THE BEEBLADE SPIN-FLOAT

An Improved Honey-Wax Separator | MEC E 460 Fall 2019

BACKGROUND

- Alberta produces almost 40 million pounds of honey every year
- Honeycombs are capped with wax
  - → Need to *separate wax from honey*
- Market spin-floats are not equipped to handle Alberta's high flow rate requirements, causing:
  - → Honey foaming
  - → Incomplete wax separation
  - → Motor overloading

OBJECTIVE

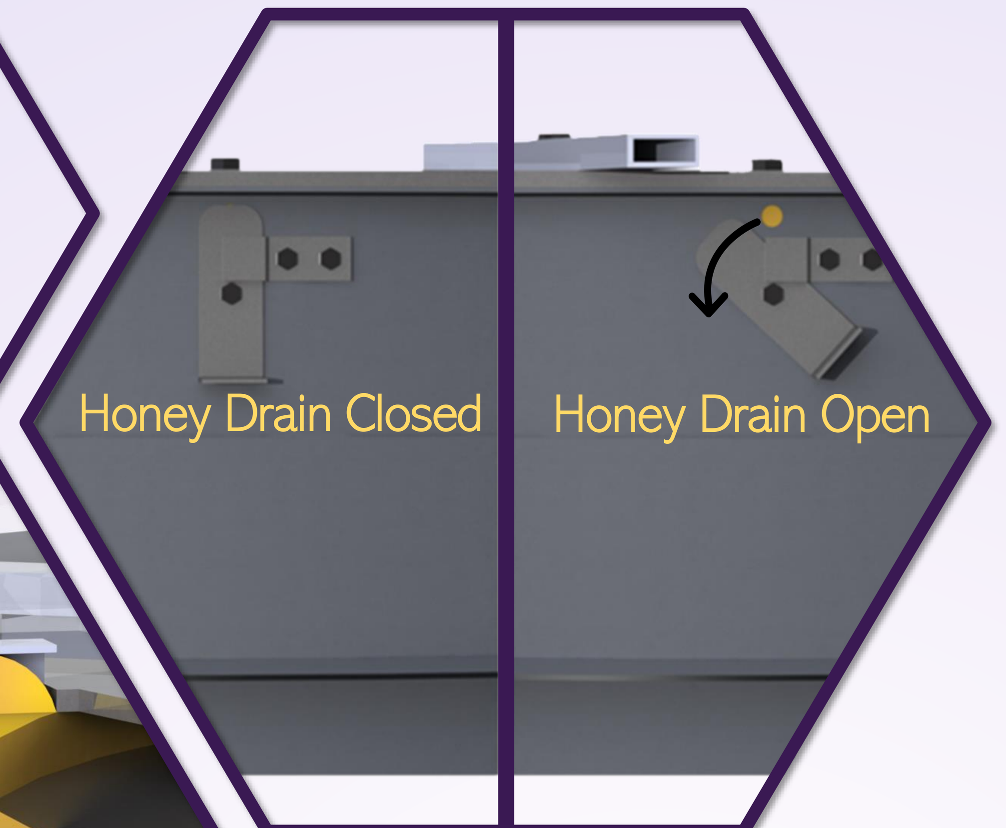
- Reducing air foam in honey
- Comfortably handling higher flow rates of honey-wax mixture
- Avoiding wax build-up in the system

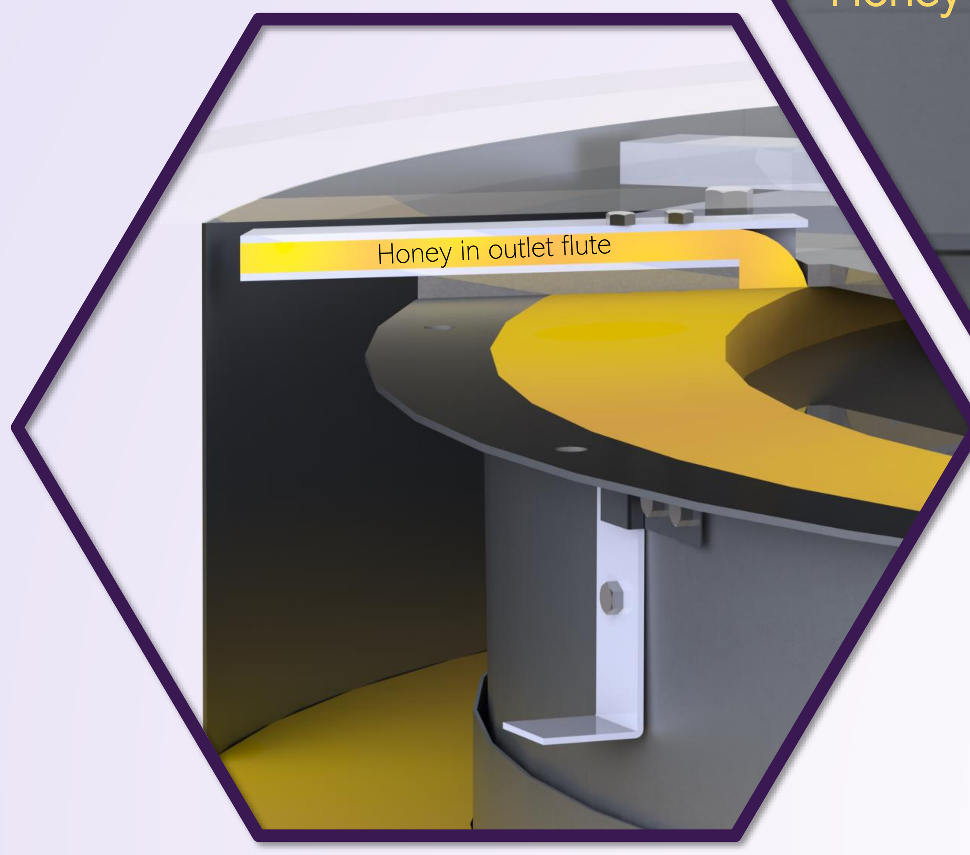
SOLUTION

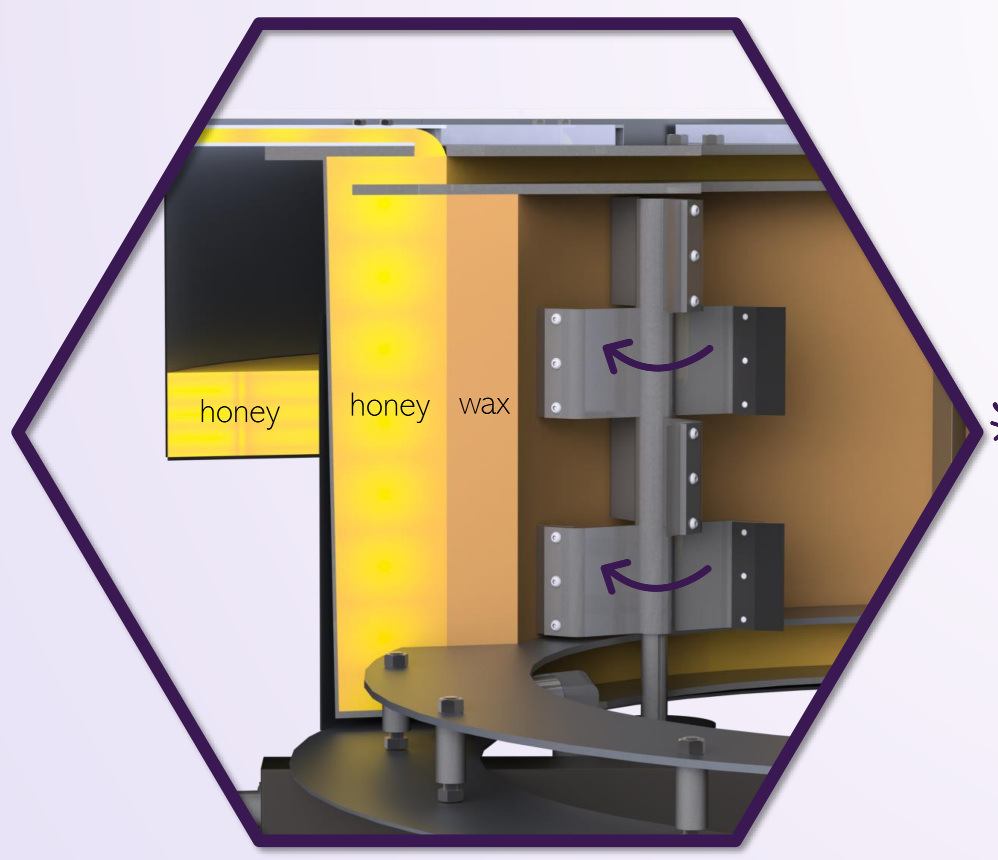
- Mixture volumetrically scaled up:
  - → Increases separation area and capacity
- Inlet feeds mixture directly to base of spinning drum
  - → Minimizes honey impact with wall and contact with air
- Adjustable rotating blades shave entire length of wax layer
  - → Prevents wax build-up in small spaces

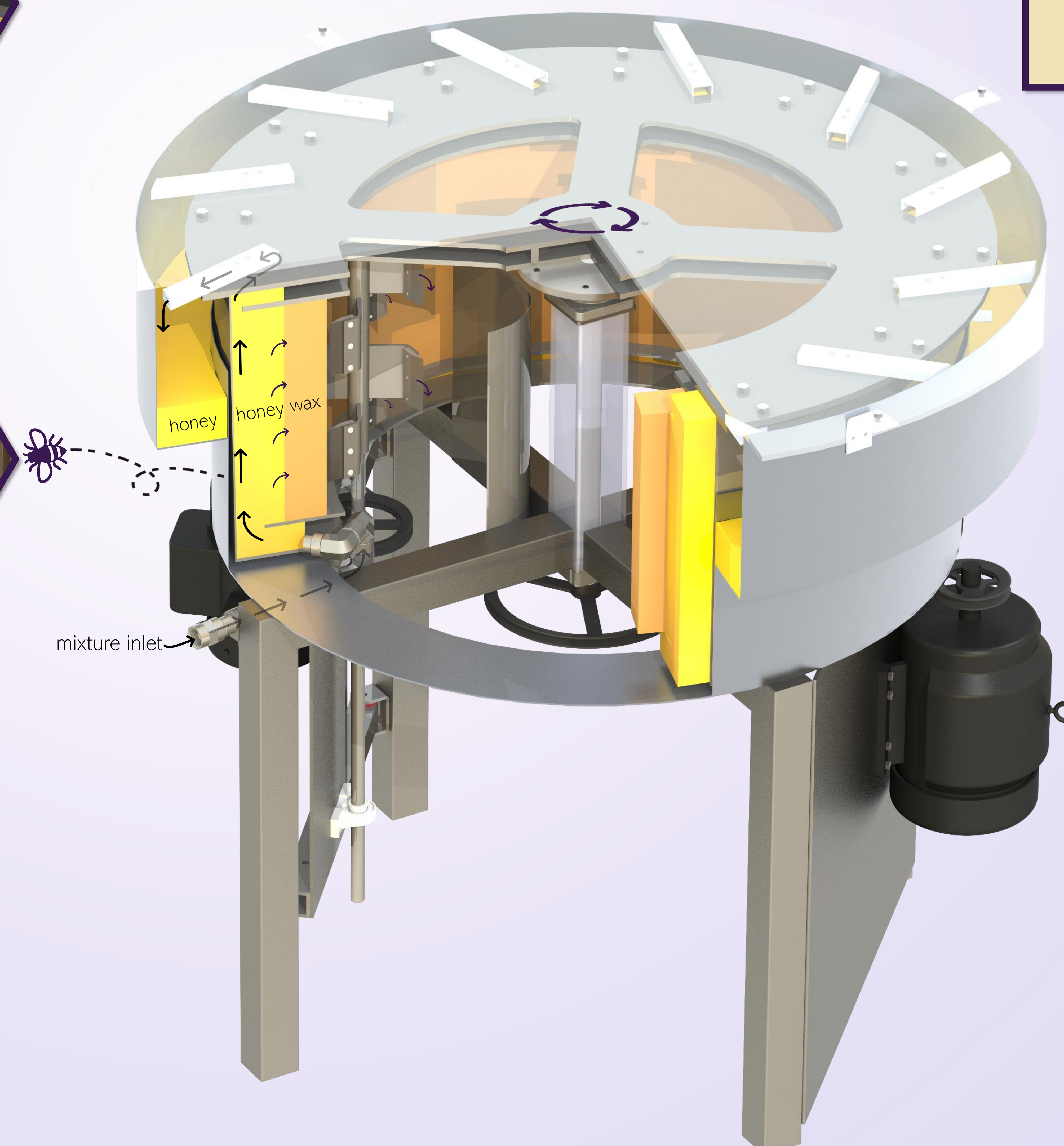
HOW IT WORKS

- Honey and wax have different densities
- Centrifugal effect separates them into distinct products:
  - → *Honey* is forced *outward* and exits through *flutes*
  - → *Wax* is forced *inward*, where *blades shave* it away







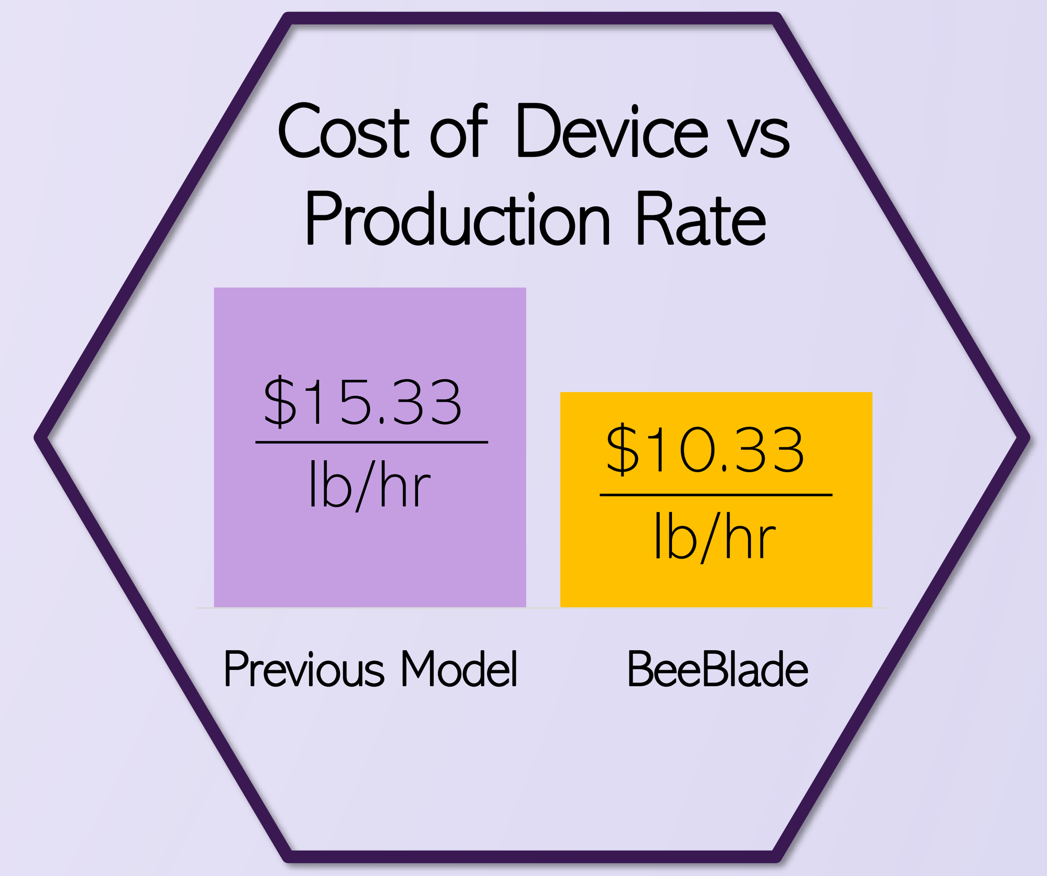


SPECIFICATIONS

- 3,000 lb per hour of honey throughput
- Two 5 hp motors with pulley systems
- Inner drum spins at 280-400 rpm
- Blades spin at 2045 rpm
- Accelerates mixture to 100 G
- 1° angle on inner drum wall
  - → 1-step water flush from bottom to top
- Top viewing ports to monitor operation
- Completely food safe

KEY ANALYSES

- Honey transit time and centrifugal acceleration made independent of size
- Motor power requirements based on force required to cut the wax layer
- FEA completed on load-bearing top plate and frame, optimizing geometry
- Vibration analysis to ensure stability and avoid resonance



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SWARM ENGINEERING

FOAM REDUCTION IN THE HONEY-WAX SEPARATION PROCESS

PHASE THREE

2019/12/02

SWARM ENGINEERING

Executive Summary

Swarm Engineering was tasked to design a system to separate honey and wax which improves on the current market devices. The most common device in Alberta is the *spin-float*, a centrifuge designed to separate wax and honey by forcing the higher-density honey to the outside of a rotating drum, while the lower-density wax collects in the middle where a spinning blade shaves it away. Using current model spin-floats, this process is effective. However, when running at the higher throughputs required by Alberta beekeeping operations, issues including lower degrees of separation, increased loading on the spinning blades, and production of foam arise. Reduction of foaming during the separation process is the primary focus of this project. Foaming, caused by air intrusion, causes an unusable foam layer and can cause the honey to ferment, both representing a loss in product.

Following Phase 2, the client and Swarm Engineering agreed to develop the BeeBlade, a spin-float that employs an angled drum wall and an upward flow of honey. The BeeBlade has multiple advantages over current spin-float models, including being designed for twice the throughput of honey, easier cleaning, reduced foaming, and improved control over honey processing. This was a deliberate increase in the project's scope.

Calculations and analyses were performed to demonstrate the feasibility and function of the BeeBlade. Engineering drawings were also produced for critical components.

The total cost of manufacturing the BeeBlade is $31,000. This was under the budget of $50,000, the cost of two current model spin-floats with upgrades. The engineering cost for Phase 3 was $39,570, which gives a total engineering cost of $84,930 for the entire project. The increase in engineering hours can be attributed to a third honey farm visit, needed to determine more measurements and process parameters.

Further work relating to this project includes the incorporation of a surge tank immediately before the spin-float, to produce a consistent and regulated inflow of honey-wax mixture into the spin-float.

Swarm Engineering recommends that the client pursues electrical engineering expertise to complete the design of the BeeBlade, so it can be manufactured and implemented into the refinement process.

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1. Background and Introduction

1.1. Honey Refinement Process

Most Alberta beekeepers use modular beehive boxes, shown in Figure 1, which each contain 8 to 10 plastic frames. Over a season, bees construct wax honeycombs on these frames, fill them with honey, and cap off each honeycomb with an extra layer of wax, as shown in Figure 2.

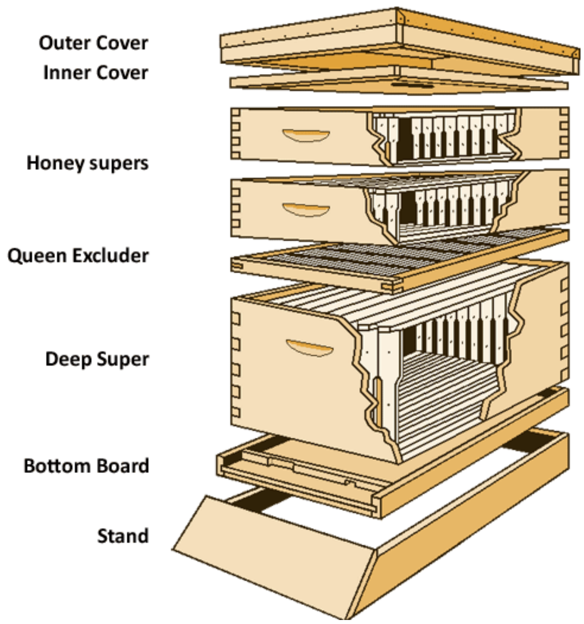

Figure 1: Beehive box layout [1].

These frames are collected and processed in a 120-frame production line, as shown in Figure 3. First, the honeycombs are sliced off the frames using an assembly line style cutting machine, as shown in Figure 4. Then, the frames are placed in an extracting centrifuge, shown in Figure 5. This extracting centrifuge spins the remaining honey and wax off of the 120 frames. The honey-wax mixture consists of a 7:1 volume ratio of honey to wax. Progressive cavity pumps transfer this honey-wax mixture to a heat exchanger, shown in Figure 6, which heats it to 38°C.

Figure 2: Full, capped honeycombs on a honey frame **[2]**.

Figure 3: 120 frame honey processing line.

Figure 4: Wax capping slicer.

Figure 5: Frame extraction centrifuge.

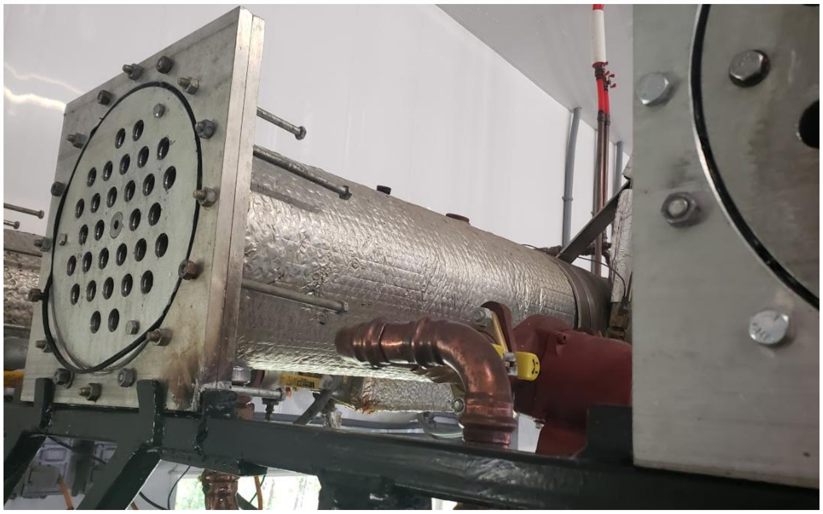

Figure 6: Honey-wax mixture heat exchanger.

Heating the honey reduces its viscosity, causing the mixture to flow more easily. This makes the separation process easier, as wax can flow more freely in the less viscous honey. This is the ideal temperature for separating the two products, because it’s the highest temperature to which the mixture can be heated without affecting the quality of the honey. At temperatures above 38℃, the sugars in the honey will caramelize, producing amber honey, which is less commercially valuable.

The heated honey-wax mixture is pumped into a separation centrifuge, called a spin-float, which is the focus of this report. The spin-float is aptly named, as it describes how the centrifuge works. Wax has a lower density than honey, so when the honey-wax mixture **spins** inside the centrifuge, the wax particles in the mixture **float** inward inside the rotating centrifuge, due to their relative buoyancy compared to honey. They form a wax layer on top of the outer layer of honey. The spin-float, and a schematic of its operation can be seen in Figure 7 and Figure 8.

Figure 7: Stock spin-float commonly used by Alberta beekeepers.

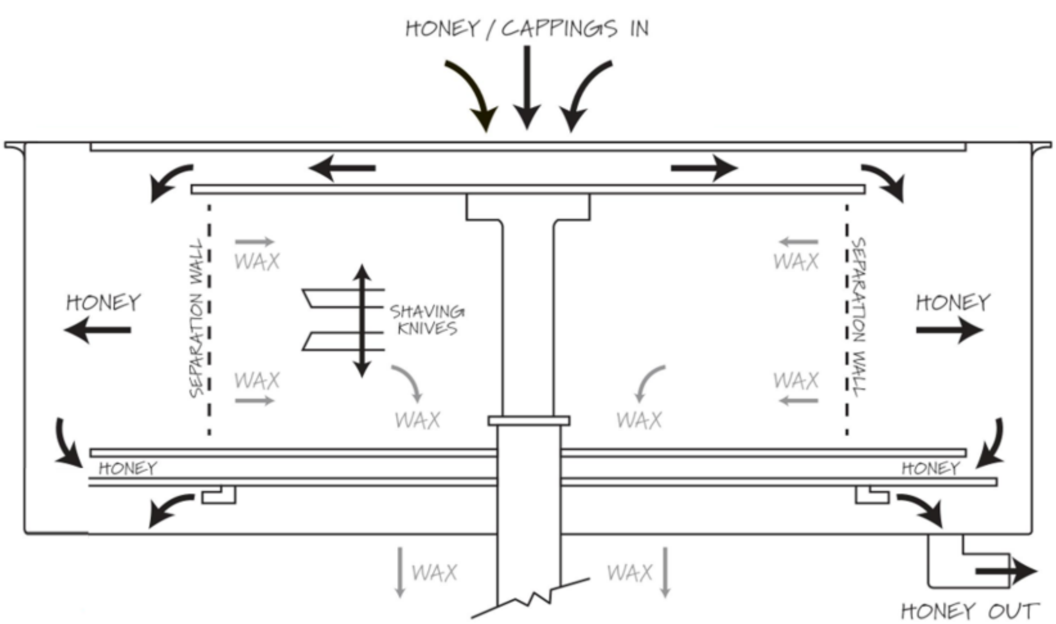

Figure 8: Schematic of spin-float operation.

The goal of separation is to obtain the purest forms of both honey and wax as two distinct products. To ensure this, a wax layer that is several inches thick is allowed to build up before it's sliced off inside the centrifuge by blades rotating in the same direction, but at a higher speed. The distance of the spinning blades from the centrifuge wall can be adjusted with a crank. By letting the wax layer become ~3 inches thick, the wax will be very dry, and there will be little chance of cutting into the honey layer. To ensure that no wax is extracted with the honey, the honey flows around a baffle at the base of the centrifuge. This baffle restricts the honey flow out of the centrifuge until the honey layer reaches a thickness of ~9 cm. The separated honey then flows out of the centrifuge to be filtered, stored, shipped, further processed, packed and then sold. The shaved wax, shown in Figure 9, falls out the centre of the centrifuge. The collected wax is melted into bricks, shown in Figure 10, to be sold for cosmetics and candles.


Figure 9: Shaved wax particles from the spin-float.


Figure 10: Processed wax bricks.

Using these wax layer buildup and baffling techniques, the current spin-float achieves a very high degree of honey-wax separation when operated within its specified flowrates. However, processing a whole 120-frame line's worth of honey overloads the spin-float, which has been seen to cause the following issues:

- Foaming in the honey as shown in Figure 11 and Figure 12.
- Excessive force on the cutting blades, causing motor breaker tripping
- Poor separation of honey and wax leading to wet wax and honey outlets plugged with wax

Our client's main concern is foam generation. Analysis of this issue shows that honey overloading is likely the primary issue, causing the foam generation. Swarm engineering determined that a scale-up would be necessary to satisfy the process requirements. Additional modifications will be made to increase overall product performance and user satisfaction.

A summary of the honey refinement process is shown in Figure 13.

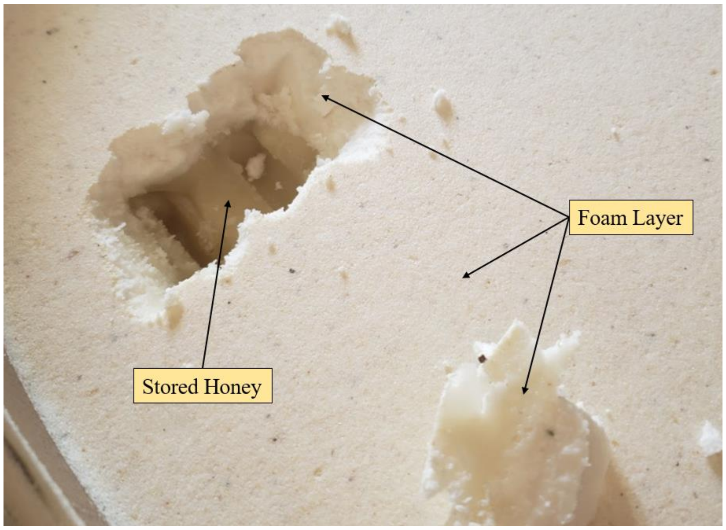

Figure 11: Foam layer on honey stored in barrels

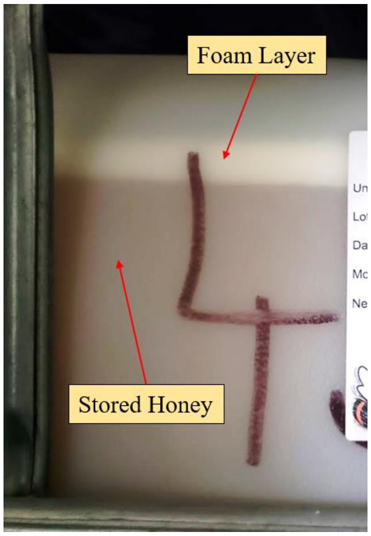

Figure 12: Foam layer on honey stored in totes.

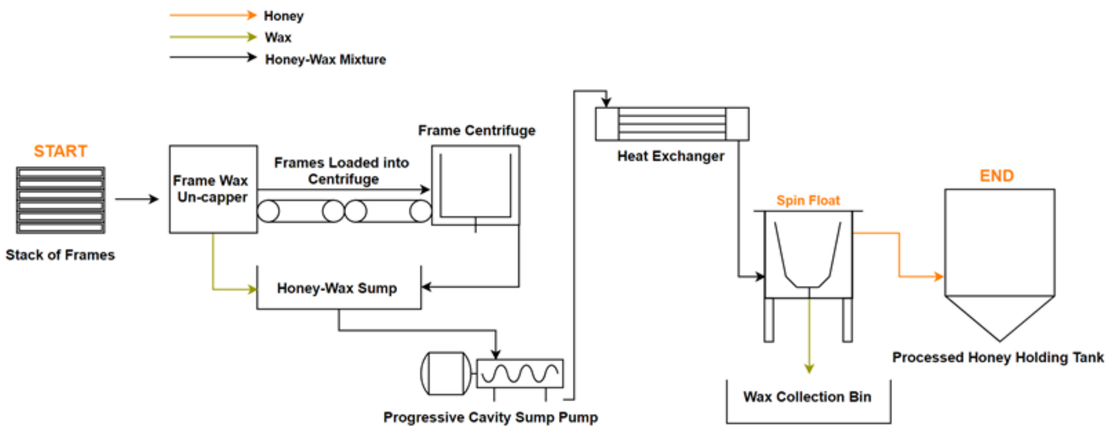

Figure 13: Honey refinement process diagram.

1.2. Project Task

Swarm Engineering was tasked with developing a system that separates wax and honey at a rate of 3,000 pounds of honey per hour and reduces the foam that accumulates through the current spin-float process. Phase 2 of this project led to the selection of the angled-wall spin-float design, which presented many advantages over the current spin-float models, including improved cleaning, better operator control, and reduced foaming. This report, marking the end of Phase 3, contains final engineering designs, calculations, and drawings for the design, referred to as the BeeBlade. Details on the project proposal and project specifications can be seen in the Phase 1 report.

2. Final Design

2.1. Complete Design Overview

The final design was compartmentalized into five systems: the main separation drum, the wax cutting blades, the support frame, the outer drum, and the inlet pipe. An engineering drawing tree and drawing package are shown in Appendix R. Honey-wax mixture from a heat exchanger is pumped into the bottom of the spin-float, where it's spun and separated into two distinct products. The dense honey is pushed to the outside and up out of the spinning drum where it drains and is collected for storage. The lighter wax builds up in the centre of the spin-float where it's cut by spinning blades and falls into a collection bin below.

The following subsections detail each of the systems. Figure 14 shows the entire spin-float.

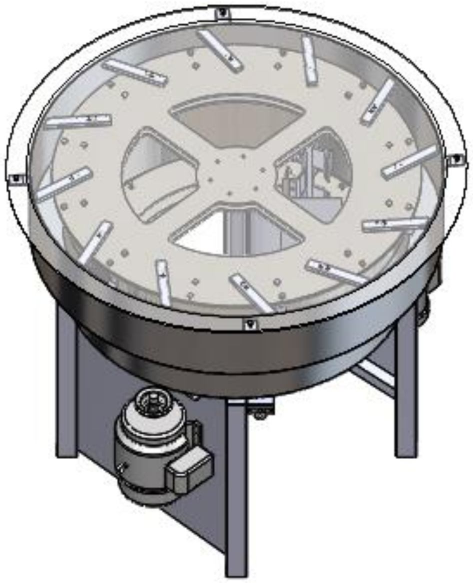

Figure 14: Complete spin-float assembly.

2.2. Main Drum and Separation System

Figure 15 shows the inner drum assembly. Figure 16 is a labelled cross-sectional view of the spinning drum showing the main parts: the honey inlet, honey/wax buildup and separation, and honey and wax removal. The baffles at the top of the drum require 9 cm of honey to build up before it can escape through flutes and collect in the collecting duct. The flutes were added to deposit the honey directly onto the wall of the collecting duct to ensure minimal splattering and mixing with air. Additionally, drains were added to the side of the drum that can be opened at the end of operation, to drain the residual honey. There is also a wax shield that protects the honey inlet from falling wax. The drum is rotated by a 5 hp motor and can be adjusted within a range of 280 to 400 rpm (see Operation section for further details). Openings on the top of the drum allow the operators to see inside and monitor separation progress. The cover can be removed to access the inside of the drum while it is not in use.

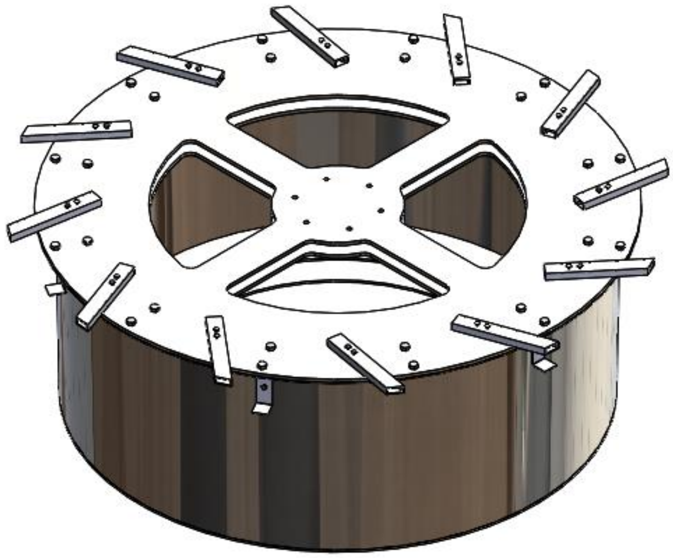

Figure 15: Inner drum.

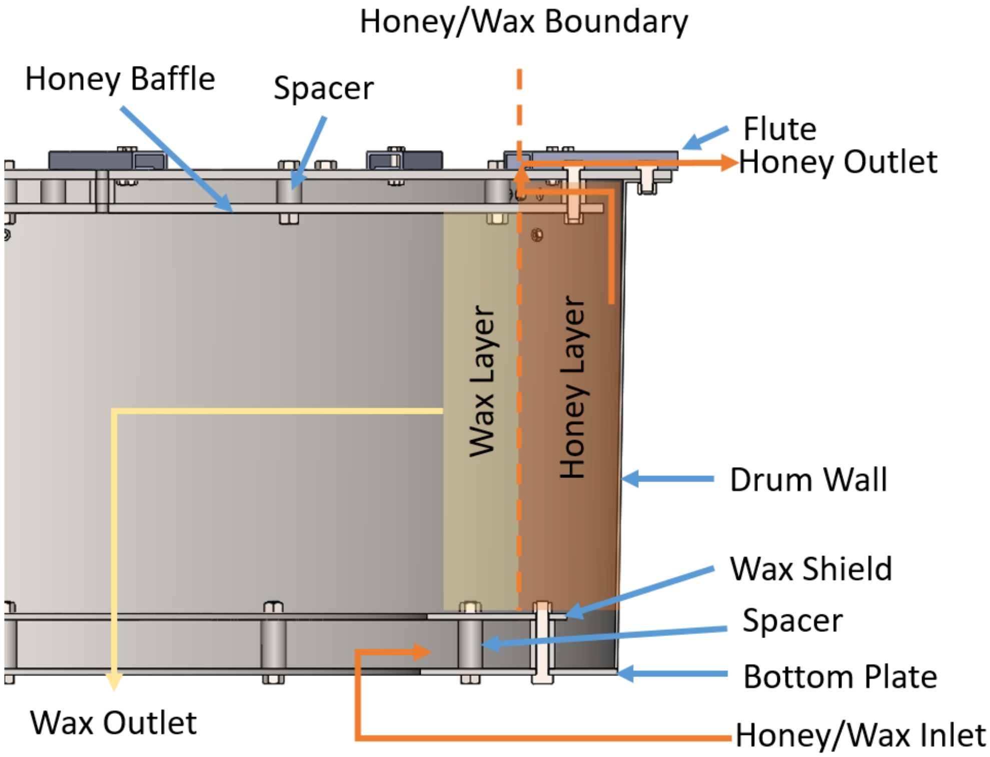

Figure 16: Half inner drum cross-section view with labeled parts and flow direction arrows.

2.3. Wax Blades

The wax builds up on the inside of the drum and is cut by spinning blades. The blades are powered by their own motor that operates at 5 hp and 3600 rpm. They have a relative tip velocity of 6.38 m/s compared to the wax in the drum. The blade shaft is attached to a hand wheel which adjusts the depth of the blades as necessary. The blades and wax are lightly sprayed with water to allow for easier cutting of wax by dispersing the wax “pellets”, and to prevent wax from sticking on the blades. Without the water, the wax becomes tightly packed together. An overall view of the cutting mechanism can be seen in Figure 17. Figure 18 shows a labeled top-down view of the frame and both rotating mechanisms. In this view, the cutting blades’ adjustment mechanism can be seen. Figure 19 shows a side-by-side comparison of the range of motion of the blades.

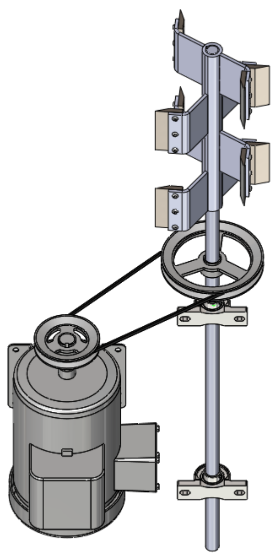

Figure 17: Cutting mechanism overview.

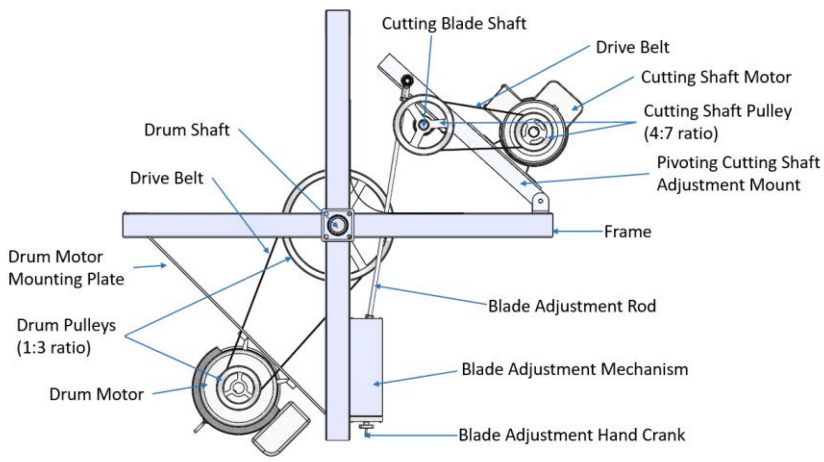

Figure 18: Top-down section view of the cutting mechanism drive train, the drum drive train, and the cutting adjustment mechanism.

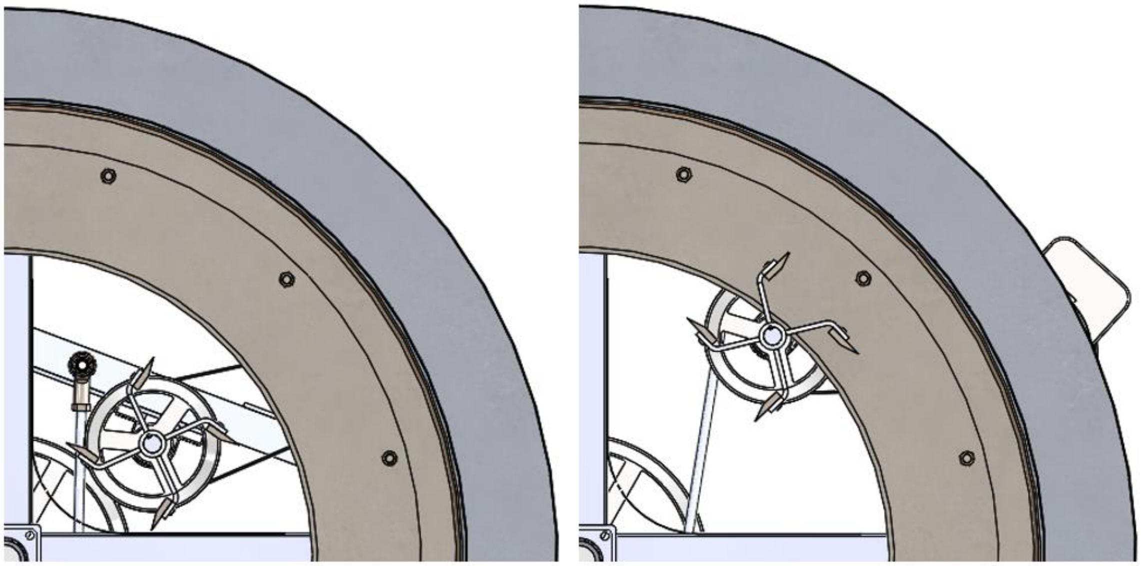

Figure 19: Blade range comparison from a top-down section view.

2.4. Support Frame

The support frame consists of four legs that merge in the centre and support the drum shaft. Figure 20 is an illustration of the support frame. The drum motor is supported by a plate between the two shafts, and the blade motor and shaft are supported by an adjustable panel.

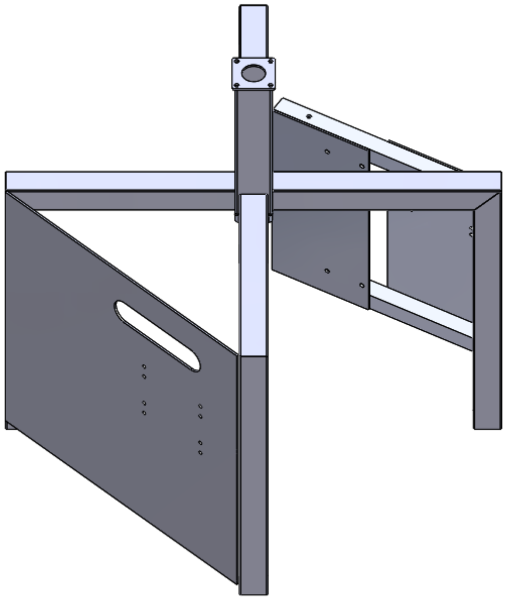

Figure 20: Frame overview.

2.5. Outer Drum

The outer drum serves a dual purpose: collecting the separated honey in a collecting duct, and covering the rotating components, protecting the operator. The top face is made of acrylic, allowing the operator to view the separation process. Figure 21 illustrates the outer drum.

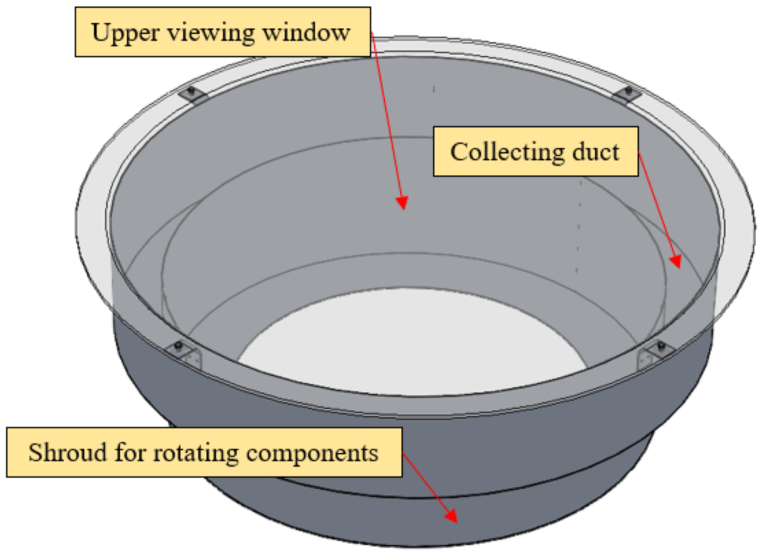

Figure 21: Outer drum.

