremely positive results for the team. While there were still stagnant zones along the edge of the container that created build up of perlite due to incomplete design of the stir; but the overall mass flow rate calculated during the field test was much better than initially anticipated during engineering analysis, as it was found to be 28.86 lb/min. Given on these results, this system is calculated to increase efficiency of the current process by over 500 percent. with the final redesign, a product can be produced that can appeal to consumers as a viable attachment to their Defender units.

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Nomenclature

A	Cross sectional area	(m^2)
B	Diameter of inlet	(m)
g	Gravitational acceleration constant	(m/s^2)
ρ	Material density	(lb/ft^3)
p	Static pressure	(psi)
u_0	Discharge rate through circular orifice	(ft^3/s)
Q	Volumetric flow rate	(ft^3/s)
m	flow constant for circular orifice	-
θ	Cone angle	(degrees)
C_1	Inlet conveying velocity	(m/s)
C_m	Minimum conveying velocity	(m/s)
m_a	mass flow rate	(kg/s)
d	pipeline diameter	(m)
T_1	Inlet temperature	(K)
R	Gas constant	(kJ/kg*K)
K_e	Loss Coefficient	-
V	Velocity	(m/s)
ω	Angular velocity	(rad/s)
f	Frequency of rotation	(rpm)

Acronyms

DMF Defender Media Feeder.

NTO National Tank Outlet.

OSHA Occupational Safety and Health Administration.

POC Proof of Concept.

PVC Polymerizing Vinyl Chloride.

QFD Quality Function Deployment.

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1. INTRODUCTION

Neptune Benson, a branch of the Evoqua Water Technologies, has been one of the most prestigious water filtration companies over the past six decades as they have been able to satisfy thousands of customers all over the world including over twenty-thousand installation in fifty states and forty-five countries. Neptune Benson offers a wide range of products including the award-winning Defender ®Regenerative Media filter and Legacy ™ sand filters as well as many others, each of which are designed for specific types of aquatic establishments ranging from local swimming pools and Olympic swimming pools to water parks and aquariums. With their experience and expertise as well as a wide variety of products Neptune Benson has been able to remain at the top of the water quality market as well as provide a safe and sufficient service for a variety of aquatic establishments. Neptune Benson has also been able to adapt and develop new water filtration and disinfectant products which has helped them retain their success in water quality.

One of the most iconic products from Neptune Benson is the Defender®regenerative media filter, which can be seen in figure 1. This product has been able to provide thousands of establishments with superior water quality while also being able to save water, energy and space as well as ensure safe, sustainable water treatment. Compared to other traditional water filtration systems which can be rather large and involve sand as the filtration media, the Defender system takes up approximately a quarter of the size of traditional systems and uses perlite to filter and disinfect the water. Perlite has the capability of filtering down to one micron, where as sand can only filter down to twenty to forty microns, and is a regenerative media which is a property that allows the substance to refresh itself when agitated, in this case 'bumped ', allowing it to be used in multiple times before it is rendered ineffective. The use of perlite helps eliminate backwash, meaning water is removed from the establishment less often, using ninety percent less water and fifty percent less energy than the traditional sand media, which in turn reduces the global water footprint. Although the Defender system is for the most part user friendly and capable of saving water, energy, space and is capable of removing more contaminants than traditional filters, there are some aspects of the system that remain unsolved and difficult for operators to handle. One of which is the loading process of new perlite media into the filtration system.

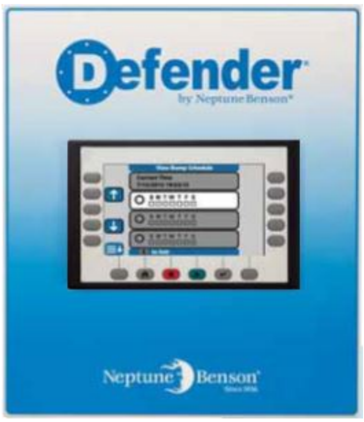
Figure 1: Defender ®Regenerative Media Filter Unit

Neptune Benson is always looking for ways to remain ahead of their competition which is why they are trying to automate the media loading process of Defender filtration system. Automating this process will allow operators to spend less time on the maintenance of the system while also reducing exposure to the perlite powder substance. The current process for loading a Defender system with new filtration media is done by manually vacuuming the substance by hand using a simple shop vac which is attached to the side of the Defender system and feeds directly to the inside of the system. The perlite is removed from its packaged paper bags and takes about five minutes per bag. The largest Defender system offered by Neptune Benson holds five bags of perlite meaning it would take twenty-five minutes for the operator to vacuum new media into the system; time that is wasted on a tedious process and could be spent doing something more important.

Neptune Benson reached out to the University of Rhode Island's mechanical engineering capstone group, Team Defender, to come up with a design and working prototype that is compatible with the current vacuum inlet system which they can utilize to automate the loading process of new perlite media into the Defender filtration system. The design must also be able to hold the maximum amount of perlite that is used in the largest defender system, approximately one-hundred gallons of media, and require little to no maintenance while remaining safe and easy to operate. Although this project was presented to a Capstone group in the previous year, known as the the Gods of Perlite, the team was unable to provide a finished product which Neptune Benson was satisfied with. For this reason the company came back to the University of Rhode Island to pursue a solution for their tedious, manual process.

In order for the team to fully understand the project at hand they were asked to research the filtration system as well as visit the Neptune Benson establishment in order to fully understand how the system works and what goals the company is trying to achieve. The team was able to see a full scale working model of a 33-48-732 Defender system, which holds two-hundred and fifty gallons of water, as well as each component of the system including the user interface, seen in figure 2, which is a 7 inch high resolution LCD control panel and includes simple push button operation which makes operation quick and easy, the inner flex tubes which the perlite sticks to in order to filter water and the vacuum inlet system which would be incorporated into the teams design. Team Defender was also able to observe the ‘bumping ’process that is done to regenerate the perlite media. Neptune Benson also provided a video to show the current process used to load the perlite media into the tank.

Figure 2: Defender ®User Interface



After the visit with Neptune Benson, Team Defender was asked to generate one hundred and twenty original design concepts that were both realistic and effective at completing the task at hand. Before generating these designs the team was also asked to perform a patent search on the project in order to assure that there would not be any form of copyright infringement, this process will be elaborated on later in the report as well. After coming up with one hundred and twenty original, unique designs, the group was then left with the difficult task to narrow down these designs to three realistic concepts that would be further investigated and reiterated. These three designs would then be presented to Neptune Benson as well as the other capstone groups where the team would receive comments and criticism on how they could critique and better their designs. After the team's second meeting with Neptune Benson, which involved analyzing the advantageous and disadvantageous of each of the three designs and eventually resulted in narrowing the teams focus down to one design which both Neptune Benson and Team Defender were comfortable with and one they thought would perform the job well.

The design chosen by team Defender and Neptune Benson, which will be elaborated on more later on in the report, involves a one-hundred and ten gallon-cone-bottom tank which will hold the perlite, a three inch ninety degree elbow which will be placed at the bottom of the tank and coupled with a three to two inch coupler which will provide a port for the Defender vacuum to attach to. The design will also include an auger motor which will be placed at the base of the stand attached to the tank and will be fed through the ninety degree elbow at the bottom of the tank. The motor will attach to a stirring mechanism which will be used to agitate the material and prevent buildup, and provide a continuous flow of media to the vacuum. Although this design is one that is sought after by both Neptune Benson and the team, there is still an immense amount of improvement and testing that must be done next semester in order to produce a final prototype that performs the process well.

2. Project Planning

The project plan was mapped out utilizing a Gantt Chart generated in the Microsoft Project software. Within the chart, all of the important meetings and project deadlines are detailed clearly and chronologically. Through the utilization of this chart, it was much easier to manage tasks between group members and complete them in a timely manner. The Gantt Chart used to map out the project plan is detailed in the appendices in Figures 74 and 75.

Additionally, weekly progress reports were documented every Monday in order to track the progress made by the team through every weekly period. This was helpful, as each report gave insight into where the progression of the project was, and more importantly, where it was headed in the next meeting period.

Team Defender was assigned with the design of an automated system for transferring new perlite media from its packaged paper bags to the existing Defender systems distributed by the corporation Neptune Benson. After each specific team member had applied and been chosen for this specific project, the team immediately got to work finding a viable solution for the problem at hand. To begin, the team looked into the specific problems that needed to be addressed when considering the optimal design of the project. The problem definition was broken up into four primary specifications; the design needed to be automated, mobile, safe, and address the major issue of flow stagnation. Based on the previous experience using perlite media, the Neptune Benson engineering team made it clear that the jagged structure of the perlite particles tended to build up very easily and halt the flow of the material through the particular orifice incorporated into the design.

With this knowledge, it was clear that some method of agitating the perlite would need to be incorporated in order to avoid this common issue involving flow of the media. Research then began by looking into existing patents that were designed to perform a similar function. Based on the patent search, it was found that there were a large number of patents that addressed this particular issue. The major areas in which designs of this nature were often found were in grain storage, brewing containers, and mixers dealing with fluids that were denser than water. These numerous relevant patents aided significantly in the premature stages of possible prototype concepts.

The concept generation process followed immediately after the completion of the thorough patent search. During this portion of project, the problem identification and subsequent design specifications had to be considered. Each member of the team was tasked with generating thirty design concepts that would present a viable solution to the problem. Each of these particular and unique designs had to be realistic solutions; leading to a wider range of possible designs than would of most likely been presented otherwise.

Once the one-hundred and twenty concepts were collectively pooled by each of the group members, it was realized that there were many common concepts that were prevalent in a vast majority of the designs. These commonalities were considered, and led to the narrowing down of these one-hundred and twenty concepts to three specific design ideas. Taking these designs, the team completed a Quality Function Deployment analysis to ensure that each of the designs met the proper specifications and addressed the project problem.

Moving forward with the design process, each of the three chosen designs were created using SolidWorks with adequate dimensions for real world usage; which were to be presented to the engineering team at Neptune Benson in order to assess their viability and receive constructive criticism to possibly improve these designs. However, due to a busy schedule for the team at Neptune Benson, the deadline for the Critical Design Review Presentation came up. During this time, the team instead met with Dr. Nassersharif for a review meeting, which resulted in beneficial feedback that allowed for better preparation for the upcoming presentation, which the sponsor would be attending. This presentation detailed the concept generation process, and demonstrated what the major problems were for the project, and how they were specifically being addressed. This was done in order to receive additional constructive criticism and some possible design solutions from both peers and Dr. Nassersharif. This presentation was the first real checkpoint in the design process, and really gave an idea of where the team was at this point in the semester.

After assessing the progress of the project following the Critical Design Review Presentation, the team decided on moving forward with one specific design out of the three designs that were originally narrowed down to. Given this one particular design, the team was able to approach a proof of concept. This process included research finding equations that would allow the team to complete relevant engineering analysis of the design. These equations will be shown in more detail later on in the engineering analysis section of the report.

This analysis included the amount of perlite that would be needed to accommodate the largest Defender Filter design currently marketed by Neptune Benson. Following a detailed analysis, the team was confident enough in the proof of concept for the chosen design.

Moving forward into the Spring Semester, the team immediately moved forward with the chosen design plan and began construction of the first generation prototype. The meeting times were every Wednesday and Friday from 12:15 pm to 3:15 pm. While most of the design components were purchased, some of them were modeled using SolidWorks and 3D printed at the Schneider Electric facility. When all of the components were properly assembled, a test was scheduled at the Neptune Benson premises. Following the completion of this test, the team found that while the design was viable, slight redesign of the stirring mechanism would need to be done in order to fully rectify the issue of flow stagnation along the edge of the container. This redesign was implemented into the second generation prototype; which also included a larger container with a steeper cone angle, a smaller outlet cross-sectional area for increased conveying air velocity, and a lid design for increased loading efficiency. This final design has been recently completed and a second test at the Neptune Benson facility has been scheduled.

2.1 Research

The research process began with patent searches on designs that performed similar functions to the system the team was attempting to construct. The patent search was conducted in order to avoid any possible copyright infringement, but also in order to give the team some creative insight into possible concepts that would address the issue presented to the team by Neptune Benson. Additional market and cost research was done in order to further gage the competition and consumer market the team would be dealing with when a final product was eventually created.

2.2 Concept Generation

During the concept generation process each member of the team produced 30 innovative designs or design components that would provide a possible solution to the presented problem. Each team member was then responsible for narrowing down this list of ideas to the most viable design concepts. These selected concepts were then discussed, refined, and analyzed in order to arrive on a initial prototype design to move forward with for further design and analysis.

2.3 Preliminary Design

This step of the process is when the initial prototype was created. This was initiated first through SolidWorks design, and eventually moved into engineering analysis. This engineering analysis involved computation of various flow parameters, which can be detailed in Section 11 on page 88. The team met with both the Neptune Benson engineering team and Professor Nassersharif in order to further discuss the viability of the design components. When it was determined that the design was viable, the team moved forward with the construction of the first generation prototype.

2.4 Testing

Once the initial prototype design had been completed, the team moved forward with analysis and testing. A meeting was scheduled with the Neptune Benson engineering team in order to conduct a field test at their facility. Various test matrices were conceived in order to gauge the viability of the design following the on site test. Following the testing, the team was able to identify what worked and what didn't work with the first generation prototype design.

2.5 Final Design

Following the testing period, the team was able to determine what were viable design components and which components needed to be amended in order to create a final product. A SolidWorks model was once again produced that mapped out the various components and assemblies that needed to be included in the final design; and parts were purchased or manufactured in accordance with these models. The final design is currently completed and ready for further testing.

3. Financial Analysis

3.1 Budget

For this project Neptune Benson has provided Team Defender with a budget of $ 3,500 which was to be used for building and testing the perlite media feeder design chosen by the team. The budget was non-fixed and is subject to change should Team Defender require more funding. Since last year's team used a similar design involving a cone-bottom tank, auger motor and Defender vacuum, which was provided by Neptune Benson, the team did not have to use any money from the budget for these components. Instead, the team used the parts from the previous year's design and made modifications to coincide with the design chosen this year. The materials recycled from last years design were strictly used for testing purposes. Once testing was completed the team proceeded to order parts to complete a one of a kind prototype. All parts ordered for this project required an order form, each of which can be found in the appendices section of this report.

3.2 Personnel Hours

Since Team Defender was assigned the task of designing and testing the Defender Media Feeder, each team member was expected to put in the necessary time needed to complete the project including team meetings, sponsor meetings, assignments, research, designing, building, testing and many other tasks that were faced along the way. The total time spent throughout the year by each teammate on each task can be found in tables 1 through 4. Each teammate was expected to focus on the needs of the team which varied on a weekly basis and expanded as the project proceeded. The project was essentially divided into two parts; last semester dealt with completing necessary assignments to understand the project at hand, researching possible designs as well as materials that could be used in the design, while this semester dealt mainly with ordering parts, designing components, building and testing the completed prototype(s). A visual representation of how each teammate allocated their time based on the needs of the team throughout the year can be found in figures 3 through 6. Collectively, the team spent a total of 818 hours on the project and were able to produce two generations of the Defender Media Feeder system. The first generation model that was presented to Neptune Benson, was used to verify the proof of concept by simulating the process of loading the Defender Filtration unit. A more in depth discussion of the tests conducted on the first generation DMF model can be found in the testing section of this report. Testing the first generation model allowed Team Defender to make modification to the original design and produce a second generation Defender Media Feeder system which corrected the errors noted during testing and also provided a safe, efficient way of transferring perlite media from its packaging into the Defender Filtration unit. Although two versions of the Defender Media Feeder were produced, Team Defender would still like to make numerous changes to the design in order to produce a near-perfect final version.

Task	Total Time Spent (Hours)
Background Information Research	9
Patent Search	6
Sponsor Meeting s	9
Concept Generation	11
Design Specifications	7
Critical Design Presentation	10
Proof of Concept Presentation	10
Design Research	20
Prototyping/Building	24
SolidWorks Modeling	6
Engineering Analysis	6
Research Materials	24
Financial Analysis	12
Competition Analysis	4
Midterm Report	20
Build & Test Presentation	5
Testing	8
Showcase	7
Final Report	14
Total	212

Table 1: Patrick Marie 2017-2018 Time Allocation

Although the team was expected to complete each assignment individually or as a team, there were also a great number of people who spent time helping the team with their task. Table 5 provides a list of contributers who assisted Team Defender by providing information, suggestions and insight which helped further the design and concept of the project. Table 5 also breaks down the hours each individual outside of Team Defender dedicated to the project as well as the dollar equivalent for their time. A total time of approximately 869 hours was spent on the project by Team Defender and the consultants listed which equated to about $28,305.

Task	Total Time Spent (Hours)
Background Information Research	9
Patent Search	6
Sponsor Meetings	9
Concept Generation	11
Design Specifications	5
Critical Design Presentation	10
Proof of Concept Presentation	10
Design Research	20
Prototyping/Building	14
SolidWorks Modeling	30
Engineering Analysis	12
Research Materials	4
FEA Analysis	8
Midterm Report	20
Build & Test Presentation	15
Testing	7
Showcase	6
Final Report	16
Total	212

Table 2: Nathan Bannon 2017-2018 Time Allocation

3.3 Estimated Totals

During the course of this semester Team Defender was able to produce two generations of the Defender Media Feeder. The materials necessary to produce each model can be found in the Detailed product Design section of this report while the total parts ordered from various distributors can be found in the order forms located in the appendices. The fact that the team was able to recycle a majority of the parts ordered by the previous years team allowed us to save most of the budget for the second generation. Collectively, Team Defender spent approximately $1062.43 throughout the course of the year, money that was used produce two generations of the Defender Media Feeder.

As mentioned before the second generation system produced by Team Defender was designed based on the changes necessary to provide a more effective agitating mechanism which would provide a more continuous flow to the outlet of the system. A break down of the parts used to create the second generation system as well as the price of each part can be found in table 6. The production of the outlet of the system solely relies on 3D printing which is why it is not included in table 6. After researching 3D printers that the team believes will produce the

Task	Total Time Spent (Hours)
Background Information Research	6
Patent Search	6
Sponsor Meeting s	9
Concept Generation	11
QFD Analysis	7
Critical Design Presentation	10
Proof of Concept Presentation	10
Design Research	20
Prototyping/Building	40
SolidWorks Modeling	4
Engineering Analysis	14
Research Materials	12
Financial Analysis	3
Competition Analysis	10
Midterm Report	15
Build & Test Presentation	5
Testing	6
Showcase	6
Final Report	10
Total	204

Table 3: Jimmy Dunwoody 2017-2018 Time Allocation

same finish as the printers used at Schneider Electric, an Original Prusa i3 MK2S 3D printer at $ 599.00 on the Prusa website should be able to replicate all three components of the outlet perfectly. Filament can also be purchased from the Prusa website, a 1kg roll costs $ 20.99 and should be able to produce at least one of the components.

Task	Total Time Spent (Hours)
Background Information Research	6
Patent Search	6
Sponsor Meeting s	9
Concept Generation	11
QFD Analysis	4
Critical Design Presentation	10
Proof of Concept Presentation	10
Design Research	16
Prototyping & Building	15
SolidWorks Modeling	4
Engineering Analysis	6
Research Materials	15
FEA Analysis	14
Midterm Report	15
Arduino Scale Assembly	22
Build & Test Presentation	5
Testing	5
Showcase	5
Final Report	12
Total	190

Table 4: Andrew Anderson 2017-2018 Time Allocation

Consultant	Time Spent (Hours)	Hourly Cost	Total Cost
Team 3 Members	818	$30	$24540
Nick DiRocco	12	$60	$1380
Andrew Creathorn	9	$60	$540
Steven Hawksley	9	$60	$540
Steven Nicolich	9	$60	$540
Stratton Tragellis	9	$60	$540
Dr. Nassersharif	3	$75	$225
Total	869	$405	$28305

Table 5: Total Cost of Project Due to Engineers and Consultants 2017-2018

3.4 Cost of mass production, market demand and Return on Investment

Although the approximate cost of producing one Defender Media Feeder prototype is $1095.84, a brief cost analysis of producing the system in mass quantities was done. In order to yield an accurate representation of the cost of mass production of the system the provider of the cone bottom tanks, which is considered to be the main component of the system, was

Figure 3: Time Distribution Patrick Marie 2017-2018

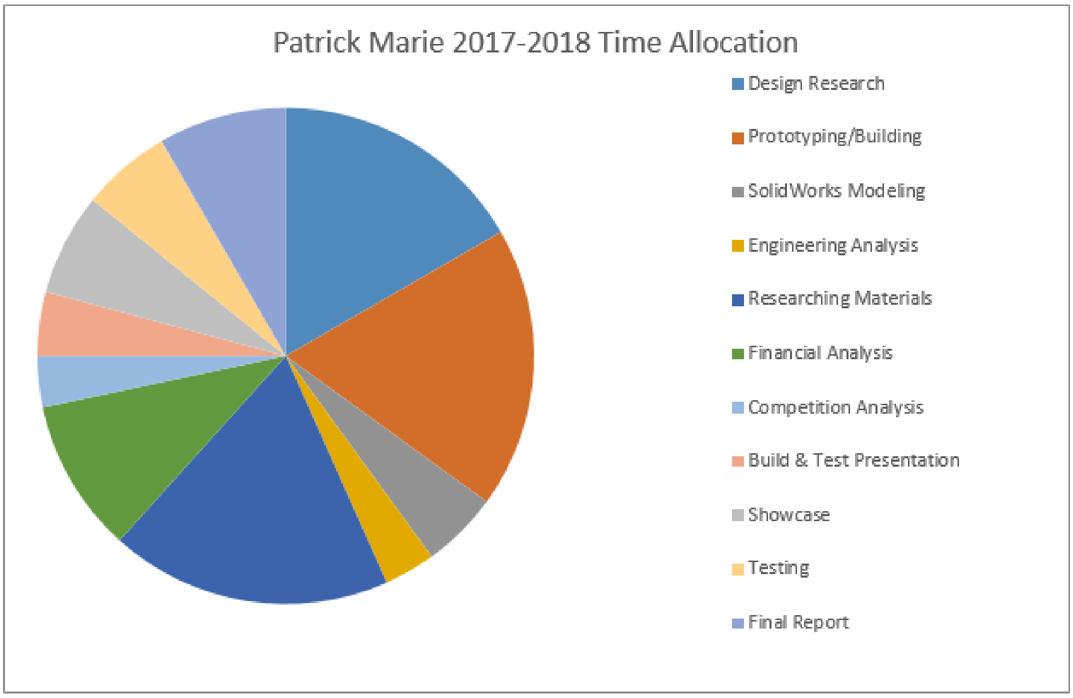
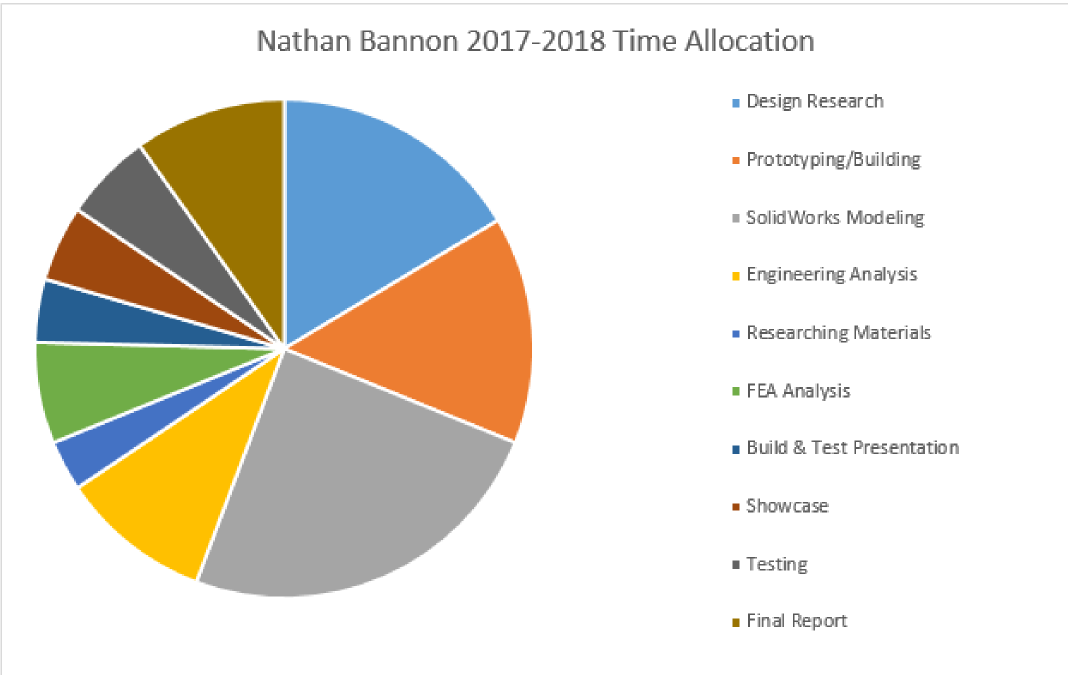


Figure 4: Time Distribution Nathan Bannon 2017-2018



contacted. National Tank Outlet was contacted to receive a price gate on the purchase of two

Figure 5: Time Distribution James Dunwoody 2017-2018

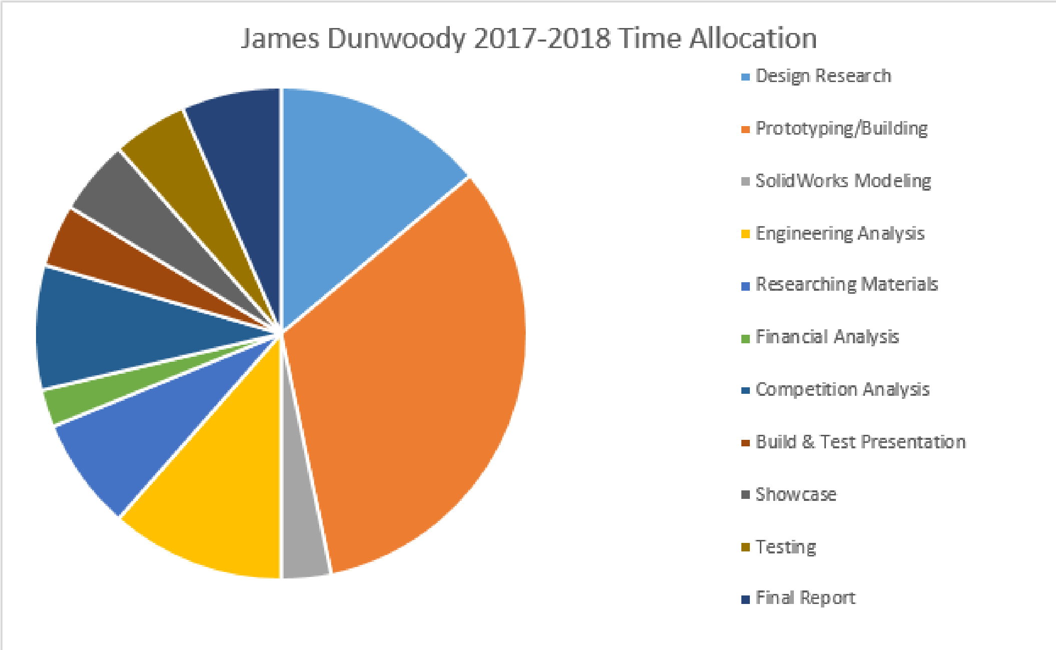
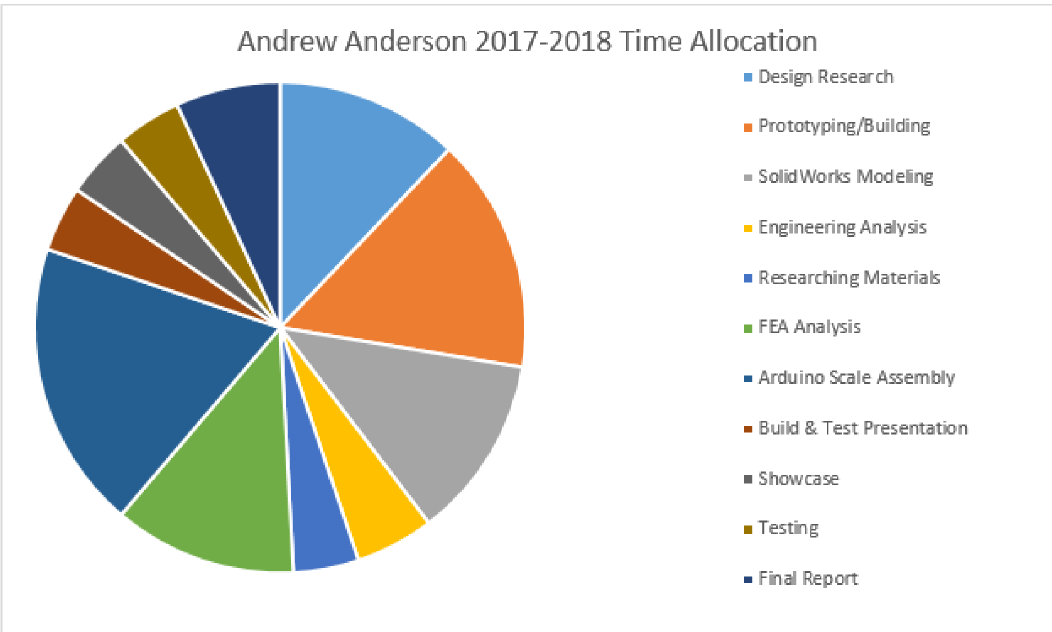


Figure 6: Time Distribution Andrew Anderson 2017-2018



hundred tanks and stands; two hundred was an arbitrary number chosen for the quote. A sales representative by the name of David Brocato was able to provide Team Defender with a quote of $68,910.00, which included two hundred tanks and stands. A break down of the

QTY	Item	Unit Cost	Subtotal
1	110 Gallon Ace Inductor Cone Bottom Tank	$209.99	$209.99
1	110 Gallon Ace Standard Inductor Tank Stand	$129.99	$129.99
2	3/4 in. diam. x 5 ft. Nylon Rod	$10.61	$21.22
1	1-1/4in. diam. x 3 ft. Nylon Rod	$16.18	$16.18
1	Black Buna-N Rubber- 1/4" Thick - 24" x 24" Sheet	$47.36	$47.36
1	30in. x 30in. x 1/4in. Acrylic Sheet - Extruded	$62.50	$62.50
1	Sponge Rubber Foam Tape 5/16-Inch	$3.29	$3.29
1	Stainless Steel Toggle Latch	$7.60	$7.60
1	BBQ Drum Smoker Hinge	$50.00	$50.00
3	8 in. Zinc-Plated Corner Brace	$4.91	$14.73
1	EVEREST: 1 in. x 6 ft. Ratchet Tie-Down Strap	$3.77	$3.77
1	3 in.-2 in. PVC Hub x Hub Reducer Coupling	$2.80	$2.80
1	PVC Shutoff Valve	$9.95	$9.95
1	Polycarbonate Round Tube (Clear) - 1-1/4" ID x 1-1/2" OD	$12.85	$12.85
1	Polyethylene/ Nylon Adhesive	$8.37	$8.37
1	Arduino Starter Kit	$28.99	$28.99
1	Arduino Weighing Sensor Module	$20.48	$20.48
4	Disk Load Cell - 200kg	$56.95	$227.80
1	3 ft x 3 ft x 1/2 in. Plywood (Base)	$14.99	$14.99
4	Standard Rubber Caster - Swivel, 4 x 1 1/4"	$10.00	$40.00
1	1200W Earth Auger Motor	$162.98	$162.98
Total			1095.84

Table 6: Total Cost of Materials Needed to Assemble the Second Generation Defender Media Feeder

quote can be found in the appendices under figure 63. It is noted that the total price of the stand as tank when purchased one at a time comes to a total of $339.98 while the price gate received from National Tank Outlet shows the tank and stand come to a price of $344.55 resulting in about a $4.57 increase in price of tank and stand, this is due to the fact that the tank and stand are sold separately. It is also due to the fact that the tank is currently on sale on the NTO website for $209.99, its original price being $419.99, while the stand is not on sale and is priced at $129.99. Taking this information into consideration, if the tank was not on sale and purchased at full price the cost of one tank and stand set would be $549.98, therefore the quote received from NTO would save Neptune Benson $205.43 per tank or $41,086.00 per 200 tanks purchased. Because the tank and stand are the main components of the system the other components were not quoted per 200 items purchased. However, As it stands the cost of production for 200 complete DMF systems, given the price gate received from the National Tank Outlet and the items included in this report would cost about $288,078. This cost is

obviously subject to change as the materials used to produce this system would be purchased in large quantities which would result in a price gate of each component purchased.
Neptune Benson currently has approximately 2,800 Defender Filtration units in the field at the moment and they sell about 350 new units per year. When considering the demand for the product being designed by Team Defender, it was assumed each establishment that uses the Defender Filtration would purchase *at least* one Defender Media Feeder system for every three Defender Filtration systems the establishment owns. Following this estimate Neptune Benson could sell up to 933 DMF systems once the product is through prototyping and becomes available for the market. Since Neptune Benson also sells 350 new units annually, this could result in about 116 DMF systems sold per year. Taking into account the potential price spent to produce one prototype being $1095.84, using the price gate per 200 tanks purchased, Neptune Benson could potentially sell one DMF unit for approximately $2,300.00, resulting in a potential profit of $1204.16 per unit sold, not including delivery, assembly and installation. As discussed previously, there are approximately 2,800 units currently installed in the field, therefore, Neptune Benson could potentially sell 933 Defender Media Feeder systems as soon as the product is ready for the market resulting in $2,145,900.00 in income, or $ 1,123,481.28 in profit. Following the same information given in the previous paragraph, Neptune Benson also sells 350 new units annually which could result in 116 DMF systems sold per year. Following the same price per DMF system, $2,300.00, This could result in an annual income of $805,000, or an annual profit of $421456.00. Again, the price of one Defender Media Feeder system was estimated by Team Defnder and the estimated profits and income portions of this report do not include other aspects which will be included in the price of the system, including shipping, assembly and installation. These values were estimated by Team Defender and are subjected to change once the product becomes available on the market. Neptune Benson could also seek profit in offering replacement parts for each Defender Media Feeder that is purchased as components of the system are subject to break due to every day use.

3.5 Cost Savings and Manufacturing Efficiencies

The Neptune Benson facility is located in Coventry, Rhode Island and is the location where Defender Filtration systems are produced. Most of the components of the filtration unit are manufactured at other companies and are shipped to Neptune Benson where they are then assembled for the final product. The Defender Media Feeder system could follow the same process as the main components could be purchased from outside vendors and then assembled at the facility to produce the final product. The company could research

3D printers to print each component of the outlet. This would cut back on cost as these portions of the product could be produced in house. Another component of the DMF system which will be fully assembled from scratch would be the stirring mechanism. The stirring mechanism could also potentially be produced in house, a break down of the process used to create the stirring mechanism can be found in section 12.1 Design components. Since this component uses a simplistic design and materials, it could be assembled in house and could save Neptune Benson money as they do not need to purchase a completed product from an outside vendor.

4. Literature and Patent Searches

As previously discussed, the patent search, and the resultant findings, played a significant role in the concept generation process. It gave the team an idea of what competing products were out on the market, and see where the design process could go in order to conceive an original solution to the problem being addressed. Inspiration was taken through researching the relevant patents that were found, and ultimately led to new ideas that generated the current prototype design being currently constructed. While a large number of related patents were found, a list of the most relevant searches is included below.

4.1 Patent Searches

US9,194,092/Mechanism for Automated Mixing of Liquid Solutions and Granular Materials

Date: January 20, 2011

Rights owned by: Kline, Mark

Abstract: Disclosed is a mixing mechanism. The mixing mechanism includes an auger, a fluid handling portion, and at least one discharge hole. The auger configured to receive granular materials from a granular material source and capable of moving the granular material along a predetermined path. The fluid handling portion is coupled to a fluid supply source and has an inlet within an interior section of the auger. The size and positioning of the discharge hole (or holes) along the auger are specifically configured to allow for optimum mixing of the materials prior to being discharged.

Relevance: This set up fulfills a similar function to the teams design, and was found to be a useful reference moving forward with the project from the preliminary stages. This incorporates elements of a concrete mixer design, which gave some different ideas for agitating the material and preventing a buildup of perlite, and a stoppage of flow into the vacuum outlet.

US9,669,370/Animal Feed Mixing and Dispensing Apparatus

Date: May 2, 2013

Rights owned by: Hughes, Samuel

Abstract: A feed mixing and dispensing apparatus includes a container mountable on a transport. The container has a longitudinal axis, a transverse axis and a vertical axis, a pair of opposite end walls, a pair of opposite side walls and a base wail and a top opening. The longitudinal axis extends substantially parallel to the direction of travel of the container, while the transverse axis is substantially perpendicular to the direction of the travel of the container. A mixing shaft connected to a drive means is rotatably mounted inside the container and comprises mixing members for breaking up and mixing the feed. The mixing shaft extends between the side wails substantially perpendicular to the longitudinal axis of the container. A feed discharge arrangement is provided for discharging the mixed feed from the container.

Relevance: This patent gives a slightly different look at the teams proposed design while performing a similar function to solve a related problem. This has continuous mixing of the material within which gives it constant motion and therefore prevents blockage/stagnation of the perlite. Also, this is a transportable design, which is also an important design specification for the project, making it a valuable reference when looking at methods of mobility for a similar design.

US9,044,719/Method and Apparatus for Mixing

Date: December 21, 2007

Rights owned by: Wyczalkowski, Wojciech R.

Abstract: An apparatus and method for mixing a liquid having particulate includes a vessel for containing the liquid and an axial impeller rotating about a substantially vertical axis.

The impeller is adapted for submerging below the liquid surface by a distance approximately one-quarter to one-half of the height of the liquid. The impeller is oriented upwardly to produce (a) an inner, upward flow region located along the vertical axis of the vessel, (b) a transition flow region above the impeller in which liquid moves radially outwardly toward the vessel sidewall, and (c) an outer, downward flow region located along the sidewall. The impeller spins at a variable speed, such that the flow is capable of entraining solid particles having a settling velocity of up to approximately 1 foot per minute in the liquid, and the speed of the impeller is chosen to enable particles having a desired settling velocity to settle to the vessel bottom.

Relevance: This patent is a useful reference for the project, as it is meant mostly for the continuous motion/mixing of fluids through an inlet/outlet design, but still gives a frame of reference for the future design. Also, the body design looks very similar to the preliminary design that was originally proposed, and provides a method can also be referenced in relation to the issue of preventing stagnation of the perlite.

