Water Pump Final Report

Water Pump Group Three

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Spring 2022

Cornell University

Contents

1 Description of Design Process

1.1 Description of Pump

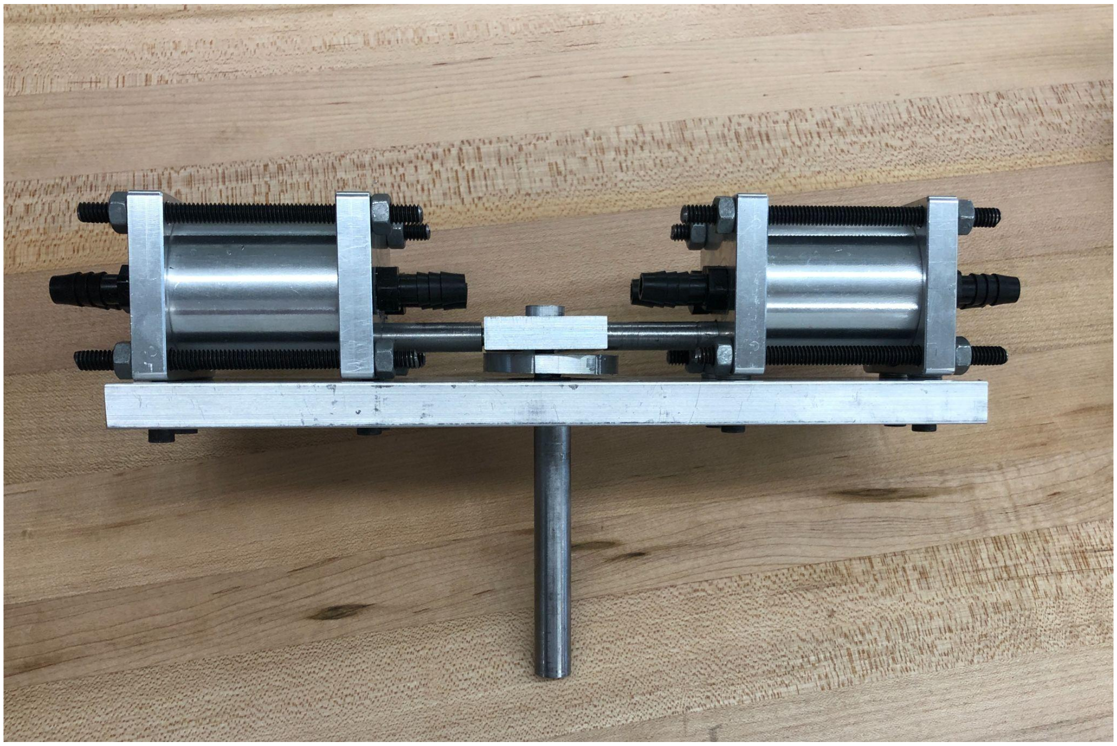


Figure 1: Final manufactured pump.

Our water pump is a dual-sided, double reciprocating pump that utilizes a scotch yoke mechanism. The pump includes two pistons that compress and expand the chambers in the bored cylinders, drawing in and releasing water at a double discharge rate. When the head of a piston undergoes a compression stroke, a vacuum is created in the cylinder that increases in volume. The vacuum causes water to be sucked into this side of the water pump and expelled out of the side that decreases in volume. An input and output valve is included on each end cap so water is drawn in and expelled with every stroke.

The scotch yoke mechanism of our pump consists of a cylindrical pin inserted into a disk. The rotating disk moves the scotch yoke back and forth, sliding the rods back and forth to drive their respective piston heads. This synchronized motion allows the water pump to convert rotational motion of the disk to linear motion of the rods, resulting in the movement of water as described above. Initial and final sketches of our design along with preliminary cost analyses for these sketches can be found in **Category One** of the Appendix.