2.6. Honey/Wax Inlet

A small pipe section and spout were implemented into the design to input the honey-wax mixture. The spout is slightly angled down to prevent honey from dripping back down the pipe. See Figure 22 for an illustration.

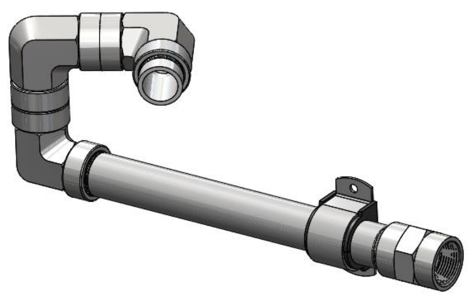

Figure 22: Honey/wax mixture inlet pipe and spout.

2.7. Electronic Control and Operation System

The drum motor is governed by a variable-frequency drive (VFD) to control the angular velocity of the drum. It allows for different drum speeds, set at the operator's discretion. However, the design and implementation of the electronic systems is out of the scope of this project.

3. Operation

3.1. Start up

While the drum is speeding up, no honey/wax mixture will be fed into the drum. Once at speed, honey and wax will enter the drum and build up until a 9 cm thick layer of honey has built up and exits the flutes on the top of the drum. During this stage, no honey or wax will be collected.

3.2. Continuous Operation

During continuous operation, the spin-float can run at speeds between 280 rpm and 400 rpm depending on honey viscosity, quality, operator preferences, and other factors. The wax layer thickness can also be adjusted by turning the hand wheel. The standard operating speed is 380 rpm.

3.3. End of Operation

At the end of operation, there will still be the build-up of honey and wax within the drum. At this point, the operator will open the drains by turning the drainage knob. This will open the drain ports and drain most of the remaining separated honey into the collecting duct. The rest of the honey wax mixture should be scraped out of the spin-float by the operator and processed the next day. Figure 23 is a side-by-side comparison of the closed and open drains on the side of the inner drum.

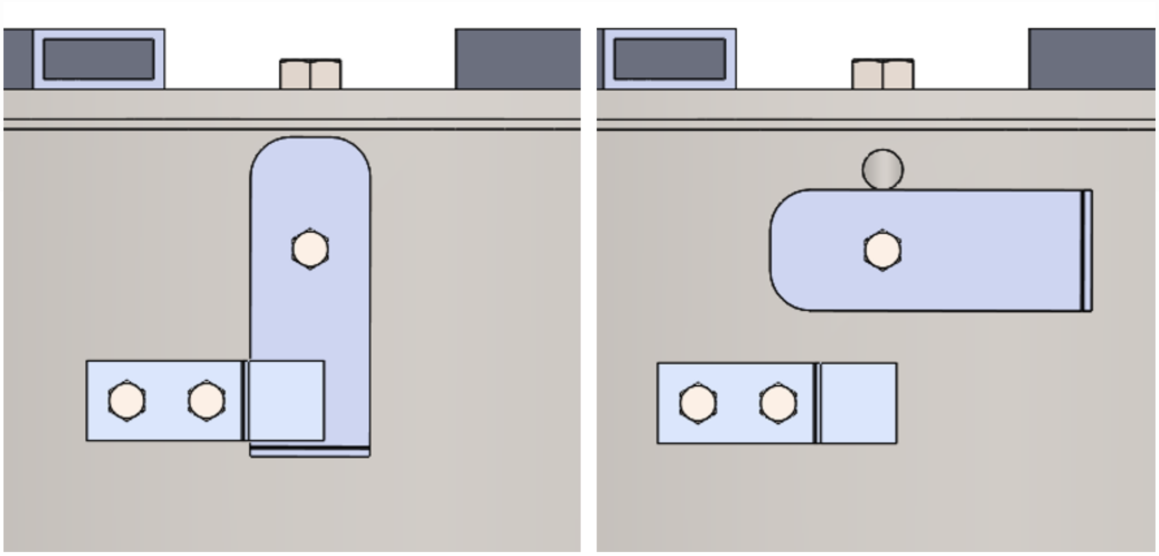

Figure 23: Comparison of closed and open drain ports on the side of the inner drum. In the open position, the drain is visible

3.4. Cleaning

Warm water will be pumped through the inlet spout to clean the spin-float. The drum will spin at a range of speeds to allow water to circulate through the drum, flutes, blades, and collecting ducts. Rotational speeds above 285 rpm result in water flowing to the top and out the flutes, and any speed below 285 rpm will result in the water changing directions and flowing out of the bottom. This allows water to circulate throughout the inner drum. The top of the drum can also be removed to be manually washed.

4. Improvements from Prior Spin-float Models

In addition to scaling up the spin-float to handle more honey, one of the client's main concerns was the creation of foam due to aeration of the honey at different points in the process. Air is hypothesized to get into the honey in two locations: the entrance and exit. At both these points, the honey is accelerated into a wall and mixes with air. This effect is amplified when the spin-float is operating above capacity. The BeeBlade improves on these specific points of aeration by applying the honey-wax mixture close to the spin-float walls at both the entrance and collecting ducts, reducing contact with air. The flutes are angled at 32^o to eliminate unwanted acceleration caused by the flutes. The number of flutes was increased from 8 to 12 of holes, and the holes flowing into the flutes are 3 times larger to accommodate the larger throughput.

Other improvements are shown in Table 1.

Table 1: Additional improvements from previous models.

Improvement	Description
Cutting Mechanism	The current spin-float model has gaps in the cutting mechanism where wax builds up. In the BeeBlade model, the blades run over the entire height of the drum so all wax is cut.
Visual Monitoring	The BeeBlade spin-float has inspection holes at the top for the operator to visually monitor the process, whereas, there is no way for an operator to visually inspect the process in previous models.
Corrosion Resistance	In the old spin-floats, multiple components, including the shafts, had started to rust. The BeeBlade uses corrosion-resistant materials if they are exposed to the product or moisture.
Cleaning	Cleaning and adjusting the flowrate are also factors that improve on previous spin-float models. These features are described in section 3.4. Previous models did not have a self-flushing cleaning method and could not be cleaned without removing the drum.

5. Key Analyses

Table 2 provides a description of each completed analysis including all key results. Column 2 of the table refers to the appendix where complete, detailed calculations for each analysis are found.

Table 2: Description of completed analysis and respective appendix locations of detailed calculations.

Analysis	Appendix	Description
Scale Up Calculations	A	The spin-float was scaled up in to reduce overloading. To run the BeeBlade at twice the original spin-float capacity, the height and radius were multiplied by $\sim\sqrt{2}$. **This yielded a height of 16” and a radius of 0.638 m**. The angular speed required for the new spin float to achieve the desired accelerations was calculated to be **381 rpm.**
Finite Element Analysis of the Inner Drum	B	A finite element analysis was performed on the inner drum assembly, which helped guide its design. The maximum displacement was found to be **3.5 mm**, the maximum equivalent strain was found to be

		0.0013 mm/mm, and the maximum equivalent stress was found to be **239.4 MPa**. This gave a safety factor of ~**1.2**.
Finite Element Analysis of the Frame	C	A finite element analysis was performed on the frame, to verify its capability of supporting the fully-filled spin-float. The maximum displacement found was **0.085 mm**, the maximum equivalent strain was **0.00039 mm/mm**, and the maximum equivalent stress was **35.3 MPa**. This gave a safety factor of **~14**.
Forced Vibrations due to Rotating Imbalance	D	Calculation for forced vibrations caused by the rotating mass imbalance were performed on the spin-float, where displacement strictly was assumed to exist in the horizontal (x) direction. Natural frequencies for two different cases, one including the honey and wax mass and second excluding honey and wax mass were considered. The operating frequency to natural frequency ratio for case one and case two were **2.74** and **2.11** respectively. These ratios lie well beyond the resonance point in the system response. The dynamic magnification factor for both cases reaches an asymptotic value significantly below the static deflection. The spin-float was concluded to be stable for both the natural frequencies discussed above. It is recommended to operate the spin-float at speeds **greater than 275 rpm** to avoid any significant vibration. Additionally, it is recommended to accelerate the spin-float as fast as possible to reach the minimum recommended speed of 275 rpm. This decreases the dwelling time near resonance frequency and any significant vibrations that may affect the stability of the system.
Rotational Rate for Draining	E	At the end of each day it is necessary to drain the honey out of the machine. The drain holes are located at the top of the spin float, to aid in cleaning. The cone angle and rotational speed create an upwards acceleration to pump the honey to the top of the spin-float. **The minimum rotational rate was calculated at 285 rpm for draining**.
Flow Calculations	F	Separation parameters such as honey transit time and average speed were calculated for the redesigned spin-float, and for the original spin-float operating at overloaded and optimal conditions. At optimal conditions (1500 lb/hr), the original spin-float had a honey transit time and average velocity of **8.64 minutes** and **0.588 mm/s** respectively. At overloaded conditions (3000 lb/hr), the original spin-float had a honey transit time and average velocity of **4.32 minutes** and **1.18 mm/s** respectively. The redesigned spin-float, operating at a

		flow rate of 3000 lb/hr, had a honey transit time of **9.80 minutes** and **0.93 mm/s** respectively, giving the most amount of time for wax to separate from the honey of the three cases.
Optimal Flute Angle	G	To avoid accelerating the honey once it exits the drum, an optimal flute angle was calculated. The flutes were mounted to the inner drum at an angle of **32°** from radial.
Motor Power Requirement	H	The main source of resistance to the rotation of the inner drum is the applied force from the cutting blade to the system as it shaves off wax. Power requirement calculations were completed based off experimental scratch test data of wax to determine the material fracture toughness [3]. The blade shaft operates at a constant 2045 rpm, thus the relative velocity between the blades and the wax layer is higher at lower drum speeds. The worst-case scenario occurs when the blades are cutting wax, but the inner drum is stationary, requiring a power input of **3.81 hp**. This is not an actual operating condition, and as the drum spins, the power requirement will decrease as relative velocity decreases. Under standard operation at an inner drum speed of 380 RPM, the power required is **1.92 hp**. Based on these calculations, **5 hp motors** were selected for both the blade and inner drum shafts. Specification sheets can be found in Appendix Q.
Energy Consumption	I	For comparison with previous spin-float models, an analysis of energy consumption was performed. The average yearly energy use was determined to be **300.321 kWh**, yielding an annual cost of **$28.21** and emissions of **240 kg$_{CO2e}$.**
Honey-Wax Mixture Mass	J	Structural analysis of the design requires the operational weight of the machine. This involved calculating the mass of honey and wax inside the machine. This calculation yielded **655lb** of honey wax mixture.
Main Drum Shaft	K	Analysis of the main drum shaft was completed to check that shaft deflection, slope and torsional deflection are within the maximum limits. Maximum deflection during operation was determined to be **0.000385 inches** with a safety factor of **13** compared to the force required to obtain the maximum allowable deflection of 0.005 inches. Shaft slope during operation at both bearings does not exceed the limit of 0.004 rad. The maximum experienced torsional deflection is **0.357 deg/m**, which is less than the maximum allowable value of 3 deg/m.
Load Bearing Bolts	L	The only significant load bearing bolts in the design are those that join the top plate and side wall of the spinning

		inner drum. It was determined that to avoid joint separation and prevent yielding, a preload of **67.5 lbs** will be applied, requiring **6.75 lb in** of torque. The factor of safety of the bolts in yielding is **110**.

6. Risk Assessment

6.1. Rotating Components

The rotating components in the mechanism are the inner drum, motor, blades, and v-belts. During operation, these components are covered and not accessible by the operator. However, there is a high probability of serious injuries if an operator accidentally comes in contact with the rotating parts. This risk is heavily mitigated by the guards.

To minimize the risk, a motor shroud is incorporated in the design. Proper operation training is mandatory before operating the spin-float.

7. Manufacturing Cost Analysis/Feasibility

7.1. Cost Analysis

The material and manufacturing cost breakdown of the final design is shown in Appendix M. Some of the design components like the motor, rubber belts and bearings were directly taken from various suppliers. The total spin-float manufacturing cost is $31,000, which is within the manufacturing budget of $50,000 provided by the client. This estimate increased by $10,000 from Phase 2 due to an increase in overall number of components in the final design.

7.2. Environmental Impact and Sustainability Considerations

Most components in the BeeBlade design are made of 3003 aluminium or 304 stainless steel alloys. While the production of these metals is quite resource-intensive, they are highly corrosion-resistant. This means most parts on the spin-float have a long life expectancy and can easily be reused in another spin-float or recycled. Materials were sourced locally, requiring minimal shipping distances.

Energy consumption of the spin-float is minimal, and it produces approximately 240 kg_{CO2e} per year on the Alberta grid. There are no emissions or pollutants directly from the spin-float.

8. Design Compliance

Based on the specifications created in the first two phases of the project, a compliance matrix was created to evaluate the spin-float. Table 4 lists all of the specifications, the regulating authority, their level of importance, notes of the design compliance. The levels of importance are explained in Table 3. All criteria were met.

Table 3: Description of importance ratings

Level of Priority	Description	
3	Mandatory	Constraint is mandated by the client and is essential for the functionality of the design
2	Nice to Have	Constraint should be accounted for if at all possible, but not mandated by the client and the product could be considered to be functional without it
1	Not Necessary	Constraint is not necessary for the functionality of the product, but is desirable

Table 4: Final Design Compliance Matrix

Item	Type of Constraint	Description	Regulating Authority	IMP.	Phase 3 Changes	Notes	Com-pliance
1	**Project Management**						
1.1	Schedule	All deliverables must be provided as required by the course schedule (Final Deadline is December 2)	Dr. Duke	3	-	All deliverables handed in on time	Yes
1.2	Budget	The cost of the device should be less than $50,000	Client	2	-	Total Spin-float Cost:	Yes
2	**Operation**						
2.1	Minimum Honey Flow Rate	Device must process 30,000 lbs of honey over a 10 hr period at a minimum (3000 lbs/hr; ~260 gal/hr)	Client	3	-	Designed for 3000lbs/hr of honey; Maximum 3500lbs/hr	Yes
2.2	Temperature Range	The honey temperature must not exceed 40°C	Client	3	Honey temperature does not have a minimum	Honey will enter the spin-float from a heat exchanger	Yes

						at 38°C and will not be heated in the spin-float	
2.3	Wax Dryness	The wax leaving the separator must be dry and contain zero extractable honey	Client	3	-	The cutting blades will be adjustable to allow for wax dryness flexibility	Yes
2.4	Honey Quality	Produced honey foaming should be reduced from 5% by volume	Client	3	-	Aeration is reduced at the honey inlet and outlet flutes.	Yes
2.5	Duration of Use	Device must durable enough to be used constantly for 10 hours per day and up-to 21 days a year	Client	3	-	All components used are high quality and designed to operate for long periods of time	Yes
2.6	Honey/Wax Buildup	Device must prevent buildup of honey or wax within the device	Client	2	-	Blades cut the wax on entire height of drum; Honey can be drained by opening drain ports	Yes

~~2.7~~	~~Conditions of Use~~	~~Device must be able to be used in temperatures ranging from 5ºC to 40ºC~~	~~ISO TS 22002-1~~	~~3~~	-	Complies with specification 2.2 and will be operated indoors	
2.8	Energy Intake	Device must be able to be powered using 220 V	Swarm Engineering	2	-	Spin-float uses two 5 hp motors, which are able to be powered with 220 V source	Yes
2.9	Continuous Operation	During steady state operation the device shall maintain constant level and flow rates with minimal user input	Swarm Engineering	3	-	Due to the baffles and cutting blades, the spin-float will run continuous without input	Yes
3	**Safety**						
3.1	Food Handling/ Material	Device must use food compatible materials, seals, bearings and lubrication (if required)	ISO 14159 [4]	3	-	All materials touching or near honey/wax is a food safe material	Yes
3.3	Honey Storage	Device should not be used to store honey for	Client	2	-	Honey is not stored in spin float for long periods of time	Yes

		more than 30 minutes (Avoid exposure to air)					
3.4	Sanitation	Device must be easy to clean (<30 minutes cleaning time & no chemicals required) and drain after operation.	ISO TS 22002-1 [5]	3	-	Device is able to self-clean on a cycle and easy to clean manually	Yes
~~**3.5**~~	~~Emergency Shutoff~~	~~Device must have emergency shutoff that is easily accessed while near the device~~	~~ISO 12100~~	~~3~~	-	Electronic Components are out of the scope of this project	
3.6	User Safety	User should not be at risk of physical injury while the device is in use	ISO 12100 [6]	3	-	There are no exposed rotating components.	Yes
~~**3.7**~~	~~Noise~~	~~NRR = 29 dB hearing protection (ear plug) is recommended~~	~~Swarm Engineering~~	~~1~~	-	No noise restriction required	
4	**Design Dimensions**						

4.1	Weight	The device should not weigh more than 3000 lbs, which is a maximum lifting capacity of the smallest forklift available in the market	Swarm Engineering	1	-	The total dry weight of the spin-float is 1301 lbs (the total weight is ~1956 lbs when loaded with wax and honey)	Yes
4.2	Size	Device should not be larger than 8ft x 8ft x 8ft	Swarm Engineering	1	-	Maximum dimensions of the spin-float are 58” x 68” x 68”	Yes
5	**Transport, Assembly and Startup**						
~~**5.1**~~	~~Shipping and Storing~~	~~The functionality or characteristics of the device shall not be adversely affected by transportation or storage conditions~~	~~ISO 14159~~	~~3~~	-	Packing and Shipping deemed out of scope for this project	
5.2	Assembly	Minimal assembly required with common tools	Swarm Engineering	1	-	After welding, component are attached with bolts.	Yes

5.3	Use	The device should be easy to use with little training involved	Swarm Engineering	1	-	The operation of the spin-float is straight forward and similar to previous spin float models	Yes
6	**Miscellaneous**						
6.1	Manufacturing and Materials	Local manufacturing and materials will be used in pricing of the device	Swarm Engineering	1	-	Materials and components were sourced from North America if possible	Yes
~~**6.2**~~	~~Standards~~	~~The device should follow all pertinent standards~~	~~See "Standards and Regulations Section"~~	~~3~~	-	All Standards were complied with as demonstrated with rest of compliance matrix	
7	**Ownership**						
7.1	Design Flexibility	The design should allow beekeepers to perform personal customization	Swarm Engineering	1	-	Many of the major components are stock or off-the-shelf components that can be changed	Yes

7.2	Integration	The design should be incorporated into current spin-float setups	Swarm Engineering	3	-	The spin-float was designed to be implemented after the heat exchanger	Yes
7.3	Sustainability	The design materials potential to be re-used or recycled	Swarm Engineering	1	-	Most materials are recyclable and corrosion resistant	Yes
7.4	Maintainability	The simple design should allow beekeepers to perform repairs and adjustments as required	Swarm Engineering	2	-	The design allows for upgrading by operators	Yes

Client Signature (This signature confirms review and approval of final design compliance by client)	Connie Phillips
Date Dec 2 2019	

9. Future Work and Recommendations

For the completion of the BeeBlade, Swarm Engineering recommends seeking electrical engineering expertise to implement the electrical components necessary to operate the spin-float. These are out of the scope of this project, but necessary for manufacturing and operation of the spin-float. A motor VFD and an emergency stop switch will be necessary.

To ensure a consistent flow into the inlet, a surge tank could be implemented before the spin-float. This would accommodate more consistent processing of honey and wax. Design and implementation of a surge tank could be another engineering project.

The flute entrance region was analyzed. However due to the high accelerations and small exit region the assumptions required for analytical and simulations could not be satisfied. Swarm Engineering recommends experimentally optimizing the flute entry.

10. Project Management

It was initially estimated that 366 junior engineering hours would be required to complete Phase 3. In reality, it took 433 hours. There are multiple reasons for this, including extra calculations being completed to ensure a comprehensive design, CAD modelling issues, and an additional meeting at a bee farm in Morinville. Figure outlines the junior engineering hour breakdown. An updated Gantt chart and a detailed breakdown of time spent can be seen in Appendix N and Appendix O, respectively. Additionally, a detailed breakdown of hours spent in Phase 3 can be seen in Figure 25.

Although the presentation and poster are not yet complete, 922 total junior engineering hours are projected, which is an increase from the initial estimate of 783 hours.

The final design cost, including senior engineering hours, is $84,930. This is $12,510 more than the initial estimate of $70,470 (~15% increase). The junior engineering costs rose by $12,510 in Phase 3. The Phase 3 increase was due to the reasons stated above. A breakdown of the costs for each phase can be seen in Table 5. The total cost of both the engineering costs and manufacturing costs is $115,930, which is comparable to the $120,470 initial estimate. There was an increase in engineering costs, and a decrease in manufacturing costs.

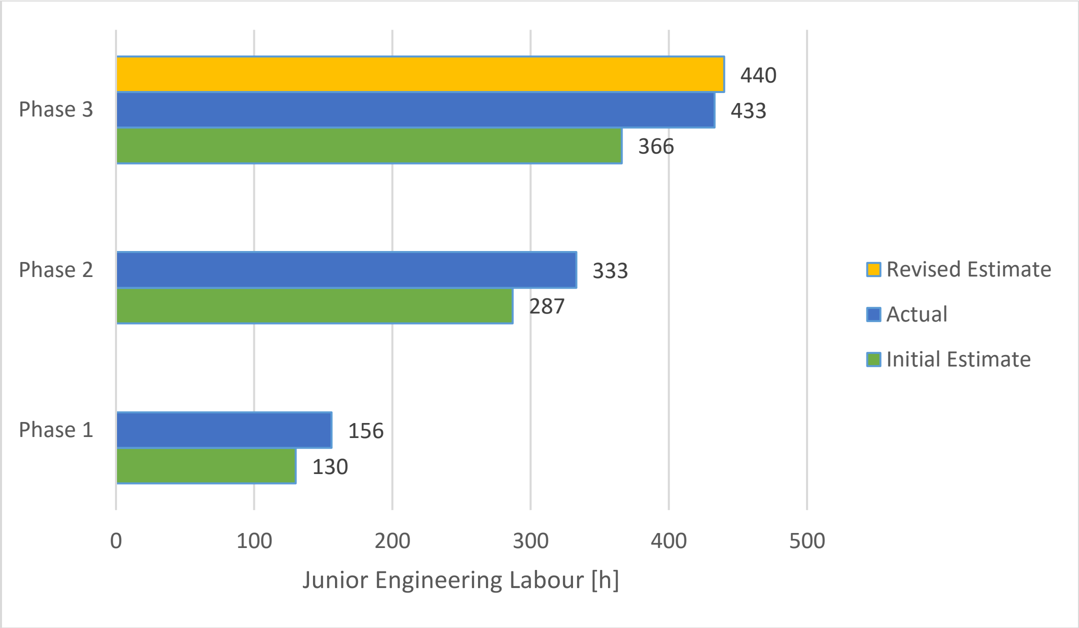

Figure 24: Junior engineering hours breakdown per phase.

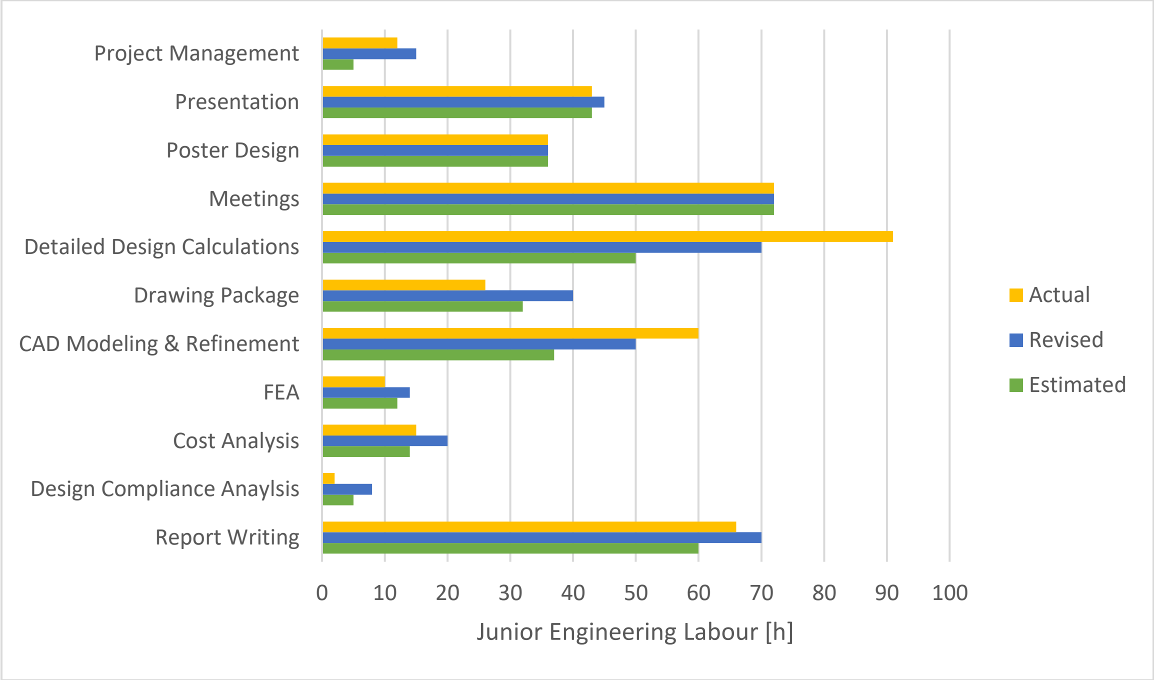

Figure 25: Junior engineering hours breakdown for Phase 3.

Table 5: Comparison of initial cost estimation verses actual cost for the engineering costs

	Rate [CAD/hr]	Baseline Cost [CAD]	Actual Cost [CAD]	% Increase
Phase 1	90	$ 11,700.00	$ 14,040.00	17%
Phase 2	90	$ 25,830.00	$ 29,970.00	14%
Phase 3	90	$ 32,940.00	$ 38,970.00	15%
Senior Design	150	$ 1,950.00	$ 1,950.00	0%
Total Cost	90/150	$ 72,420.00	$ 84,930.00	15%

11. Conclusion

The Alberta Beekeepers Commission contracted Swarm Engineering to design a solution to reduce foaming in the honey-wax separation process. Upon further investigation, Swarm Engineering identified other areas for improvement, including wax build-up and limited flow rate capacity. The BeeBlade design, a spin-float with a 1° incline on the inner centrifuge drum, has features which address these issues. It is capable of handling 3,000 lb of honey per hour, while reducing potential foaming and wax build-up, and being easier to clean than the current spin-floats. Its overall dimensions are 58”×68”×68”. Both the centrifuge drum and blade shafts are fitted with 5 hp motors operating at 1200 RPM and 3600 RPM, respectively. Manufacturing the BeeBlade is projected to cost $31,000, well below the $50,000 anticipated budget. Swarm Engineering spent a total of 922 engineering hours on this project, which corresponds to an engineering cost of $82,980. This was 15% over the initial estimate of 783 hours and $72,420. Swarm Engineering recommends that the client pursue electrical engineering expertise to complete the design for manufacturing and implementation of the BeeBlade spin-float.

12. References

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[4] I. S. f. O. (ISO), "ISO 14159 Safety of Machinery - Hygeine requirements for the design of machinery," 1 April 2001. [Online]. Available: https://www.iso.org/standard23748.html. [Accessed 26 September 2019].

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[7] Cook & Beals, "Honey-Wax Separator," Cook & Beals, [Online]. Available: https://www.cooknbeals.com/honey-wax-separator/. [Accessed 13 September 2019].

Appendix A. Spin-Float Scaling Calculations

Prepared by William Hammond, Dec 1st

Objectives:

The objective of this calculation is to determine suitable geometry and rpm for the scaled-up spin-float. This calculation was done by taking operational conditions of the old spin-float at 1500 lb/hr as a reference. The mass flow rate of honey per surface area was used to scale up the spin-float to achieve the desired 3000 lb/hr. This involved scaling up the height and radius by approximately the square root of two. With the increase in radius, the rotational speed had to change to achieve the same centrifugal accelerations as in the old spin-float. Keeping the centrifugal accelerations and the flow rate per unit area the same between the original at 1500 lb/hr and the scale-up at 3000 lb/hr should ensure the same quality of honey-wax separation between the original and new spin-float. The input parameters are:

- flowrates
- radii
- heights
- honey thickness
- rotational rates

The calculated parameters are:

- operational rpm
- scaled-up radius

Nomenclature:

Appendix Table A.1: Nomenclature table for the BeeBlade.

General Symbols	Description	Units
Accel	Centrifugal acceleration	m/s^2
New_flowrate	Desired flow rate of the new machine	lb/hr
New_height	Height of the new machine	m
New_radius	Radius of the new machine	m
New_rpm	Rotational speed of the new machine	rpm
New_separation_area	Separation area of the new spin-float	m^2
New_separation_flux	Flow rate per separation unit area	$lb/(hr\ m^2)$
New_thickness	Honey layer thickness of the new machine	m

Old_flowrate	Flow rate of the original spin-float	lb/hr
Old_height	Height of the original spin-float	m
Old_radius	Radius of the original spin-float	m
Old_rpm	Rotational speed of the original spin-float	rpm
Old_separation_area	Separation area of the old spin-float	m^2
Old_separation_flux	Flow rate per separation unit area	lb/(hr m^2)
Old_Thickness	Honey layer thickness of the old machine	m
r	Radius at the honey wax separation	m
ω	Rotational rate	rpm

Will Hammond Dec 1st

The old spin float process less honey than desired, inorder to increase this value the new spin-float will be larger in height and radius. The quantity of honey processed per unit area will reamin the same or less for the new model. this will ensure that the new machine has performace equal to or better than the old model. with changing radius the rpm will also need to be recalcuted to achice the same forces. The new height was selected by using a root 2 scale up with rounding to 16 in as off the shelf blades are compatible with 16 in blades.

Constants:

$Old\_flowrate := 1500 \frac{lb}{hr}$

$Old\_height := 10.5\ in$

$Old\_Thickness := 3\ in$

$New\_flowrate := 3000 \frac{lb}{hr}$

$New\_height := 16\ in$

$New\_Thickness := 9\ cm = 0.09\ m$

$Old\_radius := 18\ in$

$Old\_rpm := 450\ rpm$

The honey wax seperation takes place over a cylendrical section inside the spin-float the mass flowrate per unit area is calcualted and the new spinfloat must meet or exceed this old value.

$$r := Old\_radius - Old\_Thickness = 0.381\ m$$

$$Old\_Seperation\_area := Old\_height \cdot 2 \cdot \pi \cdot r = 0.6385\ m^2$$

$$Old\_seperation\_flux := \frac{Old\_flowrate}{Old\_Seperation\_area} = 0.296\ \frac{s\ Pa}{m}$$

$$New\_seperation\_flux := Old\_seperation\_flux$$

$$New\_seperation\_area := \frac{New\_flowrate}{New\_seperation\_flux} = 1.2769\ m^2$$

$$r := \frac{New\_seperation\_area}{2 \cdot \pi \cdot New\_height} = 0.5001\ m$$

$$New\_radius := r + New\_Thickness = 0.5901\ m$$

This calculation shows that the minimum radius required to achive the desired seperation area is 0.5901 m.

The average radius of the new spin-float was selected to be 0.638 m
this is to add a saftey margin as the previously calcuted radius is a minumum

$$New\_radius := 0.638\ m$$

$$\omega := Old\_rpm$$

$$Accel := \omega^2 \cdot Old\_radius = 103.5304\ g_e$$

$$Accel = 1015.2862\ \frac{m}{s^2}$$

$$\omega := \sqrt{\frac{Accel}{New\_radius}} = 380.9389\ rpm$$

$$New\_rpm := \omega = 380.9389\ rpm$$

Appendix Table A.2: Tabulated data.

General Symbols	Description	Values
New radius	New radius for the spin-float	0.638 m
New rpm	New rpm required for the same centrifugal acceleration	381 rpm

<u>Conclusions:</u>
The new rpm and radius were calculated. In order to process the required 3000 lb/hr of honey while keeping process conditions as close to the original design as possible.

Appendix B. Inner Drum Finite Element Analysis

The inner drum was analyzed using finite element analysis, using Ansys Workbench 19.2. The parts were modelled in SOLIDWORKS, then imported into Workbench to be analyzed.

The top plate was assumed to be the most critical component in the inner drum, as it supports the weight of the rest of the drum. Initially, the top plate was analyzed as an individual part with its center holes, where it would be supported by the drum shaft, acting as fixed supports and with the weight of the inner drum applied to the outer holes, where the inner drum is attached. Although, this analysis method shows uses large and unacceptable stresses and deformations, it was determined this would be an inaccurate method of determining the true stresses and deformations in the top plate, as it relies on that stability of other components in the assembly to distribute the loading and to resist deformation. To account for these added stabilities from other components, the inner drum was analyzed as using finite element analysis as an assembly.

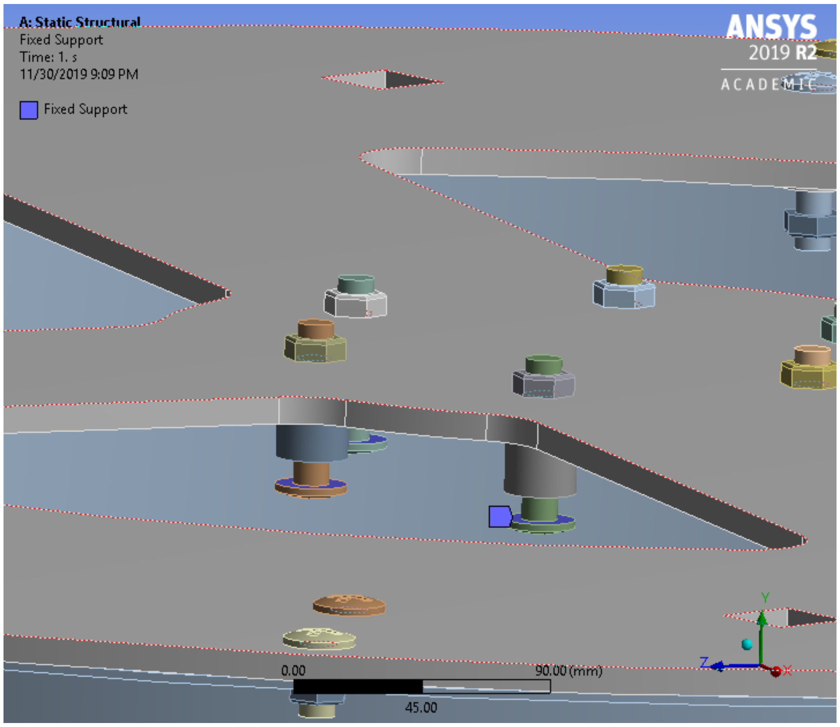
When analyzing the inner drum as an assembly, the bolts that would be coming from the inner drum hub were treated as fixed supports, as they would be supporting the inner drum. This is shown on the model in Appendix Figure B.1. A 750 lb load was applied evenly on the bottom edge of the drum, to simulate the weight of the honey-wax mixture, as shown in Appendix Figure B.2. To simulate the centrifugal force from the spinning honey-wax mixture applied on the side walls of the drum, a 0.188 MPa pressure was used, as shown in Appendix Figure B.3. An overview of the applied forces and boundary conditions is shown in Appendix Figure B.4.

All connections in this assembly are assumed to be bolted with enough preload to prevent separation, as member separation would put extra stress on the bolts and result in a failure condition. Thus, all connections in the assembly were given a “no separation” condition, where separate parts can slide relative to each other, but are incapable of separating. The exceptions to this are the connections between nuts and bolts, which were treated as “bonded” connections. In bonded connections the parts can neither slide nor separate relative to each other. This condition was applied because the threads cause these connections to be self-locking, preventing any relative movement between the nut and the bolt. The forces on the threads were not considered in this finite element analysis.

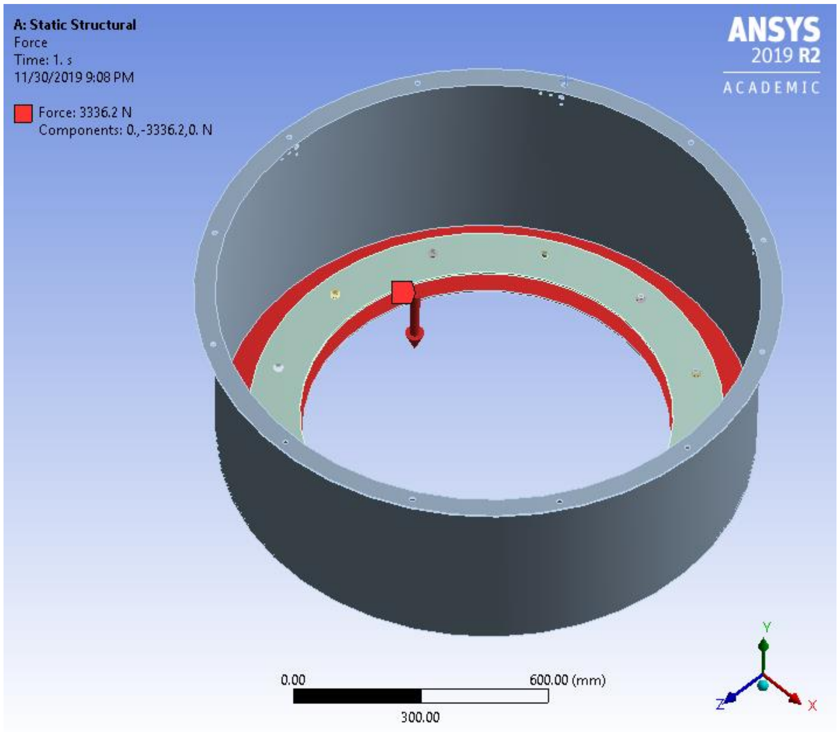
Automatic meshing was found to be sufficient for all parts except the flat parts: the top and bottom baffles, and the top plate. These were given a 2-layer sweep mesh to prevent long triangular elements. The mesh sizing was uniform for all parts except the two most critical parts: the top baffle and the top plate. The mesh was refined on these two parts to give more accurate results, as most of the stresses and strains in the model were developing in these two parts.

When analyzing the inner drum as an assembly, the top plate showed less stress and deformation, but still to an unacceptable degree. Some iterative adjustment of top plate viewing port geometry, top baffle geometry, and fastener placement was made in order to achieve an acceptable degree of loading and deformation in the assembly. From iterative runs of the finite element analysis, it was determined that the thickness of the top plate and top baffle needed to be increased from 1/4” to 3/8”,that the spacers between the top plate and top baffle needed to have an increase in outer diameter from 1” to 2”, and that the viewing port geometry needed to be matched on the top baffle to provide extra stability to the top plate, due to the increased of moment of area along the supporting “spokes” between the viewing ports.

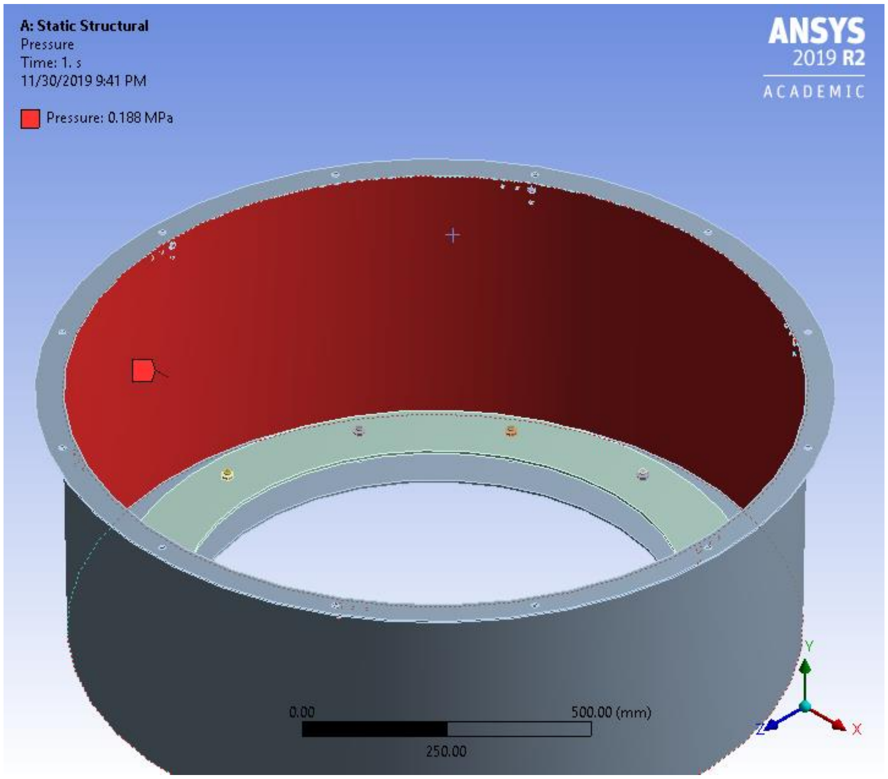
After the design was modified, and acceptably low levels of stress and deformation in the inner drum were achieved, the inner drum was analyzed again to determine the maximum deformation, maximum equivalent strain, and maximum equivalent stress in the model. The maximum deformation was 3.6 mm, as shown in Appendix Figure B.5, the maximum equivalent strain was 0.0013 mm/mm, as shown in Appendix Figure B.6, and the maximum stress was 239.4 MPa, as shown in Appendix Figure B.7, giving a safety factor of 1.21. The results are tabulated in Appendix Table B.1 below.



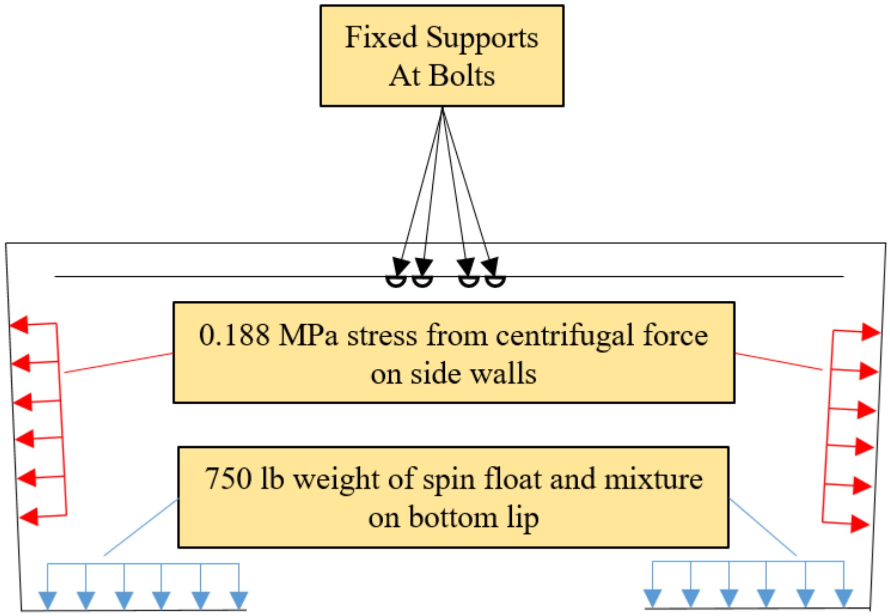
Appendix Figure B.1: Fixed support boundary condition on inner drum hub bolts.



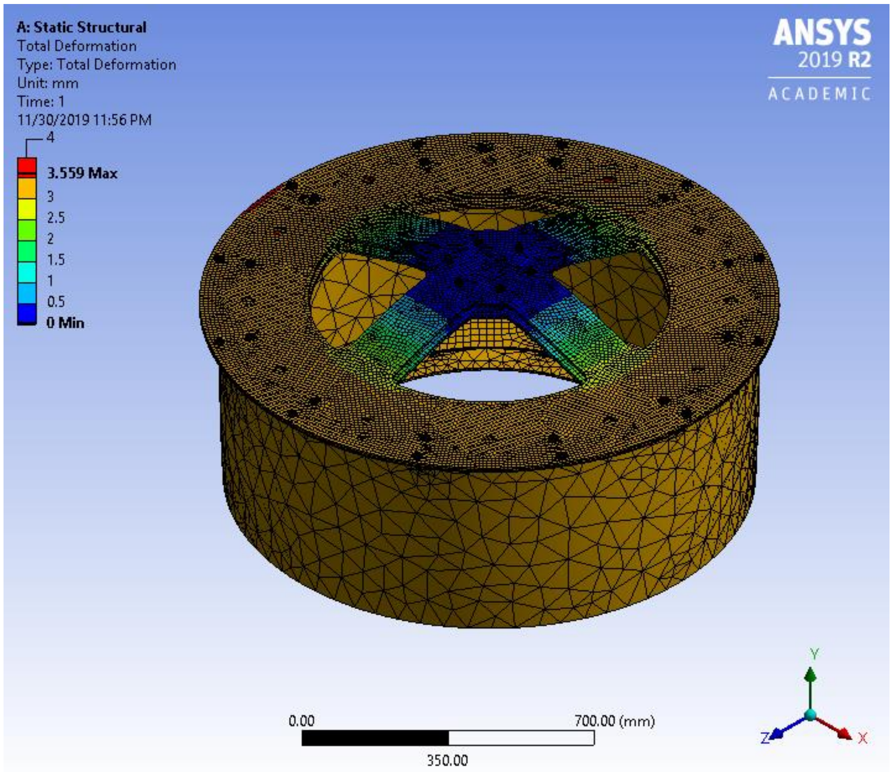
Appendix Figure B.2: Load from weight of honey-wax mixture when drum fully filled during operation.