US9,764,295/Mixing and Grinding Mechanism and Mixer Grinder Using the Same

Date: February 10, 2015

Rights owned by: Juan; Kuang-Nan

Abstract: A grinding and mixing mechanism for mixing and grinding fluid paint or fluid slurry includes a barrel, a rotor rotatably mounted in the barrel, grinding rolls rotatably mounted in the outer perimeter of the rotor and rotatably kept in contact with the inner barrel wall of the barrel for grinding a fluid paint or slurry, and a stirrer connected to the rotor for synchronous rotation with the rotor to mix the fluid paint or slurry circulated through the barrel. The invention also provides a mixer grinder using the grinding and mixing mechanism.

Relevance: The team has looked at the possibility of incorporating a method for turning the perlite into a slurry by adding water to the mixture. This could possibly help negate some of the inherent issues with the perlite structure causing build ups. The stir used is also performing essentially the same function as the chosen prototype design, which helps aid the proof of concept.

US8,764,277/Method and device for agitation of tank-stored material

Date: November 26, 2012

Rights owned by: John P. Whitney, Carl V. Wikstrom

Abstract: A device and method for use with the transportation of materials including a tank that is configured to hold the material and an inlet/outlet configured on the tank to allow the flow of the material therethrough. At least one inlet is arranged on the tank to allow the flow of the material into the tank to agitate the material in the tank.

Relevance: This patent is very relevant for the teams chosen design path, as it is a device with both an inlet for material to be entered into the body of the design, and an outlet for the exit of the material. Once again, a method for agitation of the material within is detailed, which is to prevent blockage of the flow of these material from the inlet to outlet; the projects principle issue.

4.2 Literature

While not many references of literature were utilized for this project, they did play a pivotal role, particularly in theoretical understanding of the mechanics involved within the design. Most pertinent to the project was David Mills text titled *Pneumatic Conveying Design Guide*, which detailed data and information on the conveying characteristics of a large range of different materials. This text, referred to the team by Dr. Nassersharif, provided highly practical information that helped to shape the teams eventual prototype design.

5. Evaluation of Competition

When it comes to pool filtration many companies manufacture and sell sand filtration systems. Neptune Benson along with selling these sand filters has developed a unit that can filter the water more efficiently and use less water in the process. The unit is call the Defender and it uses a series of flex tubes and a filtration media called perlite. The way the system works is the perlite is pulled onto the flex tubes and while the water is flowing through any bacteria or dirt is trapped in the perlite media. The way this system is more efficient and eco-friendly is because instead of draining the system and wasting all that water, the tubes are bumped knocking off all the media and then allowing it to reset on the flex tubes. This can be done multiple times until the media contains too much dirt molecules which is when it must be drained. Once drained the perlite needs to be added back to the defender unit but nobody except europe has been able to automate a way of adding perlite to the defender unit. After researching regenerative media filtration systems we found multiple companies with similar designs but none with an automated method of adding filtration media to the units. During the patent search we were able to find many different methods of automated feeding systems using hoppers and conveyor belts but were unable to find a patent for regenerative filtration media feeder system. The team at Neptune Benson provided us with the information on how the Europeans have automated the feeding system of perlite to defender units. The information that is provided has been given to us by the Neptune Benson facility or has been found through researching these different companies. Neptune Benson is an international business that has many facilities overseas. One of the Facilities is located in Europe and has developed a way to automate the feeding process of the perlite to the defender units. The units are the same as the ones that are manufactured and sold in the United Stated but have different method of loading the media into the units. At the locations of the units in the US the media is manually vacuumed into the hoppers where it is then used for filtration. The problem with that in Europe is they have strict codes and regulations regarding human contact with the filtration media. Due to these regulations they came up with a container that holds a slurry of the perlite and water which dispenses when the defender unit media needs to be replenished.

Figure 7: European Slurry Holding Container

Figure 7 shows the container that holds the slurry mixture, but does not show that on the other side of the wall is a larger holding container which is where the slurry is premade. The larger container takes up about the size of a conference room which is good for new installations of these units but does not cover the retro fitting aspect.

Since the European company is a branch of Neptune Benson they used the same defender unit which utilizes flex tubes. A competing company with neptune benson is Paddock pool equipment company which has a filter that uses the same flextube and bumping technology. The systems run similarly and have the same shape as you can see in the comparison figure 8. According to the Paddock website they make the unit out of stainless steel to ensure the life expectancy. Like the Defender, the regenerative media used by Paddock is perlite which the unit bumps to regenerate. Although it has a similar operating system as the defender they still have not been able to attain the automated perlite media feeder system that Team 3 is currently working on.

(a) Neptune Benson Pool Filter

(b) Paddock Pool Filter

Figure 8: Side by Side Comparison of Paddock Pool Filter and Defender Pool Filter

6. Design Specifications

When any engineer is tasked to create a product, the needs of both the product sponsor/company and the customer must be considered. While some specifications benefit one party more than the other, many of the design specification needs are beneficial to both the company and the customer if efficiently met. Some specifications are mutually beneficial such as a lower manufacturing cost, which in return will most likely lower the final product cost for the customer. While not obvious at first, a warranty being offered on a product seems like it would benefit just the customer. However, if the company offering the warranty on the product can confidently offer it without a projected loss and fulfill the promise to the customer, brand loyalty and brand quality is gained and the company now has an increased likelihood of future business with that customer.

For the product that Team 3 was selected to create, the design specification needs for Neptune Benson and the Neptune Benson customer both have to be greatly considered. Some things about the customers who will eventually be purchasing the Defender media feeder are already known and some are not known. One such known about a customer who would be purchasing the Defender media feeder created by Team 3 is that they are already a Neptune Benson customer or will be soon and already own or will soon own at least one Defender filter. This is known because the product being created by Team 3 is a direct attachment to the currently existing Defender filter with the goal of automating the perlite loading process. However, some unknowns exist about the customer such as whether they own one defender or more than one and whether they have one of the smallest Defender filters available or the largest. To meet the customer requirements of these unknowns, the product created by Team 3 must be able to hold the maximum perlite load of the largest Defender filter so that an owner of the largest Defender filter does not have to load the Defender Media Feeder more than once within one perlite loading cycle.

	Neptune Benson Requirements	Design Specification
1	Compact Size	-Operate with limited human interaction
2	Low Prototype Production Cost	-Maximum prototype cost of $3,500
3	Reduced Time for Perlite Loading	-Vacuum 125 lbs of perlite is less than 10 minutes

Table 7: Neptune Benson Requirements

1. The automation requirement that was specified by Neptune Benson means that the product Team 3 is creating must eliminate the need for an operator to manually vacuum perlite into the Defender filter. The Defender Media Feeder must be able to handle a full load of perlite needed for one perlite loading cycle and must be able to handle the maximum load for even the largest available Defender filter. Once the DMF is loaded with perlite, an operator can turn on the vacuum and automated feeder and not have to watch over it while it mixes and vacuums perlite into the Defender filter.
2. For the creation of the DMF prototype, Neptune Benson has allocated a maximum budget of $3,500 for Team 3 to use on necessary prototype parts. A majority of this budget will be used on the purchase of the hopper, the hopper stand, the motor and the pvc piping.
3. Neptune Benson requires that for the Defender Media Feeder created, the time it takes for the automated feeder to transport perlite into the filter must be less than the time it currently takes for a human operator to do manually. A skilled and experienced operator of the Defender filter can vacuum one bag of pelite (25 lbs) into the Defender in 5 minutes which equates to a maximum load of 5 bags (125 lbs) in around 25 minutes. The goal Team 3 has set for their end product is the ability for the DMF to vacuum 5 bags of perlite into the Defender filter in less than 10 minutes.

6.1 Specifications Definition

In order to define the engineering requirements that would be implemented into the final design, the costumer requirements had to first be considered. These requirements can be seen below in Table 8.

	Customer Requirements	Design Specification
1	Compact Size	-Maximum width of 3 ft -Maximum height of 5.5 ft-Minimum volume of 100 gallons
2	Reliable	-Operate for 10 years without yearly maintenance -Product can be paired with a 10 year Neptune Benson warranty
3	Easy Maneuverability	-Can be moved around for use on different Defender filters within one building -Maximum empty weight of <50lbs -Maximum filled weight of <200lbs
4	Power Efficient	-Powered by a single 120 V power outlet
5	Safe	-Limit human contact with perlite -Operator cannot lift over 50 lbs to load media feeder
6	Compatible with current Defender Filters	-Function off of preexisting Defender vacuums (force of 1.8 psi) -Able to hold a maximum load of 125 lbs of perlite

Table 8: Costumer Requirements

1. One of the customer requirements for the Defender Media Feeder is that it must be compact enough to easily fit between small areas and through doors within the building that it is being used. The average door width is around 3 feet so the product being created by the team must meet this requirement. Similarly, the average door height is around 6.5 feet so the DMF must have a height less than that but not so tall that the perlite pouring process is difficult or dangerous. Therefore, the height requirement set by the team is that the feeder can be no taller than 5.5 feet. Lastly, the volume requirement for the Defender Media Feeder is a volume no less than 100 gallons so that the feeder is able to hold the maximum perlite load needed for the largest Defender filter.
2. Reliability is important to a customer because no customer wants to purchase a product that does not last long or is one that requires unnecessary maintenance or repair. Currently, Neptune Benson offers 10 year warranties on their products and the same warranty should be applied to the Defender Media Feeder product that is created by the team.
3. Easy maneuverability is a customer requirement for the Defender Media Feeder because

most Neptune Benson customers that own a Defender filter own more than one and would likely not want to purchase more than one DMF. The feeder should be easily maneuverable so that a single DMF can be moved from filter to filter when it is time for the monthly perlite cycle change. The specification for this requirement that was set by Team 3 is that the maximum empty Defender Media Feeder weight is 50 lbs and the maximum filled weight is 200 lbs. Along with not having an excessive weight, it is an absolute must that the DMF is fitted with stable wheels so that it can easily be rolled around the building that is housing the Defenders.

4. Since the Defender Media Feeder is an attachment that was not originally planned with the Defender filter, it therefore has to use an external power source to make up for the now obsolete manual human operator labor. The simplest and most effective way to get power to the feeder motor is to have the motor compatible with 120 volt power outlets since those are the most common and accessible sources of power in the United States of America.

5. Safety is one of the most important specifications for a Neptune Benson customer because the product they purchased will be used by them or one of their workers. While perlite is not considered to be a carcinogen and is not considered to be dangerous when inhaled, it is in the best interest of Neptune Benson and the customer to limit human contact with the perlite. This can be achieved by having the Defender Media Feeder paired with a sturdy lid that prevents the escape of any perlite particles once the device is turned on. Perlite particles in the air can also be limited by having a self penetrating tool on the inside of the feeder so that a perlite bag can be punctured on the inside of the feeder inside of having to open the bag prior and then having to pour. Along with trying to limit operator contact with perlite particles, another safety concern is limiting the weight that has to be lifted by the operator when filling the feeder with perlite. The specification for this is that no operator can lift more than 50 lbs while operating the DMF. Since the largest bag of perlite sold by Neptune Benson is a 25 lb bag, this safety specification is meet.

6. Since the Defender Media Feeder that is being created will be offered to new Neptune Benson Defender customers and preexisting ones, the device has to be compatible with new Defender filters and older models. As stated by Neptune Benson to Team 3, they are not currently considering Defender filter modifications just to satisfy the DMF attachment that is being created. This means that the feeder that is created must work off the preexisting vacuum that is currently built onto Defender filters and that the feeder created by Team 3 has to effectively perform with the given vacuum force of 1.8 PSI.

7. Conceptual Design

When Team Defender was presented with the Defender media feeder system project by Neptune Benson, each team member was asked to generate thirty original and unique design concepts which were realistic and capable of performing the task. In total, the team came up with one hundred and twenty unique design concepts and can be found below along with a brief analysis of each concept.

7.1 Patrick Marie Design Concepts

The first concepts being analyzed were produced by Patrick Marie and can be found in figures 9 through 16. A brief analysis can be found below, each number corresponding with the given design.

1. The cone bottom tank is highly recommended by Neptune Benson and will most likely be used in the design. It allows material to flow easily with little to no accumulation.
2. A metal or plastic plate with an incline would provide a surface to put the perlite on and have gravity naturally pull it toward the vacuum, hopefully, with little resistance and accumulation.
3. A vacuum attachment that would fit on the existing Defender vacuum could be a simple solution. The attachment would be designed to fit directly inside of the perlite packaging and would take in more material than the existing vacuum head.
4. This design is similar to a cement mixer as it would include fins that would rotate with the body to agitate the material and move it toward the vacuum.
5. In order to agitate the material and avoid accumulation, a vibrator could be placed on the bottom of the tank.
6.Another way material could be agitated would be with an arbor. This could either be placed at the top or bottom of the tank. The fins on the axle would have to be large enough to agitate all of the material.
7. Another way material could be agitated would be with revolving paddles that would brush along the sides of the tank.

Self-piercing instruments could be placed at some point in the tank. This could include some kind of point, jagged edge, razor or spike. Some examples are shown below in designs 8-12 and would likely be incorporated in the design.

8. Design 8 involves the use of a range of small points or spikes which will be used to penetrate the bag, the dark spaces represent gaps in the plate that would allow material to fall through.

9. Design 9 uses one large single point which will be used to penetrate the bag. the dark spaces represent space to allow material to fall to the bottom of the tank where the vacuum will be.
10. This design also uses sharp or jagged points and holes would be placed around each point, as well as between points, to allow perlite to flow down into the vacuum area.
11. This design uses two long blades which would be placed at the base of the tank. the bags would be dropped directly on top of them and would penetrate said bags.
12. The following design uses points which include hollow centers to allow perlite to pass thorough once the packaging has been penetrated.
13. If possible, some form of blade would be incorporated into the tank which would manually swing out, cut the bag and swing back into its safety slot.
The next few concepts involve the transportation and storage of the cone bottom tank:
14. Simply putting the tank vertically on a cart with wheels would suffice.
15. The tank could be placed horizontally, for easier storage and hydraulically inclined when used.
16. This design includes flaps which would fold in to take up less space when stored. Similar to a shop vacuum with a hose being at the bottom.
17 and 18. Perlite is placed in a simple box and a vacuum attachment sits at the bottom of the box and sucks in perlite. Two designs are included, Design 18 may be more preferred as it covers more surface area.
19. This design includes a door placed on the side of the tank to allow easy input of material.
20. This design includes a door similar to that of a mail drop box. Jagged edges sit at the bottom of the door to pierce the bag and empty perlite. These points may be hollow to allow material through.
21. This design includes an inclined plate with self-piercing points located at its base to open perlite packaging.
22. Box will fit perlite bag inside of tank and penetrate packaging, empty into a collection chamber and be sucked into the Defender system. The points may be hollow to allow material through.
Design concepts 23-25 involve repackaging the perlite media: 23. Package the perlite in a water bottle-like container. The vacuum could connect directly to the base of the packaging. Packaging could possibly be collapsible.
24. Perlite could be packaged in thin plastic bags so material could fold in on itself when bag begins to shrink from suction. These thin plastic bags would be easily penetrable.
25. Perlite could be placed in a drum like container which a vacuum attachment could be

placed within, and fall to the bottom as perlite is removed.
26. Similar to a paint ball hopper, material is fed in one side, funneled to the bottom where a vacuum will pull it into the tank.
27. A large funnel which includes some type of rotating mixer. The motor would be attached to a beam which sits at the top of the funnel. Material is still fed through the top.
Designs 28-30 are design concepts involving the base and stand which would be used on the cone bottom tank.
28. This design includes an octagonal base and would provide support on eight points on the tank.
29. This design includes a circular base and would provide support on the edges of the tank.
30. This design includes a square base and would provide support on four points on the tank.