1.2 Design Choice Process and Rationale

After researching and presenting the different types of piston pumps, we decided it would be most efficient to manufacture a piston pump but include an additional element: a dual action piston pump. We agreed on this type of pump because a piston pump is best suited for pumping large amounts of water. Piston pumps handle high pressure fluids and high volumetric flow rates at maximum efficiency. Other pumps like the peristaltic pump and diaphragm pump have low maintenance costs, but this aspect was not of concern for our project. Our goal was to optimize the pump's water output, and the piston pump fit our aspirations. We were confident in our ability to manufacture a piston pump able to pump a liter of water in a minute instead of fabricating another design and risking failure.

To make our water pump different from the standard piston pump, our group decided to fabricate a dual-sided, double reciprocating piston pump that increased our water output. With this type of pump, water continuously expelled out of the system during each stroke of the two pistons. Theoretically, our dual sided piston pump has four times the output of one single acting piston pump. We also decided to use a scotch yoke, eliminating the need for a system of bar linkages used in a traditional crankshaft system. A scotch yoke would be easier to manufacture, and it made more sense for a system with two pistons.

1.3 Challenges

Our group faced many challenges during our water pump fabrication process. We expected to struggle with tolerancing, knowing that clearances had to be tight for a vacuum to be created. This challenge forced us to be careful and thus increased our machining time. Our water pump design also required three inches of cylindrical stock that had to be cut into three pieces and trimmed to a smaller diameter. We cut the slices of stock before trimming the diameter, leaving little material for the lathe to clamp onto. This challenge made the fabrication of the piston heads and disk difficult and time consuming. We feared the thin cylindrical slices would fall out of the lathe and ruin our design, but luckily there was enough material to make shaving the diameter feasible.

A significant challenge we did not expect to face was the difficulty of working with steel. This sturdy material was nearly impossible to thread and cut, especially for students who were beginners at operating machinery. The steel exponentially increased our machine time and made us fear we would not be able to finish the pump. Each group member doubled up on machine shop shifts and worked as efficiently as possible to make sure every water pump part was manufactured before we ran out of lab slots. A few unexpected problems also increased our fabrication time. For example, a 10-32 tap was broken inside an end cap and was unable to be removed. This meant we had to place a new order, delaying our initial progress. We also were delayed because the shop lacked an end mill that was appropriately-sized for our ball bearing. We could not create a hole in our base plate that fit the bearing until days after starting the base plate. When the end mill finally arrived, it created a hole that was too large for a press fit ball bearing. To solve this issue, we glued the outer ring of the ball bearing to the hole in the base plate.

Right before we tested our water pump, we noticed a significant complication: after all the parts were tightened down, the scotch yoke would not move. Concluding that this was due to imperfections in our base plate (i.e., not being perfectly level), our group inserted washers beneath one end cap to make the surface even. By doing this, the scotch yolk was able to move smoothly and the pump was able to run.

1.4 Performance Analysis

Given the challenges we faced as described above, our group was happy and surprised by how well our water pump performed. We tested our water pump twice in the duration of our lab time. During our first test, the pump pumped water at 500mL/min. Upon observation, we noticed that a significant amount of water was leaking out between the cylinders and end caps. After removing the water pump from the sprocket, our group tightened the threaded rods that fastened the end caps to the cylinders. We also added duct tape found in the lab to seal as much of the gap as possible between the end caps and cylinder. These steps helped us reduce water leakage. All of our adjustments served us well and our pump was able to move 1.5L/min. There was still water leakage during our second test, but it was not as prominent as the first test. Our water pump ran smoothly and our corrections made our water pump three times as efficient. We met our initial goal of fabricating a functioning water pump.