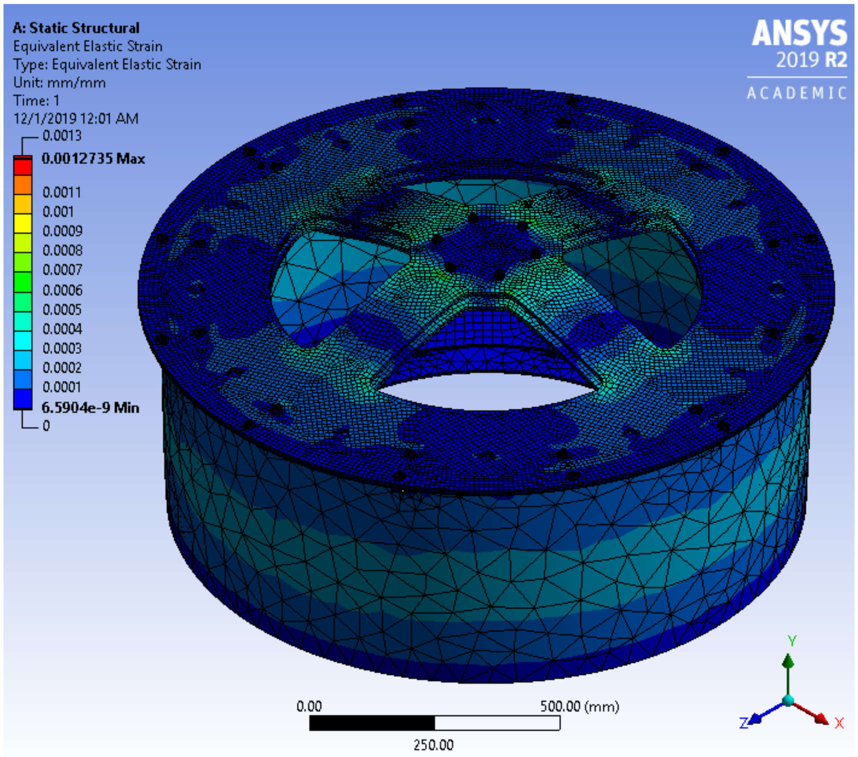
Appendix Figure B.3: Pressure from centrifugal force applied on drum walls.



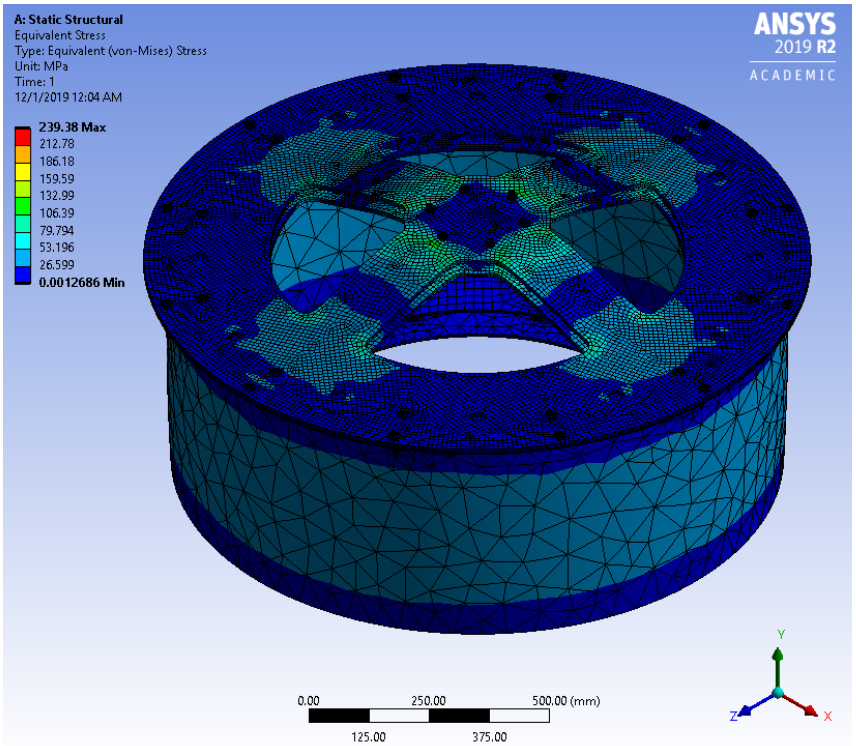
Appendix Figure B.4: Overview of boundary conditions used in finite element simulation of the inner drum.



Appendix Figure B.5: Total deformation in inner drum assembly.



Appendix Figure B.6: Equivalent elastic strain in inner drum assembly.



Appendix Figure B.7: Equivalent stress in inner drum assembly.

Appendix Table B.1: Tabulated inner drum finite element analysis results.

Value	Result
Maximum deformation	3.6 mm
Maximum strain	0.0013 mm/mm
Maximum stress	239.4 MPa
Safety Factor	1.21

Appendix C. Finite Element Analysis of Frame

A finite element analysis was done on the frame to determine if it was capable of supporting the weight of both motors and the upper drum assembly full of honey-wax mixture. The analysis was set up with the following boundary conditions:

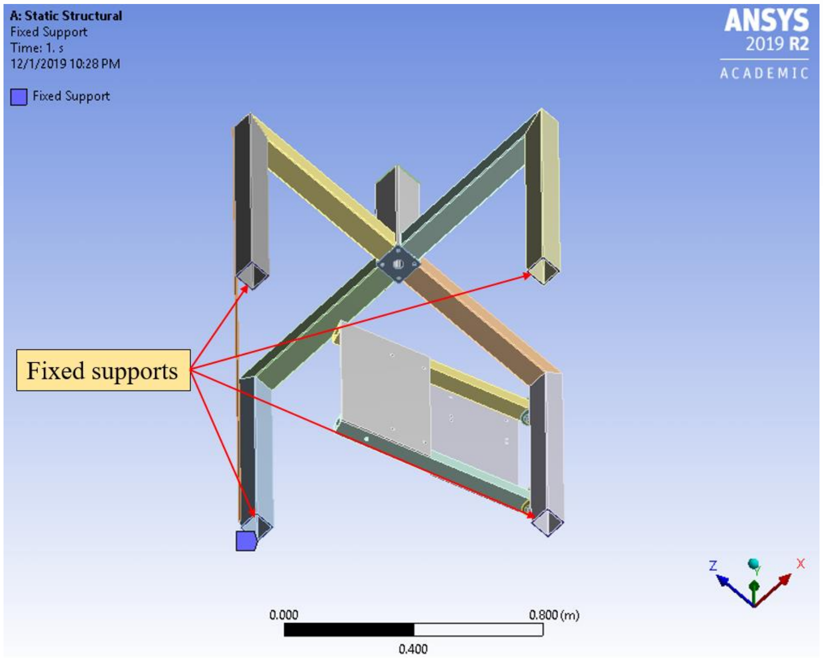
- Fixed supports at the base of each of the legs, as shown in Appendix Figure C.1, because these are often bolted to the ground in most setups
- 97 lbs of bearing force applied evenly among the holes supporting the wax cutting motor as shown in Appendix Figure C.2.
- 179 lbs of bearing force applied evenly among the holes supporting the inner drum motor, as shown in Appendix Figure C.3.
- 1000 lbs of force distributed evenly downward on the top faces of all of the legs supporting the inner drum when full of honey, as shown in Appendix Figure C.4.
- Bounded connection conditions between all parts, because all connections are either welded, or use a bolt given sufficient preload to prevent separation and sliding

Automatic meshing was used for all components except the plates holding the motors. For these components, a single layer sweep was used to avoid any long triangular elements, which could produce inaccurate results.

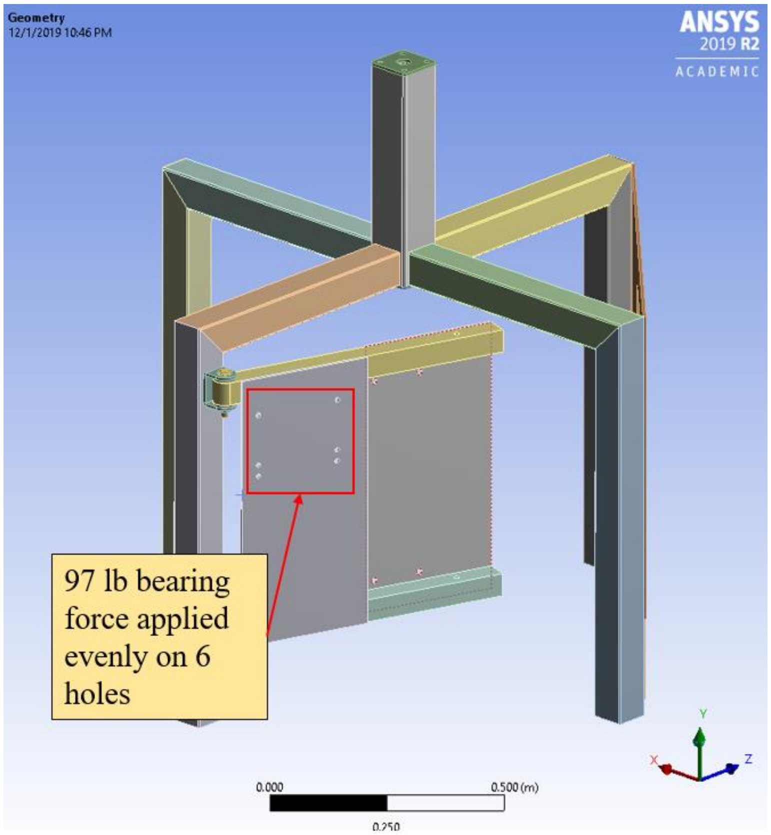
Using these conditions, Appendix Figure C.1 showing the total deformation, Appendix Figure C.5 showing the equivalent strain, and Appendix Figure C.6 showing the equivalent stress were obtained, as shown below. From these figures, the model was found to have a maximum deformation of 0.085 mm, a maximum equivalent strain of 0.00039 mm/mm, and a maximum equivalent stress of 35.3 MPa. These components are made from A513 steel, which has a yield strength of 496 MPa, so a safety factor of 14.1 is achieved. The sharper corners in the model are regions of stress and strain concentrations. Although these corners could be rounded or further supported to distribute the loads more evenly, the model already has a high factor of safety. Further changes would only add unnecessary costs to the design. These results are tabulated in Appendix Table C.1.

Appendix Table C.1: Tabulated results.

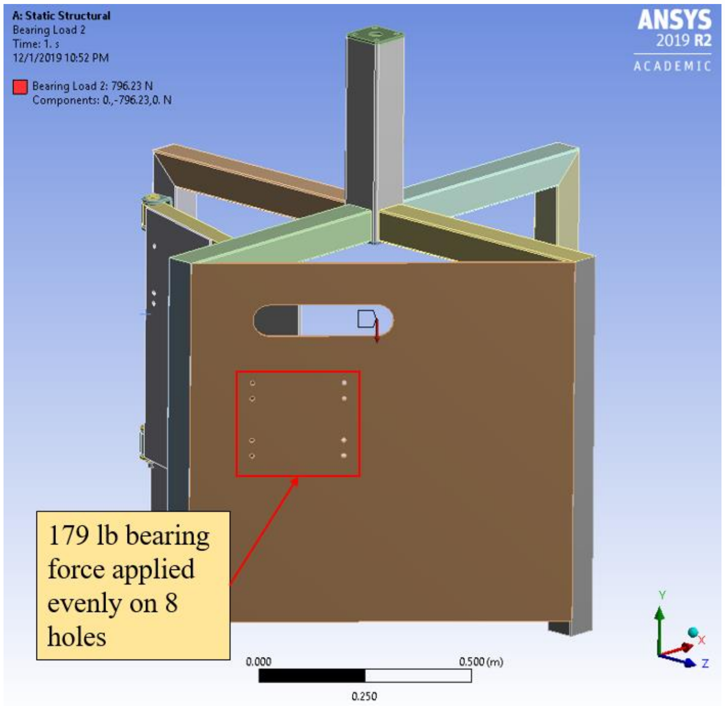
Value	Result
Maximum deformation	0.085 mm
Maximum strain	0.00039 mm/mm
Maximum stress	35.3 MPa
Safety Factor	14.1



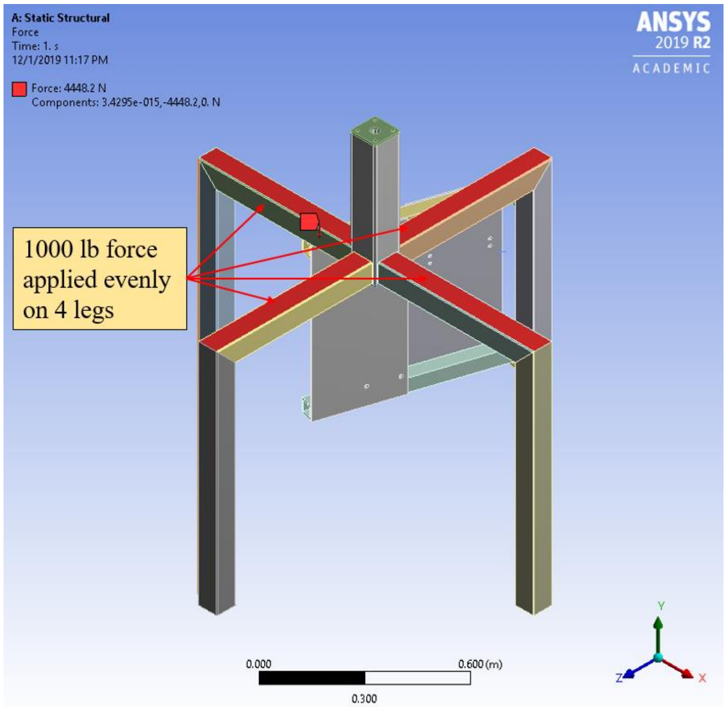
Appendix Figure C.1: Fixed support locations on finite element analysis of frame.



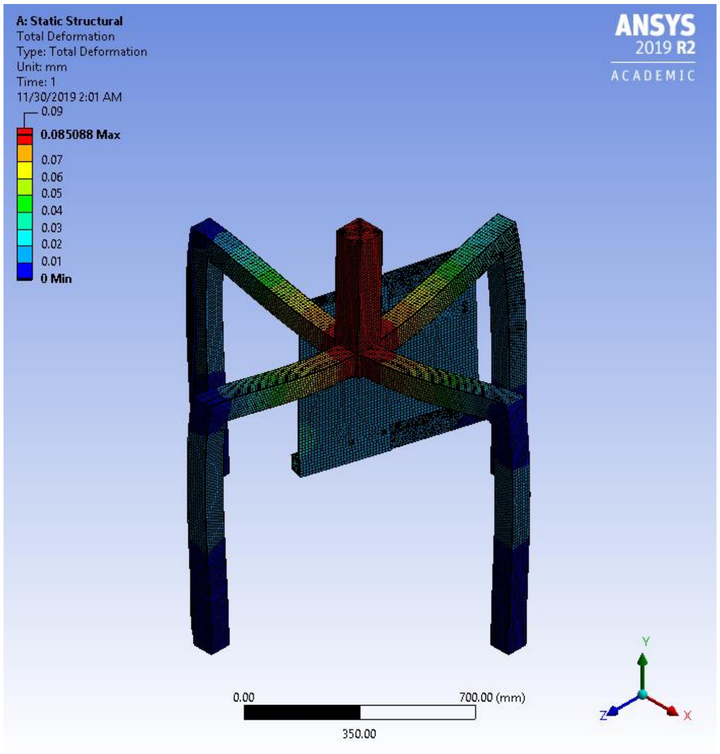
Appendix Figure C.2: Wax cutter motor weight applied in finite element analysis of frame.



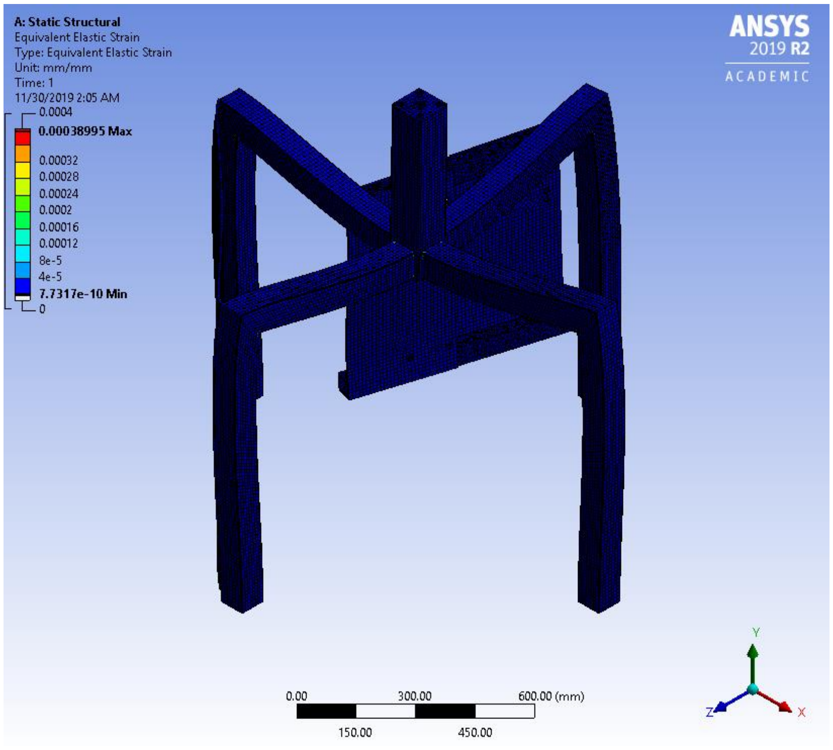
Appendix Figure C.3: Inner drum motor weight applied in finite element analysis of frame.



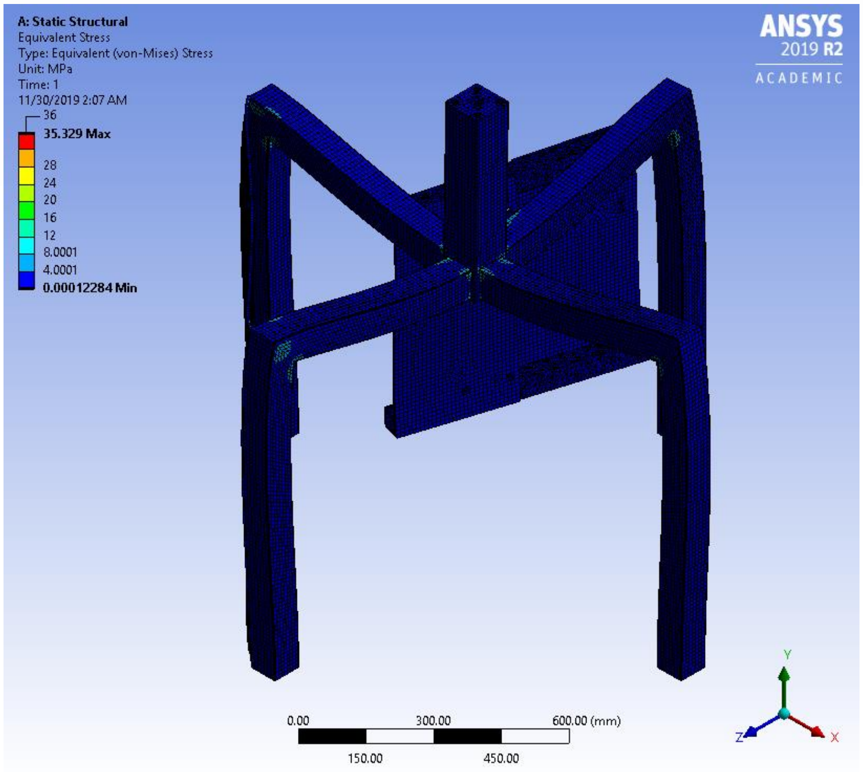
Appendix Figure C.4: Weight of filled upper components applied in finite element analysis of frame.



Appendix Figure C.5: Total deformation calculated from finite element analysis of the frame.



Appendix Figure C.6: Elastic strain calculated form finite element analysis of the frame.



Appendix Figure C.7: Equivalent stress calculated from finite element analysis of the frame.

Appendix D. Mechanical Vibration Calculations

Nomenclature

Appendix Table D.1: Nomenclature for the mechanical vibration calculations.

General Symbols	Description	Units
ω	Operating frequency	rad/sec
p	Natural frequency	rad/sec
k	Spring stiffness	N/m
K_{eff}	Effective spring stiffness	N/m
L	Length	m
A_c	Area of cross-section	m^2
E	Young's modulus	psi
e	Eccentricity	m
m_t	Total body mass	kg
m_h	Maximum honey mass in centrifuge	kg
m_w	Maximum wax mass in centrifuge	kg
m_d	Inner rotating drum mass	kg
ḿ	Rotating imbalance mass	kg
ρ_h	Honey density	kg/m^3
ρ_w	Wax density	kg/m^3
m_{eff}	Total effective mass	kg

Nov/29/2019	Forced Vibrations Due to Rotating Imbalance	→ Prepared by: Udeshwar Jaswal	1/7

- Project: Honey-Wax separator, Phase 3
- Client: Connie Phillips, Alberta's Beekeepers Commission.

OBJECTIVE:

1. Simplifying and modelling the spin-float to an appropriate linear and a single degree of freedom system.
2. Analysing the potential scenario of rotating mass imbalance to find natural frequency of the system.
3. Compare System's natural frequency to the forcing function frequency and to conclude the stability conditions for the mechanism.

Known:
1. Operating frequency (Forcing function) ⇒ $\omega = 39.8$ rad/sec
2. Maximum Honey-Wax mixture present within the centrifuge by mass = 289.5 Kg
   - where • m_h (honey) = 248 Kg
   - • m_w (wax) = 41.5 Kg
3. Rotating inner Drum mass ⇒ $m_D = 80$ Kg
4. Total mass of the mechanism during continuous operation i.e. including maximum amount of honey and wax present ⇒ $m_T \approx 700$ Kg

NOTE: Other known values required to assist the analysis are specified beside the particular calculation.

Assumptions:
1) There is 0 displacement in the vertical direction.
2) The Honey-Wax mass causing rotating imbalance is = $\hat{m}$ [Kg]
3) Eccentricity of the imbalanced mass, $\hat{m}$ is "e"
4) Displacement exists only in the x-direction

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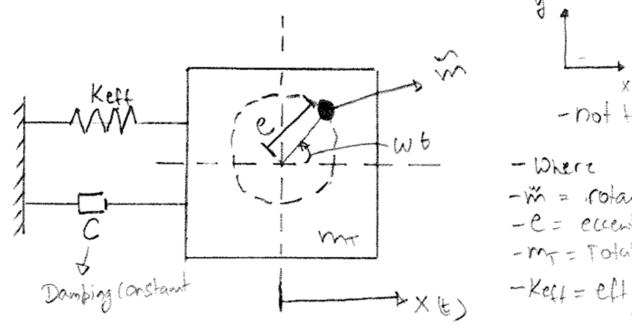
5. System is damped, however, damping caused by wax-Blade rotation, Bearings, viscous fluids (Honey & wax) is considered to be significantly small to affect the natural motion of the spin float
∴ Damping constant
$C \simeq$ very small number

6. Worst-case scenario, where vibration in x-direction is maximum, when $m_{honey} + m_{wax}$ is lumped together to one side, parallel to the rotating shaft.

7. An average radius, r_{avg}, is used for the conical Drum.

8. To restrict the spin float mechanism to a single degree of freedom and keeping the problem linear, the mechanism is modelled similar a simple spring-mass mechanism.

Sketch:



- Where
- $\tilde{m}$ = rotating mass
- e = eccentricity
- m_T = Total body wax
- K_{eff} = effective stiffness of body

FBD: MAD:

→ Where
- machine body vibrates horizontally, position described as $X(t)$
- eccentric mass, $\tilde{m}$ moves relative to the machine body
  ↳ it's horizontal component is $\boxed{x + e\sin\omega t}$

Now, Governing equation of motion of the system is determined Using Newton's Law in the horizontal direction.

3/

$$\rightarrow \Sigma F = ma = -K_{eff}x - C\dot{x} = (m_T - \tilde{m})\ddot{x} + \tilde{m}\frac{d^2}{dt^2}(x + e\sin\omega t)$$

Simplified to $\rightarrow$ $\boxed{m_T\ddot{x} + C\dot{x} + K_{eff}X = \tilde{m}e\omega^2\sin\omega t}$

↳ Governing equation of the oscillation.

- Where $\tilde{m}e\omega^2 = F_0$
i.e. magnitude of the forcing function.

- which is the centrifugal force, that produces excitation in the setup.

Now,
In order to obtain the natural frequency (P) of the system we require Total effective mass of the system and total stifness of the system.

i.e $P = \sqrt{\frac{K_{eff}}{m_{eff}}}$ $\rightarrow$ we know m_{eff}, which is equal the total mass of the body.

$\boxed{m_{eff} = m_T = 700 kg}$

However, To estimate the K_{eff}, several assumptions are required. to retain the problem in a linear system.

Assumptions:

1. A $\frac{1}{2}$" thick Neoprene vibration Pad is placed under the machine.

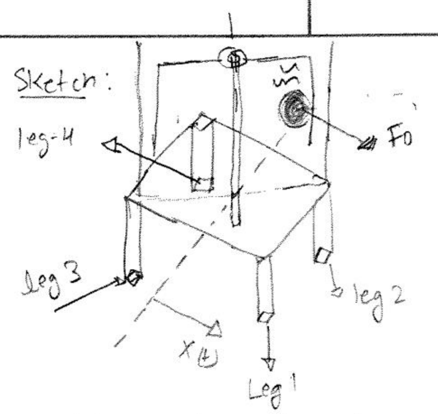
2. The vibration caused due to $\tilde{m}$ (in x-direction) shifts the entire body Load onto the right-half of the mechanism.

i.e. $\rightarrow$ Total body load rests on the right half of the Frame.

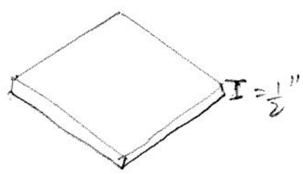
$\rightarrow$ Additionally, i.e. Left half of the frame does not loose contact with the pad (ground).

↳ this assumption avoids non-linearity within the system, and provides a model similar to the spring-max sytem. This enables us to estimate a resonable K_{eff} for this problem to aid analysis further.

Sketch:



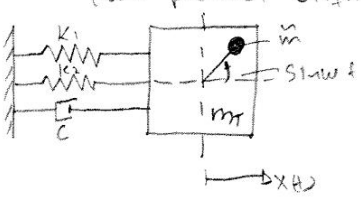
Neoprene Vibration Pad



→ Entire body Load, acts as a compression Load on leg 1 & leg 2.

Also, as soon as this assumption is achieved, just before the leg 3 & 4 may loose contact (which they donot: assumption) the oscillation reverses. This vibration in horizontal direction oscillates at P → natural frequency of the vibration.

→ This assumption results in spring – mass model with two parallel stifness, K_1 and K_2 ∵ Geometery of Frame



→ Leg 1 & Leg 2 are parallel to each other.

→ and $K_{eff} = K_1 + K_2$

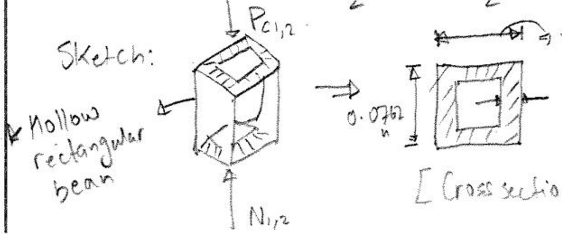
Now, Leg 1 & Leg 2 under compression Load = 700 kg × 9.81 m/s

$$\boxed{P_c = 6867\,N = 6.87\,kN}$$

Now, Due to geometry of frame (Symmetric) the Load will distribute equally on Both legs.

$$\therefore \quad P_{c_1} = P_{c_2} = \frac{P_c}{2} = \frac{6867\,N}{2} = \boxed{P_{c_1} = P_{c_2} = 3433.5\,N}$$

Sketch:



[Cross section of a leg]

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- Square Cross-Section $\Rightarrow$ $a = 0.0762\,m$
thickness $= 0.004763\,m$

$\therefore$ Area of cross section $= \boxed{A_c = 1.361 \times 10^{-3} m^2}$

$\Rightarrow$ Now, we will use vibration pad properties to estimate 'K_1 & K_2' on the Entire Body.

We know, $K_{1,2} = \dfrac{A_c E}{L}$ where E = rubber pad's elasticity modulus

L = rubber pad thickness

Know: 1. $A_c = 1.361 \times 10^{-3} m^2$

2. $E = 100psi = 689476\ Pa$

3. $L = 0.5'' \Rightarrow 0.0127\,m$

Therefore, $K_{1,2} = \dfrac{(1.361 \times 10^{-3} m^2)(689476\ Pa)}{0.0127\,m}$

$K_{1,2} = 73888\ N/m$
$= 73.9\ kN/m$ $\rightarrow$ $\therefore$ $K_{eff} = 2 \times 73.9\ kN/m$

$\boxed{K_{eff} = 147.8\ kN/m}$

Recall $\rightarrow$ $P = \sqrt{\dfrac{K_{eff}}{m_{eff}}}$; natural frequency of the Body Vibration in horizontal axis.

& m_{eff} = Total Body mass = $m_T = 700\,kg$

$P = \sqrt{\dfrac{147.8 \times 10^3\ N/m}{700\,kg}}$ $\Rightarrow$ $\boxed{P = 14.53\ rad/s}$

- Frequency at which vibrations "$x(t)$" oscillates.

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Now, relation between operating (excitation Force) frequency, ω and the natural frequency, P, of the Body Vibration equals

$$\boxed{D.M.F = \frac{1}{\sqrt{\left[1-\left(\frac{\omega}{P}\right)^2\right]^2 + \left[2\zeta\frac{\omega}{P}\right]^2}}}$$

where D.M.F (Dynamic Magnification Factor) determines how much the amplitude of the static deflection is magnified due to harmonic nature of the force being applied.

From → D.M.F vs $\frac{\omega}{P}$ graph for damped SDOF system can be observed that at $\frac{\omega}{P}$

Operating to natural ratio ⇒ $\boxed{\frac{\omega}{P} = \frac{39.8\ rad/s}{14.53\ rad/s} = 2.74}$

↳ D.M.F is significantly below resonance and static D.M.F as the response asymptotically decreases.

Summary
- Indeterminate actual rotating mass, m and eccentricity, e, at any time within the system leads to a simple, but powerful assumption to estimate the natural frequency, P = 14.53 rad/s of vibration in x-direction.
- Expectation was to avoid resonance, where the system will simply collapse due to a very large D.M.F.
- $\frac{\omega}{P} = 2.74$, ratio obtained shows that the system avoids resonance by $\approx 2.74 - 1 \approx 1.74$ frequency ratio.

7/7

→ However, some operational guidelines are important to consider.

i.e resonance occurs at $\frac{\omega}{P} \approx 1$ and calculated $\frac{\omega}{P} = 2.74$

- This means that before the system response reaches the $\frac{\omega}{P} = 2.74$ it must pass through resonance frequency.

Operational Guidelines

- Therefore, to avoid any significant vibrations, which may lead to the stability failure of the system (body) the spin-float must not be operated near the resonance frequency and advised to accelerate the spin float to high rotating speeds in short period of time. This means to reduce the dwelling time at and near resonance frequencies.

Conclusion:
The spin float will be used by the client at high rpm, Hence, stability is ensured.

Caution: If spin-float operated empty, under the same model, $P = \sqrt{\frac{142.8 \times 10^3 \, N}{(700-289.5)\,kg}} \Rightarrow P = 18.9 \text{ rad/s}$

$\therefore \frac{\omega}{P} = \frac{39.8 \text{ rad/s}}{18.9 \text{ rad/s}} \approx \boxed{2.11}$ → lies with in the stable asymptotic range.

$\therefore$ Same operational procedure as $P = 14.3$ rad/s applies.

→ Hence, the resonance rpm is $18.9 \text{ rad/s} \times \frac{60}{2\pi} \approx 180.5 \text{ rpm}$

$\approx \boxed{180.5 \text{ rpm}}$ → must avoid operating @ or near this speed.

Appendix E. Angled-Wall Rotational Rate Calculation

Prepared by William Hammond, Nov 30th

Objectives:

The objective of these calculations is to evaluate the minimum rpm of the angled-wall spin-float for draining honey. It is advantageous to have the drain holes located at the top of the spin-float because it makes the drain holes accessible for cleaning without removing the drum. However, with the drain holes located at the top, and the machine fed from the bottom, the spin-float must be able to pump honey upwards for draining. The cone angle and rpm generate the required accelerations to pump the honey upwards. The purpose of this calculation is to calculate the minimum rpm necessary to pump the honey upwards.

The input parameters are:

- Cone angle
- Cone radius top
- Cone radius bottom

The calculated parameters are:

· Minimum rpm

Nomenclature:

Appendix Table E.1: Nomenclature table for BeeBlade.

General Symbols	Description	Units
$A_{Centrifugal}$	Minimum Centrifugal Acceleration Required	m/s^2
$A_{Vertical}$	Minimum Vertical Acceleration Required	m/s^2
Cone_angle	Angle of the spin-float cone	°
Cone_Diameter_Bottom	Top diameter of the cone spin-float	m
Cone_Diameter_Top	Top diameter of the cone spin-float	m
Gravity	Acceleration from gravity	m/s^2
Rotational_speed_minimum	Required rotational speed of the spin-float	RPM
θ	Cone Angle	°

Free Body Diagram:

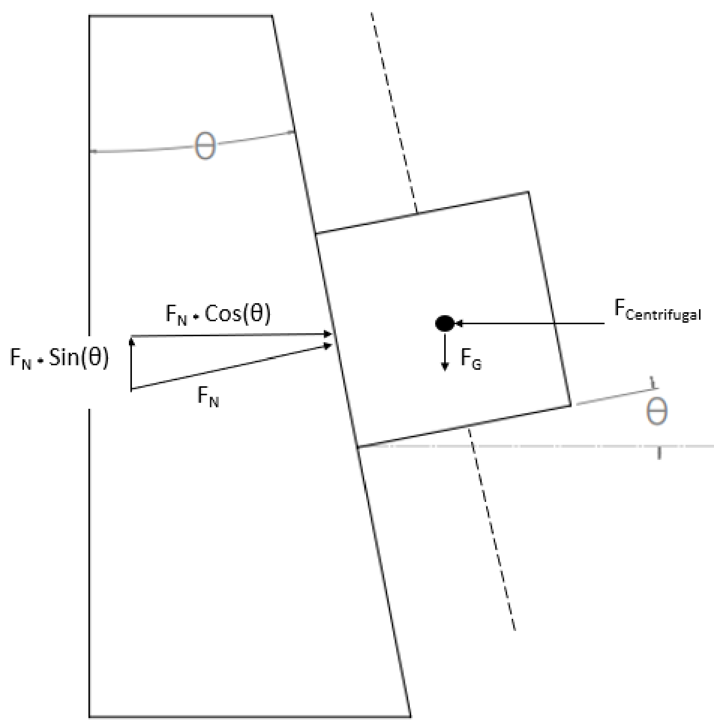


Figure 26 - Free body diagram of cone.

Will Hammond November 30th

Process conditions that are evaluated as constants

Constants: $Gravity := 9.81 \frac{m}{s^2}$

$Cone\_angle := 1\ deg = 0.0175$

$Cone\_Diameter\_Top := 25.3\ in = 0.6426\ m$

$Cone\_Diameter\_Bottom := 24.95\ in = 0.6337\ m$

At the end of the day honey will be drained out of the top drain holes. In order for this to happen the honey must be pumped upwards by an acceleration greater than Gravity. The cone angle and resultant accelerations from rotation are responsible for creating this verticle acceleration. With the fixed cone angle it is necessary to calculate the minimum rpm required to create the necessary pumping forces.

$$A_{vertical} := 1 \cdot Gravity = 9.81 \frac{m}{s^2}$$

$$A_{centripetal} := \frac{A_{vertical}}{\tan(Cone\_angle)} = 562.0145 \frac{m}{s^2}$$

$$Rotational\_speed\_top := \sqrt{\left(\frac{A_{centripetal}}{Cone\_Diameter\_Top}\right)} = 282.4022\ rpm$$

$$Rotational\_speed\_bottom := \sqrt{\left(\frac{A_{centripetal}}{Cone\_Diameter\_Bottom}\right)} = 284.3761\ rpm$$

$$Rotational\_speed\_minimum := 285\ rpm$$

From these calculations it can be concluded that as long as the drum rpm is held above 285 rpm that the spin float will be able to pump all remaining honey out of the drain holes at the end of a day.

Appendix Table E.2: Table of results for the BeeBlade.

General Symbols	Description	Values
Rotational_speed_minimum	Minimum rpm required to pump the honey upwards	285 RPM

Appendix F. Honey residence time and wax separation calculations

Prepared by Maximilian Aisenstat, November 26, 2019

Objectives:

The overall objective of these calculations is to characterize the original spin-float's fluid mechanics of separation inside the inner drum, and to apply these mechanics to evaluate the redesigned spin-float. This will allow the group to examine different parameters that cause separation of honey and wax, affect the quality of honey-wax separation, and that potentially lead to foaming. These parameters can be controlled in the scaled-up spin-float to be equal or better than those of the original spin-float. The parameters that will be determined in this analysis include the following:

- Honey transit time
- Honey average speed

Nomenclature

The naming convention for the calculations in this section are listed below in Appendix Table F.1.

Appendix Table F.1: Nomenclature for honey residence time and wax separation calculations.

General Symbols	Description	Units
h	Inner drum height	ft
mdot	Mass flow rate of honey	lb/hr
R_o	Inner drum radius	ft
R_i	Honey-wax interface radius	ft
t	Honey layer thickness	in
$t_{residence}$	Honey residence time inside centrifuge	s
u_{zave}	Average vertical speed	mm/s
ρ	Honey density	kg/m³

Known Data/Values:

The input parameters used for the calculations in this section are listed below in Appendix Table F.2

Appendix Table F.2: Known values used in honey residence time and wax separation calculations.

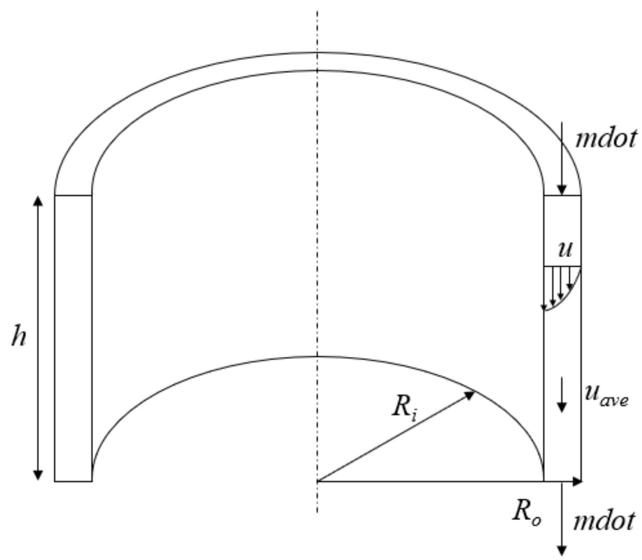
Quantity	Value
Inner drum radius (original)	1.50 ft
Inner drum radius (scale-up)	2.12 ft
Inner drum height (original)	1 ft
Inner drum height (scale-up)	19 in

Flow rate (original, overloaded/desired)	3000 lb/hr
Flow rate (original, functional)	1500 lb/hr
Flow rate (scale-up)	3000 lb/hr
Honey density	1380 kg/m^3 [1]

Assumptions:

1. Honey is approximated to be a Newtonian fluid. Although honey, in reality, is non-Newtonian, it can be approximated to be Newtonian because its shear stress and shear rate are fairly linearly related, as demonstrated in the paper “Rheological Properties of Honey in a Liquid and Crystallized State” [2]
2. It is a steady state process.
3. The process is exposed to atmosphere and the process height difference is minimal, so effects of pressure changes in function of height will be negligible.
4. Effects of wax on the honey flow will be neglected. Only honey flow will be considered.
5. Process is uniform around the centrifuge.
6. Flow is fully developed, and speed in the radial direction is negligible.
7. The thickness of the honey layer is set by the baffle (at 9 cm for the original spin-float).

Sketch:



Appendix Figure F.1: Diagram for honey flow calculations.

Analysis:

Honey residence time for original overloaded spin float

Maximilian Aisenstat
November 26, 2019

$R_o := 1.5\ \text{ft}$ $\quad \dot{m} := 3000\ \frac{\text{lb}}{\text{hr}}$ $\quad h := 1\ \text{ft}$

$R_i := 1.5\ \text{ft} - 9\ \text{cm} = 0.3672\ \text{m}$ $\quad \rho := 1380\ \frac{\text{kg}}{\text{m}^3}$

$A := \pi \cdot \left(R_o^{\ 2} - R_i^{\ 2}\right) = 0.2331\ \text{m}^2$

$v_{avg} := \frac{mdot}{\rho \cdot A} = 1.1751\ \frac{\text{mm}}{\text{s}}$

$t_{residence} := \frac{h}{v_{avg}} = 4.323\ \text{min}$

Honey residence time for original spin float at optimal flow rate

Maximilian Aisenstat
November 26, 2019

$R_o := 1.5\ \text{ft}$ $\quad mdot := 1500\ \frac{\text{lb}}{\text{hr}}$ $\quad h := 1\ \text{ft}$

$R_i := 1.5\ \text{ft} - 9\ \text{cm} = 0.3672\ \text{m}$ $\quad \rho := 1380\ \frac{\text{kg}}{\text{m}^3}$

$A := \pi \cdot \left(R_o^{\ 2} - R_i^{\ 2}\right) = 0.2331\ \text{m}^2$

$v_{avg} := \frac{mdot}{\rho \cdot A} = 0.5876\ \frac{\text{mm}}{\text{s}}$

$t_{residence} := \frac{h}{v_{avg}} = 8.6461\ \text{min}$

Required honey layer thickness (required baffle height)
for the scaled up spin float.

Maximilian Aisenstat
November 26, 2019

$t_{residence} = 8.6461\ \text{min}$ $\quad mdot := 3000\ \frac{\text{lb}}{\text{hr}}$ $\quad h := 19\ \text{in}$

$v_{avg} := \frac{h}{t_{residence}} = 0.9303\ \frac{\text{mm}}{\text{s}}$ $\quad \rho = 1380\ \frac{\text{kg}}{\text{m}^3}$ $\quad R_o := 25\ \text{in}$

$A := \frac{mdot}{\rho \cdot v_{avg}} = 0.2944\ \text{m}^2$

$R_i := \sqrt{R_o^{\ 2} - \frac{A}{\pi}} = 21.9028\ \text{in}$

$t := R_o - R_i = 3.0972\ \text{in}$

Note: The required thickness to preserve an optimal residence time is less than the previous baffle height, so residence time will be recalculated based on the height of the baffle in the current spin-float model.

Honey residence time for scaled up spin float
with original baffle height

Maximilian Aisenstat
November 26, 2019

$t := 9\ \text{cm}$ $\quad R_o = 25\ \text{in}$ $\quad mdot := 3000\ \frac{\text{lb}}{\text{hr}}$ $\quad h := 19\ \text{in}$ $\quad \rho = 1380\ \frac{\text{kg}}{\text{m}^3}$

$R_i := R_o - t = 21.4567\ \text{in}$

$A := \pi \cdot \left(R_o^{\ 2} - R_i^{\ 2}\right) = 0.3336\ \text{m}^2$

$v_{avg} := \frac{mdot}{\rho \cdot A} = 0.821\ \frac{\text{mm}}{\text{s}}$

$t_{residence} := \frac{h}{v_{avg}} = 9.7973\ \text{min}$

Results:

Appendix Table F.3: Results for current spin-float and scaled-up spin-float calculations.