Figure 9: Patrick Marie Concepts 1-3

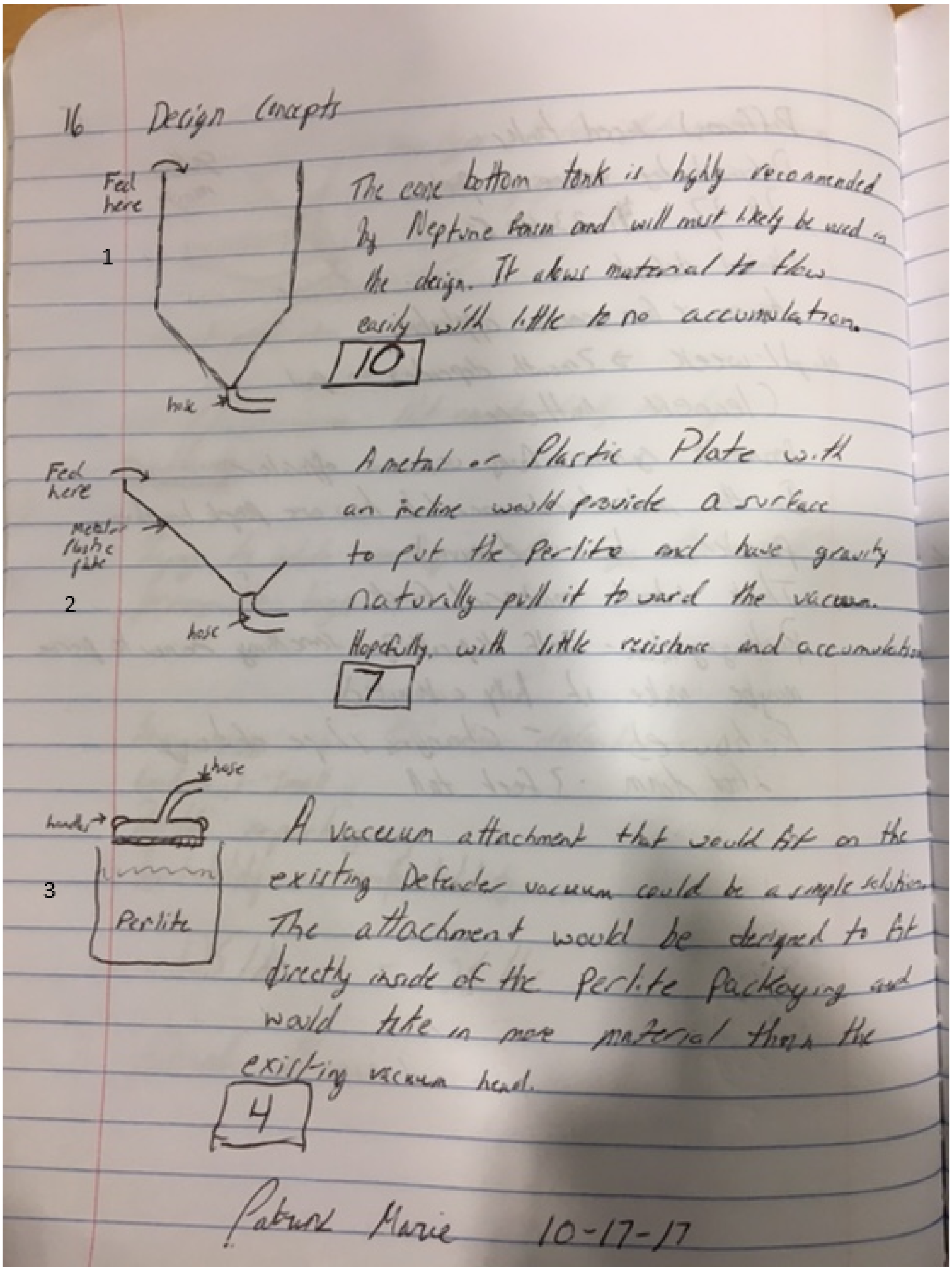


Figure 10: Patrick Marie Concepts 4-6

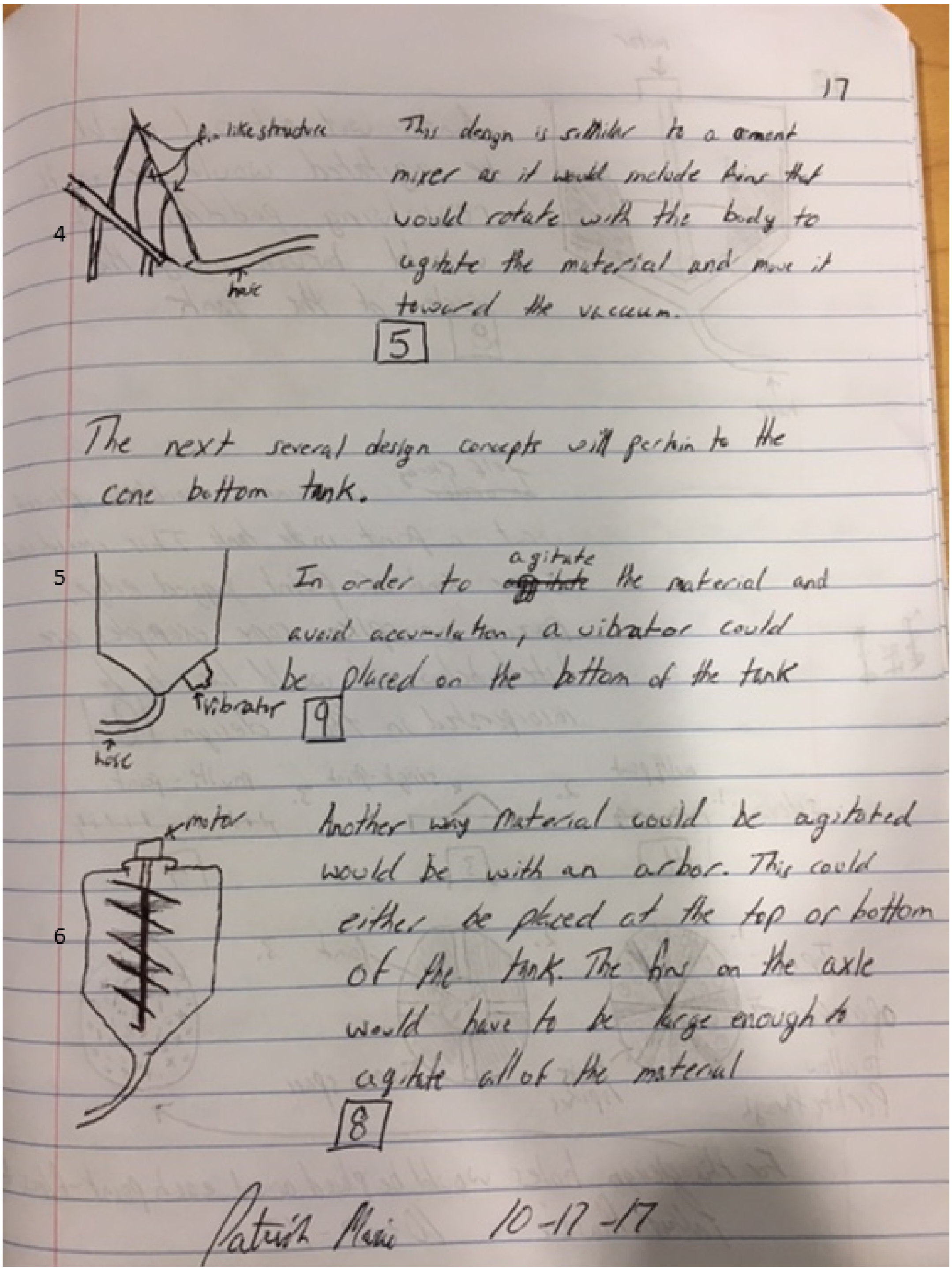


Figure 11: Patrick Marie Concepts 7-10

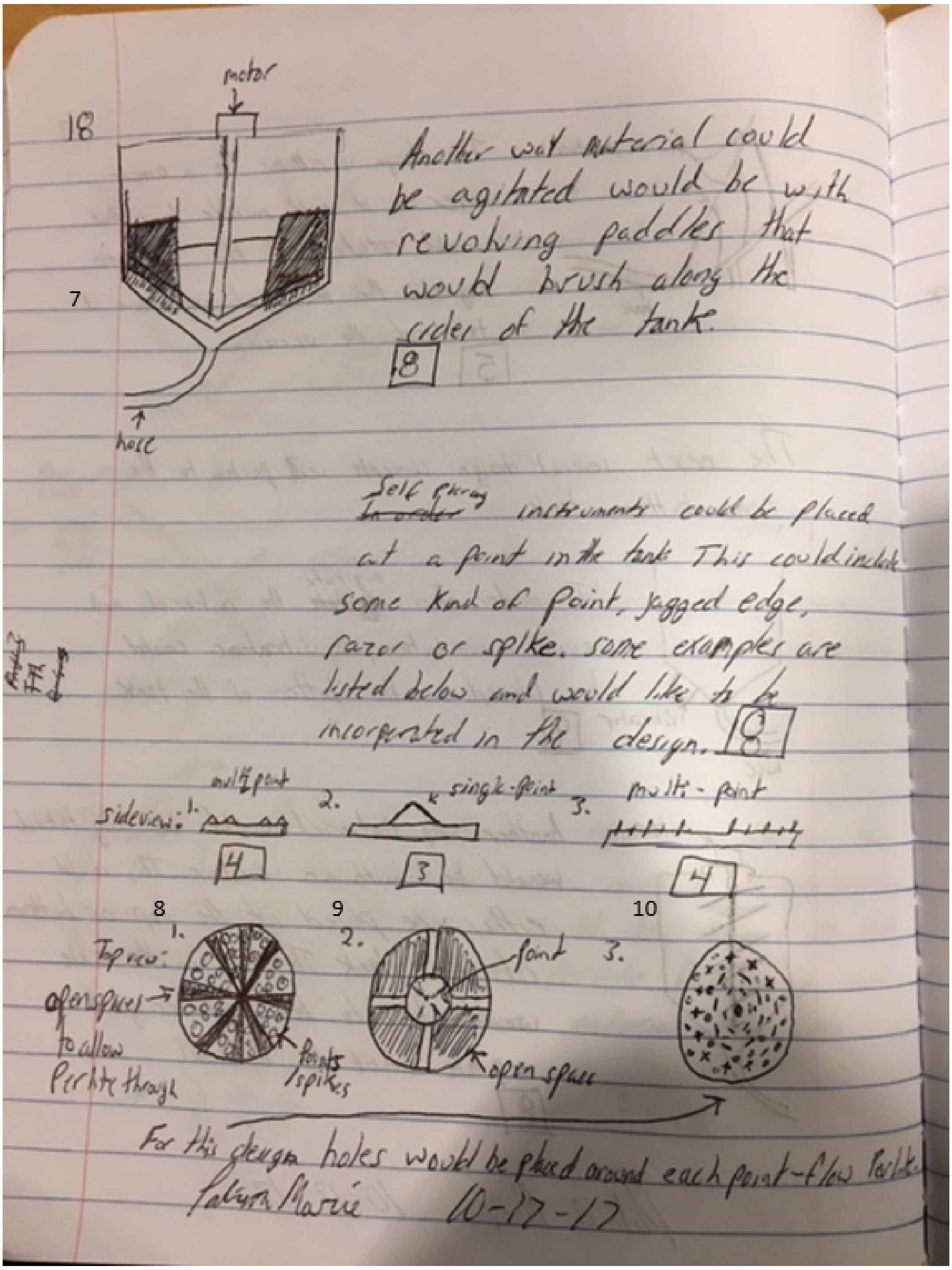


Figure 12: Patrick Marie Concepts 11-15

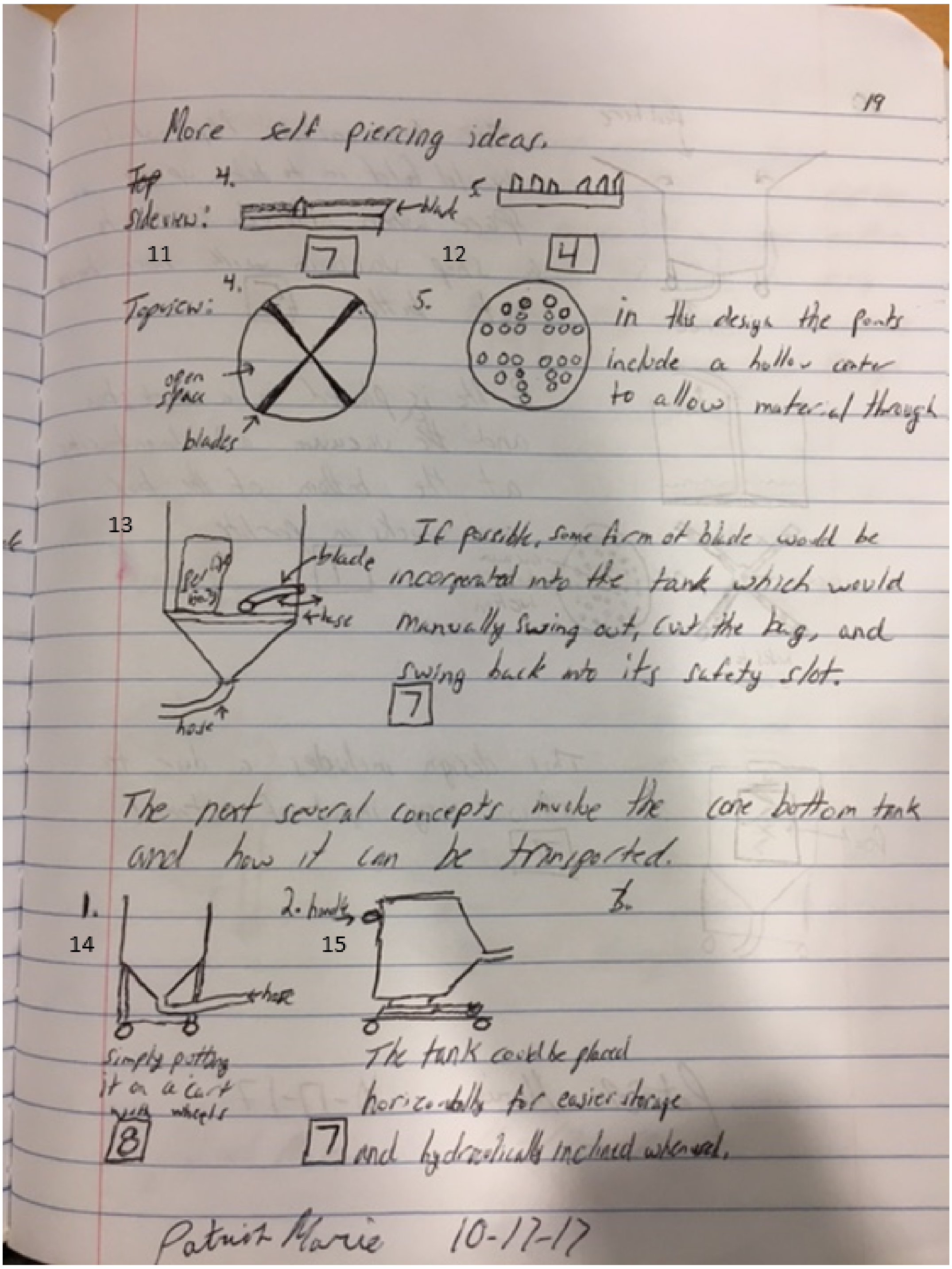


Figure 13: Patrick Marie Concepts 16-19

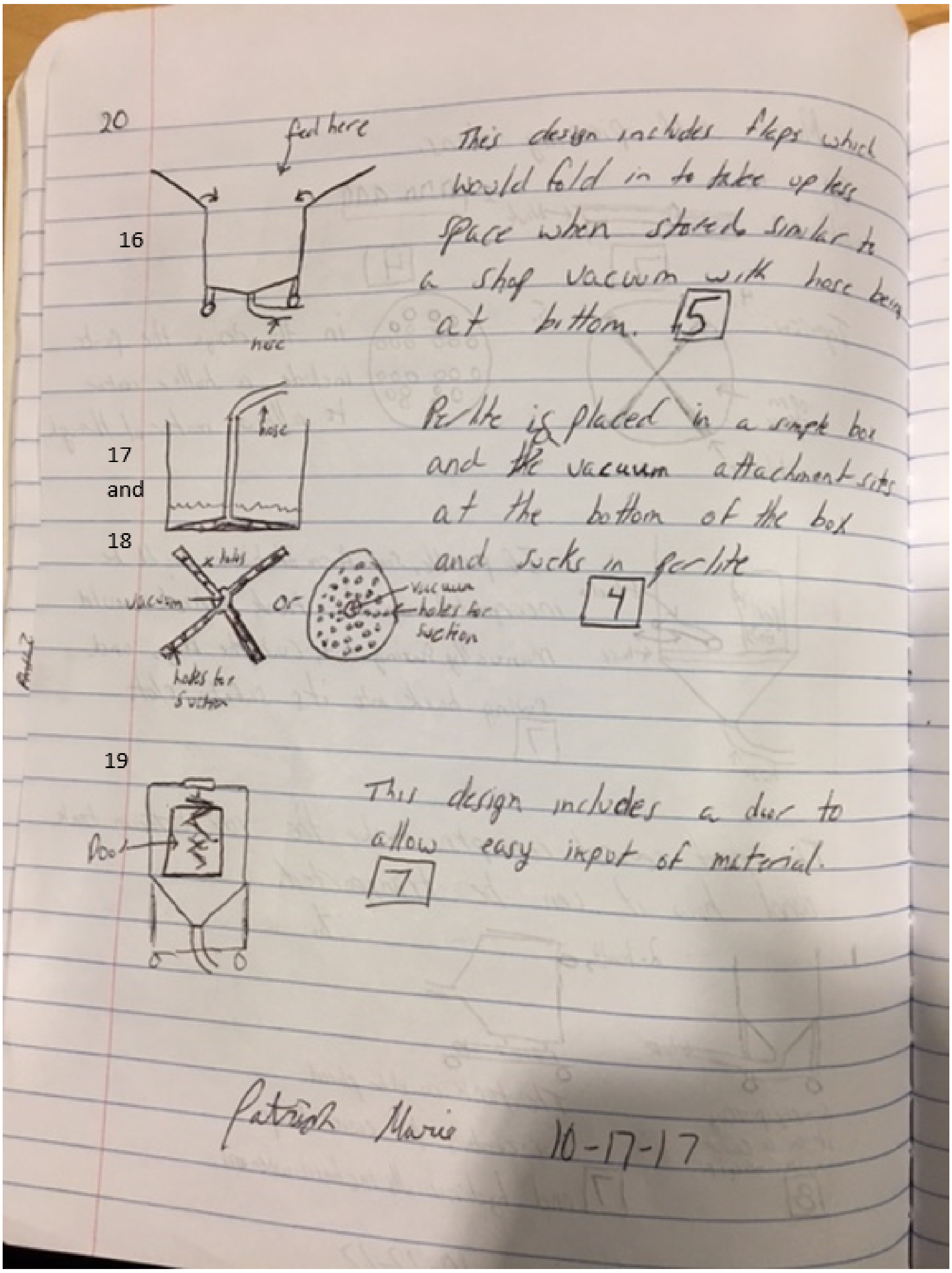


Figure 14: Patrick Marie Concepts 20-22

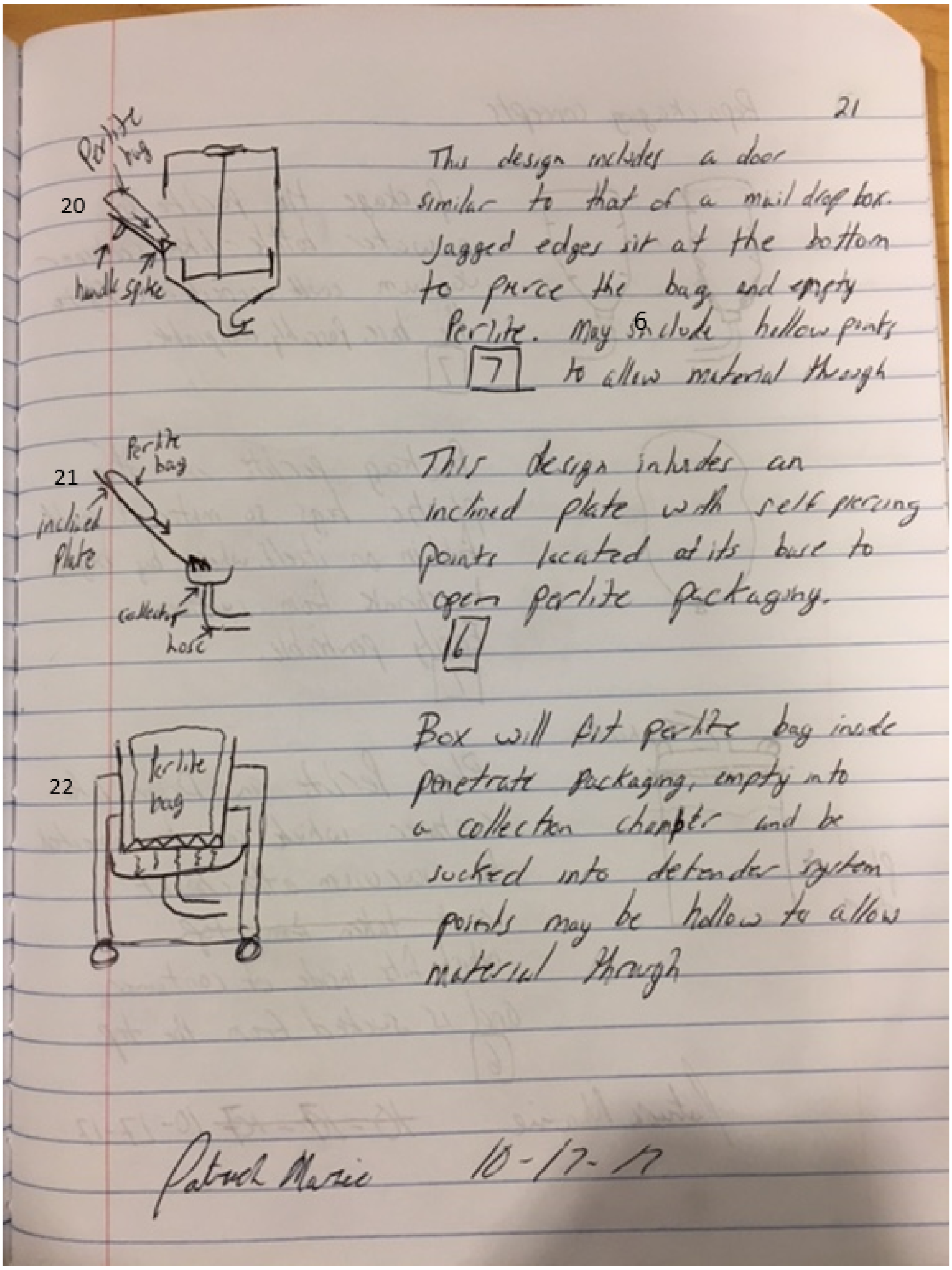


Figure 15: Patrick Marie Concepts 22-25

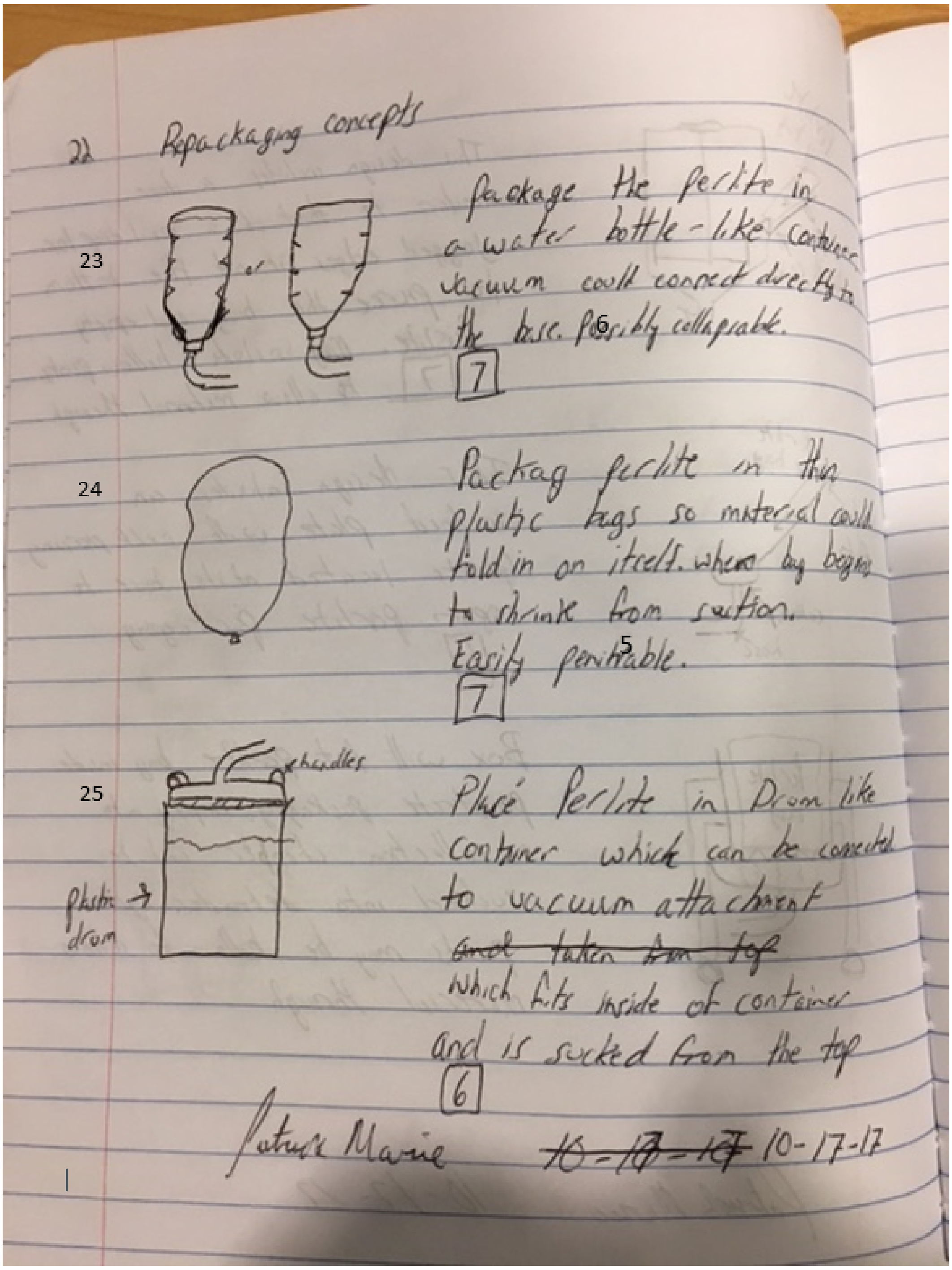
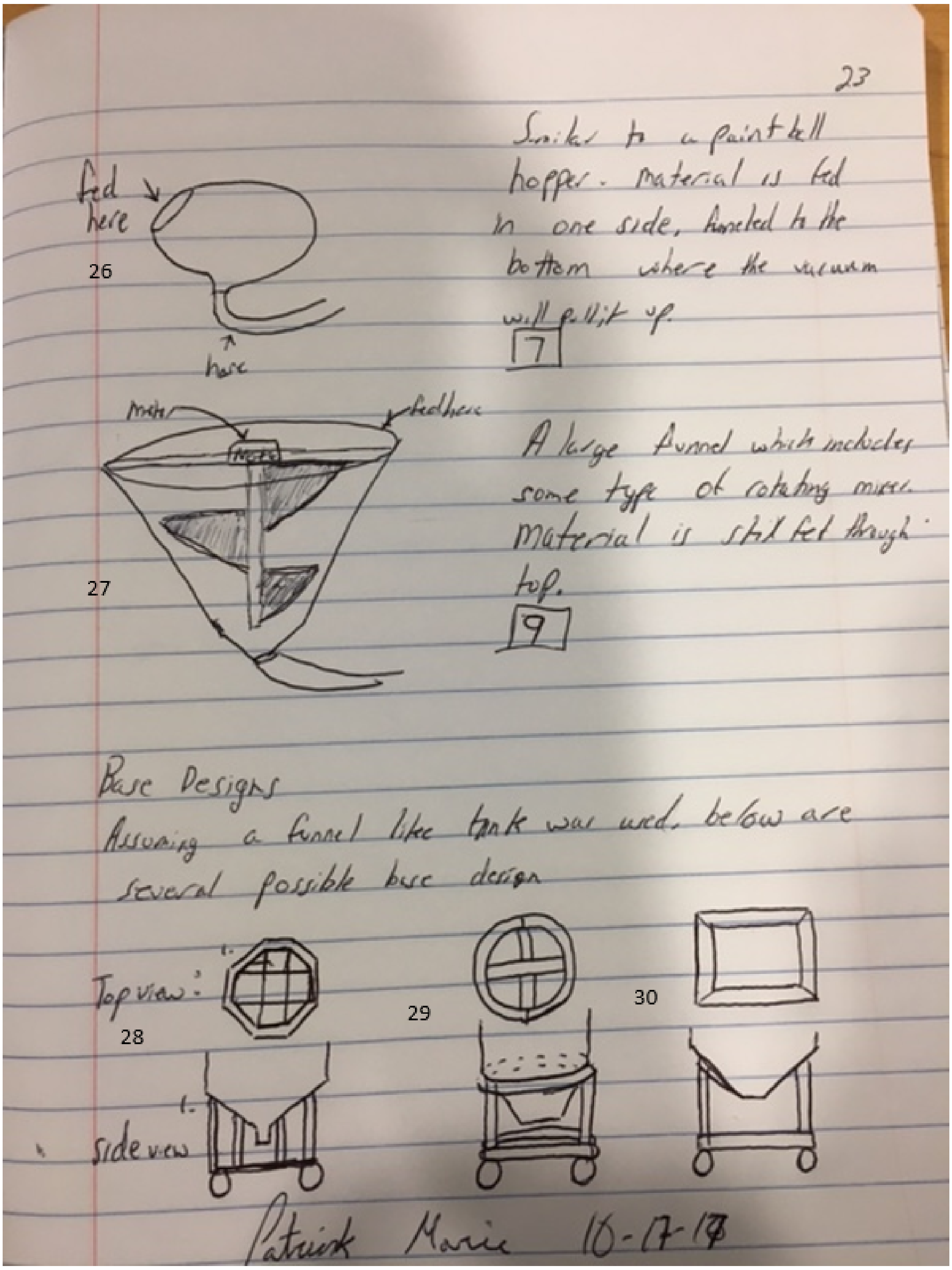


Figure 16: Patrick Marie Concepts 26-30



7.2 Nathan Bannon Design Concepts

The next set of concepts being analyzed were produced by Nathan Bannon and can be found in figures 17 through 31. A brief analysis can be found below, each number corresponding with the given design.

1. A cylindrical component with a conical shaped finish at the bottom to funnel the perlite material into the outlet connected to the vacuum; where it will eventually travel through and enter the Defender Filter. This is all meant to be a single, one piece body. This is what is believed to be the most pertinent body design for the function attempting to be achieved.
2. This is the same basic body design as the aforementioned concept, but it is two separable pieces, one being the cylinder and the other being the cone shaped base. This would perform identical functions but would be easier for disassembly and cleaning/maintenance.
3. This offers a variance in outlet size, and the subsequent vacuum attachment width. The larger the inlet vacuum width, the less likely it will be for the vacuum to become clogged. The major question with this design is if the force of the suction strong enough to compensate for the increased width.
4. This is a design for the dolly/mobility rig that will be attached to the chosen body design. This will allow maneuverability through confined spaces where the Defender Filter will be installed, or where existing Defenders are already installed. This is a basic dolly design with a simple rig that will be bolted to the body supported by four support beams. This also includes the possibility for the legs to be adjustable, which will aid in the loading of the perlite.
5. A trough shaped device that is oriented at a slope of roughly 50 degrees to create a gravity feed system. This could be beneficial for the loading of bag of perlite, as it wont need to be lifted so high. Trough walls will need to be high enough to avoid spillage of perlite over the sides; and could even be fully covered, lending to a hexagonal tunnel shape.
6. Imitates a cement mixer design, it will be a conical drum shape implemented on a slope of about 35-45 degrees, with a feeding trough at the inlet to the drum. There will be slanted fins that work like a cement mixer to funnel the perlite towards the outlet, where the vacuum will be attached.
7. Redesign of the first concept, but it is dimensioned shorter and wider. The bottom section is attached to a rotating motor at the bottom that implements a rotation of the bottom funnel. This will create a centripetal force that deters a build-up of the perlite, and creates a vortex-like flow towards the bottom of the body. Once there, the perlite will flow vertically upward through the vacuum.
8. Open trough design, which is wider in design and leveled at a steeper slope than the

aforementioned design concept 5. Additionally, a vibrating motor will be attached to vibrate the slide at a frequency adequate to agitate the perlite and avoid a build up along the slide. It will be attached to a wheeled rig to give it added mobility.

9. Attachment/component to improve the feeding of the perlite down the design concept 8. This will be a rectangular shaped box mounted on the top of the slide that the perlite bag can be put in and then opened up. There will be a small, less than 1 inch lip, to hold the entire bag from falling down the slide.

10. Another attachment for design 8âĂŹs body design. Shares the same relative idea as the rectangular box in the previous design, but there will be a hinge that can be slammed down onto the feeding end of the bag, that will open the bag with much less work being done than having to cut open the bag manually with the box cutter.

11. Another variation of the rectangular box feeding design that will be implanted into the body design of design 8. This will utilize a guillotine method of opening the end of the bag. The blade will be offset from the end of the of the box by about 1.5mm (.06 in). The major downfall with this design is the safety factor, it may not be an effective enough design to be worth the possible safety risk.

12. Original body design with the addition of a fan will be inserted into the body, attached by a rotating motor that is stationed in the center of the top lid. This fan must be set to a very low rpm setting, as a high rpm setting would result in a less than desirable irritation of the perlite; a dust cloud of sorts. The motor would only need to be active during short increments, when the flow is stagnant due to a buildup of the perlite on the walls of the body.

13. Shorter and wider variation on the original body. The cone section of the body will be significantly condensed. Spikes will be put on a platform between the cylindrical portion of the body and the cone portion. These spikes will open the bag when it is dropped through the top of the open body design. There must be a sufficient number of holes in the platform to allow a flow of the perlite. Also, the cone must be short enough that the vacuum suction is strong enough to aid the gravity flow, and allow a constant flow of the perlite. The platform must be strong enough to withstand the force of dropping a full bag of perlite on it, which has roughly 1125.95 lbf hitting it.

14. Rectangular box shaped design, that is stood vertically, and the perlite is fed into the top of it. The bottom of the box has a sloped edge that leads down to 6 or 7 vacuum feeds, that create and exit flow from the box and meet up at a central pipe. The slope of the bottom of the box will be about 35 degrees. Additionally, vibrating motors will be attached to either side of the box to aid the flow of the perlite down the sloping bottom and into the inlets of the tubes.

15. Same basic body as concept 14, except with a different vacuum feeding method being implemented. The bottom will have open flowing spikes that run the width of the bottom of the box, with a possible implementation of two tubes with open flowing spikes that lead to a central V shaped tube connected to the central vacuum leaving the body and flowing to the filter. The dimensions of the design must be barely larger than the perlite bag, as it is beneficial for the bag to be almost flush to the edges of the box. The major difference between the feeding method of this design as opposed to the previous design is that the bag can be loaded into the design unopened. This saves the labor time that it takes to open the bag manually.

16. Box fed design, wider than the concept 15, as the other design was required to be only slightly larger than the perlite bag. This requires the bag to opened previous to loading. The perlite is dumped into the box and is funneled at the bottom by a 3 way sloping shape. A vibrating motor is attached to one of the sides in order to create a frequency vibration of the slopes. These slopes will lead to a vacuum at the bottom that leads to the filter.

17. Repackaging idea that can possibly generate revenue from resale values of perlite directly from Neptune Benson. It will be branded with the company name, and it will be advertised as genuine high grade perlite. This will be compatible with a specific design, as shown in concept 18.

18. Utilizing the repackaged perlite, the drum will be placed in the sloped semicircle holder at about a 45 degree angle. The vacuum will be attached to the opening of the perlite container. You can manually spin the barrel to agitate the perlite, or an additional motor could be installed to rotate it automatically.

19. Incorporating the body of concept 1, a rotating motor installed will be installed on the top of the container and run down the center of the body with four or five paddles attached to the rotating shaft. These paddles can be analogized to a baking spatula used in cooking, used to scrape the batter of the sides of a bowl. Hopefully this will hopefully rectify the issue of perlite build up along the walls of the container.

20. Another derivation of concept 1, this design uses the same motor technique used in the previous concept 19. However, the rotating shaft has a spiral shaped design that reaches almost to the surrounding walls of the body. A potential drawback of the design is that it may not cover enough surface area along the edges of the container to adequately reach the stagnated perlite areas.

21. This uses the repackaged drum of perlite again, and uses the same exact rig that the drum will be installed into. However, it will be put on a larger slope, and will be fed into a slide with vibrating motors attached on it to enhance the flow of the perlite down the slide to the central

vacuum.

22. Addressing one of the more prevalent issues in many of the concepts, this design is meant to minimize the labor input required for the loading process. This concept attempts to be rectify this issue through the implementation of a hinge door design on the side of the body.

23. Implements the same hinge door design as described in concept 22, but at the end of the hinge door there will be a piercing device that will open up the bag. This will cut out the work needing to be done with the box opener to open the perlite bag. Due to possible issues with stability, the hinge door may need to be longer than it is in the previous design to accomplish this, and may need a support hinge that will hook into a shallow cut in the side of the body.

24. Rotational device used to scrape the walls of the concept 1 body, and agitate the perlite to maintain the flow towards the bottom of the design. This is using two rectangular paddles that will be attached to a central horizontal bar attached to the vertical bar rotating from the motor. These paddles will be flush to the sides of the body during their rotational cycles.

25. Cylindrical body, open container design that implements four vibrational motors attached equidistant along the circumference of the container. Equal distribution around the container will disturb any buildup along the walls of the body, and allow the flow to be continuous towards the bottom where the vacuum will be stationed.

26. Vertically positioned rectangle that leads on a steep downward slope towards a semi-circle slide that eventually leads towards the vacuum entrance. Addition of a spiked end to the rectangular loading box will be porous enough to allow flow of the perlite through it due to gravitational force.

27. Downward sloping slide that the perlite is manually dumped down. From there it flows down to a large bowl shaped body that has a motor slowly rotating around the bottom end of it. This will disturb the perlite enough to maintain flow towards the bottom of the bowl where the vacuum will eventually suction the perlite through and into the Defender Filter.

28. Cone design that has a motor stationed at the top in the middle of the cone, supported by beams stemming from the sides. The rotational motor is attached to a four-pronged bit whose components will be flush to the sides of the cone during their rotation. The vacuum will be placed at the bottom of the funnel.

29. Simple mixing design that implements a large bowl-shaped container. This is attached to a rotating base that is run by the motor within it. The base is attached to the sides of the container, making it a singular moving piece. This rotation will ensure there is no build up of perlite on the walls of the container. The vacuum will stem from the bottom of the bowl and through the rotating base.

30. Refined version of design 29 that uses a lid to avoid any possible mess that is caused by the

perlite being rotated around in the container. This is likely due to the behavior of the perlite when agitated in this manner, as it has the tendency to cloud up very easily. The container should be rotated in short cycles as needed, which can be programmed on a timer, as it does not need to be in perpetual motion.

31. The perlite is dumped in a cylinder attached to a cone, while the cone is hooked up to a rotating motor that turns the entire cone at the bottom, similar to what is seen in design 30. The vacuum is once again hooked up at the bottom, as this is primarily a gravity fed device. A flow regulating valve is hooked up at the inlet in order to allow a manual cut off of the flow if needed.

