Akron Honey- Honey Infuser

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Akron Honey Design Project

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Executive Summary

There is a need for a honey infuser to support Akron Honey's new product line, 'honeytune'. Akron Honey would like to be able to infuse active ingredients into their natural honey to make a balanced flavor. Currently, their process for 'honeytune' is tedious and inefficient. Thus, the goal of this project is to design an infuser that meets all specifications while remaining very efficient. The project will require the team to submit design for quotes and fabrication.

The specifications for the infuser are as follows. The infuser should be able to process a large volume of honey (up to 15 U.S. gallons), heat the contents up to 300°F, and rotate at a speed of 30 rpm . It must also have the capabilities for smoking the honey product, if necessary. Additionally, the product owner would like the ability to taste the product during the production phase. Lastly, the final design must be transportable, variable, and most significantly efficient.

Throughout the course of the design process, the team transitioned the initial plans to meet the product owner requirements. Midway, the design had changed to modifications of a current product versus reinventing the wheel. Thus, the team successfully completed these modifications with very few difficulties.

The final design requires purchasing the bottling tank and necessary heating element from Maxant industries, fabrication of the infuser lid and accessories, and purchasing of necessary components. Reference section 5.2 for a bill of materials. Moreover, the final design utilizes a 1.5 hp motor that will drive the mixing impellers at 30 rpm through 15 gallons of viscous honey. The base lid will be fabricated with 304 stainless steel to maintain a food-safe product. Also, the lid has been sent out for a fabrication quote request. Further details will be provided to the product owner upon receival. However, the design team has estimated that the final cost will be approximately $1,800.

Additionally, the team will assist the product owner in assembly and oversight of initial production use. Upon finalization, the product will allow Akron Honey to further expand the 'honeytune' product line by allowing for the product to be made in bulk sizes. Finally, the design team wishes the product owner the best of luck in future endeavors.

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1.0 Introduction

This project was assembled by a local company called Akron Honey, which focuses on producing honey from their local hives located throughout the city. The promise of the company speaks for itself, "We promise to continue working hard to ensure that we make healthy food both affordable and accessible" [1]. The business was started by a citizen of Akron, Ohio named Brent Wesley. He had a passion for his neighborhood and began by developing Akron Honey. It all began with a vacant lot, and some honeybees. Since, the company has continued to grow substantially. This growth is afforded by Wesley's innovative and creative mind to think outside of the box. To further grow, a new product line has been released called 'honeytune'. However, for this product line to be successful, the company is in need for a process to simplify the procedure. Due to this reasoning, this project was initiated to design a process for the creation of the new product, 'honeytune'.

1.1 Background

The basis of the 'honeytune' is the addition of active ingredients to natural honey. Currently, they are using a 20 gallon traditional honey extractor to mix the ingredients with the honey. This extractor uses a variable speed motor which causes a long mixing time. Also, the extractor is made of heavy stainless steel which lacks mobility of the machine. This process is tedious and inefficient and therefore, needs improvement. They would like a large scale rotating drum to help support their new infused honey product line. Thus, the goal for this project is to design and potentially manufacture a honey infuser to enhance the 'honeytune' product line process.

1.2 Literature Search

During the design process the team completed some research regarding beekeeping, honey and honey processing. The team felt that having a base understanding of honey would be helpful during the design process. Experimental research was also required for determination of the power consumption during the impeller mixing process. This information was helpful in selecting a proper motor. Furthermore, basic design research was completed to help streamline the procedures.

1.3 Principles of Operation

The purpose of the honey infuser is to allow for a mixture of active ingredients into the natural honey with occasional smoking of product. This process must be completed in a particular way, in order to meet quality standards. The process is defined by the following steps.

1. Store natural honey into a barrel.
2. Heat honey to a particular temperature
3. Infuse honey with active ingredient
4. Smoke mixture, if necessary
5. Rotate barrel to simulate stirring of mixture
6. Analyze and test the final product to meet quality standards.

To fully meet customer needs, the final product must be designed according to this procedure.

1.4 Product Definition

In order for the product to be successful, the final infuser design must meet the following specifications.

1. Ability to process a large volume of honey, up to 15 U.S. gallons
2. Ability to heat the contents up to 300°F
3. Rotate at a speed of 30 rpm
4. Smoking capabilities
5. Measurement quantities for quality purposes
6. Ability to taste product during process
7. Transportable
8. Easy to Handle
9. Quick packaging ability

These specifications were determined by the product owner through his previous experience developing the 'honeytune' product.

2.0 Conceptual Design

The conceptual design process is a systematic structured approach as shown below:

1. Generate a large number of concept solutions/brainstorming
2. Create a functional flow diagram to break the problem into smaller easy-to-handle parts
3. Create a morphological chart to map out different ideas for each main task of the infuser
4. Develop an objective tree to weigh the importance of each objective and subjective specifications
5. Select one concept solution using the weighted design matrix

2.1 Brainstorming of Concept Solutions

The brainstorming process was quickly achievable due to the amount of specifications and prior work completed by the product owner. The design team was able to discuss and prepare many ideas/concepts that met all specifications. These newly created ideas/concepts were used for further development in the conceptual design stage. However, through quick screening many of these designs were eliminated. Reference Section 2.4 for a few of the acceptable concept sketches.

2.2 Function Structure Diagrams

The functional flow diagram allows for the breakdown of the problem into smaller easy-to-handle parts. Figure 1 shown on the page below, is a representation of the functional flow diagram.

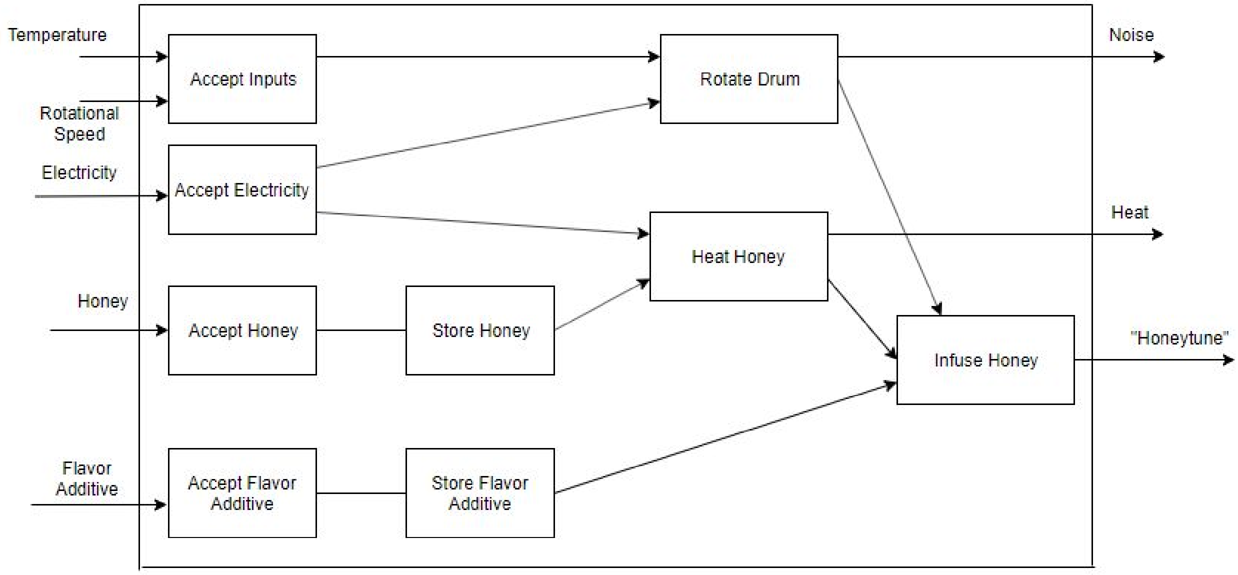


Figure 1: Function Structure Diagram for Honey Infuser

The diagram depicts the input-output functionality of the honey infuser. The inputs are basic terms that help to simplify the needs for the objective of "honeytune". The diagram ensures the main tasks which will be used in the development of the morphological chart.

2.3 Morphological Chart

The Morphological Chart, Figure 2 shown on the page below, allows for the exploration of many different design possibilities. This chart is a creative way to view the design in simple easy-to-handle tasks, which help to further design the product.

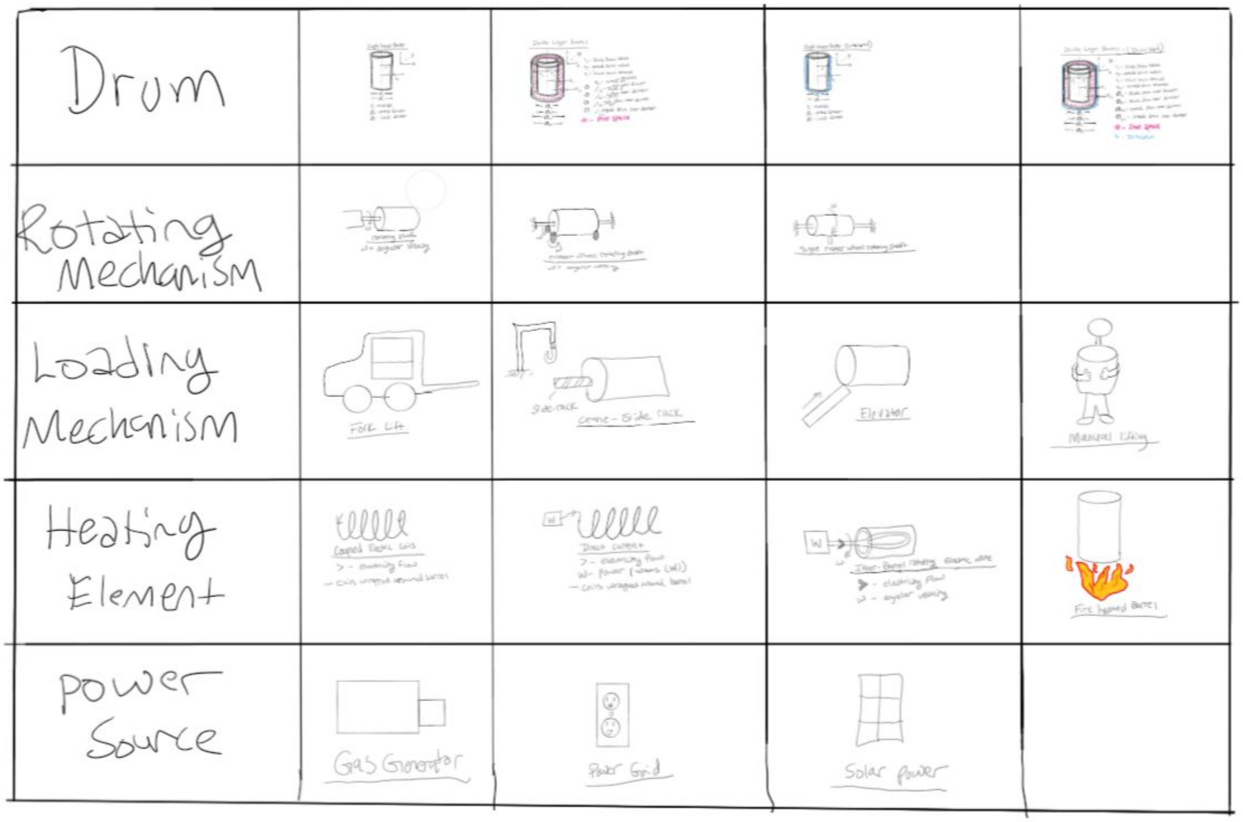


Figure 2: Morphological Chart

Reference Appendix A for enlarged pictures of the hand-drawn sketches.

2.4 Concept Sketches

From the Morphological Chart, six designs were selected using quick screening and eliminating the invalid designs. These six designs were continued for evaluation, meaning concept sketches were created to further analyze the benefits and weaknesses of each design. For report simplicity, the concept sketches are attached in Appendix B.

2.5 Objective Tree

To help determine the optimal design, an objective tree was developed to analyze the importance of the customer's criteria. Reference Figure 3 below. Each criterion was separated into Objective or Subjective specifications. This separation allows for the determination of the weight for each criterion which will be used for the Weighted Decision Matrix.

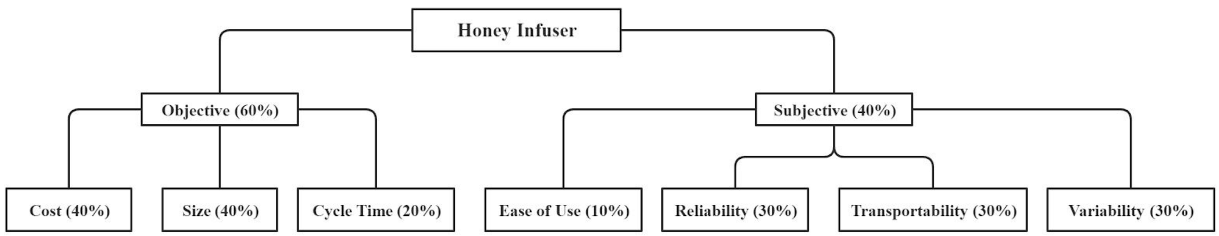


Figure 3: Objective Tree for Honey Infuser

Each criterion was separated into Objective or Subjective specifications. This separation allows for the determination of the weight for each criterion which will be used for the Weighted Decision Matrix.

2.6 Weighted Decision Matrix

With many design options from the Morphological chart, a few were selected as being valid. Through quick screening, logical reasoning, combined experience, and the customer requirements, three designs were selected for further evaluation. These designs are listed below.

