Final Report for a Project to Develop an Appliance to Replace Handwashing for Students Without Dishwashers

To: Bijay Chhetri

April 22, 2025

Team Members:

Lucas Rodrigues

Lucas Rodrigues (rodr1053@purdue.edu)

Austin Rohe

Austin Rohe (rohe0@purdue.edu)

Rohant Naithani

Rohant Naithani (rnaithan@purdue.edu)

Henrik Stjernfeldt

Henrik Stjernfeldt (hstjernf@purdue.edu)

ME 263 Lab 201

Executive Summary:

Objective: This report presents the three stages that make up the development of the Compact Dishwasher; the problem definition phase, the concept generation phase, and the design realization phase.

Procedure: The team began by identifying a common challenge faced by fellow university students and ultimately landed on the issue of students not cleaning their dishes for extended periods of time. With a problem in mind, the team could begin conducting research into why this is something that college students face, and if this is actually something that students would like to see remedied. Upon confirmation that this was an issue worth investigating, further research was done into what has already been done within this field. This was not only limited to products already on the market, but of patents as well. Once the pros and cons of similar solutions had be found, a problem definition was able to be established, detailing all the qualitative and quantitative requirements that were to be expected of the solution. With this, time could now be devoted towards creating a unique solution, beginning by identifying key features that must be present in the concept, and drawing up several different ideas for how exactly the product would function. Several processes were conducted ~~in order~~ to decide which concept would best fit the needs of the customer. Once a design was chosen as the one to follow, the team began refining this concept into something that was ready to be produced. Several financial analyses were then done to establish whether or not the product would be a success. With these showing that the product was ready for the market, a final prototype was produced and showcased to the public. With the public onboard, plans for mass production were made, which will begin shortly.

Results: A fully functioning prototype was created to illustrate essentially how the product would function and look upon entering mass production and was also displayed for students to see. Now that the research and development phase of the project has been completed, it is time to carry out the plans made for a mass-market introduction of the Compact Dishwasher.

Conclusion: Pristine Solutions has constructed a compact dishwasher that is accessible and appropriate for college students to solve the problem of dishes piling up in apartments.

Table of Contents:

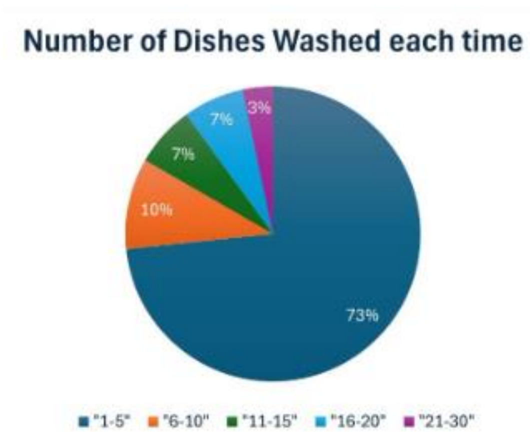
Section 1.0: Introduction

The purpose of this report is to discuss Pristine Solution's project to develop a product that can replace handwashing dishes for college students. Dirty dishes are an all-too-common issue for college students. Whether you are living in an apartment, dorm, or off campus, dirty dishes are a main source of strife between roommates. A large reason why dirty dishes always seem to pile up is because hand washing dishes is boring, laborious, and slow. For those without a dishwasher, there is no reasonably affordable or effective alternative to hand washing. By creating a mechanical and compact dishwashing device, the team hopes to capture this customer base of dishwasher-less college students and provide them with a product they will gladly use.

This report can be organized into three sections: the problem definition and its development, concept generation and product operation, and the final assembly and performance analyses. In the first section, the team explains the development of the Problem Definition in the previous project phase and then reworks the engineering requirements to fit later findings. Following this, the second section records the process of concept selection and end-user product operation to optimize design decisions and improve final product quality. Lastly, this report closes with engineering drawings of the final product, a bill of materials, and analysis of the overall assembly and performance against benchmarks.

Section 2.0: Problem Definition Development

To develop the Problem Definition for the project, the team conducted detailed research, including consumer, market, benchmark, and patent research. For consumer research, college student responses were analyzed, with specific focus on students that do not have access to a dishwasher. The qualities found to be most vital are that a dishwasher replacement needs to be cheap, easy to use, and clean dishes faster than hand washing, based on surveys done. Furthermore, students were asked to describe their satisfaction with their current dishwashing solution on a scale from 1-5, and of those who do not have a dishwasher and do their own dishes, the average satisfaction rating of handwashing dishes is 2.6 stars out of 5. This shows how students on average are generally not happy to do their dishes, but also not too terribly burdened by it. This is something the team is looking to correct, however, as the overall average was 3.4/5.0 stars including those with dishwashers. An unexpected result was that all but one of those without dishwashers stated that they only clean between 1 to 5 dishes at a time (see figure 2.2), something that is also reflected in the data drawn from all respondents. This indicates that the product will only need to clean a small number of dishes at one time. Pristine Solutions has also concluded that due to the target audience of this product being college students, the desired cost of this product will need to be less than $35 to be competitive (see figure 2.1).



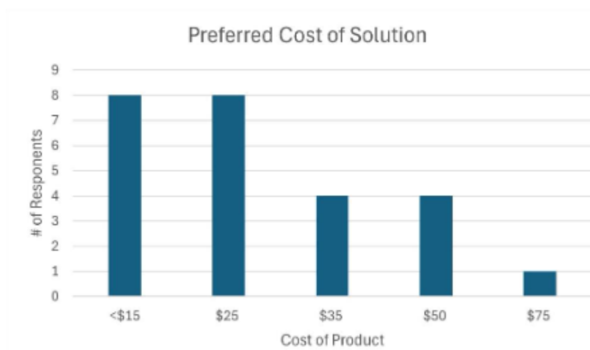


Figure 2.1: Desired Cost of Solution

Figure 2.2: Number of Dishes Washed

Additionally, Pristine Solutions conducted market research to prove that there are willing buyers for the team’s product. In 2020, a survey by EIA was conducted found that 27% of people do not have a dishwasher and 14% of people who do have a dishwasher, don’t use it every week. These numbers were only a 1% improvement from data in 2015 so the team can assume the effects of covid did not change these numbers drastically. Digging into this data even further, the team saw a trend of dishwashers being used less and less as household income decreases. Additionally, it was found that the compact dishwasher market is set to increase, showing that the growth of the market is set to increase due to urbanization with a study period from 2020- 2029. The market size in 2024 is 6.28 billion and is projected to be at 9.09 billion by

2029. This shows that entering the compact dishwasher market has potential in terms of market size. Mordor Intelligence attributes “The rise in single-person households and dual-income families [to accelerate] the demand for compact dishwashers.” Mordor also mentions that “Compact dishwashers offer the advantage of being both space-efficient and efficient in terms of water and energy consumption.” Pristine Solutions kept these benefits in mind as the team designed the solution for the problem statement.

This led us to research potential products through an analysis of four benchmark products that could fit within this niche market. Pristine Solutions found that most products currently on the market were either too expensive for the target audience of college students or were cheaply made, resulting in a bad product. To ensure that the team did not repeat the same mistakes of these products, Pristine Solutions researched patents that have been filed to see what methods have been tried before and what has not. After gathering research from consumers, current market trends, and products currently sold, the team can conclude that there is a place for a countertop dishwasher with a price of $35 for college students that don’t have access to a normal dishwasher.

Section 3.0: Problem Definition

To establish the problem definition, the results of both the research conducted and House of Quality were analyzed to form a list of engineering requirements for the innovative dishwashing solution the team plans to create. The resulting list consists of both Qualitative and Quantitative requirements and is heavily influenced by the specific needs and wants of the market and its customers.

The Qualitative requirements are as follows:

1. *Features a drying ability*
2. *Has a viewport/clear lid*
3. *Has accessible cleaning components*
4. *Is aesthetically pleasing (as determined by a jury rating)*

5. *Can access soap*
6. *Can access water*
7. *Features rubber sealing*
8. *Can Be Assembled Simply*

Additionally, a great deal of Quantitative requirements have also been identified:

1. *Survive a drop of 4 feet*
2. *Cost less than $20 to produce*
3. *Produces less than 50 Decibels during operation*
4. *Taking up less than a 12” by 12” space on a counter*
5. *Can dry up to 5 dishes per drying cycle*
6. *Leaves zero residue after a cleaning cycle*
7. *Able to clean a dish within 30 seconds*
8. *Having an installation time less than 1 minute*
9. *Leaves less than 50 mL of water/soap on counter*
10. *Weighs less than 10 lbs.*
11. *Can clean 5 dishes before needing to be drained*
12. *Operates within 35°F to 100°F*
13. *Can perform 100 washes without considerable damage*
14. *Has 2 cleaning methods or choices*
15. *Available in 2 colors*
16. *Available in 2 sizes*
17. *Takes less than 10 lbs. of force to operate*
18. *Change dishes in less than 5 seconds*
19. *Takes less than 10 seconds to change between washing and drying ability*
20. *Can dry a dish within 30 seconds*

21. *Breaks less than 1 dish per 100 washes*
22. *Moves less than an average of ¼ inch during each use*
23. *Leaves 0 marks on a wood surface when pushed*
24. *Can fit a plate up to 11 inches in diameter*
25. *Can fit a bowl up to 5 inches high*
26. *Full Shippable Product can be assembled in less than 10 steps*

As can be seen, the team's Problem Definition has changed from the prior phase to account for new findings and to adjust to the project's scope. For example, two requirements were removed, "*Takes between 500 to 1500 Watts to power*" and "*Can be connected to a water supply*". This was done to allow for a greater variety of solutions during the Concept Generation phase, such as hand-operated washers or designs with integrated water tanks. If these new requirements can be met while maintaining a sale price of less than $35, Pristine Solutions anticipates selling 30,000 units within the first year.