Figure 17: Nathan Bannon Concepts 1-5

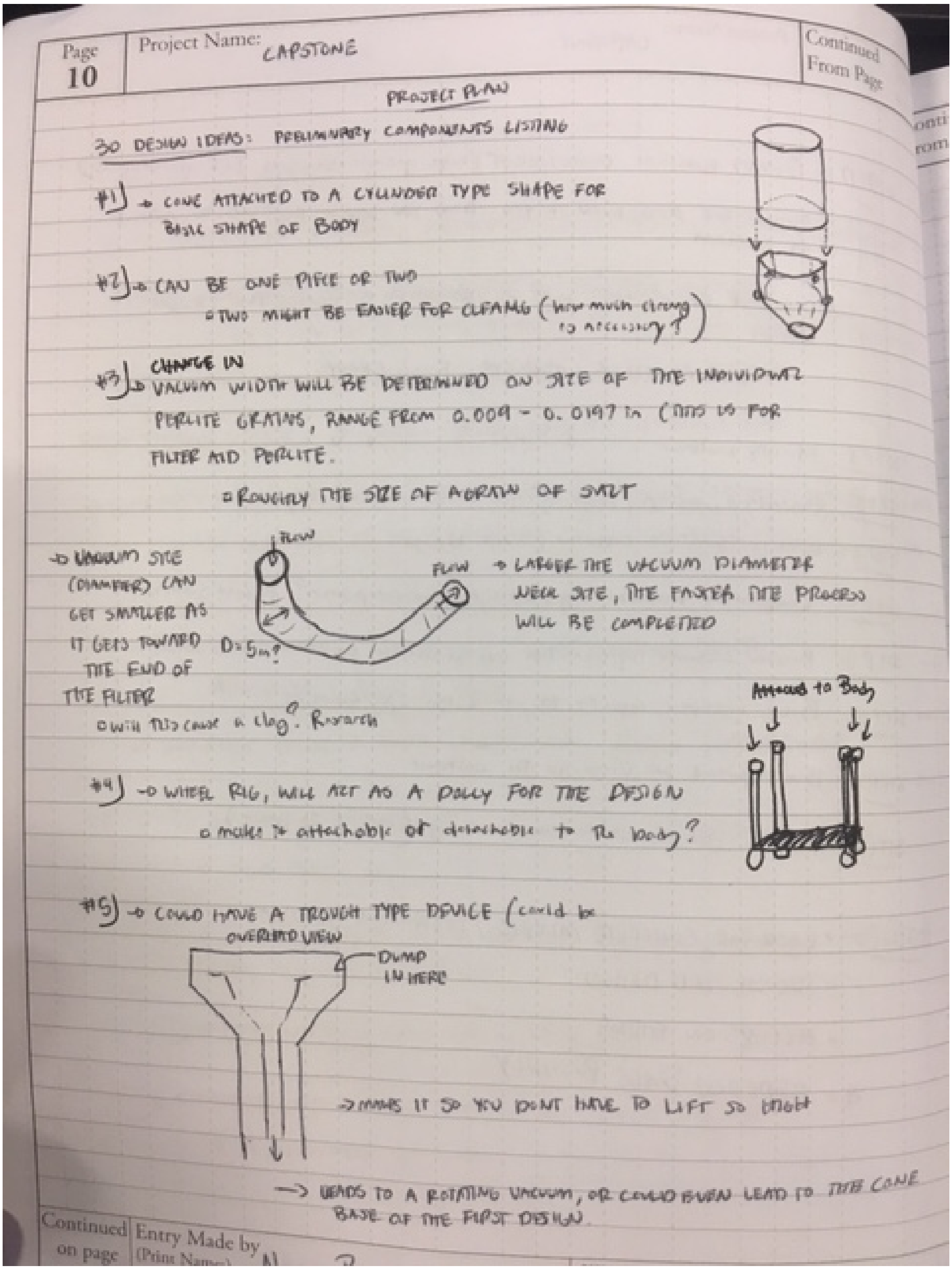


Figure 18: Nathan Bannon Concepts 6-7

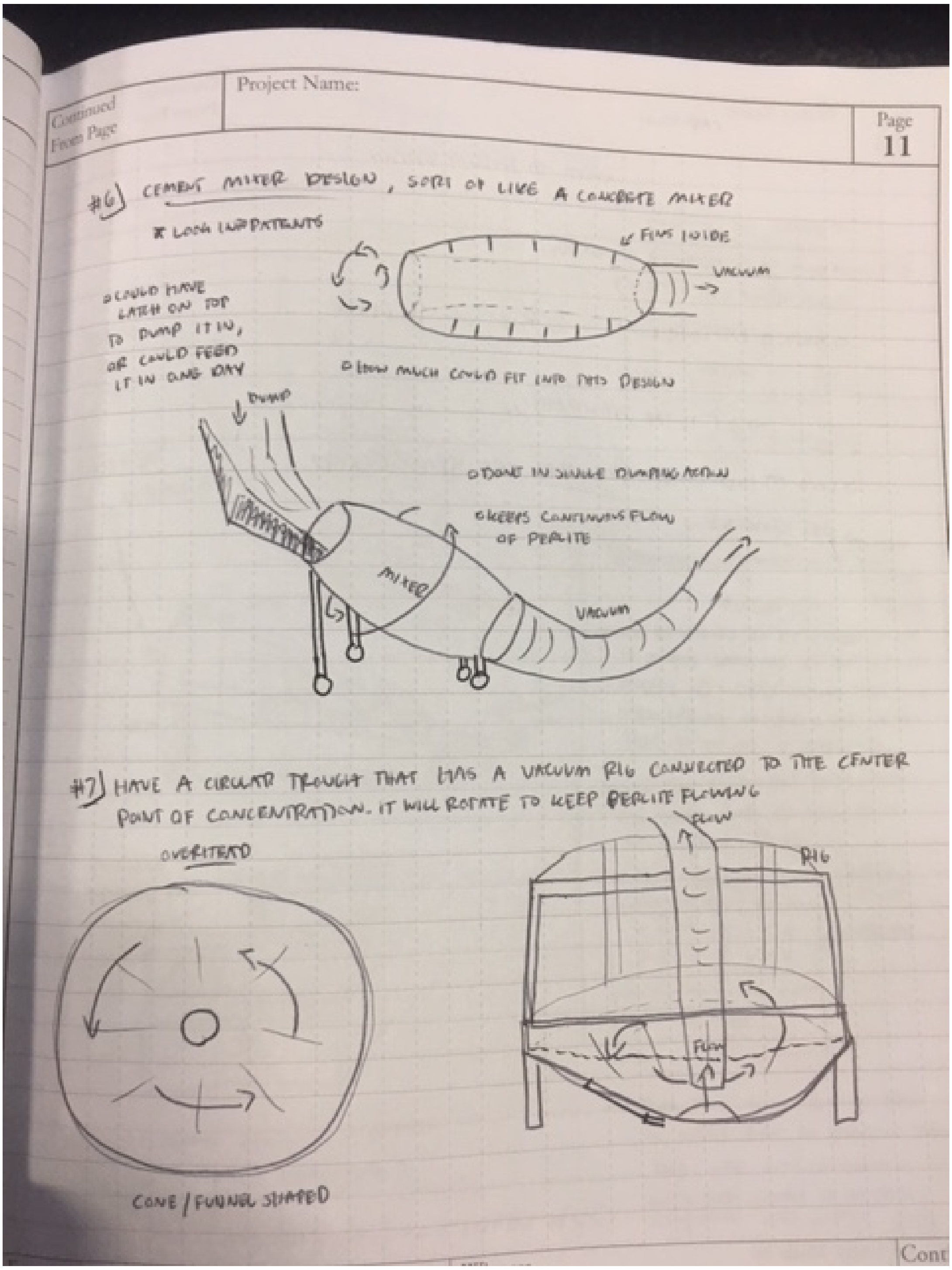


Figure 19: Nathan Bannon Concepts 8 and 11

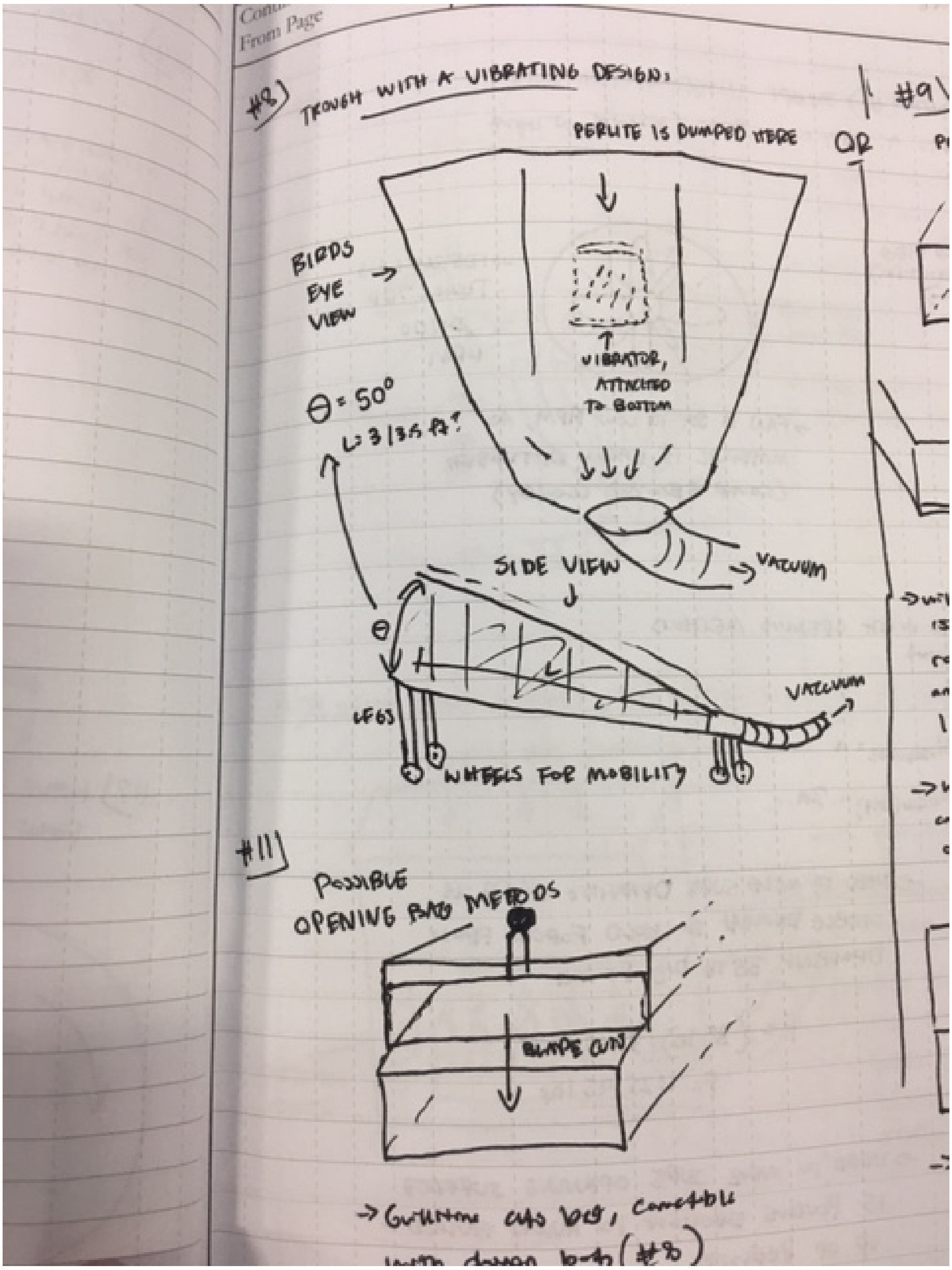


Figure 20: Nathan Bannon Concepts 9 and 10

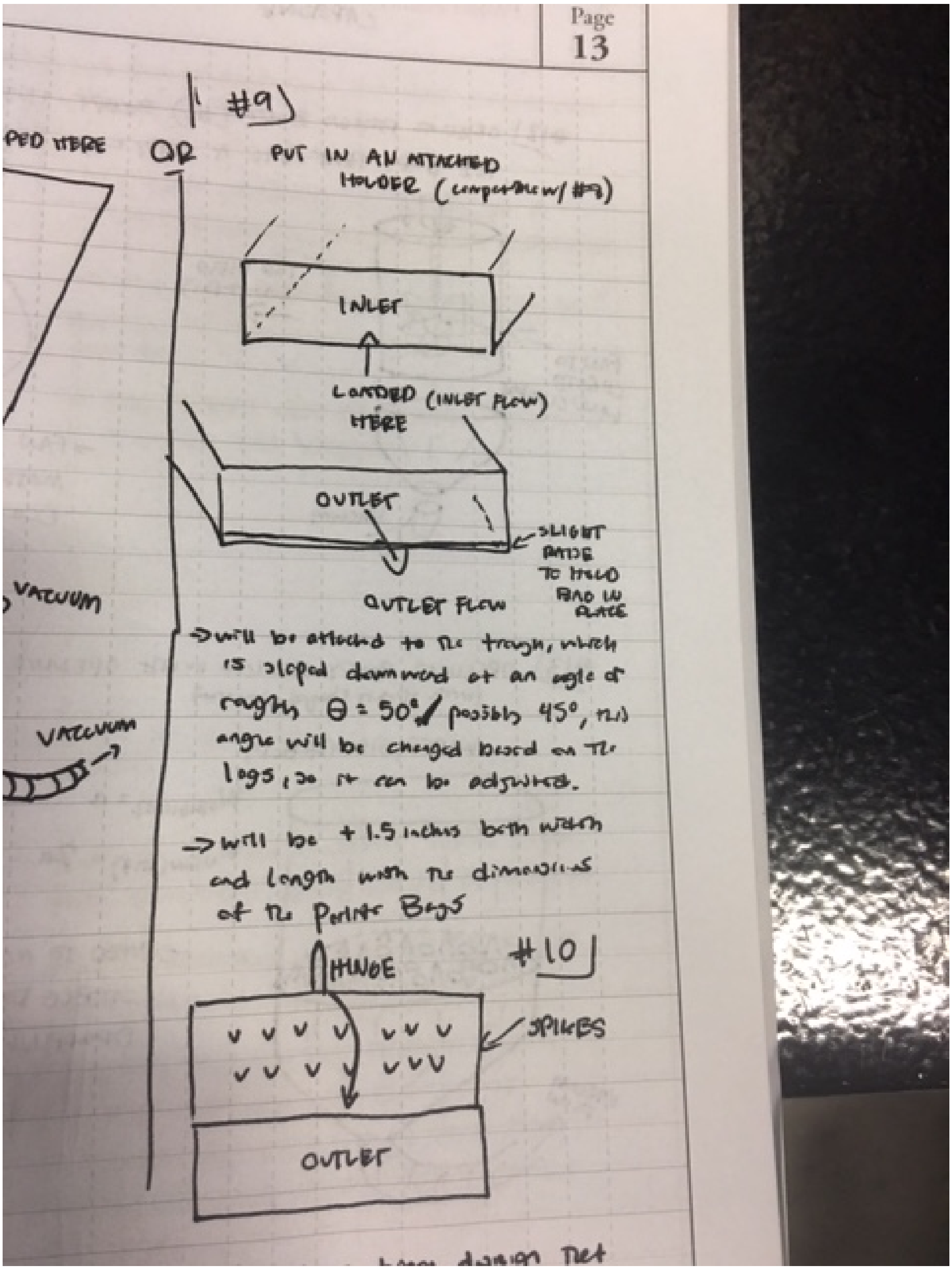


Figure 21: Nathan Bannon Concepts 12-13

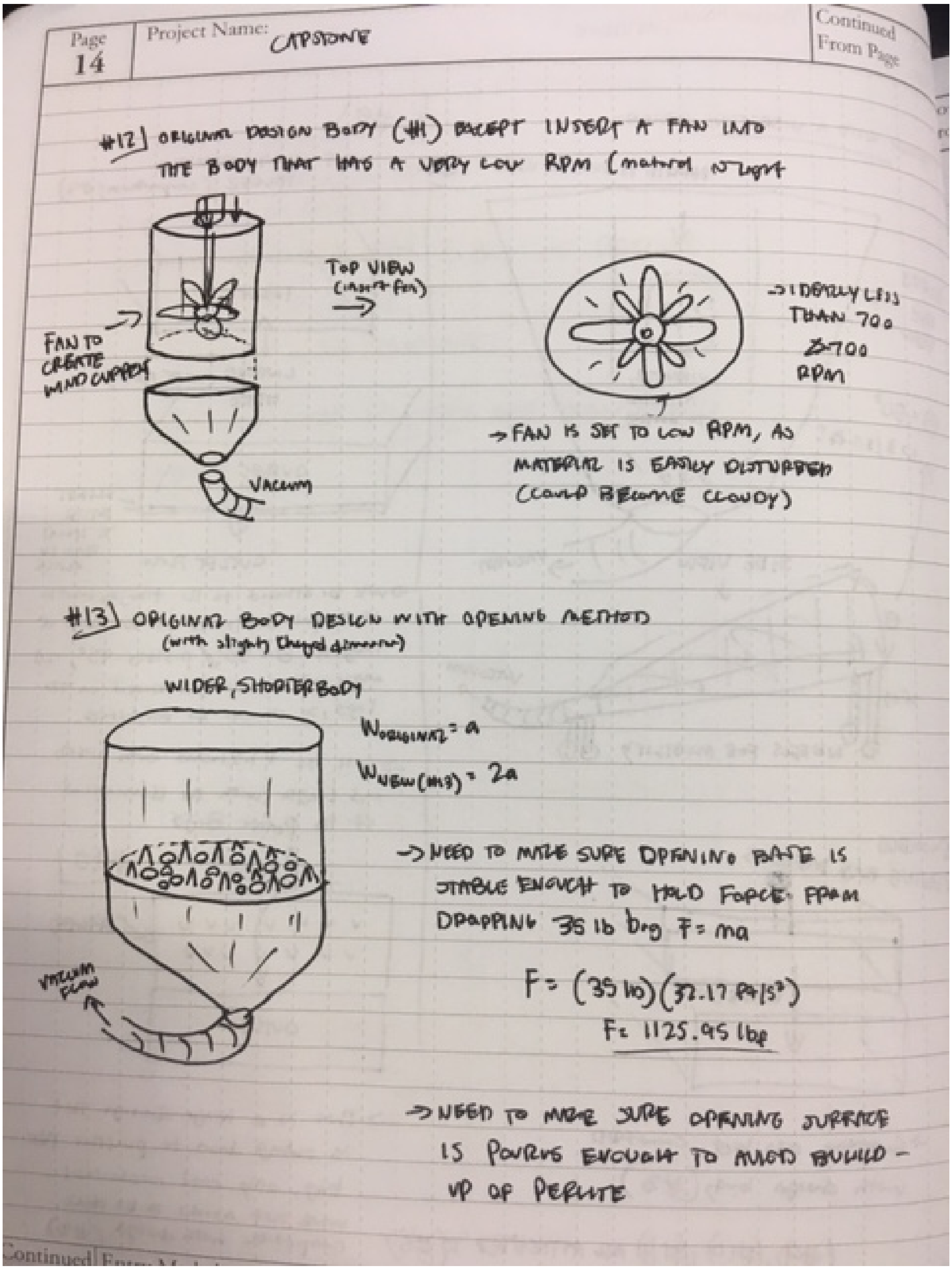


Figure 22: Nathan Bannon Concepts 14-15

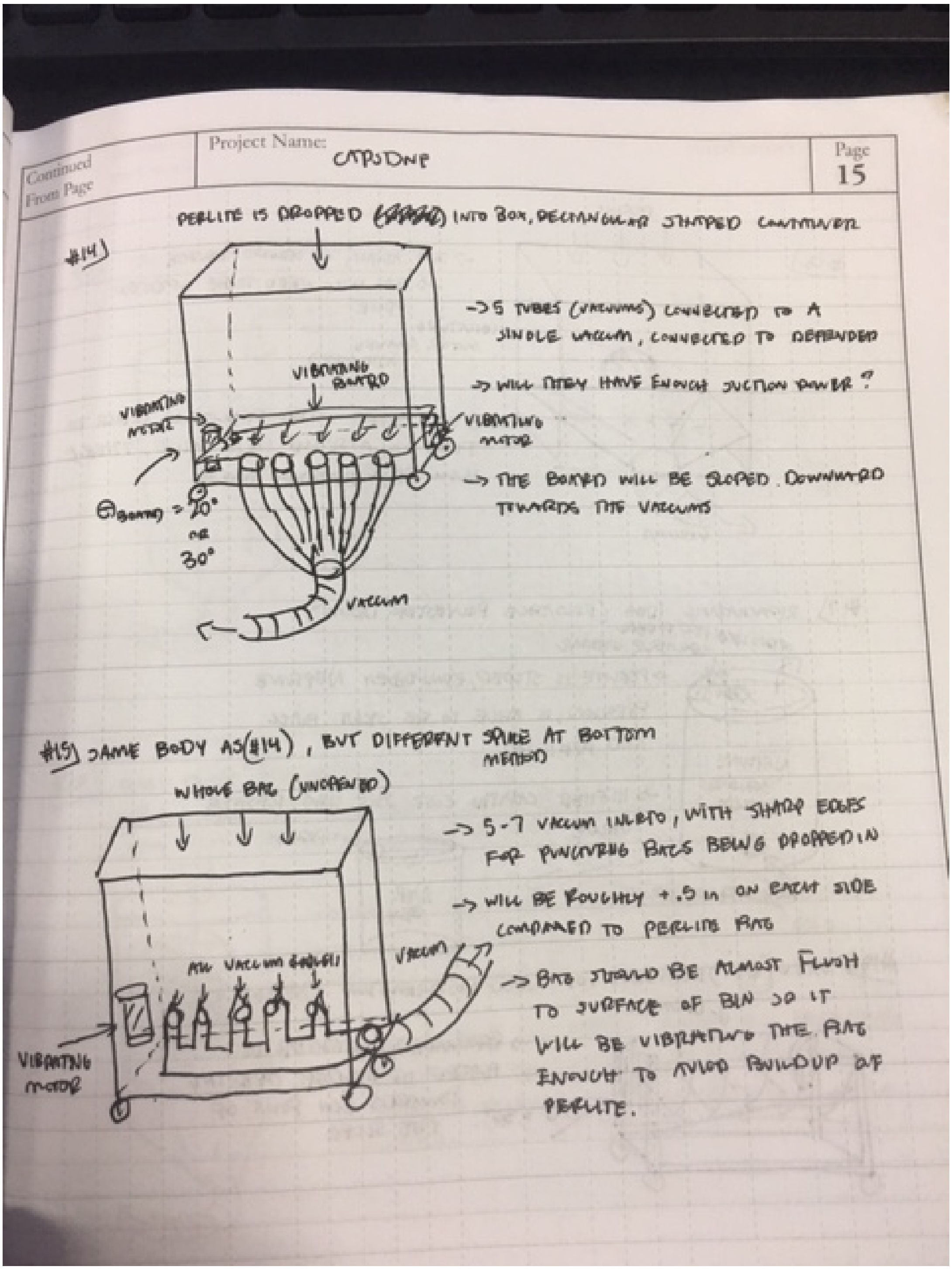


Figure 23: Nathan Bannon Concepts 16-18

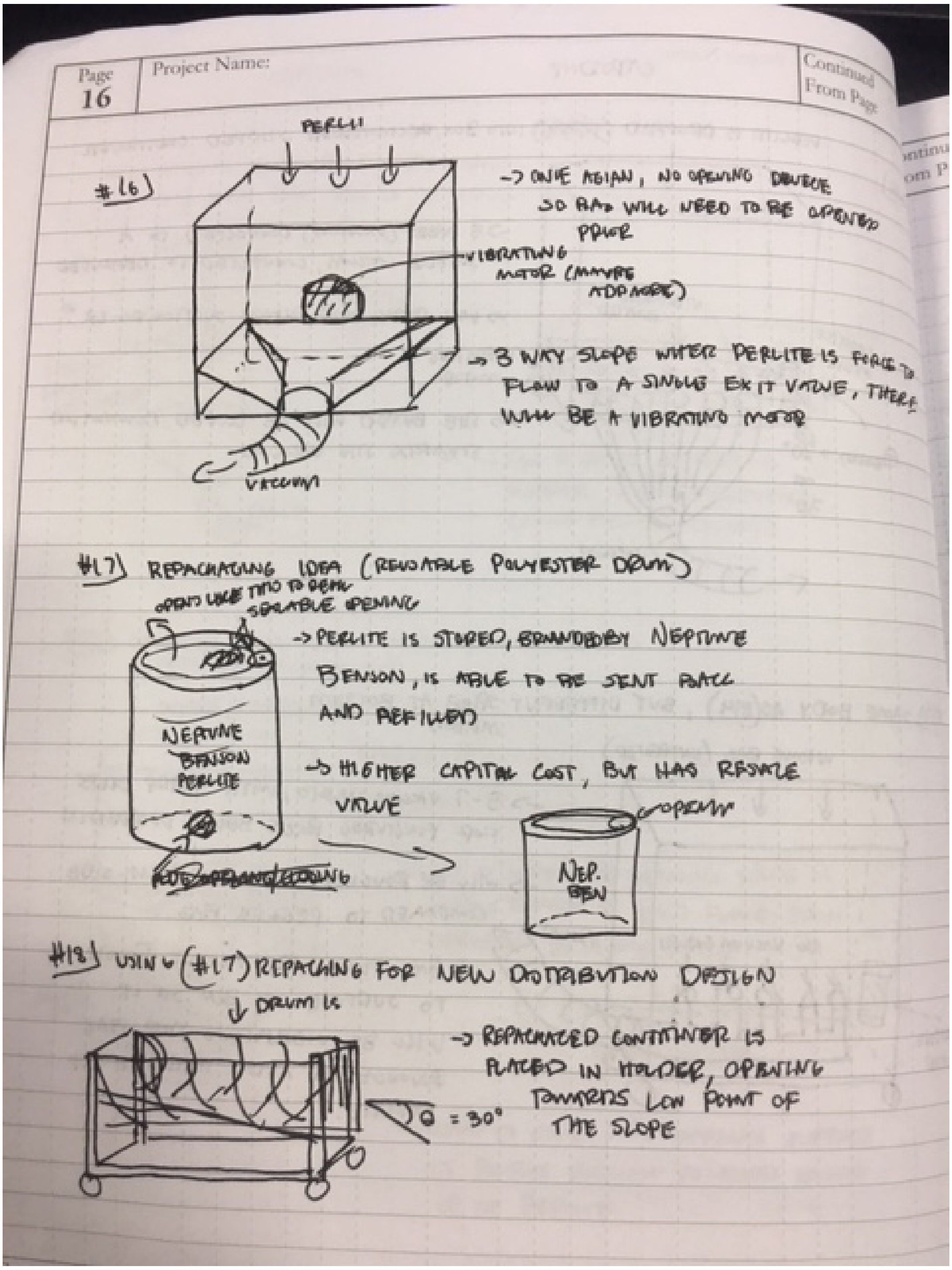


Figure 24: Nathan Bannon Concepts 19-20

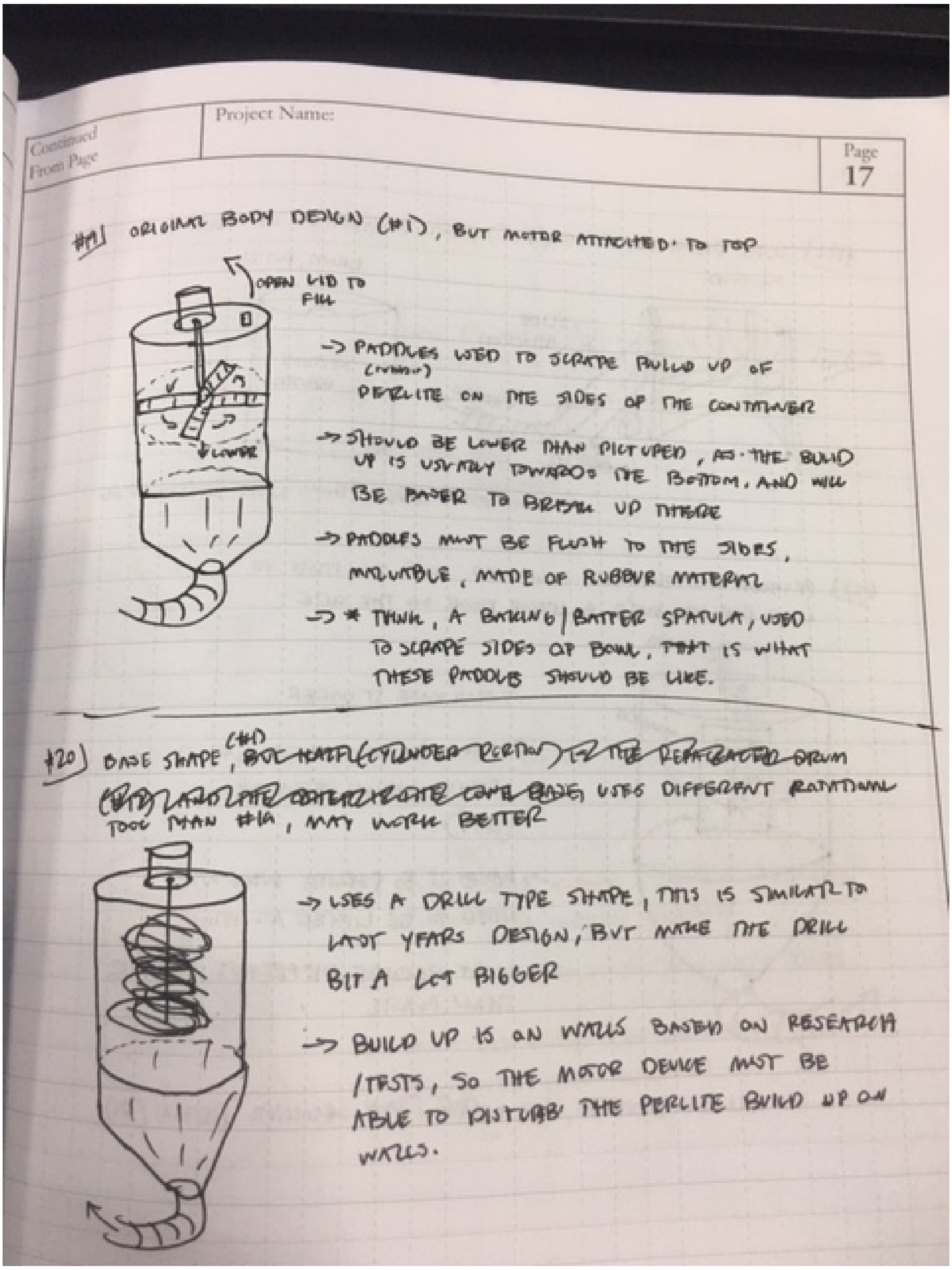


Figure 25: Nathan Bannon Concepts 21-22

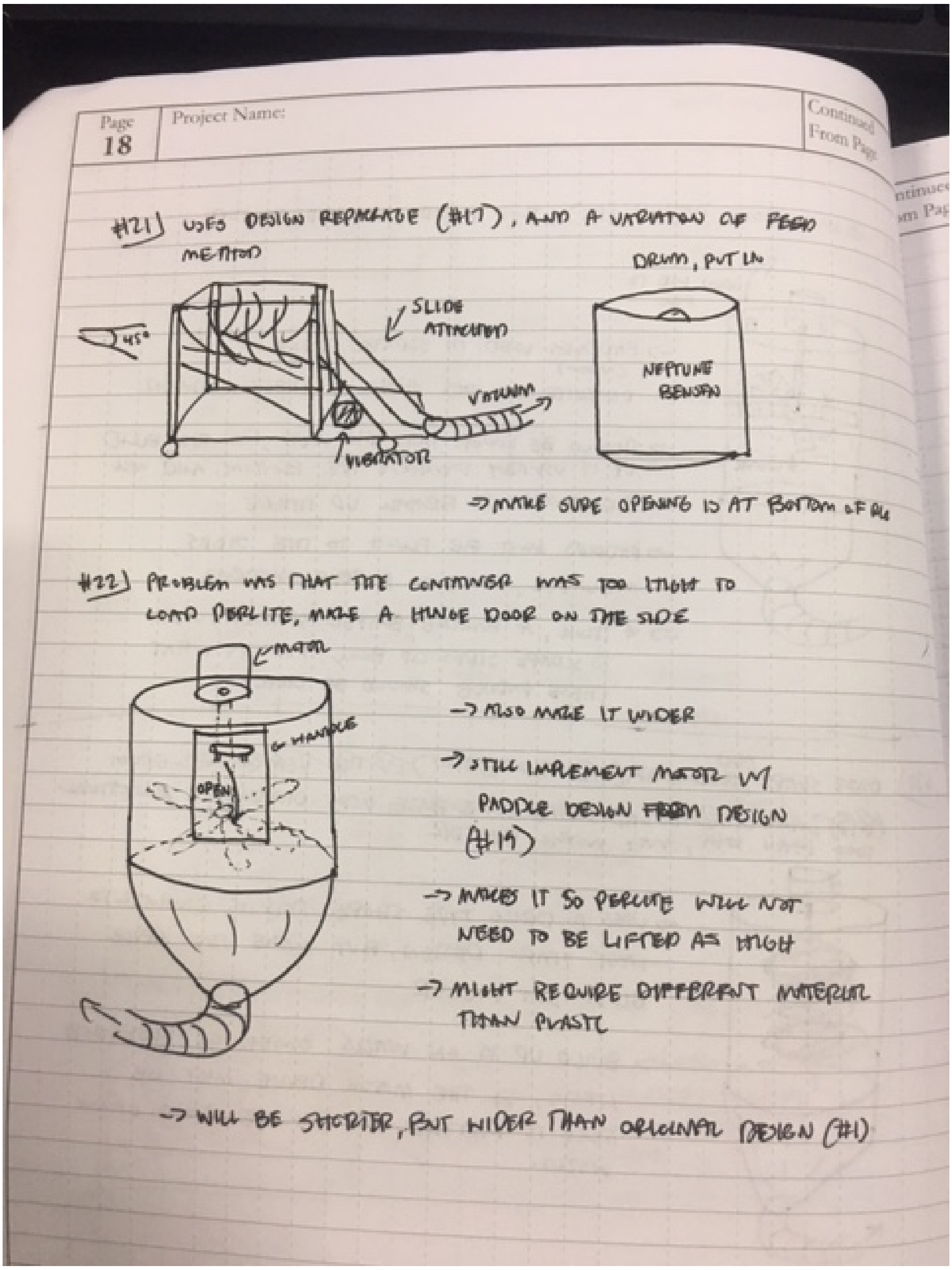


Figure 26: Nathan Bannon Concepts 23-24

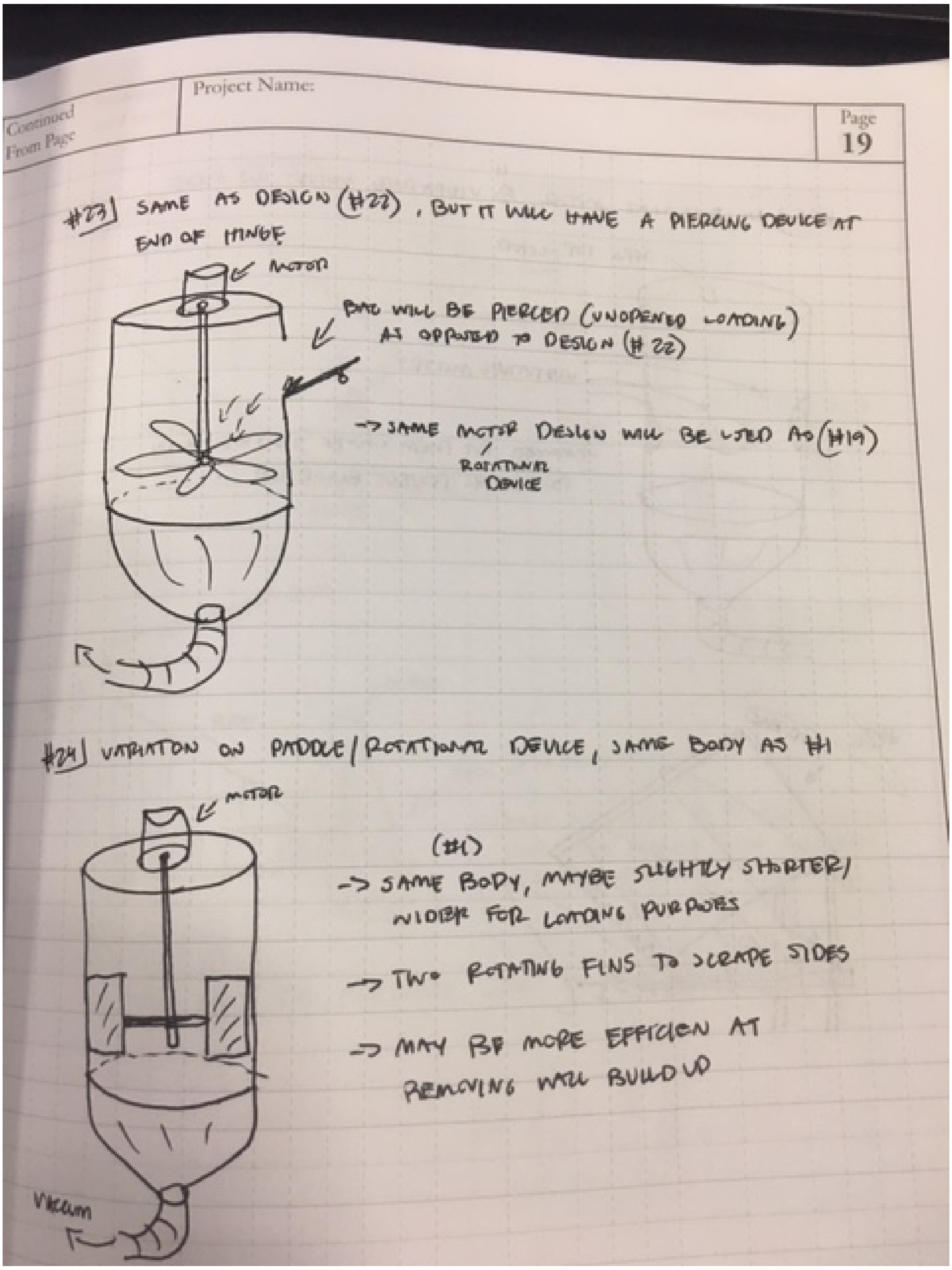


Figure 27: Nathan Bannon Concept 25

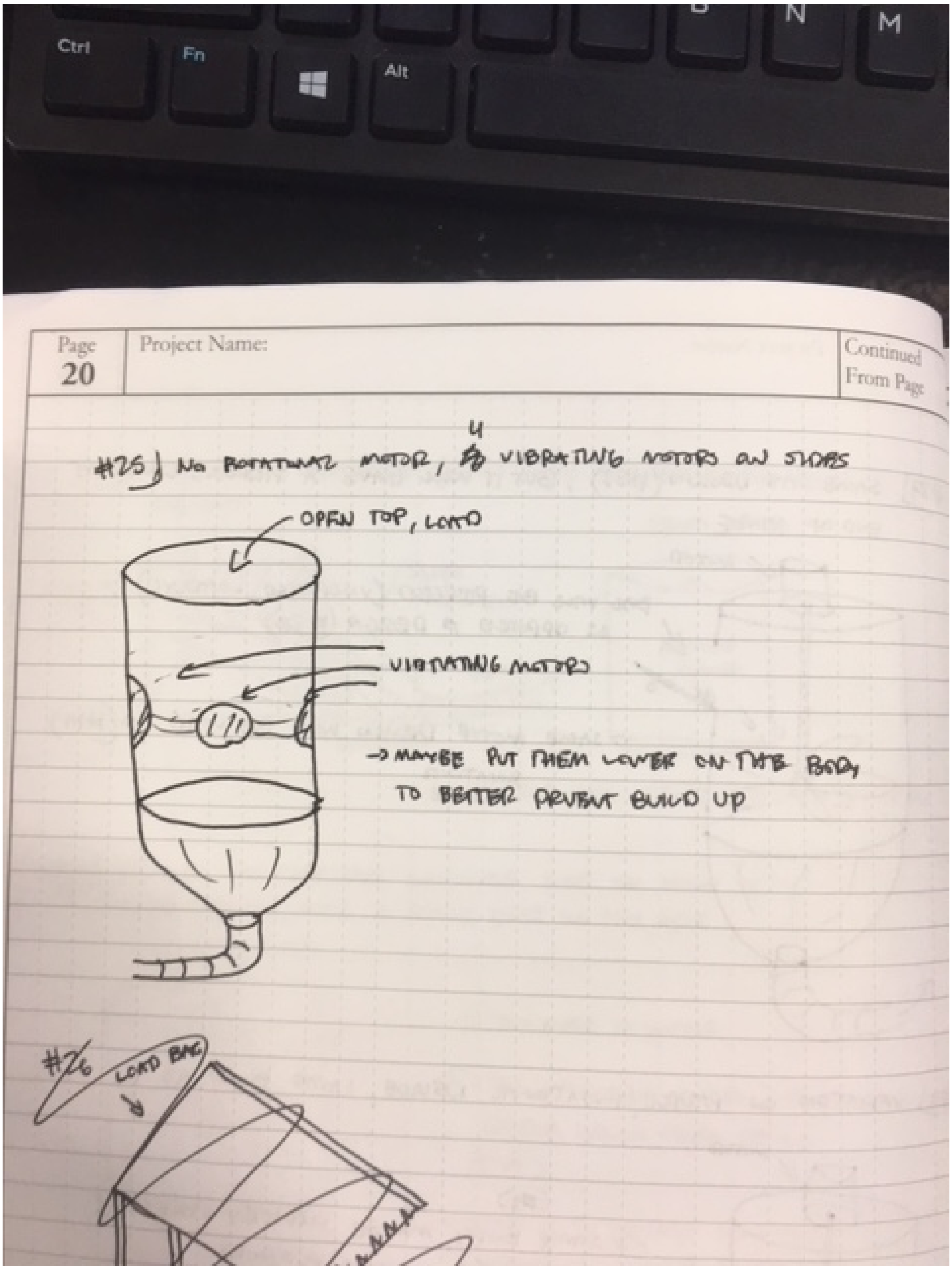


Figure 28: Nathan Bannon Concepts 26-27

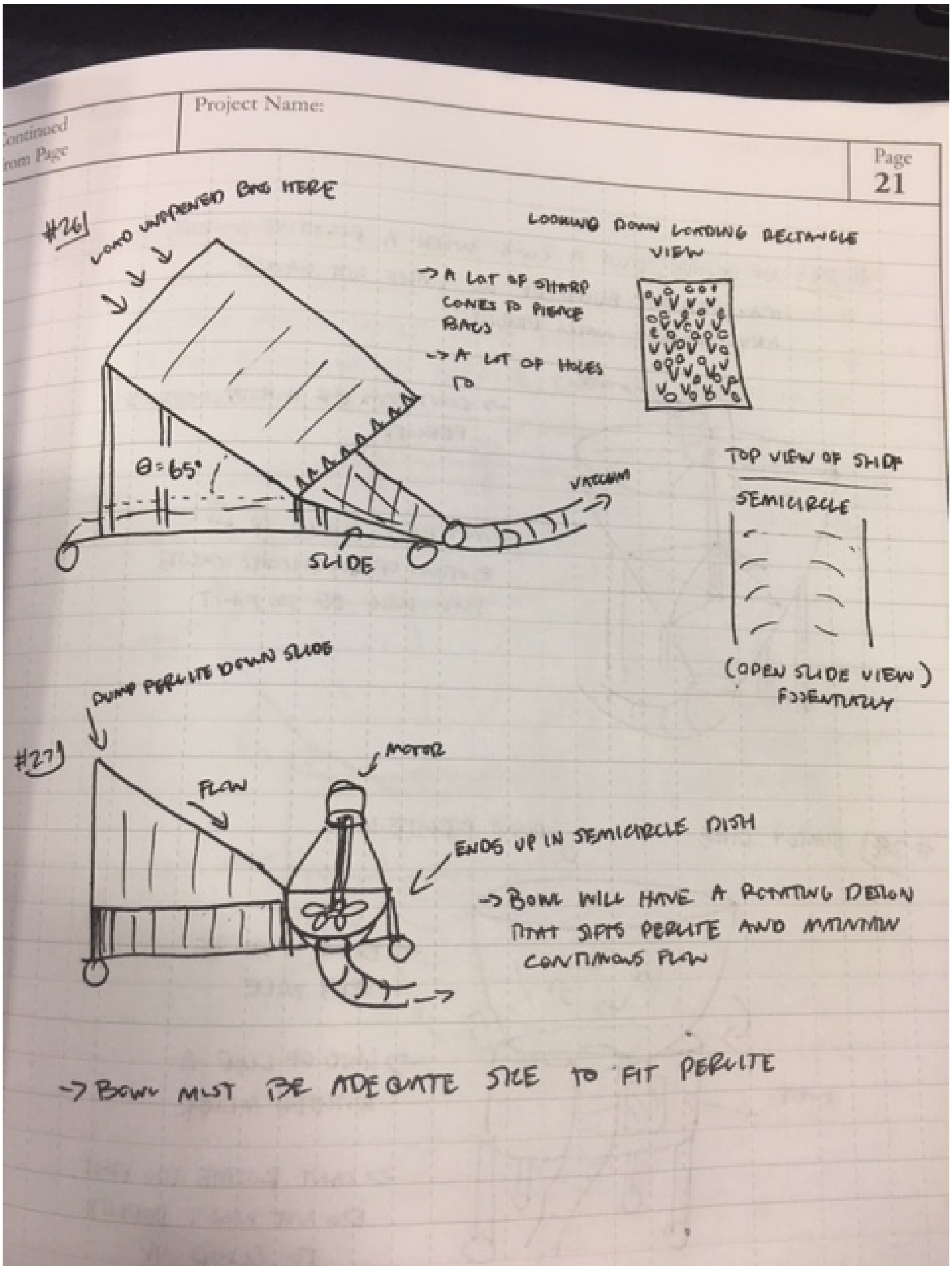


Figure 29: Nathan Bannon Concepts 28-29

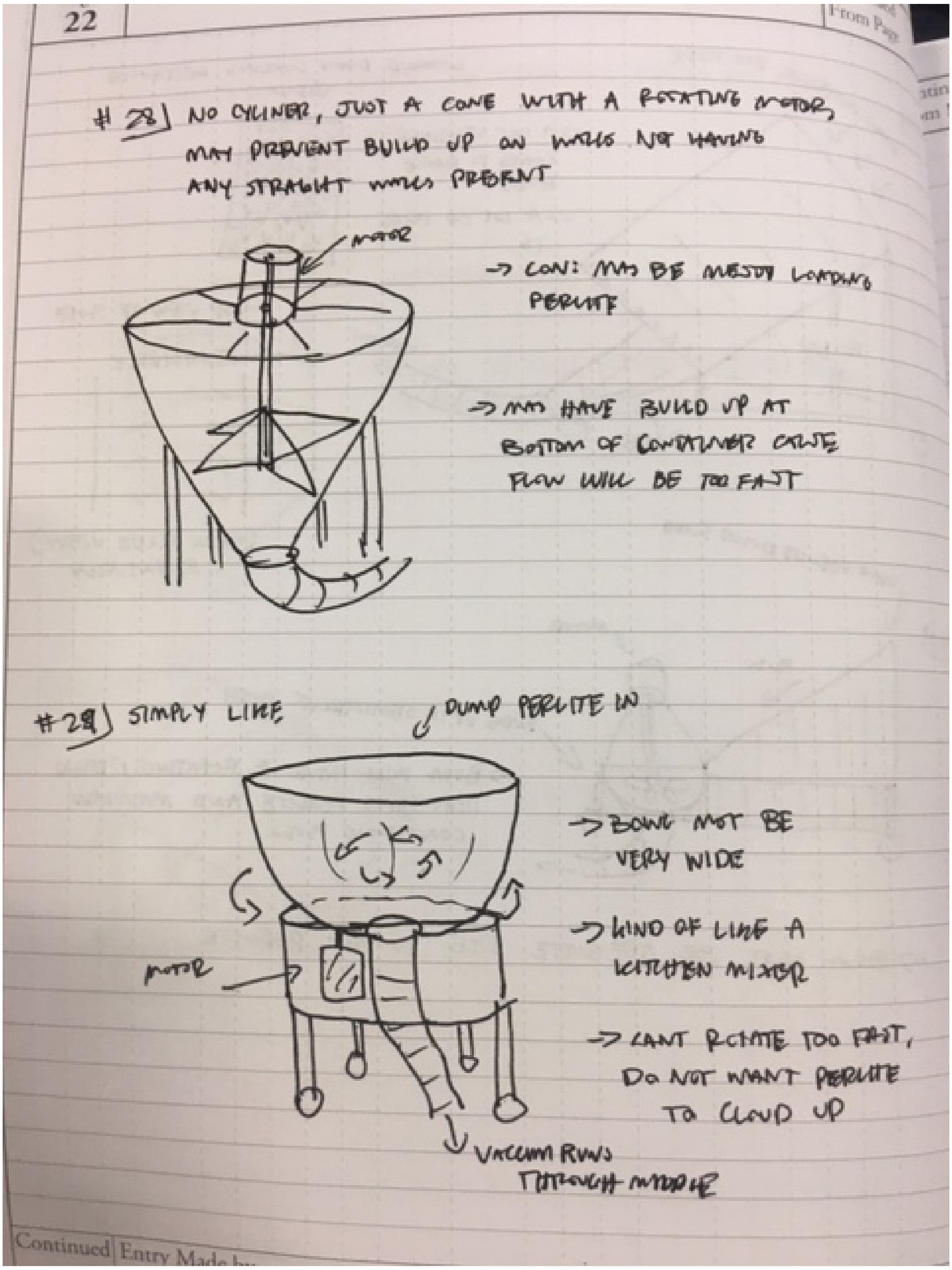


Figure 30: Nathan Bannon Concept 30

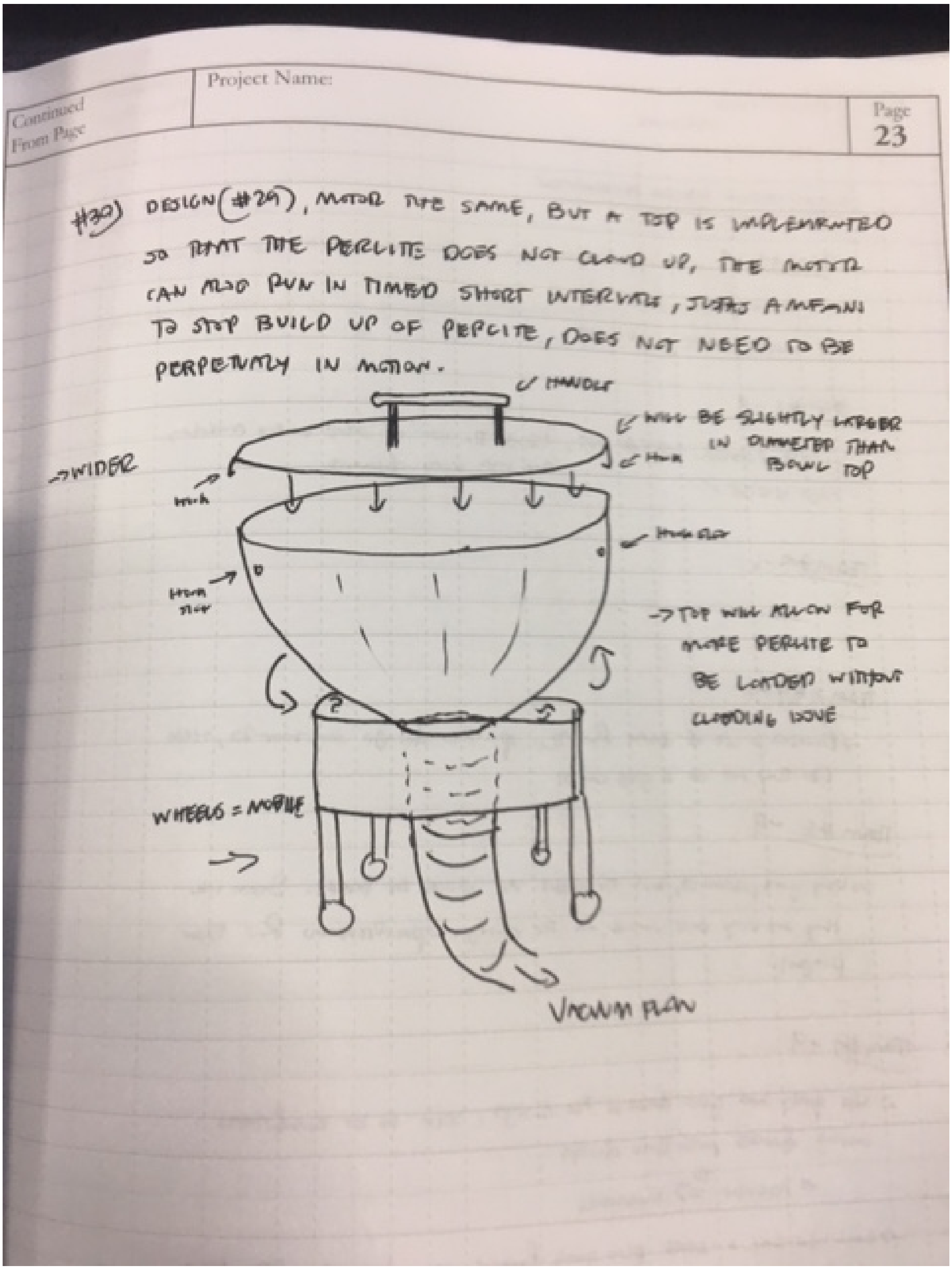
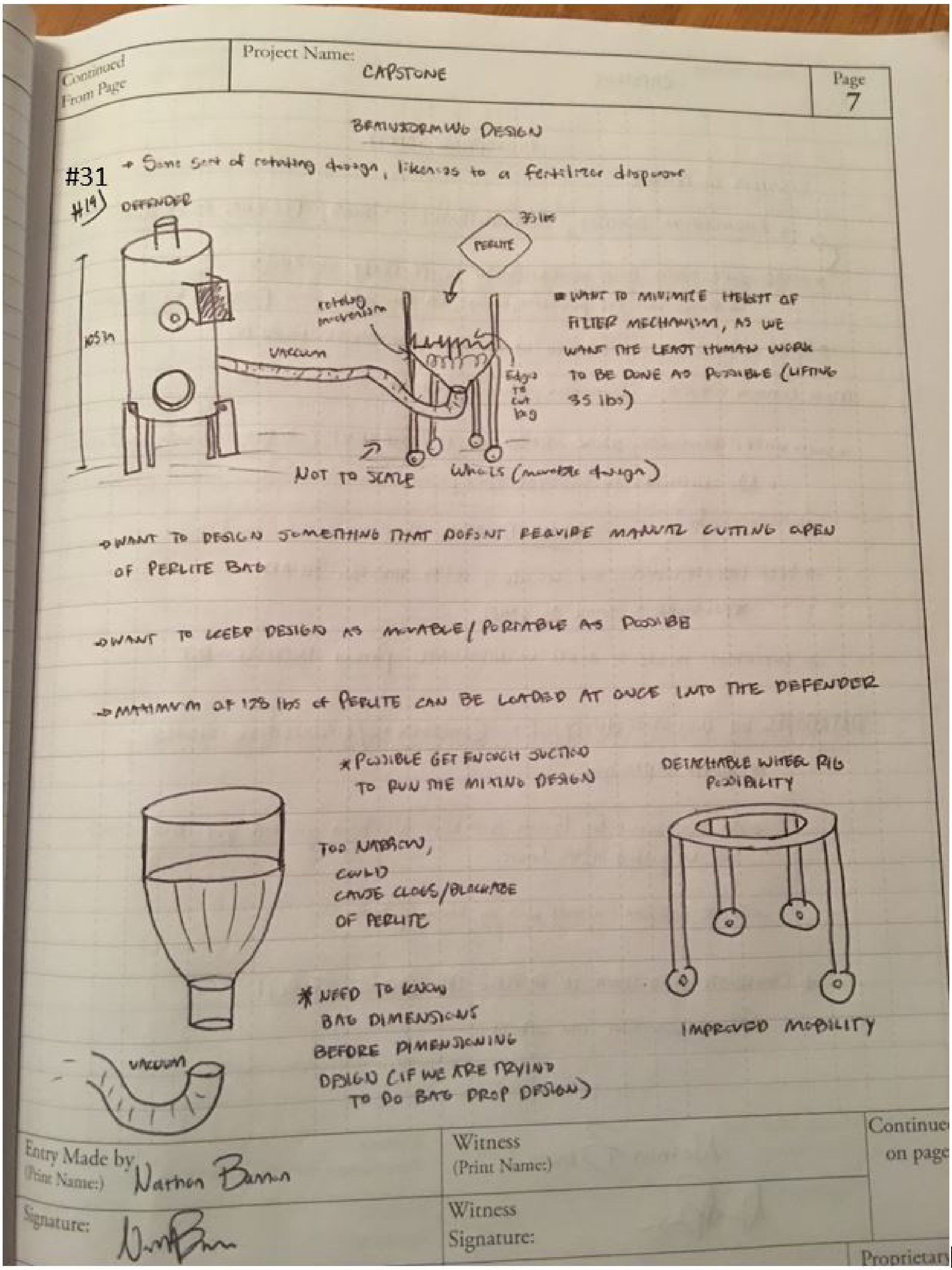


Figure 31: Nathan Bannon Concept 31



7.3 Jimmy Dunwoody Design Concepts

The next set of concepts being analyzed were produced by Jimmy Dunwoody and can be found in figures 32 through 40. A brief analysis can be found below, each number corresponding with the given design.

1.This idea was the first idea that came to mind because gravity would just pull the perlite into the vacuum while a mixer mixes it.
2. With this design it uses a motor with an auger on top of the drum which would stir the perlite. The drum would then be loaded through the side where a door on a hinge would be placed.
3. Since the perlite gets caught on itself and builds up this design uses vibrators which would be able to keep the perlite from building up on the sides of the drum and moving down into the vacuum.
4. Since perlite is jagged it gets stuck on itself so the metal screening will sift it so it falls into the vacuum hose broken up preventing clogs.
5. In this design the perlite falls onto a propeller that is mixing the perlite so a constant flow gets sucked in by the vacuum.
6. This design uses a sifter followed by a mixer that reaches both sides of the bin. This is in place so that no perlite can build up on the sides of the drum.
7. In this design a blade would be placed at the top of the drum and would be used to break open the bags of perlite. This would allow for easy loading since the bags would break and the perlite would fall into the drum.
8. This design uses steel tubes to break the bag open when dropped in. Below the bag is a screen which will sift and break down the perlite to prevent clogging and build up.
9. With this design the razor is placed on a bag holder and slides across the bag to cut open the top. Once the bag is open the operator lifts the handle dumping the bag into the drum.
10. In this design a hose is attached to a clamp that attaches to the top of the bags. Once attached a motor pushes the hose down into the bag slowly while rotating it to pick up the perlite.
11. With this design the drum sits on a bearing stand which rotate spinning the drum and then the perlite falls through to the screen and then to the vacuum.
12. This is a cement mixer design that when spinning the perlite gets broken up by the fins on the inside and then falls into the vacuum.
13. This opening design is to make sure that the bag doesnâĂŹt fall into the drum after loading. Since it is crossed the bag will make contact every time and break open to minimize

loading time of the drum.

14. When opening the bags for dumping this razor attached to the side of the drum would precisely slice the bags. It would be more efficient then manually opening the bag and be a simpler solution then a person cutting them.

15. In this design the perlite drops into the drum and then is sifted the table by the vibrator into the hose of the vacuum.

16. In the meeting with the sponsor they talked about changing the packaging design which is what this design demonstrates. The drum is reusable and can be refilled and shipped to the desired customer and all the customer would have to do is hook up the vacuum and turn on the mixer.

17. With this design the drum will be collapsible for storage and also for when the defender doesnâĂŹt need all 5 bags of perlite.

18. If the cement mixer has fins that are reverse threaded which would bring the perlite that is piled at the bottom of the drum to the top where the vacuum is.

19. Once the perlite is added to the drum a metal disc would go down the top and put a small pressure on the perlite as vibrators break the material up through the screen.