Design 1: Double Layer Barrel (Insulated), Rotating Shaft, Crane-Slide Rack, Direct Current Coil, Power Grid

Design 2: Double Layer Barrel, Multiple Rubber Wheels, Forklift, Coupled Electric Coils, Gas Generator

Design 3: Single Layer Barrel (Insulated), Single Rubber Wheel, Conveyor, Rotating Electric Wire, Power Grid

Objective	Weight	Design 1	Design 2	Design 3
Cost	0.24	3	2	2.5
Size	0.24	2.5	2.5	2
Cycle Time	0.12	4	3	2
Ease of Use	0.04	4	2.5	2.5
Reliability	0.12	3	2.5	2.5
Transportability	0.12	3	1.5	2.5
Variability	0.12	3	3	2
Total Weights	1	3.04	2.38	2.26

Figure 4: Weighted Decision Matrix

Subsequent to creating the shown weighted decision matrix (Figure 4), it was determined that the optimal design for the honey infuser was Design 1. It significantly outweighed Design 2 and 3 with a weighted value of 3.04 while Design 2 and 3 weighed in at 2.38 and 2.26 respectively. For this reason, Design 1 was chosen for the embodiment design procedure.

3.0 Embodiment Design

The embodiment design is an expansion of the conceptual design. This section is about applying more detail to the concepts which were developed previously. Furthermore, the selected design will be placed through various engineering considerations, allowing the team to fully define and achieve an optimal design. Connection methods and required power calculations will be analyzed to further the design towards completion.

3.1 Design Transition

During the course of the project, Mr. Wesley informed the team that he would like to take the project into a different direction. Being a smaller company, Akron Honey was motivated to change the project scope to make it more financially practical . Instead of designing an entire mixing tank from scratch, Mr. Wesley discovered the company, Maxant Industries, who already manufactures a mixing tank. However, this mixing tank does not meet all of Mr. Wesley's needs, namely, it lacked the capacity to integrate a system to smoke the honey. The new scope of the team's task is to design modifications for the existing mixing tank. These modifications are summarized below.

1. Design a lid for the existing barrel with the following features:
    a. Ability to attach a smoking system
    b. Opening to add ingredients mid-operation
    c. Able to support the weight of the motor
    d. Able to fasten to the barrel to counteract motor torque
2. Design a drive shaft
    a. Transmit torque from motor to blades
    b. Ability to attach impeller blades
3. Design impeller blades
    a. Agitate/mix honey and ingredient
    b. Three design styles
        i. Upward 45° angle
        ii. Downward 45° angle
        iii. Center blade aligned vertically (90° angle)
4. Drive Motor Selection
    a. Motor must provide necessary power and torque
    b. Variable speed controller
    c. 3-phase, 120 V electrical power supply

3.2 Detailed Layout of Functions

Table 1 shown below details the function of each modification feature and the particular source from which the feature will be achieved.

Modification Feature	Function	Source
Motor	Provide necessary power to mix honey	Purchase through McMaster-Carr
Shaft	Transmit power to the impeller blades	Fabricate through third party
Impeller Blades	Mix honey	Fabricate through third party
Barrel Lid	Enclose contents of barrel and support load of motor	Fabricate through third party
Barrel Latch	Secure lid to barrel	Fabricate through third party
Smoke Port	Location to input smoke into the barrel mixture	Fabricate through third party
Handle	Provide removal capabilities of lid	Purchase through McMaster-Carr
Shaft Coupling	Secure motor to driving shaft	Purchase through McMaster-Carr
Mounting block	Attaches blades to driving shaft	Fabricate through third party

Table 1: Detailed Layout of Feature Functions

3.3 Design Rules and Principles

The aforementioned modification designs will be controlled by the following rules and principles.

1. Simplicity
    a. Easy to manage
    b. Blades and shaft are removable
2. Safety
    a. Lightweight increasing maneuverability
    b. Moving and heated components are encapsulated
3. Division of Tasks
    a. Motor provides torque, shaft rotates blades, and blades mix the honey
    b. Water heats barrel, barrel contains heat
4. Force Transmission
    a. Motor produces necessary torque required
5. Stability
    a. Strong yet lightweight materials
    b. Corrosion resistant

Utilizing these simple rules and principles will allow for a design that is safe, efficient, and effective.

3.4 Mixing Impeller Power Consumption

The following sequence of advanced calculations are required to find the power necessary to drive the impeller shaft inside the mixing barrel, while fully submerged in the viscous honey. The subsequent formulas were derived from experimentation performed by Haruki Furukawa, Yoshihito Kato, Yoshiro Inoue, Tomoho Kato, Yutaka Tada, and Shunsuke Hashimoto, which consisted of filling a vessel to a height equivalent to that of its diameter, utilizing various liquids, including desalted water and varying starch-syrup solutions. Furthermore, the power consumption was measured utilizing equation 1 below.

$$P = 2\pi n T \quad (1)$$

Where P on the left side of the equation represents power, n is the rotational speed, and T is the torque of the shaft. The torque of the shaft was measured by taking advantage of two torque meters, the ST-1000 and ST-3000. The rotational speed varied from 60 to 540 revolutions per minute, which was a pivotal constraint in the performed experiments, as it served to avoid large vortices from forming on the free surface of the liquid in the center of the vessel. The experiment consisted of unbaffled, partially baffled, and fully baffled conditions, albeit, for the purpose of the honey infuser only the unbaffled condition results were utilized here. From the results of the testing, graphs were created relating numerous variables to Reynolds number, Re_d, and the power number, N_{P0}, which were subsequently extrapolated into the succeeding equations. Equation 2, below, is utilized to calculate the power number in the unbaffled condition.

$$N_{PO} = \{[1.2\pi^4\beta^2]/[8d^3/(D^2H)]\}f \quad (2)$$

The N_{P0} term is the power number for the unbaffled condition, f is the friction factor, d is the impeller diameter measured in $[m]$, D is the vessel diameter measured in $[m]$, H is the liquid depth measured in $[m]$, and β is a correlation coefficient, which can be obtained from equation 3 below.

$$\beta = 2ln(D/d)/[(D/d) - (d/D)] \quad (3)$$

The aforementioned friction factor can be obtained as follows from equation 4.

$$f = C_L/Re_G + C_t\{[(C_{tr}/Re_G)^{-1} + (f_{\sim}/C_t)^{1/m}\}^m \quad (4)$$

C_t is the clearance term coefficient, in the turbulent region, C_L is the clearance term in the laminar region of the liquid flow rotation. The C_{tr} term is another clearance term formulated from the experiments, m is a correlation coefficient when in the turbulent region, Re_G is the modified reynolds number, and finally $f\sim$ is an approximation for the friction factor utilized to calculate the overall friction factor. Re_G, C_L, C_t, m, C_{tr}, and $f\sim$ can be calculated from equation 5, 8, 9, 12, 13, and 14 respectively.

$$Re_G = \{[\pi\eta\ln(D/d)]/(4d/\beta D)]\}Re_d \tag{5}$$

From the above equation, η is a correlation coefficient, D is the diameter of the vessel $[m]$, d is the impeller diameter $[m]$, and Re_d is the Reynolds number. The terms, η and Re_d, can be calculated from equations 6 and 7 respectively.

$$\eta = 0.711\left\{0.157 + \left[n_p ln(D/d)\right]^{0.611}\right\}/\{n_p^{0.52}[1-(d/D)^2]\} \tag{6}$$

Here n_p is the number of impeller blades, D is the diameter of the vessel $[m]$, and d is the impeller diameter $[m]$.

$$Re_d = nd^2\rho/\mu \tag{7}$$

The d term, as mentioned previously, is the impeller diameter $[m]$, ρ is the density of the liquid measured in $[\frac{kg}{m^3}]$, μ is the viscosity of the liquid measured in $[Pa \cdot s]$, and n is the impeller rotational speed. Next, the laminar clearance term can be defined by equation 8 as follows.

$$C_L = 0.215\eta n_p(d/H)[1-(d/D)^2] + 1.83(bsin\theta/H)(n_p/2sin\theta)^{1/3} \tag{8}$$

Where the θ term is the angle of the impeller blade, n_p is the number of impeller blades, b is the height of the impeller blades $[m]$, d is the impeller diameter $[m]$, H is the liquid depth $[m]$, η is a correlation coefficient, and D is the diameter of the vessel $[m]$. The C_t clearance term coefficient can be obtained from equation 9.

$$C_t = [(1.96X^{1.19})^{-7.8} + 0.25^{-7.8}]^{-1/7.8} \tag{9}$$

Where X is another coefficient term based upon the geometric design of the agitation device, and can be calculated using equation 10.

$$X = \gamma n_p^{0.7} bsin^{1.6}(\theta/H) \tag{10}$$

Here, the θ term is the angle of the impeller blade, n_p is the number of impeller blades, b is the height of the impeller blades $[m]$, H is the height of the liquid $[m]$, and γ is a coefficient calculated from equation 11.

$$\gamma = [\eta ln(D/d)/(\beta D/d)^5]^{1/3} \quad (11)$$

Observing the right hand side of the equation, d is the impeller diameter $[m]$, η is a correlation coefficient, and D is the diameter of the vessel $[m]$. The m term in equation 4 can be calculated from equation 12 utilizing X from equation 12 as follows.

$$m = [(0.71X^{0.373})^{-7.8} + 0.333^{-7.8}]^{-1/7.8} \quad (12)$$

C_{tr} is obtained from equation 13 with the same X term as previously mentioned.

$$C_{tr} = 23.8(d/D)^{-3.24}(bsin(\theta)/d)^{-1.18}X^{-0.74} \quad (13)$$

The θ term is the angle of the impeller blade, d is the impeller diameter $[m]$, and D is the diameter of the vessel $[m]$. Lastly, the estimated friction factor calculation required by equation 4 is obtained through equation 14.

$$f^{\sim} = 0.0151(d/D)C_t^{0.308} \quad (14)$$

With the power number obtained from equations 2-14, the correlation between the dimensionless power number term N_{P0}, and the actual power consumed by the agitation device (the honey infusing equipment) required to drive the shaft when submerged in a viscous fluid (honey with a viscosity of of $10\ Pa \cdot s$) is given by equation 15.

$$P = 0.0013N_{P0}n^3d^5\rho \quad (15)$$

Here, n represents the rotational speed, and d is the impeller diameter $[m]$. It is important to note however that the 0.0013 number is not part of the original power equation, but was added to convert units from J/s into Hp. This power will be then calculated based upon the honey infuser impeller blades as follows: top and bottom blades at 45° and the intermediate blade at an angle of 90°.

The resulting power of each of the components will then be summed together as seen by equation 16.

$$P_{total} = \sum P_n \tag{16}$$

Where the P_n term represent the power at each impeller blade angle as follows: $2P_{45} + P_{90}$. This will result in the total minimum power required to agitate the system. All of the aforementioned computations were performed utilizing MATLAB with a similar chronological process as exemplified above.

3.5 Results from Power Calculations

Table 2 below quantifies the results obtained from the MatLab code. Hand calculations were utilized to verify the accuracy of the code. The Matlab code can be found in the Appendix C while the hand calculations can be found in Appendix D.

Variable	Symbol	Meaning	Calculation Result
Power Number	N_{P0}	Dimensionless term directly related to the power required to drive the shaft.	$N_{P0}(45°) = 1.0787$ $N_{P0}(90°) = 1.4157$ $(Dimensionless)$
Power	P_n	The power required to run the device with respect to a specific blade based upon its angle.	$P_{45°} = 0.3585\ hp$ $P_{90°} = 0.4705\ hp$ $(Horsepower)$
Total Power	P_{Total}	The total power required to run the agitation device	$P_{Total} = 1.1875\ hp$ $(Horsepower)$

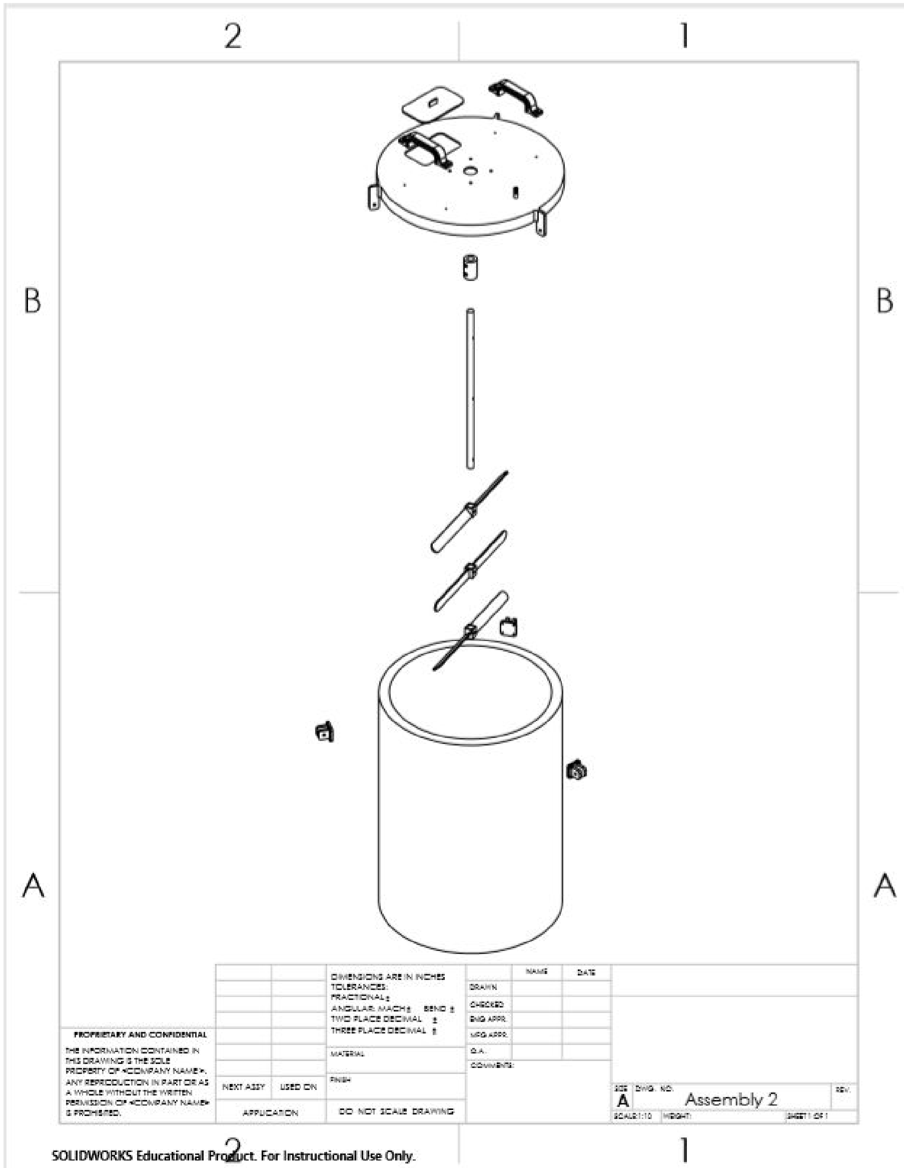
4.0 Detail Design

An iterative design process was utilized upon arrival at the suggested and final designs. The suggested design is the optimal design, disregarding budget, best manufacturing methods, and ease of assembly. The final design is an iteration which accounts for Mr. Wesley's budget, assembly concerns, and simplifies the manufacturing process. Refer to the following sections for drawings and a detailed description of each design.