Section 4.0: Concept Generation and Selection

To begin with Concept Generation, a functional decomposition was conducted to show the team where resources should be diverted in order to create a successful dish-cleaning machine (Figure 4.1). The primary first level sub-function was determined to be the "setup" process, which essentially covers the initialization of the machine, such as installing the desired cleaning head and acquiring a water source.

The next first level subfunction is the "securing" process, which dictates not only how the machine will keep water from escaping its confines but also how the dish should be kept from moving around while in the machine, something that had not been previously considered. Preliminary solutions to this might include rubber studs and/or clamping of the dish. The following first level sub-function describes the main purpose of the machine, which is the "washing" process, and is thus relatively self-explanatory. The final first level sub-function is the "drying" process, which breaks down "drying" into wiping away the water and a final shine function.

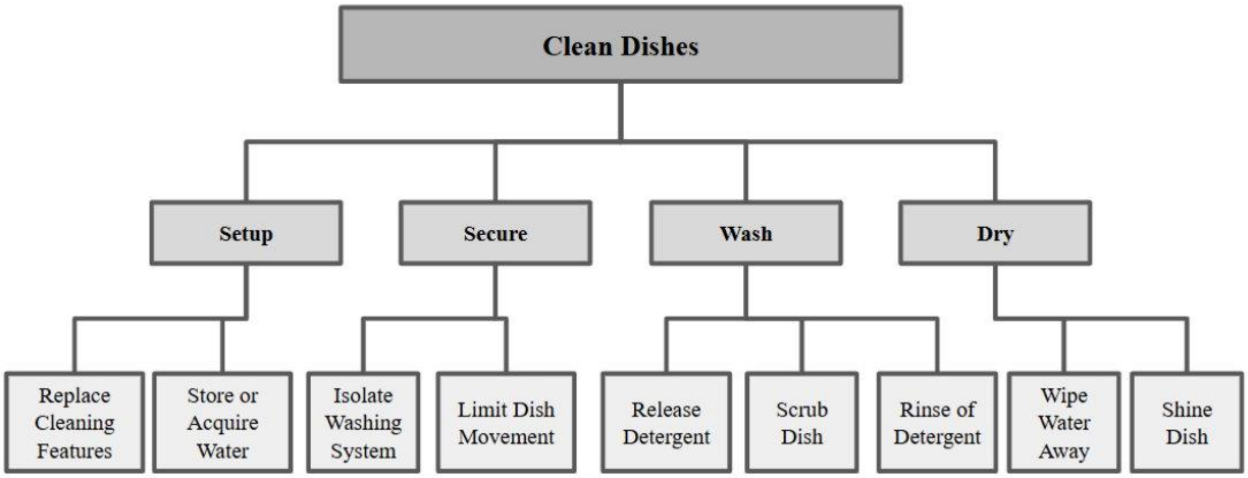
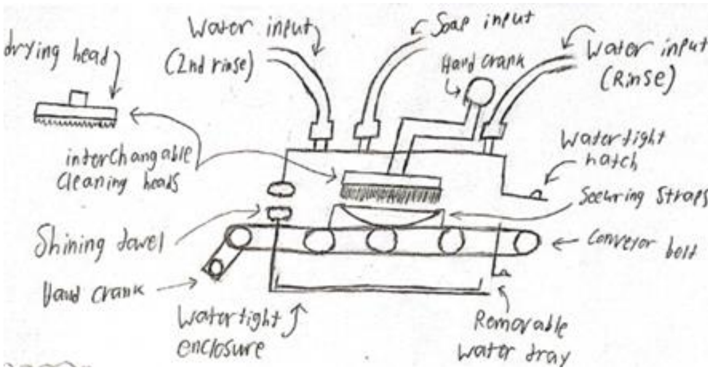


Figure 4.1: A Tree Diagram of the Functional Decomposition of a Compact Dishwasher

Following the functional decomposition, the team began generating preliminary concepts in a three-step process. First, a general idea or gimmick was thought of, like a washer that used gravity to pull plates through or a ripcord to spin a sponge against a plate. Then, basic orthographic sketches of the concepts were made, with enough views to highlight or show all key features. Lastly, the key features were labeled with their purposes clearly defined to waste no space or resources. These features were then compared to those found in the second level sub functions of the functional decomposition to see if there were any bases not covered or features that were unnecessary and overcomplicated the system. The sketches were updated accordingly to fix all issues noted, and the team was left with four preliminary concepts (Figure 4.2, Figure 4.3, Figure 4.4, Figure 4.5).



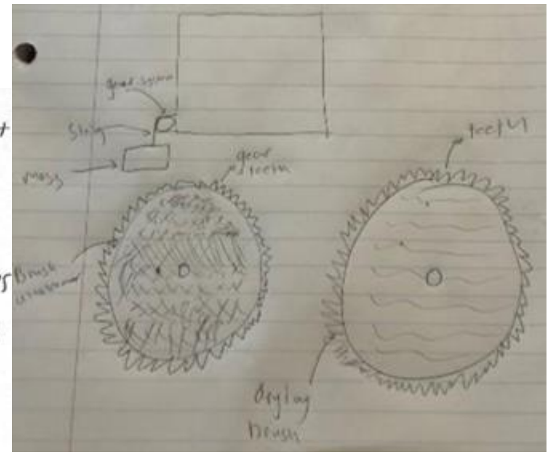
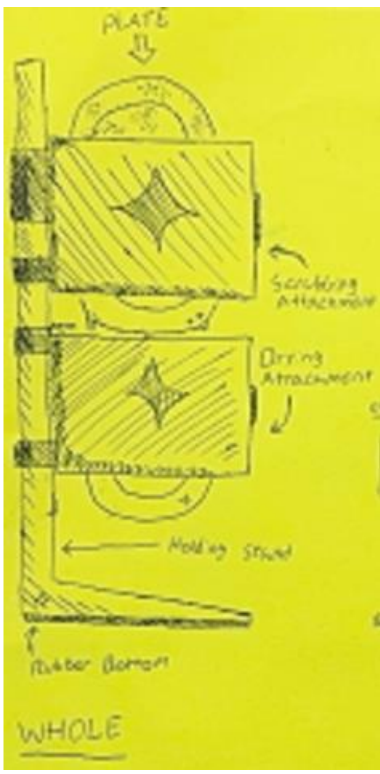


Figure 4.2: Concept 1

Figure 4.3: Concept 3



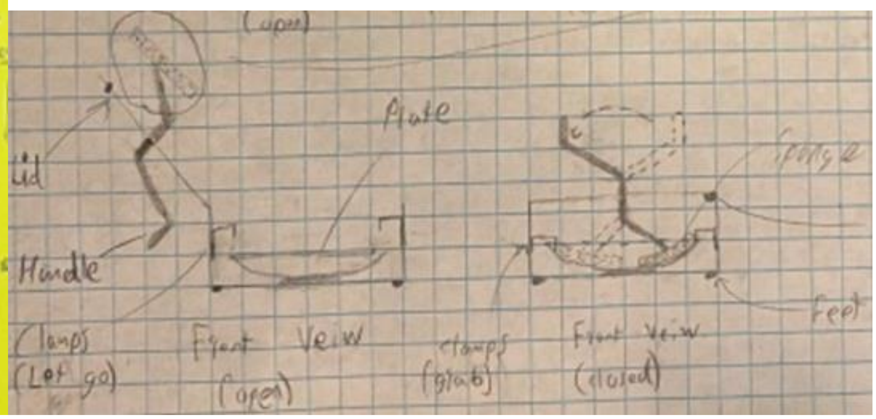


Figure 4.4: Concept 2

Figure 4.5: Concept 4

Initial concept selection was then conducted to find the design with the best balance of feasibility and effectiveness. Overall, concepts were assessed based purely on the number of subfunctions they could fulfill. This approach was deemed not enough however, as certain concepts with obvious potential, or a creative approach fell behind overly complicated concepts that just crammed every function necessary into their design. To combat this, concepts were also assessed on how well they fulfilled each function, like how well they would be able to secure a dish and not just if they could. To conclude the initial selection, the feasibility of each concept, in terms of manufacturing and customer adoption, were discussed as a team to find a common consensus on which concept should be further developed and pursued.