20. Since the drum has to hold 5 bags it will be big so a side access would be a good way to load the drum and minimize the manual labor.

21. When the bags are thrown into the drum one of the 4 blades will slice the bag open. The screen will catch any of the bag but will let all the perlite fall through to the vacuum.

22. This twist shut off valve will twist a ball on the inside of it stopping the flow of perlite to the vacuum.

23. This steel plate will be able to slide in and out to open and close the flow of the perlite into the vacuum of the Defender unit.

24. When the bag is dropped into the drum it is punctured and the perlite falls onto the vibrating table to the vacuum hose.

25. The shape of this vibrating table will help with not having a buildup of perlite on the sides also the screen will help break it up as the table vibrates.

26. As perlite is loaded onto the hopper the blades spin breaking it up and pushing it to the vacuum.

27. Similar to a feeder found on farms the perlite falls on top of the plate until it is disrupted by the vibrators which then drops it to the vacuum.

28. Since a cone is completely smooth on the inside it would be hard for the perlite to build up and stick to the sides but with added vibrators it would fall smoothly into the vacuum without building up.

29. Since the perlite is not good to breathe in a lid would help with the dust. A plexi-glass lid would be best so that you can see the level of the perlite.
30. This design would be the optimal design because it moves the material twice while being enclosed not allowing any particles to get into the operators lungs.

Figure 32: Jimmy Dunwoody Concepts 1-3

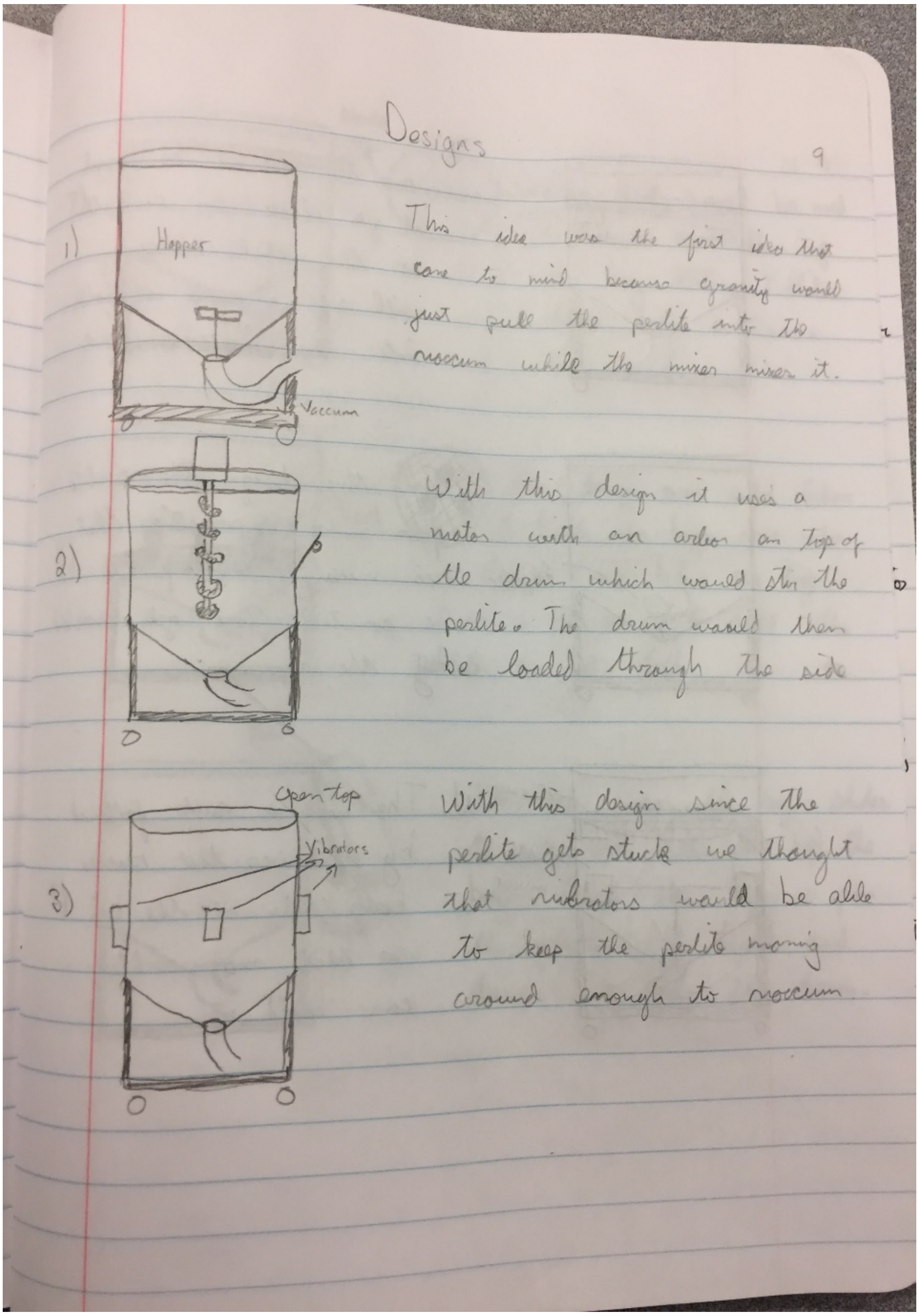


Figure 33: Jimmy Dunwoody Concepts 4-6

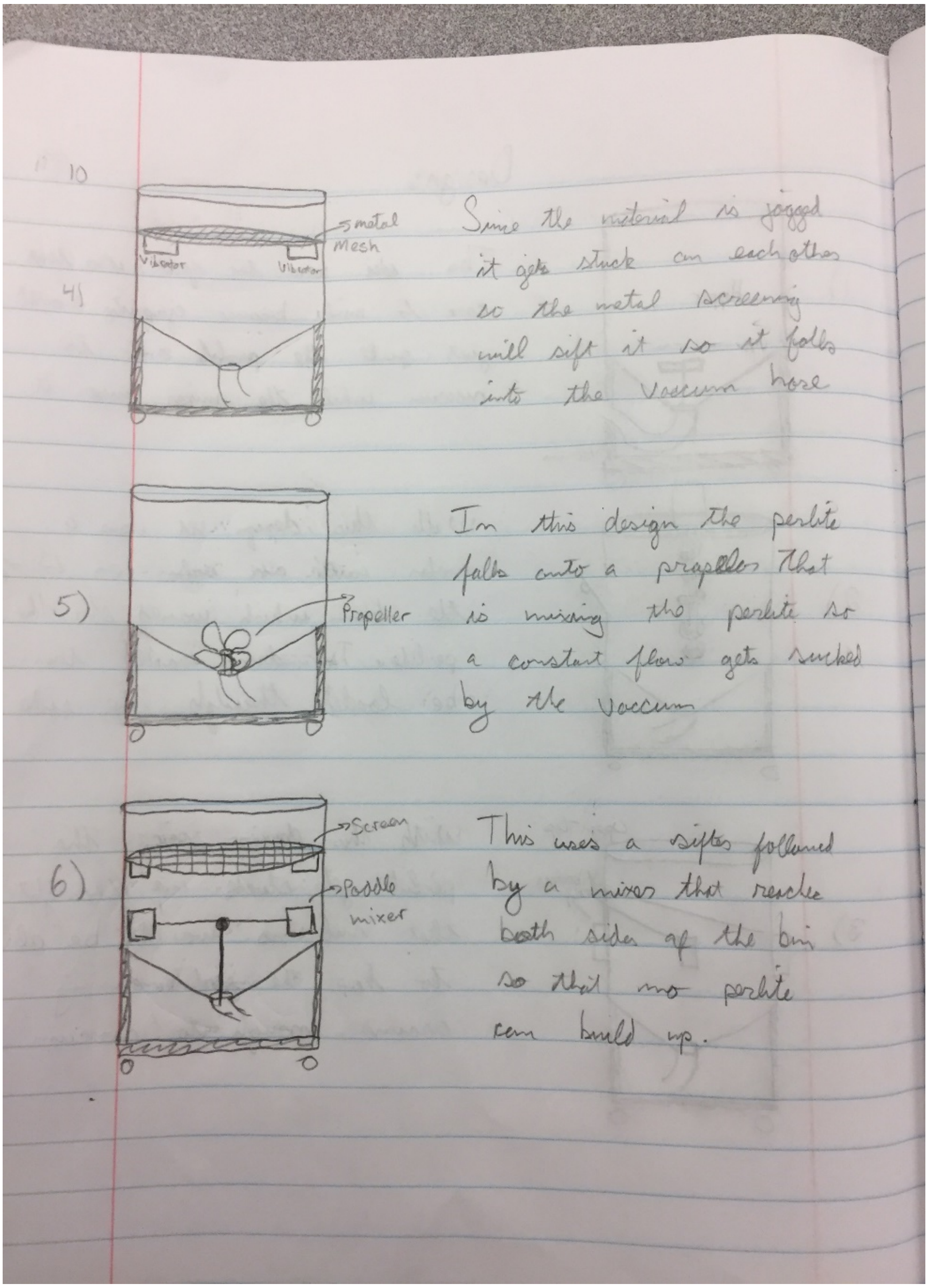


Figure 34: Jimmy Dunwoody Concepts 7-9

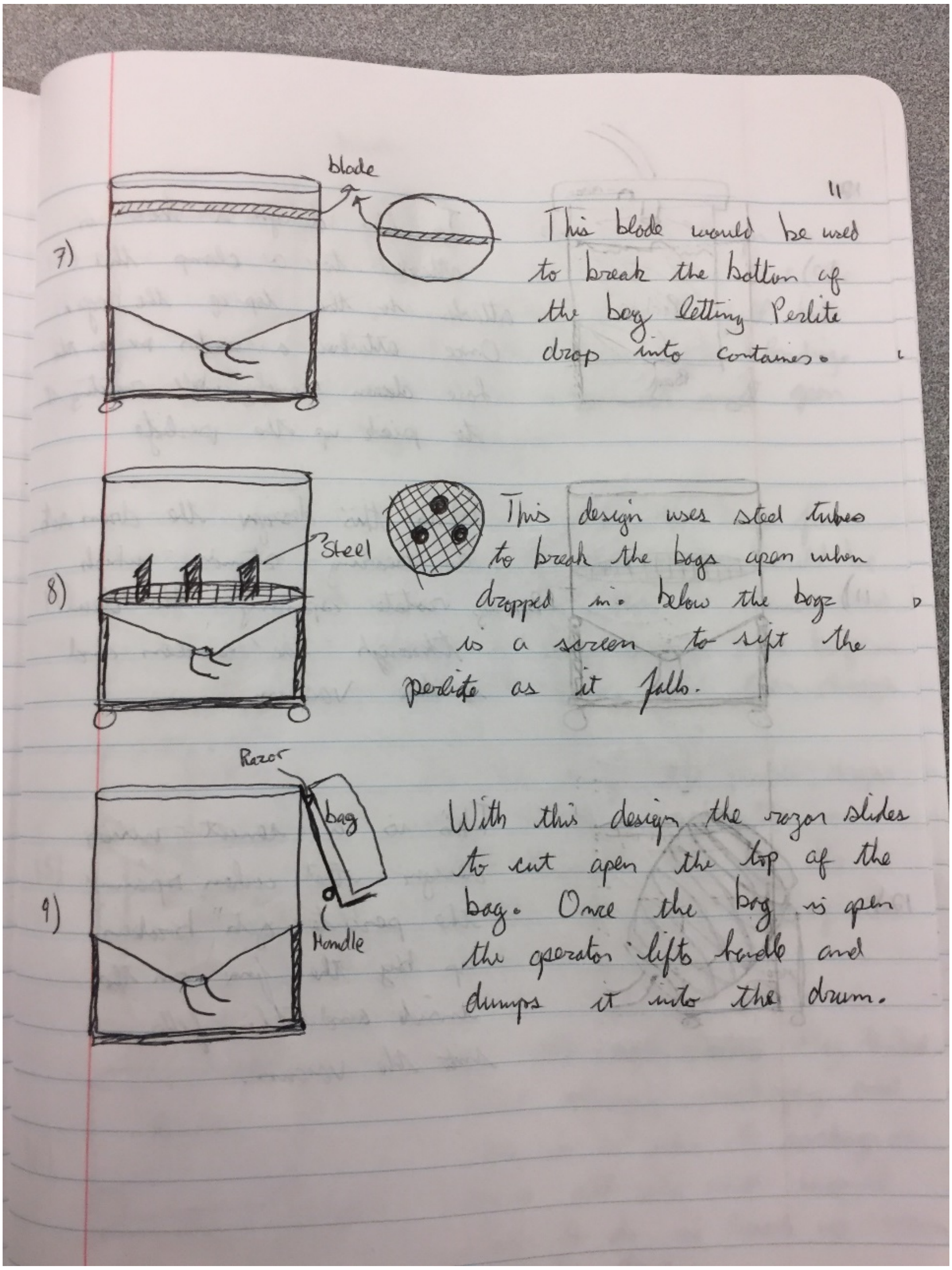


Figure 35: Jimmy Dunwoody Concepts 10-12

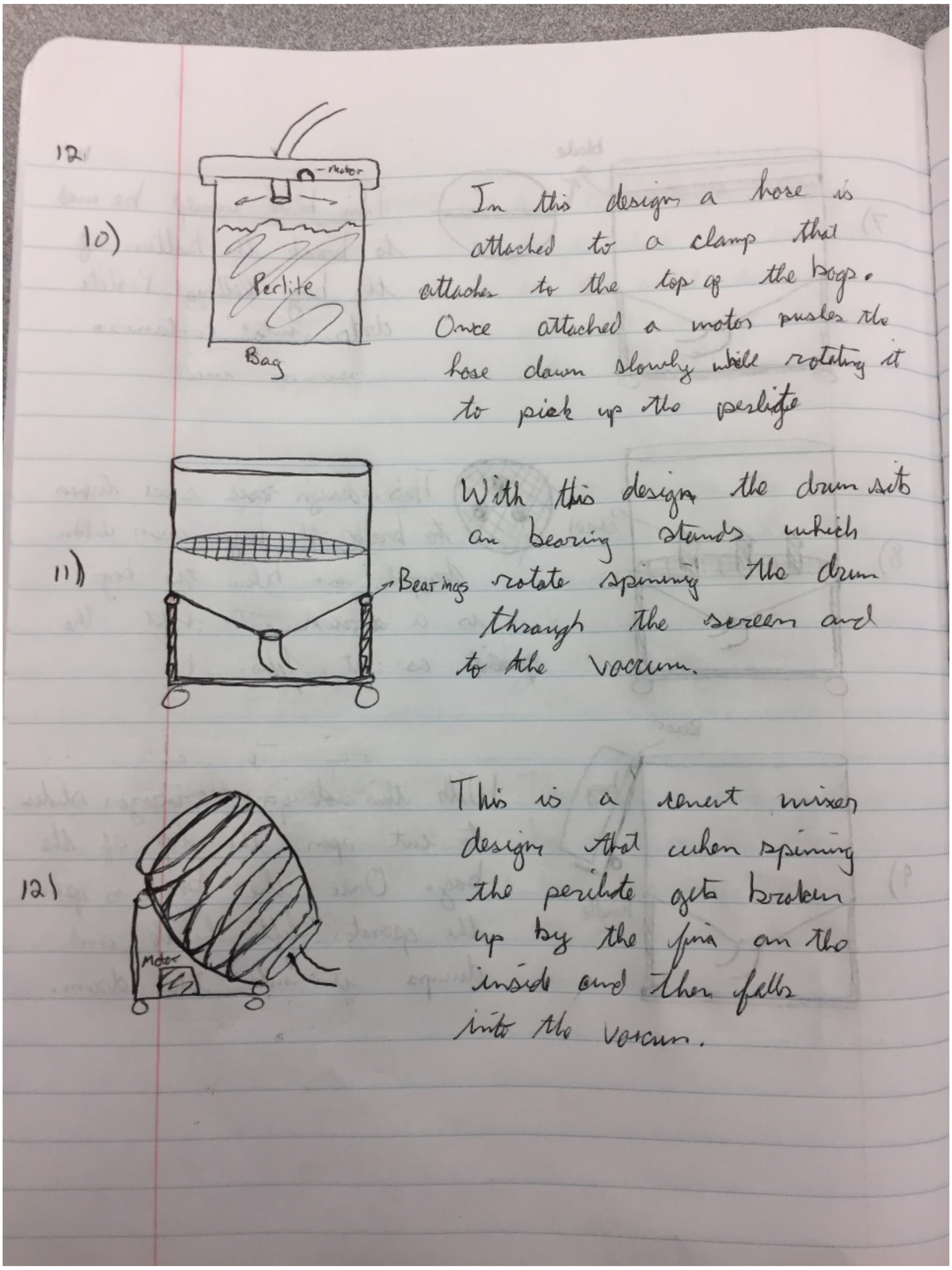


Figure 36: Jimmy Dunwoody Concepts 13-16

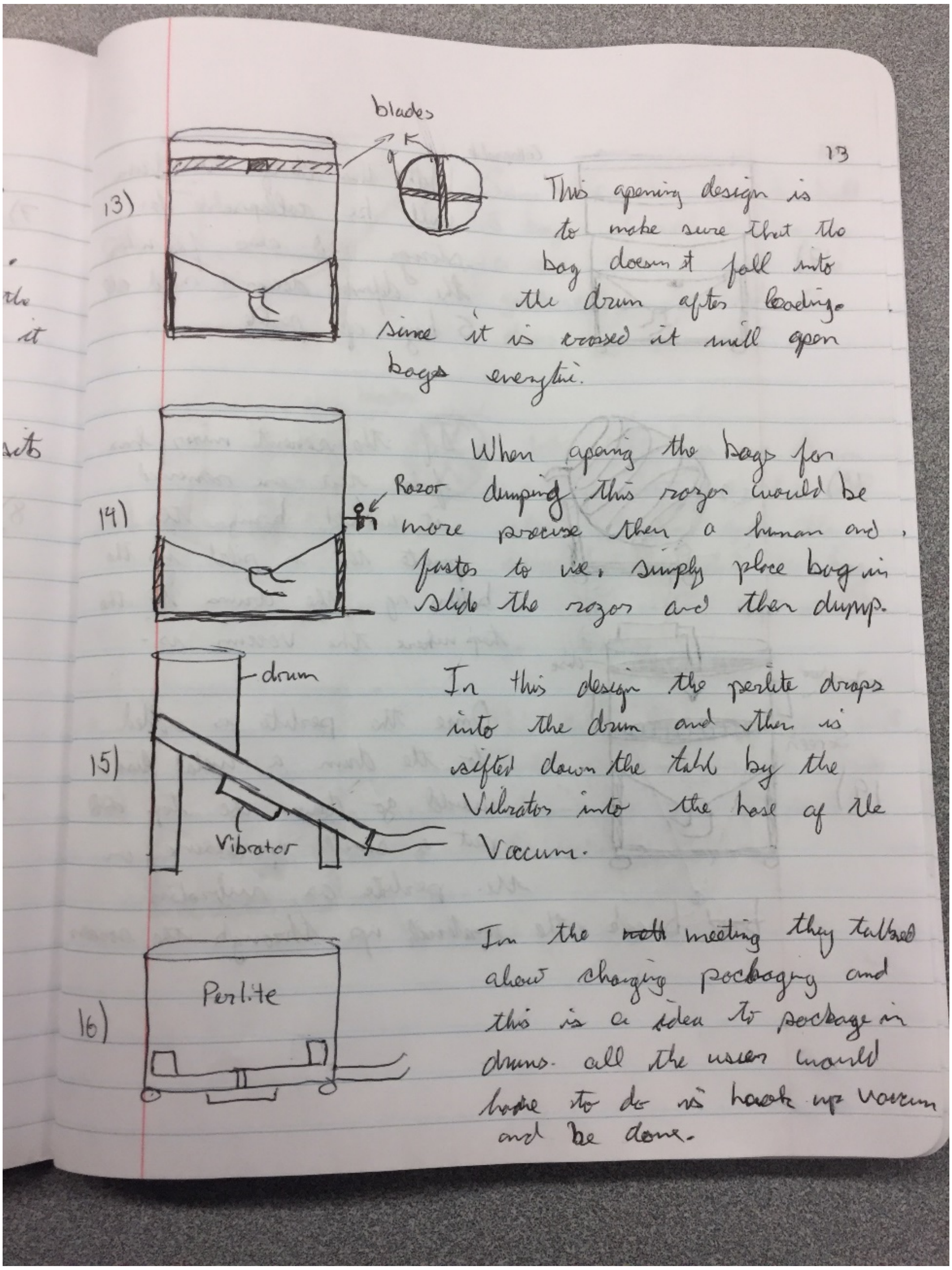


Figure 37: Jimmy Dunwoody Concepts 17-19

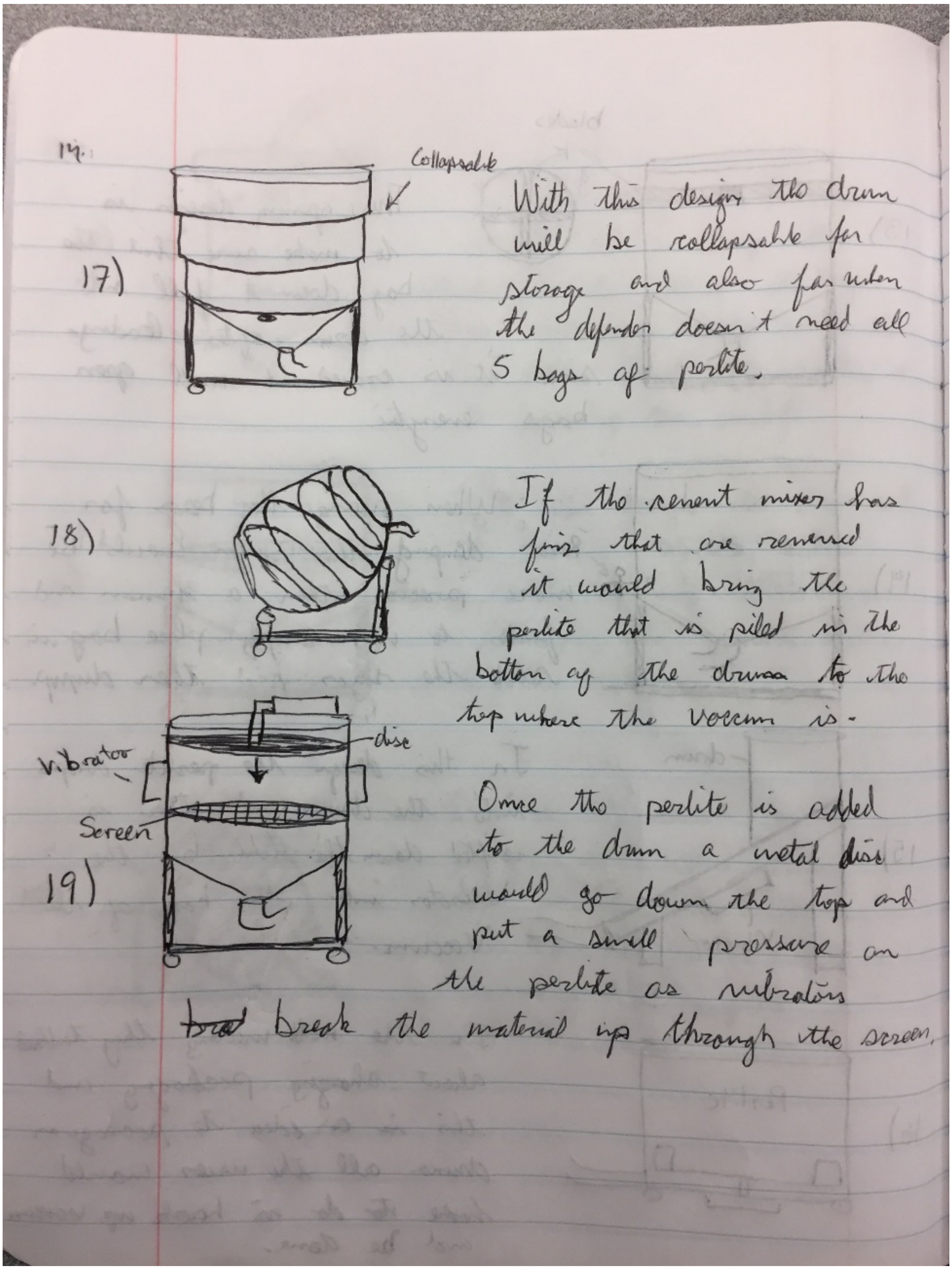


Figure 38: Jimmy Dunwoody Concepts 20-22

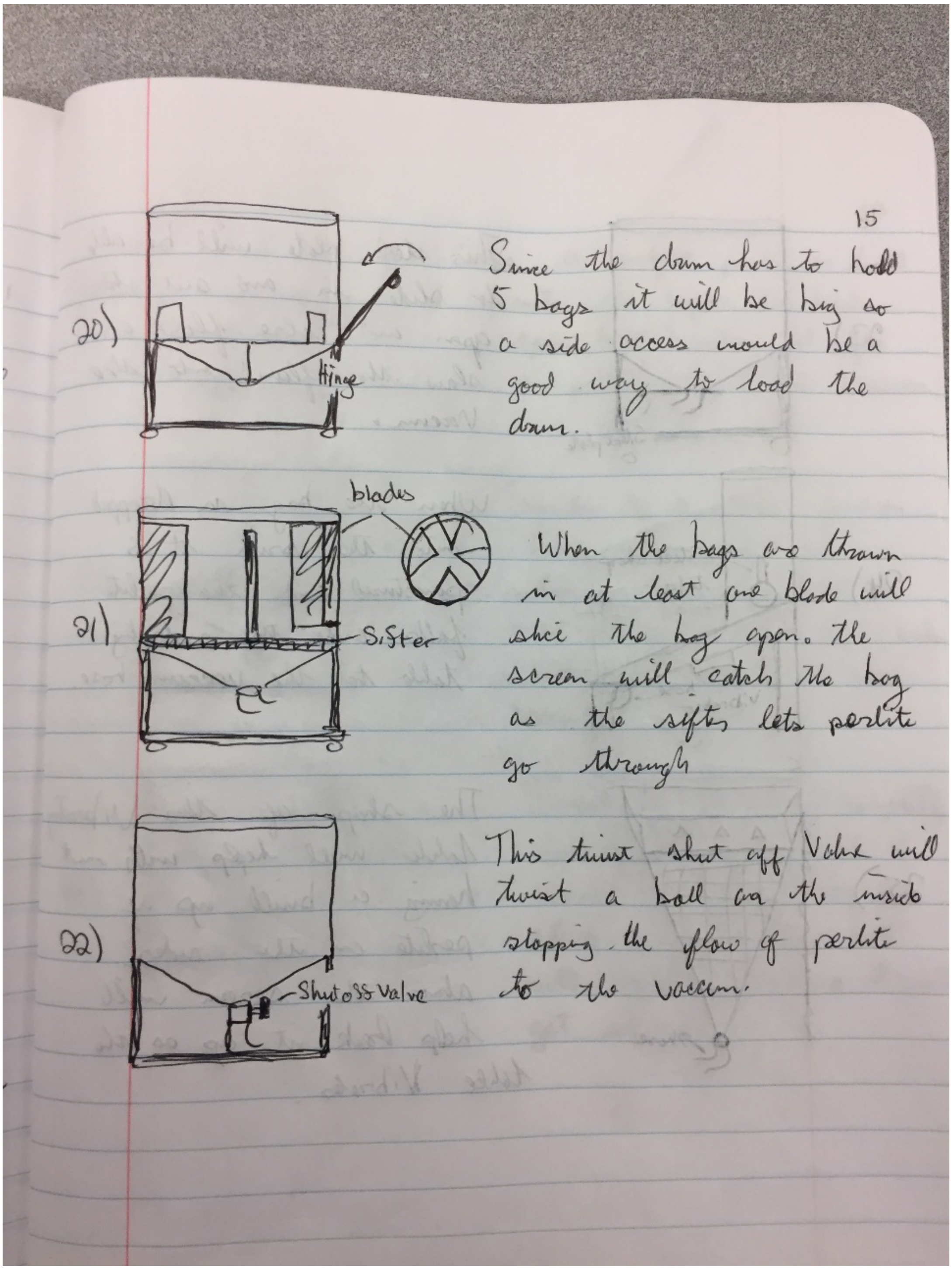


Figure 39: Jimmy Dunwoody Concepts 23-25

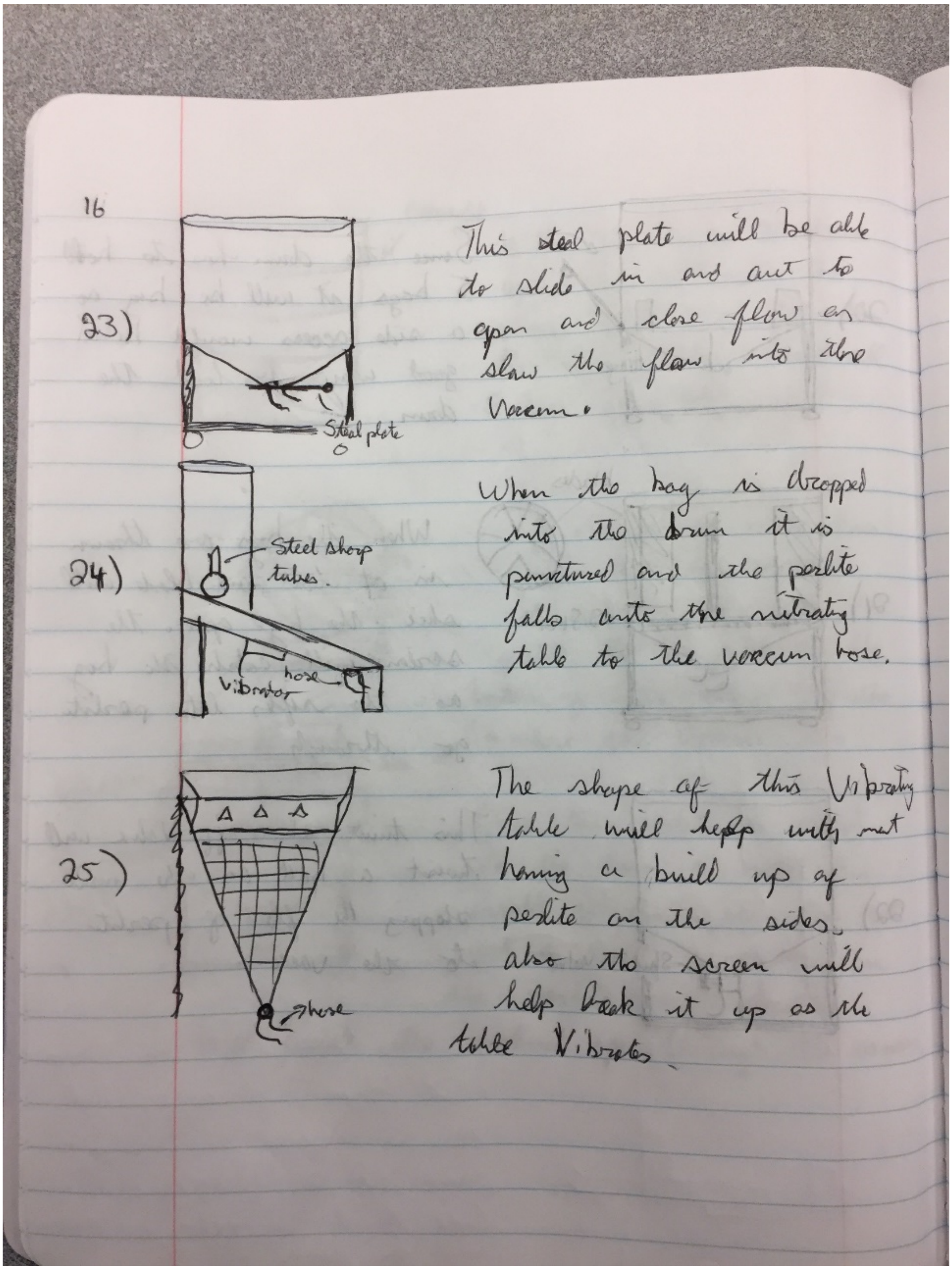


Figure 40: Jimmy Dunwoody Concepts 26-28

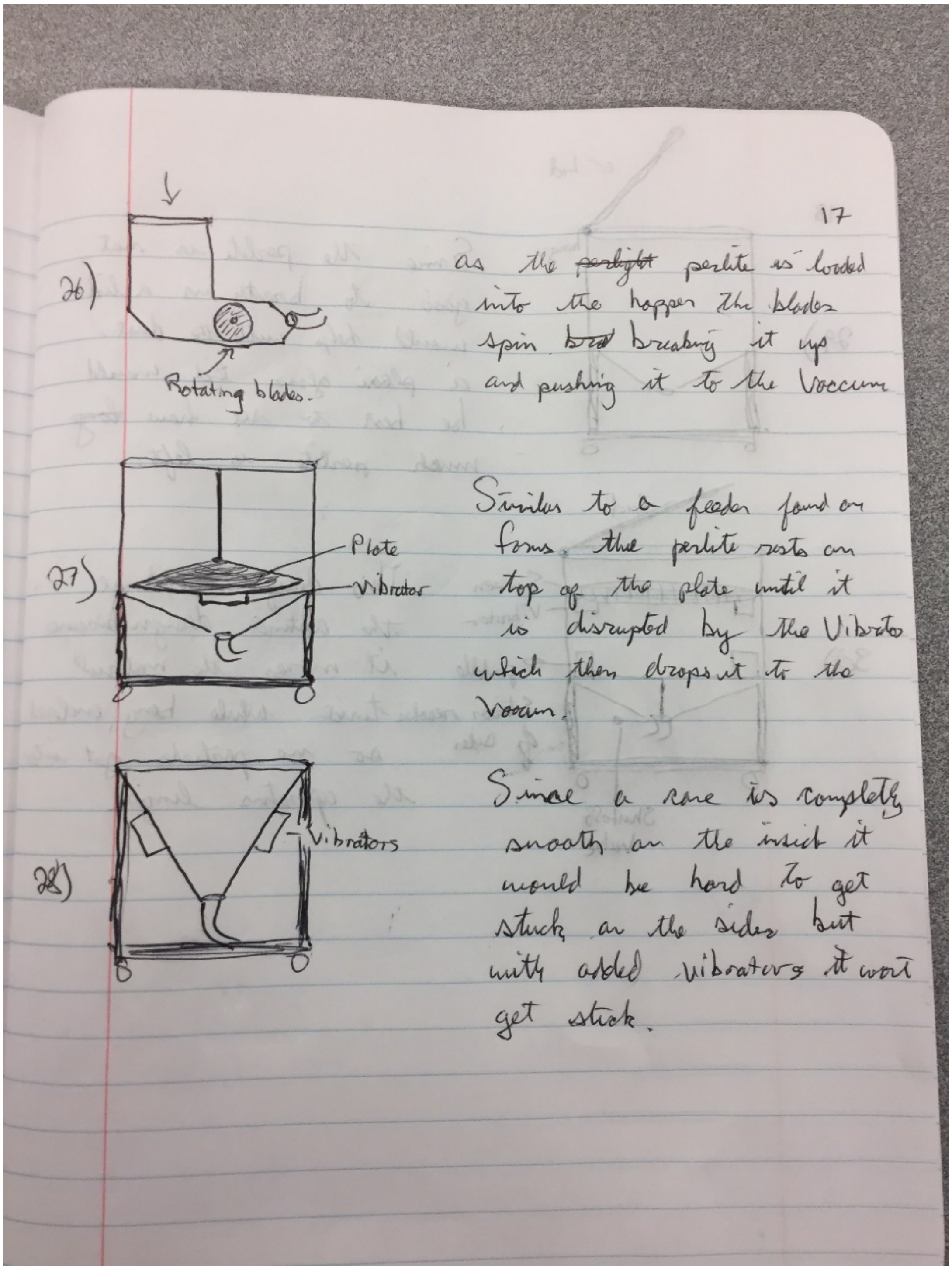
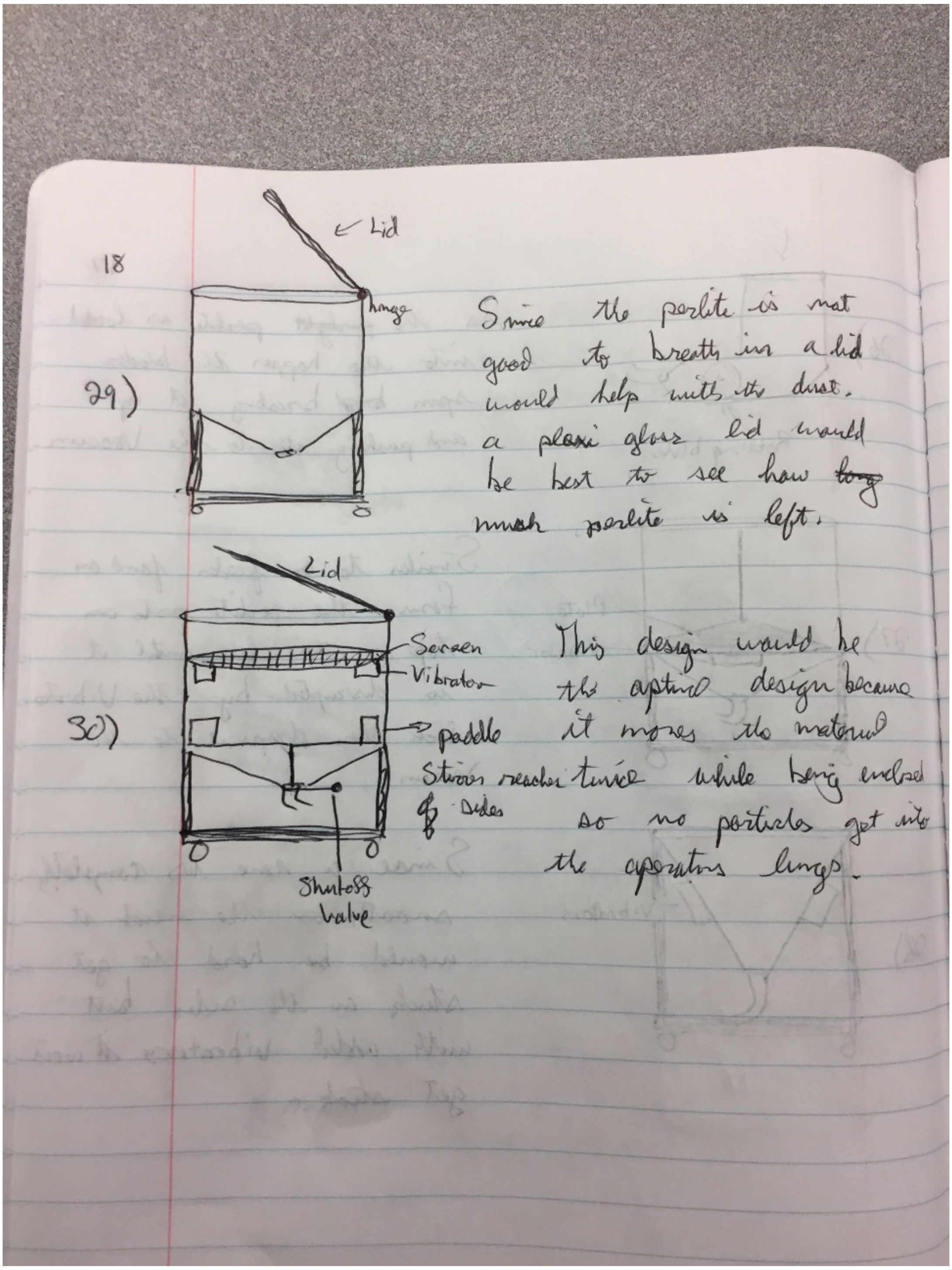


Figure 41: Jimmy Dunwoody Concepts 29-30



7.4 Andrew Anderson Design Concepts

The next set of concepts being analyzed were produced by Andrew Anderson and can be found in figures 42 through 45. A brief analysis can be found below, each number corresponding with the given design.