2 Images and Renders

2.1 CAD Model

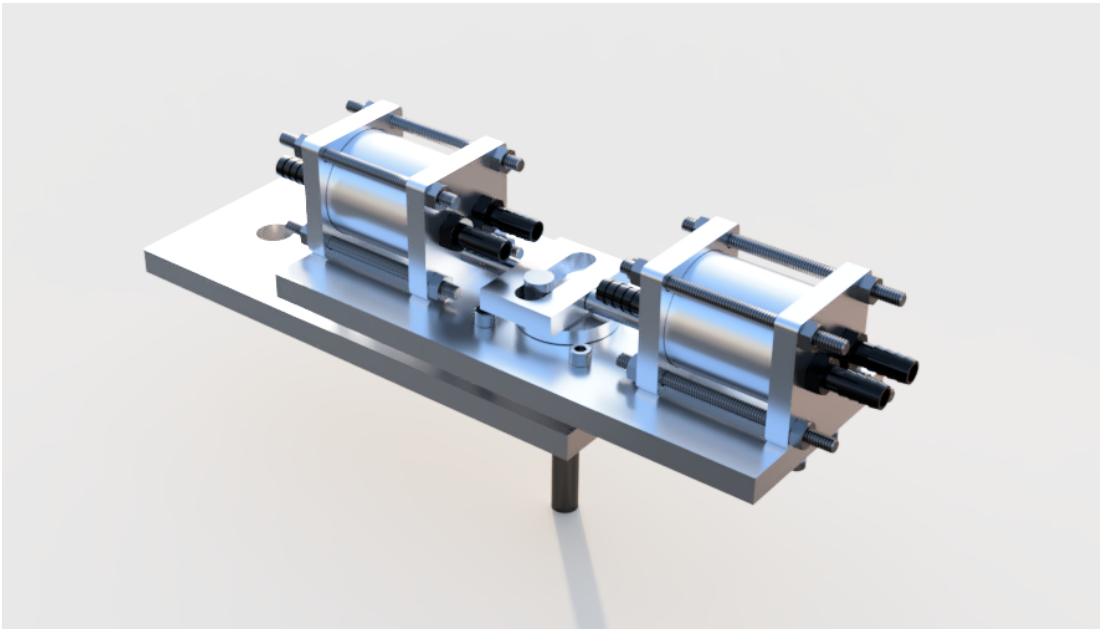


Figure 2: A rendering of our final CAD design.

The image above shows a Fusion 360 rendering of our final design. It is 10.00 inches long (excluding the outer-tube fittings), 4.00 inches wide, and 2.74 inches tall (from baseplate to end cap). This image depicts the pump's orientation relative to the mounting plate provided by course staff.

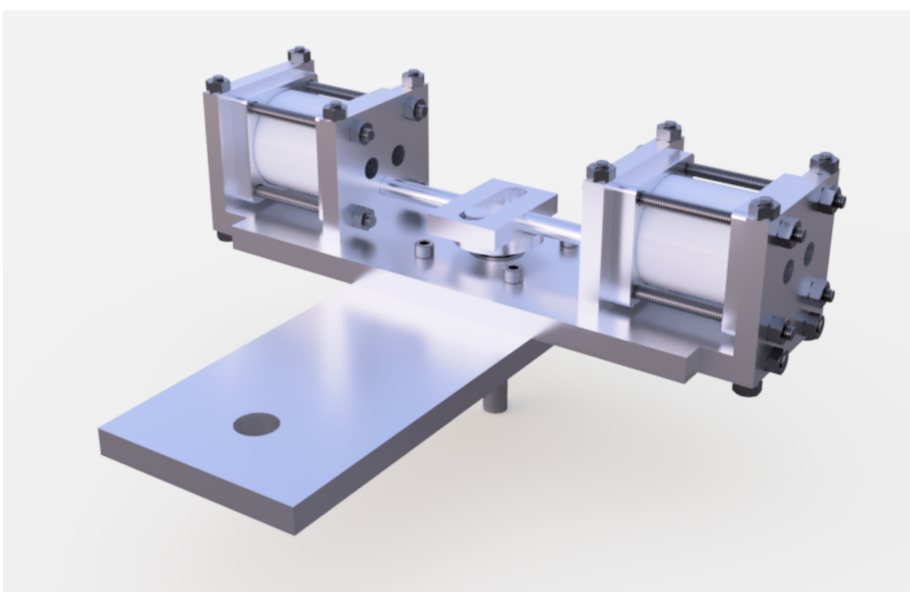


Figure 3: Design presented at FDR.