The most important, and definitive, part of the team's concept selection is the decision matrix (Figure 4.6). The team began the decision matrix process by giving weight to the customer requirements found in the Problem Definition phase based on importance to the customers and importance to product functionality. After this, all the generated concepts were assessed using a system with scores ranging between -2 and +2 in comparison to the selected datum.

	Weights	Concept 1	Concept 2	Concept 3	Concept 4	Datum
Customer Requirements	Scale (1-5)					
Dries dishes	5	2	2	2	2	0
Can be connected to a water supply	3	2	0	0	2	0
Has accessible cleaning components	4	-1	1	1	0	0
Aesthetically pleasing	3	0	1	1	-1	0
Cleans utensils	4	-1	-2	1	1	0
Durable	4	0	0	0	1	0
Affordable	5	1	2	0	1	0
Quiet	3	1	2	1	0	0
Small footprint	5	0	2	1	1	0
Can clean multiple dishes at once	2	-2	-2	1	-2	0
Cleans dishes effectively	4	1	-1	1	0	0
Cleans dishes quickly	5	1	2	-2	1	0
Easy to install	2	-1	-2	1	-1	0
Watertight/does not leak	5	0	-1	1	0	0
Lightweight	1	1	2	0	1	0
Multiple cycle options	3	-1	-2	0	1	0
Easy to use	5	0	1	2	1	0
Rarely breaks a dish	5	1	0	0	-1	0
Stays still while operating	3	0	0	0	-2	0
Fits all dish types	4	1	-2	-2	2	0
	Total +	11	15	13	14	0
	Total -	-6	-12	-4	-7	0
	Overall Total	5	3	9	7	0
	Weighted Total	26	21	34	36	0

Figure 4.6: Weighted Decision Matrix

The CaraMart dishwasher was chosen as the datum due to its relatively low cost in comparison to the other dishwasher-like benchmark products and its high functionality. Even though some of the other benchmarks may meet the customer requirements better, it is important to note that some requirements are far more important than the others, like cost, which is a make-or-break requirement for product success.

After scoring all the concepts for each requirement, a total and weighted total score were calculated. All concepts performed better than the datum, suggesting that there is real room for product improvement in the compact dishwasher market. Out of the four concepts, the one that had the highest total weighted score was concept #4 (Figure 4.5). The main areas where this concept excelled are in its versatility and durability. While durability is self-explanatory, this product is highly versatile in that it features multiple cycle options, has the ability to fit all dish types, and can be connected to a water supply. Additionally, concept #4 boasts improved drying capabilities than the benchmark product. This concept resulted in being the teams' primary concept that would be developed into a low fidelity prototype. Given that in the decision matrix it had the highest weighted score out of all four concepts, it was the overall best design. Pristine Solutions also noticed that it offered the best opportunity to feature reoccurring purchases with the ability to reattach sponges, which helped make the final decision. While there are areas for concept improvement, because of its exceptional weighted performance in comparison to the other concepts, it was determined as most fit to be the project's primary concept.

The concept generation and selection process conducted by the team began with a functional decomposition, where core functions for the product were defined to help assess the later created concepts. Then, the team moved onto preliminary concept generation, where sketching and group discussion generated a wide array of unique solutions to the problem defined by the team in the first project phase. These initial concepts were improved by finding subfunctions not addressed and redesigning them so that as many core needs are met by each concept as possible. Finally, the team concluded the process with a final selection using a weighted decision matrix. The concepts were scored against the team's customer requirements in comparison to each other and an existing product, leaving the team with the most successful concept to further flesh out and improve, concept 4 (Figure 4.5).

Section 5.0: Operational Description

After careful consideration in the design matrix, the team took concept #4 into the primary concept phase. Using the perspective of the end user, the team's primary concept is an effective compact dishwasher. A user would begin by placing a plate into the rectangular shaped box, angling it while lowered so that the dish grippers can hold the dish securely (Figure 5.1). Then the lid is closed like a book, sealing the plate inside the washer with its rubber lining and automatically lowering the clamps (Figure 5.2). The lid is clear so that the cleanliness of the plate can be judged without the need to reopen and close the lid to check if it needs more cleaning.

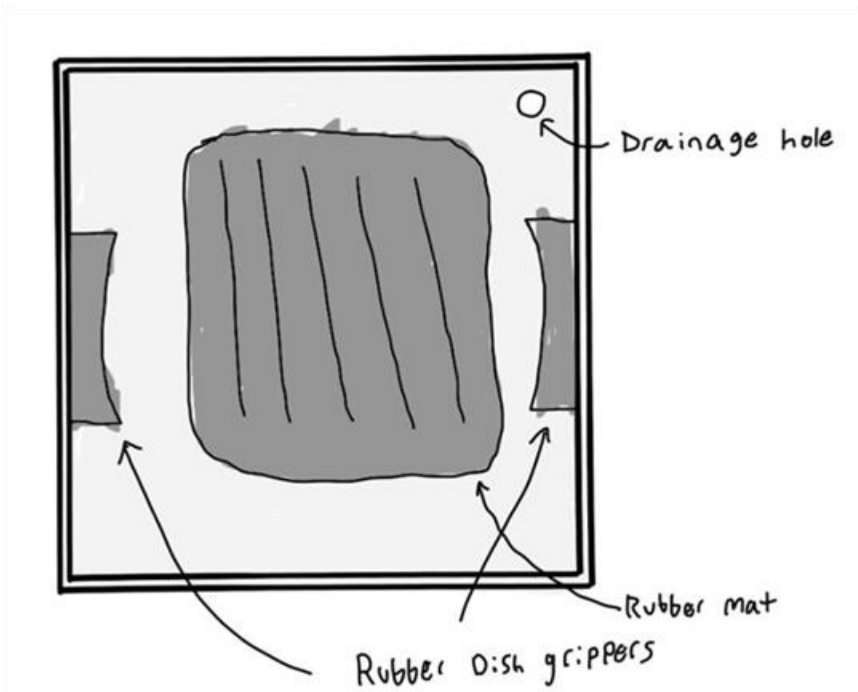


Figure 5.1: Top View without Handle/Lid

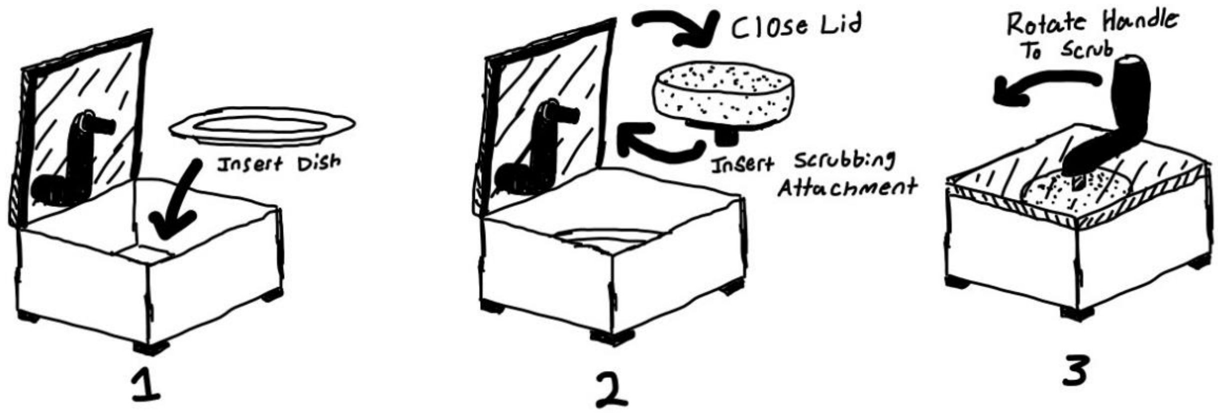


Figure 5.2: Basic First Steps of Product Operation Visualized

Seated in the center of the lid is a crank attached to a sponge that is pushed against, and conformed to, the shape of the plate. A user would then grab the handle outside the washer and rotate it like stirring a pot as fast or as hard as they would like (Figure 5.3). The rubber feet of the washer keep it from moving around on the counter if a user is handling the crank harshly (Figure 5.3). The choice of Plexiglas material for the lid ensures that if a user's hand slips down from the handle, hitting the lid, it will not shatter or hurt.