	Original, Overloaded	Original, Optimal	Scaled-Up
Honey Layer Thickness (in)	3.54	3.54	3.54
Honey Average Vertical Speed (mm/s)	1.17	0.59	0.93
Honey mass flow rate (lb/hr)	3000	1500	3000
Honey Residence Time (min)	4.32	8.64	9.80

Conclusions:
Operating conditions for scaled-up centrifuge are better than the optimal settings for the smaller centrifuge, because the honey spends more time inside the spin-float undergoing separation. This should improve the quality of separation and reduce foaming.

References:

[1] M. Oroian, "Measurement, prediction and correlation of density, viscosity, surface tension and ultrasonic velocity of different honey types at different temperatures," *Journal of Food Engineering*, vol. 119, no. 1, pp. 167-172, 2013.

[2] S. Bakier, "Rheological Properties of Honey in a Liquid and Crystallized State," in *Honey Analysis*, 2017.

Appendix G. Optimal Flute Angle Calculation

Prepared by William Hammond, Nov 30th

Objectives:

The overall objective of this calculation is to determine the optimal angle for the flutes. The flutes are responsible for transferring the honey out of the rotating inner drum and onto the stationary outer wall. During this process the honey undergoes a large change in velocity. Because of this, it is necessary to angle the flutes backwards to minimize the velocity change.

The input parameters are:

- Radius
- Rotational speed
- Flute length

The calculated parameters are:

· Flute angle

Nomenclature:

Appendix Table G.1: Nomenclature.

General Symbols	Description	Units
Angular_displacement	Angular displacement, with the origin set as the rotating reference	°
Angular_location	Angular location, with the origin set as stationary	°
Flute_angle	Optimal flute angle	°
Flute_length	Radial length of the flutes	m
Radial_displacment	Radial particle displacement, with the origin at the flute entry	m
Radial_location	Radial particle location as measured from the center of the drum	m
Radius	Radius of the drum where the honey enters the flute	m
Rotational_speed	Rotational speed of the spin-float	rpm
time	Discrete points in time	s
X_displacment	X axis particle location measured in cartesian coordinates	mm
Y_displacment	Y axis particle location measured in cartesian coordinates	mm
θ	Cone Angle	°

Will Hammond November 30th

The radius that the flutes start at is 0.587 meters, and the flutes are 0.177 m in length radially

Constants:

$Radius := 0.587\ m$

$rotation\_speed := 380\ rpm = 39.7935\ \frac{rad}{s}$

$Flute\_length := 0.177\ m$

The honey leaving the flutes of the spin float follows a coriolis path.
The path of a particle following this coriolis path will be calculated at different discrete time points using polar coordinates and saved in a table.

$$time := 0.01\ s$$

$$Radial\_location := Radius \cdot \left(\sqrt{rotation\_speed^{2} \cdot time^{2} + 1}\right) = 0.6318\ m$$

$$Radial\_displacment := Radial\_location - Radius = 0.0448\ m$$

$$Angular\_location := \operatorname{acos}\left(\frac{1}{\sqrt{rotation\_speed^{2} \cdot time^{2} + 1}}\right) = 21.6993\ deg$$

$$Angular\_displacment := time \cdot rotation\_speed - Angular\_location = 1.1007\ deg$$

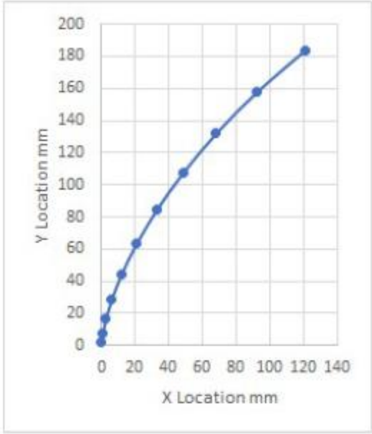
Location values are then switched from polar coordinates to cartesian coordinates, with the y axis being radially outward, and the x axis being tangential to the drum. The origin of the cartesian axis is at the entry to the flute

$$X\_displacemnt := Radial\_location \cdot \cos(90\ deg - Angular\_displacment) - 0 = 12.1356\ mm$$

$$Y\_displacemnt := Radial\_location \cdot \sin(90\ deg - Angular\_displacment) - Radius = 44.6526\ mm$$

This calculation was conducted for mutiple points in time and can be seen in the table belo
A Plot of these points to show the honey's natural coriolis path is seen below

Time (s)	X mm	Y mm
0	0.0	0.0
0.002	0.1	1.9
0.004	0.8	7.4
0.006	2.6	16.5
0.008	6.2	29.0
0.01	12.1	44.7
0.012	20.8	63.2
0.014	32.8	84.1
0.016	48.5	107.2
0.018	68.3	131.8
0.02	92.5	157.5
0.020935	105.5	169.7



Next, the time required for the honey to leave the flute was calculated. This was done with iterations until the radial displacement equals the flute length, as follows:

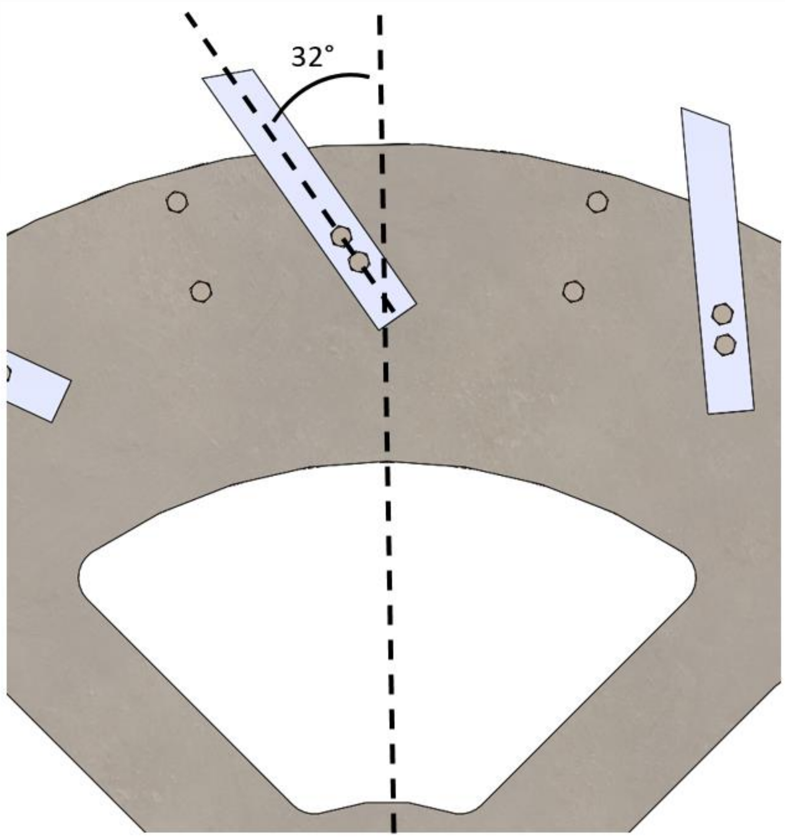
$$time := 0.020935\ s$$

$$Radial\_displacment := Radius \cdot \left(\sqrt{rotation\_speed^2 \cdot time^2 + 1}\right) - Radius = 0.177\ m$$

For ease of manufacturing, it was decided to use straight flutes. The flute angle was calculated from taking the tangent of the final X and Y displaments. This resulted in,

$$Flute\_angle := \operatorname{atan}\left(\frac{105.5}{169.7}\right) = 31.8686\ deg$$

Appendix Figure G.1 shows a schematic of the flute mounting.



Appendix Figure G.1: Inlet spout angle diagram.

Results:

Appendix Table G.2: Table of results for flute angle.

General Symbols	Description	Values
Flute_angle	Optimal flute angle in degrees	32°

Conclusions:
The optimal flute angle was determined to be 32° and this was used in the modeling.

Appendix H. Power Requirement Calculations

Power Requirement Calculations

November 22nd, 2019

Prepared by Cale Benko and William Hammond

Project: Spin-float Capstone, Phase 3

Customer: Connie Phillips

Objectives:

1. Determine the force needed to cut the wax, which is applied to both the cutting blades and the inner drum.
2. Determine the power requirement to cut the wax to source motors for the blade and inner drum shafts.

Known:

1. There are 8 inches of blade by height cutting the wax layer at any given time.
2. The outside surface of the wax layer during operation is 6 inches from the wall of the inner drum.
3. The edge of any given cutting blade is 4.76 inches from the centre of the blade shaft.
4. The blade shaft rotates at a constant 2045 rpm.
5. Honey is produced at 3000 lbs/hr. Wax occupies 1/7 of the honey-wax mixture by volume.
6. The density of honey, ρ_h, is 1380 kg/m^3
7. The fracture toughness, K_c, of wax is 0.14 MPa m$^{1/2}$ [1]
8. The inner drum and blades spin in the same direction (clockwise, from above).

Assumptions:

1. The calculation in this report assumes the blade angle is perpendicular to the wax layer. This gives the worst-case scenario compared to angle blades in the real model.
2. Neglect friction from bearings.

Nomenclature:

ω: Rotational speed [RPM]

ρ_h: Density of honey [kg/m^3]

A_{LB}: Horizontally projected load bearing area

K_{LB}: Horizontally projected load-bearing contact area [m^2]

d: Depth of cut [m]

F_T: Scratch horizontal force [N]

K_c: Fracture toughness [MPa m$^{1/2}$]

p: Scratch probe perimeter [m]

P: Power [W]

Q_a: Wax flowrate (added) [m^3/s]

Q_r: Wax flowrate (removed) [m^3/s]

v_r: Relative velocity [m/s]

w: Width of blade in the wax layer [m]

Analysis:

The main basis of these calculations is that the flow rate of wax into the device is equal to the flow rate of wax being removed.

In one hour, 3000 lbs of honey is processed. The volumetric flow rate of honey is as follows.

$$Q_h = (3000\frac{lbs}{h})\left(\frac{0.453592\ kg}{lbs}\right)\left(\frac{m^3}{1380\ kg}\right)$$

$$V_h = 0.986\ m^3/h$$

In one hour, 4.79 m^3 of honey is processed. Wax is produced at 1/7 this rate by volume yielding.

$$Q_w = \left(0.986 \frac{m^3}{h}\right)(1/7)$$

$$Q_w = 0.141\ m^3/h$$

In one hour, $0.141\ m^3/h$, or $3.91 \times 10^{-5}\ m^3/s$, of wax is processed.

Therefore, $Q_a = 3.91 \times 10^{-5}\ m^3/s$.

The flow rate of wax out of the device, Q_r, should always be equal to Q_a for a steady state process, and is defined as:

$$Q_r = wdv_r$$

The horizontal force needed to cut the wax is given by:

$$F_T = K_c\sqrt{2pA_{LB}}$$

Where:

$$p = w\left(1 + \frac{2d}{w}\right)$$

$$A_{LB} = wd$$

Power is calculated by:

$$P = F_T v_r$$

As relative velocity increases, the cut depth and horizontal force decrease. However, by trial and error, power increases overall as relative velocity increases.

The blade shaft rotates at a constant 3600 RPM, so relative velocity is higher the lower the inner drum RPM is. Theoretically, the worst-case scenario (highest power) would occur when the inner drum is stationary. The device could never operate under this condition, but incidental contact could occur if the inner drum motor was turned off and the blades were still turning. Therefore, this will be analyzed as the worst-case scenario.

Case 1: Stationary inner drum

$$v_r = v_{blade} - v_{wax}$$

$$v_r = \left(\frac{2045\,rev}{min}\right)\left(\frac{2\pi\,rad}{rev}\right)\left(\frac{min}{60\,s}\right)(4.76\,in)\left(\frac{0.0254\,m}{in}\right) - 0$$

$$v_r = 25.89\,m/s$$

$$Q_r = wdv_r$$

$$0.141\frac{m^3}{h} = (8\,in)\left(\frac{0.0254\,m}{in}\right)d\left(25.89\frac{m}{s}\right)$$

$$d = 7.4 \times 10^{-6}\,m$$

$$p = (8\,in)\left(\frac{0.0254\,m}{in}\right)\left(1 + \frac{2(7.4 \times 10^{-6}\,m)}{(8\,in)\left(\frac{0.0254\,m}{in}\right)}\right)$$

$$p = 0.203\ m$$

$$A_{LB} = (8\ in)\left(\frac{0.0254\ m}{in}\right)(7.4 \times 10^{-6}\ m)$$

$$A_{LB} = 1.5 \times 10^{-6}\ m^2$$

$$F_T = (0.14\ MPa\sqrt{m})\left(\frac{10^6\ Pa}{MPa}\right)\sqrt{2(0.203\ m)(1.5 \times 10^{-6}\ m^2)}$$

$$F_T = 109.8\ N$$

$$P = (109.8\ N)(25.89\ \frac{m}{s})$$

$$P = 2843\ W$$

$$\boldsymbol{P = 3.81\ hp}$$

The maximum required power for cutting in a worst-case scenario is 3.81 hp.

This is not on operating condition; the drum must always be spinning in operations and thus the power will always be lower than this.

Case 2: Operation conditions (Inner drum is rotating at 380 RPM)

The typical operating inner drum speed is 380 RPM, and the blades operation speed is 2049 RPM. This case is analyzed as follows.

$$v_r = v_{blade} - v_{wax}$$

$$v_r = \left(\frac{2044.8\ rev}{min}\right)\left(\frac{2\pi\ rad}{rev}\right)\left(\frac{min}{60\ s}\right)(4.76\ in)\left(\frac{0.0254\ m}{in}\right) - \left(\frac{380\ rev}{min}\right)\left(\frac{2\pi\ rad}{rev}\right)\left(\frac{min}{60\ s}\right)(19.3in)\left(\frac{0.0254\ m}{in}\right)$$

$$v_r = 6.38\ m/s$$

$$Q_r = wdv_r$$

$$0.141\frac{m^3}{h} = (8\ in)\left(\frac{0.0254\ m}{in}\right)d\left(6.38\frac{m}{s}\right)\left(3600\frac{s}{h}\right)$$

$$d = 30.21 \times 10^{-6}\ m$$

$$p = (8\ in)\left(\frac{0.0254\ m}{in}\right)\left(1 + \frac{2(2.1\times10^{-5}\ m)}{(8\ in)\left(\frac{0.0254\ m}{in}\right)}\right)$$

$$p = 0.203\ m$$

$$A_{LB} = (8\ in)\left(\frac{0.0254\ m}{in}\right)(30.21 \times 10^{-6}\ m)$$

$$A_{LB} = 6.14 \times 10^{-6}\ m^2$$

$$F_T = (0.14\ MPa\sqrt{m})\left(\frac{10^6\ Pa}{MPa}\right)\sqrt{2(0.203\ m)(6.14 \times 10^{-6}\ m^2)}$$

$$F_T = 221\ N$$

$$P = (221\ N)(6.47\ \frac{m}{s})$$

$$P = 1430.1\ W$$

$$\boldsymbol{P = 1.92\ hp}$$

The required power for cutting under standard operation is 1.92 hp.

Conclusion

As seen from these results, the power requirement decreases as drum speed increase because the relative velocity between the wax and the blade decrease. Power would increase as drum speed increases after a certain speed, but this speed is very high and far beyond reasonable operating conditions.

Based on these results, two **5 hp electric motors** will be sourced; one for the blade shaft and one for the main inner drum shaft. Blades should not be placed in contact with the wax until the inner drum has reached its desired operating speed.

Appendix Table H.1: Table of results for the motor power requirement calculations.

Scenario	Power Requirement
Worst-case scenario	3.81 hp (2.84 Kw)
Standard operating conditions	1.92 hp (1.43 Kw)

References:

[1] A.-T. Akono, F.-J. Ulm and Z. P. Bazant, "Discussion: Strength-to-fracture scaling in scratching," *Engineering Fracture Mechanics*, vol. 119, pp. 21-28, 2014.

Appendix I. Energy Consumption Calculations

Objectives:

The overall objective of these calculations is to determine the yearly electricity cost and greenhouse gas emissions of the design. This is will aid in evaluating process cost and quantifying the carbon footprint of the machine.

Nomenclature

Appendix Table I.1: Nomenclature for energy consumption calculations.

General Symbols	Description	Units
$Cons$	Consumption greenhouse gas emissions intensity	g_{CO2e}/kWh
$Cost$	Yearly electricity cost	$
E_{yearly}	Average yearly energy use	kWh
m_{CO2e}	Mass of yearly CO2 equivalent emissions released	g_{CO2e}
N_d	Days of use every year	day
P_{ave}	Average power draw	kW
R	Average August 2019 electricity regulated rate	¢/kWh
t_d	Daily usage	hr/day

Known Data/Values:

Appendix Table I.2: Known values for energy consumption calculations.

Quantity	Value
Average power draw, obtained from power calculations in Appendix H	1.4301 kW
Daily usage	10 hr/day
Days of use every year	21 days
Average August 2019 electricity regulated rate	9.42 ¢/kWh
Greenhouse gas emissions intensity	800 g/kWh

Assumptions:

1. All assumptions necessary for the power requirement calculations in Appendix H will also apply in these calculations.
2. The August 2019 average electricity rate [1] is appropriate for future use, since the device will mostly be in use in August every year.
3. The emissions intensity factor for 2017 [2] is appropriate for future use, as it is the most recent data from Environment Canada. It is important to note that Alberta's electricity sector is currently undergoing a shift towards less emissive production.

4. The usage values are an approximation.

Analysis:

Electricity Consumption Calculations November 30, 2019

Gabriel Risbud-Vincent

Average power draw, P.ave (kW): $P_{ave} := 1.4301\ kW$

Daily usage, t.d (hr/day): $t_d := 10\ \frac{hr}{day}$

Days of use every year, N.d (day): $N_d := 21\ day$

The total amount of hours can be calculated by multiplying t_d and N_d

$t_d \cdot N_d = 210\ hr$

The average yearly energy use, E.yearly (KWh) can now be obtained

$E_{yearly} := t_d \cdot N_d \cdot P_{ave} = 300.321\ kW\ hr$

From this value, we can now obtain the yearly greenhouse gas emissions and electricity cost.

Greenhouse gas emissions intensity, $Cons := 800\ \frac{g}{kW\ hr}$

Mass of yearly CO2 equivalent emissions released,

$$\boxed{m_{CO2e} := Cons \cdot E_{yearly} \cdot 0.001\ \frac{kg}{g} = 240.2568\ kg}$$

Average August 2019 electricity regulated rate, $R := 9.42 \cdot \frac{1}{kW\ hr}$ cents

Yearly electricity cost,

$$\boxed{Cost := \frac{R}{100} \cdot E_{yearly} = 28.29}\ \boxed{\text{dollars per year}}$$

Results:

Appendix Table I.3: Results for energy consumption calculations.

Description	Value
Average yearly energy use (kWh)	300.321
Mass of yearly CO_{2e} emissions (kg)	240.257

Yearly operation electricity cost ($CAD)	28.29

Conclusions:

The BeeBlade's annual emissions correspond to approximately one 20th of a typical passenger vehicle's CO_{2e} emissions [3]. As the design is entirely reliant on electric power, these emissions will change as Alberta phases out coal-powered plants. The annual energy use corresponds to a 100 W light bulb being lit for approximately 8 hours every day for one year. The cost of this electricity is negligible compared with other costs in the business.

References:

[1] Government of Alberta Utilities Consumer Advocate, "Regulated Rates – Year at a Glance." [Online]. Available: https://ucahelps.alberta.ca/regulated-rates.aspx. [Accessed: Nov. 20, 2019]

[2] Environment Canada: Greenhouse Gas Division, "National inventory report 1990-2017: greenhouse gas sources and sinks in Canada." [p. 68] *Government of Canada*, En81-4E-PDF, 2019. [Online]. Available: http://publications.gc.ca/collections/ collection_2019/eccc/En81-4-2017-3-eng.pdf. [Accessed: Nov. 20, 2019]

[3] United States Environmental Protection Agency, "Greenhouse Gas Emissions from a Typical Passenger Vehicle." [Online] Available: https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle. [Accessed: Nov. 24, 2019]

Appendix J. Honey Wax Mixture Mass

Prepared by William Hammond, Nov 30th

Objectives:

The objective of this calculation is to determine the mass of honey and wax inside the spin-float during operation. This is necessary to calculate the total rotating mass for vibrations, as well as mass for the frame structural analysis.

The input parameters are:

- Honey thickness
- Densities
- Radii
- Height
- Wax thickness

The calculated parameters are:

· Total Mixture Mass

Nomenclature:

Appendix Table J.1: Nomenclature.

General Symbols	Description	Units
Drum_bottom_radius	Bottom radius of spin-float	m
Drum_top_radius	Top Radius of the spin-float	m
h	Height of inner drum	m
Honey_Mass	Mass of honey inside the spin-float	kg
Honey_thick	Internal thickness of the honey layer	m
Honey_Volume	Volume of honey inside the spin-float	m^3
r	Internal radius of honey wax interface	m
Total_Mixture_Mass	Total mass of honey and wax inside the spin-float	kg
Wax_Mass	Mass of wax inside the spin-float	kg
Wax_thick	Internal thickness of the wax layer	m
Wax_Volume	Volume of wax inside the spin-float	m^3
ρ_{Honey}	Honey density	kg/m^3

ρ_{wax}	Wax density	kg/m^3

Will Hammond November 29th

Process conditions that are evaluated as constants

Constants:

$inner\_drum\_height := 16\ in = 0.4064\ m$

$drum\_bottom\_radius := .63373\ m$

$drum\_top\_radius := .64262\ m$

$Wax\_thick := 3.5\ in = 0.0889\ m$

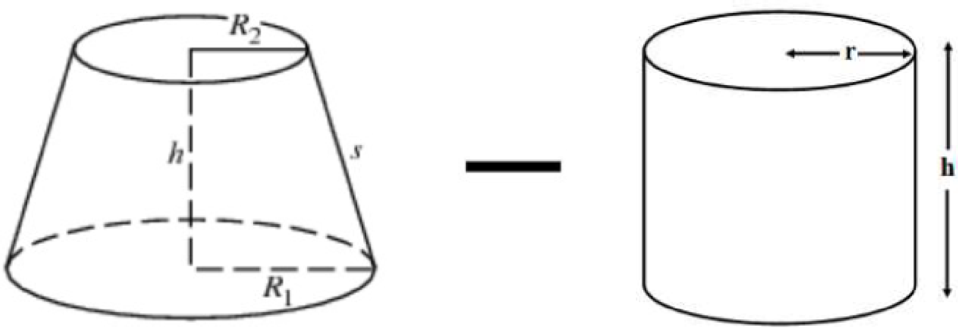
$Honey\_thick := 9\ cm$

$\rho_{honey} = 1380\ \frac{kg}{m^3}$

$\rho_{wax} = 960\ \frac{kg}{m^3}$

The volume of honey forms the shape of a frustrum with a center section removed.

The honey volume and mass is calculated as follows:



$R2 := drum\_bottom\_radius = 0.6337\ m$

$R1 := drum\_top\_radius = 0.6426\ m$

$h := inner\_drum\_height = 0.4064\ m$

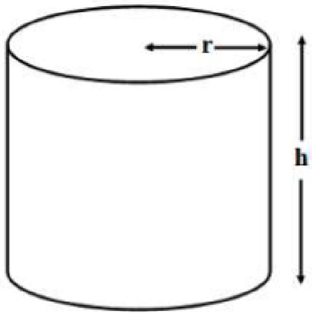
$r := drum\_top\_radius - Honey\_thick = 0.5526\ m$

$$Honey\_Volume2 := \frac{1}{3} \cdot \pi \cdot h \cdot \left(R1^2 + R1 \cdot R2 + R1^2\right) = 0.5248\ m^3$$

$$Honey\_Volume := \frac{1}{3} \cdot \pi \cdot h \cdot \left(R1^2 + R1 \cdot R2 + R1^2\right) - \pi \cdot r^2 \cdot h = 0.1349\ m^3$$

$$Honey\_Mass := \rho_{honey} \cdot Honey\_Volume = 186.1758\ kg$$

The volume and mass of the wax can be calculated using the volume of a cylinder as follows:



$$Wax\_Volume := \pi \cdot h \cdot \left((drum\_top\_radius - Honey\_thick)^2 - (drum\_top\_radius - Honey\_thick - Wax\_thick)^2 \right) = 0.1154\ m^3$$

$$wax\_Mass := \rho_{wax} \cdot Wax\_Volume = 110.7428\ kg$$

$$Total\_Mixture\_Mass := Honey\_Mass + wax\_Mass = 296.9186\ kg$$

$$Total\_Mixture\_Mass := Total\_Mixture\_Mass = 654.5936\ lb$$

Appendix Table J.2: Tabulated outputs.

General Symbols	Description	Values
Total_Mixture_Mass	Weight of the honey and wax inside the drum during operation	655 lbs

<u>Conclusions:</u>

The total mass of honey and wax during continuous operation within the spin float is 655 lbs.

Appendix K. Shaft Calculations

Shaft Deflection Analysis

November 22nd, 2019

Prepared by Cale Benko

Project: Spin-float Capstone, Phase 3

Customer: Connie Phillips

Objective:

1. Determine the maximum deflection in the main drum shaft and ensure that it is less than the accepted limit of 0.005 in operation.
2. Determine the slope at both bearings on the main drum shaft and ensure that they are less than the accepted limit of 0.004 rad.
3. Determine the torsional deflection in the shaft and ensure it is less than the accepted limit of 3 deg/m.

The following calculations are not to find minimum diameter required with a small safety factor, but rather to ensure the selected shaft size is sufficient.

Known:

1. The radial load on the shaft caused by cutting of the wax layer is 214 N (48.2 lbs), shown by force ‘P’ in the free body diagram under the analysis section.

Assumptions:

1. All the radial load is carried by the thrust and radial bearings on the shaft.
2. To simplify the calculations and err on the side of the worst case, the entire shaft is assumed to be 1 7/16” in diameter.

Nomenclature:

θ: Slope of the shaft deflection [rad]

ϕ: Torsional deflection in the shaft [deg/m]

a: Location of the radial bearing, 20 in

b: Location of the load from cutting, 22.5 in

C: Constant of integration

d: Shaft diameter [in]

E: Young's modulus, 28000 ksi

G: Shear modulus, 12500 ksi

I: Moment of inertia [in^4]

J: Polar moment of inertia [in^4]

L: Effective length of the shaft, 22.5 in

M: Moment [lb in]

N: Safety factor

q: Shear flow [lb/in]

P: Force on shaft caused by wax cutting [lb]

R: Resultant force [lb]

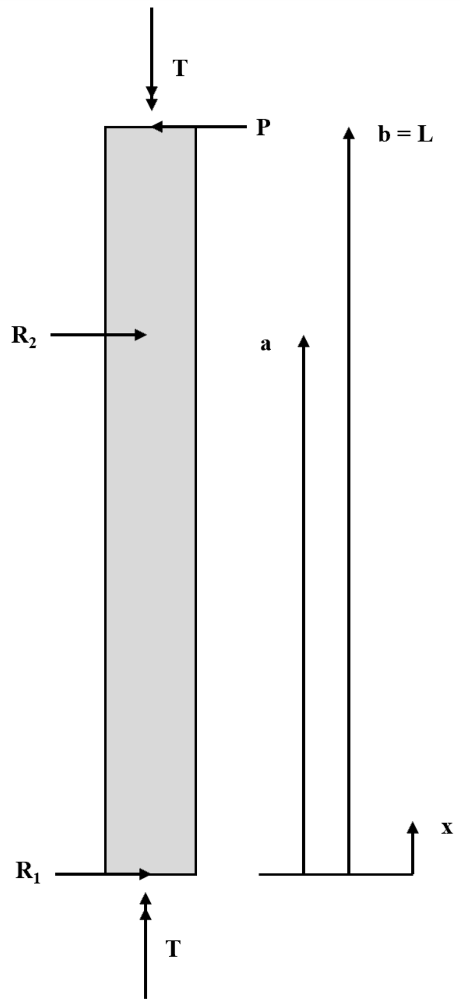
T: Torque [lb in]

V: Shear [lb]

y: Shaft deflection [in]

Analysis:

A free body diagram of the shaft is shown in Appendix Figure B.1. Axial forces are neglected as they do not contribute to shaft deflection.



Appendix Figure K.1: Drum shaft free body diagram.

$$+CW \sum M_{R_1} = 0$$

$$R_2 a + \frac{b}{a} P = 0$$

$$\boldsymbol{R_2 = \frac{b}{a} P}$$

$$+\rightarrow \sum F = 0$$

$$R_1 + R_2 - P = 0$$

$$R_1 + \frac{b}{a} P - P = 0$$

$$\boldsymbol{R_1 = \frac{a-b}{b} P}$$

Shear flow, shear and moment equations as a function of position ‘x’ are determined using singularity functions.

$$q_y(x) = R_1 \langle x \rangle^{-1} + R_2 \langle x - a \rangle^{-1} - P \langle x - b \rangle^{-1}$$

$$V_y(x) = \int_0^x q_y(x) dx$$

$$V_y(x) = R_1 \langle x \rangle^{0} + R_2 \langle x - a \rangle^{0} - P \langle x - b \rangle^{0}$$

$$M_z(x) = \int_0^x V_y(x)dx$$

$$M_z(x) = R_1\langle x\rangle^1 + R_2\langle x-a\rangle^1 - P\langle x-b\rangle^1$$

Subbing in the reaction forces in terms of P,

$$M_z(x) = P\left(\frac{a-b}{a}\langle x\rangle^1 + \frac{b}{a}\langle x-a\rangle^1 - \langle x-b\rangle^1\right)$$

The equation for slope of the deflection at a position ‘x’ is defined by:

$$\theta(x) = \int_0^x \frac{M_z(x)}{EI}dx + C_1$$

$$\theta(x) = \frac{1}{EI}\int_0^x P\left(\frac{a-b}{a}\langle x\rangle^1 + \frac{b}{a}\langle x-a\rangle^1 - \langle x-b\rangle^1\right)dx + C_1$$

$$\theta(x) = \frac{P}{2EI}\left(\frac{a-b}{a}\langle x\rangle^2 + \frac{b}{a}\langle x-a\rangle^2 - \langle x-b\rangle^2\right) + C_1$$

The equation for deflection at a position ‘x’ is defined by:

$$y(x) = \int_0^x \theta(x)dx + C_1x + C_2$$

$$y(x) = \frac{P}{2EI}\int_0^x \left(\frac{a-b}{a}\langle x\rangle^2 + \frac{b}{a}\langle x-a\rangle^2 - \langle x-b\rangle^2\right) dx + C_1 x + C_2$$

$$y(x) = \frac{P}{6EI}\left(\frac{a-b}{a}\langle x\rangle^3 + \frac{b}{a}\langle x-a\rangle^3 - \langle x-b\rangle^3\right) + C_1 x + C_2$$

The boundary conditions on the shaft are y(0) = 0 and y(a) = 0 because the shaft cannot deflect at the bearing locations. Applying these boundary conditions leads to:

$$\theta(x) = \frac{P}{2EI}\left[\frac{a-b}{a}\langle x\rangle^2 + \frac{b}{a}\langle x-a\rangle^2 - \langle x-b\rangle^2 - \frac{a(a-b)}{3}\right]$$

$$y(x) = \frac{P}{6EI}\left[\frac{a-b}{a}\langle x\rangle^3 + \frac{b}{a}\langle x-a\rangle^3 - \langle x-b\rangle^3 - a(a-b)x\right]$$

The moment of inertia, I, is calculated by:

$$I = \frac{\pi d^4}{64}$$

$$I = \frac{\pi(1\frac{7}{16}in)^4}{64}$$

$$I = 0.210\ in^4$$

Maximum deflection occurs at x = L.

$$y_{max} = y(L) = \frac{48.2\ lbs}{6(28000 \times 10^3\ psi)(0.210\ in^4)}\left[\frac{20\ in - 22.5\ in}{22.5\ in}\langle 22.5\ in\rangle^3 + \frac{22.5\ in}{20\ in}\langle 22.5\ in - 20\ in\rangle^3 - \langle 22.5\ in - 22.5\ in\rangle^3 - 20\ in(20\ in - 22.5)22.5\ in\right]$$

$$\boldsymbol{y_{max} = -0.000385\ in}$$

In operation, the maximum deflection in the shaft is -0.000385 inches, which is less than the absolute limit 0.005 in.

Solving for the applied force, P_{limit}, that would yield the deflection limit of 0.005 inches:

$$0.005\ in = \frac{P_{limit}}{6(28000 \times 10^3\ psi)(0.210\ in^4)}\left[\frac{20\ in - 22.5\ in}{22.5\ in}\langle 22.5\ in\rangle^3 + \frac{22.5\ in}{20\ in}\langle 22.5\ in - 20\ in\rangle^3 - \langle 22.5\ in - 22.5\ in\rangle^3 - 20\ in(20\ in - 22.5)22.5\ in\right]$$

$$\boldsymbol{P_{limit} = 626\ lbs}$$

The safety factor for shaft deflection in operation is as follows:

$$N_{deflection} = \frac{P_{limit}}{P}$$

$$N_{deflection} = \frac{626\ lbs}{48.2\ lbs}$$

$$\boldsymbol{N_{deflection} = 13.0}$$

The next objective is to determine the slope at the bearing locations during operation.

Lower thrust bearing (x = 0)

$$\theta(x) = \frac{P}{2EI}\left[\frac{a-b}{a}\langle x\rangle^2 + \frac{b}{a}\langle x-a\rangle^2 - \langle x-b\rangle^2 - \frac{a(a-b)}{3}\right]$$

$$\theta(0) = \frac{48.2\ lbs}{2(28000 \times 10^3\ psi)(0.210\ in^4)}\left[-\frac{20\ in(20\ in - 22.5\ in)}{3}\right]$$

$$\boldsymbol{\theta(0) = 6.84 \times 10^{-5}\ rad}$$

The slope at the lower bearing is less than the absolute limit of 0.004 rad.

Upper radial bearing (x = a)

$$\theta(x) = \frac{P}{2EI}\left[\frac{a-b}{a}\langle x\rangle^2 + \frac{b}{a}\langle x-a\rangle^2 - \langle x-b\rangle^2 - \frac{a(a-b)}{3}\right]$$

$$\theta(x) = \frac{48.2\ lbs}{2(28000 \times 10^3\ psi)(0.210\ in^4)}\left[\frac{20\ in - 22.5\ in}{20\ in}\langle 20\ in\rangle^2 - \frac{20\ in(20\ in - 22.5\ in)}{3}\right]$$

$$\boldsymbol{\theta(a) = -0.000137\ rad}$$

The slope at the lower bearing is less than the absolute limit of 0.004 rad.

To determine the torsional deflection of the shaft, the following equation is used:

$$\phi = \frac{TL}{GJ}$$

Here, the equation for polar moment of inertia, J, is:

$$J = \frac{\pi d^4}{32}$$

$$J = \frac{\pi(1\frac{7}{16}in)^4}{32}$$

$$J = 0.419\ in^4$$

The torsional deflection will be evaluated at the maximum possible torque. This is when the drum drive motor is operating at its maximum horsepower of 5 hp at the operating speed of 380 hp.

$$T = \frac{(5\ hp)(63025)}{380\ rpm}$$

$$T = 829\ lb\ in$$

Calculating for the worst-case torsional deflection:

$$\phi = \frac{(829\ lb\ in)(22.5\ in)}{(12500 \times 10^3\ psi)(0.419\ in^4)}$$

$$\phi = 0.00356\ rad$$

Per unit length the torsional deflection is:

$$\frac{\phi}{L} = \frac{0.00356\ rad}{(22.5\ in)\left(\frac{2.54\ m}{100\ in}\right)} \frac{180\ deg}{\pi\ rad}$$

$$\boldsymbol{\frac{\phi}{L} = 0.357\ deg/m}$$

The worst-case torsional deflection is 0.357 degrees per meter, which is less than the limit of 3 degrees per meter.

Conclusion

In conclusion, the selected shaft size is more than acceptable for the application. Under standard operating conditions, the factor of safety for shaft deflection is 13.0. Additionally, the shaft does not exceed the limits of 0.004 rad in deflection slope at the bearing or the limit of 3 degrees per meter in torsional deflection in the worst-case scenario.

The justification for oversizing the shaft is that in terms of pricing, the selected shaft is only a small fraction of the overall pricing (~ 1%), and the size of shaft selected is easily sourced.

Tabulated Results

Appendix Table K.1: Table of results for the drum drive shaft calculations.

Parameter	Value
Maximum operating deflection	-0.000385 in
Deflection safety factor	13.0
Slope at the thrust bearing	6.84E-05 rad
Slope at the radial bearing	-0.000137 rad
Maximum torsional deflection per unit length	0.357 deg/m

Appendix L. Bolted Connections Calculations

Bolted Joints Analysis

November 22nd, 2019

Prepared by Cale Benko

Project: Spin-float Capstone, Phase 3

Customer: Connie Phillips

Objective:

The most important bolts in the spin-float assembly are the 12 bolts that secure the top plate to the side wall of the spinning inner drum. These bolts bear the load of the entire inner drum and honey wax mixture that is contained in it.

The objective of these calculations is to:

1. Determine the minimum preload required to prevent joint separation.
2. Determine the maximum preload that can be applied to prevent bolt yielding.
3. Determine the safety factor bolts in yielding.

Known:

1. The type of bolt selected is a 0.75" long ½"-20 UNF 316 stainless steel bolt.
2. The weight of the drum the drum and honey wax mixture carried by the bolts is 900 lbs total.

Assumptions:

1. The total load, which is the sum of the weight of the part of the inner drum being supported and the honey wax mixture, is divided evenly between each bolt.
2. There is no dynamic loading of the bolts. The assumption of static loading can be made.

Nomenclature:

σ_y: Yield stress, 73.2 ksi

σ: Normal stress [psi]

A_b: Major cross-sectional bolt area [in^2]

A_t: Tensile stress area, 0.1419 in^2

C: Fraction of bolt stiffness to sum of bolt and member stiffness

d: Major bolt diameter, 0.5 in

E_b: Bolt Young's modulus, 28000 ksi

E_m: Joined member Young's modulus [ksi]

F_i: Preload [lbs]

F_b: Bolt force [lbs]

k_b: Bolt stiffness [lb/in]

k_m: Member stiffness [lb/in]

K: Thread coefficient

l_s: Shank length [in]

l_t: Thread length [in]

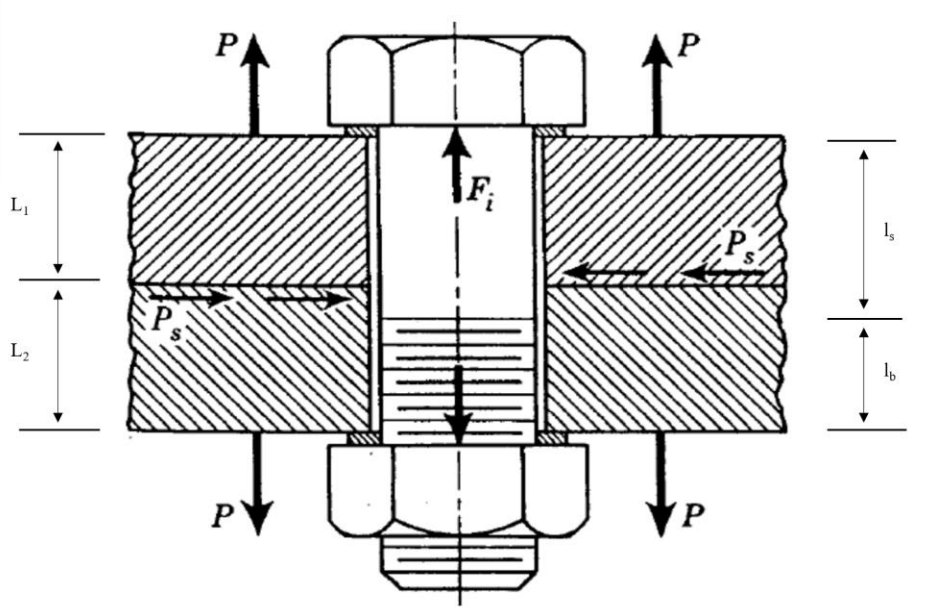
L: Length of joined member [in]

N: Factor of safety

T: Required torque for preload [lb in]

Analysis:

A schematic of a single bolted connection is shown below:



Appendix Figure L.1: Schematic of a bolted member.

L_1 refers to the length of the stainless steel top member and is equal to 0.375 inches.

L_2 refers to the length of the aluminum bottom member and is equal to 0.125 inches.

The bolts used are fully threaded so that $l_s = 0$ and $l_t = 0.5\ in$.

The major area of the bolt is:

$$A_b = \frac{\pi}{4} d^2$$

$$A_b = \frac{\pi}{4} (0.5)^2$$

$$A_b = 0.196\ in^2$$

The bolt stiffness is calculated by:

$$k_b = \frac{A_t A_b E_b}{A_t l_s + A_b l_t}$$

$$k_b = \frac{(0.1419\ in^2)(0.196\ in^2)(28000 \times 10^3\ psi)}{(0.1419\ in^2)(0) + (0.196\ in^2)(0.5\ in)}$$

$$\boldsymbol{k_b = 7.95 \times 10^6\ lb/in}$$

The material stiffness of the stainless steel top member is:

$$k_{m1} = \frac{\pi E_{m1} d}{2\ln\left(5\left[\frac{L_1 + 0.5d}{L_1 + 2.5d}\right]\right)}$$

The Young's modulus of the top member is 28000 ksi.

$$k_{m1} = \frac{\pi(28000 \times 10^3\ psi)(0.5\ in)}{2\ln\left(5\left[\frac{0.375\ in + 0.5(0.5\ in)}{0.375\ in + 2.5(0.5\ in)}\right]\right)}$$

$$k_{m1} = \frac{\pi(28000 \times 10^3\ psi)(0.5\ in)}{2\ln\left(5\left[\frac{0.375\ in + 0.5(0.5\ in)}{0.375\ in + 2.5(0.5\ in)}\right]\right)}$$

$$\boldsymbol{k_{m1} = 33.6 \times 10^6\ lb/in}$$

The material stiffness of the aluminum bottom member is:

$$k_{m2} = \frac{\pi E_{m2} d}{2\ln\left(5\left[\frac{L_2 + 0.5d}{L_2 + 2.5d}\right]\right)}$$

The Young's modulus of the bottom member is 9860 ksi.

$$k_{m2} = \frac{\pi(9860 \times 10^3\ psi)\ (0.5)}{2\ln\left(5\left[\frac{0.125\ in + 0.5(0.5\ in)}{0.125\ in + 2.5(0.5\ in)}\right]\right)}$$

$$\boldsymbol{k_{m2} = 14.3 \times 10^6\ lb/in}$$

The overall member stiffness can be determined by modelling the member as a spring system such that:

$$k_m = \left(\frac{1}{k_{m1}} + \frac{1}{k_{m2}}\right)^{-1}$$

$$k_m = \left(\frac{1}{33.6 \times 10^6\ lb/in} + \frac{1}{14.3 \times 10^6\ lb/in}\right)^{-1}$$

$$\boldsymbol{k_m = 14.3 \times 10^6\ lb/in}$$

The material stiffness is only ~ 1.8 times greater than the bolt stiffness. Typically, member stiffness is designed much to be much higher than bolt stiffness, so the member carries most of the load. In this case, in order to not damage the expensive inner drum components, the system as designed so that the stiffnesses are more comparable. Appropriate washers will be used to further distribute the load over the members.