4.1 Suggested Design

A design with all of the previously mentioned modification features was created by the team which meets all of Mr. Wesley's operational needs. This design iteration was considered the most optimal on the basis of the team's opinion, and customer needs. The design was presented to Mr. Wesley for approval.

4.1.1 Suggested Assembly Drawing



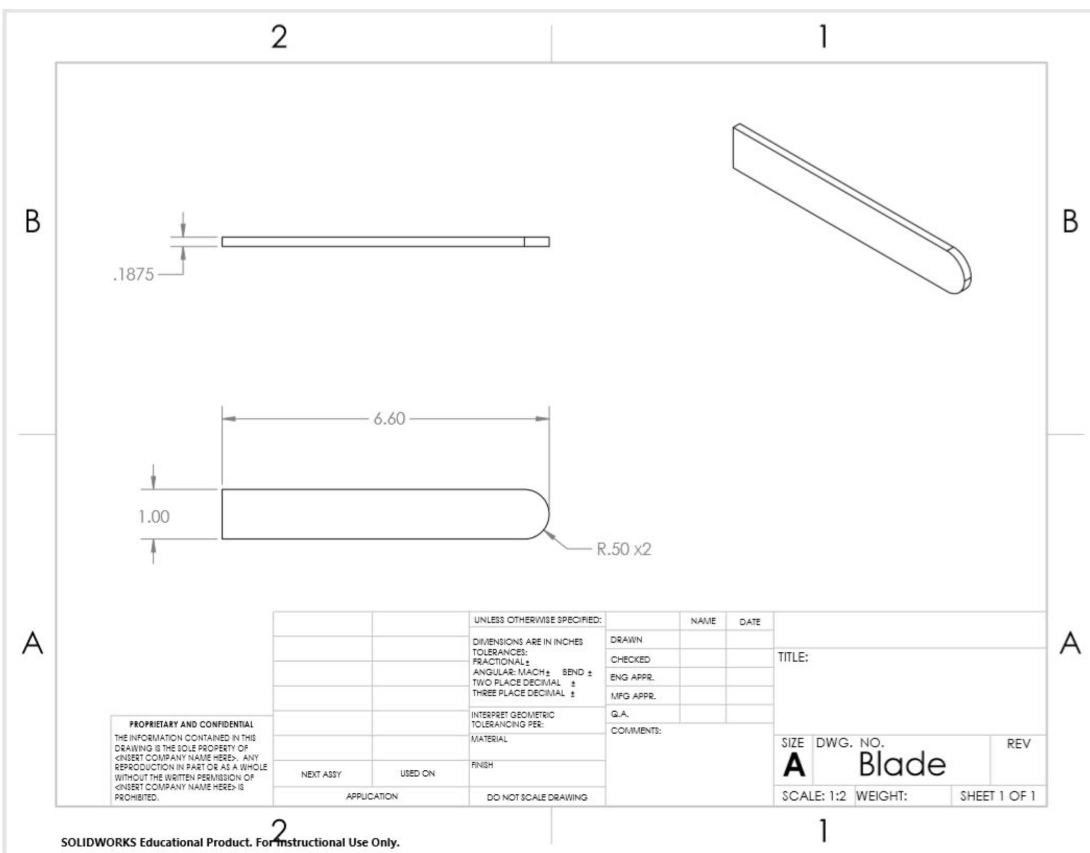
Exploded Drawing 1: Suggested Design Assembly

The above drawing depicts the assembly of the suggested design which is the most optimal. This design incorporates three tabs that align with fasteners for safety purposes, eliminating movement of the lid during operation. These fasteners would be riveted to the side of the barrel to ensure that there is no slippage of the lid. However, the product owner was uncomfortable with this invasive option and asked the design team to modify the attachment method to avoid any damage of the barrel.

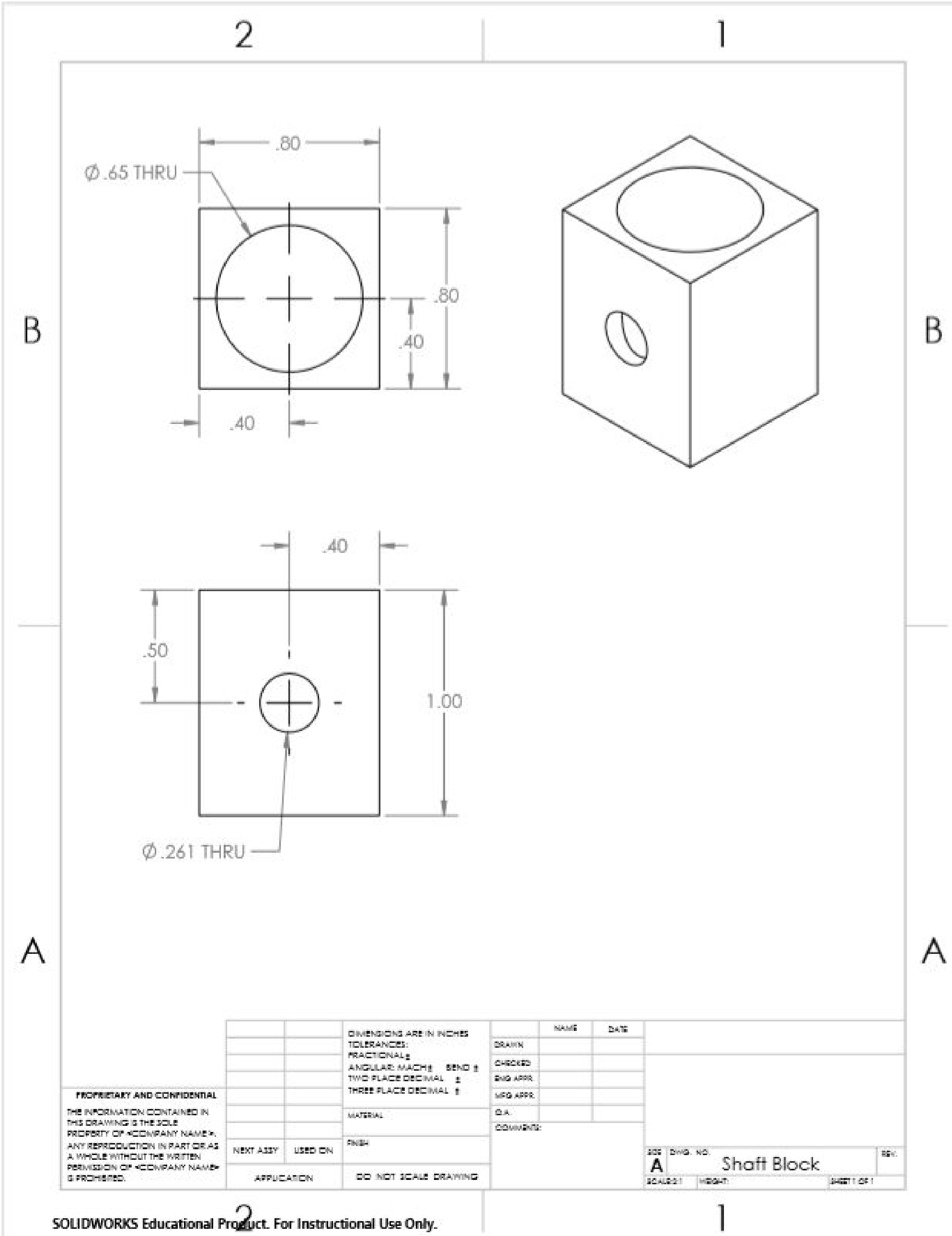
4.2 Final Design

Upon presenting the suggested design to Mr. Wesley, he had some concerns regarding the manufacturing costs. To meet his needs and requirements, the team, along with Mr. Wesley brainstormed ideas to simplify the design, thus, eliminating some of the unnecessary manufacturing costs. Instead of using riveted-on barrel latches to secure the lid to the barrel, the lid will be secured to the barrel through ratchet straps or bungee cords per Mr. Wesley's request. Not only will this reduce manufacturing costs, but this method is not invasive to Mr. Wesley's mixing tanks. It is the team's opinion that Mr. Wesley's proposed idea to secure the lid to the barrel will be sufficient.