1. This design is for a bag puncturing method/process. The design contains 4 blades connected at the base and side of the container and holes in the base plate to allow reliable perlite flow.
2. This design is for a bag puncturing method/process. This design contains multiple sharp points or blades at the base plate and holes in the base plate to allow the perlite to fall through but not parts of the bag.
3. This design is for a bag puncturing method/process. This design contains four blades on the inside of the container similar to Design #1 except this design has the blades resting solely on the sides and much higher off the base plate.
4. This design is for a bag puncturing method/process. This design contains four separate sharp cylindrical tubes that rest on the base plate and allow perlite to flow through and around the tubes once the bag is puncturing by the tubes sharp edges.
5. This design is for a lower container mixer. Similar in design to a yard fertilizer mixer, this stirring method contains one mixing arm that revolves around a center axis while coming in close contact with the insides on the container.
6. This design is for a lower container mixer. Similar to design #5, this mixer revolves around a center axis but instead of having a single straight stirring arm, this mixer arm has a corkscrew design. This mixer would also come in very close contact to the inner wall of the container to effectively stir the perlite.
7. This design is for a lower container mixer. This mixer revolves around a center axis and has a design similar to a plant cage. Like the designs before this, the mixer would come in close contact to the inner walls to ensure constant perlite flow.
8. This design is for a lower container mixer. This design revolves around a center axis and has a mixing arm similar to a spoon or scoop. Unlike the previous lower mixing designs, this mixing arm would actually make contact with the inside walls and scrape off stuck perlite instead of just coming close.
9. This design is for a mixer arm that is to be lowered into the container from the open top. While being lowered into the container, the mixer has all 16 arms folded. Once placed in the container, the arms will unfold completely and come in close contact to the inner walls to help stir the perlite.

10. This design is for a mixer arm that is to be lowered into the container from the open top. Similar to Design #9, this mixer is inserted into the container while folded and expands once placed completely in. Unlike the previous design, this mixer has only two arms but the arms make contact with the inner walls and have the same spoon/scoop design found in Design #8.
11. This design is for a mixing method in which the mixer revolves around a center axis in the upper body on the container. The mixing arm for this design closely resembles a corkscrew and would come in very close contact to the inner walls of the container body to help stir the perlite.
12. This design is for a bag insertion and puncturing method. Within the containers body, there will be an opening allowing the bags to be poured or inserted in. At the base of the container âĂIJdoorâĂİ, there will be a small blade so that someone could slide in the perlite bag and it would open within the container.
13. This design is for a container brace and transportation method. This brace grasps completely around the middle outside of the container and has four legs connecting the brace and container to the wheeled base. The base would have four wheels on each corner of the square base.
14. This design is for a container brace and transportation method. This brace design contains three legs to support the container and connect it firmly to the containers square base. Similar to Design #13, the base for this design is square and has a wheel placed at each corner.
15. This design is for a perlite mixing method for the upper container inside. This mixer would revolve around the center axis and has three long beams that come in close contact the inner walls of the container. The beams would be fastened to the center axis using three arms on the top and bottom but would be hollow in the middle to allow the perlite to flow more freely.
16. This design is for a perlite mixing method that uses vibrators instead of a mechanical rotating mixer arm. For this design, there is a smaller cylinder within the cylindrical outer container that is connected to the outside body via three vibrators. These vibrators will shake the inner container while keeping the outer container stationary and allow the perlite to be shaken free if there is any stuck perlite.
17. This design explains one possibility of how the central axis rotational movement can be obtained without the movement coming directly parallel from the motor. Similar to a differential on a rear wheel driven automobile, this design has the motor parallel to the ground and make a perpendicular change in direction so that it can be used to move a mixing arm on the inside base.

18. This design is for a possible perlite bag redesign. Currently, the perlite bags have to be cut using a knife or box cutter. This bag redesign would allow the bag to be inserted into the container and pulling a string at the top of the bag would de-stitch the opening at the base of the bag allowing the perlite to escape the bags base into the container.
19. This design is for a container in which the perlite can be poured into a drawer and then once the drawer is closed, the perlite can begin the process of being mixed and eventually vacuumed into the filter.
20. This design is for the box container design seen above and would have a corkscrew mixer all along the base of the container before the vacuum at the base. Once the perlite is poured in, the mixer at the base would ensure that the perlite is being stirred and would assist in keeping reliable perlite flow.
21. This design is for a bag puncturing method once the bag/bags are already placed into the container. For this design, the bags are placed in the container and a sliding blades can be manually moved from one side to the other effectively slicing the bag or bags. After the bags are cut, the perlite can seep out to the base using gravity and the empty bags can be removed.
22. This design is for a bag puncturing method for the rectangular container design. The bags of perlite are to be lowered into the container through the top and to be sliced on their way down by one of the four blades on each of the inner walls. Once the bags are cut and the perlite released, the empty perlite bags can be taken out via the top.
23. This design is for a bag puncturing method and also a perlite stirring method. Similar to Design #20, this design contains the rotating corkscrew mixer at the base but the mixer has 5 blades places strategically around the screw. For every rotation of the screw, the blades will make one sweep through the plate screen and cut any bag placed on top of the screen plate.
24. This design is for a motor mechanism lid in which the lid for the container is directly connected to the stirrer rod and arm. This design would allow the operator to pour in the bags of perlite and then place the lid and stirrer onto the container ready for mixing.
25. This design is for a motor mechanism lid for the container. Unlike Design #24, this design has components similar to a puzzle in which the motor lid is placed on top of the container and then connected to the stirrer via a key. This would allow the motor and lid to be takes on and off without actually having to manually insert and remove the stirrer rod and arm each time.
26. This design is for a perlite mixing method in which the perlite bags are emptied into the container and are shaken loose via four vibrators. Once the perlite is shaken free, it can flow freely down the slope and into the vacuum at the base.
27. This design is for a vibrating container where there is one vibrator at each corner vibrating

a slightly smaller inner container. For this design, one bag is placed or poured into each of the three sections and shaken down into the vacuum at the base.

28. This design is for a bag puncturing method for the rectangular container design. Using the drawer method as seen in Design #19, the bags are to be sliced once they are placed in the drawer and the drawer is closed via 3 blades on the back wall of the container.

29. This design is for a perlite mixing method. Once the perlite is placed into the conical container, the inner cone rotates at an angle mixing and moving the perlite down using gravity and into the vacuum at the base. This design closely resembles the mixing method that is used for transporting liquid concrete.

30. This design is for a mixer in which the perlite is poured in through the top and the inner cylinder moves about the horizontal axis. Unlike previous designs, the corkscrew mixer for this one stays stationary since the cylinder is moving about it. Once the perlite is free, is can move through the base into the vacuum.

Figure 42: Andrew Anderson Concepts 1-10

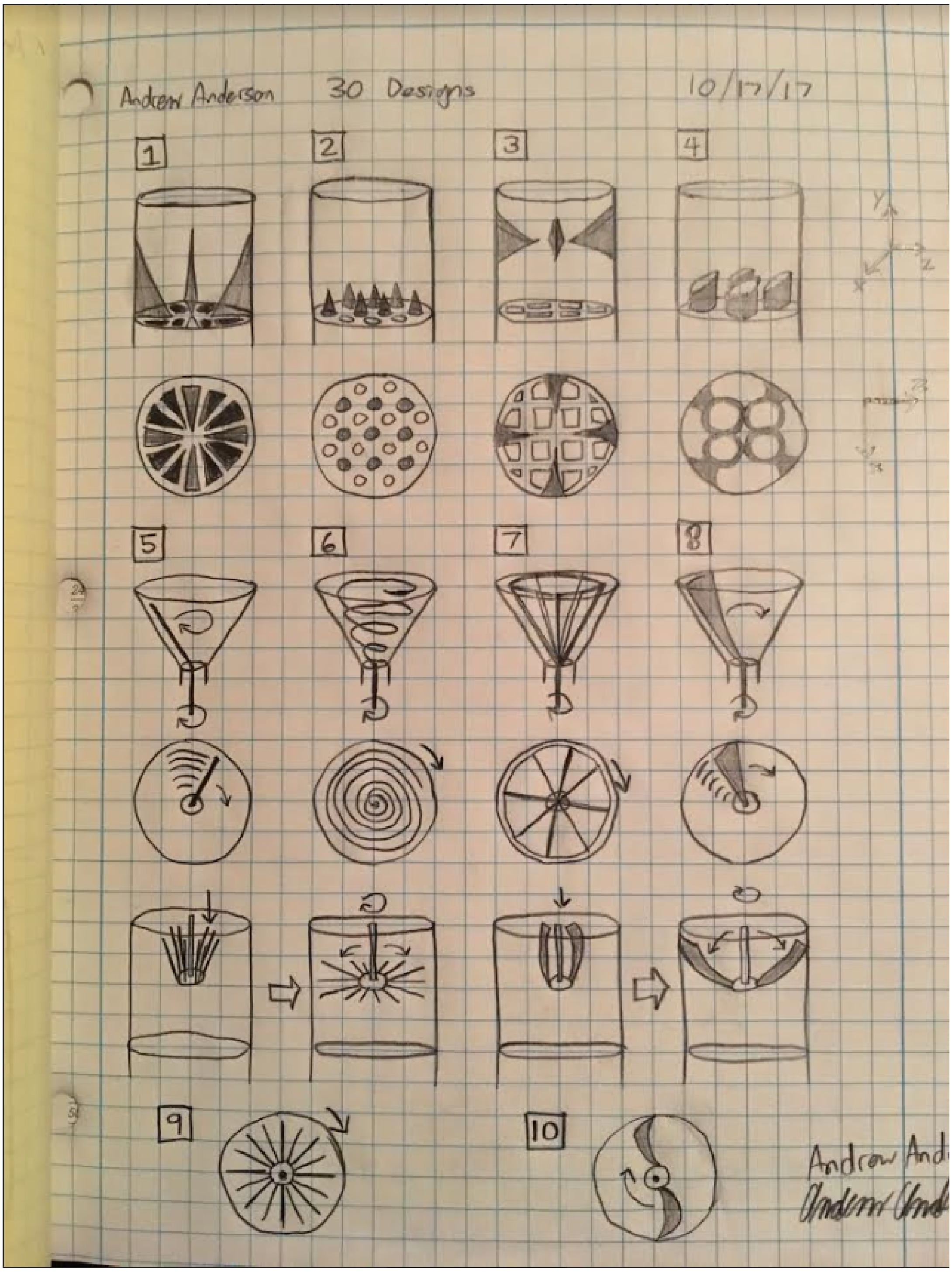


Figure 43: Andrew Anderson Concepts 11-17

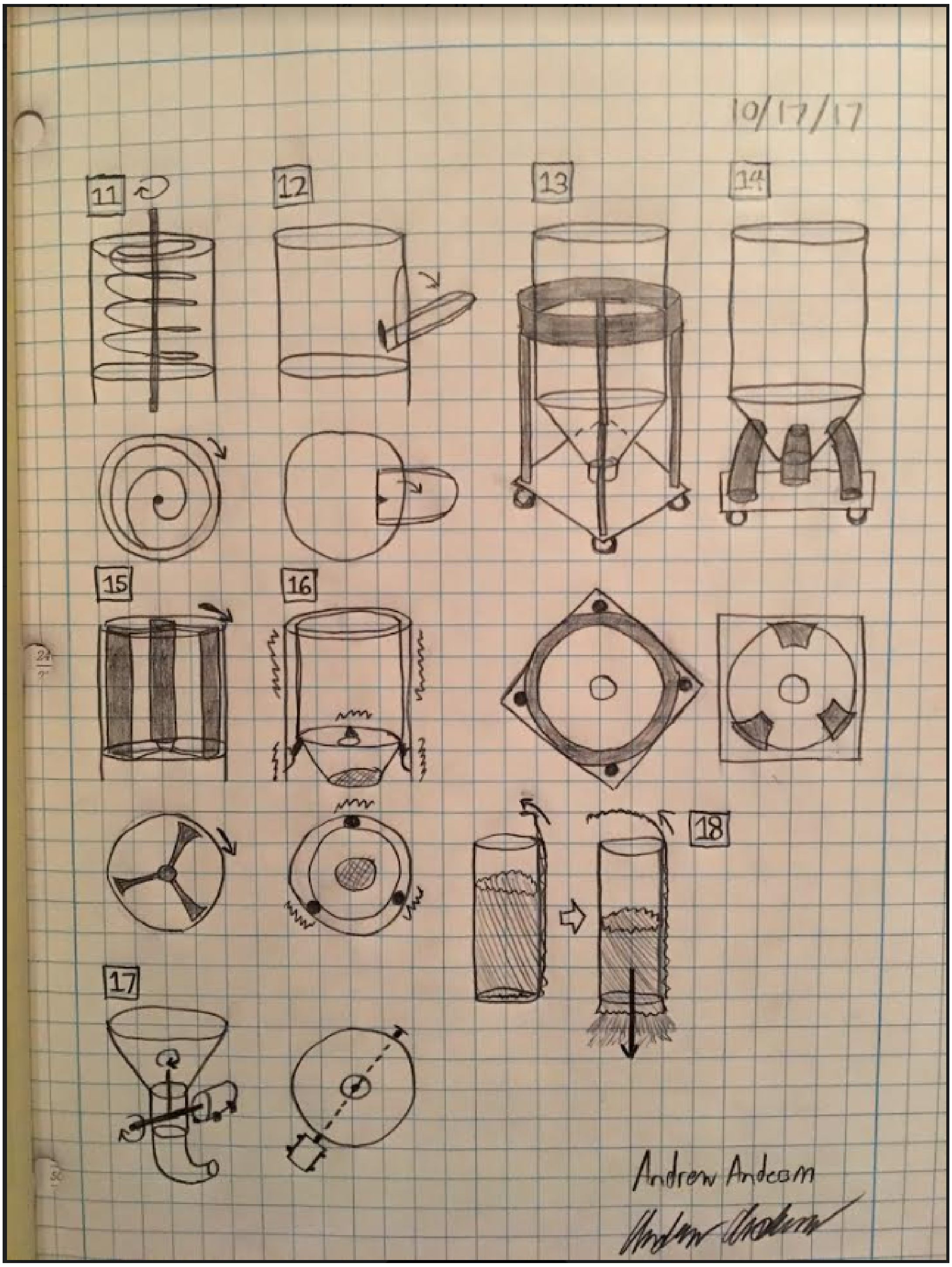


Figure 44: Andrew Anderson Concepts 18-22

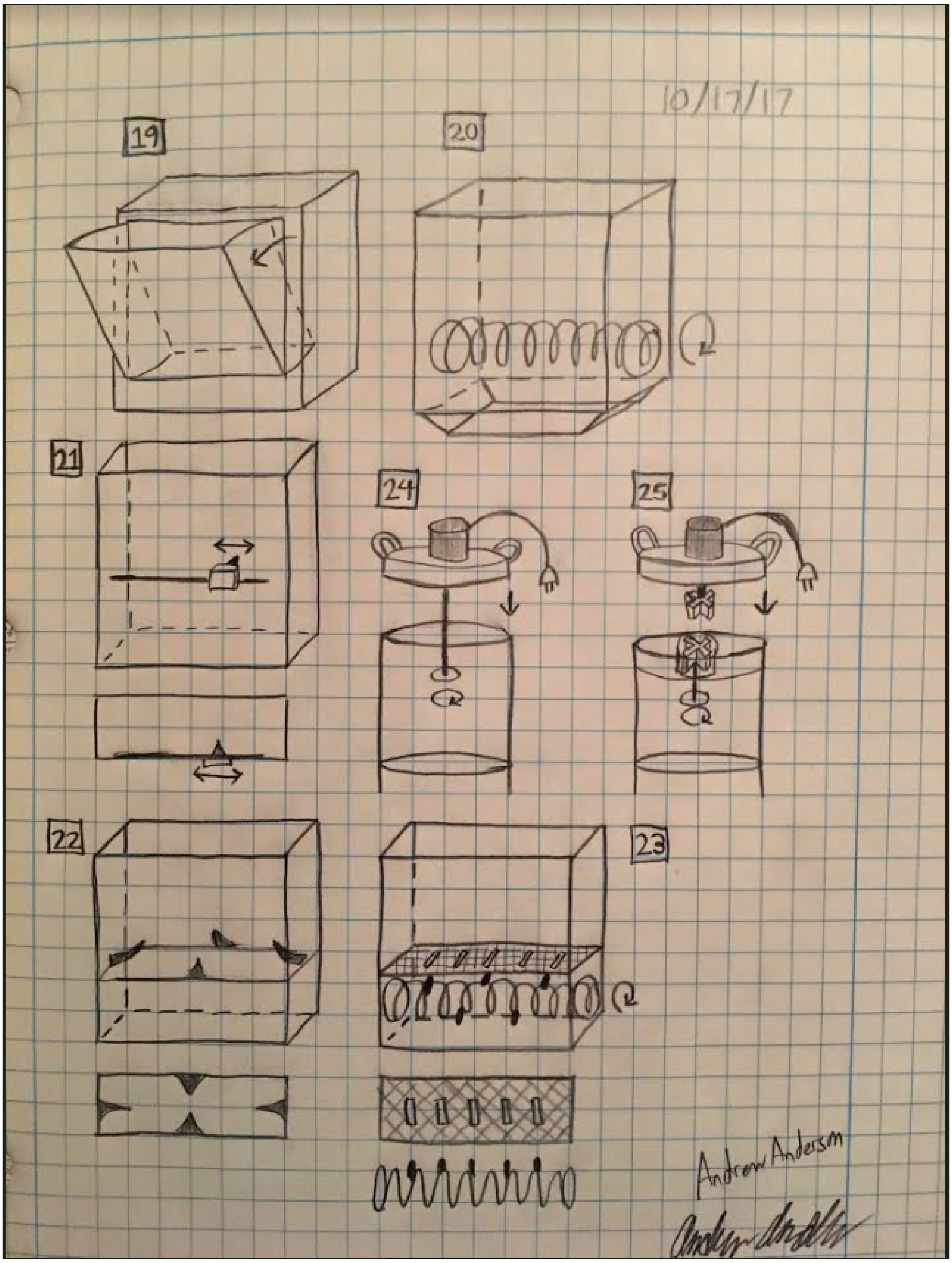
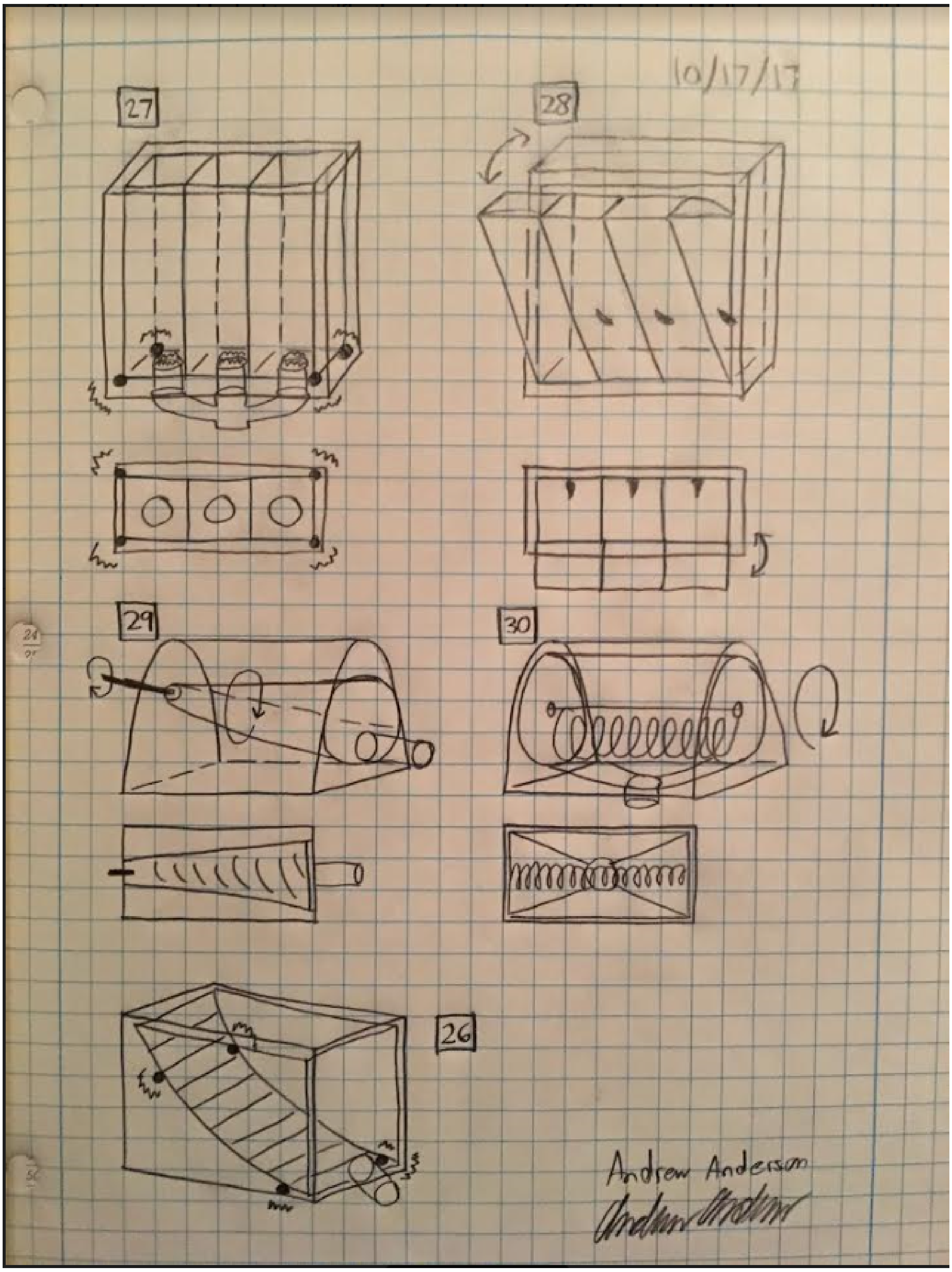


Figure 45: Andrew Anderson Concepts 23-30



8. DESIGN FOR X

8.1 Design for Cost

Just like any product that is created and engineered to eventually be put on the consumer market, the thoughts and concerns of the customer are of the highest importance. Potential customers that would purchase the Defender Media Feeder would already be Neptune Benson Defender owners and would have to deem the price of the DMF lower than their perceived cost of having to load and vacuum the perlite manually. To combat this issue, Team 3 has worked to build their DMF prototypes with inexpensive and affordable materials without sacrificing the quality or safety of the product. One such way that the team has worked to limit manufacturing costs is to use plastic and polyvinyl chloride (PVC) parts since these materials are cheaper than metal alternatives and are readily available and abundant. Similarly, the team has worked to make the design as simple as possible while still being effective so that the final design doesn't require more parts than is necessary. Making the design simple and allowing it to be created with readily available parts results in less custom manufactured pieces having to be made by Neptune Benson and cuts down significantly on the total manufacturing cost. When the DMF is designed to be cheaper for Neptune Benson to make, it therefore results in a lower market price which in return makes the product more appealing to possible customers.

8.2 Design for Manufacturing

Since the DMF that is being designed by Team 3 is made with the goal that the product will eventually be mass produced, the object has to be designed with the knowledge that it will have to be recreated many times by people outside of Team 3 in much less time. Similar to what was stated in the Design for Cost, the DMF was designed to include already available components, such as the main feeder, the motor and the shutoff valve. Aside from attempting to cut down on the manufacturing cost, the decision to use these parts results in a more easily manufactured final product. When the majority of the parts for the DMF are easily accessible and do not require custom manufacturing, the device can be made in less time and at a lower cost. The Team 3 DMF design was also made with simplicity in mind so that a team of builders could assemble the DMF without an excessive number of complicated components or steps.

8.3 Design for Safety

When Team 3 was tasked by Neptune Benson to create this perlite media feeder, safety for the operator and those in the vicinity was taken very seriously. The product created by Team 3 had to be designed so that its operation was within OSHA standards so that it could be legally and responsibly sold, owned and operated. The three safety concerns that Team 3 recognized was the stability of the DMF, the perlite loading process, and any perlite leakage in the air. The DMF was designed so that while in operation, the device did not shake so much that it would be even close to falling over or moving around. The DMF was also designed so that no operator would have to lift over 25 pounds while loading perlite into the top of the feeder. Lastly, the product was design with weather stripping ("rubber foam") around the circumference of the lid so that while in operation, very little perlite escapes the DMF and gets released in the surrounding air. While perlite is harmless to inhale and is not carcinogenic, it was still important to try and prevent any perlite leakage so that the safety of the operator is never jeopardized and so that the product would be following European safety standards.

8.4 Design for portability

When creating the DMF, its portability and maneuverability had to be implemented into its design. Some unknowns exist about the customers who would purchase the DMF, such as the Defender size they have, if they have more than one filter, and how far apart are these filters? To appeal to all Neptune Benson Defender customers, it had to be assumed that our device should be able to be easily maneuvered around a facility where the filters would be housed and can fit without issue through standard doors. To solve the maneuverability concern, four 360 degree rotating wheels were added to the base of the DMF that also can lock in place when the device is being operated. These wheels allow the DMF to be rolled around to different Defender filters with little effort and eliminate the need for the device to be stationary or hard to move. The DMF was also designed with a width that does not exceed 36 inches so that it would be able to fit through a standard 3 feet door frame.

8.5 Design for Durability

Many of Neptune Benson's currently marketed products are paired with a 10-year warranty so when Team 3 started designing and building the DMF, quality of materials and construction methods was important. Team 3 wanted to make a product that could be easily implemented into the current line of Neptune Benson products so trying to obtain this 10-year warranty with limited maintenance was a set goal. Certain strides were made to try and make this product durable, such as using thicker materials where needed and performing multiple different tests and simulations to find where the points of wear and deterioration would be. Different materials were selected for different components that were seen to face different stresses or wear. This can be seen in the decision to use nylon in the construction of the stirring arms since they will face the most stress and using a polyethylene tank since the material was relatively light but could support great loads without bending or showing deformation.

9. Project Specific Details & Analysis

This project involved product design, which was sponsored by the pool filtration company Neptune Benson. The objective of the project was to design a product that automated the process of replacing the perlite media used within the company's existing Defender Filter models. Additional goals of this project were to minimize process time and cost of manufacturing, ensure safety, and maintain a small product footprint.

The process followed for the project was very procedural; beginning with research and basic concept generation, and eventually moving into more exact design specifications and final prototype details. There were many deadlines that involved completion of patent searches, concept generation, critical design reviews, and eventual proof of concept.

In relation to the market for water filtration, the DMF design created by the team looks to meet the same sales demographic as the Defender Filter sold by Neptune Benson.

9.1 Quality Function Deployment

The quality function deployment method is used to transform the customer needs and requirements into the engineering characteristics of the product. The requirements given by Neptune Benson for the customers needs consisted of things like overall safety, minimal manual labor, easy operation, aesthetically please and many more. The customers needs were then judged on their relationship to requirements which consisted of things like overall weight of unit, operation time, hookup time and more. Once the relationships were compared the relative weight and importance are calculated for each requirement. The QFD also compares competitors and different designs to see which product meets the customers needs. In Team 3's QFD comparison it compared the top three designs to each other that were chosen since no other company has been able automate the media feeding system. The top three designs consisted of a hopper that used a agitator attached to a motor located on top of the hopper, a box with needles and a vacuum on the bottom, and finally a hopper with a motor placed at the bottom with the auger sticking into the drum. The QFD can be found in the appendices in figure 76.

9.1a Overall safety

The overall safety of the unit is very important and is the first customer requirement. Design 2 and design 3 both scored a four out of five on this requirement. Design 1 scored a three out of five because the design requires the user to lift the heavy motor and auger out of the hopper to load in the 5 bags of perlite. The other designs have fail safes and easy methods of loading which is why they scored a 4.

9.1b Consistent functioning

The consistent functioning of the unit is important for customers because they want a product that will do the job completely every time. Design 1 and 3 both scored a four due to the agitator which will mix the media and ensure that all of the perlite get vacuumed every time. Design 2 scored a 2 since the spikes at the bottom of the box may not puncture the bag. Another problem with the design with respect to this requirement is that since it is a box the perlite will build up in the corners and the filter wont recieve the proper amount of perlite.

9.1c Cost must be low

Since the designs must be movable each customer will only require one unit to feed all defenders so each unit must be made cheap and sold for a profit. Design 1 and 3 both scored a 4 because the hoppers can cost upwards of $500 and the motors can cost hundreds of dollars and more. Design 2 scored a 5 because it does not require motors or massive hoppers.

10. DETAILED PRODUCT DESIGN

When the team met up for the first time during the beginning of the fall semester, all four members had an extremely similar initial concept for what the automated Defender Media

Feeder should look like. All members imagined a large hopper with a cylindrical upper half and a conical lower half in which the perlite is fed to the vacuum at the bottom via gravity. At the start of the semester, Team 3 was still in the process of deciding whether the motor to power the internal mixer in the feeder should be placed at the top of the hopper or at the base. Both options had very reasonable positive and negative aspects but after thorough consideration, Team 3 decided to place the motor at the bottom. The consensus to place the motor at the base came after realizing that a top motor design would complicate the process of filling the feeder with perlite since the motor would have to be moved every refill cycle.

10.1 Design of hopper

The hopper that Team 3 has chosen for the POC prototype is the 65 gallon tank that was used by the Neptune Benson team from last year and can be seen in figure. This tank is good for prototyping because it follows the cylindrical shape and conical lower half that Team 3 has specified as their design. However, because of the size specification that was set for a minimum volume of 100 gallons for the final prototype, this hopper is being used solely for testing and initial prototyping and not for final design or final prototyping. The hopper that was selected for final prototyping was one that could fit enough perlite to fill the largest available Defender filter, that being one that could hold at least 100 gallons. The hopper that Team 3 decided would best suit the final Defender Media Feeder is a 110 gallon Polyethylene Ace Roto-Mold tank that can be found in the appendices in figure 59. The tanks design coincides with Team 3's specifications and concepts in that it is cylindrical and contains a conical lower section. This tank has a diameter of 30 inches and a height of 62 inches which is within the acceptable size specifications and has a 2 inch outlet drain at the base of the cone. The tank also has a 12 inch diameter threaded lid at the top which will allow for easy perlite insertion and sealing. Since the design that Team 3 is pursuing has the motor and mixing axis/arm protruding from the bottom and into the inside of the tank, the outlet at the bottom is being used for both the mixing mechanism and as an outlet for perlite flow. The top of the tank was sealed off by using a 30 inch diameter Plexiglas lid, which was mated to the top of the container through use of weather strips and attached to the container using a hinge joint.

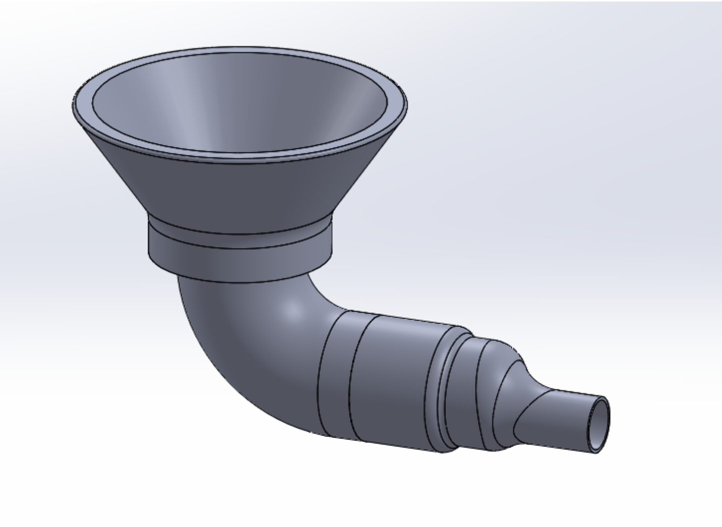
10.2 Design of motor

The motor that is being used for Defender Media Feeder prototype is a Arksen 1200 watt Auger motor that can be seen in figure and is powered off a 120 volt wall power source. With a maximum horsepower of 1.6 and a torque of 90 ft-lbs, Team 3 has calculated that this motor will provide more than enough power to mix the densely packed perlite within the DMF. Since the biggest problem that last year's Neptune Benson team faced was the perlite getting stuck on the inner wall of the hopper, it is very important that the motor selected by Team 3 can efficiently mix the perlite without being slowed or stuck. Without any physical resistance, this motor rotates at a speed of 200 RPM that calculates down to 3.33 revolutions per second. This speed may be too much and not necessary but with some easy tinkering, the high speed of the motor can be exchanged for higher torque.

10.3 Design of vacuum port

The vacuum port that the preexisting Defender filter vacuum will attach to is connected to the Defender Media Feeder via PVC piping that is connected to the base of hopper. This piping system can be seen in figure. After perlite leaves the hopper through the outlet at the bottom of the tank, the perlite enters a 3 inch diameter inlet that is shaped into a 90 degree elbow that alters the directional flow of perlite from perpendicular to parallel to the floor. After the perlite exits the 90 degree elbow, it enters a 3 inch to 1.5 inch diameter pipe that reduces the inner pipe diameter as the perlite is vacuumed through. This 1.5 inch piping connects directly to the vacuum inlet, and is then fed to the Defender Filter.

Figure 46: First Generation Prototype Stir



10.4 Design of mixing arm

The mixing arm that is being used for the final Defender Media Feeder design is custom manufactured and constructed of steel. A first generation prototype can be seen in Figure 46.

Team 3 has decided to custom make the mixing arm because the outermost regions of the arms have to come in very close contact with the inner wall of the hopper and most premade stirrers would not match the selected hopper. The mixing arm design that Team 3 is using contains 12 cylindrical rods that are inserted perpendicularly through the axis rod that is directly connected to the motor. The 12 cylindrical rods have the same diameter but have varying lengths so that each rod can come within an inch of the inner wall of the hopper. This design of the stirring mechanism has been modified multiple times, the different designs for the stirring mechanism can be found in the appendices in figures 60 through 62. After testing, the final mixing design has been constructed, which includes 4.5 inch x 3 inch rubber flanges inserted into the ends of each of the stir arms. This is in order to create much more targeted contact points on the edges of the container, which will hopefully eliminate any stagnant zones that will build up in the conical section. This final stir design can be seen in Figure 48.

Figure 47: Section-View Final Stir Design

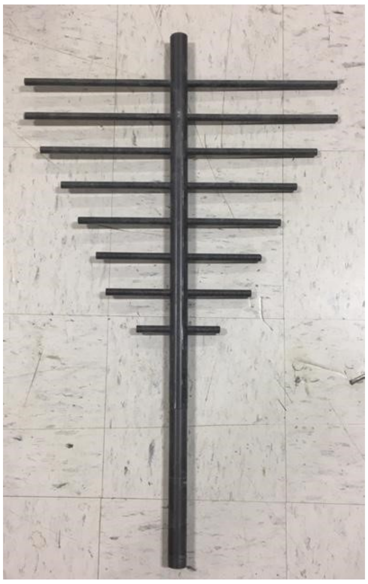
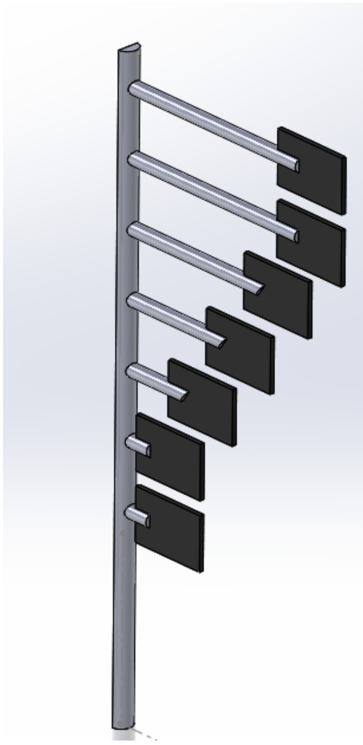


Figure 48: Section-View Final Stir Design



10.5 Design of DMF base

When Team 3 designed the base that supports the Defender Media Feeder, safety and easy maneuverability were the priorities. Since a completely filled DMF weights more than 175 lbs, it was paramount to Team 3 to ensure that the device would not tip over while being moved around from filter to filter. To provide the best stability and allow for easy moving, the design that Team 3 decided upon was one that has a square base with one 360 degree rotating wheel located at each corner as seen in figure 49. The square base that is currently being used for the POC prototype 65 gallon hopper is 26 inches wide and 27 inches lengthwise and has one 3 inch diameter 360 rotating wheel at each corner. While this base suits the 65 gallon POC prototype well, the base that is designed for the 110 gallon hopper has the dimensions 30 inches by 30 inches so that it is wide enough to match the 30 inch diameter of the hopper. Although larger than the POC prototype base, this base is still within the customer design specifications for size in that it is less than 36 inches and will be able to fit between the average sized industrial door. Similar to the POC prototype, the base for the final 110 gallon prototype contains one 3 inch 360 rotation wheel at each corner that will allow for easy rolling and simple maneuvering.

Figure 49: Base for Current Prototype

11. Engineering Analysis

11.1 Existing Conditions and Parameters

When approaching the engineering analysis of the chosen design, it was important to consider the most rudimentary concern of the project: steady flow rate. The shop vacuum used in the current process is rated at 130 ft^3/min, with the pressure of the system being 1.805 psi. This was the first and foremost issue that needed to be addressed when considering the geometry and dimensions of the prototype design. The geometry, as well as the material being used for the conveying of the perlite through the inlet of the body connecting to the vacuum, is very important when accounting for head loss. While flow rate and head loss were the two most important points of analysis for the team, there were multiple parameters at the inlet were needed to be initially addressed. A list of these inlet parameters can be seen below in Table 9.