The load on the bolts is as follows:

$$P = \frac{Total\ Load}{Number\ of\ Bolts} = \frac{900\ lbs}{12}$$

$$P = 75\ lbs$$

Dimensionless constant ‘C’ is defined by:

$$C = \frac{k_b}{k_b + k_m}$$

$$C = \frac{7.95 \times 10^6\ lb/in}{7.95 \times 10^6\ lb/in + 14.3 \times 10^6\ lb/in}$$

$$C = 0.357$$

The required preload required to prevent separation of the members is determined as:

$$F_{i,min} = P(1 - C)$$

$$F_{i,min} = 75\ lbs(1 - 0.357)$$

$$\boldsymbol{F_{i,min} = 48.2\ lbs}$$

The maximum preload that can be applied before the bolts yield, with a safety factor of 2 is:

$$F_{i,max} = \frac{A_t \sigma_y}{N}$$

$$F_{i.max} = \frac{(0.1419\ in^2)(73200\ psi)}{2}$$

$$\boldsymbol{F_{i,max} = 5194\ lbs}$$

It is typical that 75% of the expected static load be applied as preload. Therefore,

$$F_i = 0.75P$$

$$F_i = 0.75(90\ lbs)$$

$$\boldsymbol{F_i = 67.5\ lbs}$$

This preload is between the determined minimum and maximum preloads of 48.2 lbs and 5194 lbs; thus, it is deemed to be acceptable. Joint separation will be prevented, and the bolts will not yield.

The torque required to apply this preload is given by:

$$T = KF_i d$$

Where K = 0.2 for dry threads.

$$T = (0.2)(67.5\ lbs)(0.5\ in)$$

$$\boldsymbol{T = 6.75\ lb\ in}$$

The factor of safety for yielding in the bolt can also be determined. The normal stress experienced by a single bolt is:

$$\sigma = \frac{F_b}{A_t}$$

$$\sigma = \frac{CP + F_i}{A_t}$$

$$\sigma = \frac{(0.357)(75\ lbs) + 67.5\ lbs}{(0.1419\ in^2)}$$

$$\sigma = 664\ psi$$

The factor of safety is determined by:

$$N = \frac{\sigma_y}{\sigma}$$

$$N = \frac{73200\ psi}{664\ psi}$$

$$\boldsymbol{N = 110}$$

This large factor of safety is justified by the fact that bolts are extremely cheap, and it is best to err on the side of caution to ensure reliability and low maintenance.

Conclusion

In conclusion, a preload of 67.5 lbs will be applied to the bolts. This preload will prevent joint separation and avoid yielding. A torque of 6.75 lb in is required to obtain this preload. A safety factor of 110 was calculated for yielding of the bolts.

Tabulated Results

Appendix Table L.1: Table of results for the main bolted joints calculations.

Parameter	Value
Minimum preload	48.2 lbs
Maximum preload	5194 lbs
Applied preload	67.5 lbs
Required torque	6.75 lb in
Factor of Safety in yielding	110

Appendix M. Cost Estimations

Table K1 provides a complete, detailed cost estimation for the final BeeBlade design including the cost of raw materials, off the shelf purchases and manufacturing cost. Shop time was estimated to be $120/hr and it was assumed that an individual can weld 150 inches in an 8-hour shift. The total cost of the spin float was determined to be $30,098.19 CAD.

Appendix Table M.1: Detailed cost analysis of the BeeBlade including raw materials, off the shelf purchases and manufacturing costs

Raw Materials				
Item Description	**Quantity**	**Unit Cost**	**Total Cost**	**Purpose**
3/8" x 55" x 55" 304 Stainless Plate	1	$1,870.59	$1,870.59	Inner drum top plate
0.190" x 52" x 52" Aluminum Sheet	1	$553.61	$553.61	Inner drum bottom ring
3/8" x 55" x 55" Aluminum Plate	1	$801.13	$801.13	Inner drum baffle plate
1/8" x 55" x 55" Aluminum Plate	1	$339.15	$339.15	Inner drum wax shield and top bolt ring
1/8" x 20" x 7" Aluminum Plate	2	$320.37	$640.74	Inner drum side wall
1/2" x 12" x 12" 304 Stainless	1	$155.13	$155.13	Inner drum mounting hub
1 1/2" x 3/4" x 1/8" Aluminum Rectangular Tube (10 ft.)	1	$56.80	$56.80	Honey flutes
1/8" x 12" x 24" Aluminum Plate	1	$37.93	$37.93	Honey drainage covers
1" 304 Stainless Shaft (36")	1	$254.50	$254.50	Blade drive shaft
1 3/4" 304 Stainless Shaft (36")	1	$452.24	$452.24	Drum drive shaft
1/8" x 12" x 105" Aluminum Plate	2	$150.16	$300.31	Outer drum large cylinder
1/8" x 15" x 96" Aluminum Plate	2	$313.35	$626.70	Outer drum small cylinder
1/8" x 36" x 36" Aluminum Plate	2	$154.07	$308.13	Outer drum collecting duct
1/8" x 60" x 60" Aluminum Plate	1	$339.15	$339.15	Outer drum frame mounting plate
1/4" x 72" x 96" Acrylic Sheet	1	$466.43	$466.43	Outer drum transparent top cover

1/4" x 3" x 3" A513 Steel Sq. Tube (230")	1	$310.21	$310.21	For frame stand structure	
1/4" x 4" x 4" A513 steel Sq tube (20")	1	$54.89	$54.89	For frame bearing mount structure	
1/32" x 12" x 24" 304 Stainless Sheet	1	$16.09	$16.09	Blade shroud	
1" ID Sched 40 x 2 ft. 304 Stainless Pipe	1	$32.24	$32.24	For mounting blades to shaft	
1/4" x 12" x 24" 304 Stainless Plate	3	$145.34	$436.03	Blade mounts and motor mounting plate	
1/4" x 2" x 2" 304 Stainless Sq. Tube (26")	1	$116.55	$116.55	Blade motor mount supporting bars	
1/4" x 35" x 34.5" 304 Stainless Plate	1	$563.03	$563.03	Drum motor mounting plate	
Raw materials subtotal			**$8371.58**		
Off the Shelf Purchases					
Item Description	**Quantity**	**Unit Cost**	**Total Cost**	**Description**	**Supplier**
Max Motion MPSP-506T 5 HP 3600 rpm Motor	1	$1,276.30	$1,276.30	Blade shaft drive motor	Motion Canada
4" Stainless Steel Blades	8	$70.00	$560.00	Wax cutting blades	Baucor
3.55" Cast Iron V-Belt Pulley (For 1 1/8 " Shaft)	1	$33.45	$33.45	Blade drive pulley (motor connection)	McMaster-Carr
6.25" Cast Iron V-Belt Pulley (For 1" Shaft)	1	$33.45	$33.45	Blade drive pulley (shaft connection)	McMaster-Carr
Blade Mechanism Adjustment Mechanism	1	$821.94	$821.94	Mechanism to adjust the blade position	McMaster-Carr
1/2" 304 Stainless Threaded Rod	1	$6.49	$6.49	Threaded rod for blade adjustment mechanism	McMaster-Carr
1/2" 304 Stainless Female Rod Ends	2	$26.39	$52.77	Rod ends for adjustment mechanism threaded rod	McMaster-Carr
Timken 1" Thrust Bearing	1	$338.35	$338.35	Thrust bearing for blade drive	The Timken Company

1" Food Grade Radial bearing	1	$123.82	$123.82	Radial bearing for blade drive	McMaster-Carr
B V-belt (45”)	1	$17.50	$17.50	V-belt for blade drive pulleys	Global Industrial
Max Motion MPSP-506T 5 HP 1200 rpm Motor	1	$1,518.00	$1,518.00	Drum shaft drive motor	Motion Canada
4.25" Cast Iron V- Belt Pulley (For 1 3/8" Shaft)	1	$49.05	$49.05	Drum drive pulley (motor connection)	McMaster-Carr
12.75" Cast Iron Pulley (For 1 7/16" Shaft)	1	$129.42	$129.42	Drum drive pulley (shaft connection)	McMaster-Carr
Timken 1 7/16" Thrust bearing	1	$380.66	$380.66	Thrust bearing for drum drive	The Timken Company
1 7/16" Food Grade McMaster-Carr Radial Bearing	1	$172.87	$172.87	Radial bearing for drum drive	McMaster-Carr
B V-belt (80”)	1	$22.50	$22.50	V-belt for drum drive pulleys	Global Industrial
316 Stainless Pipe, Nipples and Fittings Package	1	$460.01	$460.01	Inlet spout piping system	McMaster-Carr
Vibration Damping Routing Clamp	1	$7.65	$7.65	Inlet spout vibration damper	McMaster-Carr
Leeson 17444.00 VFD	1	$1,281.93	$1,281.93	VFD for drum drive motor	eMotors Direct
1/2” ID 304 Stainless Spacer (1”)	12	$21.89	$311.86	Spacers between inner drum baffle and top plates	McMaster-Carr
1/2” ID 304 Stainless Spacer (2”)	12	$34.73	$479.12	Spacers between inner drum wax shield and bottom ring	McMaster-Carr
Various 304 Stainless Bolts, Washers and Nuts	1	$244.00	$244.00	Various bolts, washers nuts for the 122 bolts in the assembly	Bolt Depot
Off the Shelf Components Subtotal			**$8321.15**		

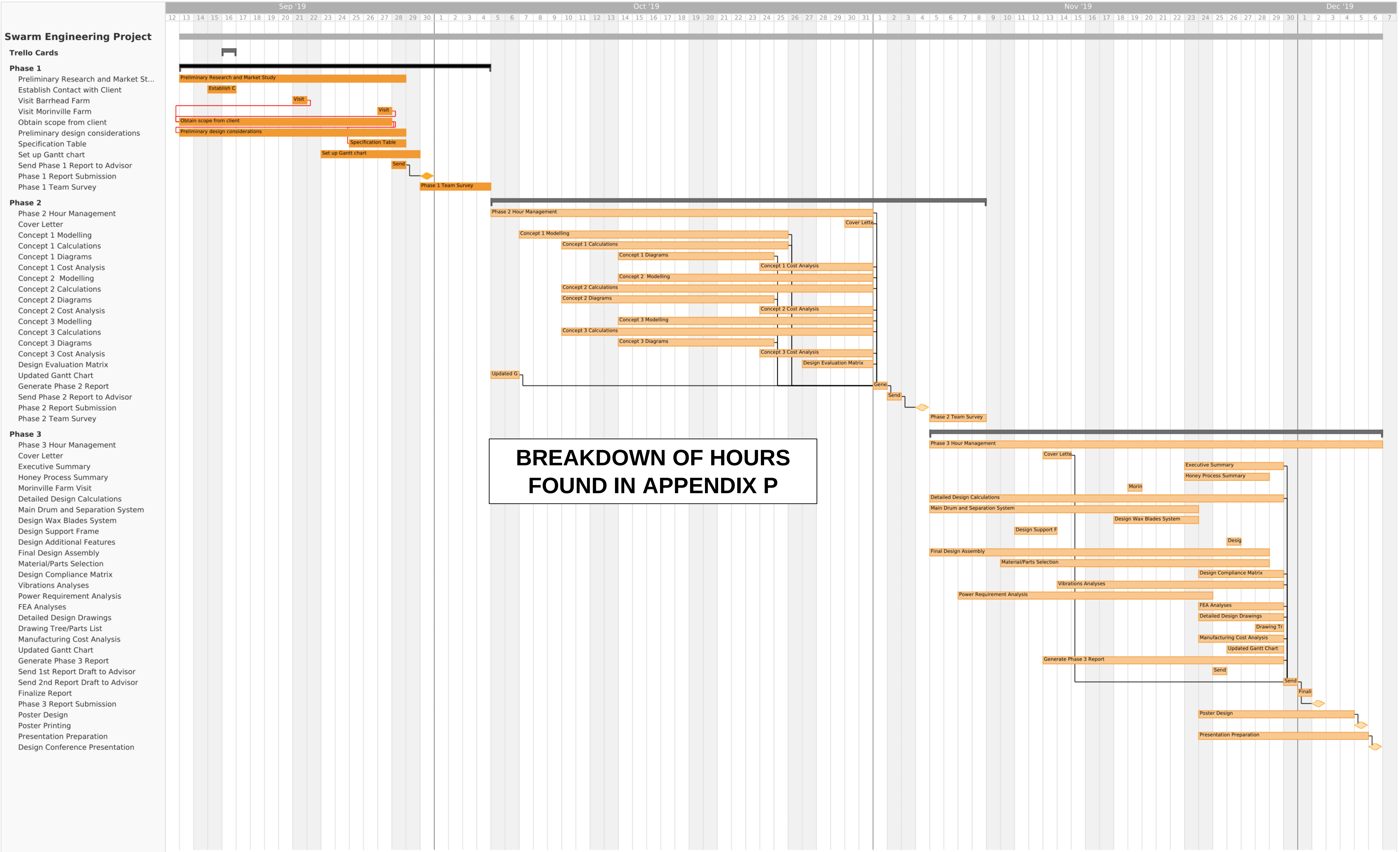
Manufactured Components

Part	Material	Quantity	Shop Time (hrs)	Inches of Welding	Total Cost	Required Work
Inner drum top plate	304 Stainless	1	1.5	-	$180.00	Water cutting
Inner drum bottom ring	3003 Aluminum	1	1	-	$120.00	Water cutting

Inner drum baffle plate	3003 Aluminum	1	1.5	-	$180.00	Water cutting
Inner drum top ring	3003 Aluminum	1	1	-	$120.00	Water cutting
Inner drum wax shield	3003 Aluminum	1	1	-	$120.00	Water cutting
Inner drum side wall	3003 Aluminum	1	3	-	$360.00	Cut to shape, roll to shape
Inner drum mounting hub	304 Stainless	1	0.75	-	$90.00	Water cutting
Honey flutes	3003 Aluminum	12	0.25	-	$360.00	Cut into lengths and drill holes
Honey drainage covers	3003 Aluminum	1	1.5	-	$180.00	Cut and bend pieces
Outer drum large cylinder	3003 Aluminum	1	2	-	$240.00	Cut to shape, roll to shape
Outer drum small cylinder	3003 Aluminum	1	2	-	$240.00	Cut to shape, roll to shape
Outer drum collecting duct	3003 Aluminum	1	1.5	-	$180.00	Water cutting
Outer drum frame mounting plate	3003 Aluminum	1	1	-	$120.00	Water cutting
Outer drum transparent top cover	Acrylic	1	1	-	$120.00	Laser cutting
Blade drive shaft	304 Stainless	1	1	-	$120.00	Stepping and keying
Drum drive shaft	304 Stainless	1	1	-	$120.00	Stepping and keying
Assembly frame	A513 Steel	1	1	-	$120.00	Cut into 12 lengths
Blade shroud	304 Stainless	1	0.5	-	$60.00	Bend to shape
For mounting blades to shaft	304 Stainless	1	1	-	$120.00	Fitting to blade drive shaft
Blade mounts	304 Stainless	8	1	-	$120.00	Bend to shape
Blade drive motor mounting plate	304 Stainless	1	1	-	$120.00	Water cutting
e	304 Stainless	1	1	-	$120.00	Water cutting
Blade adjustment mechanism	N/A	1	1		$120.00	Assembly of mechanism
TOTAL ASSEMBLY WELEDING REQUIRED	-	-	-	1339.9	$8,575.47	Total welds required in complete assembly
Manufacturing Costs Subtotal					**$13,045.47**	
GRAND TOTAL COST: $30,098.19						

Appendix N. Updated Gantt Chart

Below is the updated Gantt chart of the project. It has been revised since Phase 2 to provide a more accurate timeline for the different tasks. **These tasks correspond exactly to those outlined in appendices O and P, for a direct look at the hours required**. Please refer to Appendix P for more details on the division of hours and tasks. These details could not be added to the Gantt chart itself due to software limitations.



Appendix Figure N.1: Gantt chart of overall team progress.

Appendix O. Detailed Breakdown of Time Spent on Project

Below is a breakdown of the time spent by each member on Phase 3 of the report.

		Max		Cale		Aiden		Gabe		Udeshwar		William	total
05-Nov-19	4	Lecture/Meeti	4	Lecture/Meeti	4	Lecture/Meeti	4	Lecture/Meeti	4	Lecture/Meeti	4	Lecture/Meeti	24
06-Nov-19													0
07-Nov-19	4	Solid Modelin	4	Modeling/brai	4	Report Templ	4	Template refinement					16
08-Nov-19									8	Risk/Frame	8	Frame assesr	16
09-Nov-19			5	Solid Modeling									5
10-Nov-19													0
11-Nov-19													0
12-Nov-19	3	Meeting	3	Meeting	3	Meeting	3	Meeting	3	Meeting	3	Meeting	18
13-Nov-19													0
14-Nov-19													0
15-Nov-19	4	Report writing					8	Blade modelling			6	Blade Modelir	18
16-Nov-19													0
17-Nov-19													0
18-Nov-19	1	Lecture	1	Lecture	1	Lecture	1	Lecture	1	Lecture	1	Lecture	6
19-Nov-19	3	Meeting	3	Meeting	3	Meeting	3	Meeting	3	Meeting	3	Meeting	18
20-Nov-19													0
21-Nov-19					4	report writing							4
22-Nov-19													0
23-Nov-19			5	Parts Selectic	5	parts selection							10
24-Nov-19	5	FEA							4	Vibration Calcs			9
25-Nov-19	1	Lecture	1	Lecture	1	Lecture	1	Lecture	1	Lecture	1	Lecture	6
26-Nov-19	3	Meeting	3	Meeting	3	Meeting	3	Meeting	3	Meeting	3	Meeting	18
27-Nov-19	8	FEA											8
28-Nov-19	7	FEA	8	Cost Analysis			6	Blade force c	4	Vibration Calc	6	blade calc	31
29-Nov-19	8	FEA											8
30-Nov-19	12	FEA/Modeling	8	Report Writing	8	Report Writing	8	Report Writing	8	Vibration/ writ	8	Report Writing	52
01-Dec-19	6	report refinem	8	report refinem	8	report refinem	8	report refinem	8	report refinem	8	report refinem	46
02-Dec-19	5	report review	5	report review	5	report review	5	report review	5	report review	5	report review	30
03-Dec-19	4	Lecture/Meeti	4	Lecture/Meeti	4	Lecture/Meeti	4	Lecture/Meeti	4	Lecture/Meeti	4	Lecture/Meeti	24
04-Dec-19	4	Practice	4	Practice	4	Practice	4	Practice	4	Practice	4	Practice	24
05-Dec-19	4	Practice	4	Practice	4	Practice	4	Practice	4	Practice	4	Practice	24
06-Dec-19	3	Presentation	3	Presentation	3	Presentation	3	Presentation	3	Presentation	3	Presentation	18
Phase 3 Tota	89		73		64		69		67		71		433

Appendix Figure O.1: Time sheet of all group members for Phase 3

Appendix P. Engineering Hours

Table 17 illustrates the repartition of hours per task, as well as the members primarily assigned to each task. These tasks correspond to those shown in the Gantt chart in Appendix N.

Appendix Table P.1: Breakdown of project tasks and associated engineering hours.

Project Section	Task	Assigned To	Estimated Hours	Actual Hours
Phase 1: Design Specification	Meetings	All members	36	42
	Preliminary Research and Market Study	All members	18	20
	Establish Contact with Client	Maximilian	2	2
	Visit Barrhead Farm	Aiden, Maximilian, Udeshwar	12	12
	Visit Morinville Farm	Aiden, Cale, Gabriel, Maximilian, William	25	20
	Obtain Scope from Client	All members	4	6
	Preliminary Design Considerations	All members	16	22
	Specification Table	Aiden, Udeshwar	3	8
	Set up Gantt Chart	Gabriel	2	6
	Phase 2 Report Writing/Review	All members	12	18
	SUBTOTAL		**130**	**156**
Phase 2: Conceptual Designs	Meetings	All members	102	108
	Cover Letter/Executive Summary	Maximilian, Aiden	4	6
	Concept 1 Modelling	Gabriel, William	6	12
	Concept 1 Calculations	Maximilian, William	12	20
	Concept 1 Diagrams	Maximilian, Gabriel	4	5
	Concept 1 Cost Analysis	Cale, Udeshwar	6	8
	Concept 2 Modelling	William	4	8

Phase 2: Conceptual Designs	Concept 2 Calculations	Maximilian, William	6	8
	Concept 2 Diagrams	William	4	4
	Concept 2 Cost Analysis	Cale, William	4	6
	Concept 3 Modelling	Cale	2	4
	Concept 3 Calculations	Aiden, Cale	6	10
	Concept 3 Diagrams	Aiden, Cale	4	4
	Concept 3 Cost Analysis	Cale	4	5
	Design Evaluation Matrix	All members	28	32
	Phase 2 Hour Management	Gabriel, Udeshwar	2	2
	Gantt Chart Update	Gabriel	5	7
	Phase 2 Report Generation	All members	60	60
	Phase 2 Report Review	All members	24	24
	SUBTOTAL		**287**	**333**
Phase 3: Final Design	Meetings	All members	72	72
	Cover Letter	Maximilian	1	1
	Executive Summary	All members	2	2
	Honey Process Summary	Maximilian	2	2
	Morinville Farm Visit	Maximilian, William	-	6
	Design Compliance Matrix	Aiden	5	2
	Detailed Design Calculations	All members	50	53
	Drawing Tree/Parts List	Gabriel	2	3
	Manufacturing Cost Analysis	Cale	4	5
	FEA Analysis	Maximilian	12	10
	Main Drum and Separation System	All members	30	42
	Support Frame	Gabriel	1	2
	Additional Features	Aiden, Cale	2	2
	Final Design Assembly	All members	4	6

Phase 3: Final Design	Detailed Design Drawings	All members	30	23
	Material/Parts Selection	All members	10	10
	Phase 3 Hour Management	Gabriel, Udeshwar	4	4
	Gantt Chart Update	Gabriel	1	8
	Phase 3 Report Generation	All members	40	49
	Phase 3 Report Review	All members	15	12
	Poster Design	All members	35	35
	Poster Printing	Gabriel	1	1
	Presentation Preparation	All members	40	40
	Design Conference Presentation	All members	3	3
	Blade Design	William, Gabriel	-	2
	Blade Cutting Force	Cale, William, Aiden, Gabriel	-	18
	Shaft Analysis	Cale, Udeshwar	-	8
	Mechanical Vibration	Udeshwar	-	12
	SUBTOTAL		366	433
Overall Project	TOTAL		783	922

Appendix Q. Motor Specification Sheets

Below are the specification sheets for the two AC motors selected for the BeeBlade.

PRODUCT INFORMATION PACKET

marathon® Motors

Model No: 184TTWD16004
Catalog No: N486A
5,3600,TEFC,184TC,3/60/230/460
Washdown Duty

REGAL®

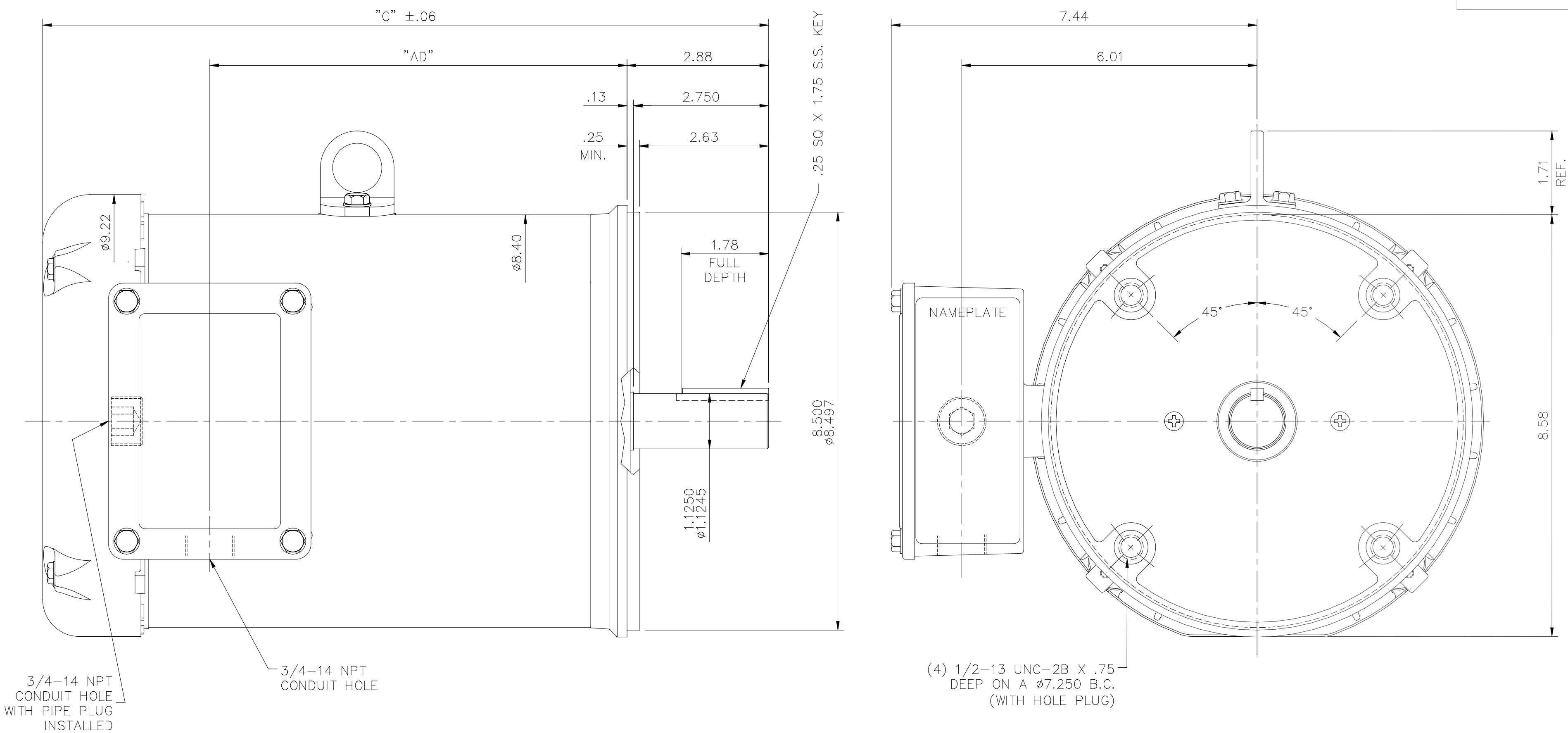
Nameplate Specifications

Output HP	**5 HP**	Output KW	**3.7 kW**
Frequency	**60 Hz**	Voltage	**230/460 V**
Current	**12.0/6.0 A**	Speed	**3495 RPM**
Service Factor	**1.15**	Phase	**3**
Efficiency	**88.5 %**	Duty	**Continous**
Insulation Class	**F**	Design Code	**B**
KVA Code	**J**	Frame	**184TC**
Enclosure	**Totally Enclosed Fan Cooled**	Overload Protector	**No**
Ambient Temperature	**40 °C**	Drive End Bearing Size	**6207**
Opp Drive End Bearing Size	**6207**	UL	**Recognized**
CSA	**Y**	CE	**Y**
IP Code	**56**		

Technical Specifications

Electrical Type	**Squirrel Cage Inverter Rated**	Starting Method	**Line Or Inverter**
Poles	**2**	Rotation	**Reversible**
Mounting	**Round**	Motor Orientation	**Horizontal**
Drive End Bearing	**Ball**	Opp Drive End Bearing	**Ball**
Frame Material	**Stainless Steel**	Shaft Type	**T**
Overall Length	**15.27 in**	Frame Length	**9.50 in**
Shaft Diameter	**1.125 in**	Shaft Extension	**2.88 in**
Assembly/Box Mounting	**F1 Only**		
Outline Drawing	**035438ME-950**	Connection Diagram	**005010.01**

035438ME



MAXIMUM FACE RUNOUT TO BE .004 T.I.R.
MAXIMUM PILOT ECCENTRICITY TO BE .004 T.I.R.
PERMISSIBLE SHAFT RUNOUT TO BE .002 T.I.R.

SPECIAL FEATURES:
1) DOUBLE LIP OIL SEALS BOTH ENDS
2) GASKETS THROUGHOUT
3) O-RING SEALED ENDBELLS & THRU BOLTS
4) LOCKED BEARING W/SEALED LOCK SCREWS

DASH NO.	"C"	"AD"
850	14.27	7.99
900	14.77	8.49
950	15.27	8.99
1000	15.77	9.49

NO.	REVISION	BY & DATE	CHK
02	ADDED DASH # 1000	LK 11/27/15	GR
01	ADDED DASH # 850	PVR 03/25/14	JD

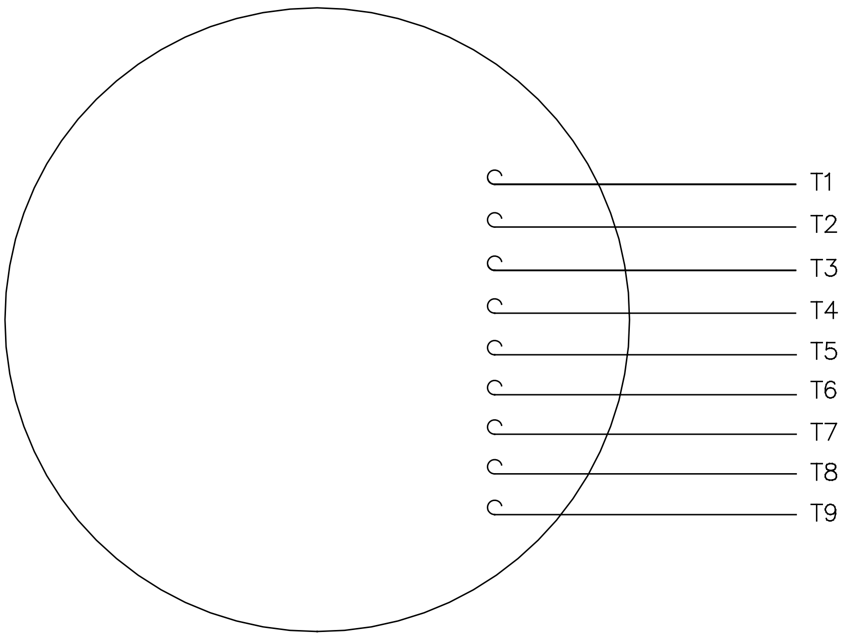
TOLERANCES UNLESS SPECIFIED	
DEC.	INCHES
.X	±.1
.XX	±.03
.XXX	±.005
.XXXX	±.0005
ANG	±1/2°

MARATHON ELECTRIC

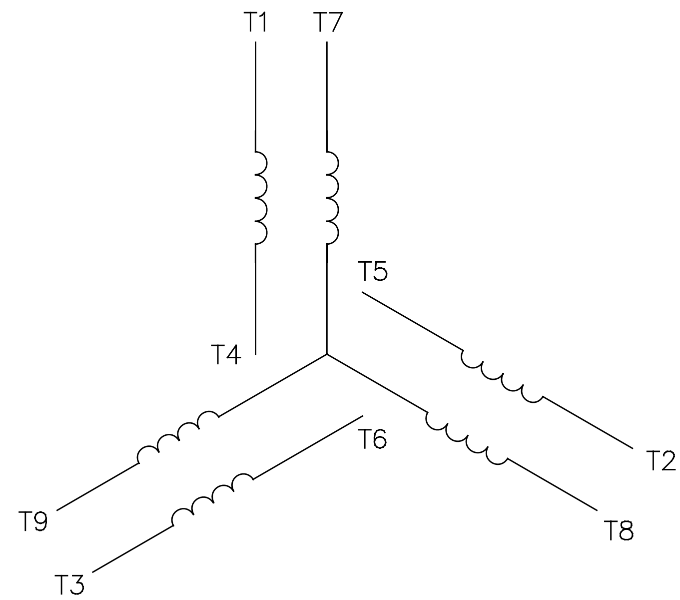
TITLE	OUTLINE – 180TC FRAME TEFC – "C" FACE
MAT'L.	STAINLESS STEEL DUCK
FINISH	
CAD FILE	035438ME
SIZE	B
DRAWING NO.	035438ME
REV.	02
DRAWN	TJW 7/6/2007
CHK	ML 7/6/2007
APPD	GK 7/6/2007
SCALE	1=2
REF	
FMF	
PREV	
RFP	
DIST	NLV

005010−01

VIEW FROM OUTSIDE OF MOTOR AT SWITCH END.



LINE LEADS



VOLTAGE	L1	L2	L3	JOIN & INSULATE
HIGH	T1	T2	T3	(T4,T7) (T5,T8) (T6,T9)
LOW	T1,T7	T2,T8	T3,T9	T4,T5,T6

NO.	REVISION	BY & DATE	CHK
A	UPDATED TO REGAL LOGO	SAJ 06/26/15	AJY

TOLERANCES UNLESS SPECIFIED

DEC.	INCHES
.X	±.1
.XX	±.01
.XXX	±.005
.XXXX	±.0005
ANG	±1/2°

REGAL™ Regal Beloit America, Inc.

TITLE EXTERNAL WIRING DIAGRAM 3 PHASE W/O PROTECTOR

MAT'L. DECAL − 004014

FINISH

DRAWN RDW 04/12/02

CHK

APPD

SCALE 1=1

REF FIG.2−51

FMF

PREV

RFP 04/12/02

DIST BRF−NLV

CAD FILE 00501001

SIZE A

DRAWING NO. 005010−01

REV. A

CERTIFICATION DATA SHEET

Model#:	184TTWD16004 AA	**WINDING#:**	T82103 R1 3
CONN. DIAGRAM:	005010.01	**ASSEMBLY:**	F1 ONLY
OUTLINE:	035438ME-950		

TYPICAL MOTOR PERFORMANCE DATA

HP	KW	SYNC. RPM	F.L. RPM	FRAME	ENCLOSURE	KVA CODE	DESIGN
5&3	3.70&2.24	3600	3495&2920	184TC	TEFC	J	B

PH	Hz	VOLTS	FL AMPS	START TYPE	DUTY	INSL	S.F	AMB°C	ELEVATION
3	60/50	230/460#190/380	12/6&9.2/4.6	LINE OR INVERTER	CONTINUOUS	F4	1.15/1.0	40	3300

FULL LOAD EFF: 88.5&87.5	3/4 LOAD EFF: 89.1	1/2 LOAD EFF: 87.9	GTD. EFF	ELEC. TYPE	NO LOAD AMPS
FULL LOAD PF: 89.5&86	**3/4 LOAD PF: 87.5**	**1/2 LOAD PF: 81.1**	86.2	SQ CAGE INV RATED	3.4 / 1.7

F.L. TORQUE	LOCKED ROTOR AMPS	L.R. TORQUE	B.D. TORQUE	F.L. RISE°C
7.5 LB-FT	92 / 46	16 LB-FT 213	26 LB-FT 347	55

SOUND PRESSURE @ 3 FT.	SOUND POWER	ROTOR WK^2	MAX. WK^2	SAFE STALL TIME	STARTS /HOUR	APPROX. MOTOR WGT
75 dBA	85 dBA	0.3 LB-FT^2	13 LB-FT^2	15 SEC.	2	125 LBS.

*** SUPPLEMENTAL INFORMATION ***

DE BRACKET TYPE	ODE BRACKET TYPE	MOUNT TYPE	ORIENTATION	SEVERE DUTY	HAZARDOUS LOCATION	DRIP COVER	SCREENS	PAINT
C-FACE	STANDARD	ROUND	HORIZONTAL	FALSE	NONE	FALSE	NONE	NO PAINT

BEARINGS		GREASE	SHAFT TYPE	SPECIAL DE	SPECIAL ODE	SHAFT MATERIAL	FRAME MATERIAL
DE	**OPE**						
BALL 6207	BALL 6207	POLYREX EM	T	NONE	NONE	303 STAINLESS (C-501)	STAINLESS STEEL

THERMO-PROTECTORS				THERMISTORS	CONTROL	SPACE /n HEATERS
THERMOSTATS	**PROTECTORS**	**WDG RTDs**	**BRG RTDs**			
NONE	NOT	NONE	NONE	NONE	FALSE	NONE VOLTS

If Inverter equals NONE, contact factory for further information

*
N
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T
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*

INVERTER TORQUE: CONSTANT 3:1
INV. HP SPEED RANGE: NONE

ENCODER: NONE
NONE NONE
NONE NONE PPR

BRAKE: NONE NONE
NONE P/N NONE
NONE NONE
NONE FT-LB NONE V NONE Hz

DATE: 06/28/2017 07:44:30 AM
FORM 3531 REV.3 02/07/99
** Subject to change without notice.

Data Sheet

Date:	29-06-2017
Customer:	
Attention:	
Submitted by:	FAREEDA DUDEKULA

marathon® electric

184TTWD16004

Submittal

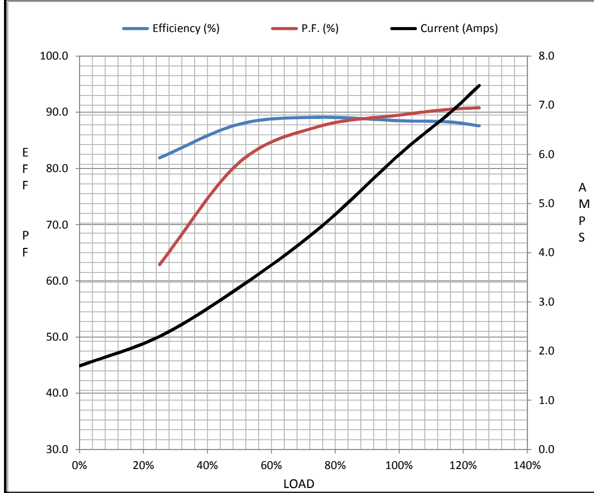
Data @ 460 V

Motor Load Data

Load	0%	25%	50%	75%	100%	115%	125%	LR	
Current (Amps)	1.70	2.30	3.3	4.5	6.0	6.8	7.4	46.0	
Torque (ft-lb)	0.00	1.80	3.7	5.6	7.5	8.7	9.5	16.0	
RPM	3600	3576	3551	3526	3495	3,477	3463	0	
Efficiency (%)		81.9	87.9	89.1	88.5	88.3	87.6		
P.F. (%)	12.5	62.9	81.1	87.5	89.5	90.5	90.8	45.5	

Motor Speed Data

	LR	Pull-Up	BD	Rated	Idle
Speed (RPM)	0	170	2850	3495	3600
Current (Amps)	46.0	47.0	30.0	6.0	1.70
Torque (ft-lb)	16.0	15.5	26.0	7.5	0.00



Information Block

HP	5.0	
Sync. RPM	3600	
Frame	180	
Enclosure	TEFC	
Construction	TFW	
Voltage	230/460#190/38(V	
Frequency	60	Hz
Design	B	
LR Code letter	J	
Service Factor	1.15	
Temp Rise @ FL	55	° C
Duty	CONT	
Ambient	40	° C
Elevation	1,000	feet
Rotor/Shaft wk²	0.30	Lb-Ft²
Ref Wdg	T82103 R1	
Sound Pressure @ 1M	75	dBA
VFD Rating	CONSTANT 3:1	
Outline Dwg	035438ME-950	
Conn. Diag	005010.01	

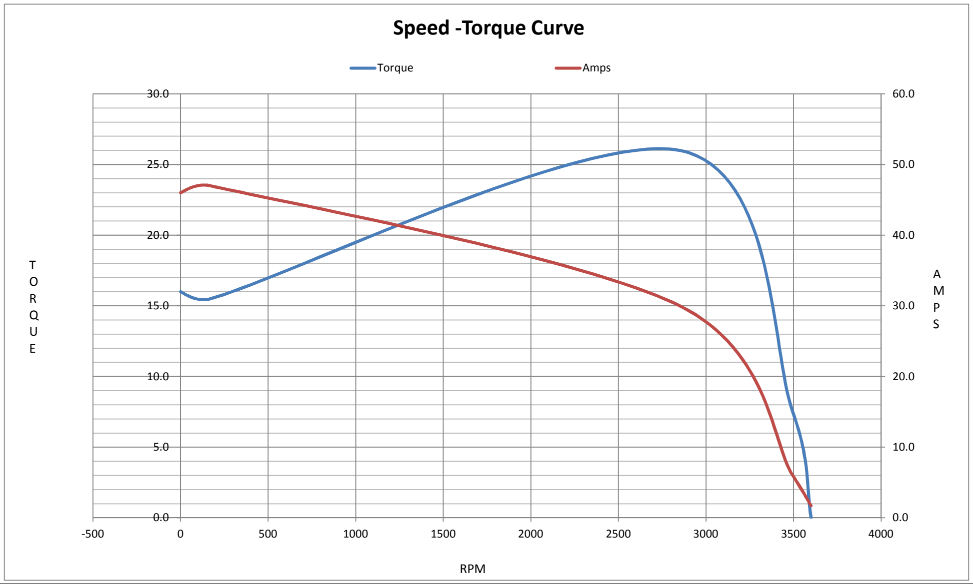
Additional Specifications:

0

365THFS8036

EQUIV CKT (OHMS / PHASE)

R1	R2	X1	X2	Xm
1.3920	1.1300	4.8110	1.8460	124.9600



PERFORMANCE DATA SHEET
EPACT NR CAN NEMA 12 - 11

MEP — MaxMotion

Catalogue #: MQS-506T

HP	kW	Voltage	S.F. @ 60Hz	EFF.	P.F.	Frame	Design	L.R. Amps
5	3.73	230/460	1.15	87.5%	0.74	215TC	B	46

60 Hz								
FLA							Code	F.L. RPM
208	230	416	460	480	575	600		
15.6	14.2	7.8	7.1	6.8	/	/	J	1170

50 Hz								
FLA			S.F. @ 50Hz		Efficiency	Power Factor	Code	F.L. RPM
190	380	415						
17.0	8.5	7.8	1.00		85.5%	0.78	G	960

Wgt. Lbs	PH	Duty	Insul. Class	Amb.	Elevation	Temp. Rise° C
162	3	Cont.	F	40°C	1000M (3300 Ft)	< 80

% Efficiency		% Power Factor		Torque			
Full Load:	87.5%	Full Load:	0.74	Full Load Ft/Lbs	22.5	Winding Resist. Ω	Safe Cold Start (Secs)
3/4 Load:	87.0%	3/4 Load:	0.65	Locked Rotor %	250		
1/2 Load:	85.0%	1/2 Load:	0.51	Break Down %	290	0	20

Rotor Inertia Wk2 Lb-Ft2	Max Load Inertia Wk2 Lb-Ft2	Shaft Material	Frame Material	DE Bracket Type	ODE Bracket Type	Enclosure	NEMA Rating	Lead Wire Size
0.81	100	Standard	Rolled Steel	Standard	Standard	TEFC	IP65	14 AWG

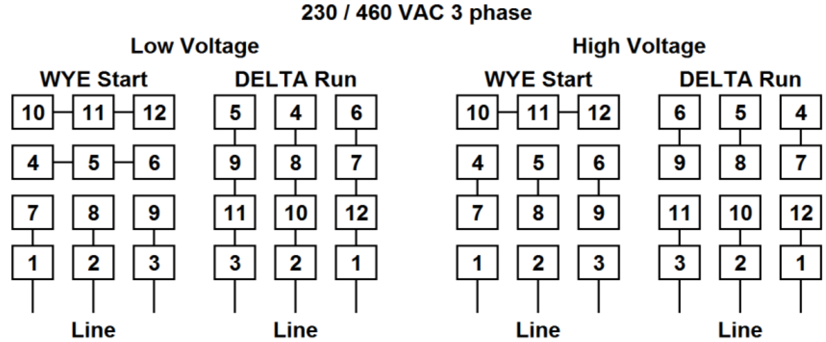
Ball Bearings		Grease	Mount Type	Orientation	Paint	Sound Pressure @ 3FT	Sound Power
DE	ODE						
6308	6308	Sealed Bearings	Rigid	Horizontal	Stainless Stee	61	71

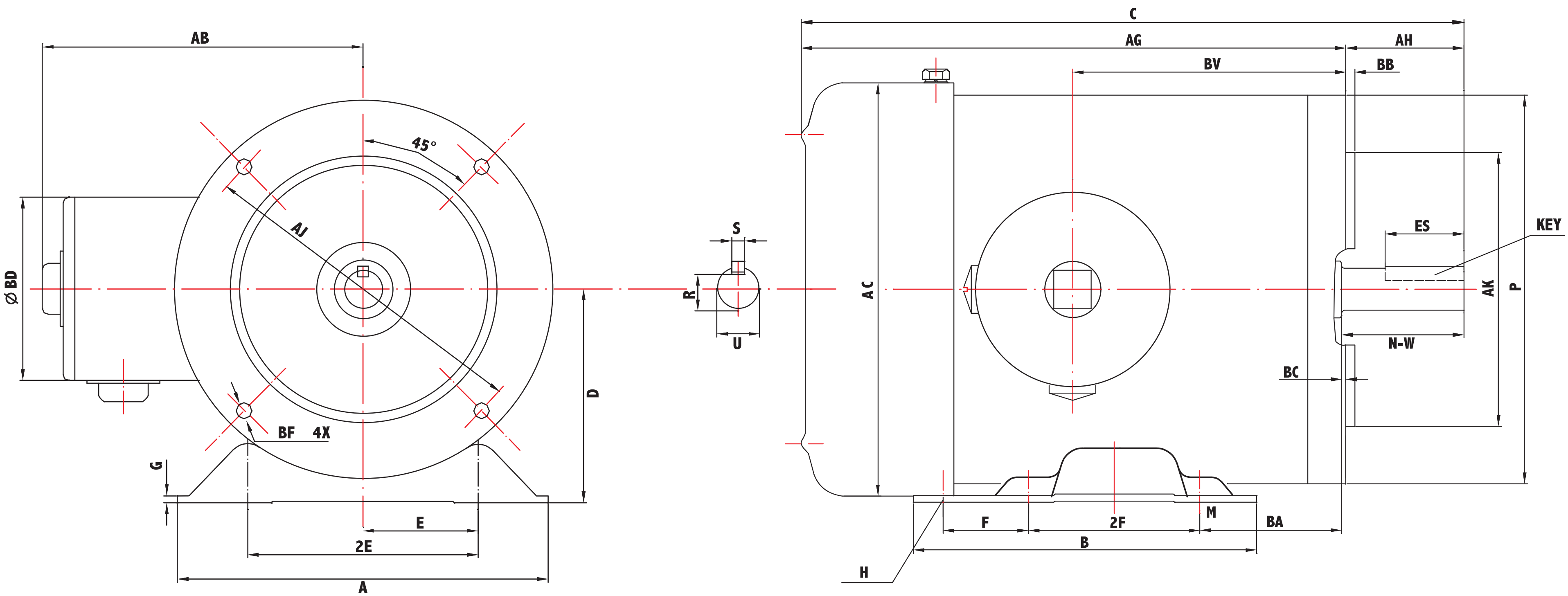
Inverter Duty. Motor meets MG1 parts 31.4.4.2	Constant Torque Range	Variable Torque Range	Constant HP RPM
	10:1	20:1	1800

WIRING CONNECTION DIAGRAM : B

213T - 405T, Dual Voltage, 12 Leads Connection

230 / 460 VAC 3 phase





Frame	MOUNTING						CONDUIT BOX			MOTOR DIMENSIONS SHAFT EXENSION KEY SEAT																		BRG	
	E	2E	2F	F	H	BA	AB	BD	BV	A	B	C	D	G	R	S	U	P	AH	AG	AJ	AK	BB	BC	BF	ES	N-W	DE	ODE
215TC	5.25	10.5	7.00	0.00	0.41	4.25	7.52	3.95	11.1	9.60	8.10	22.3	5.25	0.157	1.201	0.312	1.375	10.0	3.12	19.18	7.25	8.50	0.25	0.25	1/2'-13	2.41	3.38	6308	6208

MaxMotion

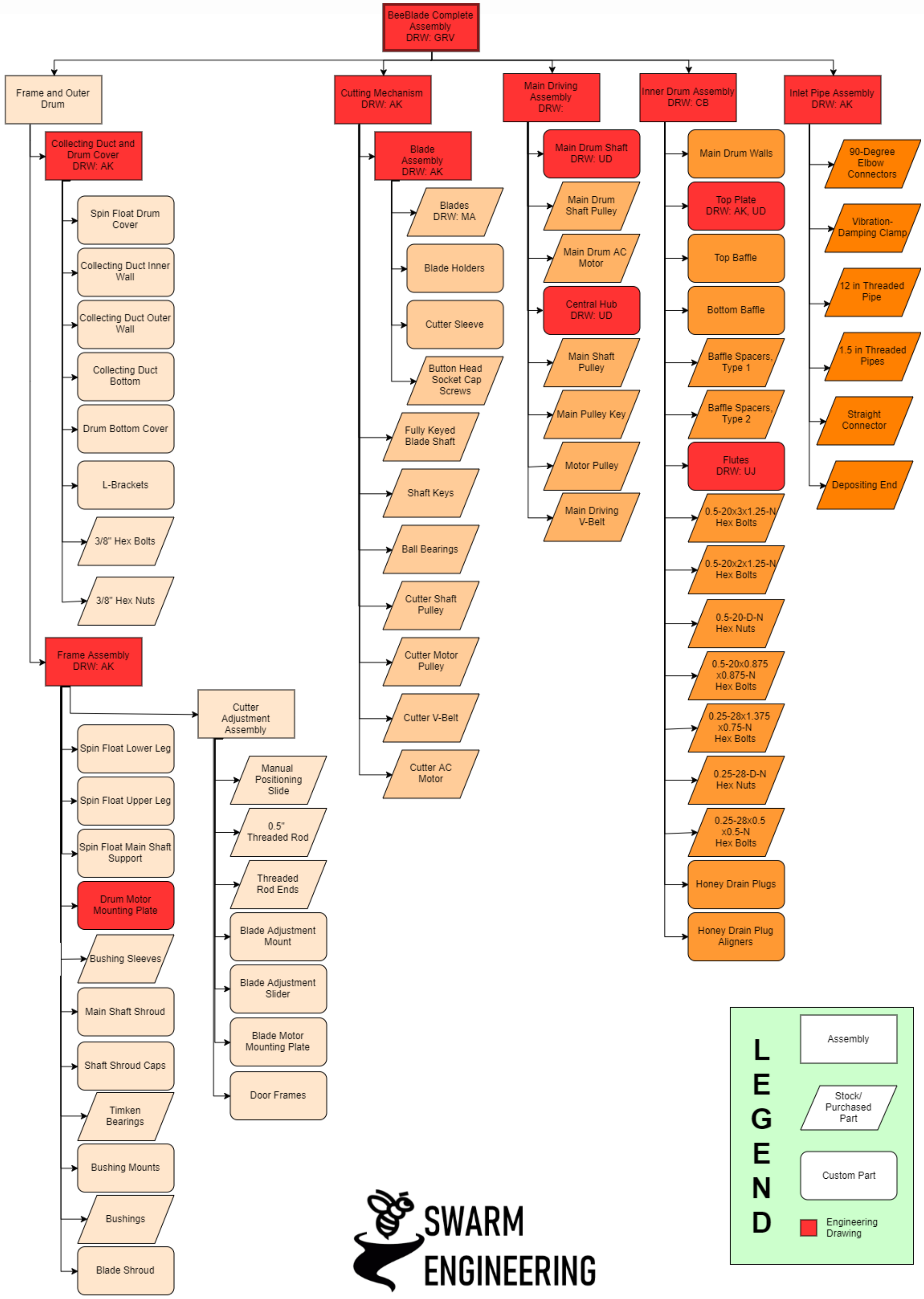
Stainless Steel TEFC Outline 210TC

Measurements are in inches. Drawing is not certified, please contact factory for certification.