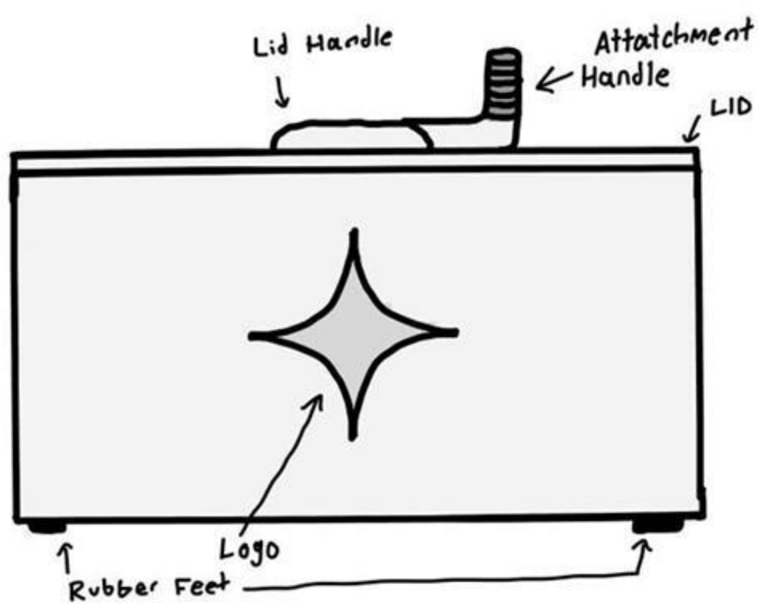


Figure 5.3: Front view of washer closed

If the sponge becomes dry or it isn't cleaning as effectively, which will happen over time, opening the lid, wetting it a bit, and adding some more dish soap will reset the sponge back to full effectiveness. Ideally a user would only need to do this after many uses so that it does not become a hassle.

While there are some areas for further improvement of the primary concept, it still stands as a fast and efficient cleaning device that would satisfy the customer's needs. Its simplicity allows any user to easily understand how to properly use the device without any instruction, and its compact design makes it a great fit for desks, kitchen counters, or storage in small spaces

Section 6.0: Bill of Materials/ Materials Selection/Fabrication Process

To understand the financial costs of continuing the project and a future production cycle, a Bill of Materials (BOM) has been developed (Figure 6.1). The parts listed in the BOM are separated into three categories: assembled, manufactured, and purchased.

The key parts to be manufactured are the base and handle. The base, or shell of the dishwasher, will be injection molded to ensure perfect watertightness as well as save money when producing a high number of units annually. The handle will be injection molded plastic as well due to its unique shape and the cost savings of in-house production. It can be seen in the BOM that this process is very inexpensive, adding to its appeal.

As for purchased parts, the key items are the sponge and bearing. The sponge is obviously important as it is one of the few parts contacting the actual dishes and needs to be able to clean them. An adequate vendor was found to maintain a balance between cost and effectiveness. The bearing is too complicated to be fabricated, so it will be purchased from elsewhere. This will guarantee that it can effectively spin to help the handle in cleaning. An appropriate vendor was chosen once again and was able to offer a high-quality bearing for reduced bulk-order cost.

Item No.	Part No.	Part Name	Units	Qty	Material / Decription	Source	Catalog No.	Unit Cost ($)	Unit Processing Cost ($)	Assembly Cost ($)	Line Total Cost ($)
1	M1	Handle	lbs	1	Plastic / Injection Molding	-	-	1.97	0.12		2.09
2	M2	Dish Gripper	lbs	1	Aluminum/ Keeps dish in place while washing	-	-	1.97	0.12		2.09
3	M3	Interior Grip Mat	pcs	1	Neoprene Rubber	Home Depot		1.25	0.17		1.42
4	M4	Custom Base	kg	1	Plastic/Model to fit any dish	-	-	4	0.17		4.17
5	P1	Sponge	pcs	1	Scrubbing sponge	Go! Food Service	74BWK MD	0.962	-	-	0.962
6	P2	Rubber Feet	pcs	4	Rubber to grip to surface	Temu	QN50805	0.0146	-	-	0.0584
7	P3	Acrylic Sheet	pcs	1	Acrylic sheet for framing	estreetplastics	X-100250	4.83	-	-	4.83
8	P4	Caulk	pcs	1	Caulk/Water seal framing	Premier Re Fractory	PRS-01110	1.45	-	-	1.45
9	P5	Screws	pcs	8	Stainless Steel	Fasten Solutions	793036	0.0275	-	-	0.22
10	P6	Bearing	pcs	1	Bearing for handle	PGN Bearings	BB-R8-ZZ/1	0.73	-	-	0.73
11	P7	Hinges	pcs	2	Lid Hinges	Harfington	1031740	0.221	-	-	0.442
12	A1	Screwing	-	-	Adding hinges	-	-	-	-	1.5	1.5
13	A2	Drilling	-	-	Holes for bearing and plugs	-	-	-	-	1	1
14	A3	Glueing	-	-	Water tight liner and plug seals, bearing	-	-	-	-	1	1
										Total Purchased Parts $	8.6924
										Total Custom Manufactured Parts $	9.77
										Total Assembly Cost $	3.5
										Total Cost $	21.9624

Figure 6.1: Bill of Materials for a Full-Scale Production of The Team's Product

Finally, the key part being reworked during assembly is the base. After injection molding, it will undergo a process of drilling, screwing, and glueing to help integrate all manufactured and purchased parts effectively. Some examples of this are the bearing that will be put into the hole drilled in the lid, the holes drilled into the integrated hinges between the base and the lid, and the act of inserting pins into these hinges to make them function properly.

As previously mentioned, the primary way that in-house products will be fabricated is via injection molding. This is the process of feeding a molten material into a mold cavity through a nozzle and then allowing this material to harden, taking the shape of the mold. In the case of Pristine solutions, ABS plastic would be the desired material to be used. This material has been chosen because it is very easy to work with, meets all the quality standards required for this product, and is relatively inexpensive. Injection molding is also an unbelievably efficient process once it is all set up, making it ideal for mass production. This process will be used to create the base, handle, and the adapter used by the attachments. Together with all other components of the compact dishwasher, it will be made up of a total of 10-15 parts. This is a small number of parts and will thus result in a simple manufacturing process and allow for speedy assembly.

Section 7.0 Drawings

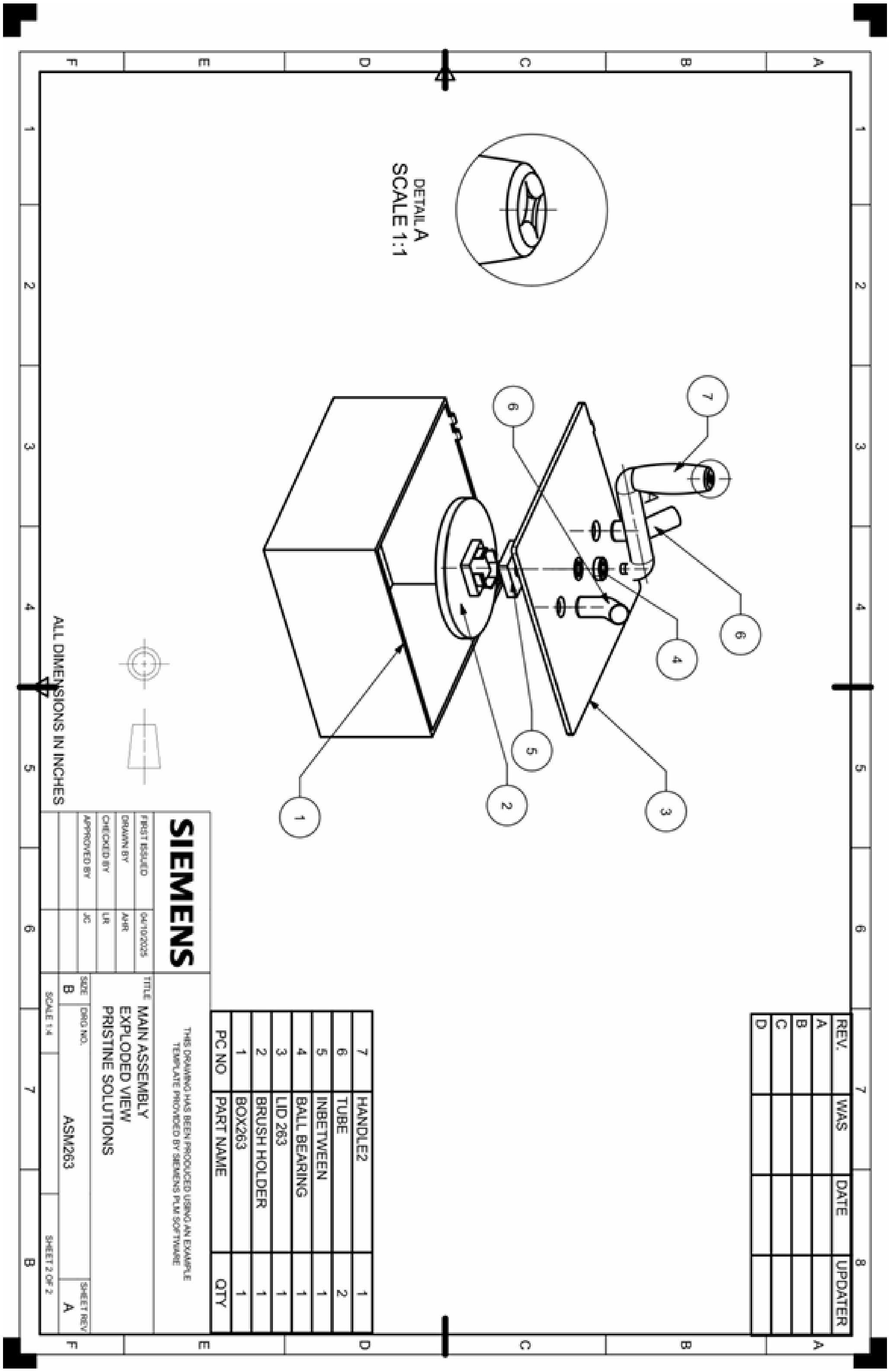


Figure 7.1: Assembly Drawing

Above is the assembly drawing of our final product (Figure 7.1). Individual drawings can be found in the Appendix. They include the scrubbing attachment (C1), handle (D1), lid (E1), and base (F1). The rest of the parts used in the final product are purchased parts and do not need individual drawings.