In addition to the inlet parameters, some basic parameters involving the body design also needed to be considered. In accordance with the design specifications, the body of the design was required accommodate a minimum of 5 bags of perlite. Knowing this, volume and weight considerations needed to be addressed for the design of the prototype body. The design parameters for the container and perlite packaging can be seen listed below in Table 10.

Inlet Parameters	Values
Vacuum rating (ft^3/min)	130
System pressure (psi)	1.805
Ambient Pressure (psi)	14.69
Diameter of vacuum inlet (in)	2.0
Air density (lb/ft^3)	0.0765
Specific Gravity of perlite	2.3
Coefficient of friction for PVC	0.4
Primary inlet diameter (in)	4
Secondary inlet diameter (in)	2

Table 9: Inlet Parameters

Container/Packaging Parameters	Values
Bag width (in)	17
Bag height (in)	34
Bag thickness (in)	8
Density of perlite (lb/ft^3)	5.5
Container height w/ stand (in)	62
Container width (in)	30
Container weight (lb)	44
Container Volume (gal)	110
Cone angle (degrees)	55

Table 10: Container/Packaging Parameters

11.2 Volume Analysis

The first step in determining the design parameters required for the prototype container was calculating the minimum volume required to satisfy the largest Defender Filter currently marketed by Neptune Benson. The largest Defender Filter, the 61.75 inch model, takes 5 perlite bags to properly replenish the media for filtration. In order to determine how much volume would be required for the body, a simple calculation for volume of each individual perlite bag needed to be conducted. Using the known dimensions of the bag, it was calculated that each bag held a volume of 20.02 gallons. This lent to a minimum container volume required of 100.1 gallons. Knowing this, the prototype container purchased has a volume of 110 gallons.

11.3 Flow Analysis

The gravity flow characteristics of microscopic granular materials through static conical shaped containers have been long been a case of study based on the variance of the cone angles implemented in the design. There are two primary flow patterns that are commonly seen in containers of this geometry, those being mass flow and funnel flow. The Defender Media Feeder design would like to perpetuate mass flow, which is flow where the particles are in continuous motion from the time of loading to when material is discharged from the outlet. The behavior of mass flow prevents formation of stagnant regions within the container, which is the most prevalent issue faced with using perlite media in this design. In contrast with mass flow, funnel flow creates a flow channel that results results in material stagnation along the periphery of the container. This results in erratic flow, particle degradation within the stagnant regions, and inordinate stresses on the container that may reduce the design life expectancy. In order to maximize chances of mass flow, the friction of the container walls must be minimized, and the cone angle needs be at an adequately steep angle [7].The Venturi effect details flow reduction through an orifice. The flow rate through the container to the inlet follows this such effect. The volumetric flow rate of the perlite through the container to the inlet can be quantified through the use of the equation for Q [2]:

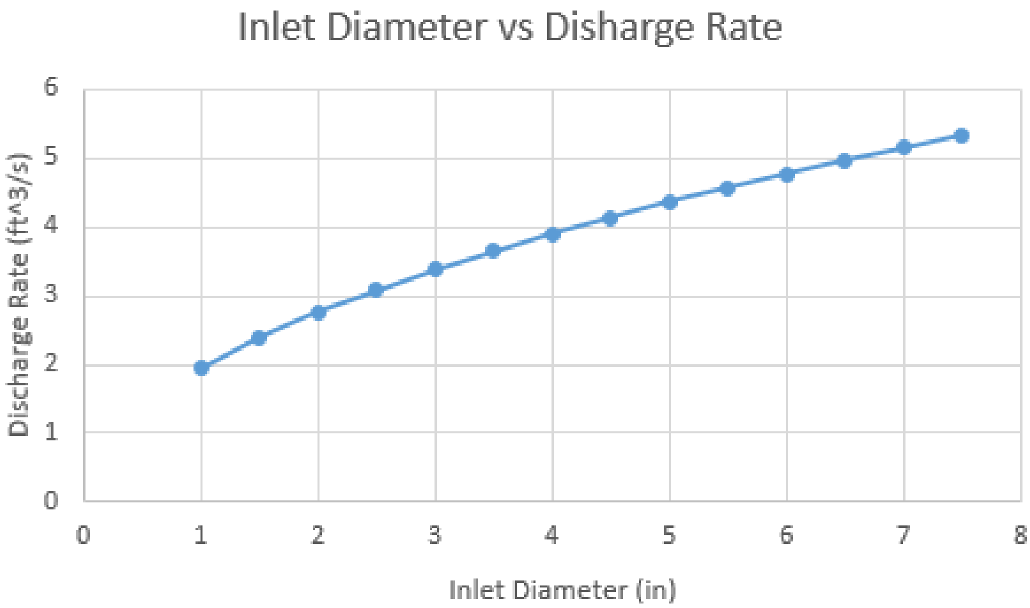
$$Q = A_1\sqrt{\frac{2}{\rho} * \frac{(p_1 - p_2)}{((\frac{A_1}{A_2})^2) - 1}} \tag{1}$$

Where A_1 is the cross sectional area of the container, A_2 is the cross sectional area of the inlet, ρ is the perlite density, p_1 is the static pressure within the container, and p_2 is the static pressure at the inlet. Utilizing this equation, the volumetric flow rate can be calculated at 1130.87 in^3/s, which converts to 0.654 ft^3/s. As previously mentioned, the angle of the cone was very important in order to determine the possible ramifications of flow stagnation. In order to determine the ideal cone angle, various iterations of the discharge rate as a function of the cone angle needed to be determined for the differing prototype designs. For coarse, powdery materials such as perlite, the following equation can be utilized [2]:

$$u_0 = \sqrt{\frac{Bg}{2(1+m)tan(\theta)}} \tag{2}$$

In this equation, B is the inlet diameter, g is the acceleration due to gravity,m is a parameter for circular outlets known to be 1, and Îÿ is the cone angle. Using this equation, the discharge rate for the most ideal prototype design was determined to be 1.37 ft^3/s. The discharge rate is shown to increase with an increase in inlet diameter and can be seen in **??**.

Figure 50: Inlet Diameter vs Discharge Rate



While these computations mapped the flow of the perlite through the container, the conveying air velocity within the inlet still needed to be determined. This was found using an equation from David Mill's text, cited in references [1], which was:

$$C_1 = \frac{4 m_a R T_1}{\pi d^2 p_1} \tag{3}$$

Where ma is the air mass flow rate, determined by the 130 CFM rating of the vacuum to be 0.7179 kg/s; T_1 is standard ambient temperature at 273.15K; R is the gas constant 0.287 kJ/kg*K, d is the inlet diameter, and P1 is the operating pressure which is assumed to be standard atmospheric pressure 101.3kPa. Using these known values, the conveying air velocity was found to be 68.53 m/s. Knowing this value, the minimum conveying air velocity could be found using the equation [1]:

$$C_{\text{min}} = C_1/1.2 \tag{4}$$

Based off this equation the minimum conveying air velocity C_{min} was found to be 57.1 m/s. This is an important value to consider when designing the piping stemming from the container to the vacuum inlet. According to information provided from studies detailed in David Mill's text, a build up will most likely occur within the pipe if the conveying velocity drops 10 percent or more below the value of C_1 [1]. In order to help rectify this issue, the elbow used as a connection from the container to the inlet will be modified from a straight 90 degree elbow to a rounded 90 degree elbow. There is an identifiable correlation between inlet diameter and intake velocity. This relationship can be seen in figures 51 and 52, where both the intake velocity and minimum intake velocity are plotted.

Figure 51: Inlet Diameter vs Intake Velocity

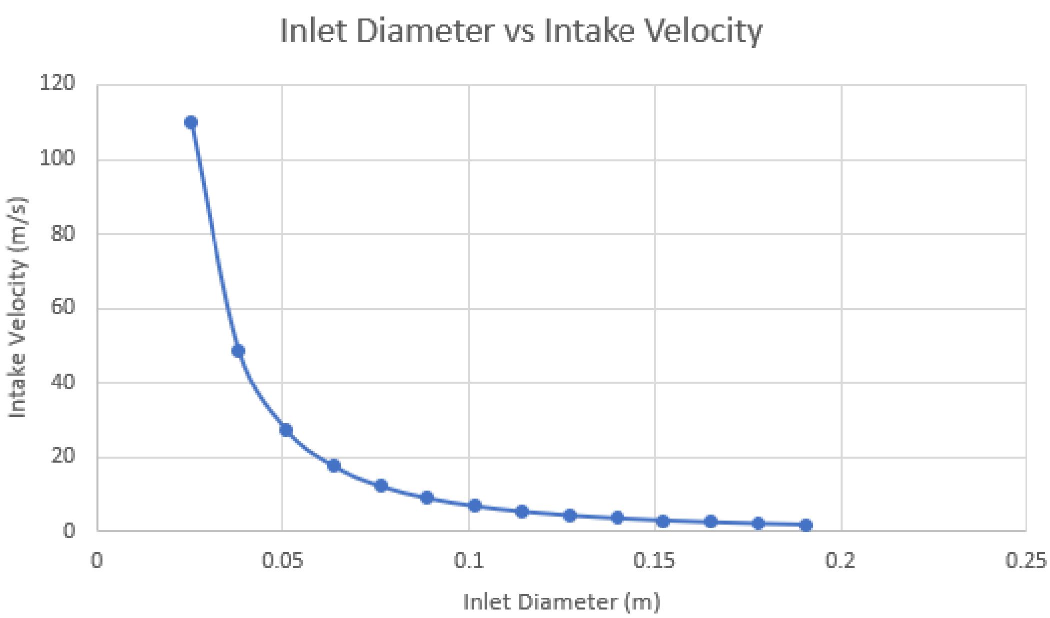
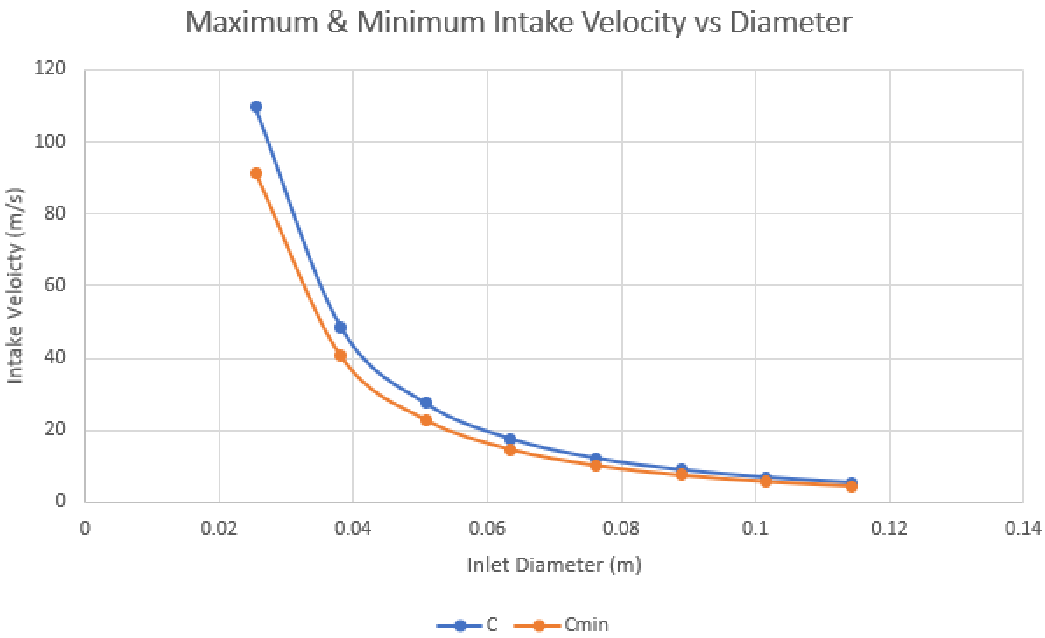


Figure 52: Maximum & Minimum Intake Velocity vs Diameter



Clearly, there is a correlation between inlet diameter and intake velocity displayed in these plots. The direct relationship shows that as the inlet diameter decreases, the intake velocity increases. However, the analysis needs to take into account the correlation between inlet diameter and particle flow as well, as this is not a one dimensional issue that needs to be addressed. While the conveying air velocity increases with a decrease in inlet diameter, the decrease in inlet diameter will most certainly lead to an increased chance of saltation occurring within the pipeline. Due to the fact that the density of the air within the pipe will decrease with the decrease in pressure as the pipe gets closer to the vacuum source; the conveying air velocity will similarly be shown to increase in accordance with Bernoulli's principle. This principle states that where an increase in velocity of a fluid is seen, a decrease in pressure will be seen simultaneously [9]. However, the air mass flow rate will remain constant throughout the pipeline as it is independent of the other variable changes. The equation used to calculate mass flow rate is:

$$m_a = \frac{2.74 P_1 C_1}{d^2 T_1} \tag{5}$$

Where T_1 is standard temperature, P_1 is standard atmospheric pressure, C_1 is the previously calculated inlet air velocity, and d is the chosen pipeline diameter. The value of mass flow rate given from this equation for the 4 inch diameter inlet was found to be 0.719 kg/s. Since an adaptor from 4 inches to 2 inches will be used for the inlet pipeline, it was very important that head loss calculations needed to be made. The head loss was calculated using the equation [3]:

$$h_L = K_e * \frac{(V_1 - V_2)^2}{2g} \tag{6}$$

Where K_e is the loss coefficient that coincides with a 30 degree pipeline adapter, V_1 and V_1 are the velocities seen at the smaller and larger pipeline diameters, respectively; and g is simply the gravitational acceleration constant. With these known values, head losses within the pipeline were found to be 0.434 m.

11.4 Analysis of Motor

As previously mentioned, the most pertinent issue faced during the design of the DMF was how was the issue of flow stagnation within the container going to be solved. The concept created to rectify this issue was a stirring mechanism attached to a motor that provides a rotational motion in order to generate enough agitation to ensure a consistent mass flow of the perlite. To properly analyze the mechanics provided by the chosen prototype motor, several calculations had to be made. The motor rotates at a rate of 200 revolutions per minute, or 3.33 revolutions per second. Knowing this, angular velocity, ω , can be calculated using the following equation:

$$\omega = 2\pi f \tag{7}$$

Where f is the frequency of rotation, known to be 200 rpm. Utilizing this equation, the angular velocity was found to be 20.94 radians/second. This velocity lent itself to a period of full revolution being 0.3 seconds.

12. Manufacture and Build

12.1 Design Components

Although Team Defender was tasked with the responsibility of creating a one of a kind Defender Media Feeder prototype, the team also had to consider the manufacturability of the design and how realistic the design had to be for a company to reproduce the same model while remaining cost efficient and accessible. The teams largest and most important component in the design is the 110-gallon tank. The tank and stand were purchased from National Tank Outlet (NTO) for a sale price of $349.98 and were some of the more expensive components of the overall design. National Tank Outlet was asked for a price gate of 200 tanks which resulted in each tank and stand combination costing $344.55 each. It may be necessary for Neptune Benson to consider researching other companies to purchase this component from.

Another important component of the DMF system is the 1200W, 200RPM earth auger motor located at the base of the design. This motor was not purchased by Team Defender but rather last year's group, The Gods of Perlite, and when researching the same motor online it was believed the team purchased this motor from Walmart for $159.97. If the team were to purchase a motor, the team would have chosen a brushless motor to avoid any type of combustion that may occur during the loading process. The group also would have chosen a motor whose specifications included lower RPM while remaining high in torque and one whose overall height is much shorter. The current motor is approximately 14 inches from end to end and takes up a lot of space; ideally the team would like this height to be about 6-7 inches.

One of the team's biggest concerns going into the designing process of the first prototype was the material used to create a stirring mechanism that would agitate the media enough to create a continuous flow to the vacuum. The material would have to be strong enough to overcome the force of static friction created by the perlite. Ideally, the material would be lightweight, inexpensive and extremely durable. After researching materials online that followed the desired specifications mentioned, the team decided to make the stirring mechanism out of Nylon rod. In the final design of the stirring mechanism, rubber flanges were attached to the ends of the arms, which were purchased 2 ft x 2 ft sheets of that had a thickness of 0.25 inches.

The design of the stirring mechanism, which would later be known as the Agitator 8.0 due to its 8 arms, included a one and a quarter inch diameter rod measuring at 36 inches in height as the center rod that would connect to the motor and hold the arms that would extend outward to interior of the tank. The arms would also be made from Nylon and would measure at half an inch in diameter and vary in length to accommodate the inner diameter of the cone bottom tank. The equipment used to produce the first prototype of the Agitator 8.0 included a drill press, lathe and band saw. The band saw was used to cut each individual arm to the desired length; the same process could potentially be done using a fine blade hand saw or a chop saw. The drill press was used to bore holes in the main 1-1/4" diameter rod. These holes would then house the arms and would be a tight enough clearance where adhesive would not need to be used. A hole would also need to be bored in the bottom of the main rod in order to connect the stirring mechanism to the motor and a slot would need to be drilled through the same portion of the rod to house the push pin that connects the nub of the motor to the stirring mechanism. The stirring mechanism needed to fit through a one and a quarter inch inner diameter Nylon bushing which would run through the bottom of the outlet. Initially the team thought the Nylon rod and the Nylon bushing would be paired together without issue but this was not true. In order to accommodate for this issue approximately twenty-five thousandths of an inch had to be taken off the main rod. Only approximately 5 inches of the rod had to be lathed so the process was relatively quick and easy. Without the proper equipment it may be very difficult for this portion of the design to be replicated.

A majority of the outlet of the design was 3D printed at Schneider electric. Without a 3D printer these components may be very difficult to reproduce although PVC components could be used. The first prototype included a 4.5-inch inner diameter flange, the angle of the flange matching the angle of the cone bottom tank. The flange then connected to a 90-degree elbow and included a hole drilled directly through its center, housing the bushing which the Agitator 8.0 would be placed through. The bushing was cut to 3 inches using the band saw and was held in place using a polycarbonate adhesive. The 90-degree elbow was then connected to a four inch to 2-inch reducer which was also 3D printed. A surface coating made for 3D printed models was applied to these components to provide a smoother finish. This process took about 3 minutes to apply to each component and was left in a box to dry for twenty-four hours. The final portions of the outlet included a 2 inch PVC water gate shutoff valve and a 2-inch PVC reducer which connected the outlet of the system to the vacuum inlet of the Defender system. These components were purchased through amazon and required no preparation before installation. Each component of the outlet was bonded together using a polycarbonate adhesive and then caulk was then applied to the joint of each component to assure no leaks would occur.

12.2 Design Assembly

The assembly of the components previously discussed in this design are relatively rudimentary. In order to assemble the final design we took all the new components that we ordered and 3-D printed and put them together. First we cut the circular base out of a piece of plywood and fastened casters to the bottom using 1/4 inch bolts and lock nuts. Once the base had the casters attached we used a jigsaw to cut a hole in the base so that the motor would drop 6 inches into the base. Once the motor sat at the perfect high three L brackets were screwed in surrounding the motor. After the L brackets were secure a ratchet strap was used to secure the motor to them holding it at the height it needed to be at. After the motor was set into the base the metal frame was placed and centered over the motor axle. After the metal frame is secured to the base using bolts the adapter which receives the hopper outlet is then secured to the frame using 1/8 inch bolts. Then we cut the hoppers outlet to fit the adapter that we 3D printed. Once the cut was made on the outlet we then cut the top off of the hopper since the inlet hole was too small for loading. After the cuts were made the hopper then was placed in the factory stand which stand which was secured to the circular base. After dropping the hopper into place the agitator was created by pushing 1/4 in nylon rods through a 1 inch nylon rod and then securing the rubber scraper tips with an adhesive. After the agitator is assembles it is dropped through the bushing in the elbow and then sits on the motor and connects using a cotter pin. After the arm is in place the elbow that was 3D printed screws into the adapter. After being screwed in it creates an airtight seal. The lid was then fastened to the to the top of the hopper using bolts and latches that hold it firmly to the top of the hopper. A weather seal foam is then attached to the top so that when latched it creates an airtight seal. After the lid is secured a hole is drilled and a pipe is inserted that controls the amount of airflow into the system. Once the air intake was created the unit is ready for testing.

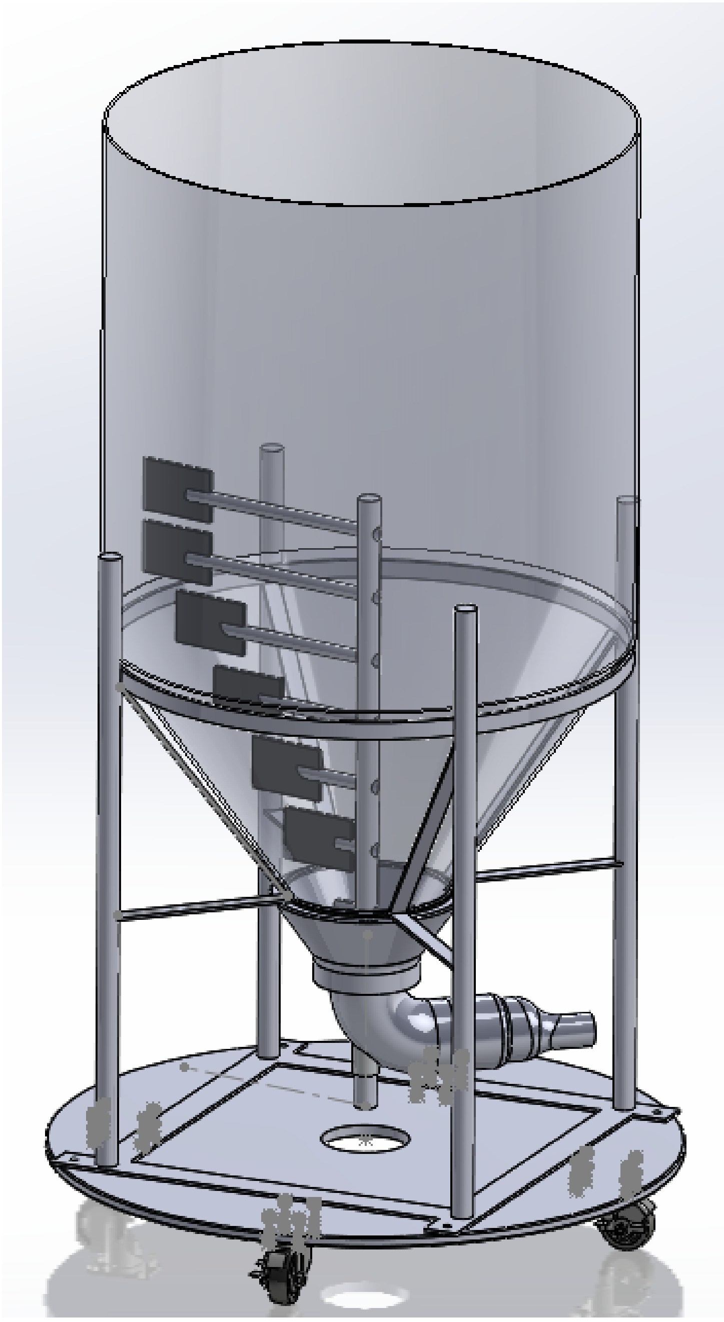
12.3 Reproducibility of Design

While the design is not overly complex in its assembly, certain changes would have to be made in order to allow for mass production of the DMF. For one, the outlet would most likely become a single component, specifically manufactured to a design contract outsourced to a designer of custom piping. The 3D printing of three separate outlet components, while convenient, is not a feasible method for mass production. The stirring mechanism is the biggest hindrance in production, as it takes the most manufacturing time out of any of the components.

Once the stirring mechanism and the outlet piping had been custom ordered from an outsourced company, the additional parts, which are stock parts, would be ordered by the company responsible for manufacturing. The detailed assemblage of these parts would be sent in the order contract, which is a relatively simple process once the custom parts have been acquired. The fact that the outlet and the stirring mechanism may have to be outsourced to a third party could introduce some issues in the way of mass production, but possible in house solutions at Neptune Benson could rectify this issue; specifically for the outlet production.

As far as the amount of DMF designs that would need to be produced, this number is entirely contingent on the number of Defender Filters that are marketed by Neptune Benson. The current numbers for Defender Filter orders are about 350 annually, with 2,800 already sold to this point. Seeing as the DMF is a compatible design with the Defender Filter, the initial influx of orders would be large, leading to a need for mass production at first; but would stabilize significantly when the already marketed filters had been taken care of. For this reason, and the fact the DMF is not a design that would be particularly easy to mass produce; Neptune Benson may want to consider only marketing this as an addition to new Defender Filter sales. An assembly of the final DMF design that would be marketed can be seen on the next page in Figure 53.

Figure 53: Final Design Assembly



13. TESTING

On April 2nd 2018, Team Defender was able to test the Defender Media Feeder System at the Neptune Benson facility. These tests were conducted in order validate the final design the team hopes to eventually present as a marketable product to Neptune Benson. These field tests were also completed to validate the proof of concept analysis previously executed by the team. If proven valid, the team will analyze the data taken from the field tests and move forward with a second-generation prototype that meets the overall design requirements to full effect. A detailed description of the tests conducted on April 2, 2018 can be seen in the following section.

The Defender Media Feeder was tested at the Neptune Benson facility on April 2nd, 2018. DMF Test 01 (DMFT01) consisted of a fully assembled Defender Media Feeder System prototype, one- twenty-gallon bags of perlite, and the Defender Filter Simulation Tank located in the warehouse of the Neptune Benson facility. The simulation tank at Neptune Benson was used in order to conduct this test, therefore, it was very important to coordinate a specific date and time with Neptune Benson to accomplish this portion of the project. In order to conduct this test, users had to be familiar with the loading process of the DMF system, as well as the Defender Filtration system and the components of each system. Since the loading process of the DMF system is manual, the only restriction that must be followed is the system must be turned off before loading, and the shutoff valve must be closed in order to avoid any setback. Since Team Defender is not familiar with operating the Defender Filtration unit, an engineer from Neptune Benson was present to assure the test was conducted accurately and safely. DMFT01 was conducted and observed by members of Team Defender and the engineering team of Neptune Benson.

13.2 DMF Generation I, Complete Assembly Test

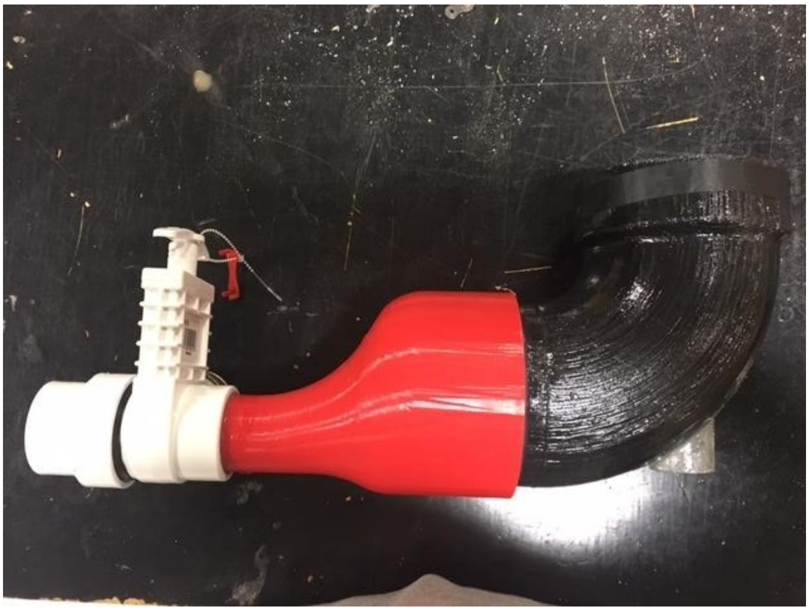
During DMFT01, one bag of perlite was loaded from its packaging into the 65-gallon tank, assuring a minimal amount of perlite escaped into the surrounding atmosphere, and was then sealed using a lid constructed of plexiglas/acrylic. The vacuum inlet of the Defender Filtration system was then connected to the outlet of the DMF system and the wheels were locked into place. After the vacuum was attached, the motor connected to the stirring mechanism was turned on, the shut off valve was opened and the vacuum was activated. At this point group members observed the performance of the DMF system, paying close attention to the flow of material through each component of the design. It is assumed that perlite would flow through the bottom of the tank to the outlet of the DMF, through the vacuum and into the Defender Filtration system. The stirring mechanism was able to agitate the material enough to keep a steady flow of media to the vacuum. This test is being conducted in order to observe the success of the DMF system and the flow results of each component were recorded. If, at any point, any component resulted in failure, the test would be stopped immediately, the failure would be noted and a planned resolution would be developed. The developed resolution may be able to be applied at the scene of the test or may result in a retest at a later date depending on the severity of the failure. The whole system that was being tested can be seen below in Figure 54.

Figure 54: Defender Media Feeder Generation I

13.3 DMF Outlet Test

Another portion of DMF Test 01 that was conducted on April 2, 2018 at the Neptune Benson facility was the flow of material exiting the outlet. To conduct this test, the outlet was removed from the bottom of the tank after the initial loading test was concluded. This test was done in order to observe the flow through the outlet and note any build up that may have occurred during DMFT01. This portion of testing was very important as the group was curious to see how the 3D printed parts and the coating used on the outlets would affect the flow of perlite media to the Defender unit. A closer look at the outlet assembly can be seen in Figure 55.

Figure 55: Prototype Outlet Assembly



13.4 Arduino Weight Scale Test

The accuracy of the Arduino scale, placed at the base of the DMF system, was also observed during DMF Test 01. To test the accuracy of the Arduino scale, the load cells were placed under a metal plate, each cell placed at under each corner of the plate. Using a laptop which had the Arduino scale software previously installed on it, the weight scale was tared to read a measurement of zero pounds. Next, three aluminum cylinders, whose masses were previously known to be 10.1 lbs, 20.9 lbs, and 30.2 lbs, were then placed individually in the center of the plate and the weight of the object was then displayed on the laptop. This was done with each weight three times.

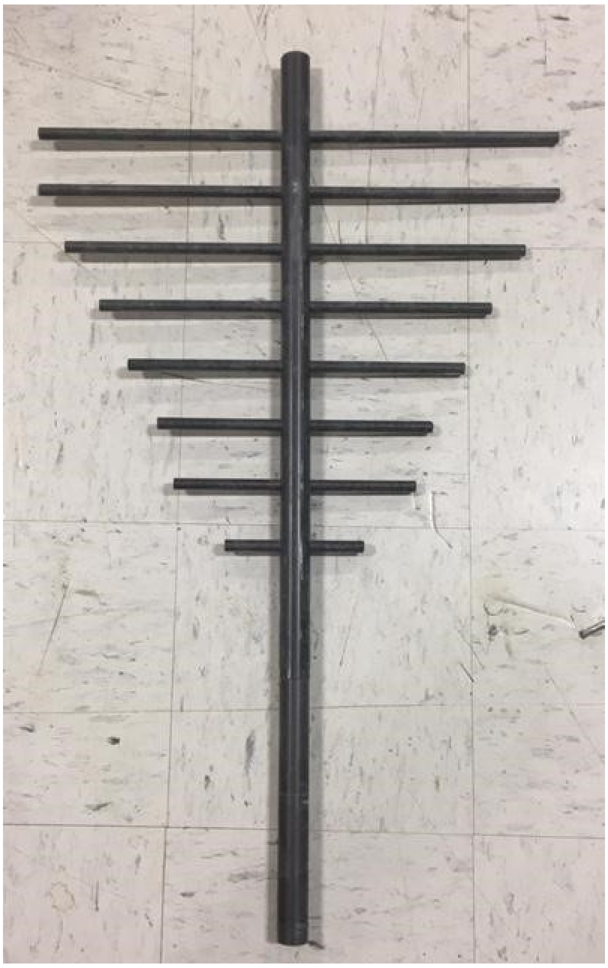
13.5 The Agitator 8.0

Another important component of the DMF system is the stirring mechanism that agitates the material and provides a continuous flow. A separate test was conducted on the longest member of the stirring mechanism in order to achieve the maximum stress the member can withstand before fracturing occurred. This test was conducted in Pastore room 120 at the University of Rhode Island using the Instron machine. A 22 3/8" piece of nylon rod was placed on two blocks, located at each end of the member. The Instron head was lowered until it was just touching the rod and the Force measurement on the Instron software was reset to zero. At this point force was added on to the member until failure occurred. The testing apparatus can be seen in Figure 56.

Figure 56: Instron Test

During the test, once failure occurred, the force obtained was recorded. Although the stress specifications of nylon were already known from previous tests conducted by other members of society, this value was very important as it reiterates exactly how much force can be applied on the stirring mechanism arms used in our design until failure occurs. A look at the overall design of the Agitator 8.0 used for the initial test can be seen in Figure 57.

Figure 57: Prototype Stirring Mechanism



14. Test Results and Discussion

The results of the first tests conducted on the first generation Defender Media Feeder, DMFT01, can be found below, each portion of the test separated by the component that was observed on April 2, 2018.

14.1 DMF Generation I, Complete Assembly Results

The test performed on the entire assembly of the first generation Defender Media Feeder system was done to test for the overall success of the feeder as well as record the mass flow rates and volumetric flow rates observed and compare them to the theoretical values calculated previously. After loading one 20-gallon bag of perlite into the DMF system and observing the flow of perlite through the system created by the vacuum it was noted that the stirring mechanism and motor did create enough agitation to provide a continuous flow of media to the vacuum. This continuous flow of perlite allowed one bag of media to be fed into the Defender Filtration unit in just under 55 seconds. Should this measurement of time hold true for multiple bags of perlite, this would result in five bags of perlite being emptied into the Defender unit in under five minutes, which was much less than the theoretical value calculated of thirteen minutes and would meet the goal set by Team Defender.

After observing how much time it took to transfer one bag of perlite from the Defender Media Feeder system to the Defender filtration unit, the team calculated the mass flow rate and volumetric flow rate created through the system. As mentioned before the team to found the theoretical value for the mass flow rate of the system which was calculated to be 9.5 lb/min and the theoretical value for volumetric flow rate to be 0.654 ft3/min. After the tests were completed, the experimental value for the mass flow rate of the system was determined to be 28.86 lb/min and volumetric flow rate was found to be 5.25 ft3/min. These values were much higher than anticipated which ultimately resulted in a much faster loading time. The team believes this could be due to the vacuum specs given by Neptune Benson as the Specifications of the actual vacuum used were much higher and the theoretical values used for perlite to be much different than the actual perlite used in the filtration process.

One negative result noted from DMFT01 was the accumulation of perlite along the cone bottom portion of the tank. Although this tank will not be used in the final prototype, and was strictly used for testing purposes, the accumulation that occurred was due to the angle of the cone not being steep enough and the stirring arms not being long enough to create contact points along the sides of the tank. This occurrence of funnel flow during the test can be seen below in Figure (9).

The final prototype tank will include the desired cone angle and the stirring mechanism arms will be long enough to create contact points on the tank. A more in depth discussion of changes to the first generation design will be discussed in the redesign portion of this report.

Figure 58: Flow Stagnation during Testing

14.2 DMF Outlet Results

After the testing of the overall system had concluded, the outlet of the DMF system was removed in order to observe any accumulation that may have occurred during the process. After removing the outlet, it was noted that there was no accumulation that occurred due to the surface finish of the 3D printed parts, material seemed to flow through these components with ease and the surface finish that was chosen was the correct application for the process at hand. However, it was noted that slight build up did occur behind the bushing that housed the stirring mechanism. This accumulation was something the team expected as the vacuum would not be able to provide enough force to pull the perlite from the opposite side of the bushing. Although slight build up did occur, the team does have a plan in place to correct this error and can be found in the redesign portion of this report.

14.3 The Agitator 8.0 Results

The nylon stirring arms are subject to stress when movig through the perlite media. The static force is calculated at 38 N, assuming the maximum weight encountered to be be 125 lbs and the static coefficient of friction in perlite is 0.67. After researching the properties of nylon rod, it was found that the Maximum Theoretical Flexural Strength of nylon is approximately 12,000 psi.

When testing the Nylon rods, we chose the longest member as all shorter members should be able to handle a greater force. Initially we wanted to test the member for failure, meaning a load would be placed in the center of the member until failure, or in this case fracture, occurred. However, at approximately 409N, about 66mm of deformation, the machine would not apply a greater force as the load frame limit for the Instron machine was tripped. Since this member was able to withstand the maximum force the Instron machine could produce, the team concluded that the material being used would be strong enough to overcome the static force of the perlite media.

15. Redesign

Based off of the results found through testing we have already started to redesign our DMF. The overall results for each test allowed us to pinpoint the thing that needed to be improved in order to make the DMF more efficient and function properly

15.1 Hopper

We have already started making changes to our prototype such as the overall containing unit. For our prototype we used the previous year's hopper. Based off of our calculations we found that the hopper was too small to fit the 5 bag minimum of perlite media. What we did was we researched and selected a 105-gallon hopper which will hold 5 bags of perlite. For the new tank we removed the top because the tank inlet hole was not large enough to allow for easy loading of perlite bags.

15.2 Lid

In our original design, we designed a lid on the DMF incorporating a hinged piece of plexiglas that would cover the top of the unit. During the test it was discovered that loading the perlite into the unit caused a dust cloud escaping through the open space on top of the unit. We redesigned the plexiglass cover to reduce the perlite dusting problem. In the new design, we cut the plexiglas in half and hinged them together. This new design reduces the open area by 50

15.3 Stand

Initially we designed and created 2x4 studs as support legs for the prototype tank. The new tank was purchased with factory support stand. The frame although slightly heavier will provide more stability. The new base also will facilitate our design addition of a precise electronic scale running on an Arduino microprocessor.

Use my comments and edit style to rewrite the rest of the article. Much rewriting is needed before this can be ready for publication.

15.4 Adapter

The adapter that was used on the base of the prototype tank was secured to the tank by bolting it in. The bolts on the inside of the tank create stagnant points which could cause a buildup of perlite. In order to prevent this, we will be fastening the outlet adapter to the stand. When the hopper is placed in and loaded the weight of the tank and media will create an airtight seal. The elbow containing the bushing will then be fastened into the adapter.

15.5 Elbow

The elbow that was used in the prototype worked well and did not allow for any leakage during operation time. One of the problems that we found was that perlite was getting caught behind the bushing and agitator arm. We found this problem and immediately changed the design from a 90-degree angle to a 45-degree angle. After printing the elbow, we found that it would fit or allow for easy flow given the space he have underneath the hopper. After seeing the issue, we went back to the 90-degree angle but reduced the size from a 4-inch hole to 3-inch hole which increases the intake velocity allowing for more suction to prevent those build ups.