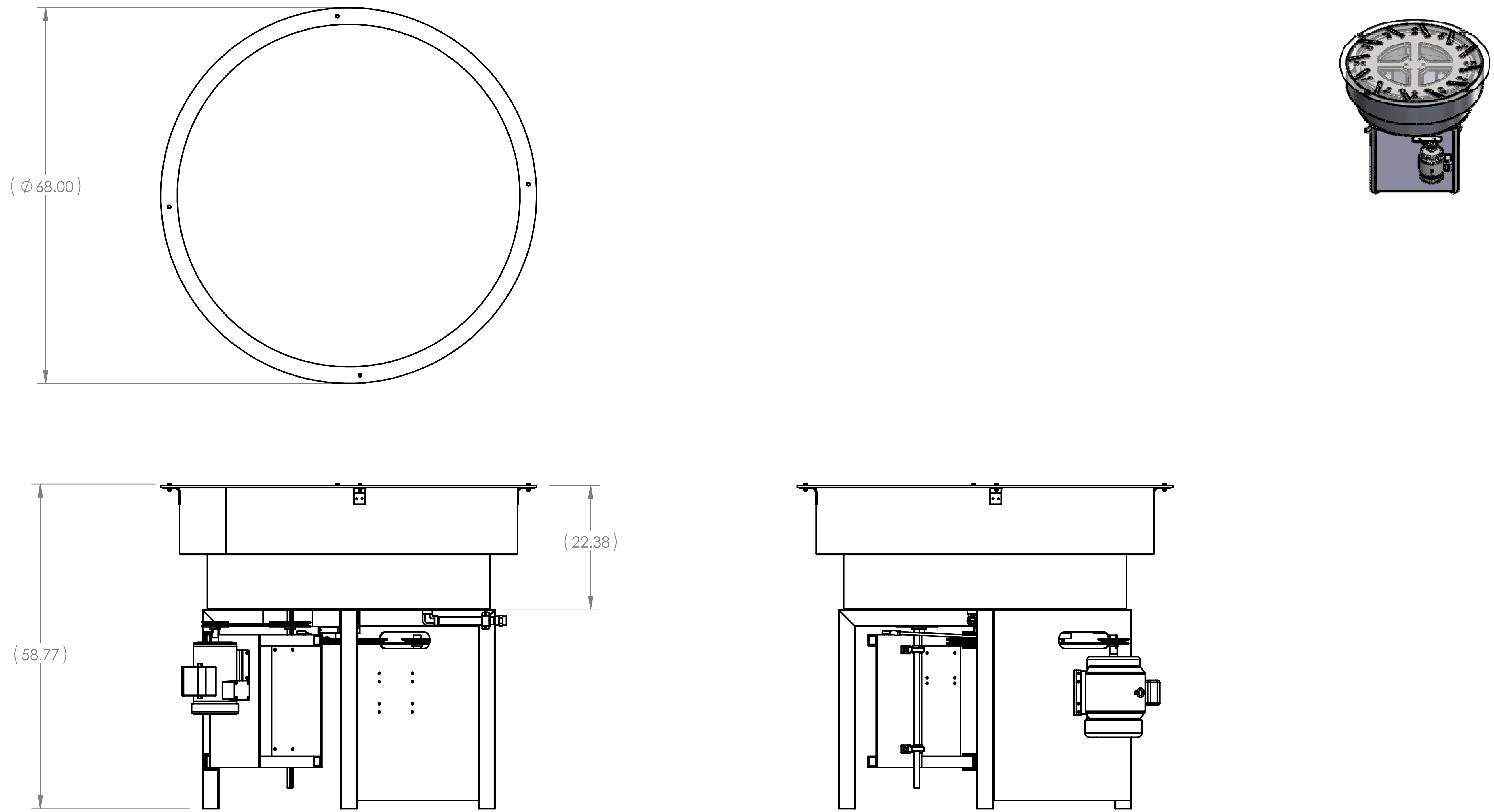
www.mep.ca

Appendix R. Detailed Engineering Drawings

Engineering drawings were made for assemblies and five critical parts. Appendix Figure R.1 outlines the overall assembly hierarchy. The following pages contain the drawings.



Appendix Figure R.1: Drawing tree of BeeBlade assembly.



UNLESS OTHERWISE SPECIFIED:	Description:
DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ± 0.5° LINEAR X.X = ± 0.05 X.XX = ± 0.005 X.XXX = ± 0.001 SURFACE FINISH µin 24 DO NOT SCALE DRAWING	Project: BEEBLADE SPIN FLOAT Comments: REVIEWED BY: MAXIMILIAN AISENSTAT Drawing Last Saved: Sunday, December 1, 2019 7:19:07 PM
MATERIAL:	SM Last Saved: Sunday, December 1, 2019 7:19:06 PM
FILE NAME: Complete Assembly November 28, 2019V2	

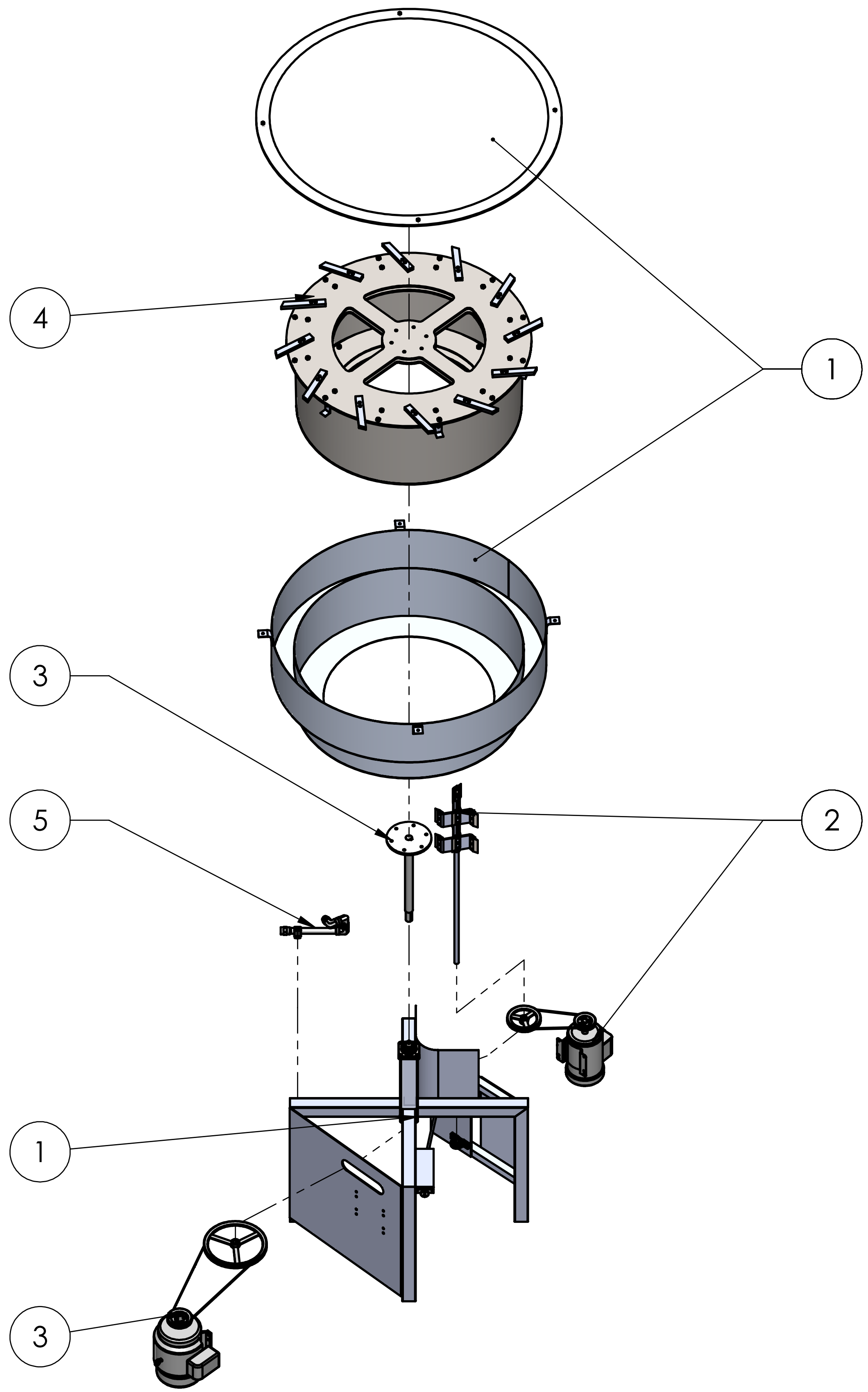
SWARM ENGINEERING

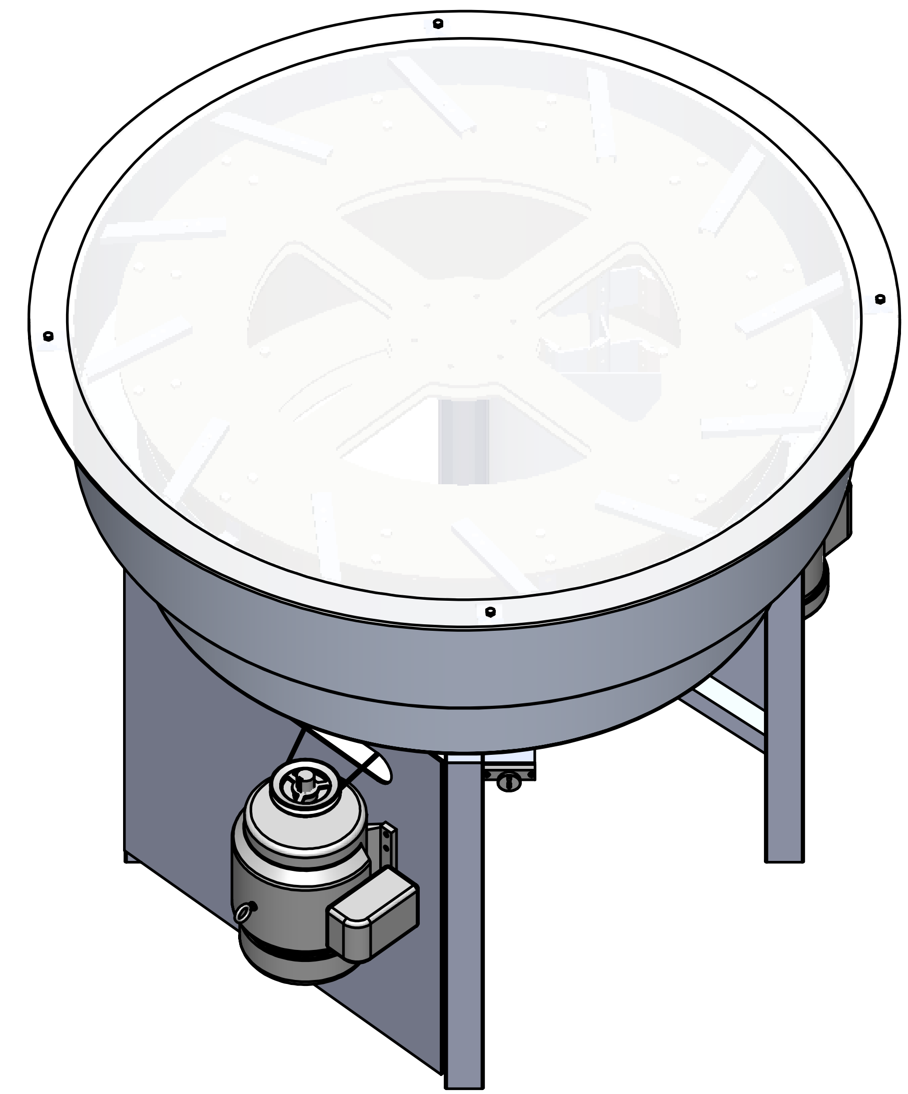
Part Number

TITLE: SPIN FLOAT ORTHOGONAL VIEW

SIZE	DRAWN BY:	AIDEN KOOYMAN	REV
B	SM By:	WILLIAM HAMMOND	0
SCALE: 1:20	Mass: (lbs)		SHEET 1 OF 1

ITEM NO.	PART NUMBER	QTY.
1	FRAME AND OUTER DRUM	1
2	CUTTING BLADE MECHANISM	1
3	MAIN DRIVING ASSEMBLY	1
4	INNER DRUM ASSEMBLY	1
5	INLET PIPE ASSEMBLY	1





UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X.X = ± 0.05
X.XX = ± 0.005
X.XXX = ± 0.001
SURFACE FINISH μin 24
DO NOT SCALE DRAWING
MATERIAL:

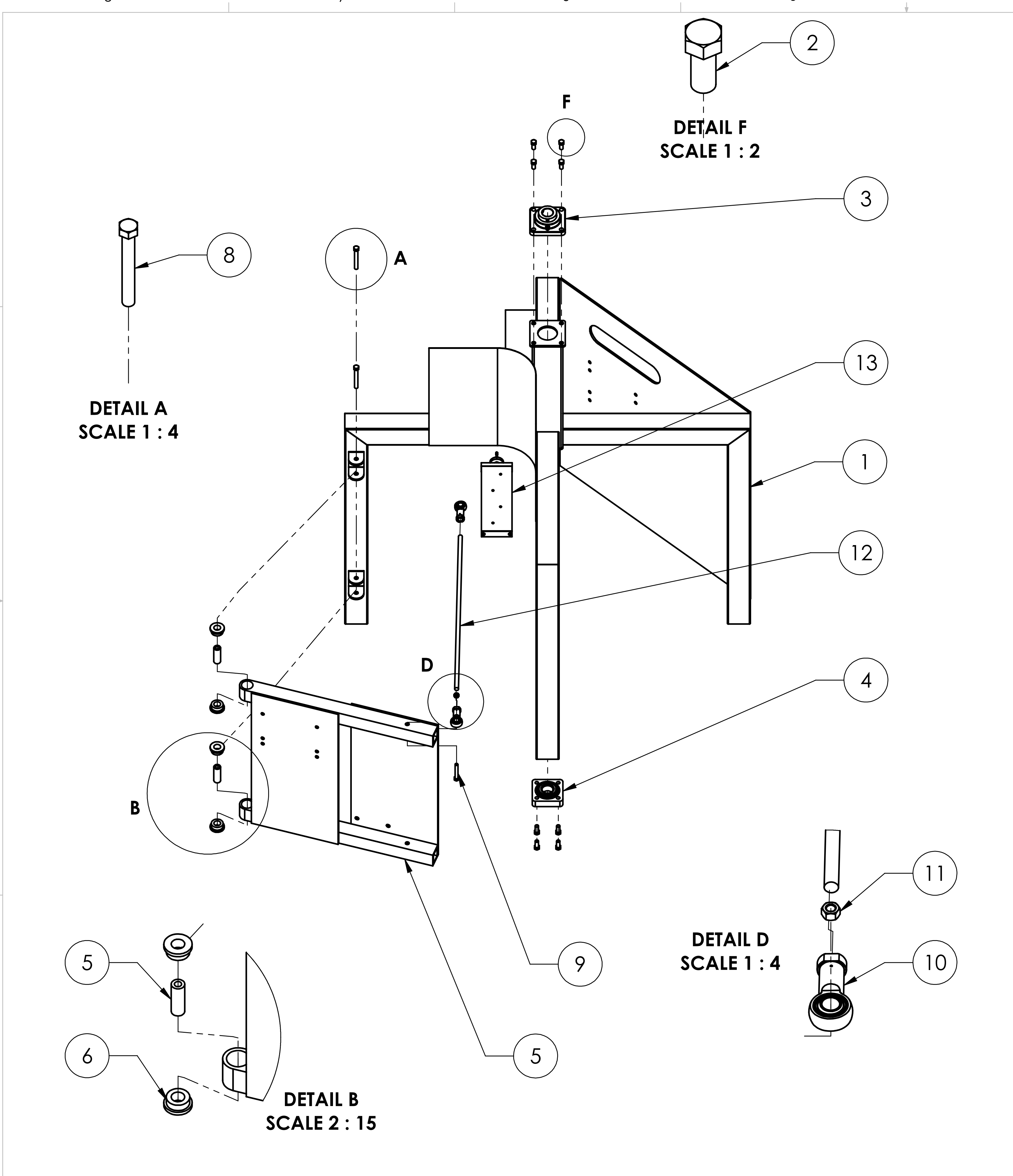
Description: High-level look at the device's subassemblies
Project: BeeBlade
Comments:
Drawing Last Saved: Sunday, December 1, 2019 5:53:31 PM
SM Last Saved: Sunday, December 1, 2019 5:53:30 PM
FILE NAME: Complete Assembly November 28, 2019V2

SWARM ENGINEERING

Part Number

TITLE: Complete BeeBlade Assembly

SIZE	DRAWN BY:	Gabriel Risbud-Vincent	REV
B	SM By:	Aiden Kooyman	
SCALE: 1:20	Mass: (lbs)		SHEET 1 OF 1



ITEM NO.	PART NAME	DESCRIPTION	QTY.
1	Main Frame	Individual components welded together	1
2	HBOLT 0.4375 20X1X1	304 Stainless Steel	8
3	1 7/16 Food Grade Radial Bearing and Housing		1
6	1 7/16 Food Grade Thrust Bearing and Housing		1
5	Pivoting Motor Mount		1
6	Hinge Bushing		4
7	Stainless Steel Hinge Pin		2
8	HBOLT 0.4375 20X3.5X1	304 Stainless Steel	2
9	HBOLT 0.3750 16X2.5X1		1
10	Swiveling Female Mechanism		2
11	0.3750 HEX NUT		1
12	0.5" Adjustment Rod		1
13	Blade Adjustment Mechanism		1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X.X = ± 0.05
X.XX = ± 0.005
X.XXX = ± 0.001
SURFACE FINISH µin 24
DO NOT SCALE DRAWING
MATERIAL:

Description:
Project: BEEBLADE Spin Float
Comments:
REVIEWED BY: CALE BENKO
Drawing Last Saved: Monday, December 2, 2019 12:08:17 AM
SM Last Saved: Monday, December 2, 2019 12:08:17 AM

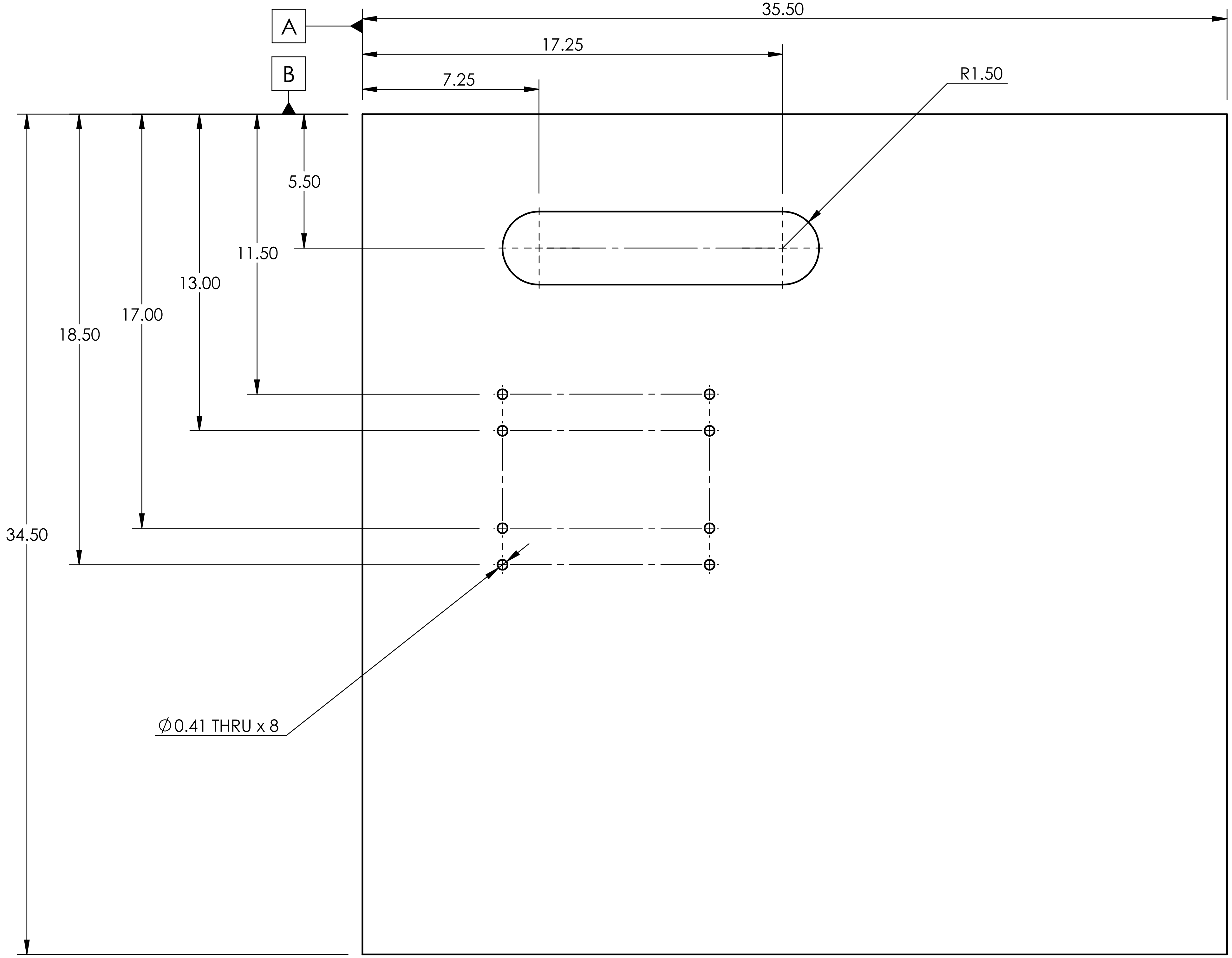
FILE NAME: Frame and Outer Drum November 28, 2019

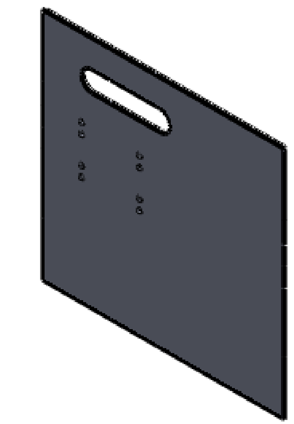
SWARM ENGINEERING

Part Number

TITLE: ISOMETRIC EXPLODED VIEW OF FRAME ASSEMBLY

SIZE B | DRAWN BY: AIDEN KOOYMAN | REV 0
SM By: WILLIAM HAMMOND
SCALE: 1:15 | Mass: (lbs) | SHEET 1 OF 1





Made from 1/4" A513 Steel Plate
Edges will be ground for welding to frame

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X.X = ± 0.05
X.XX = ± 0.005
X.XXX = ± 0.001

SURFACE FINISH 24 µin

DO NOT SCALE DRAWING

MATERIAL:
A513 Steel

FILE NAME:
Main_Frame_Cover

Description:
Drum mounting cover welded to frame

Project:
BeeBlade Spin-Float

Comments:
Reviewed by: Cale Benko

Drawing Last Saved:
Monday, December 2, 2019 3:52:25 AM

SM Last Saved:
Monday, December 2, 2019 3:46:57 AM

SWARM ENGINEERING

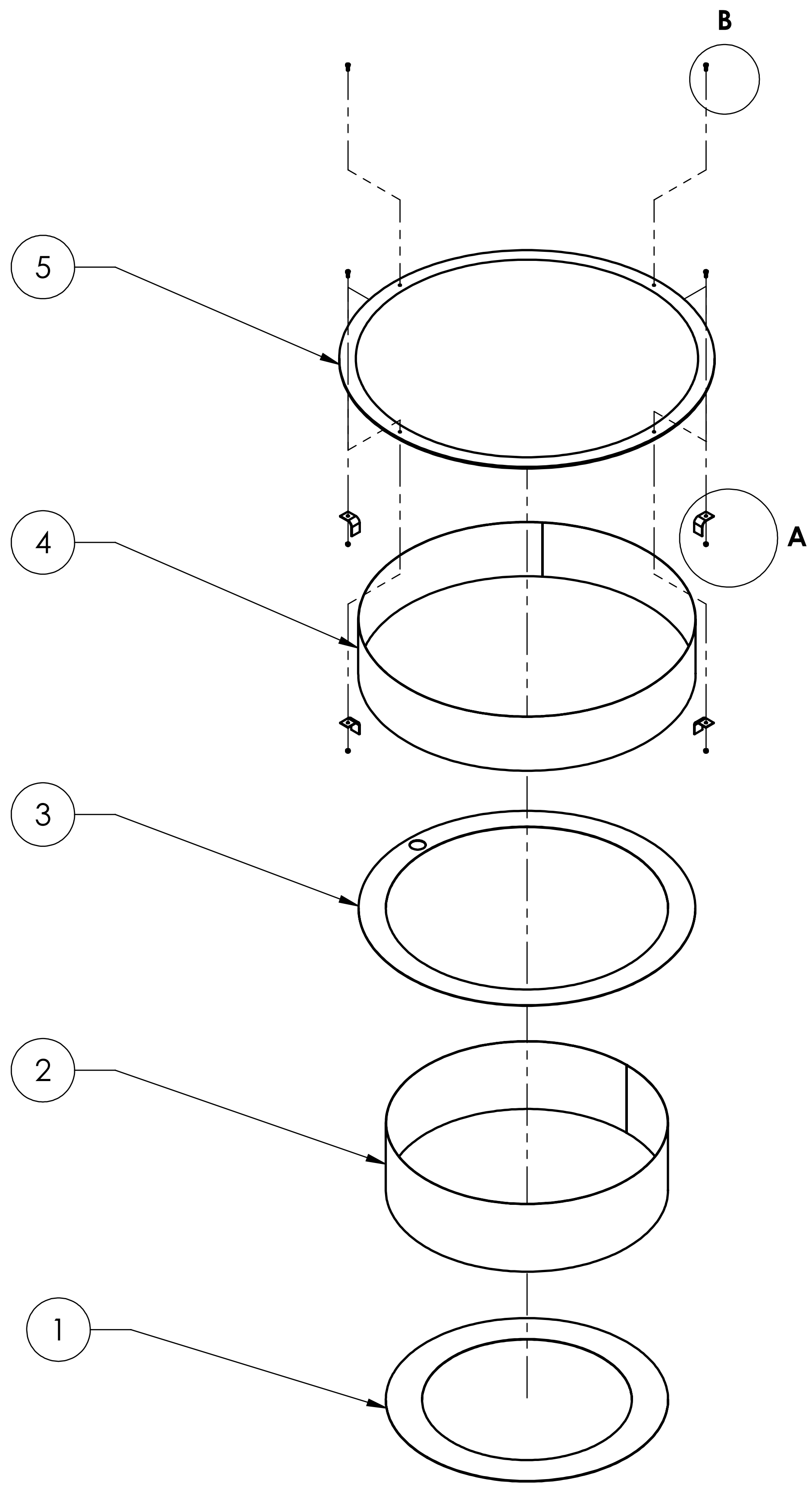
Part Number

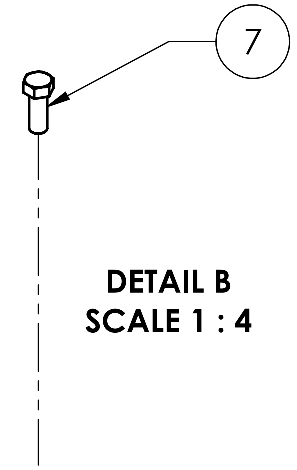
TITLE:

Drum Motor Mounting Plate

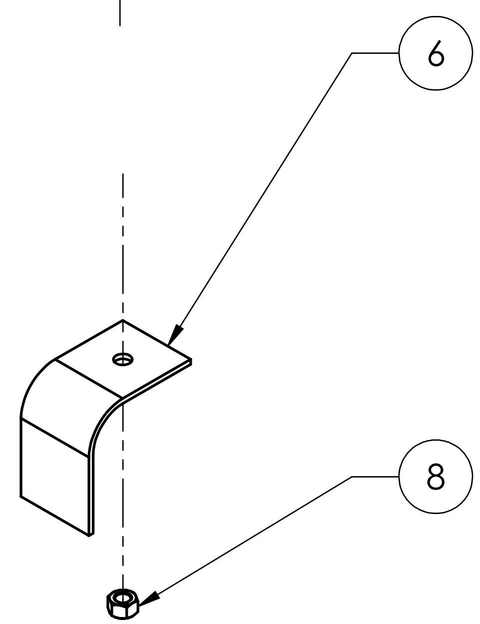
SIZE	DRAWN BY:	Max Aisenstat	REV
B	SM By:	William Hammond	
SCALE: 1:5	Mass: (lbs)		SHEET 1 OF 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Drum Bottom Covre	0.125" 3003 ALUMINUM PLATE	1
2	Collecting Duct Inner Wall	0.125" 3003 ALUMINUM PLATE	1
3	Collecting Duct Bottom	0.125" 3003 ALUMINUM PLATE	1
4	Collecting Duct Outer Wall	0.125" 3003 ALUMINUM PLATE	1
5	Spin float top cover	0.125" 3003 ALUMINUM PLATE	1
6	L-Bracket		4
7	HBOLT 0.3750-24x1x1-N		4
8	HNUT 0.3750-24-D-N		4

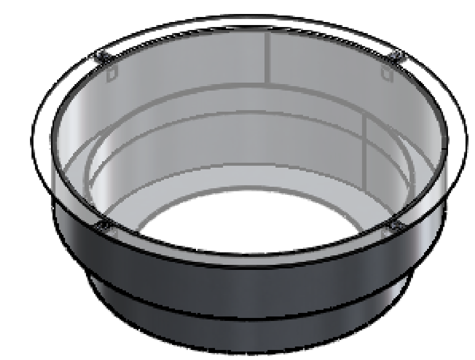




DETAIL B
SCALE 1 : 4

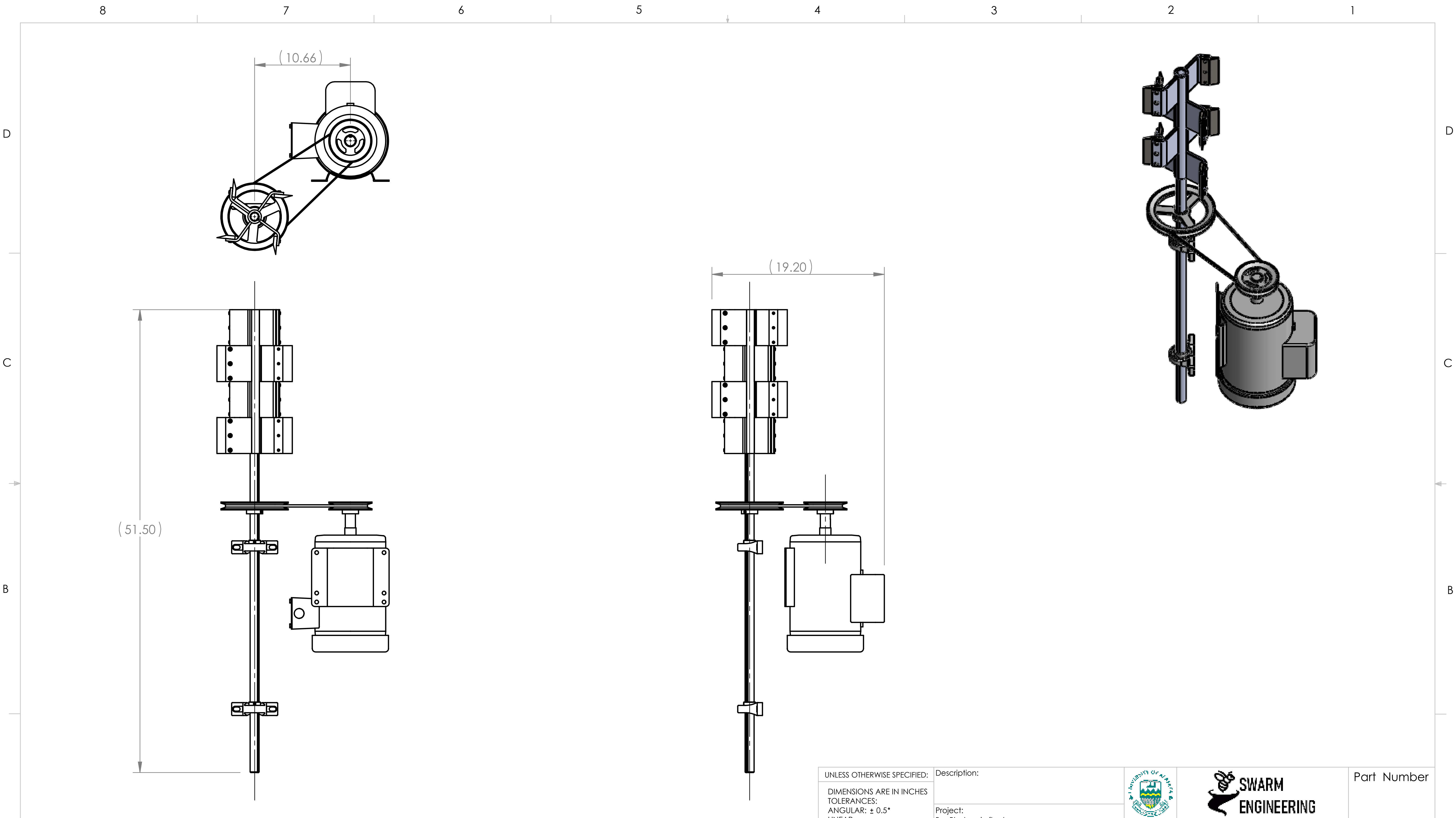


DETAIL A
SCALE 1 : 4



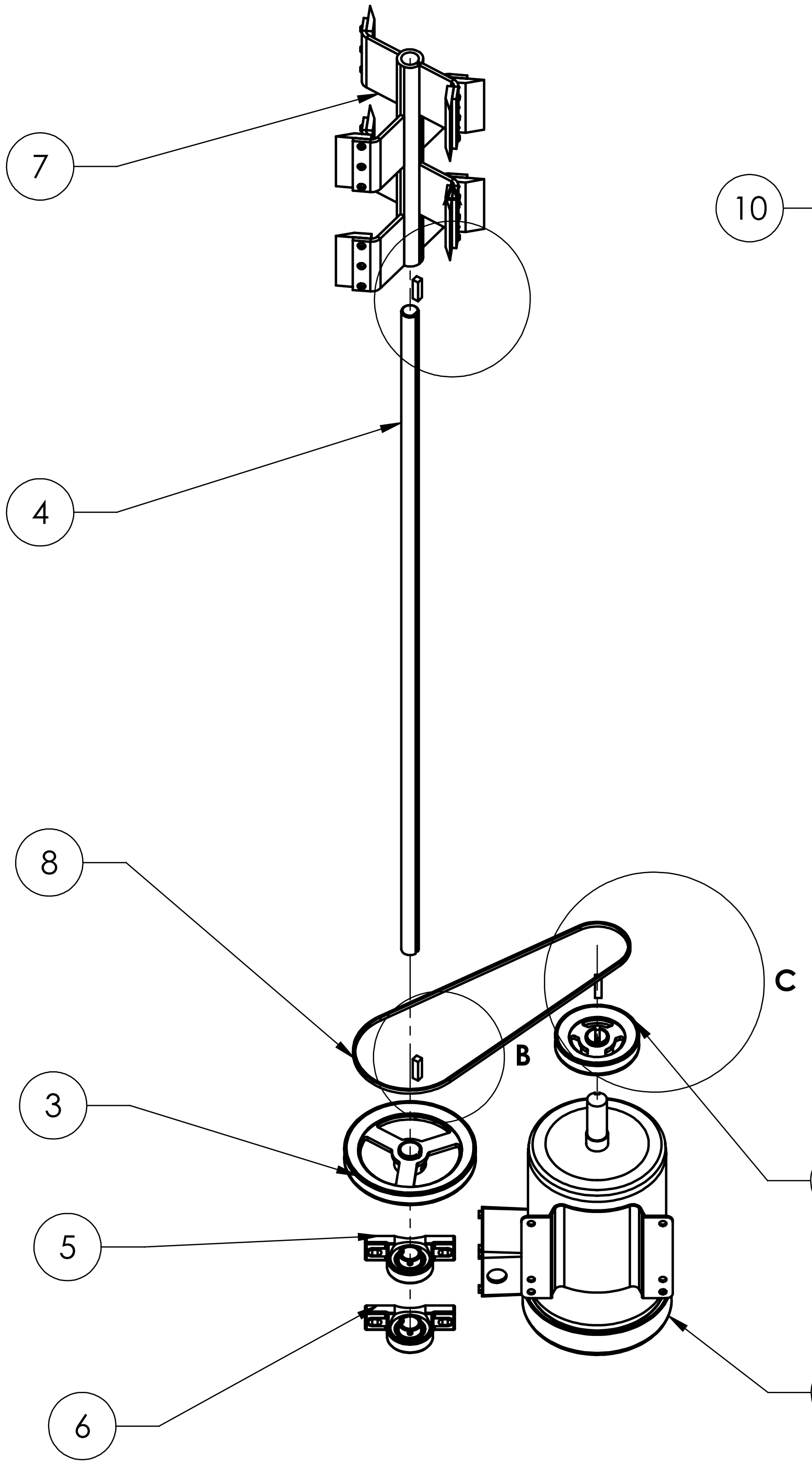
ALL SHEET METAL PLATE IS 0.125" 3003 ALUMINUM PLATE
AND ARE WELDED TOGETHER
WATERJET CUT ALL SHEET METAL
BREAK ALL EDGES