The design we presented at FDR differs from our actual design in a few ways. First, our FDR design incorporates rectangular mounting plates that are fastened to the end caps. We called these end cap fasteners. These plates would be fastened to the base plate, securing the pump in place. We originally wanted to drill ¼"-20 holes in the end caps' thin edges to mount the end caps directly to the base plate. However, the edges were too thin for us to accomplish this without risking part failure. For this reason, we incorporated the end cap fasteners to hold the pump in place. For our actual design, we decided to purchase 10-32 screws so we could fasten the end caps directly to the base plate. Threaded holes were safely drilled directly into the end caps to fit these 10-32 screws. This helped us cut down on materials and costs.

The end cap fasteners took up a significant amount of space in our FDR design, so we had to add extensions to the edges of the base plate to accommodate them. For this reason, we would have needed to orient the pump perpendicular to the mounting plate provided by course staff. This probably would have resulted in more water leakage since water would exit the pump downward. We reduced the size of our pump in our actual design, enabling us to mount it horizontally with the mounting plate. Overall, our actual design was cheaper, lighter, and easier to manufacture than the one presented at FDR.

2.2 Part Drawings

Part drawings can be found in **Category Two** of the Appendix.

2.3 Exploded View

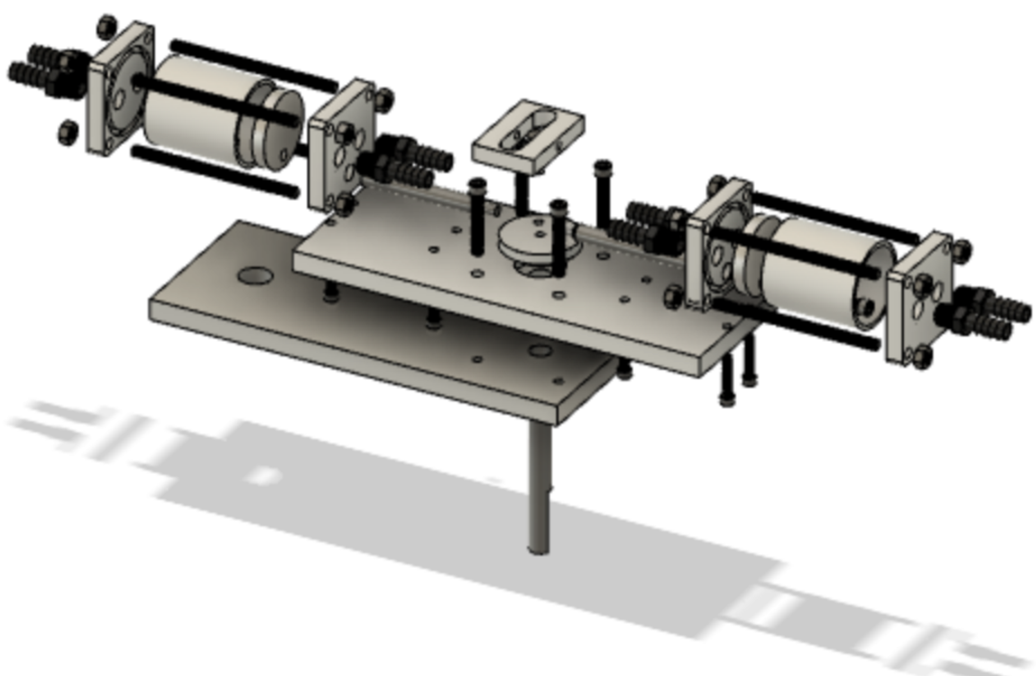


Figure 13: Exploded view of our final CAD design.

3 Fabrication Plan

3.1 Manufacturing and Ordering Analysis

The majority of our parts, with the exception of the ball bearing, threadlockers, and a few 10-32 socket head screws, were ordered from Emerson. In the end, most of our parts had to be machined manually from stock components. We also utilized manual machines to modify parts we ordered directly from Emerson, including the end caps and bored cylinders. We originally wanted the disk for our scotch yoke to be CNC machined in order to cut down on the amount of time we spent in the shop, but it was rejected due to its simplicity.