15.6 Push Valve

On the prototype we used a shut off valve that was engaged by pushing a plate through grooves to block the flow. One problem that we have already had with the system after one test is that the perlite builds up in the groove preventing the valve from completely closing. This problem is going to be addressed and fixed by switching the push valve to a twist valve that will allow for a full cut off of flow every time with no grooves for perlite to be caught and built up in.

15.7 Agitator 8.0

The agitator 8.0 got its name for the 8 arms that rotate in the hopper scrapping perlite from the sides. The problem we ran into with the prototype was that the arms don't fully reach the sides of the tank. If we were to increase the lengths of the arms we would increase the risk of the motor blowing due to snag points or for the arms to shatter due to the not perfectly circular inside. The solution we have come up with for this design flaw is to add flexible scraper tips to the arms. The tips will be made up of a quarter inch thick piece of rubber that will slide into the arms and fastened using an adhesive. The tips being added will have the rigidity and stiffness to cut through the perlite build up but also have the flexibility to glide and flex over and imperfections in the hopper with causing shear on the arms.

15.8 Arduino Scale

One problem we saw with the overall test of the unit was that regardless of what we do the unit will always have a little bit of perlite build up in any crack or crevice. In order to fix this, we decided to put a scale under the unit that will compute a weight reading. The scale will be used to make sure the proper amount of pounds of media enter the system before the flow is shut off. The new base we have for the new hopper provides a perfect connected square base where the scale can be placed at all four corners giving an accurate weight reading.

16. Operation

The final DMF created by Team 3 contains the 110 gallon feeder for the perlite to be poured into and a powerful motor at the base that is used to agitate the perlite above. With any product, instructions for correct operation are important to maintain the durability of the device, and the safety of the operator. When using the DMF to automatically load a Defender filtration system, the first thing an operator must do is make sure that the surface the DMF is being used on is level and will not allow the DMF to shake excessively or move while the motor is turned on. Once an appropriate location is found for the DMF, the operator must lock the four wheels found underneath the wooden base. After the wheels are locked to ensure little movement of the DMF, the operator must attach the Defender vacuum to the DMF via the outlet coming out the bottom of the feeder. After attaching the vacuum to the DMF, the operator must plug the motor into a 120 volt wall power source. The operator should also make sure that the motor is in the off position prior to plugging the motor into the power source. The next step for the user is to load the preferred number of bags of perlite into the DMF through the opening at the top of the DMF. Once the small metal latch that holds the plexiglass lid in place is released, the lid can be lifted back and locked in place while the DMF is loaded. Because of the relatively large size and height of the DMF, it is recommended that the operator that loads perlite into the feeder is of moderate human height and can lift the bags of perlite individually with ease. To make loading of the DMF easier, it is recommended that the operator uses a small stepping stool to give the operator an extra foot or two of height. Once the preferred amount of perlite is loaded into the DMF, the operator must close and latch the lid at the top of the DMF and can then unlock the shutoff valve located on the DMF outlet and turn on the Defender filters vacuum. After turning on the vacuum and allowing perlite to be sucked into the filter, the motor can be turned on to assist in agitating the perlite within the DMF. If the Arduino scale is being used in conjunction with the DMF, the operator can observe the perlite weight within the DMF and turn off the vacuum and motor when the appropriate perlite load is vacuumed into the filter. Once the sufficient amount of perlite is loaded into the Defender filter and the vacuum and motor are turned off, the shutoff valve can be closed and the off vacuum disconnected from the DMF outlet. After disconnecting the vacuum, the motor should be unplugged from the power source and the wire wrapped up and hung on the DMF cable hook. If the DMF is to be used on other Defenders in the area, the wheels at the base of the DMF can be unlocked and the device can be moved for the perlite loading cycle to repeat.

When an operator is using the DMF to load perlite into a Defender filter, they should be aware of the potential hazards that using such a large and powerful device could pose. When moving the DMF from one filter to another, the operator should avoid rolling the DMF at excessive speeds and should avoid any inclines or declines on ground surfaces. This should be done to prevent any tipping of the DMF that could result in the device falling over. Similarly, the operator should avoid rushing any part of the perlite loading process so that one step is not completed poorly or forgotten that could result in injury. When loading the DMF with perlite, the operator should make sure they do not have to lift the perlite bags above their head and should use a stable stepping stool or small ladder to assist them. Although the lid should always be latched down when the vacuum and motor are on, the operator should never place their hands or material other than perlite into the device while the motor is on. Doing so could cause serious injury to the operator due to the high rotational speed and high torque of the motor. Lastly, the lid should always be latched down when perlite is not being loaded into the device to prevent the escape of perlite and its release into the air around the operator. Although perlite is not a carcinogen, its inhalation should be avoided and those with breathing problems such as asthma should take extreme precaution when loading in the perlite.

17. MAINTENANCE

17.1 Upon Arrival

When the assemblage arrives at the Neptune-Benson facility or any other facility for installation, the DMF will be checked for any pre-existing damages. It will then be checked to make sure that it is clean and free of any outside contaminants or excessive moisture. Any moisture or other foreign substances must be removed prior to loading of perlite into the DMF container.

17.2 General Maintenance and Cleaning

The DMF is a closed contained system that moves dry media making it a very easy system to maintain and clean. The DMF is broken up into multiple components that can be disassembled for easy cleaning or servicing. Since the media is used in pools it can easily be cleaned by hosing down or spraying with water. The outlet system that is used will be connected together using threaded counterparts which will allow for each piece to be removed and cleaned or in the case of a repair, easily interchangeable. According to our calculations the system will need to run for a maximum of 7 minutes in order to completely empty the hopper. Depending on the amount of defender units the company has, it will only need to run 7 minutes per unit about once every month. That being said the system should be reliable and have a long shelf life. Since the hopper is made of a 1/4 inch polyethylene plastic it will have a long life but eventually need changing due to wear. The outlets parts will be easily interchangeable and when worn out or broken they are easily disposable in any recycling bin or trash can. The motor has a 10 year warranty and will need to be replaced or refurbished after the warranty is up. The rubber tips attached to the agitator are very easy to replace if they fall out or are worn down. Since the rubber tips will be in contact with the side of the hopper they will need to be replaced yearly due to wear. Since the system is easily accessible and contains independent parts it will be easily maintained and easy to fix if any parts were to fail or break.

18. ADDITIONAL CONSIDERATION

18.1 Economic Impact

Since Neptune Benson has the intentions of selling the DMF to current customers that own a Defender filter, the device could have a huge economic impact both for Neptune Benson and the consumer. With a total materialistic cost of approximately $1100, the DMF if marketed would bring profit to Neptune Benson depending on the price they advertise the device for. Along with bringing profit to Neptune Benson, the device would save Defender customers money through the elimination of the time consuming manual perlite loading process. Since the DMF cuts down perlite loading time into the Defender by nearly one-fifth the original time, Neptune Benson customers that own the DMF will see themselves paying less to the workers that would originally have to spend greater time loading the perlite into the filters.

18.2 Environmental Impact

The only possible environmental impact that could arise from the use and operation of the DMF is the energy consumption from years of use. While the motor used in the DMF design uses electricity from an average US 120 volt wall power supply that is not present with human labor, the time saved from automation process will definitely reduce the total electric energy used by loading perlite into the filter. Since the time is takes to load the perlite using the DMF is one-fifth the time is takes to do it manually, this means that the defender vacuum will be on one-fifth of the time is was with human labor. This change even with the additional energy drawn from the motor included will certainly reduce the environmental impact and will create a cleaner and greener system despite adding more electric components to the design.

18.3 Societal Impact

The biggest societal impact that will result from the implementation of the DMF into the perlite loading process will be to the workers whose job it was to originally vacuum the perlite manually. Although the automated DMF still requires some human labor, such as loading the perlite into the DMF, the time saved in the process will allow for the worker to get the loading process done quicker. This time saved will allow Defender maintenance workers to work on matters of more serious importance instead wasting their time and skills vacuuming the perlite by hand.

18.4 Political Impact

One of the political impacts that the DMF may have is on European customers that live in countries with stricter worker-inhalation regulations and laws than the United States. Most of these European laws prevent workers from closely handling materials that can spread easily in the air like perlite even though perlite is non-carcinogenic. An attachment to the Defender filter like the DMF will allow for workers to have less contact with perlite and in certain countries could attract possible customers to Neptune Benson over a competitor due to the added legality of the worker safety process.

18.5 Ethical Considerations

One of the biggest ethical considerations when addressing the creation of the DMF and its intended sale to Defender owners is how it is advertised. When advertising a product, it is important not to lie to the customer or make false claims about the products performance. If the product was to go on sale, more comprehensive tests about the DMFâĂŹs safety, energy usage, durability and long term maintenance would have to be conducted to ensure the legal sale of the device and the ethically moral advertising of the product to customers.

18.6 Health, Ergonomics and Safety Considerations

When creating the DMF, safety of the operator was considered the most important among any other considerations. One of the biggest concerns was limiting the escape of perlite and this was addressed by using tight weather stripping around the lid and tight bushings to avoid perlite leaks. Along with limiting perlite releasing into the air, another health consideration when designing the DMF was following OSHA standards so that this device could be legally manufactured and sold. These issues were address by limiting the operators required force to move the device and by making sure the operator did not have to lift excessive weight to load the device.

18.7 Sustainability Considerations

When the DMF was being designed, the team wanted to make an extremely reliable and durable product given the knowledge that most Neptune Benson products are paired with a ten-year warranty. Through successful tests, the team concluded that the device operated well under the given stresses of operation and that the product would not require constant maintenance if taken care of and used by a trained operator.

19. CONCLUSIONS

Team Defender was tasked by Neptune Benson with the automation of perlite media transfer from the material packaging into the compatible Defender units. The product had to adhere to a design outline that incorporated safety, efficiency, sustainability, and compatibility. While this product would require an investment on the part of the consumer, it would provide a significant improvement on labor time that would otherwise be wasted by the laborer involved in the process. After arduous concept development, the team decided on a conical hopper design that implemented a stirring mechanism powered by a motor stationed below the vessel. While there are pros and cons to the design, based on the proof of concept, this is seen to be the most viable solution available.

The Defender Media Feeder, or DFM, needed to adhere to a number of initial design specifications. These specifications can be seen, detailed below in Table 11.

Specifications	Requirement
Automated	Transfers perlite to filter with no human interaction
Size	Max Width of 3ft Max Height of 5.5ft Min Volume of 100 gal
Maintenance	Every 10 years
Life Expectancy	10 year guarantee
Cost	Less than $1000
Safety	Failsafe included, Less than 50 lbs
Maneuverability	Can navigate tight spaces with relative ease
Compatibility	Adheres to existing Defender Filter models

Table 11: Projected Total Cost for Materials purchased Next Semester

As seen in these specifications, automation was the first and foremost concern with the design team. Secondly, the design needed to satisfy the requirement of compatibility with the largest Defender Filter model currently sold by Neptune Benson; which requires the transfer of 5 bags of perlite media. As each bag holds roughly 20 gallons of perlite, the design was required to be a minimum of 100 gallons in volume.

Since it was marketed strictly towards current and prospective owners of Defender Filters, the cost of the design was not needed to be severely minimized; considering the large capital investment made on these filters by the consumers. However, there did need to be a strict requirement on the life expectancy of the DMF, as Neptune Benson provides a 10 year guarantee on each Defender model. As a complementary product to the Defender, the DMF needed to mirror these standards.

Regarding the safety of the product, a failsafe needed to be included in the final design. The DMF implements a simple push-valve as a means to meet this requirement. The valve simply cuts off the flow to the vacuum, at which time the operator is provided adequate time to turn off the motor. As far as weight requirements for the model, OSHA requires a maximum lifting weight of 50 pounds for employees [6]. This is due to possible health and safety concerns that the employer can be found liable for. In accordance with this, the DMF was designed at a weight of 44 pounds.

Maneuverability was also a point of emphasis during the design process of the DMF. The establishments in which the Defender Filters are currently installed, while unique case by case, share the similarity of being relatively tight quarters. As a result of this, the design is installed with an easily maneuverable wheel rig that allows unrestricted movement within these tight spaces. Additionally, the width of the design is 30 inches, which allows for 6 inches of space to move between the standard doorway width of 3 feet.

Following testing and redesign of some of the components of the original prototype, the team believes that they have created a viable product to be manufactured and sold to the public. Tests have shown that the DMF is even more efficient than originally anticipated, working at a pace of about 5 bags every 5 minutes; or a minute per bag. This is significantly reduced from the current process time, which takes about 5 minutes per bag. Given this level of efficiency, it is reasonable to assume that this could be a viable product for sale as a compatible addition to Neptune Benson's Defender Filter designs currently being marketed.The team will meet with Neptune Benson one final time for field testing and general discussion of the DMF's future marketing and production options.

The team would like to thank Nick DiRocco, Neptune Benson's engineering team of Stratton Tragellis, Steven Hawksley, Steven Nicolich, and as well as Dr. Nassersharif for their continued guidance and help throughout the entire process.

REFERENCES

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APPENDICES

Figure 59: 110 Gallon Polyethylene Ace Roto-Mold Tank

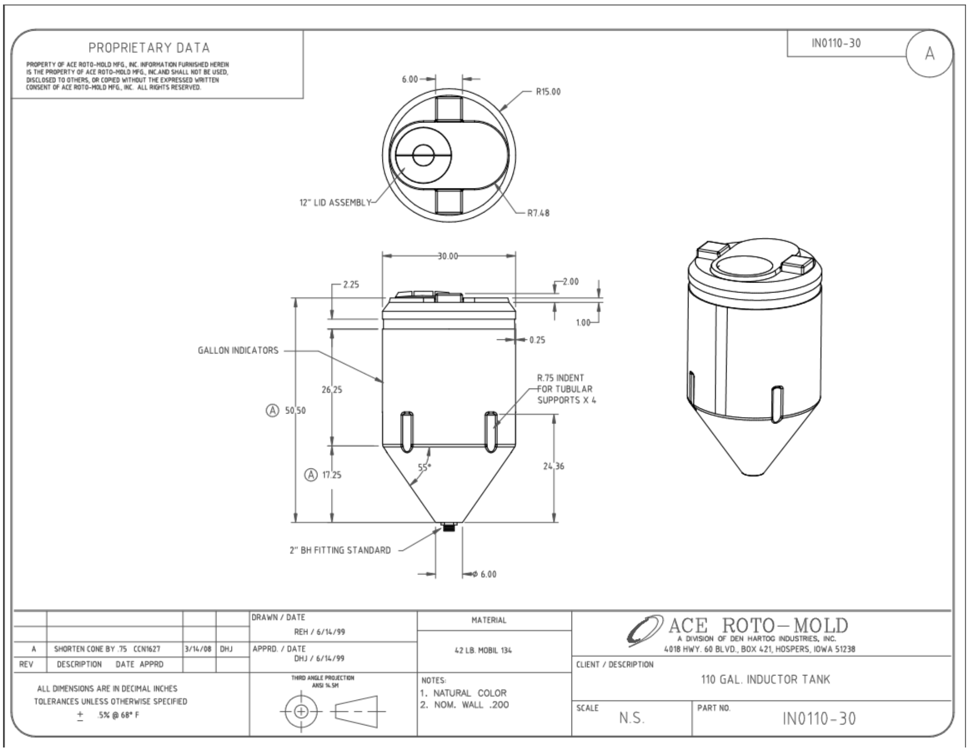


Figure 60: Stirring Mechanism Design 1

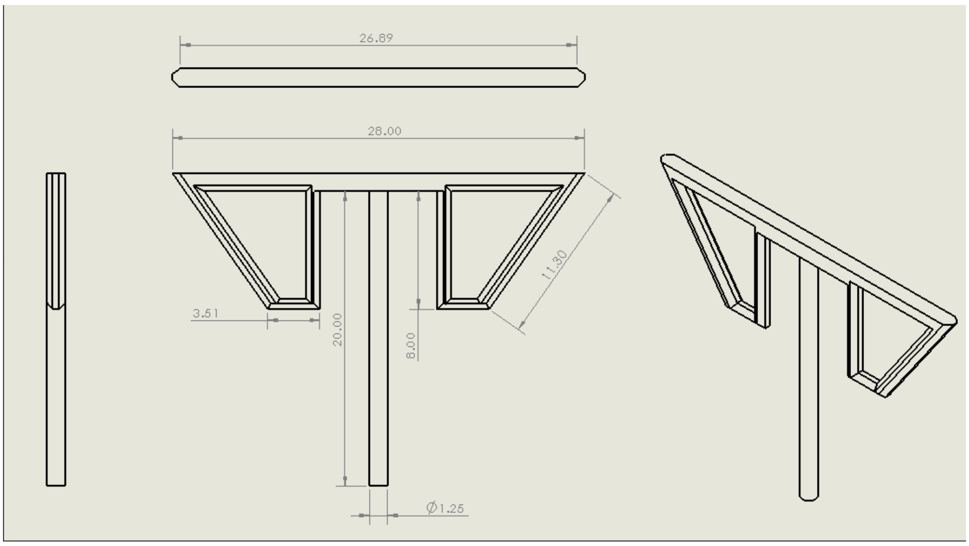


Figure 61: Stirring Mechanism Design 2

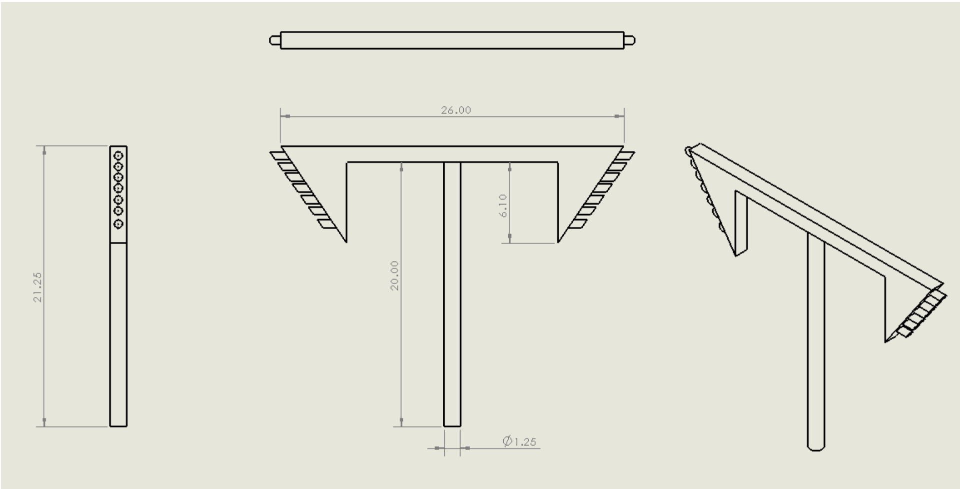


Figure 62: Stirring Mechanism Design 3

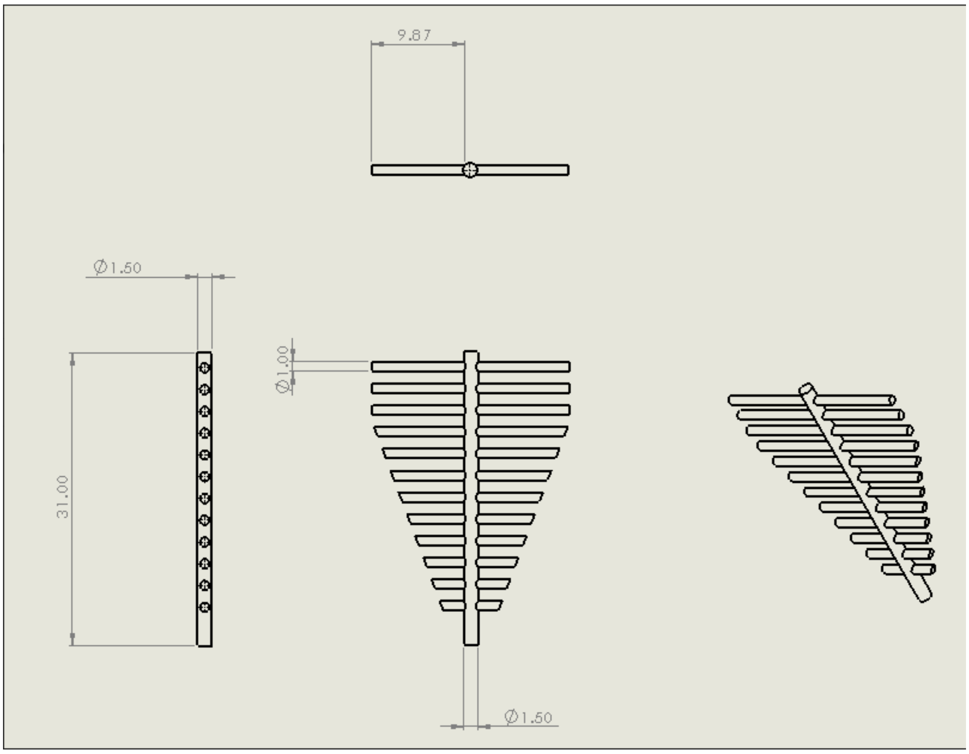


Figure 63: National Tank Outlet quote for 200 Tanks and Stands

NATIONALTANK OUTLET

QUOTATION

4728 Spottswood Ave, Ste 328
Memphis, TN 38117
Phone: 888-686-8265

Date	Quote #
12/15/2017	25544

Name / Address
Neptune Benson Coventry RI 02816 Attn: Patrick Marie P#: 888-565-1712

Email sales@ntotank.com
Website www.ntotank.com

Chemical Application	Lead Time	Rep	Terms	FOB
	Approx 4 w...	FDB	TBD	IA

Qty	Item	Description	Price Each	Total
		* DELIVERED PRICE FOR 200 TANKS AND STANDS to COVENTRY RI 02816		
200	DIN0110-30	110 Gallon LHDPE 30 Degree Cone Bottom Inductor Tank w/12" Manway & 2" PP Bulkhead 30" dia x 51" ht	344.55	68,910.00
200	DIN40/85-...	Painted Steel Stand for a 30" Diameter, 60 Degree Cone Bottom Inductor Tank * 12" Bottom Clearance		0.00

Subtotal	$68,910.00
Sales Tax (0.0%)	$0.00
Total	$68,910.00

The Nation's Largest Plastic Tank Supplier

Figure 64: Order Form

MCISE Capstone Order Request Form

4103 **ASAP**

Auto-fill

Nationcal Tank Outlet

Street Address 4728 Spottswood Ave, Ste 328 Phone Number

City, State Zip Memphis, TN 38117 (888)686-8265

Shipping From Iowa

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 3 **MPA #:**

Project Sponsor: Neptune Benson

Project Name: Defender Media Feeder

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

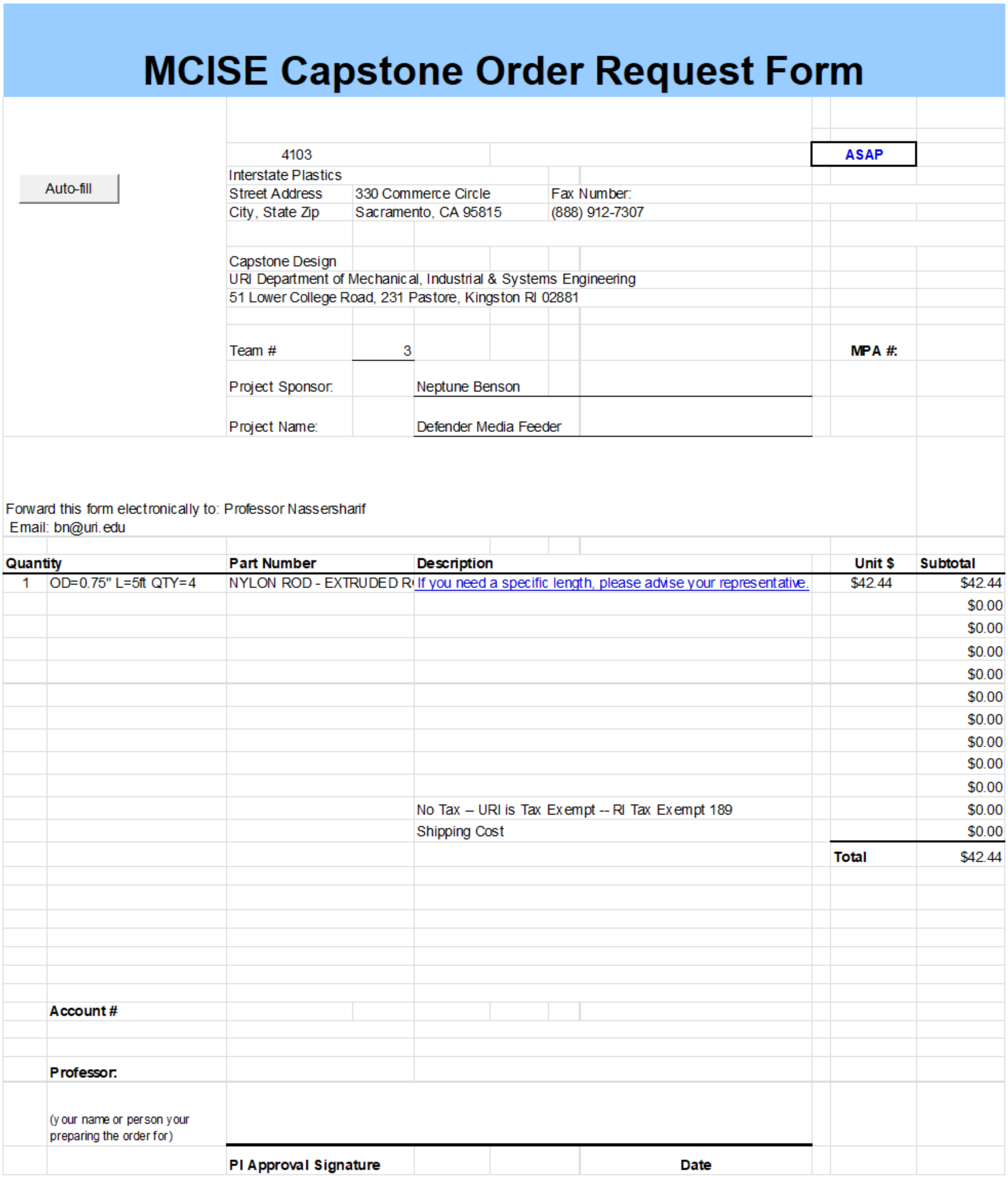
Quantity	Part Number	Description	Unit $	Subtotal
1	110 Gallon / MPN: INFD110-30 / Store ID: X6641160	n/110gallon-acerotomold-white-cone-bottom-tank-x6641160	$209.99	$209.99
1	110 Gallon / Store ID: X8090815 / Prod. Part #: INFD40/85-ST	https://www.ntotank.com/acerotomold-40-60-85-110gallon-t	$139.99	$139.99
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$349.98

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

Figure 65: Order Form



MCISE Capstone Order Request Form

Auto-fill

4103 ASAP

Interstate Plastics

Street Address	330 Commerce Circle	Fax Number:	
City, State Zip	Sacramento, CA 95815	(888) 912-7307	

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 3 MPA #:

Project Sponsor: Neptune Benson

Project Name: Defender Media Feeder

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity		Part Number	Description	Unit $	Subtotal
1	OD=0.75" L=5ft QTY=4	NYLON ROD - EXTRUDED R	If you need a specific length, please advise your representative.	$42.44	$42.44
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
			No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
			Shipping Cost		$0.00
				Total	$42.44

Account #

Professor:

(your name or person your preparing the order for)

PI Approval Signature **Date**

Figure 66: Order Form

MCISE Capstone Order Request Form

4103 ASAP

Auto-fill

Amazon
Street Address Fax Number:
City, State Zip XXX-XXX-XXXX

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 3 MPA #:

Project Sponsor: Neptune Benson

Project Name: Defender Media Feeder

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description	Unit $	Subtotal
1	ASIN: B00B95SMUA	UTF8&qid=1518902139&sr=8-41&keywords=pvc+shut+off+valve	$9.95	$9.95
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt – RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$9.95

Account #

Professor:
(your name or person your preparing the

PI Approval Signature **Date**

Figure 67: Order Form

MCISE Capstone Order Request Form

4103 asap

Auto-fill

Amazon
Street Address Fax Number:
City, State Zip XXX-XXX-XXXX

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 3 **MPA #:**

Project Sponsor: Neptune Benson

Project Name: Defender Media Feeder

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description	Unit $	Subtotal
1	B0000CBIFC	qid=1523562553&sr=1-4&keywords=weather%2Bstripping&th=1	$3.98	$3.98
1	50ENEL	https://www.amazon.com/dp/B00G56XFZK?pd_rd_i=B00G56XF	$7.60	$7.60
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt – RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$11.58

Account #

Professor:
(your name or person your preparing the

PI Approval Signature **Date**

Figure 68: Order Form

MCISE Capstone Order Request Form

ASAP

Auto-fill
4103
Equaseal.com
Street Address
City, State Zip

Fax Number:
(330) 538-8630

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 3 **MPA #:**

Project Sponsor: Neptune Benson

Project Name: Defender Media Feeder

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description	Unit $	Subtotal
1	NA	https://www.equalseal.com/ShoppingCart.asp?	$47.36	$47.36
	^^	Black Buna-N Rubber Rubber - 60 Durometer - 1/4" Thick - 24" x		$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$47.36

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

Figure 69: Order Form

MCISE Capstone Order Request Form

ASAP

Auto-fill

4103
Interstate Plastics
Street Address 330 Commerce Circle Fax Number:
City, State Zip Sacramento, CA 95815 (888) 912-7307

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 3 **MPA #:**

Project Sponsor: Neptune Benson

Project Name: Defender Media Filter

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity		Part Number	Description	Unit $	Subtotal
1	OD=1.25" L=3ft QTY=3	NYLON ROD - EXTRUDED R	ameter=1.250&dim2=3&qty=3&recalculate.x=39&recalculate.y=25	$48.55	$48.55
1	OD=0.5" L=5ft QTY=6	NYLON ROD - EXTRUDED R	https://www.interstateplastics.com/Nylon-Extruded-Round-Md-Roc	$27.70	$27.70
3	1-1/4" ID, 1-1/2" OD, 1 1/2"	202424	https://www.interstateplastics.com/Bushing-Cylindrical-Md-Filled-N		$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
			No Tax – URI is Tax Exempt – RI Tax Exempt 189		$0.00
			Shipping Cost		$0.00
				Total	$76.25

Account #

Professor:

(your name or person your preparing the order for)

PI Approval Signature **Date**

Figure 70: Order Form

MCISE Capstone Order Request Form

4103
Acme Plastics
Auto-fill

ASAP

Street Address 222 Browertown Rd
City, State Zip Woodland Park, NJ 07424 US
Phone number: 1.888.278.3386

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 3

MPA #:

Project Sponsor: Neptune Benson

Project Name: Defender Media Filter

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description	Unit $	Subtotal
1	CODE: CTS-9-44	s://www.acmeplastics.com/cut-to-size-clear-acrylic-sheet-extruded	$62.50	$62.50
	^^	Dimensions: thickness: 1/4" Length: 30 inches Width: 30 inches		$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$62.50

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

Figure 71: Order Form

MCISE Capstone Order Request Form

ASAP

Auto-fill

4103
Big Poppa Smokers
Street Address 63973 hook street
City, State Zip Coachella Califoma 92236
Fax Number:
1-877-884-4090

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 3

MPA #:

Project Sponsor: Neptune Benson

Project Name: Defender Media Feeder

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description	Unit $	Subtotal
1	SKU: 924UKH	)obChMIlta5heWH2QIViYizCh1cQAnQEAQYBSABEgIP6vD_BwE	$50.00	$50.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$50.00

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

Figure 72: Order Form

MCISE Capstone Order Request Form

4103 **ASAP**
Auto-fill Amazon
Street Address Fax Number:
City, State Zip XXX-XXX-XXXX

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 3 **MPA #:**

Project Sponsor: Neptune Benson

Project Name: Defender Media Feeder

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description	Unit $	Subtotal
1	ASIN: B01MA398MH	8027578&sr=8-6&keywords=arduino+uno+r3+ultimate+starter+kit	$28.99	$28.99
1	ASIN: B00NPZ4CPG	https://www.amazon.com/Keyes-Weighing-Sensor-Module-Arduin	$20.48	$20.48
3	ASIN: B0044FBB8C	https://www.amazon.com/Loctite-Plastic-0-85-Fluid-Syringe-13631	$8.37	$25.11
1	ASIN: B00B29A5K8	https://www.amazon.com/FiberFix-Repair-Tape-Wrap-Waterproof	$9.99	$9.99
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$84.57

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

Figure 73: Order Form

MCISE Capstone Order Request Form

4103 **ASAP**

Auto-fill

SparkFun Electronics
Street Address 6333 Dry Creek Parkway Fax Number:
City, State Zip Niwot, Colorado 80503 (303)284-0979

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 3 **MPA #:**

Project Sponsor: Neptune Benson

Project Name: Defender Media Feeder

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity		Part Number	Description	Unit $	Subtotal
4	Load Cell - 200kg, Disc (TAS606)	SEN-13332	https://www.sparkfun.com/products/13332	$56.95	$227.80
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
			No Tax -- URI is Tax Exempt – RI Tax Exempt 189		$0.00
			Shipping Cost		$0.00
				Total	$227.80

Account #

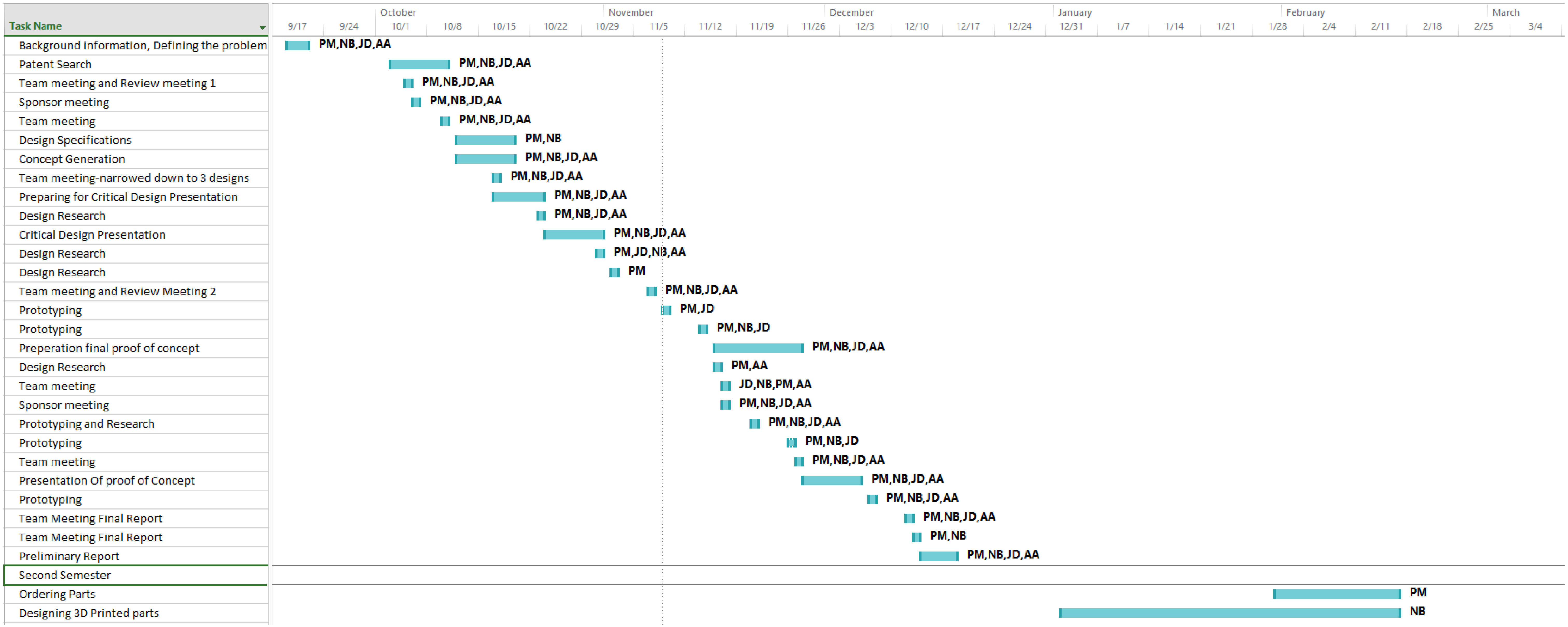
Professor:

(your name or person your preparing the order for)

PI Approval Signature **Date**

APPENDICES

Figure 74: Project Plan Part 1



APPENDICES

Figure 75: Project Plan Part 2

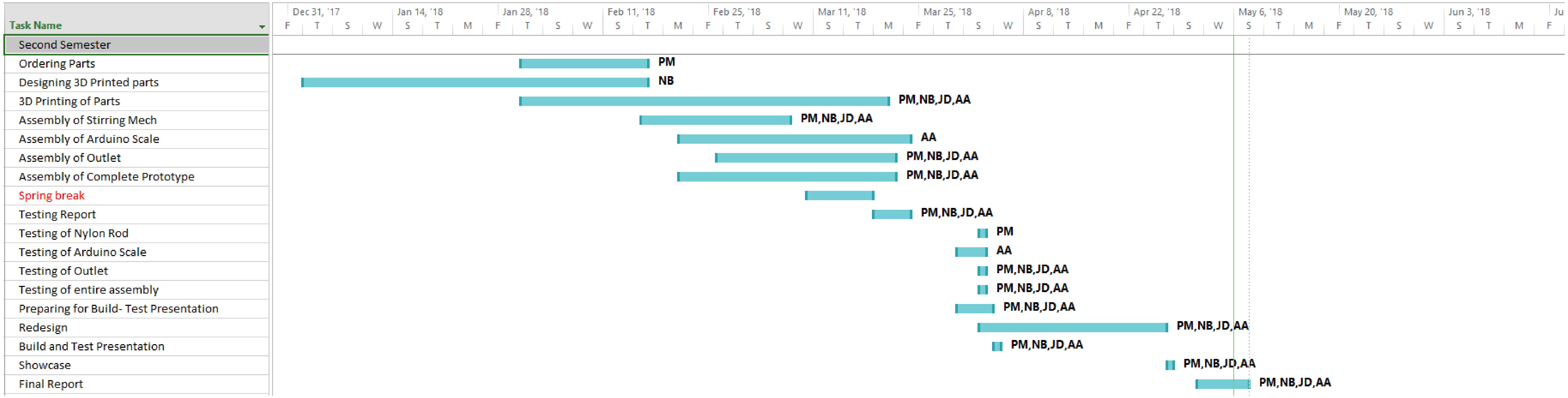


Figure 76: QFD