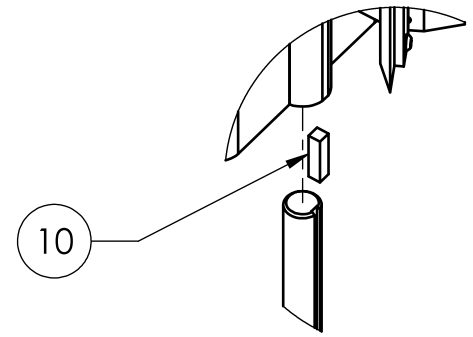
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ± 0.5° LINEAR X.X = ± 0.05 X.XX = ± 0.005 X.XXX = ± 0.001 SURFACE FINISH μin 24 DO NOT SCALE DRAWING	Description:	SWARM ENGINEERING	Part Number
	Project: BEEBLADE Spin Float	TITLE: Collecting Duct Drum and Cover	
	Comments: Reviewed By: Maximilian Aisenstat		
	Drawing Last Saved: Monday, December 2, 2019 2:37:51 AM	SIZE B DRAWN BY: AIDEN KOOYMAN	REV 0
MATERIAL:	SM Last Saved: Monday, December 2, 2019 2:33:59 AM	SM By: AIDEN KOOYMAN	
FILE NAME: Collecting Duct and Drum Cover		SCALE: 1:30 Mass: (lbs)	SHEET 1 OF 1



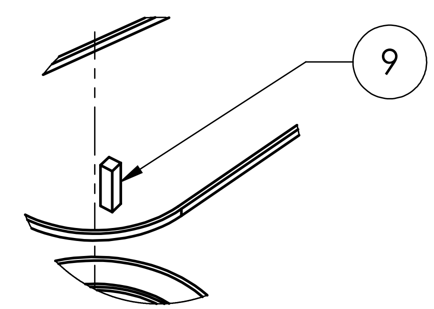
UNLESS OTHERWISE SPECIFIED:	Description:		SWARM ENGINEERING	Part Number
DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ± 0.5° LINEAR X.X = ± 0.05 X.XX = ± 0.005 X.XXX = ± 0.001 SURFACE FINISH µin 24 DO NOT SCALE DRAWING	Project: BeeBlade spin float Comments: Drawing Last Saved: Sunday, December 1, 2019 8:19:35 PM	TITLE: Cutting blade assembly		
		SIZE B	DRAWN BY: Udeshwar Jaswal	REV
MATERIAL:	SM Last Saved: Sunday, December 1, 2019 6:59:52 PM		SM By: Aiden Cumin	
FILE NAME: Cutting Blade Mechanism November 28, 2019		SCALE: 1:20	Mass: 33.52 lbs	SHEET 1 OF 1

ITEM NO.	PART NAME	DESCRIPTION	QTY.
1	AC Motor	3600 rpm, 5hp	1
2	3.55" Motor Mounted Pulley		1
3	6.25" Shaft Mounted Pulley		1
4	1" Keyed Shaft		1
5	1" Deep Grove Ball Bearing and Casing		1
6	1" Thrust Bearing and Casing		1
7	Blade Holder Assembly		8
8	B V-Belt	45" Belt Length	1
9	1.1875" X 0.375" Shaft-Pulley Key	304 Stainless Steel Square Keystock	2
10	1.5" X 0.375" Shaft-Blade Holder Key	304 Stainless Steel Square Keystock	1

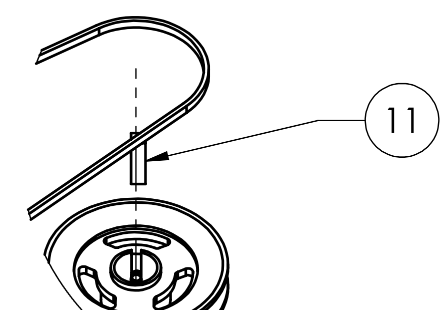




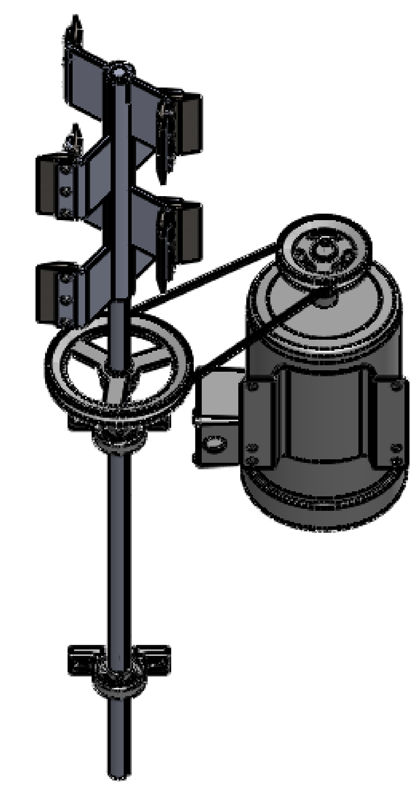
DETAIL A
SCALE 1 : 5



DETAIL B
SCALE 1 : 5



DETAIL C
SCALE 1 : 5

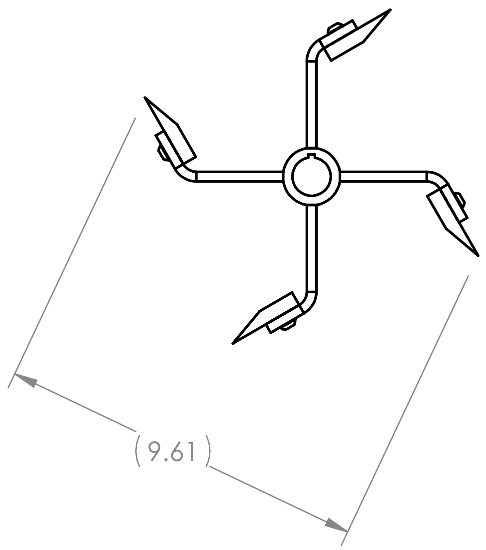


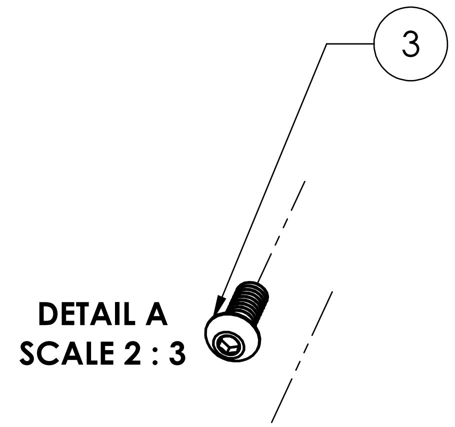
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X.X = ± 0.05
X.XX = ± 0.005
X.XXX = ± 0.001
SURFACE FINISH µin 24
DO NOT SCALE DRAWING
MATERIAL:

Description:
Project: BEEBLAD ASSEMBLY
Comments:
Reviewed by: CALE BENKO
Drawing Last Saved: Monday, December 2, 2019 3:48:32 AM
SM Last Saved: Monday, December 2, 2019 3:41:20 AM
FILE NAME: Cutting Blade Mechanism November 28, 2019

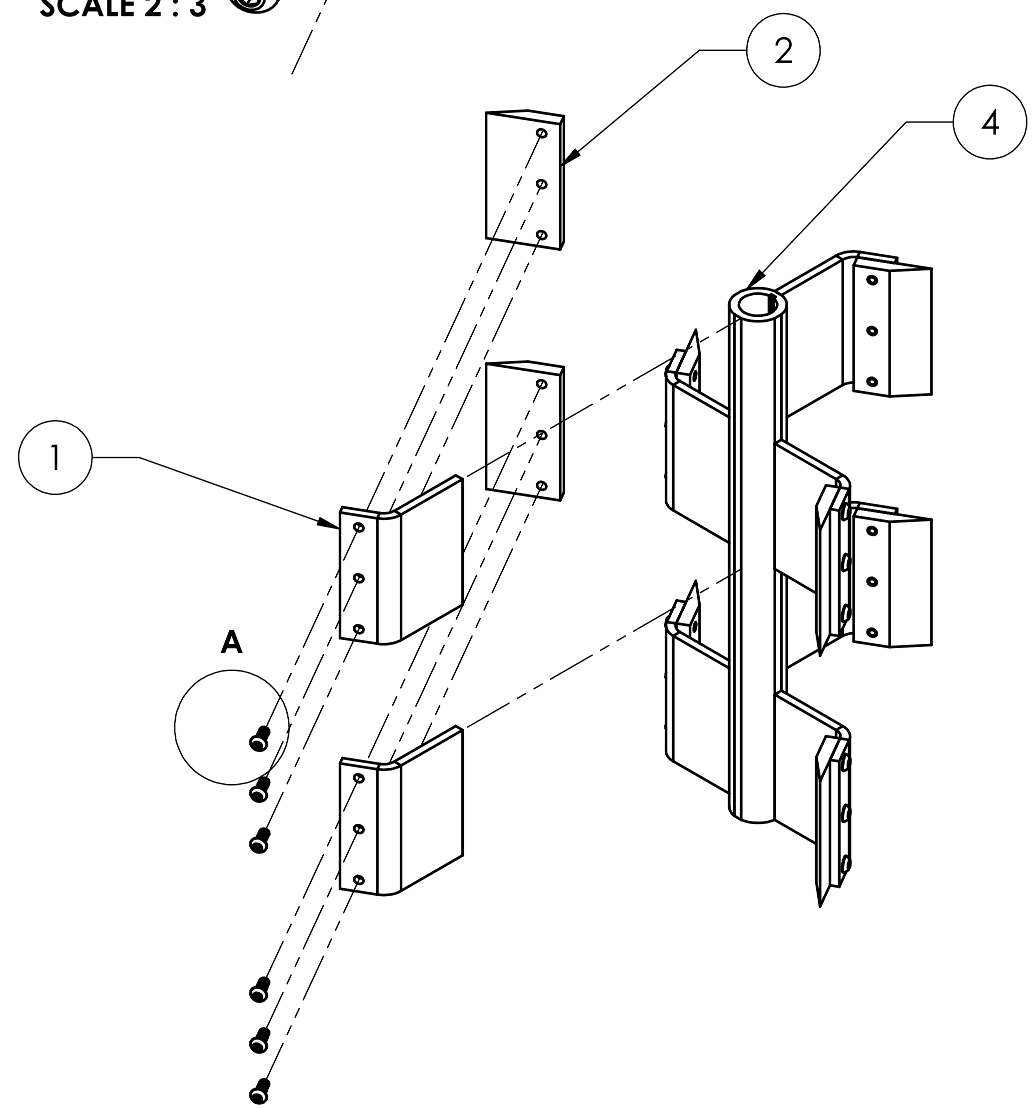
SWARM ENGINEERING
Part Number
TITLE: Wax Cutting Assembly
SIZE B
DRAWN BY: AIDEN KOOYMAN
SM By: GABRIEL VINCENT
REV 0
SCALE: 1:10
Mass: (lbs)
SHEET 1 OF 1

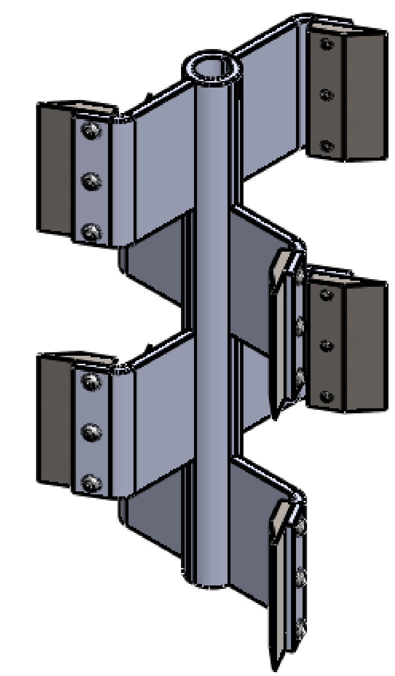
ITEM NO.	PART NAME	DESCRIPTION	QTY.
1	Bade Holder	0.25" 304 Stainless Steel Sheet	8
2	Blade		8
3	0.25 X 0.625 Button Head Socket Cap Screw	316 Stainless Steel	24
4	CutterSleeve	Machined from 0.5" ID (1.25" OD) 304 SS Pipe	1

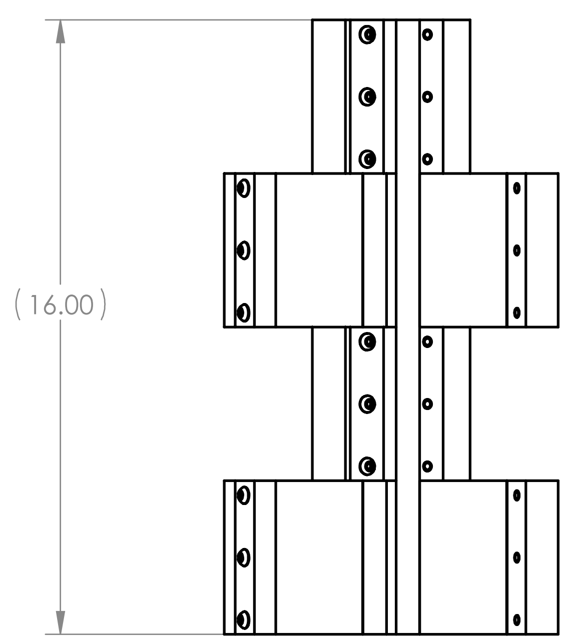




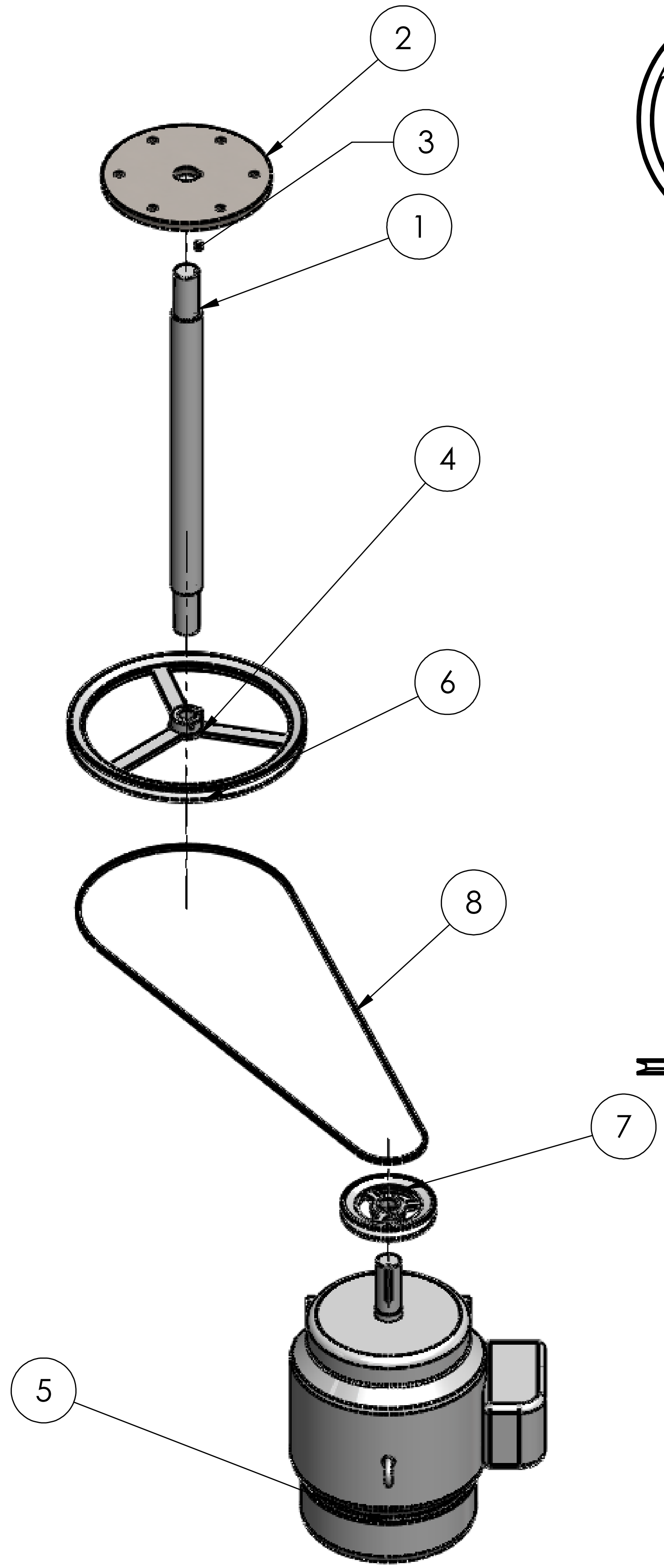
DETAIL A
SCALE 2 : 3

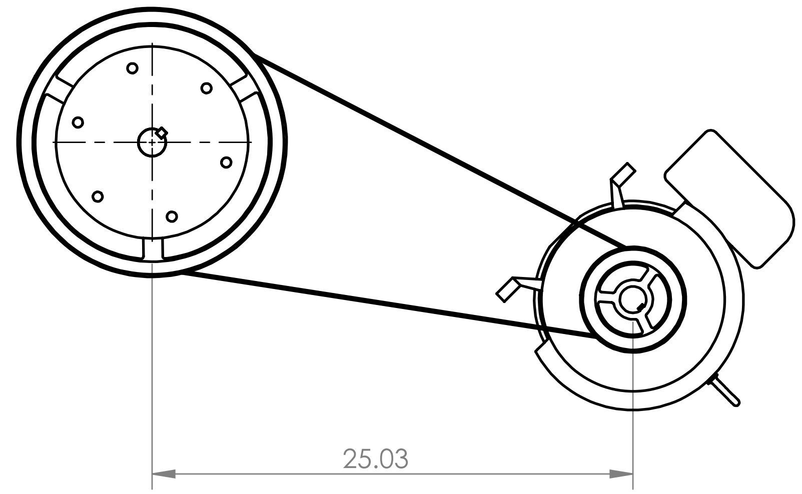




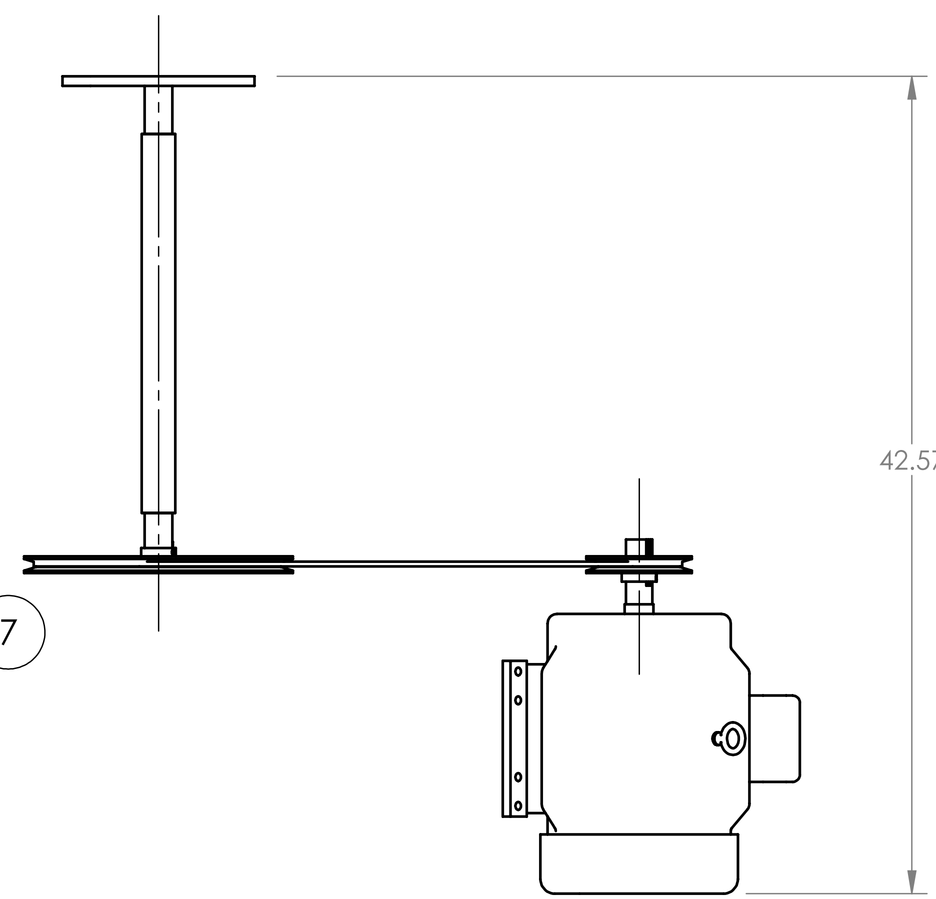


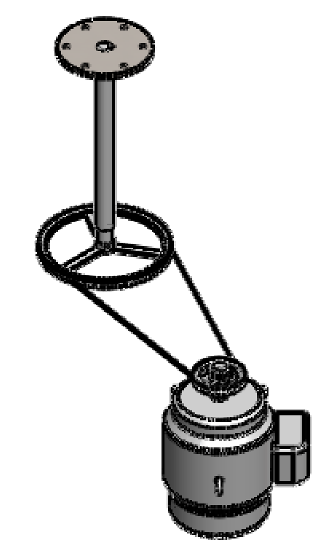
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ± 0.5° LINEAR X.X = ± 0.05 X.XX = ± 0.005 X.XXX = ± 0.001 SURFACE FINISH µin 24 DO NOT SCALE DRAWING	Description: Project: BEEBLADE Spin Float Comments: REVIEWED BY: MAXIMILIAN AISENSTAT	SWARM ENGINEERING	Part Number
		TITLE: BLADE HOLDER	
MATERIAL: Material <not specified>	Drawing Last Saved: Monday, December 2, 2019 3:04:51 AM SM Last Saved: Monday, December 2, 2019 3:01:36 AM	SIZE B / DRAWN BY: AIDEN KOOYMAN / SM By: WILLIAM HAMMOND	REV 0
FILE NAME: 4inbladeholder		SCALE: 1:5 / Mass: 6.70 (lbs)	SHEET 1 OF 1





ITEM NO.	PART NAME	DESCRIPTION	QTY.
1	Final main shaft	Main shaft of the BeeBlade	1
2	SpinFloatHub	An attatchment to power inner drum	1
3	Spin Float Hub Key	An attatchmen for shaft and hub	1
4	Main Pulley Key	An attatchment for pulley and shaft	1
5	Motor	5 hp motor	1
6	12.75" Drum Pulley		1
7	4.25" Drum Pulley		1
8	Main Driving Belt		1





UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X.X = ± 0.05
X.XX = ± 0.005
X.XXX = ± 0.001

SURFACE FINISH 24 µin

DO NOT SCALE DRAWING

MATERIAL:

FILE NAME:
Main Driving Assembly

Description:

Project:
BeeBlade spin float

Comments:
Review by: William Hammod

Drawing Last Saved:
Monday, December 2, 2019 3:45:22 AM

SM Last Saved:
Monday, December 2, 2019 3:02:41 AM

SWARM ENGINEERING

Part Number

TITLE:
Main driving assembley

SIZE B

DRAWN BY: Udeshwar Jaswal

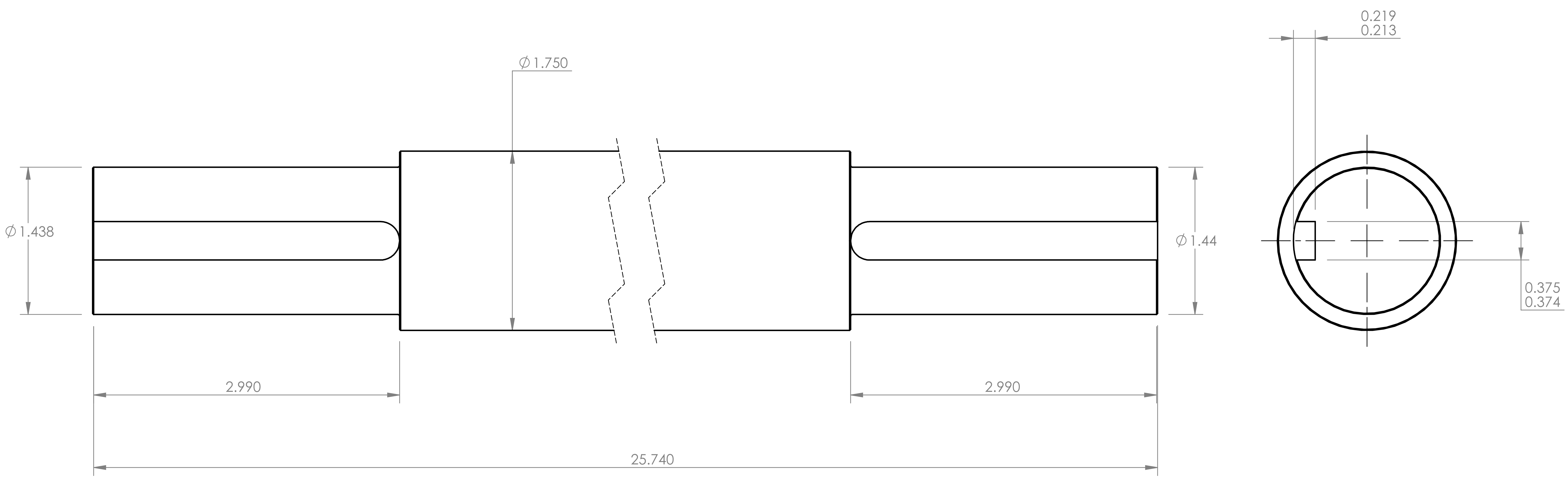
SM By: Aiden Kooyman

REV

SCALE: 1:20

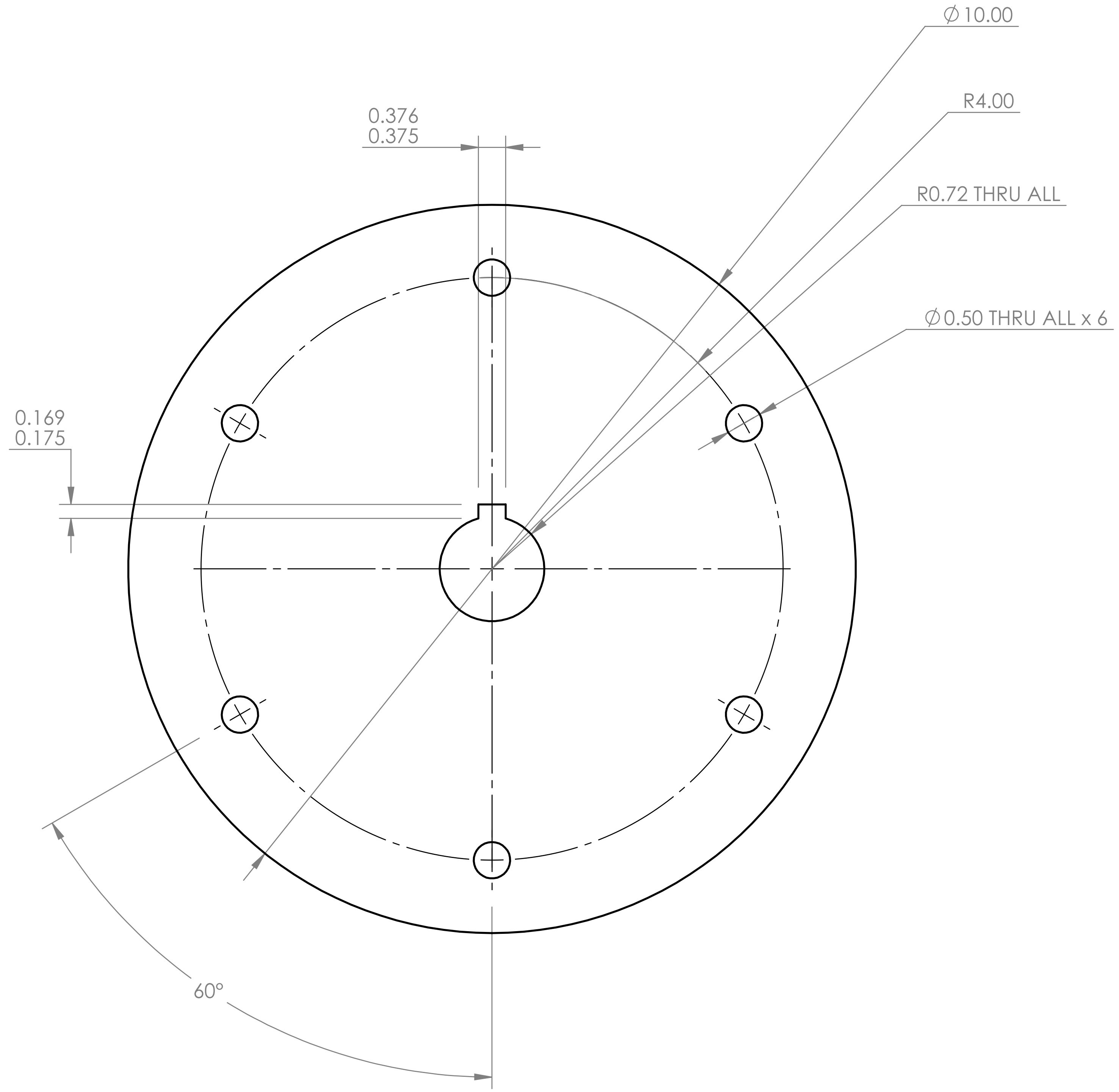
Mass: (lbs)

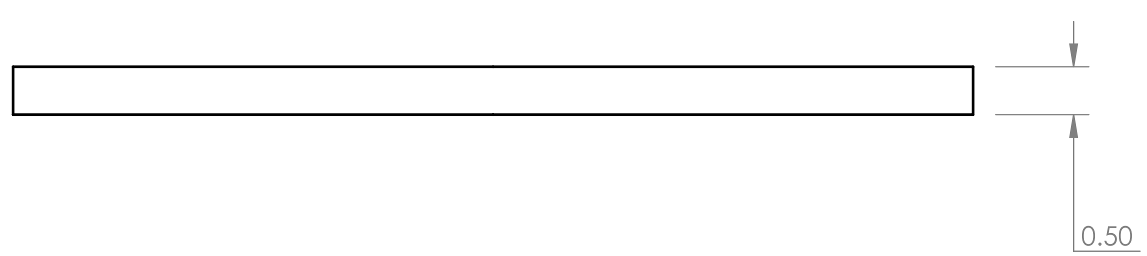
SHEET 1 OF 1

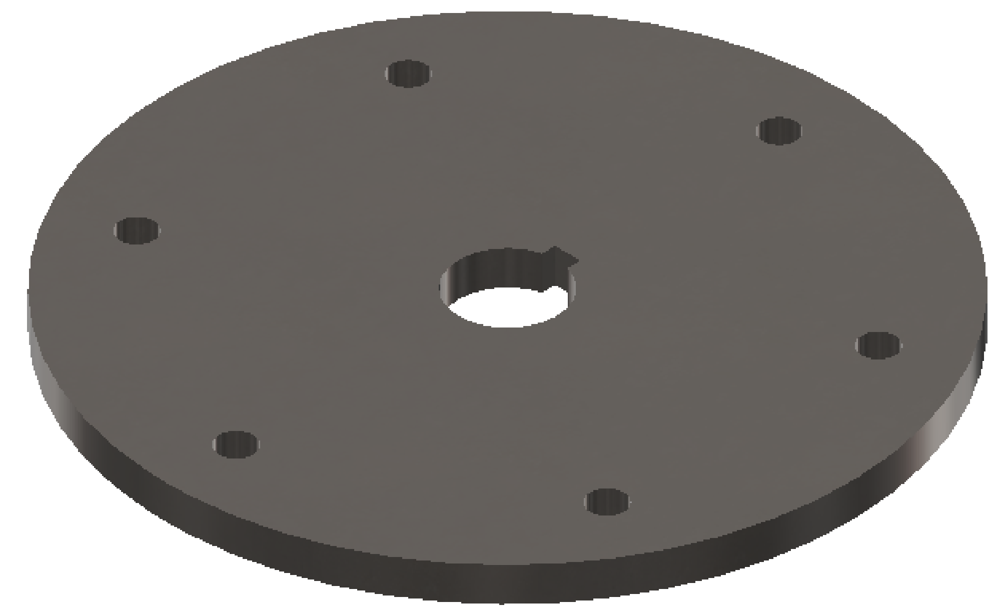


NOTE: STEPS AND KEYWAYS ARE IDENTICAL ON EITHER SIDE OF SHAFT

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ± 0.5° LINEAR X.X = ± 0.05 X.XX = ± 0.005 X.XXX = ± 0.001 SURFACE FINISH µin 24 DO NOT SCALE DRAWING	Description: Main shaft of the BeeBlade Project: BeeBlade Comments: Reviewed by: William Hammod	SWARM ENGINEERING	Part Number
		TITLE: Drum Shaft	
	Drawing Last Saved: Monday, December 2, 2019 4:10:21 AM	SIZE B DRAWN BY: Udeshwar Jaswal	REV A-01
MATERIAL: AISI 316 Annealed Stainless Steel Bar (SS)	SM Last Saved: Monday, December 2, 2019 1:40:38 AM	SM By: Gabriel Risbud-Vincent	
FILE NAME: FINAL MAIN SHAFT		SCALE: 1:1 Mass: 16.41 (lbs)	SHEET 1 OF 1







UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X.X = ± 0.05
X.XX = ± 0.005
X.XXX = ± 0.001

SURFACE FINISH μin 24

DO NOT SCALE DRAWING

MATERIAL:
AISI 316 Annealed Stainless Steel Bar (SS)

FILE NAME:
SpinFloatHub

Description:
Inner drum mounting hub

Project:
Foam reduction in honey-wax separating process

Comments:
All dimensions are in Inches.

Drawing Last Saved:
Sunday, December 1, 2019 2:45:55 PM

SM Last Saved:
Sunday, December 1, 2019 2:29:01 PM

SWARM ENGINEERING

Part Number

TITLE:
Spin float hub

SIZE B

DRAWN BY: **Udeshwar Jaswal**

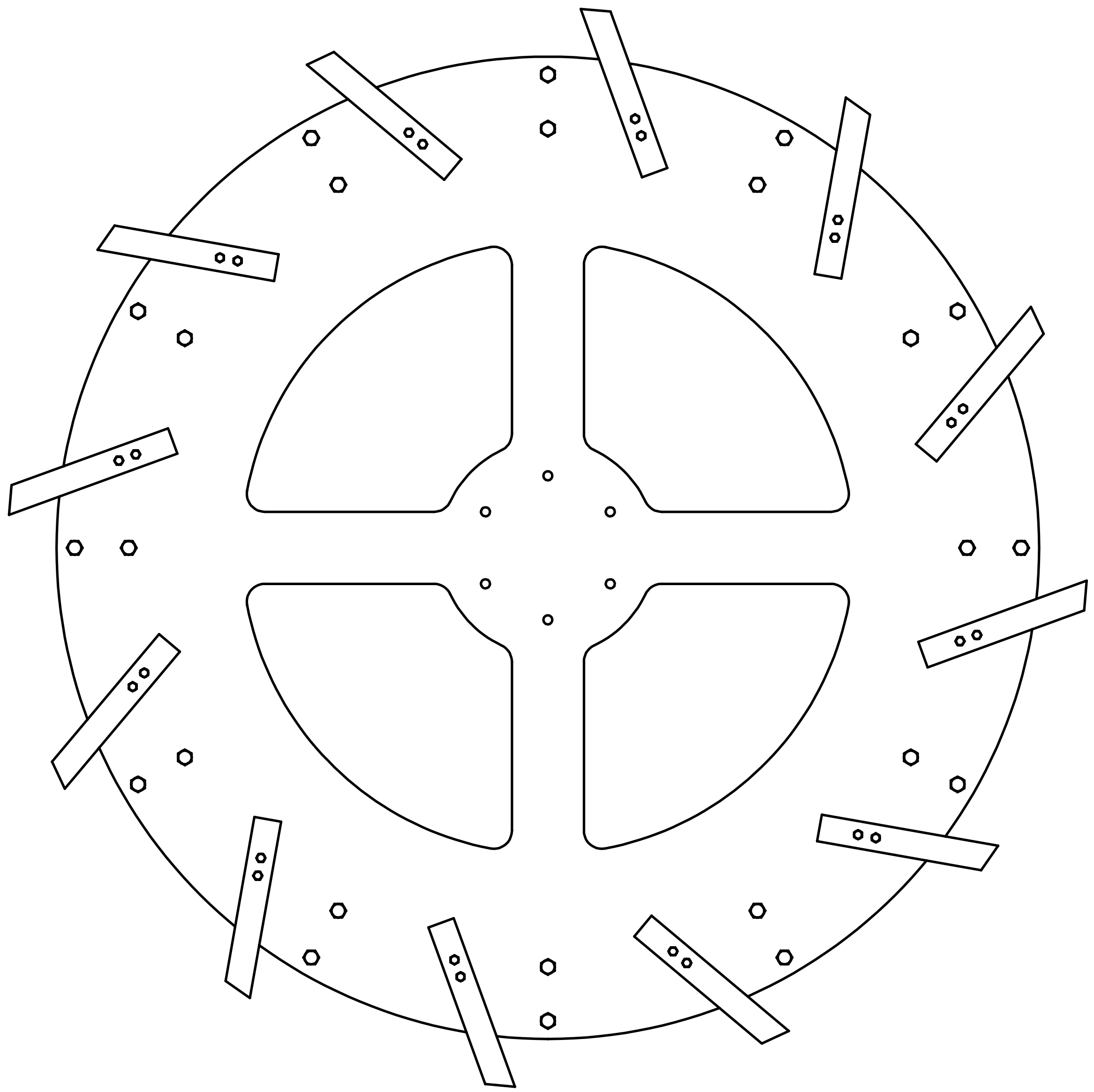
SM By: **Gabriel Risbud-Vincent**

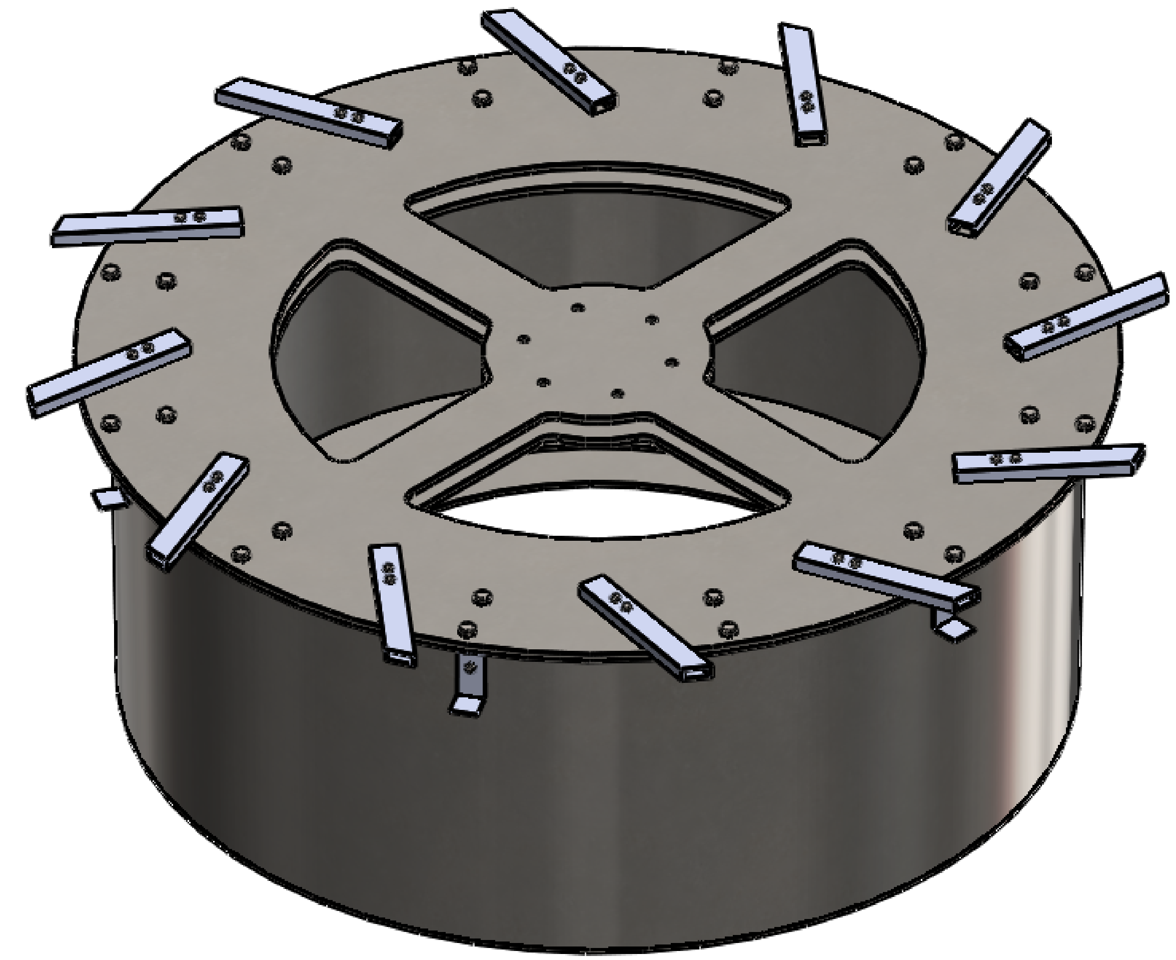
REV

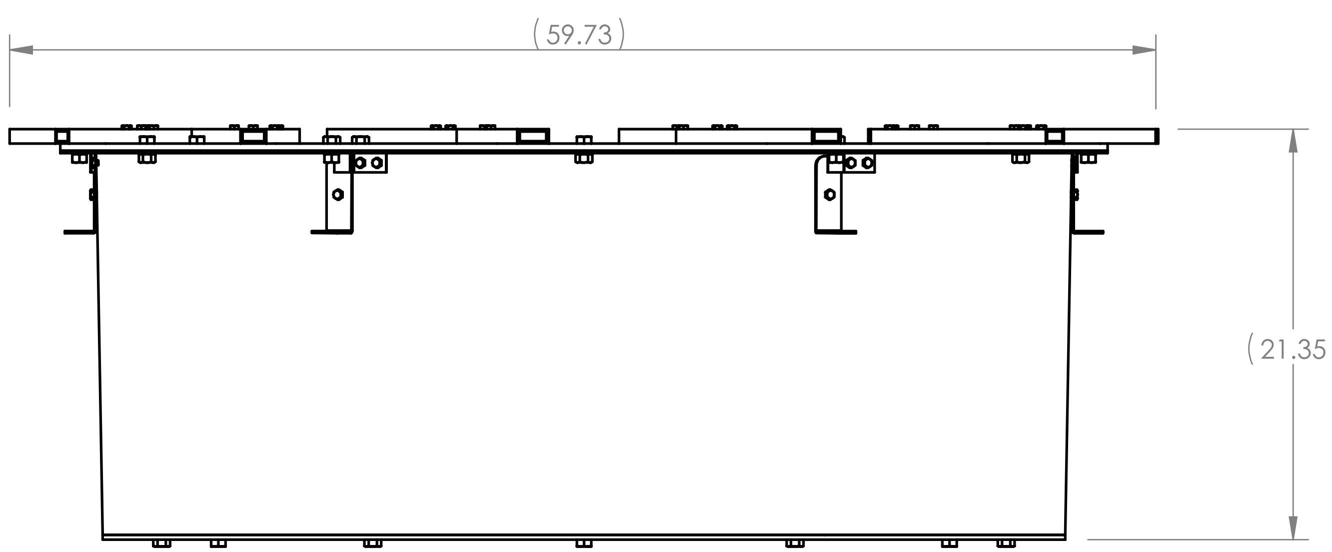
SCALE: 1:5

Mass: 10.94 (lbs)

SHEET 1 OF 1







UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X.X = ± 0.05
X.XX = ± 0.005
X.XXX = ± 0.001

SURFACE FINISH 24 µin

DO NOT SCALE DRAWING

MATERIAL:
Various

FILE NAME:
Inner Drum

Description:

Project:
BeeBlade Spin-Float

Reviewed by:
William Hammond

Drawing Last Saved:
Monday, December 2, 2019 3:59:32 AM

SM Last Saved:
Monday, December 2, 2019 2:14:13 AM

SWARM ENGINEERING

Part Number

TITLE:
Inner Drum

SIZE B

DRAWN BY: Cale Benko

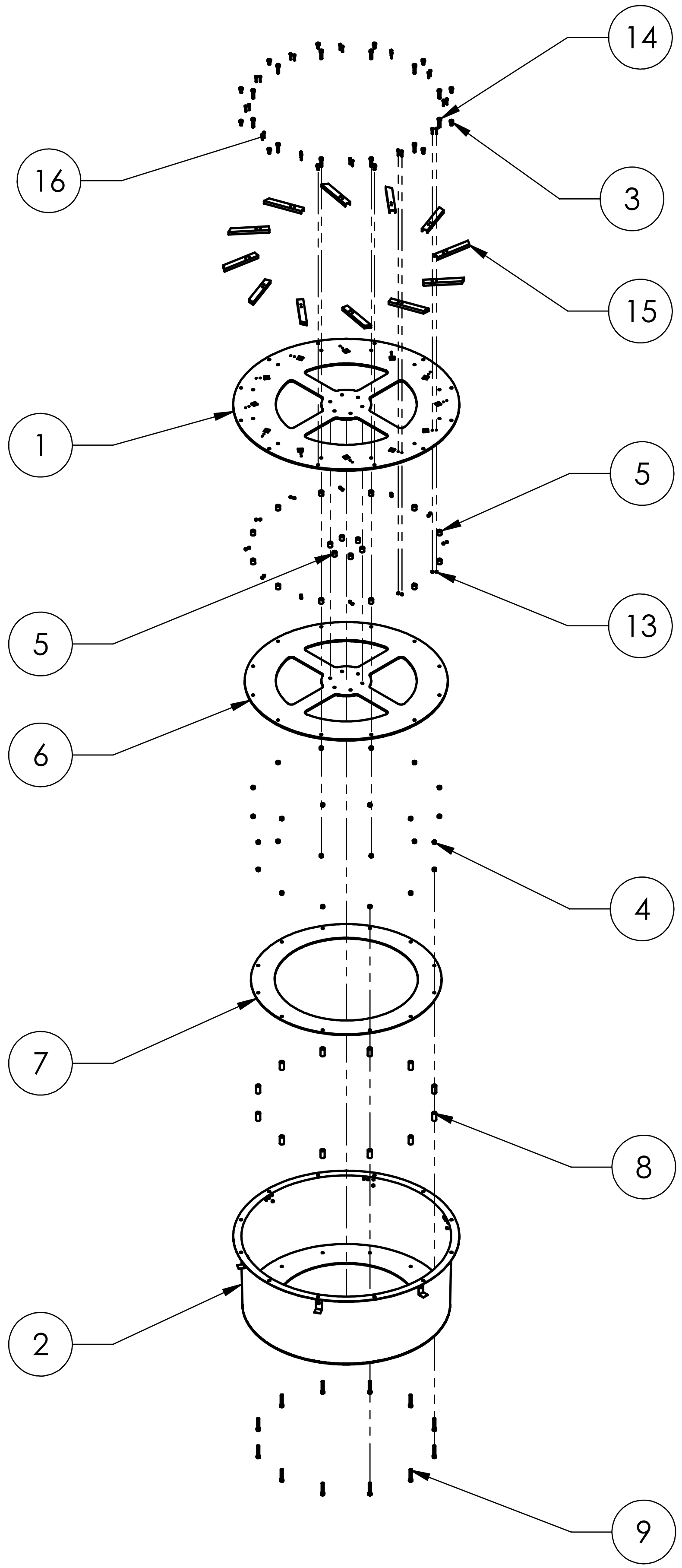
SM By: Group

REV

SCALE: 1:20

Mass: 585.98 (lbs)

SHEET 1 OF 1



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Inner Drum Top Plate	304 Stainless Steel	1
2	Inner Drum Side Wall	Aluminum	1
3	HBOLT 0.5000-20x0.875x0.875-N		12
4	HNUT 0.5000-20-D-N		36
5	Baffle Plate Spacer	1" 304 Stainless Steel	18
6	Baffle Plate	Aluminum	1
7	Wax Shield	Aluminum	1
8	Wax Shield Spacer	2" 304 Stainless Steel	12
9	HBOLT 0.5000-20x3x1.25-N		12
10	Drain Plug	Aluminum	6
11	Drain Plug Aligner	Aluminum	6
12	HBOLT 0.2500-28x0.5x0.5-N		18
13	HNUT 0.2500-28-D-N		42
14	HBOLT 0.5000-20x2x1.25-N		12
15	Honey Flute	304 Stainless Steel	12
16	HBOLT 0.2500-28x1.375x0.75-N		24

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X.X = ± 0.05
X.XX = ± 0.005
X.XXX = ± 0.001

SURFACE FINISH 24 µin

DO NOT SCALE DRAWING

MATERIAL: Various

FILE NAME: Inner Drum

Description:

Project: BeeBlade Spin-Float

Reviewed by: Aiden Kooyman

Drawing Last Saved: Monday, December 2, 2019 2:01:40 AM

SM Last Saved: Monday, December 2, 2019 1:15:22 AM

SWARM ENGINEERING

Part Number

TITLE: Inner Drum Exploded View

SIZE B

DRAWN BY: Cale Benko

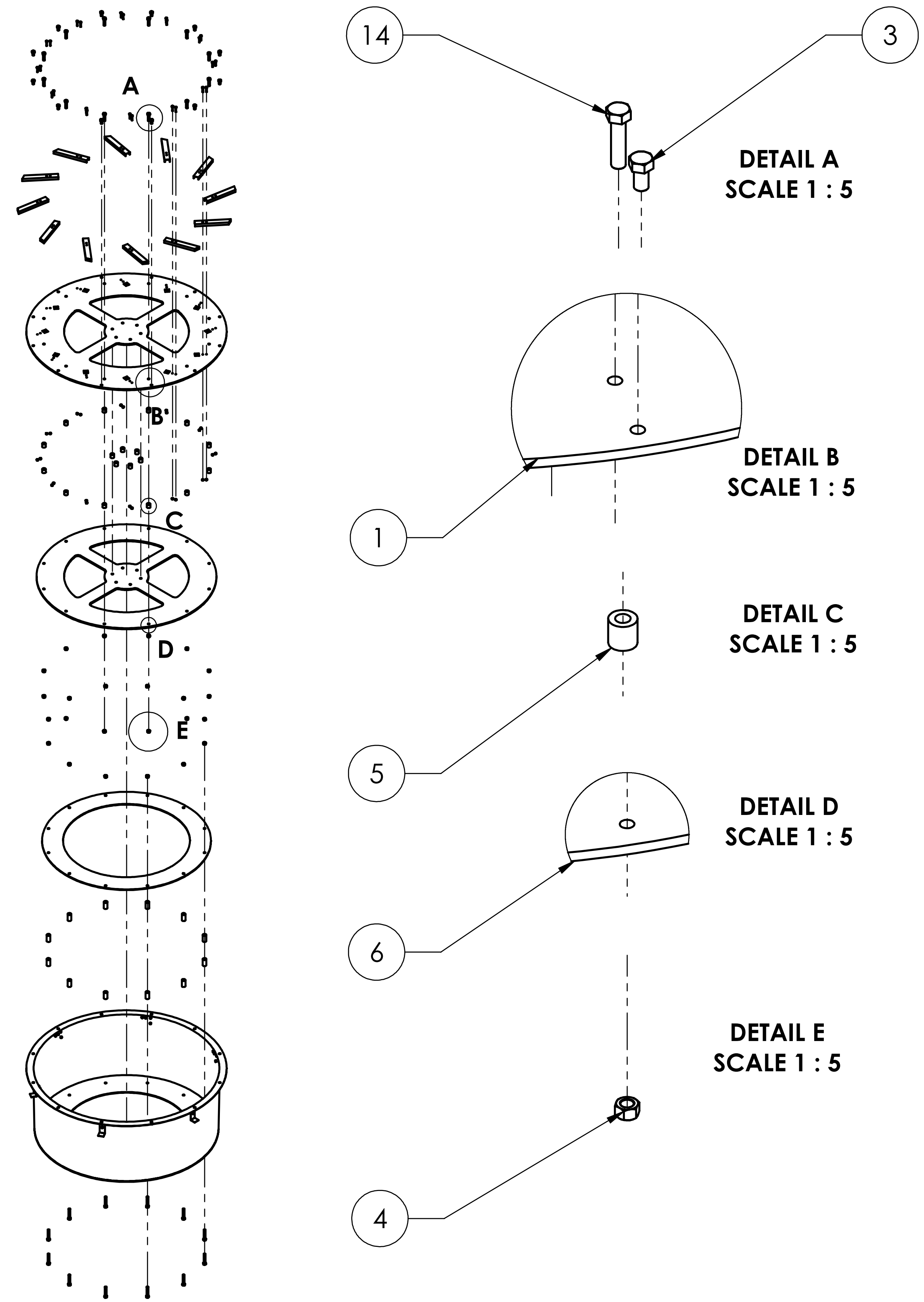
SM By: Group

REV

SCALE: 1:100

Mass: 585.98 (lbs)

SHEET 1 OF 4



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Inner Drum Top Plate	304 Stainless Steel	1
2	Inner Drum Side Wall	Aluminum	1
3	HBOLT 0.5000-20x0.875x0.875-N		12
4	HNUT 0.5000-20-D-N		36
5	Baffle Plate Spacer	1" 304 Stainless Steel	18
6	Baffle Plate	Aluminum	1
7	Wax Shield	Aluminum	1
8	Wax Shield Spacer	2" 304 Stainless Steel	12
9	HBOLT 0.5000-20x3x1.25-N		12
10	Drain Plug	Aluminum	6
11	Drain Plug Aligner	Aluminum	6
12	HBOLT 0.2500-28x0.5x0.5-N		18
13	HNUT 0.2500-28-D-N		42
14	HBOLT 0.5000-20x2x1.25-N		12
15	Honey Flute	304 Stainless Steel	12
16	HBOLT 0.2500-28x1.375x0.75-N		24

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X.X = ± 0.05
X.XX = ± 0.005
X.XXX = ± 0.001
SURFACE FINISH 24 μin
DO NOT SCALE DRAWING
MATERIAL: Various
FILE NAME: Inner Drum

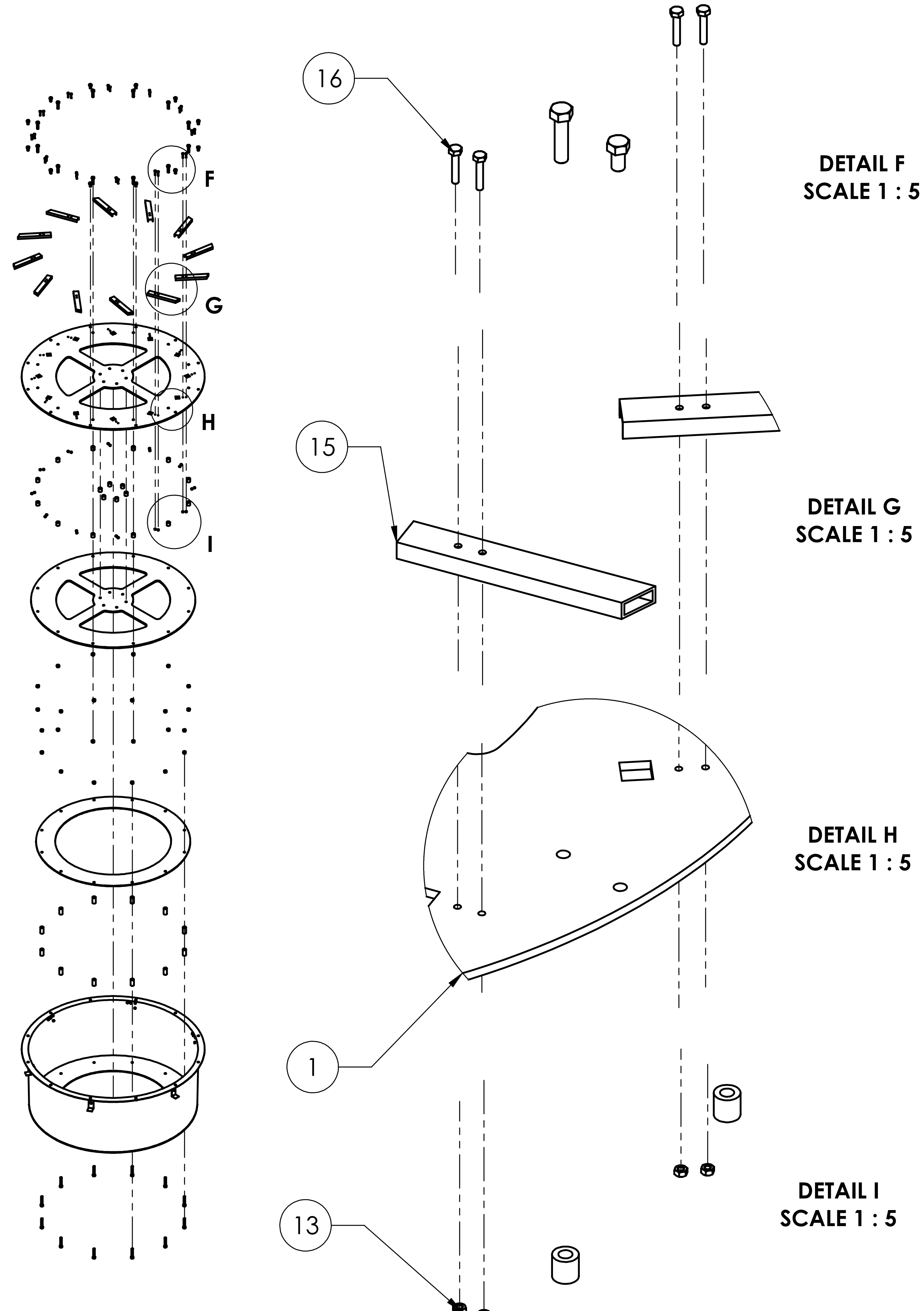
Description:
Project: BeeBlade Spin-Float
Reviewed by: Aiden Kooyman
Drawing Last Saved: Monday, December 2, 2019 2:01:40 AM
SM Last Saved: Monday, December 2, 2019 1:15:22 AM

SWARM ENGINEERING

Part Number

TITLE: Inner Drum Exploded View

SIZE B
DRAWN BY: Cale Benko
SM By: Group
REV
SCALE: 1:100
Mass: 585.98 (lbs)
SHEET 2 OF 4



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Inner Drum Top Plate	304 Stainless Steel	1
2	Inner Drum Side Wall	Aluminum	1
3	HBOLT 0.5000-20x0.875x0.875-N		12
4	HNUT 0.5000-20-D-N		36
5	Baffle Plate Spacer	1" 304 Stainless Steel	18
6	Baffle Plate	Aluminum	1
7	Wax Shield	Aluminum	1
8	Wax Shield Spacer	2" 304 Stainless Steel	12
9	HBOLT 0.5000-20x3x1.25-N		12
10	Drain Plug	Aluminum	6
11	Drain Plug Aligner	Aluminum	6
12	HBOLT 0.2500-28x0.5x0.5-N		18
13	HNUT 0.2500-28-D-N		42
14	HBOLT 0.5000-20x2x1.25-N		12
15	Honey Flute	304 Stainless Steel	12
16	HBOLT 0.2500-28x1.375x0.75-N		24

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X.X = ± 0.05
X.XX = ± 0.005
X.XXX = ± 0.001
SURFACE FINISH 24 µin
DO NOT SCALE DRAWING
MATERIAL: Various
FILE NAME: Inner Drum

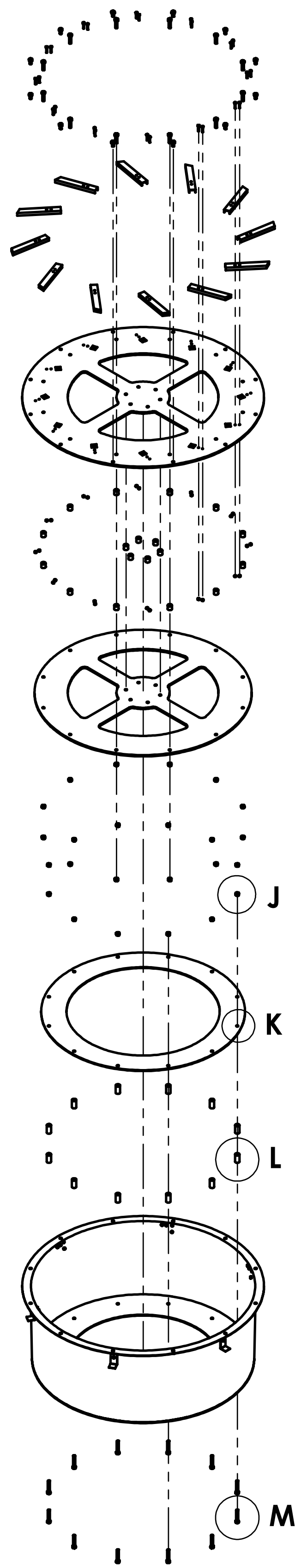
Description:
Project: BeeBlade Spin-Float
Reviewed by: Aiden Kooyman
Drawing Last Saved: Monday, December 2, 2019 2:01:40 AM
SM Last Saved: Monday, December 2, 2019 1:15:22 AM

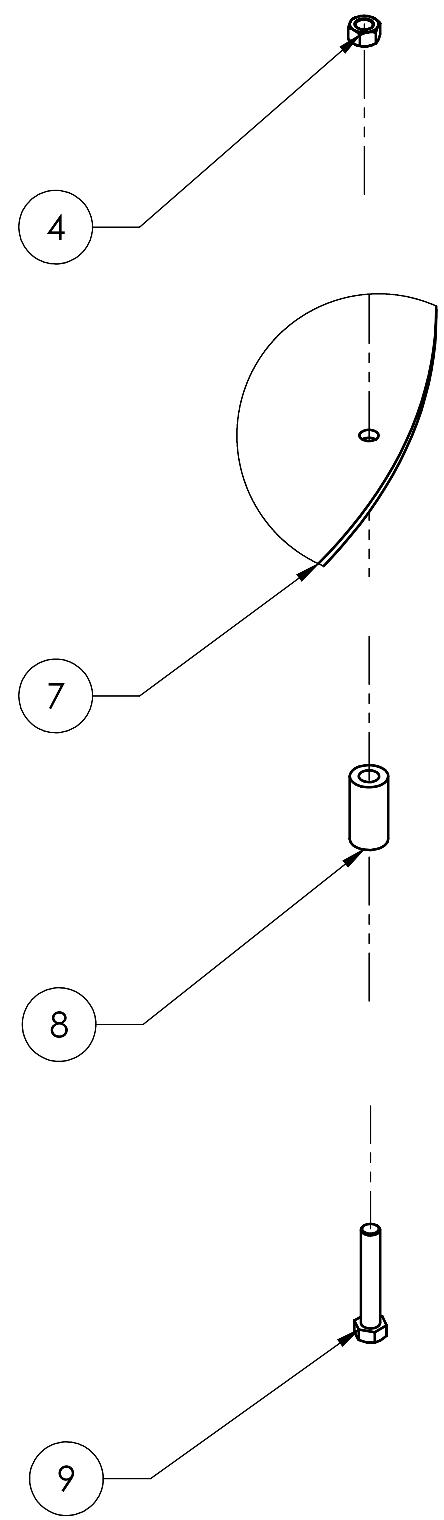
SWARM ENGINEERING

Part Number

TITLE:
Inner Drum Exploded View

SIZE B | DRAWN BY: **Cale Benko** | REV
SM By: **Group**
SCALE: 1:100 | Mass: 585.98 (lbs) | SHEET 3 OF 4





DETAIL J
SCALE 1 : 5

DETAIL K
SCALE 1 : 5

DETAIL L
SCALE 1 : 5

DETAIL M
SCALE 1 : 5

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Inner Drum Top Plate	304 Stainless Steel	1
2	Inner Drum Side Wall	Aluminum	1
3	HBOLT 0.5000-20x0.875x0.875-N		12
4	HNUT 0.5000-20-D-N		36
5	Baffle Plate Spacer	1" 304 Stainless Steel	18
6	Baffle Plate	Aluminum	1
7	Wax Shield	Aluminum	1
8	Wax Shield Spacer	2" 304 Stainless Steel	12
9	HBOLT 0.5000-20x3x1.25-N		12
10	Drain Plug	Aluminum	6
11	Drain Plug Aligner	Aluminum	6
12	HBOLT 0.2500-28x0.5x0.5-N		18
13	HNUT 0.2500-28-D-N		42
14	HBOLT 0.5000-20x2x1.25-N		12
15	Honey Flute	304 Stainless Steel	12
16	HBOLT 0.2500-28x1.375x0.75-N		24

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X.X = ± 0.05
X.XX = ± 0.005
X.XXX = ± 0.001
SURFACE FINISH μin 24
DO NOT SCALE DRAWING
MATERIAL: Various
FILE NAME: Inner Drum

Description:
Project: BeeBlade Spin-Float
Reviewed by: Aiden Kooyman
Drawing Last Saved: Monday, December 2, 2019 2:01:40 AM
SM Last Saved: Monday, December 2, 2019 1:15:22 AM

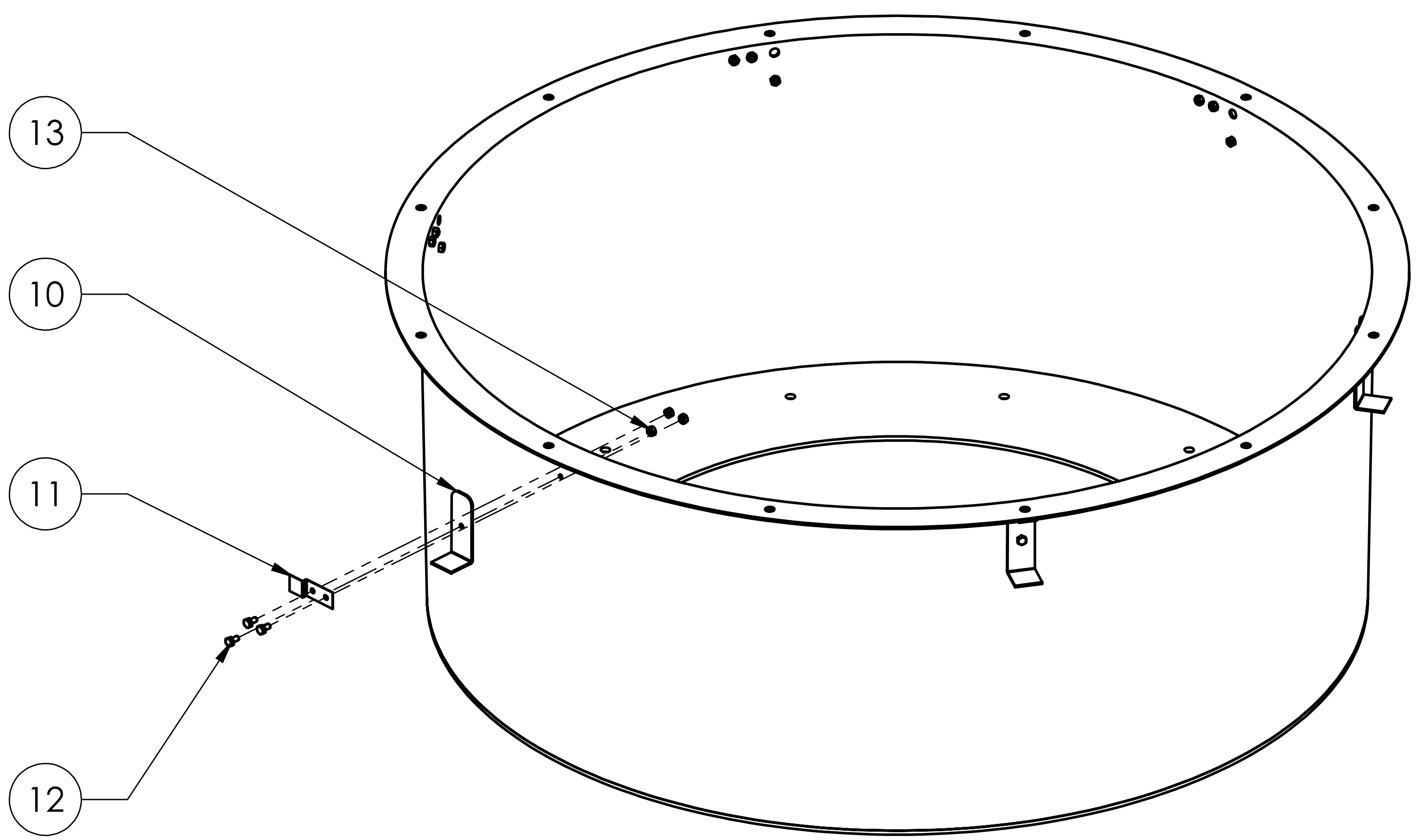
SWARM ENGINEERING

Part Number

TITLE:
Inner Drum Exploded View

SIZE B
DRAWN BY: Cale Benko
SM By: Group
REV
SCALE: 1:100
Mass: 585.98 (lbs)
SHEET 4 OF 4

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Inner Drum Top Plate	304 Stainless Steel	1
2	Inner Drum Side Wall	Aluminum	1
3	HBOLT 0.5000-20x0.875x0.875-N		12
4	HNUT 0.5000-20-D-N		36
5	Baffle Plate Spacer	1" 304 Stainless Steel Spacer	18
6	Baffle Plate	Aluminum	1
7	Wax Shield	Aluminum	1
8	Wax Shield Spacer	2" 304 Stainless Steel Spacer	12
9	HBOLT 0.5000-20x3x1.25-N		12
10	Drain Plug	Aluminum	6
11	Drain Plug Aligner	Aluminum	6
12	HBOLT 0.2500-28x0.5x0.5-N		18
13	HNUT 0.2500-28-D-N		42
14	HBOLT 0.5000-20x2x1.25-N		12
15	Honey Flutes	304 Stainless Steel	12
16	HBOLT 0.2500-28x1.375x0.75-N		24



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X.X = ± 0.05
X.XX = ± 0.005
X.XXX = ± 0.001
SURFACE FINISH 24 µin
DO NOT SCALE DRAWING
MATERIAL: Various
FILE NAME: Inner Drum

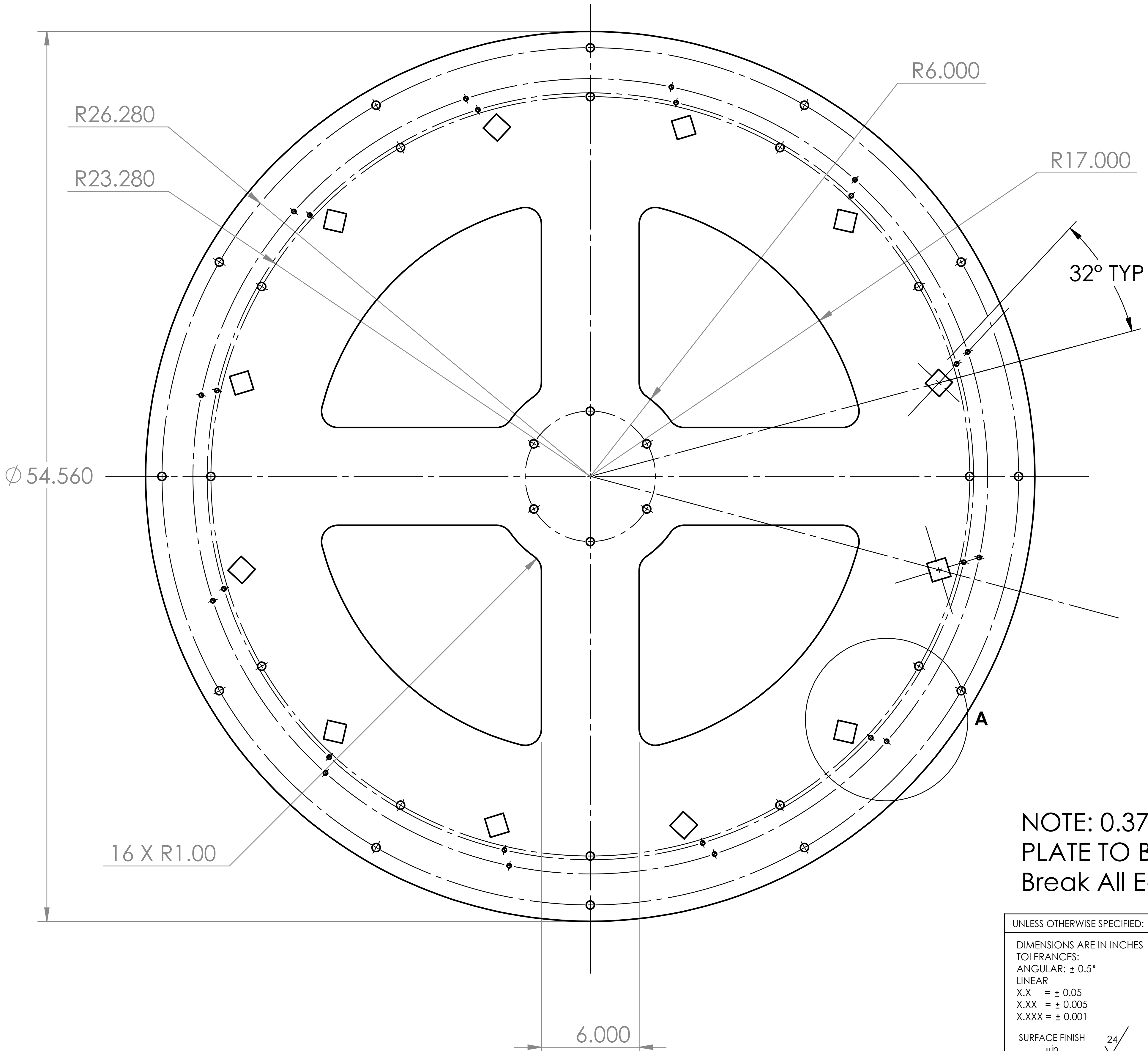
Description:
Project: BeeBlade Spin-Float
Reviewed by: Aiden Kooyman
Drawing Last Saved: Monday, December 2, 2019 2:14:14 AM
SM Last Saved: Monday, December 2, 2019 2:14:13 AM

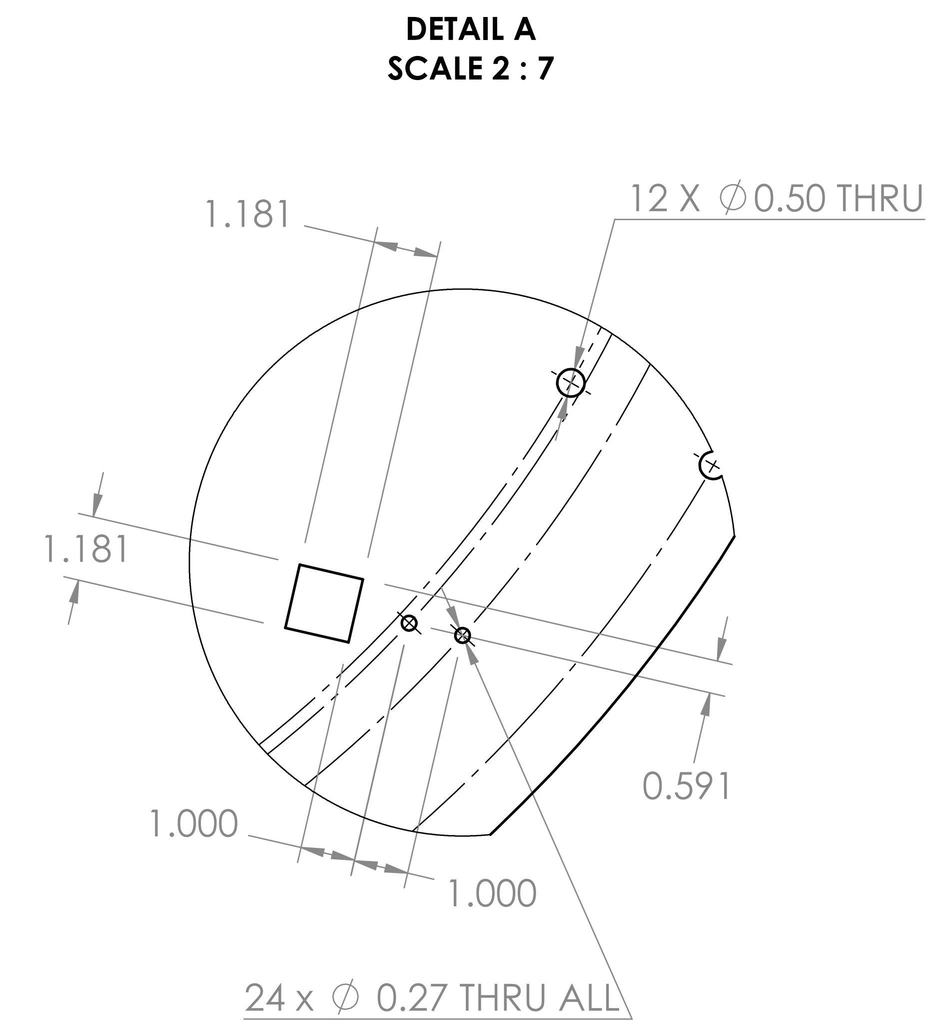
SWARM ENGINEERING

Part Number

TITLE: Inner Drum - Honey Drain View

SIZE B
DRAWN BY: Cale Benko
SM By: William Hammond
REV
SCALE: 1:20
Mass: 585.98 (lbs)
SHEET 1 OF 1





NOTE: 0.375" 304 STAINLESS STEEL PLATE
PLATE TO BE WATERJET CUT
Break All Edges

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X.X = ± 0.05
X.XX = ± 0.005
X.XXX = ± 0.001
SURFACE FINISH µin 24
DO NOT SCALE DRAWING

MATERIAL: AISI 304

FILE NAME: Willtopplate3

Description:

Project: BEEBLADE Spin Float

Comments:
Reviewed by: Gabriel Risbud-Vincent
To be waterjet cut

Drawing Last Saved: Monday, December 2, 2019 2:04:20 AM

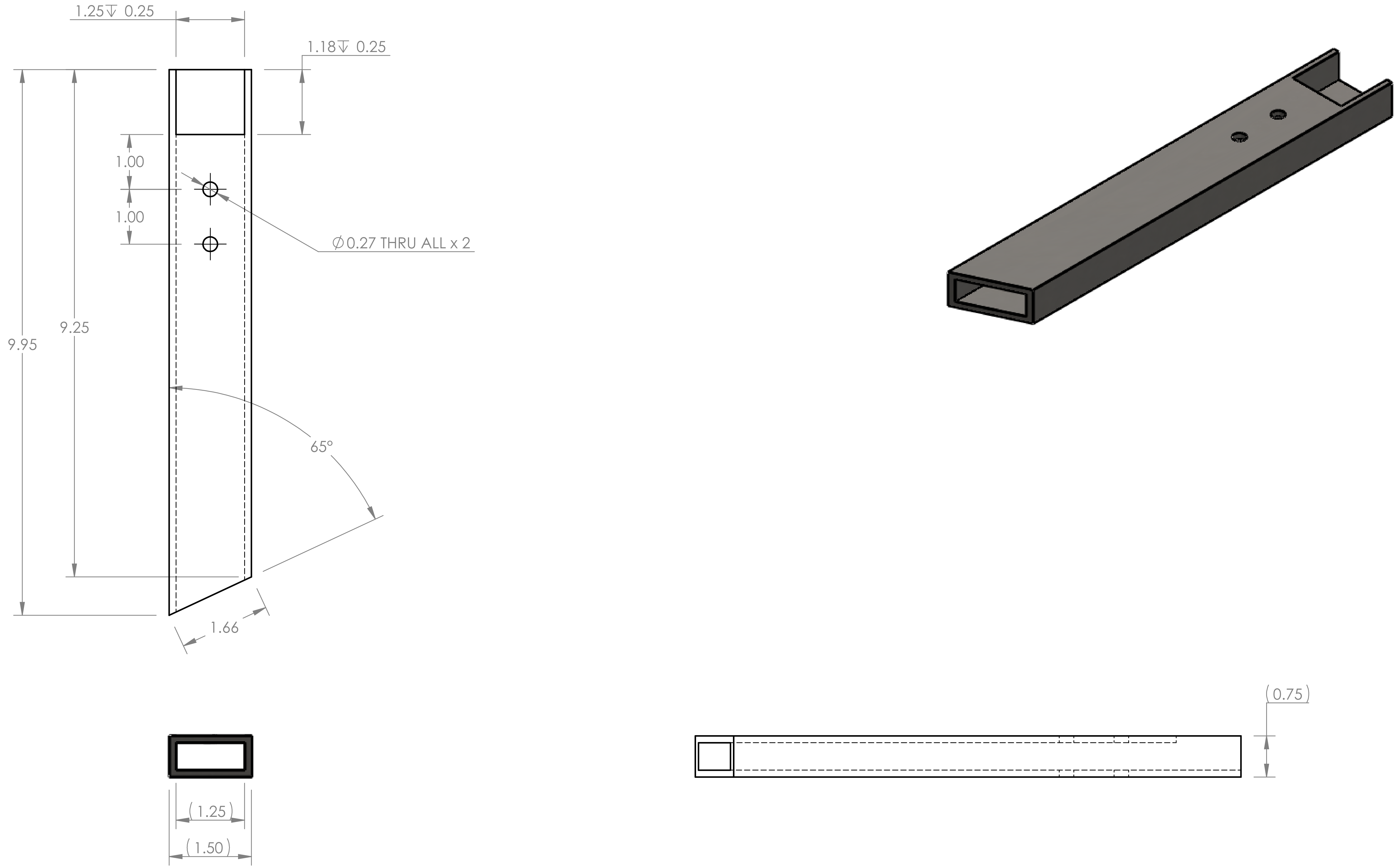
SM Last Saved: Monday, December 2, 2019 1:52:43 AM

SWARM ENGINEERING

Part Number

TITLE: Inner Drum Top Plate

SIZE	DRAWN BY:	Aiden Kooyman	REV
B	SM By:	William Hammond	0
SCALE: 1:7	Mass: 194.06 (lbs)		SHEET 1 OF 1



NOTE: CUT FROM 1.5" X 0.75" RECTANGULAR TUBING WITH 0.125" WALL THICKNESS

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X.X = ± 0.05
X.XX = ± 0.005
X.XXX = ± 0.001

SURFACE FINISH 24 µin

DO NOT SCALE DRAWING

MATERIAL:

FILE NAME: Flutes

Description:

Project: BeeBlade spin float

Comments:

Drawing Last Saved: Sunday, December 1, 2019 9:37:35 PM

SM Last Saved: Sunday, December 1, 2019 9:05:44 PM

SWARM ENGINEERING

Part Number

TITLE: Honey flute

SIZE B

DRAWN BY: Udeshwar Jaswal

SM By: Aiden Cumin

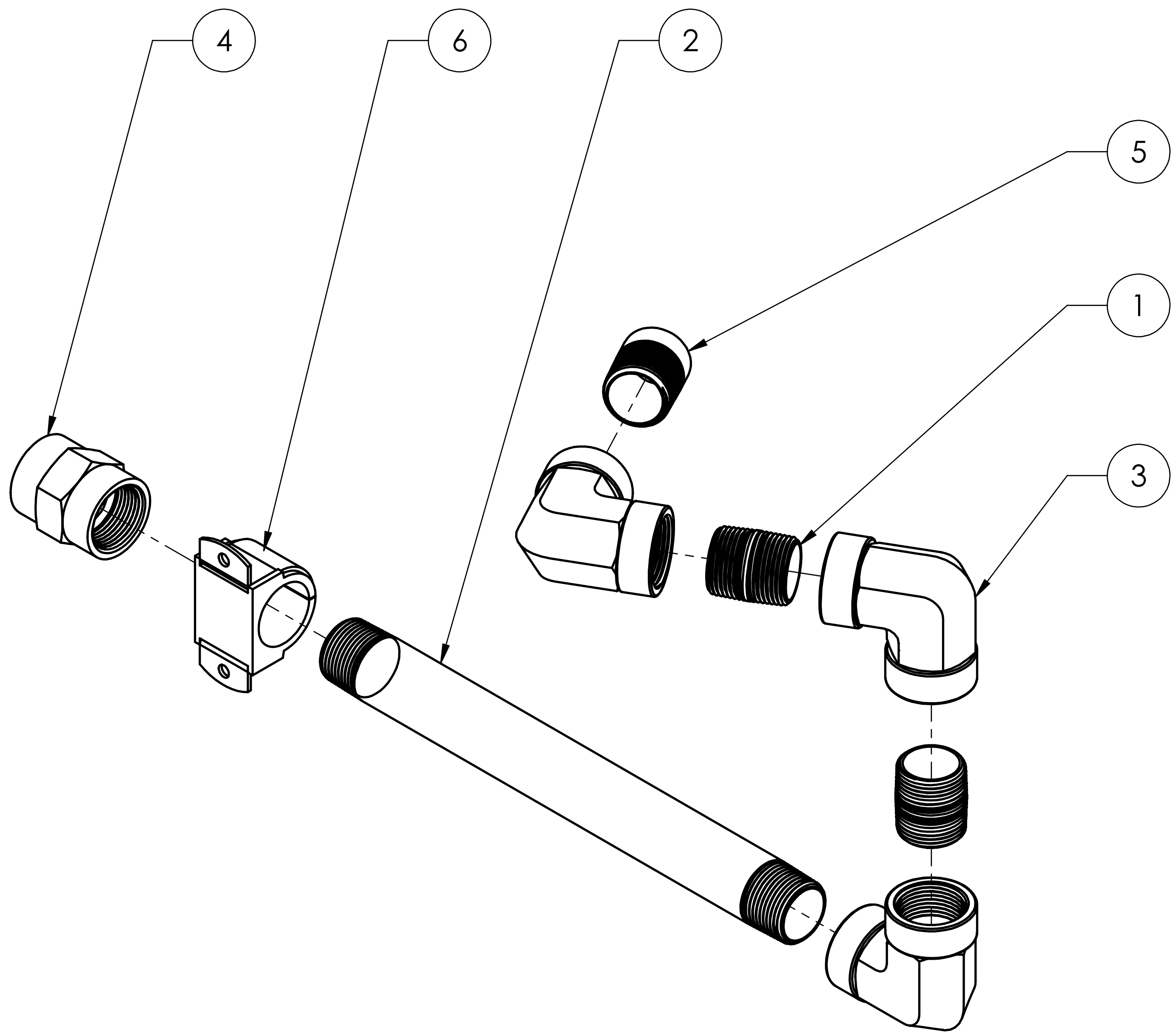
REV

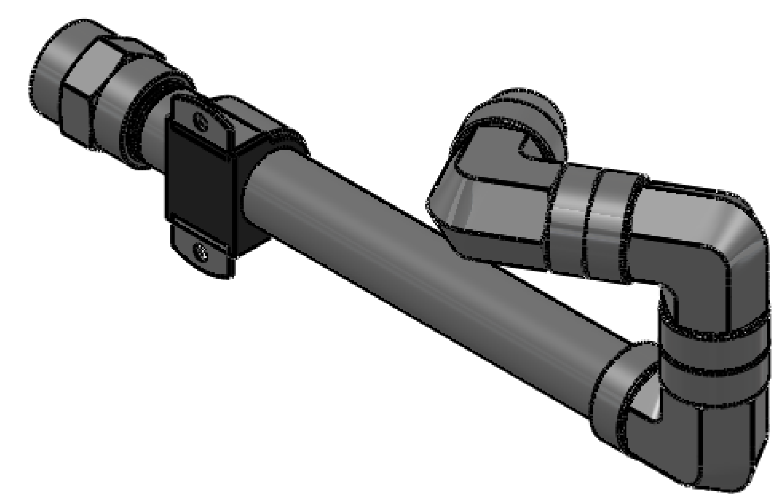
SCALE: 1:2

Mass: 1.33 lbs

SHEET 1 OF 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	4548K221	Elbow Connectors	2
2	4548K232	1" ID Stainles Steel Pipewith OD threaded ends	1
3	48805K716	90 Elbow	3
4	48805K722	Inet Connection for 1" ID Pipe	1
5	9110T25	Outlet Spout	1
6	11355T83	Mounting Bracket	1





UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X.X = ± 0.05
X.XX = ± 0.005
X.XXX = ± 0.001
SURFACE FINISH 24 µin
DO NOT SCALE DRAWING
MATERIAL: Various
FILE NAME: Inlet pipe assembly

Description:
Project: BEEBLADE Spin Float
Comments:
Reviewed by: Cale Benko
Drawing Last Saved: Monday, December 2, 2019 12:36:28 AM
SM Last Saved: Monday, December 2, 2019 12:36:28 AM

SWARM ENGINEERING

Part Number

TITLE: Inlet Pipe Assembly

SIZE B | DRAWN BY: Aide Kooyman | SM By: Gabriel Risbud-Vincent | REV 0

SCALE: 1:3 | Mass: 0.84 (lbs) | SHEET 1 OF 1