Section 8.0: Assembly Analysis and Tolerance Discussion

The assembly process for the current product design is simple and straightforward. While competitors may use welding or other processes that require complex machinery and specially trained staff, the team's product can be assembled all by hand (although machining is necessary for manufacturing individual parts).

The first step in assembly is adhering the dish gripper (a suction cup) to the inner base of the washer frame (Figure 8.1). By opting to use adherent rather than screwing, we maintain the watertight seal and reduce any potential wear from water damage on the product. Next, the acrylic lid is lined up with the hinges on the washer frame and pinned in place (Figure 8.1). The purchased bearing is then inserted into the circular cut out in the center of the lid and adhered around the edges to ensure water does not leak out of the lid and the bearing remains fixed (Figure 8.1).

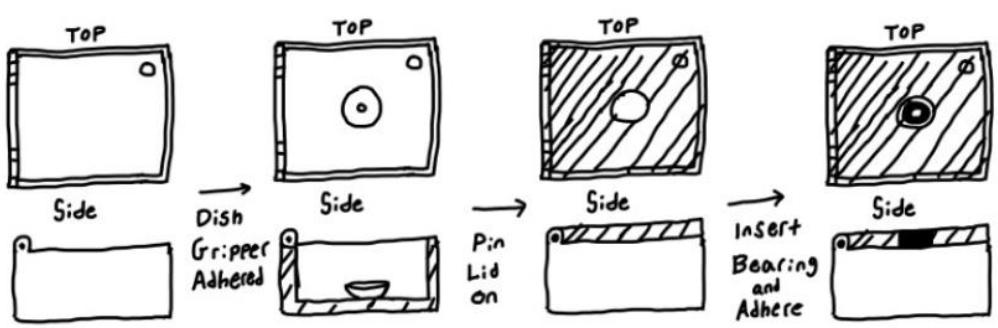


Figure 8.1: First Assembly Steps (Frame, Dish Gripper, Lid, Bearing)

Following the addition of the bearing, the lid is closed, and the washer is flipped upside down. Once upside down, the rubber feet are adhered to the bottom frame in the pattern shown below (Figure 8.2). This pattern was chosen to maintain relative aesthetic and stability while leaving the drainage hole uncovered. Something notable about this step is that the rubber feet come prepared with their own adhesive, so assembly consists of peeling off the protective film and hand pressing the feet to the product corners.

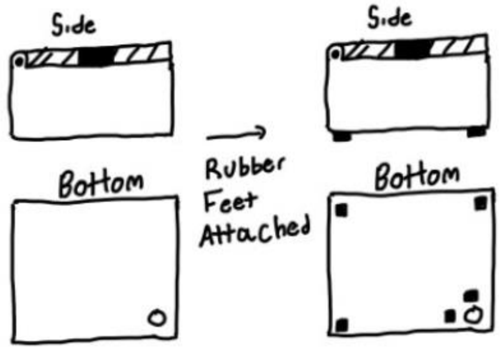


Figure 8.2: Addition and Arrangement of Rubber Feet

The scrubbing and drying attachments are assembled separately from the washer system. In a simple one step process, glue is applied to the underside of injection molded fittings that can slide onto the handle and one of the manufactured attachment pieces is centered and stuck (Figure 8.3). No matter the type of attachment, the assembly process is the same, so all attachments can be made on the same assembly line.

Figure 8.3: Assembly of Basic Attachment (Sponge can be A Towel or Different Shape Depending on Attachment Type)

Once all the parts are fully assembled, they are ready for packaging (Figure 8.4). The lid of the washer is lifted and the handle, scrubbing attachment that comes with the base product, and other product extremities are placed inside the washer. The lid is closed, and the product is placed into a cardboard box with foam beneath it and an instruction manual on top. The packaging is branded with the company logo and a picture of the product so that it is ready immediately for store shelves.

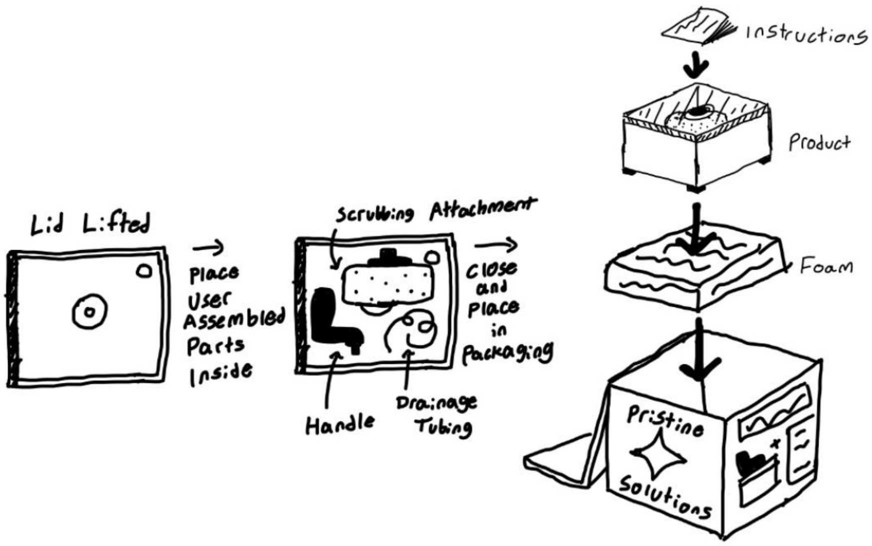


Figure 8.4: Final Assembly Packaging Steps

In the prior Problem Definition, there are a number of engineering requirements that the assembly process the team has developed must address. Most obviously, the requirements “can be assembled simply” and “Fully shippable product can be assembled in less than 10 steps.” While very similar, these requirements are not the same. It is possible to have an assembly process that is only one or two steps but requires complex machinery or custom fixtures and it is also possible to have an incredibly simple process that is over ten steps. Addressing both, the current assembly process for a fully shippable product is 5 steps (6 including packaging) and can be done fully by hand. This saves the team money on assembly costs and staff training, allowing the product’s prices to be cut further without sacrificing profit margins. This also brings the assembly time of a single unit down to less than a minute, making the production of a target 30,000 units a year more feasible. Another engineering requirement this process addresses is “having an installation time less than 1 minute”. By controlling what the team and the end user assemble, a careful balance has been found that allows for simpler packaging and assembly while still keeping product setup a quick 2 step process of attaching the handle and the attachment through the bearing.

When it comes to mating different parts during the assembly process, tolerancing is incredibly important. For the purposes of the team's assembly process only three tolerance stack-ups are highly important: The width of the hinges, the diameter of the hole in the lid with the bearing, and the diameter of the handle and the inside of the bearing. If the width of the hinge on the lid is too wide, or the gap in the hinges on the washer frame is too small, then the lid cannot be fit or pinned to the frame. If the hole cut into the lid is too small and the bearing cannot be fit, then the part cannot be used, and if it is too big it increases the amount of glue needed during assembly. Finally, if the part of the handle that goes through the center of the bearing is too large then the handle cannot be used, and if too small then there won't be enough grip for the handle to actually spin effectively. By designing all of our parts with these stack-ups in mind, the team has ensured that during assembly these parts will not become issues.

The team's assembly process for the compact dishwasher is simple, fast, and can be done fully by hand. Each of the 5 steps are straight forward and build on themselves to create the full-fledged product. By keeping in mind tolerance stack-ups during the design process, the team has guaranteed that an acceptable number of parts will be effective, and that assembly can be done without the use of screws, bolts, or excessive amounts of adhesive.

Section 9.0: Benchmarks and Performance Analysis

To verify the quality of Pristine Solutions' solution, a weighted decision matrix was made with benchmark products (Figure 6.1). The most notable competitors are listed, and major discrepancies in the most important customer requirement scores are highlighted in red and green, worse and better than the datum respectively.