4.2.1 Component Drawings

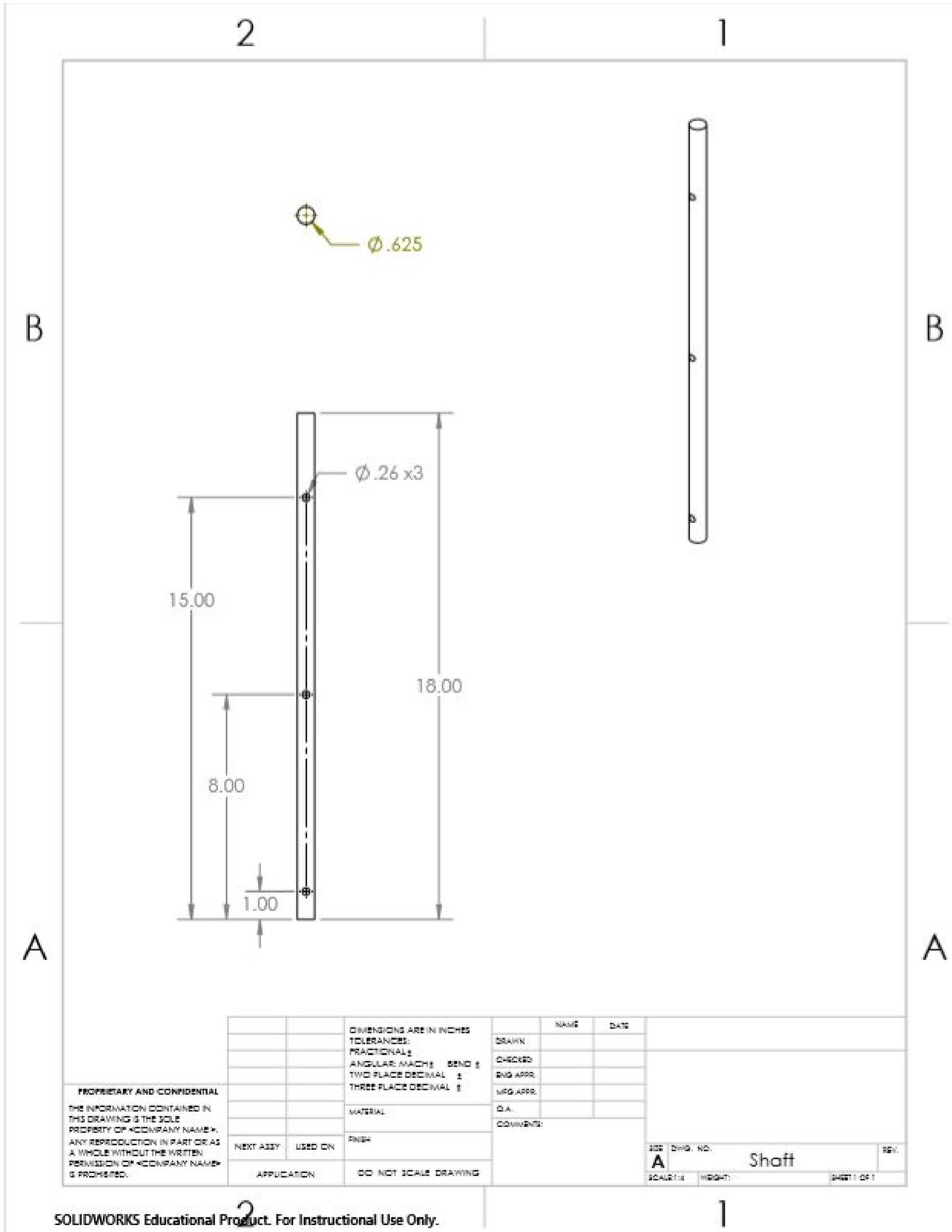


Drawing 1: Impeller Blade



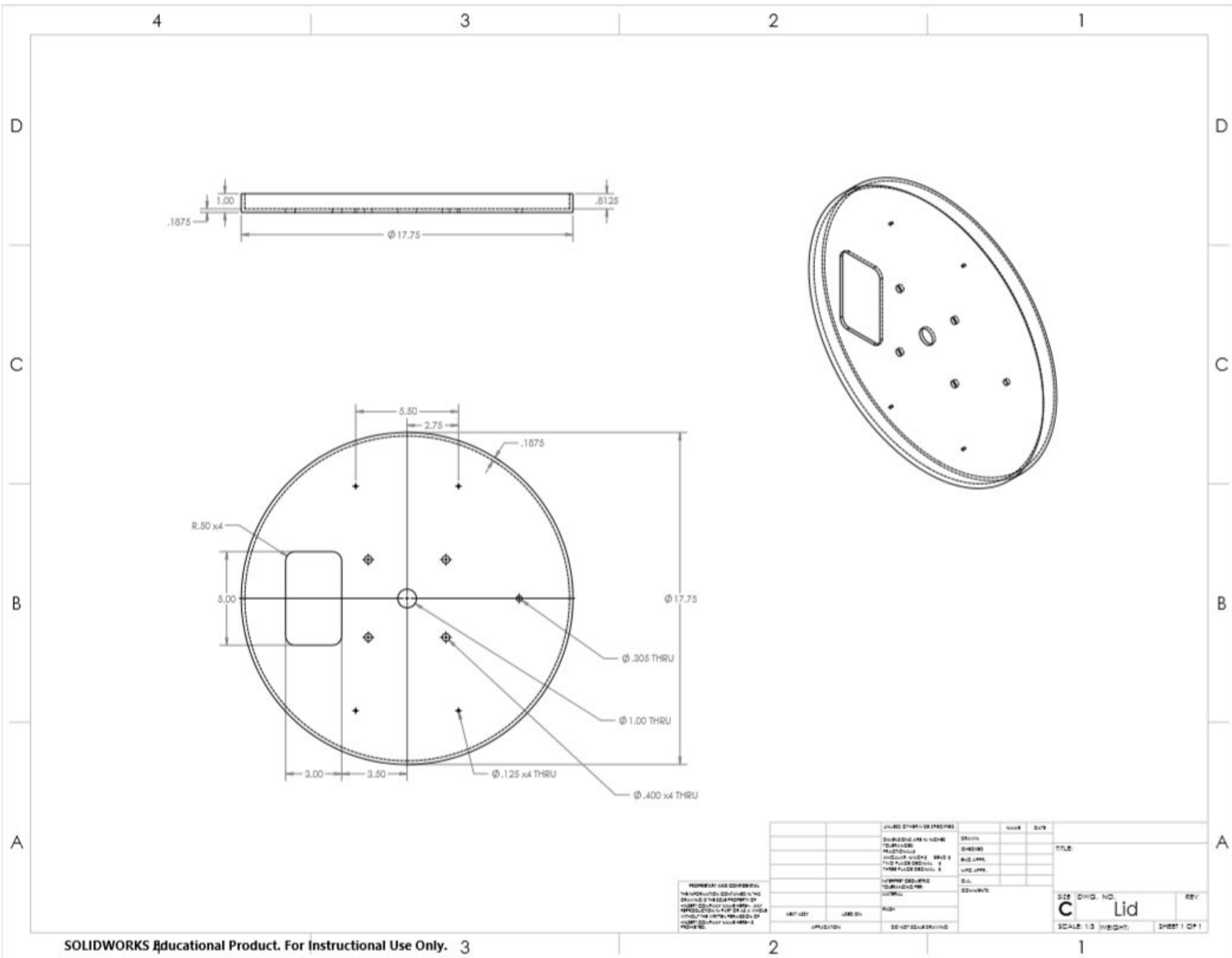
Drawing 2: Shaft Block

The two drawings above depict the impeller blade and shaft block. The blades were designed such that, once attached to the shaft block in the proper configuration, the entire blade will be 14 inches in length. This will ensure that there is a ⅝ inch gap between the end of the blade and the walls of the tank. As stated previously, the blades will be attached to the shaft block in three different configurations; at a 45° angle for the bottom blade to push honey upward, -45° angle for the top blade to push honey down, and vertically (90°) for the middle blade to mix the honey.

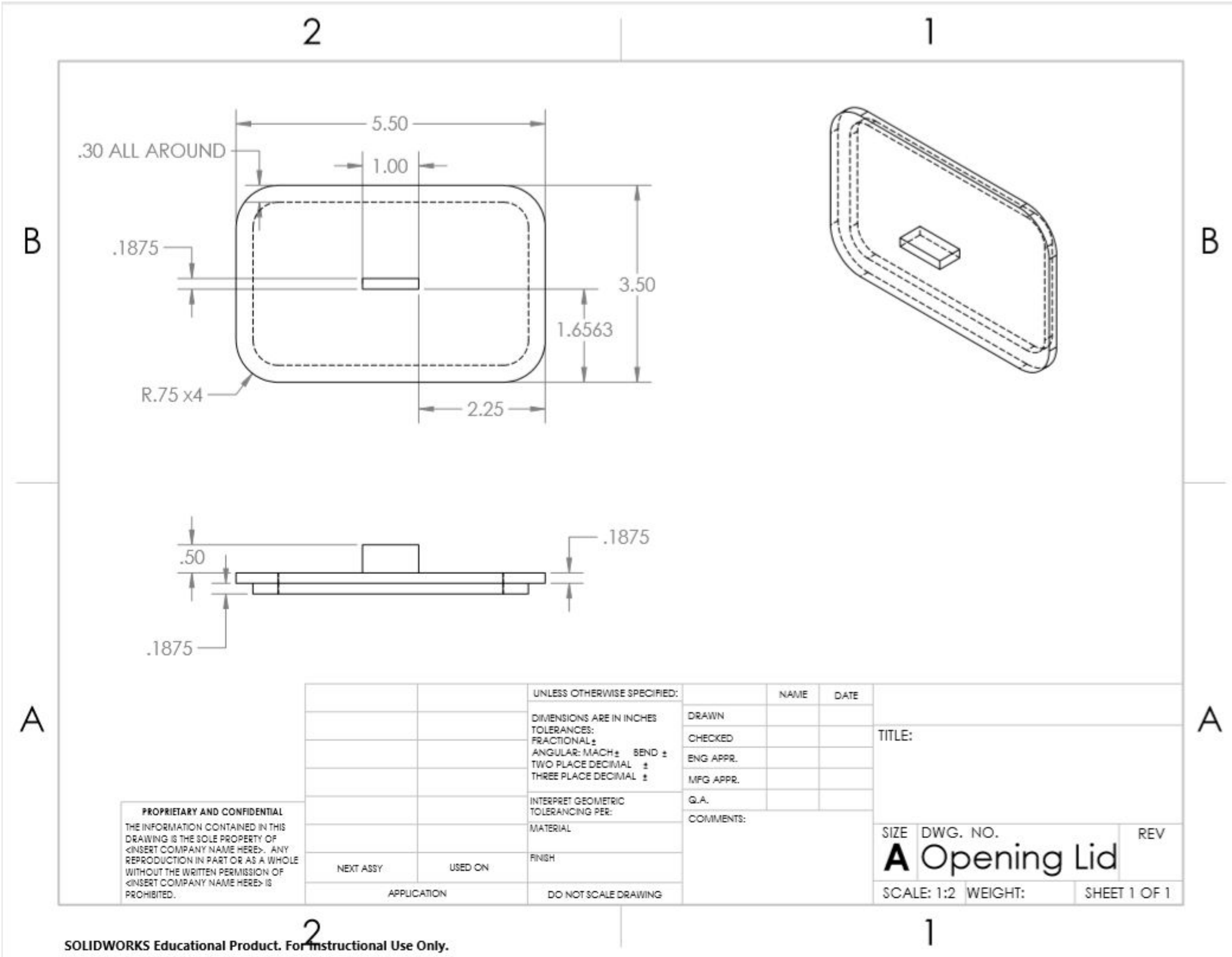


Drawing 3: Drive Shaft

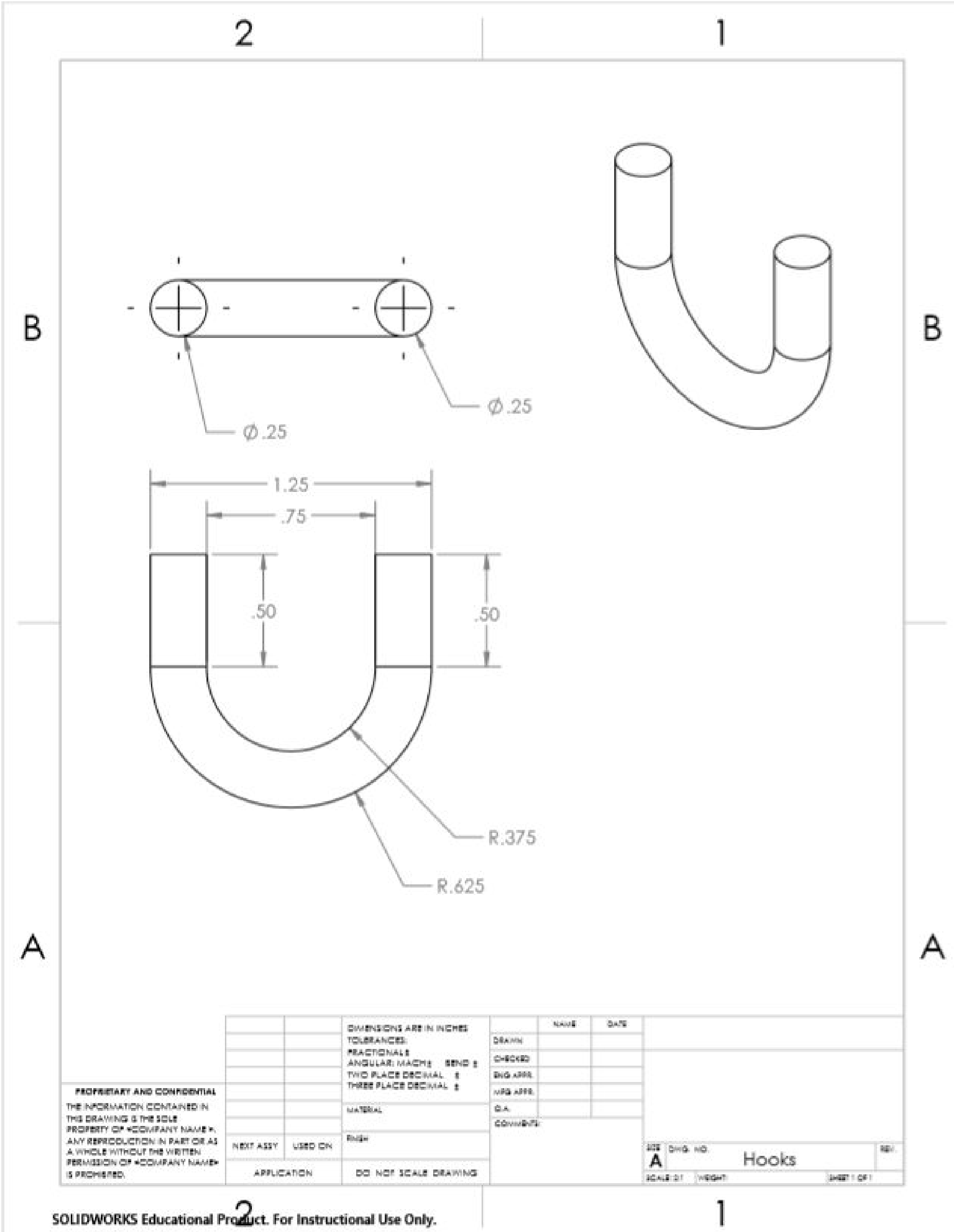
The drawing above shows the central shaft. The three blade configuration will be attached to this shaft by means of ¼” bolt and nut. The drive shaft will be attached to the motor through a shaft coupler, which is shown in the bill of materials.. The shaft length was designed such that, once attached to the motor, the bottom of the shaft will have a clearance of roughly 1 inch from the bottom of the barrel. The locations for attaching the blades to the shaft were determined by calculating the height of the honey needed to obtain 15 gallons with the given barrel dimensions. The top blade was then set below the surface of the liquid, and equally spacing the remaining two blades..