The following list of parts were mostly machined on the lathe due to their circular geometry:

- Rotating shaft: This piece could be cut to size from cylindrical steel stock on the lathe before making the necessary groove and threads. The flat portion on the opposite end for the set screw was machined on the mill.
- Piston Shafts: These two pieces were machined on the lathe using a process very similar to the rotating shaft, except instead of a flat portion on one end, a threaded hole was added.
- Piston heads: Both piston heads were made from the same stock material. The stock material was cut into slices on the bandsaw. The slices were then trimmed to the appropriate thickness and diameter using the lathe. Since the clearance holes on these parts were not centered, however, they needed to be drilled on the mill.
- Rotating disk: This part was originally intended for the CNC, but it was modified to be machineable on the manual lathe. It was cut similarly to the piston heads, with one hole in the center made on the lathe and one hole off-center for the knob on the scotch yoke drilled on the mill.
- Knob for scotch yoke: This was machined exactly like the piston shafts, except on a much smaller scale and without the threaded hole on the opposite of the external threads.
- Cylinders: These hollow cylinders were ordered from Emerson mostly machined, but due to our design had to be cut down to 2.5 inches long from their original 3 inches. This was a simple task that was conducted on the lathe.

The following list of parts were machined on the mill due to their square geometry:

- Base plate: The plate we ordered from Emerson was already cut to our desired size, so all we had to do was drill clearance holes.
- End caps: These end caps came mostly machined from Emerson. We added two 10-32 threaded holes on each so they could be fastened to the baseplate. We also drilled clearance holes on two end caps for the piston shafts. All modifications to the end caps were made on the mill.
- Slotted scotch yoke piece: Since this piece had a rectangular outline, it was cut down to size on the mill before the slot was added by multiple runs of an endmill. We also added threaded holes on the sides of the scotch yoke for the piston shafts.

The following list of parts was not machined, but rather ordered from McMaster:

- Ball bearing: This was press-fit into the base plate to allow easier movement of the rotating shaft.
- 10-32 Socket head screws: These screws were ordered from McMaster rather than Emerson because we needed this particular size in order to screw the end caps into the base plate without any interference with the cylinders.
- Threadlocker: We ordered this as backup in case some of our parts began unscrewing, or if the sprocket turned in the opposite direction we anticipated and unscrewed our rotating shaft. This did not end up happening.

3.2 Bill of Materials

A list of materials was created, including materials from Emerson and McMaster along with a description of the use of each part, the quantity, the unit cost, the total cost, and the status of the material (i.e. whether it has been ordered or received). The bill of materials from both Emerson and McMaster are listed in **Category Three** of the Appendix (Figures 3A and 3B). The total cost from each vendor is listed in bold at the bottom of the "Total Cost" column.

An extensive effort was made to order parts as efficiently as possible—for example, using the same piece of stock for more than one part. Our bill of materials had to be redone multiple times due to overstepping the budget, but along with a few design changes we were able to cut the cost down with a reasonable buffer.

3.3 Fabrication Timeline

Each team member was assigned a part to machine in preparation for the Final Design Review, and those assignments can be found in **Category Three** of the Appendix (Figure 3C). We assigned people to certain parts based on their experience with certain machines and their willingness to produce the part. Since our pump required extensive machining due to the double piston design, we needed to make sure that the time spent in the machine shop was as efficient as possible. The Figure 3C lists the parts to be made, who is to machine the part, the status of the part (not started, started, in progress, complete), and a few extra notes pertaining to the status. Since every member functioned on different schedules, we decided on using an honors system where people who committed to machining something would machine it by the deadline.

As the project was underway, however, and we realized how time consuming machining is, certain changes had to be made. We adjusted the original assignments based on availability, and those finalized changes are listed in Figure 3D in the Appendix. We completed machining on March 30, meaning we finished with three available machining days to spare. We were not significantly pressured by the due date for our machined pump, but we were pressured by the maximum number of machining slots allotted to each group. Creating a dual-action, double-piston pump meant we had a significant number of parts to machine. By the end of the project, we used six of our eight allotted out-of-lab machining slots for both the mill and the lathe.