	Weights	Dish Buddy	Hava	Pristine Solutions
				
Customer Requirements	Scale (1-5)			
Dries dishes	5	-2	2	0
Small footprint	5	2	-2	0
Affordable	5	0	-2	0
Cleans dishes quickly	5	-1	-2	0
Easy to use	5	2	1	0
Can be connected to a water supply	5	0	0	0
Watertight/does not leak	5	-2	0	0
Cleans dishes effectively	4	-1	1	0
Durable	4	-2	2	0
Cleans utensils	4	0	0	0
Fits all dish types	4	0	2	0
Has accessible cleaning components	4	0	-1	0
Rarely breaks a dish	3	-2	0	0
Aesthetically pleasing	3	0	0	0
Multiple cycle options	3	-2	2	0
Stays still while operating	3	-2	0	0
Quiet	3	0	1	0
Can clean multiple dishes at once	2	-2	2	0
Easy to install	2	1	-2	0
Lightweight	1	2	-2	0
	Total +	7	13	0
	Total -	-16	-11	0
	Overall Total	-9	2	0
	Weighted Total	-25	18	0

Figure 6.1: Critical Benchmark Products vs Preliminary Concept Weighted Decision Matrix

When analyzing Dish Buddy against Pristine Solutions, the Dish Buddy loses out due to its inability to dry dishes, it not being watertight, and not being durable according to customer reviews. The Dish Buddy does better in having a small footprint and being easy to use. It's important to note that while the Dish Buddy performs poorly compared to Pristine Solutions, the Dish Buddy is relatively affordable, unlike the Hava dishwasher. The Hava dishwasher on paper performs much better than the Pristine Solution's due to its superior drying ability, proven durability, and vast versatility, however this is a premium product not made for economy. While these benefits put the Hava 18 points higher than Pristine Solutions, the cost nullifies the edge the Hava has on the datum. The team's product aims to be $35, however the Hava Dishwasher is priced at $250. This is a whopping 615% increase in price, which makes the Hava impractical for most college students in need of a handwashing alternative.

To summarize: Pristine Solutions outperforms the Dish Buddy on grounds of drying ability, durability, and watertightness. While the Hava outperformed Pristine Solutions, the Hava's high price nullifies its benefits.

To further verify the preliminary solution's adherence to the engineering standards, mathematical engineering models were formulated to simulate real world situations. To state from the engineering standards, the impact durability of the dishwasher must be able to survive a drop of 4ft, a similar height to a countertop. This model **(A.1.)** was derived from using physics principles of conservation of energy and impulse to calculate impact force and uses a calculated maximum impact force using average tensile strength and impact surface area. It was found that the final production dishwasher using ABS injected plastic would be able to endure a maximum force of 1.6*10^6N, while a 4ft drop would have an impact force of 555N. The maximum tensile force, being so much higher than the 4ft drop force, verifies the structural durability of the dishwasher. It is also realized that dishes in the dishwasher may be present during a drop, increasing the effective mass of the dishwasher. The model accounts for this in the form of a mass (Kg) vs impact force (N) graph (A.2.), in which the model verifies no matter the weight of the dish, the dishwasher will survive the drop. While the model is roughly accurate, the assumptions of impact time and impact surface area introduce some variability.

Another critical engineering requirement that requires verification is that the dishwasher moves less than a quarter inch during use. To verify this, formulation was performed to calculate the maximum force that can be applied to the washer with a horizontal pushing force applied through the center of mass. This model tests the effectiveness of the rubber feet added to the bottom of the dishwasher to prevent slippage during normal use. Principles of friction forces were used to calculate, and it was found that the washer with an average weighted dish would be able to withstand a 17.8 Newton force before beginning to move, as shown in **(A.3.)**. This is around the same amount of force it takes to push a heavy textbook on a finished wooden surface. Considering the bearing during the rotating motion of the handle will contribute near to zero to the overall force, it is unlikely that 17.8 N of force will act through the center of mass, thus fulfilling the product's engineering goal of moving less than a quarter inch during use. This model is presented in a mass (Kg) vs maximum force (N) given a hypothetical weight of the dish within the washer **(A.4.).** Like the previous model, there are some assumptions that hinder the exactness of the results. The static friction constant was estimated for a rubber compound on a wooden countertop-like surface. During operation the force applied by the user would be acting at a point on the handle a distance away from the center of mass, closer to one rubber foot than the other, and affect how the force is distributed. Either way, the model is a good estimate on the ability for the dishwasher to resist motion under use.

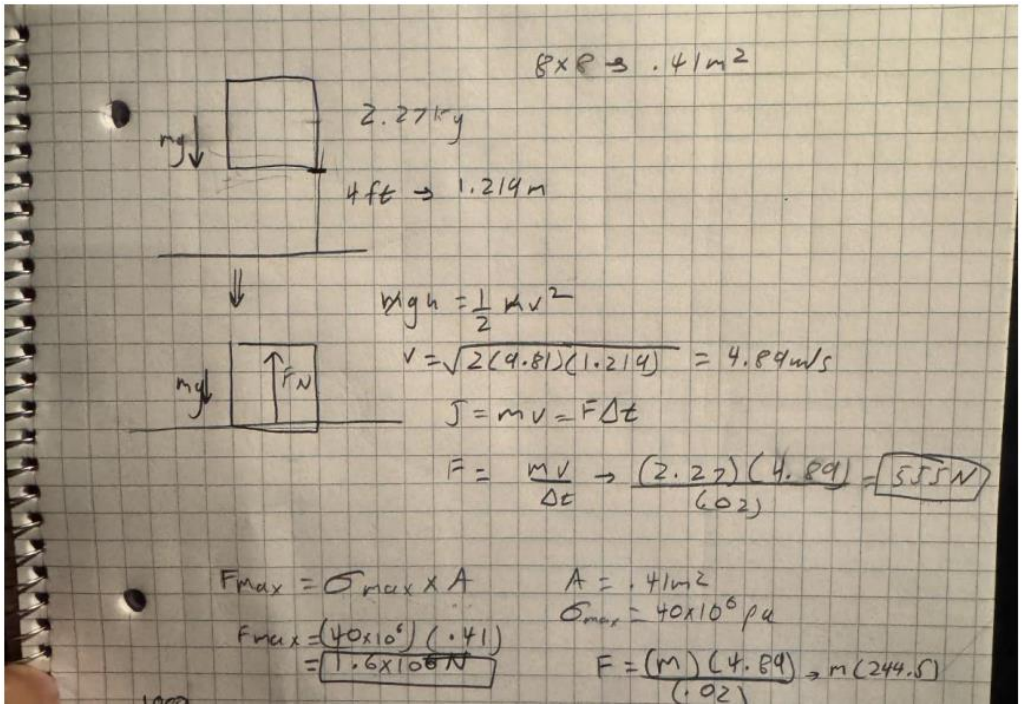
Section 10.0: Conclusion

In the design realization phase, Pristine Solution executed on concepts outlined in previous weeks to answer to the design requirements planned at the start of the project. The most crucial design requirements for the product were to make a compact dishwasher that was cheap to make and still effectively cleaned a dish. By researching materials and modeling CAD figures to a functional product, Pristine Solutions were able to follow up on these crucial design requirements by specifying the lid as the only piece made of plexiglass, creating attachments for different types and sizes of dishes, and keeping the size down to still fit on a countertop. The finished high-fidelity prototype gives a representation of what the final product will look like in form and function to give better understanding of each function.

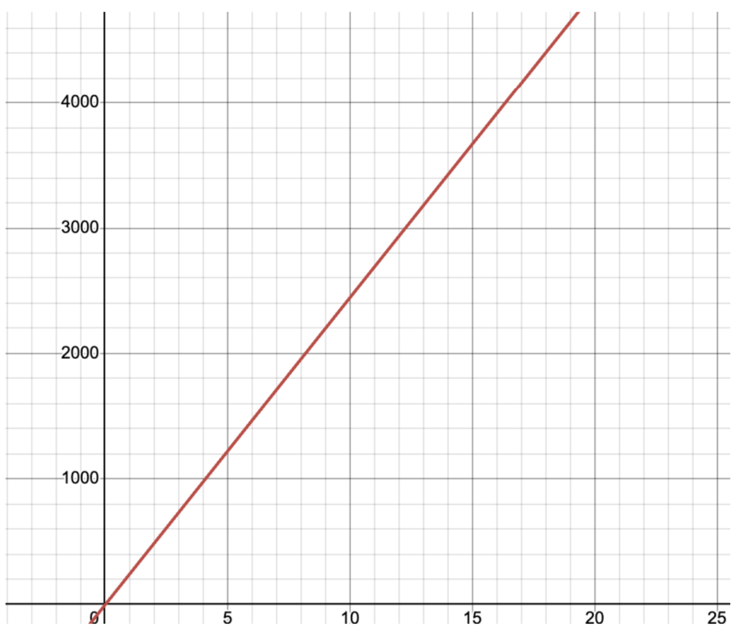
To highlight some main concerns when transferring to production, it should be kept in mind the different machinery needed to create all parts for the entirety of the product (laser cutter, injection model, etc.). It is Pristine Solution's recommendation to potentially outsource some of these functions first in order to keep initial investment costs as low as possible to keep break-even point as realistic as possible.