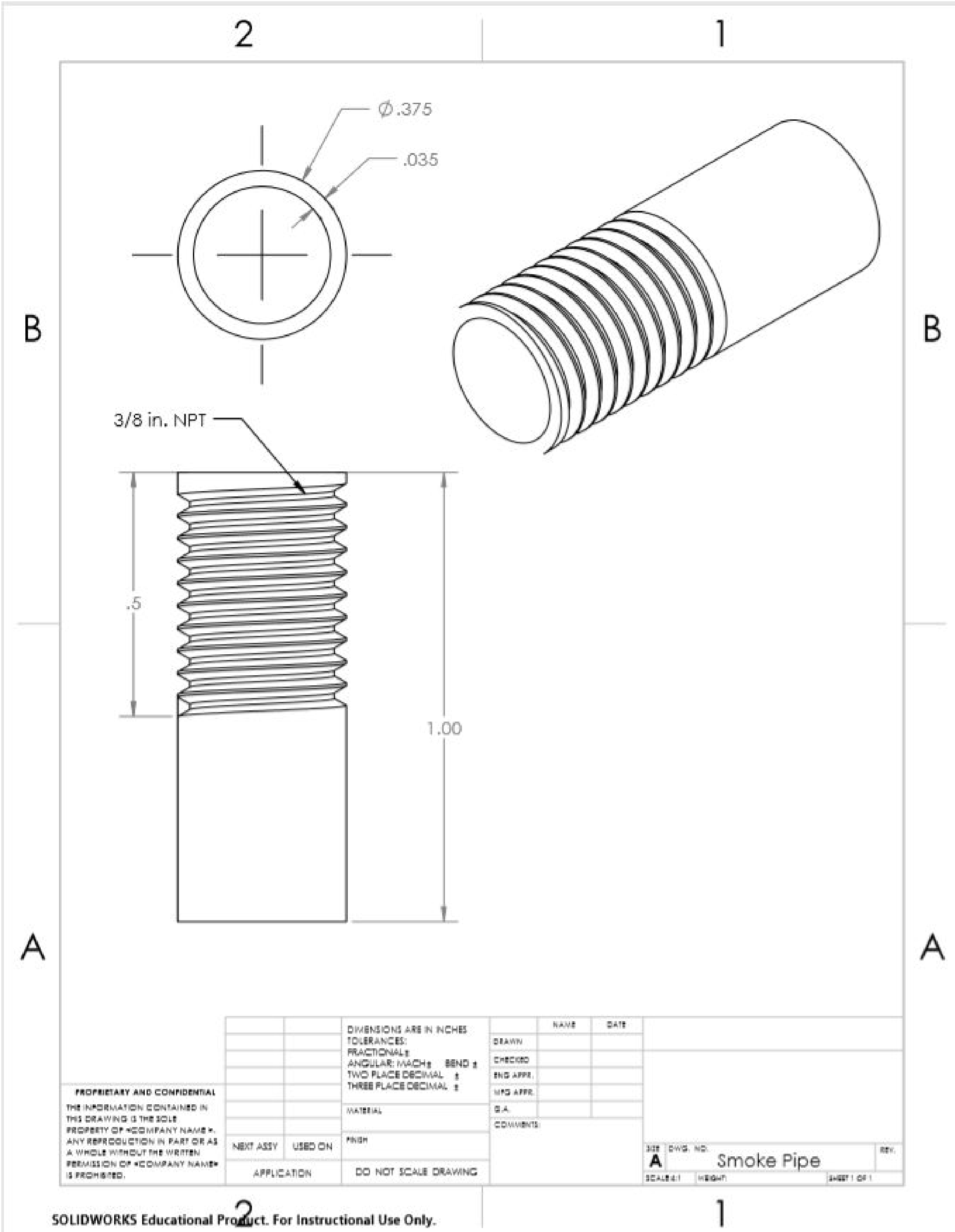
Drawing 5: Infuser Lid



Drawing 6: Opening Lid



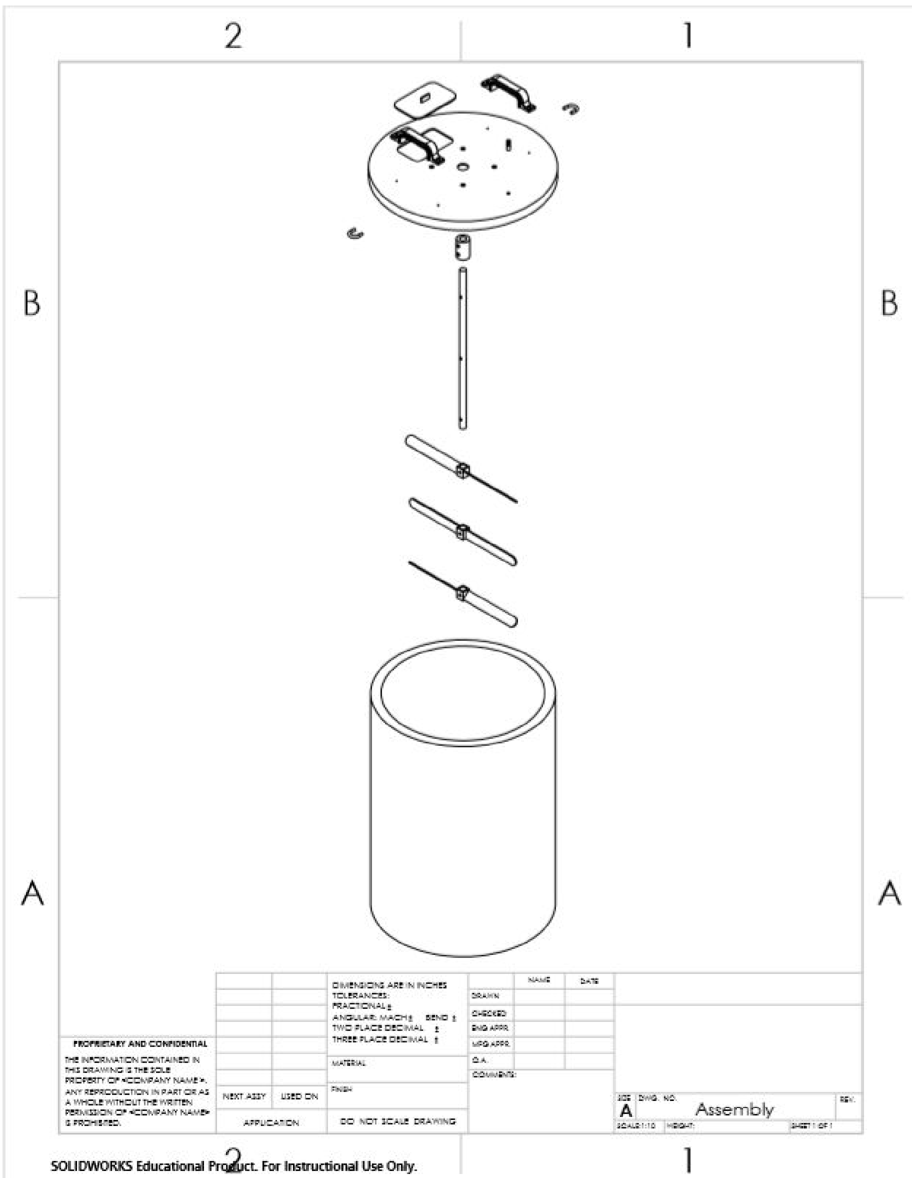
Drawing 7: Hooks



Drawing 8: Smoking Port

The infuser lid was designed with an opening to easily allow the adding of ingredients to the honey during the infusing process. This opening requires a lid to be placed over it during the operational period, to eliminate spillage and conserve energy. Moreover, the infuser lid has four holes spaced around the center, which allow for the fastening of the drive shaft motor. The four holes toward the outside are for two handles. These handles can be purchased through McMaster Carr. Additionally, there are then two U-hooks that will be welded onto the side of the lid so that it can be strapped to the barrel. Finally, there is a threaded port that will be welded in line with the hole in the right side of the lid. This is so that a quick connect hose coupling can be attached allowing for the smoking capabilities, which are provided through a tube from the already obtained beekeeper smoker.

4.2.2 Final Assembly Drawing



Exploded Drawing 2: Final Design Assembly

The above image is the exploded drawing for the final design that satisfies the product owner's modification request to simplify the lid attachment method. This method is applied through the use of straps or bungee cords which will be hooked through the two U-hooks and down to a stable surface. This will secure the lid to the barrel during the infusing operation.

5.0 Discussion

5.1 ANSYS Analysis

In order to determine whether or not the lid would be able to support the weight of all of the components, a finite element analysis was performed using ANSYS Workbench. The team was able to optimize strength of material vs weight of the lid using the following method. Since the lid will be manually lifted, it needs to be as lightweight as possible, but be able to support the weight of all of the components without excessive bending or breaking. Therefore, using ANSYS, the team compared the total deformations of three lids of different thicknesses to determine the thinnest lid possible while still remaining completely safe. The same estimated force with a factor of safety was applied to each lid. The following image shows the ANSYS results.

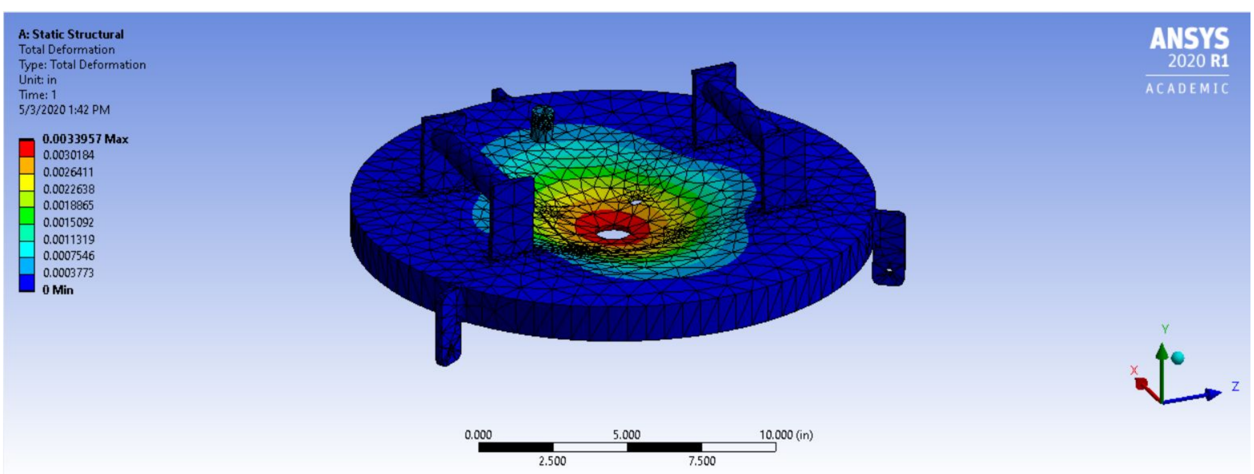


Figure 5: Ansys Analysis

It can be seen that the total deformation of the chosen design will roughly be 0.003 inches. This is a very small amount of deformation.

It should be noted that this ANSYS analysis was done on a previous lid design different from the final. Due to COVID-19, the team did not have access to ANSYS in order to provide an analysis for the final design. However, the team does not feel that the changes made will significantly affect the performance of the product. If it was discovered that the changes did in fact pose problems with structural integrity, some of the proposed fixes would be to add a support rib along the underside of the lid or to increase the thickness of the lid.

5.2 Material Selection, Bill of Materials, and Cost Analysis

The following table is the compiled material list that will need to be either purchased through a retailer or manufactured. The material cost in Table 3 below is estimated based on what 304 stainless steel typically costs and is estimated for the minimum sheet metal required to manufacture the lid. An official quote request was sent to a manufacturer which will then be sent to Brent Wesley of Akron honey once the quote has been finalized (the quote was not obtained in time for this report and therefore no official values will be mentioned, only estimations). All other items will be purchased through McMaster Carr with the exception of the motor and the variable frequency drive which will be purchased through different suppliers for cost savings. It is important to note, however, that Brent Wesley is looking into purchasing a used motor through different connections for further cost savings, albeit, the chosen motor will still be listed in the case that he is unable to find another suitable motor.

Item	Cost (Quantity)	Description	Link to Purchase
Plastic Hose Coupling (Socket) [1]	$49.38 (1)	This will be threaded into the spout on the top of the infuser lid.	https://www.mcmaster.com/4821k51
Plastic Hose Coupling (Plug) [2]	$13.03 (1)	This will be attached on to the plastic hose coupling [1]	https://www.mcmaster.com/4821k9

Super Flow Barbed Fitting	$7.11 (1)	This will be thread on to the female end of the plastic hose coupling [2]	https://www.mcmaster.com/2808k33
Set Screw Shaft Coupling	$37.80 (1)	This will be utilized to attach the shaft with the impeller blades to the motor shaft	https://www.mcmaster.com/6099k25
Unthreaded-Hole Rectangular Pull Handle	$24.21 (2)	Pull Handle will be attached to the top of the honey infuser lid	https://www.mcmaster.com/1298a33
Material Cost (Estimated)	$600 (1)	304 stainless steel plate to manufacture the infuser lid (3/16” x 20” x 56”)	https://www.midweststeelsupply.com
Face Mount AC Motor	$548.83 (1)	1.5 hp, 1725 rpm motor to drive shaft and impeller blades	https://www.mcmaster.com/6135k207
Variable Frequency Drive	$479.08 (1)	100-120V AC 1 Phase input for 1.5 hp	https://www.mcmaster.com/7786k53
Total Cost	**$1,783.65**	Estimated cost based on team’s selection.	

Table 3: Bill of Materials and Cost Analysis

5.3 Design Difficulties

The first notable difficulty the team encountered was a large shift in the scope of the project which was discussed earlier. This shift occurred in the spring semester when the first design was being finalized. This created difficulty for the team because a new plan needed to be developed with little time left, which compounded with the Covid-19 pandemic, created a lot of uncertainties during the spring semester.

One of the largest sources of difficulties that was encountered during the design process was created from the Covid-19 pandemic. Early in the design process, a meeting schedule was created and adhered to strictly, however due to the pandemic, communication amongst group members became increasingly difficult between the shift to online classes and the shift to a hands off design approach being created from remote video chatting. It also meant that there was no longer access to campus facilities and equipment which provided some software difficulties. Furthermore, this altogether eliminated any further meeting with Brent Wesley. The way this issue was approached was by shifting the workload from a fully collaborative approach towards a divide and conquer approach where we would then meet up utilizing a video chat to discuss our accomplishments and re-divide up any new or remaining work. This process, although not optimal, seemed to provide the best solution to a difficult problem.

Finally, another prominent issue that was experienced during the design process was the advanced calculations required in order to analyze the power consumption of the aforementioned agitation device, which were beyond the scope of the fundamental fluid mechanics courses required by the mechanical engineering discipline. In order to overcome this issue, extensive research was done on the topic of fluid agitation within a mixer and agitator. Combining this research with current fluid mechanics knowledge obtained through the engineering curriculum, the team was able to perform the necessary calculations.

6.0 Conclusion

The final design utilizes a 1.5hp motor that will be able to rotate the impeller blades at 30rpm through 15 gallons of viscous honey. The base lid will be cut from 304 stainless steel which was chosen for its properties that make it food-safe. A request for a quote has been sent out to manufacturers but a response is yet to be received. This lid will be used with a bottling tank which will be purchased from Maxant Industries.