Our first shifts were spent performing relatively simple tasks so we could familiarize ourselves with the machines again. For instance, the first items we worked on were the end caps, base plate, and bored cylinders. These parts required simple modifications that allowed us to practice on the machines. As the project continued, we became faster at machining our complex parts including the scotch yoke, piston heads, knob, and shafts. Starting with the simple parts allowed us to utilize our time more effectively in the early stages of the project. By the end of the project, we were all more efficient when utilizing the mill and the lathe.

4 Graphs, Charts, and Tables

4.1 Power Calculation

The calculation shown below analyzes the horsepower of our pump given the dimensions of our pump and the specifications of the motor and sprocket. The second line, the conversion to horsepower, is multiplied by four since our pump is dual sided and double acting. An original sketch of this calculation can be found in **Category Four** of the Appendix.

$$P = \rho g h \dot{Q} = (997 kg/m^3)(9.81 m/s^2)(1m)(.0085 m^3/min) = 83W$$
$$(83W * 4) * (1hp/746W) = 0.45hp$$

4.2 Functional Decomposition Chart

Figure 4B under **Category Four** of the Appendix illustrates the functional decomposition chart for our pump. We organized our piston pump into three main categories to focus on, and continued to branch out into slightly more specific categories. Organizing the parts of the pump as shown ultimately allowed us to design and create a pump that would be feasible to manufacture.

4.3 Morphological Chart

Figure 4C of the appendix shows our Morphological Chart, which was based on our functional decomposition chart. Once we figured out what we needed to make, we had to decide what our options were for each aspect. This allowed us to narrow down to an even greater degree. It also allowed us to see what shapes and designs would not be as effective.

4.4 Gantt Chart

Our team developed a Gantt Chart to organize our various tasks and keep track of important deadlines. The chart was also useful in seeing the layout of our schedule, so we could pinpoint areas that had too much involvement as well as areas with not enough involvement. This chart can be found in **Category Four** of the Appendix, labeled Figure 4D.