Appendices

A.1. Engineering Model for Drop Test (Derivation)

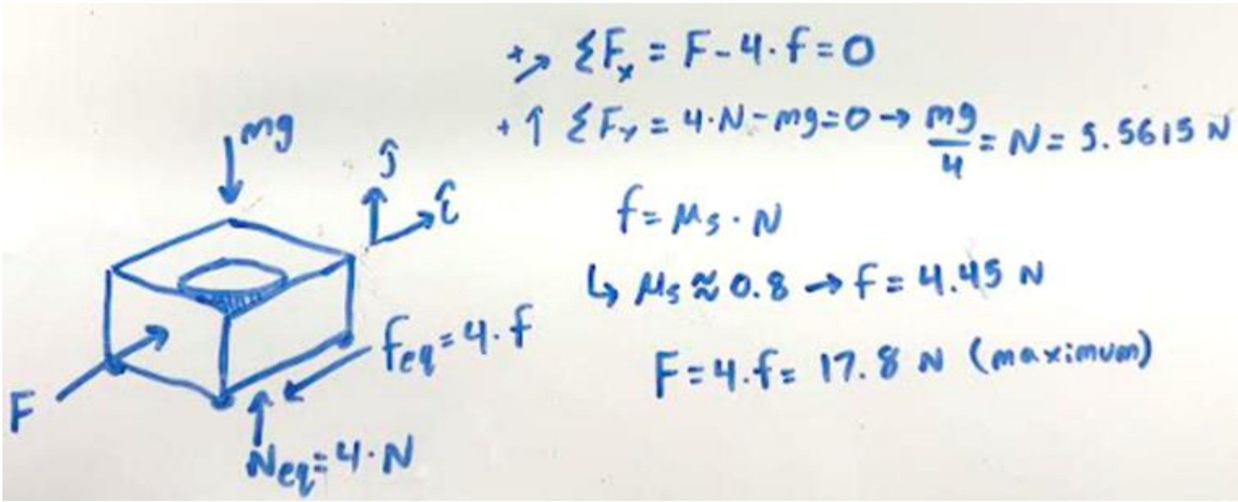


A.2. Engineering Model for Drop Test (Graph)

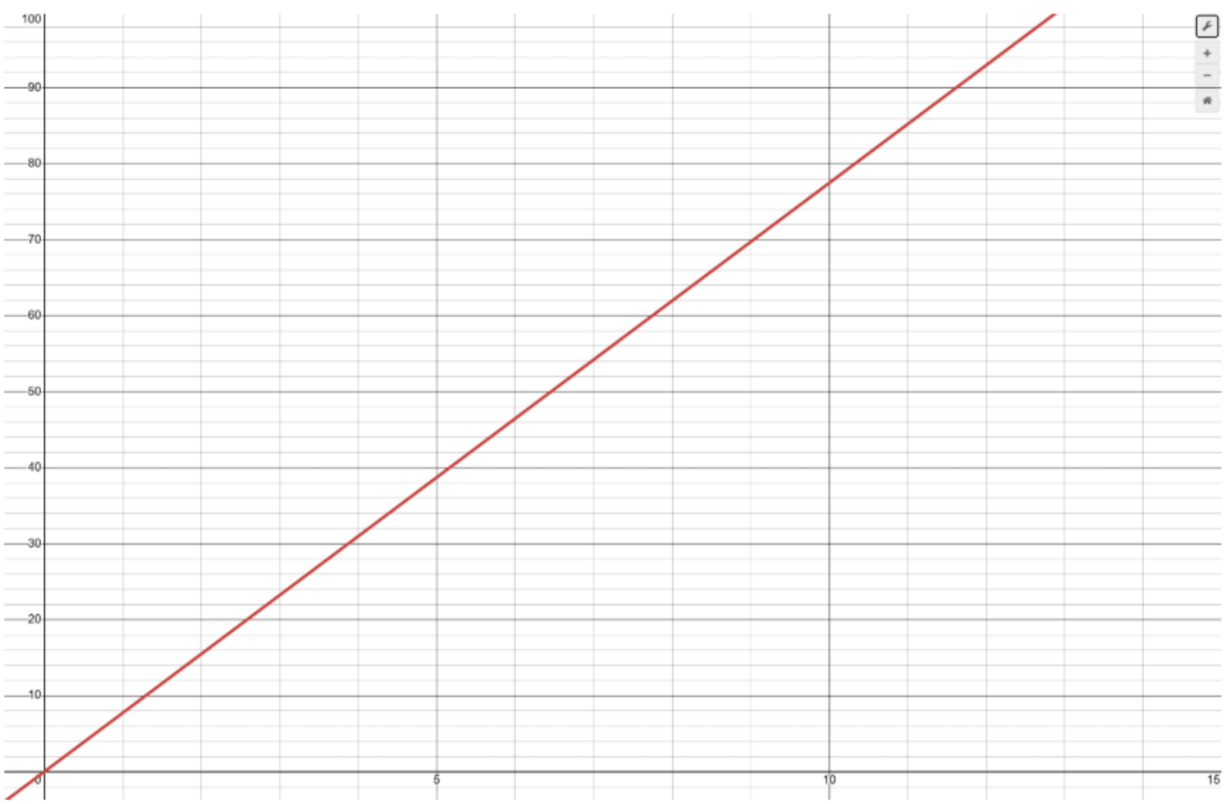


X axis – Mass (Kg), Y axis- Impact Force (N)

B.1. Engineering model for Movement Under Usage (Derivation)

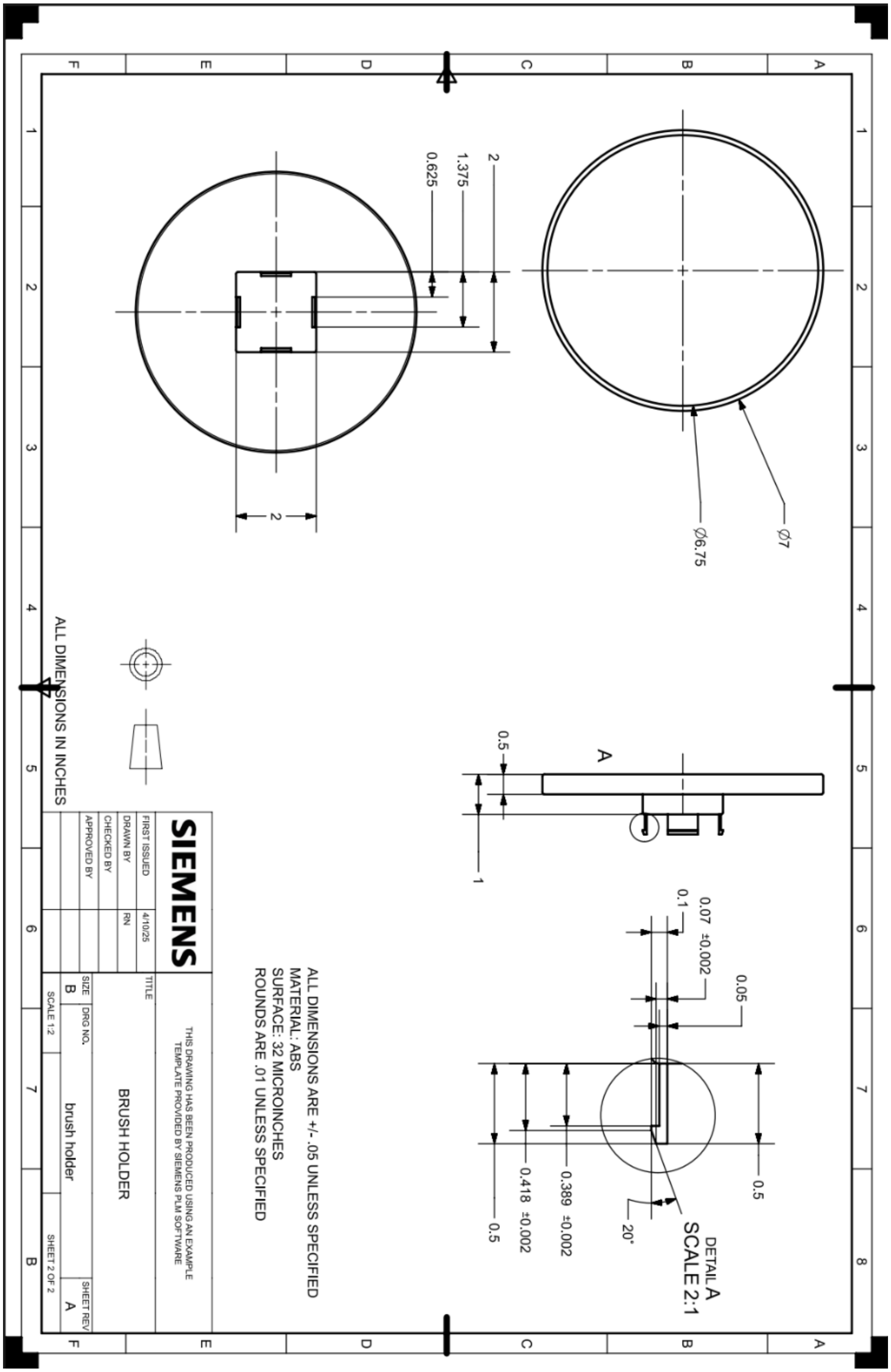


B.2. Engineering model for Movement Under Usage (Graph)