The team's involvement with Akron Honey will continue post-graduation. All members have decided to continue until Brent Wesley has a finished product that will operate effectively. Some design changes may occur due to manufacturing limitations or for cost savings. Thus, the team will continue with minor design iterations until approval from the fabricator that the product is sufficient. Once the product is fabricated, the team would like to assist in assembly of the product and oversee the operation a few times to better understand the safety and quality of our design product.

Overall, this Senior Design Project allowed the team to utilize learnings from core engineering courses and apply these learnings to real world applications. The team was able to work directly with a local industry to advance their product and business. Furthermore, the design work from the team was completed successfully with minor difficulties. The final design was given high praise from the project sponsor, Brent Wesley. Finally, the team will continue to evolve engineering skills and utilize these for many years to come.

References

[1] *Akron Honey Company*, Akron Honey, 2019, akronhoney.com/.

[2] Furukawa, Haruki, et al. "Correlation of Power Consumption for Several Kinds of Mixing Impellers." *International Journal of Chemical Engineering*, Hindawi, 26 Apr. 2012, www.hindawi.com/journals/ijce/2012/106496/.

[3] *McMaster-Carr*, 2020, www.mcmaster.com/.

[4] Peter, Novak. "The Basics of Variable-Frequency Drives." *StackPath*, 2009, www.ecmweb.com/power-quality-reliability/article/20891324/the-basics-of-variablefrequenc

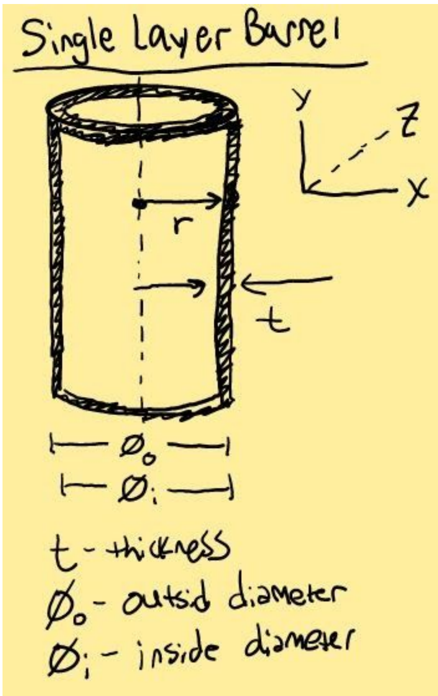
y-drives.

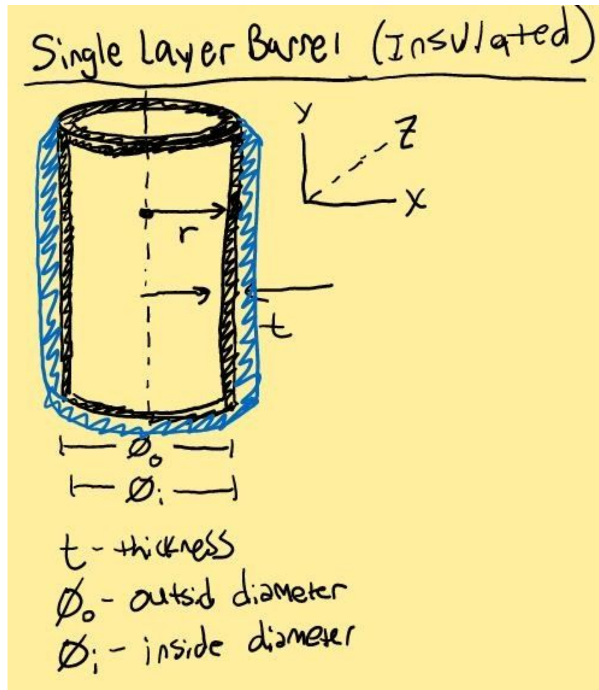
[5] "What Is the Difference between an AC Motor and a DC Motor?" *What Is the Difference between an AC Motor and a DC Motor?*, Ohio Electric Motors, 21 July 2015, www.ohioelectricmotors.com/2015/07/what-is-the-difference-between-an-ac-motor-and-a-d

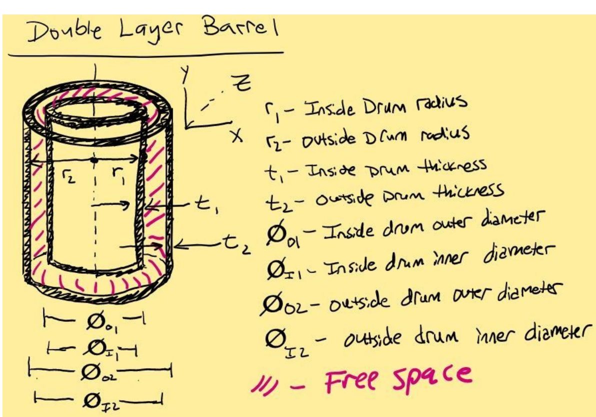
c-motor/.