5 Appendix

Category One: Initial and Final Sketches and Cost Analyses

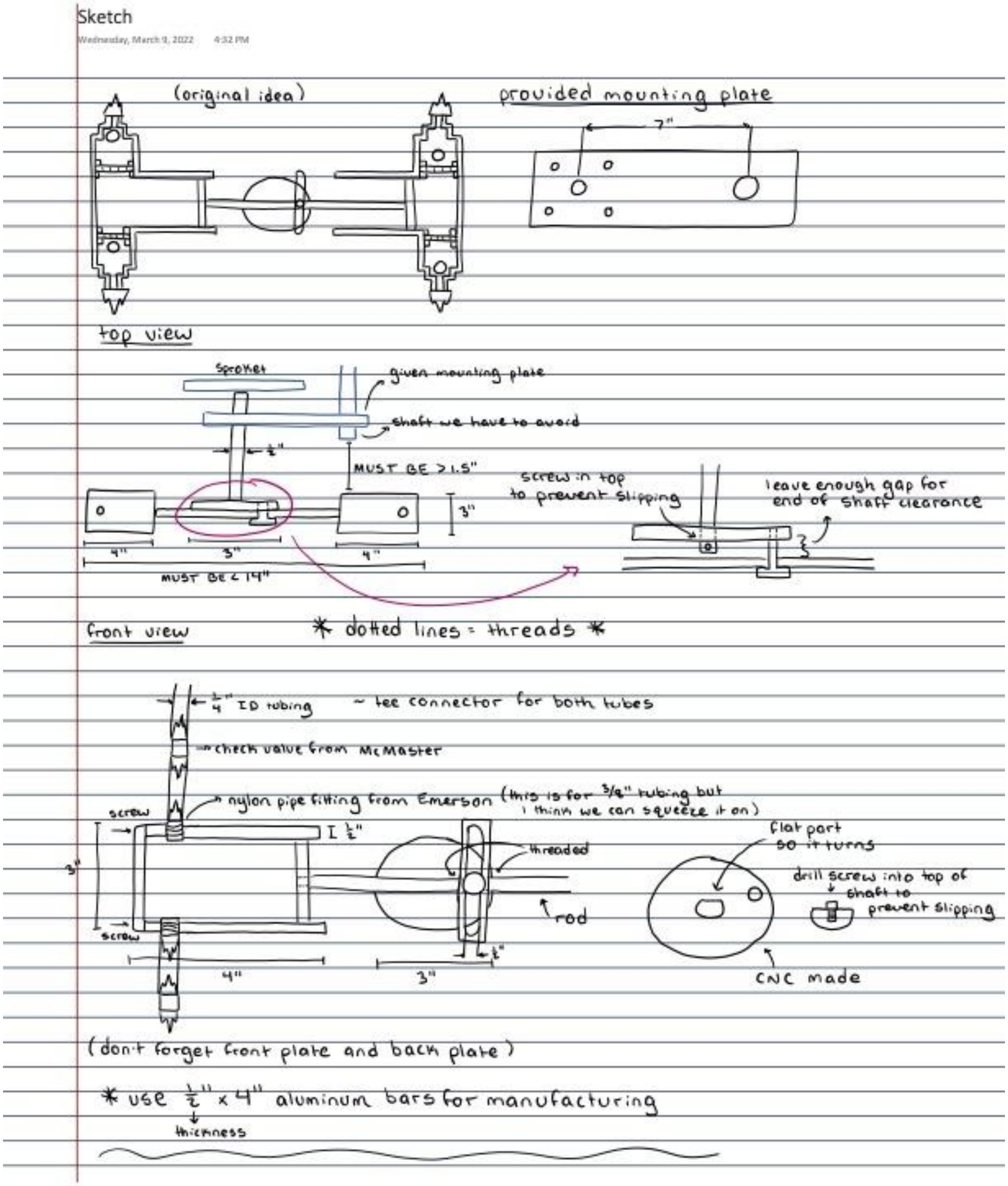


Figure 1A: Preliminary sketches and design ideas.