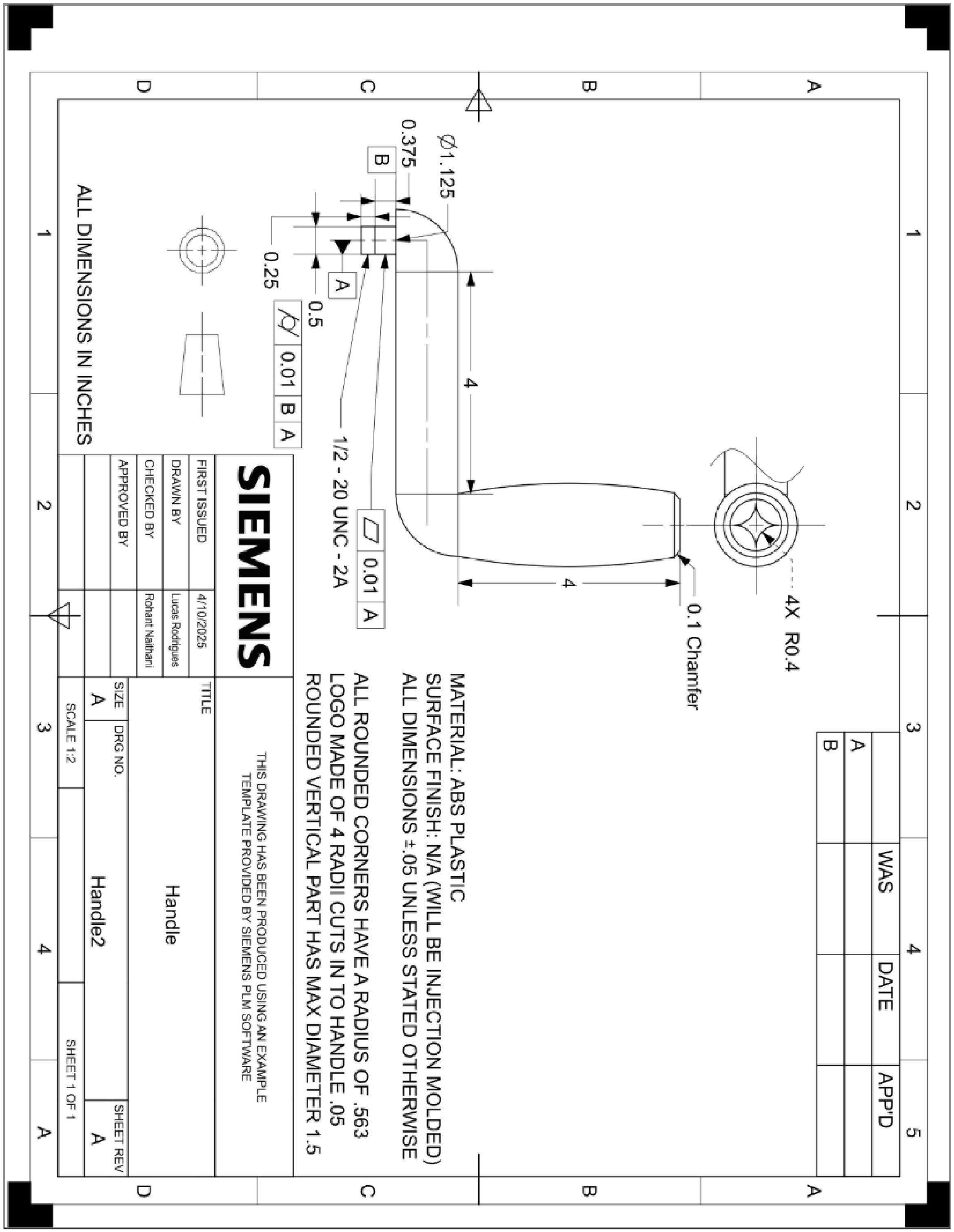


X Axis - Weight (Kg) vs Y Axis - Sliding force (N)

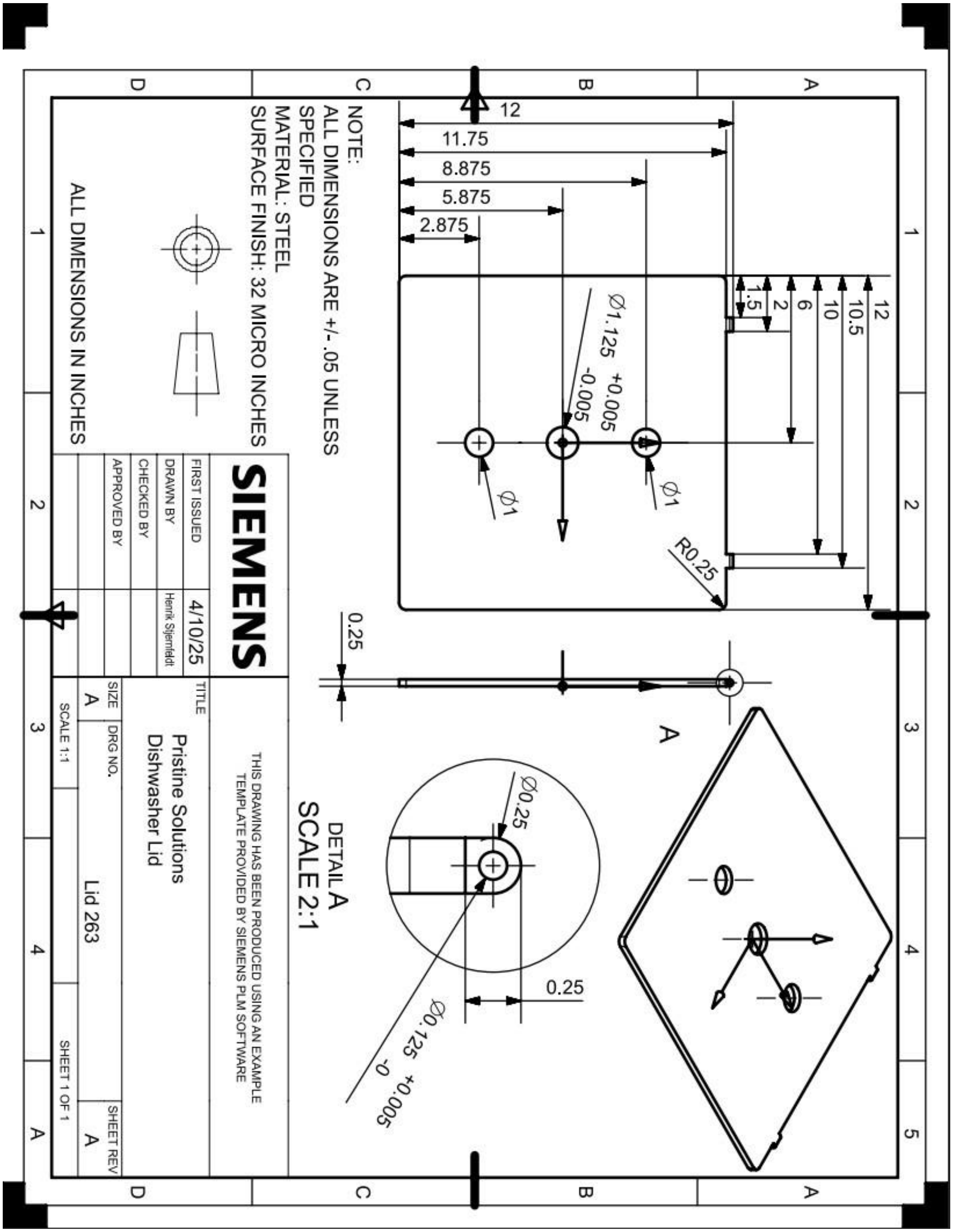
C.1. Detail Drawing of Attachment Piece



D.1. Detail Drawing of Handle



E.1. Detail Drawing of Lid



F.1. Detail Drawing of Washer Frame