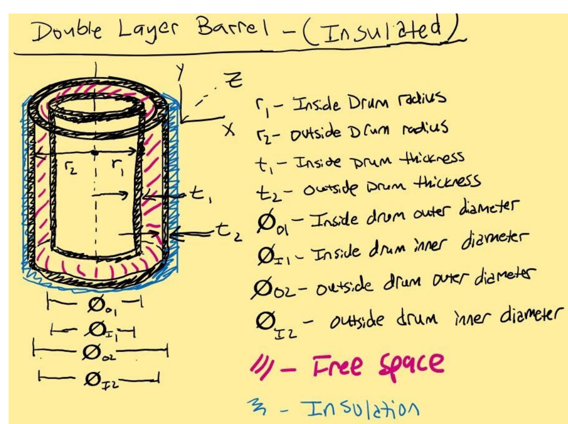
Appendices

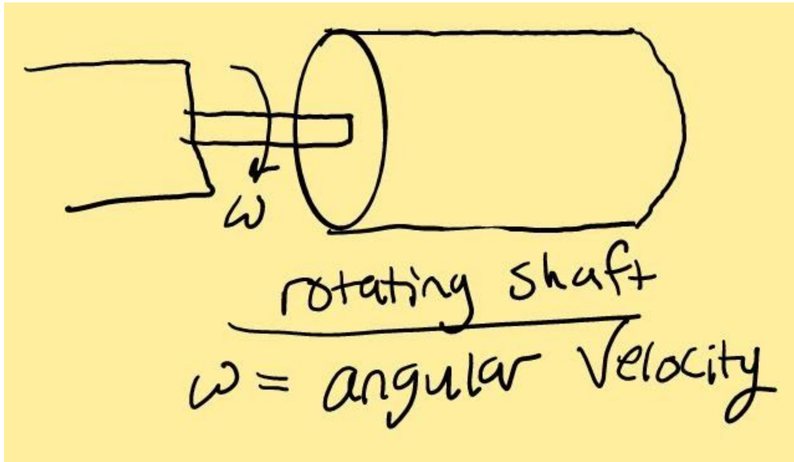
Appendix A

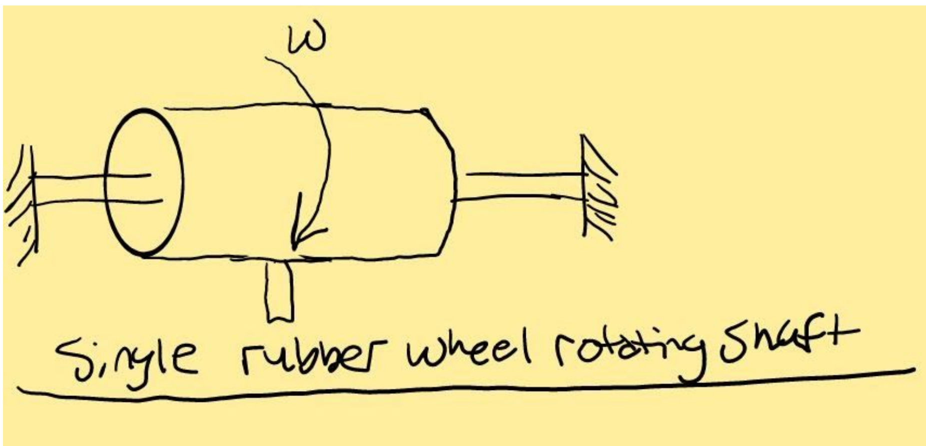


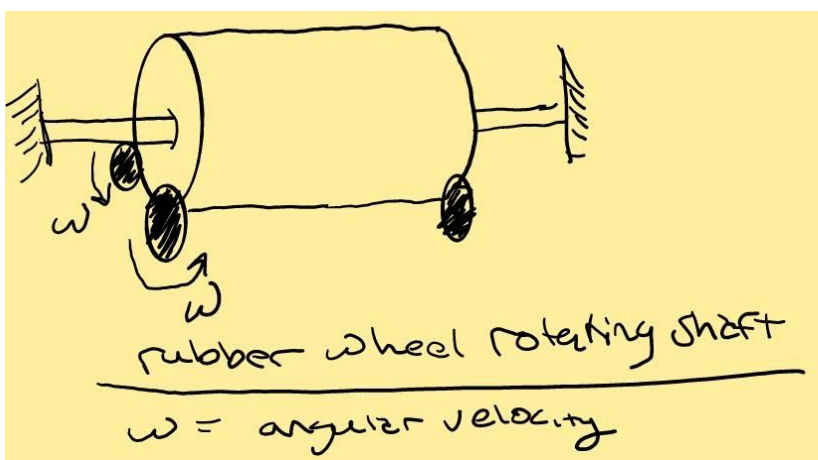


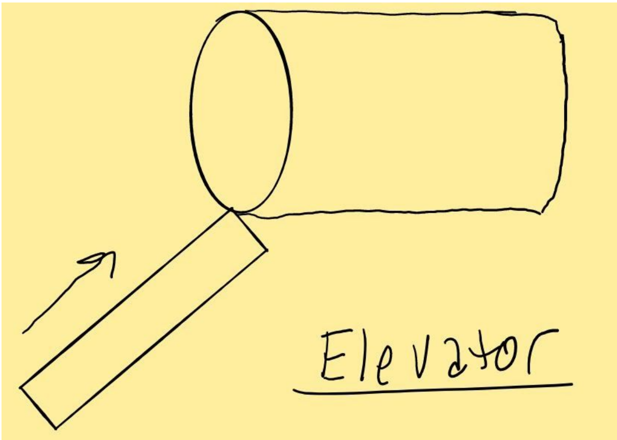


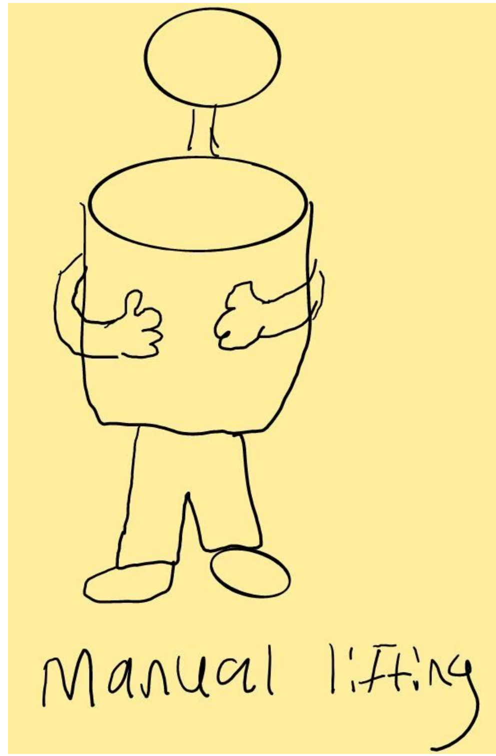


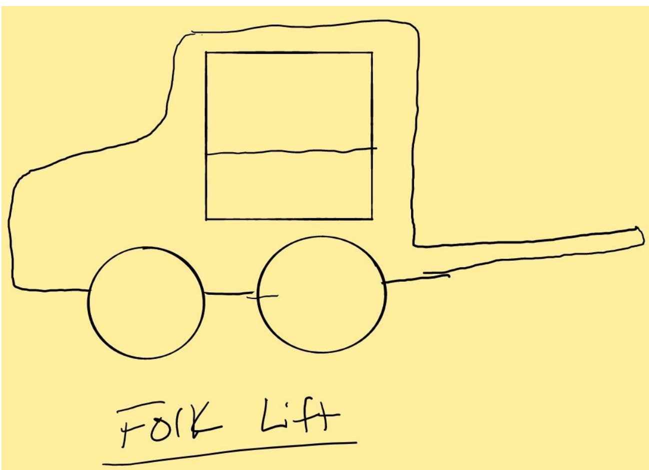

ω
rotating shaft
ω = angular Velocity

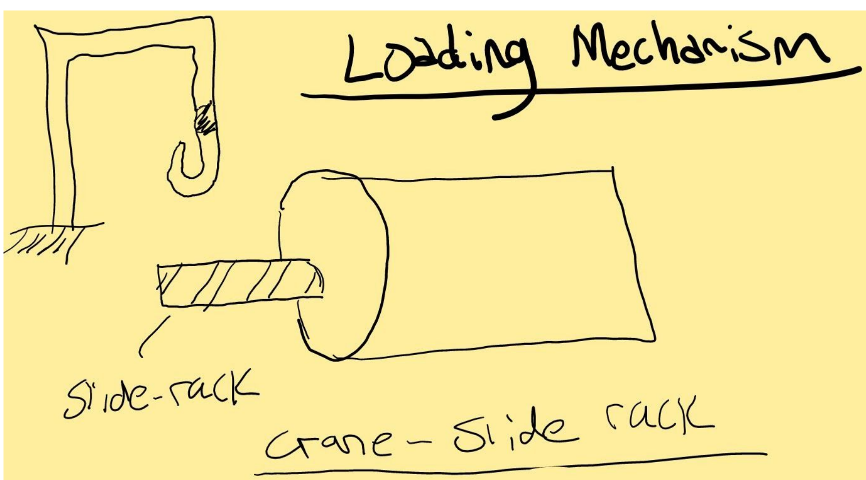

ω
Single rubber wheel rotating shaft

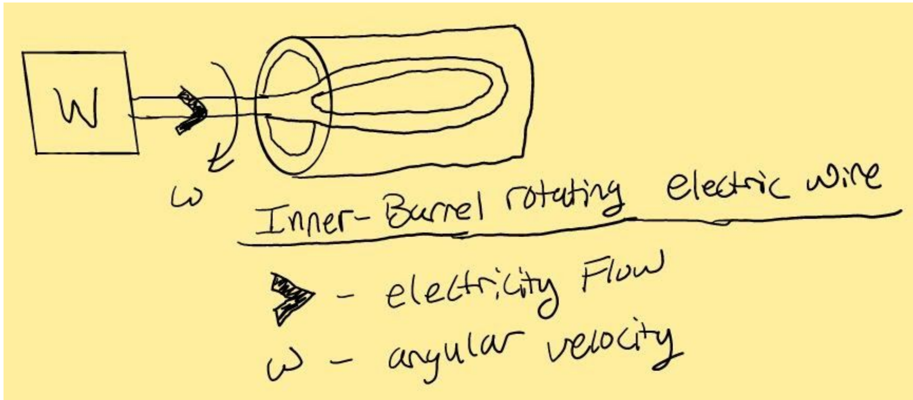

ω
ω
rubber wheel rotating shaft
ω = angular velocity

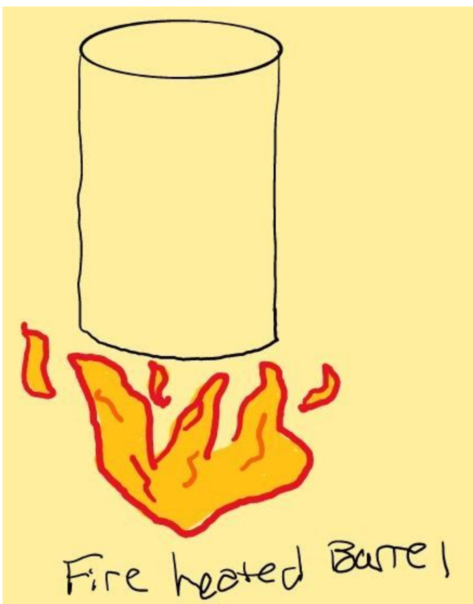

Elevator

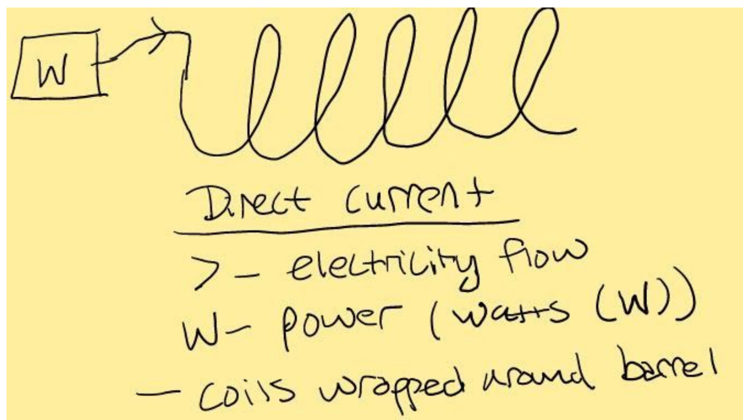

Manual lifting

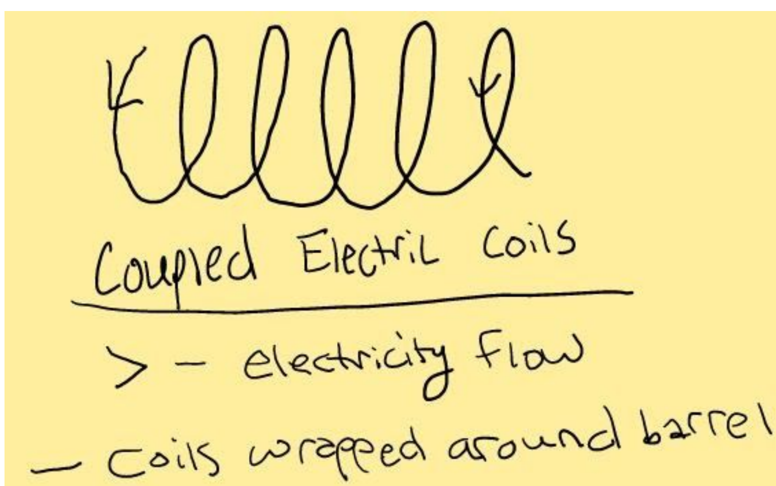

Fork Lift

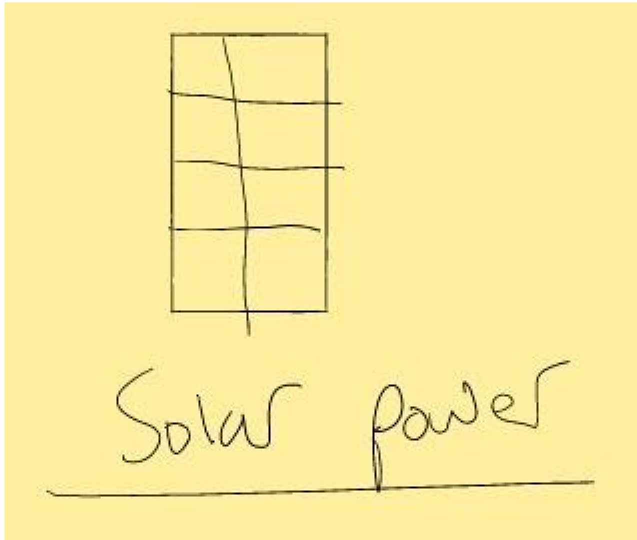

Loading Mechanism
Slide-rack
Crane - Slide rack

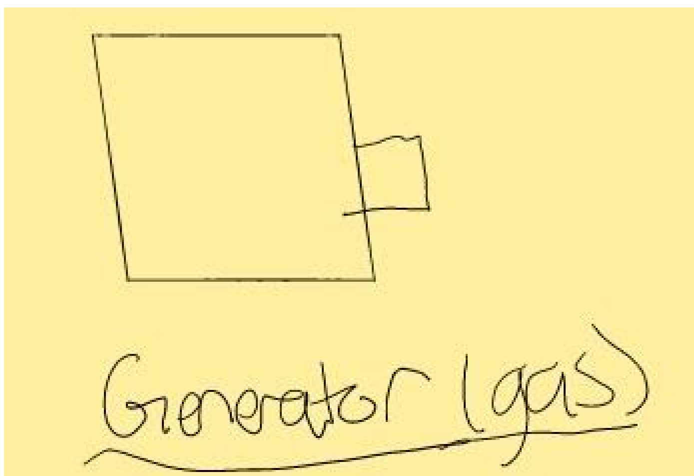

W
ω
Inner-Barrel rotating electric wire
- electricity Flow
ω - angular velocity


Fire heated Barrel


W
Direct current
> - electricity flow
W - power (watts (W))
- coils wrapped around barrel

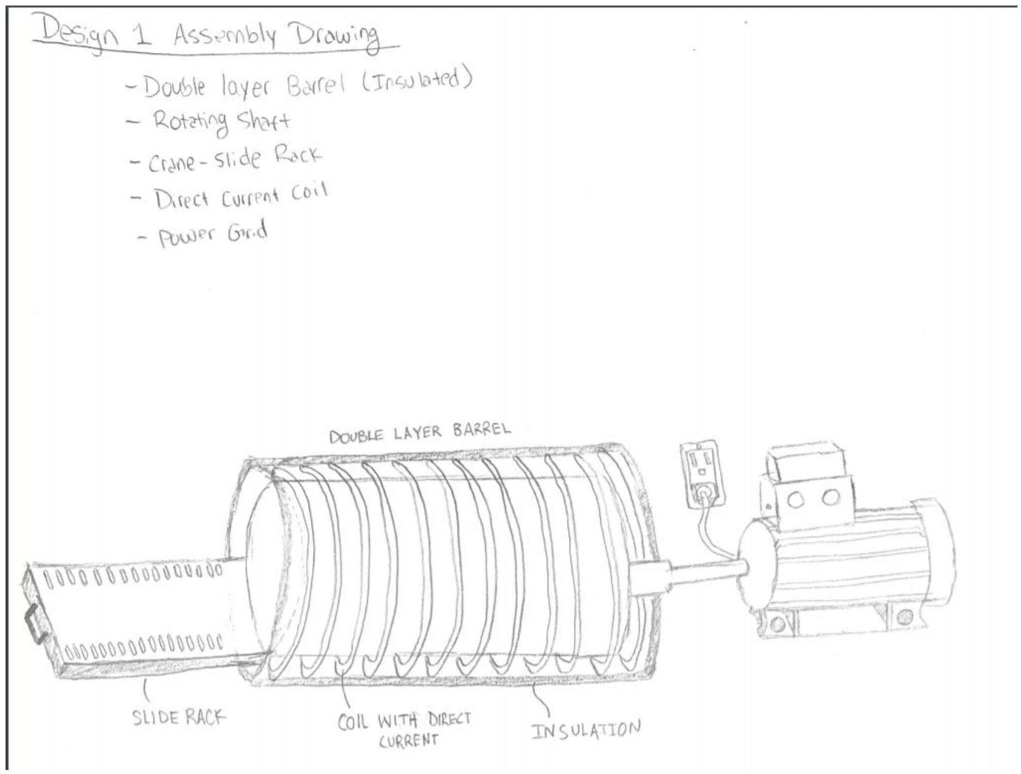

Coupled Electric Coils
> - electricity flow
- coils wrapped around barrel

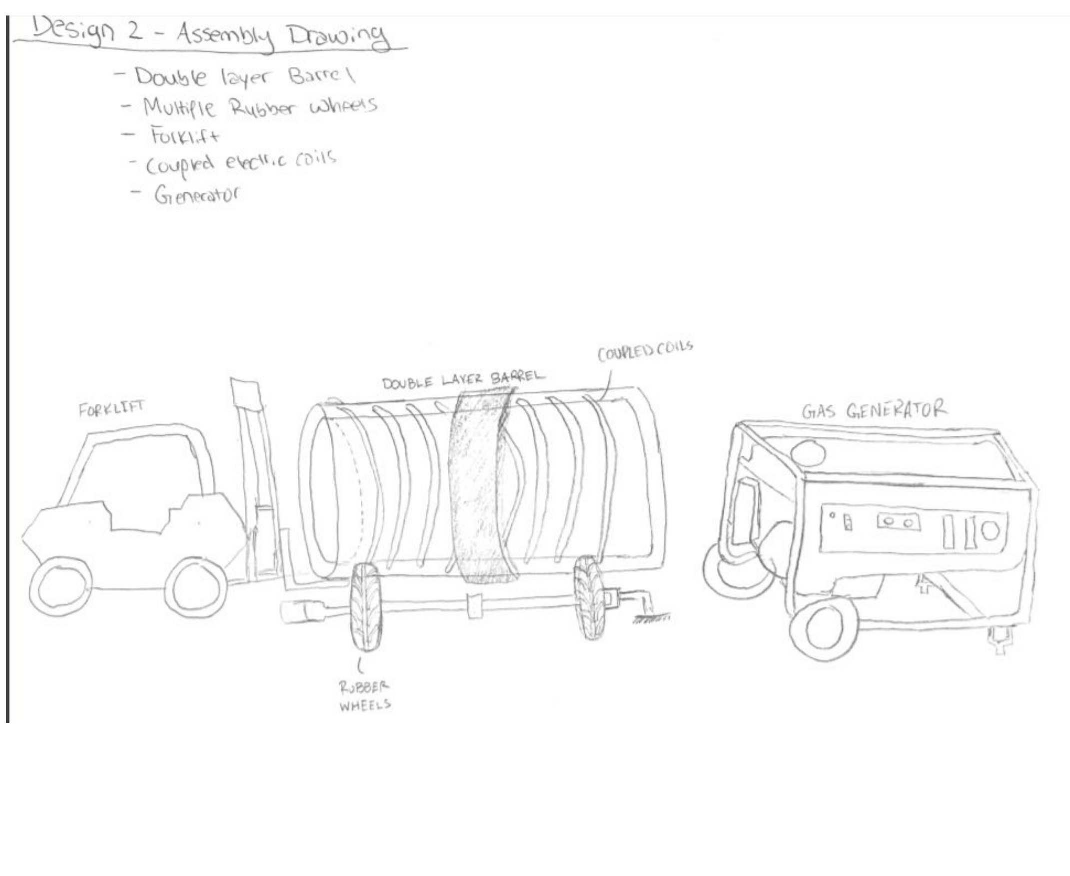

Solar power


Generator (gas)


Power Grid

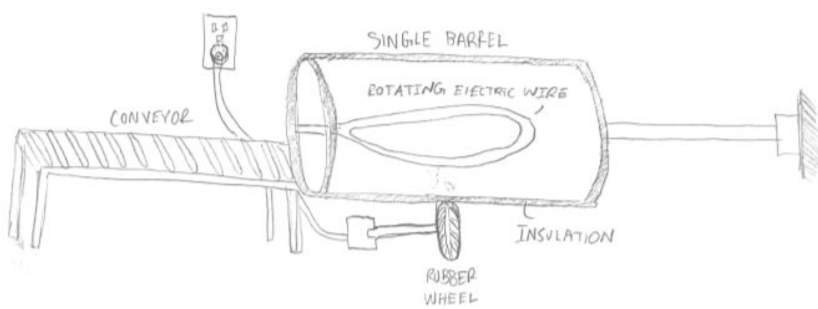
Appendix B


Design 1 Assembly Drawing
- Double layer Barrel (Insulated)
- Rotating Shaft
- Crane-Slide Rack
- Direct Current Coil
- Power Grid
DOUBLE LAYER BARREL
SLIDE RACK
COIL WITH DIRECT CURRENT
INSULATION


Design 2 - Assembly Drawing
- Double layer Barrel
- Multiple Rubber wheels
- Forklift
- Coupled electric coils
- Generator
COUPLED COILS
DOUBLE LAYER BARREL
FORKLIFT
GAS GENERATOR
RUBBER WHEELS

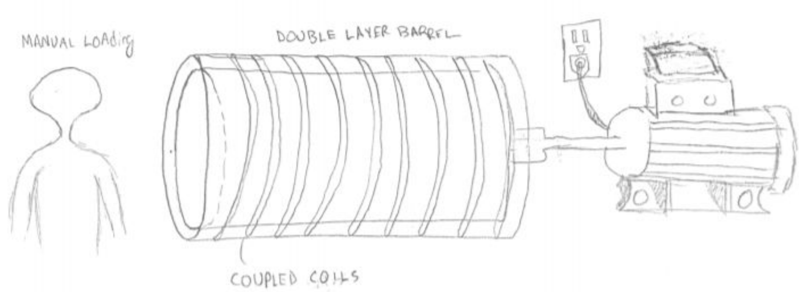
DESIGN 3 - Assembly Drawing

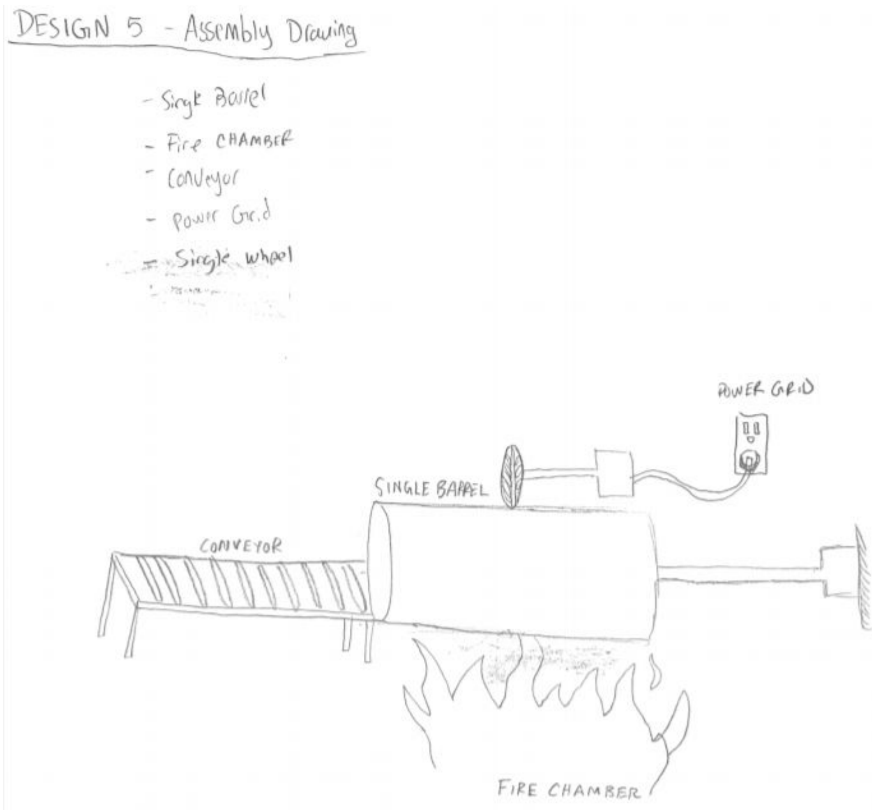
- Single LAYER BARREL (INSULATED)
- Single Rubber Wheel
- Conveyor
- Rotating Electric wire
- Power Grid

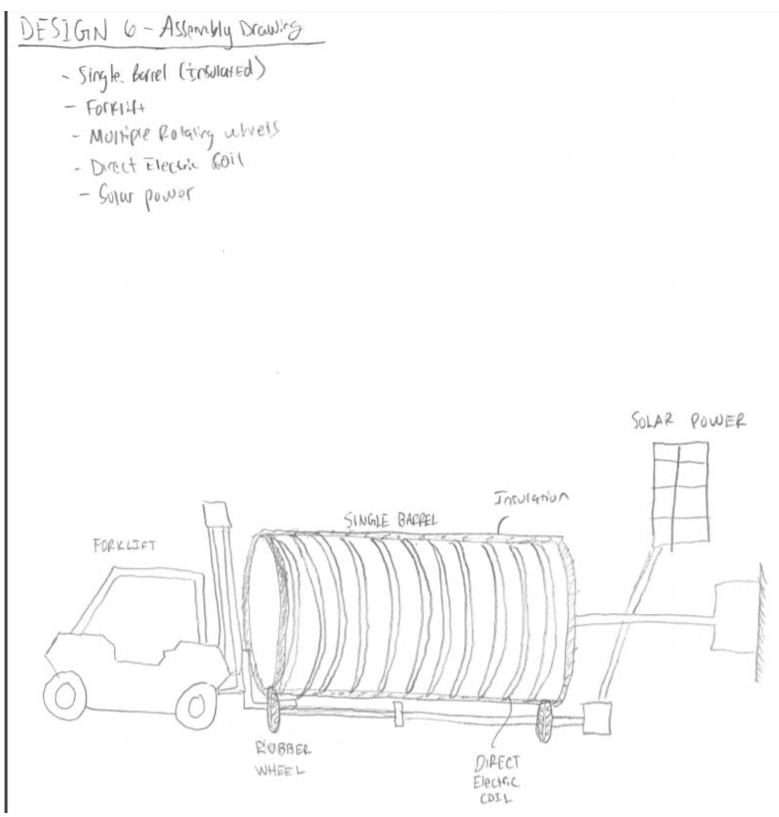


DESIGN 4 - Drawing ASSEMBLY

- Double layer Barrel
- Coupled Coil
- Rotating Shaft
- Manual loading
- Power Grid




DESIGN 5 - Assembly Drawing
- Single Barrel
- Fire CHAMBER
- Conveyor
- Power Grid
- Single wheel
POWER GRID
SINGLE BARREL
CONVEYOR
FIRE CHAMBER


DESIGN 6 - Assembly Drawing
- Single barrel (insulated)
- Forklift
- Multiple Rotating wheels
- Direct Electric Coil
- Solar power
SOLAR POWER
Insulation
SINGLE BARREL
FORKLIFT
RUBBER WHEEL
DIRECT Electric COIL

Appendix C

```
clear;clc;

d=14/39.37; %Impeller Diameter (in-->m)
D=15.25/39.37; %Barrel Diameter (in-->m)
np=2; %Number of Paddles
V=(15*231)/(39.37^3); %Volume (gal-->in^3)
H=V/(pi*(D^2/4)); %Liquid Height (in-->m)
th=45; %Impeller Angle Blades 1 and 3 (deg)
th2=90; %Impeller Angle Blade 2 (deg)
b=2/39.37; %Impeller Height (in-->m)
n=30*((2*pi)/60); %Rotational Speed (rpm-->rad/s)
rho=1450; %Density of Honey (kg/m^3)
mu=10; %(Pa*s or kg/(m*s))


eta=(0.711*((.157+((np*log(D/d))^(.611))))/((np^.52)*(1-(d/
D)^2))); %Dimensionless Parameter
CL=.215*(eta)*(np)*(d/H)*(1-(d/D)^2)+1.83*(b*sind(th)/H)*(np/
(2*sind(th)))^(1/3);
beta=2*log(D/d)/((D/d)-(d/D));
gamma=(eta*log(D/d)/(beta*D/d)^5)^(1/3);
X=gamma*np^(.7)*b*(sind(th)^1.6)/H;
Ct=((1.96*X^(1.19))^(-7.8)+.25^(-7.8))^(-1/7.8);
m=((.71*X^(.373))^(-7.8)+.333^(-7.8))^(-1/7.8);
ft=0.0151*(d/D)*Ct^(0.308);
Ctr=23.8*(d/D)^(-3.24)*(b*sind(th)/D)^(-1.18)*X^(-.74);
Red=n*d^2*rho/mu;
Reg=((pi*eta*log(D/d))/(4*d/(beta*D)))*Red;
f=(CL/Reg)+Ct*(((((Ctr/Reg)+Reg)^(-1))+(ft/Ct)^(1/m))^m);
Np0=(1.2*pi^4*beta^2)/(8*d^(3)/(D^(2)*H))*f;
Power=Np0*n^(3)*d^(5)*rho*.0013;  %(J/s-->Hp)

eta2=(0.711*((.157+((np*log(D/d))^(.611))))/((np^.52)*(1-(d/
D)^2))); %Dimensionless Parameter
CL2=.215*(eta2)*(np)*(d/H)*(1-(d/D)^2)+1.83*(b*sind(th2)/H)*(np/
(2*sind(th2)))^(1/3);
beta2=2*log(D/d)/((D/d)-(d/D));
gamma2=(eta2*log(D/d)/(beta2*D/d)^5)^(1/3);
X2=gamma2*np^(.7)*b*(sind(th2)^1.6)/H;
Ct2=((1.96*X2^(1.19))^(-7.8)+.25^(-7.8))^(-1/7.8);
m2=((.71*X2^(.373))^(-7.8)+.333^(-7.8))^(-1/7.8);
ft2=0.0151*(d/D)*Ct2^(0.308);
Ctr2=23.8*(d/D)^(-3.24)*(b*sind(th2)/D)^(-1.18)*X2^(-.74);
Red2=n*d^2*rho/mu;
Reg2=((pi*eta2*log(D/d))/(4*d/(beta2*D)))*Red2;
f2=(CL2/Reg2)+Ct2*(((((Ctr2/Reg2)+Reg2)^(-1))+(ft2/Ct2)^(1/m2))^m2);
Np02=(1.2*pi^4*beta2^2)/(8*d^(3)/(D^(2)*H))*f2;
Power2=Np02*n^(3)*d^(5)*rho*.0013;  %(J/s-->Hp)

Total_Power=(2*Power)+Power2


Total_Power =

    1.1875
```

Appendix D

$$\beta = \frac{2\ln\left(\frac{D}{d}\right)}{\left[\left(\frac{D}{d}\right) - \left(\frac{d}{D}\right)\right]} = \frac{2\ln\left(\frac{0.38735}{0.3556}\right)}{\left(\frac{0.38735}{0.3556} - \frac{0.3556}{0.38735}\right)} = 0.9988$$

$$\eta = \frac{0.711\left\{0.157 + \left[n_p \ln\left(\frac{D}{d}\right)\right]^{0.611}\right\}}{\left\{n_p^{0.52}\left[1 - \left(\frac{d}{D}\right)^2\right]\right\}} = 1.567$$

$$Y = \left[\frac{\eta \ln\left(\frac{D}{d}\right)}{\left(\frac{\beta D}{d}\right)^5}\right]^{1/3} = 0.445$$

$$X = \frac{Y n_p^{0.7}\, b \sin^{1.6}(\theta)}{H} = \frac{0.445\,(2)^{0.7}\, 0.0254 \sin^{1.6}(45^\circ)}{0.4826}$$

$$X = 0.0218$$

$$C_L = 0.215\, \eta\, n_p \left(\frac{d}{H}\right)\left[1 - \left(\frac{d}{D}\right)^2\right] + 1.83\left(\frac{b\sin\theta}{H}\right)\left(\frac{n_p}{2\sin\theta}\right)^{1/3}$$

$$C_L = 0.1545$$

$$C_t = \left[\left(1.96\, X^{1.19}\right)^{-7.8} + (0.25)^{-7.8}\right]^{-1/7.8}$$

$$C_t = 0.0206$$

$$C_{tr} = 23.8 \left(\frac{d}{D}\right)^{-3.24} \left(\frac{b \sin\theta}{D}\right)^{-1.18} X^{-0.74}$$

$$C_{tr} = 19967.55$$

$$f_{\infty} = 0.0151 \left(\frac{d}{D}\right) C_t^{0.308} \Rightarrow f_{\infty} = 0.00419$$

$$m = \left[(0.71 X^{0.373})^{-7.8} + (0.333)^{-7.8}\right]^{-1/7.8}$$

$$m = 0.1703$$

$$Re_d = \frac{n d^2 \rho}{\mu} = \frac{(1.256)(0.3556)^2(1450)}{10} = 23.03$$

$$Re_G = \left\{\frac{[\pi \eta \ln(\frac{D}{d})]}{\left(\frac{4d}{\beta D}\right)}\right\} Re_d \Rightarrow Re_G = 2.637$$

$$f = \frac{C_L}{Re_G} + C_t \left\{\left[\left(\frac{C_{tr}}{Re_G}\right) + Re_G\right]^{-1} + \left(\frac{f_{\infty}}{C_t}\right)^{1/m}\right\}^{m}$$

$$f = 0.0635$$

$$N_{P_0} = \left\{\frac{[1.2\pi^4 \beta^2]}{\left[\frac{8d^3}{D^2 H}\right]}\right\} f \Rightarrow \boxed{N_{P_0} = 1.49}$$