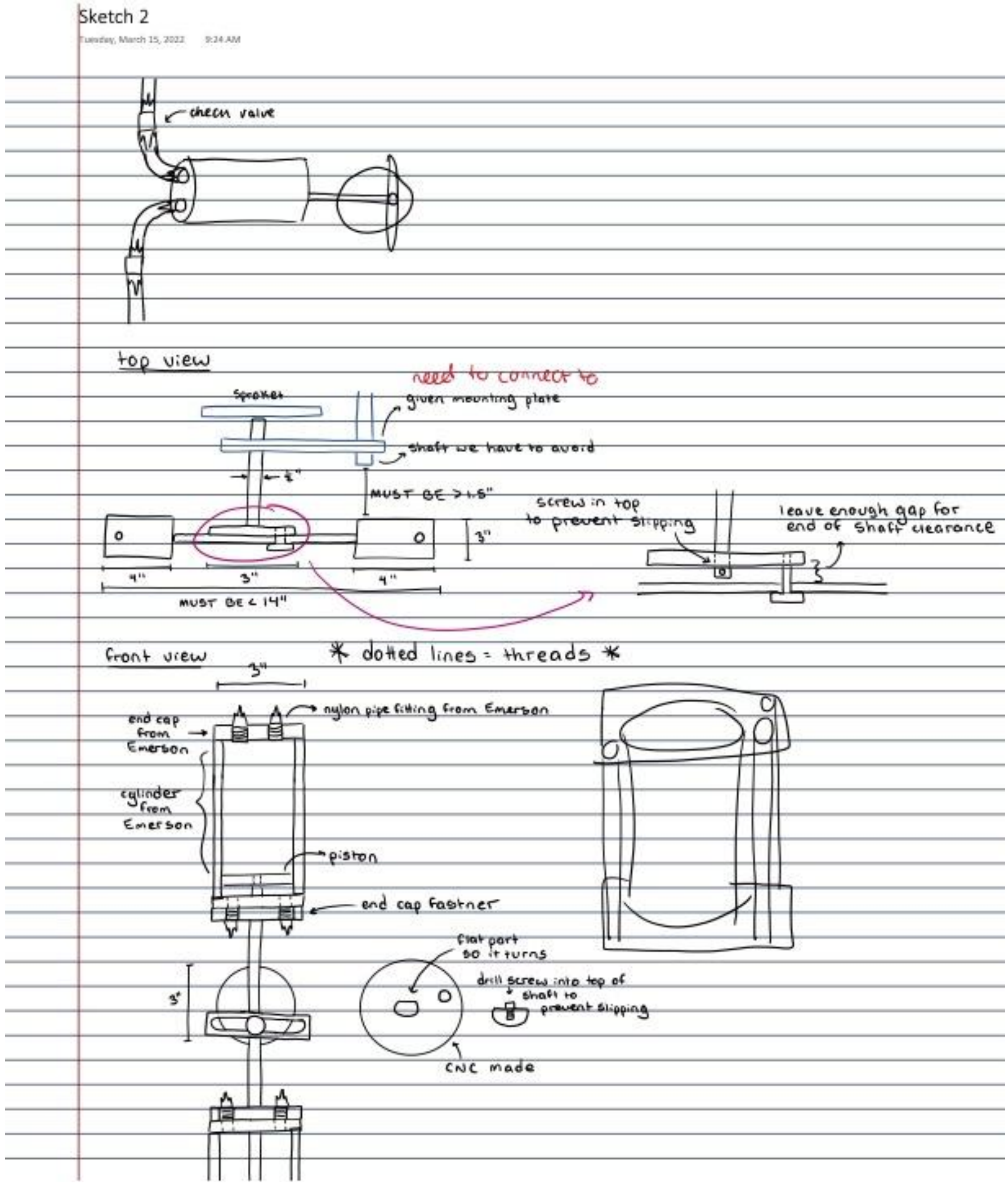


Figure 1B: A second design that more closely resembles the final design.

CAD based BOM $\frac{1}{2}'' \times 4'' \rightarrow (10 + 9.8 + 2) = 21.8''$ total

10" from emerson   rest from mcmaster

aluminum

$\underbrace{\tfrac{1}{2}'' \times 4'' \times 10''}_{\text{base}}$ $4\underbrace{(.4'' \times 3'' \times 2.45'')}_{\text{end cap fasteners}}$

$\underbrace{.4'' \times 1.5'' \times 2.25''}_{\text{slotted piece}}$ $\underbrace{(3'' \times 1'' \times 0.5'')}_{\text{extensions}}2$

$\frac{1}{2} \times 2.25 \times 1.5 \rightarrow 1.5''$ total

rods

$\underbrace{\tfrac{1}{2}''\text{ diam} \times 4''\text{ length}}_{\text{shaft}}$ $(\underbrace{0.38''\text{ diam} \times 4.35''\text{ length}}_{\text{lever arm}})2$

½" → 14" total

$(\underbrace{1.78''\text{ diam} \times 0.3''\text{ length}}_{\text{piston head}})2$ ~~1.8" diam × 0.65" dish including knob~~ $\underbrace{0.97\text{ height } 1.8\text{ diam}}_{\text{dish w/ knob}}$ CNC

2" × 5" rod diam

screws

socket head screws 1.5" length ¼-20 $\underbrace{4}_{\text{base}}$ ✓

½" length ¼-20 $\underbrace{1}_{\text{shaft lock}}$ ✓

hex nuts

¼-20

$\underbrace{12}_{\text{base}} + \underbrace{(6)2}_{\text{end}} + \underbrace{(4)2}_{\text{top}} + \underbrace{(4)2}_{\text{other end}} + \overbrace{2}^{\text{piston}}$ 42

threaded rod 4" length 8, 3.5" length 8, 2.25" length 4 } total length: 69 in (5.75 ft)

drawing progress:

rotating shaft

baseplate

Figure 1C: A continuation of Figure 1B including a cost analysis.

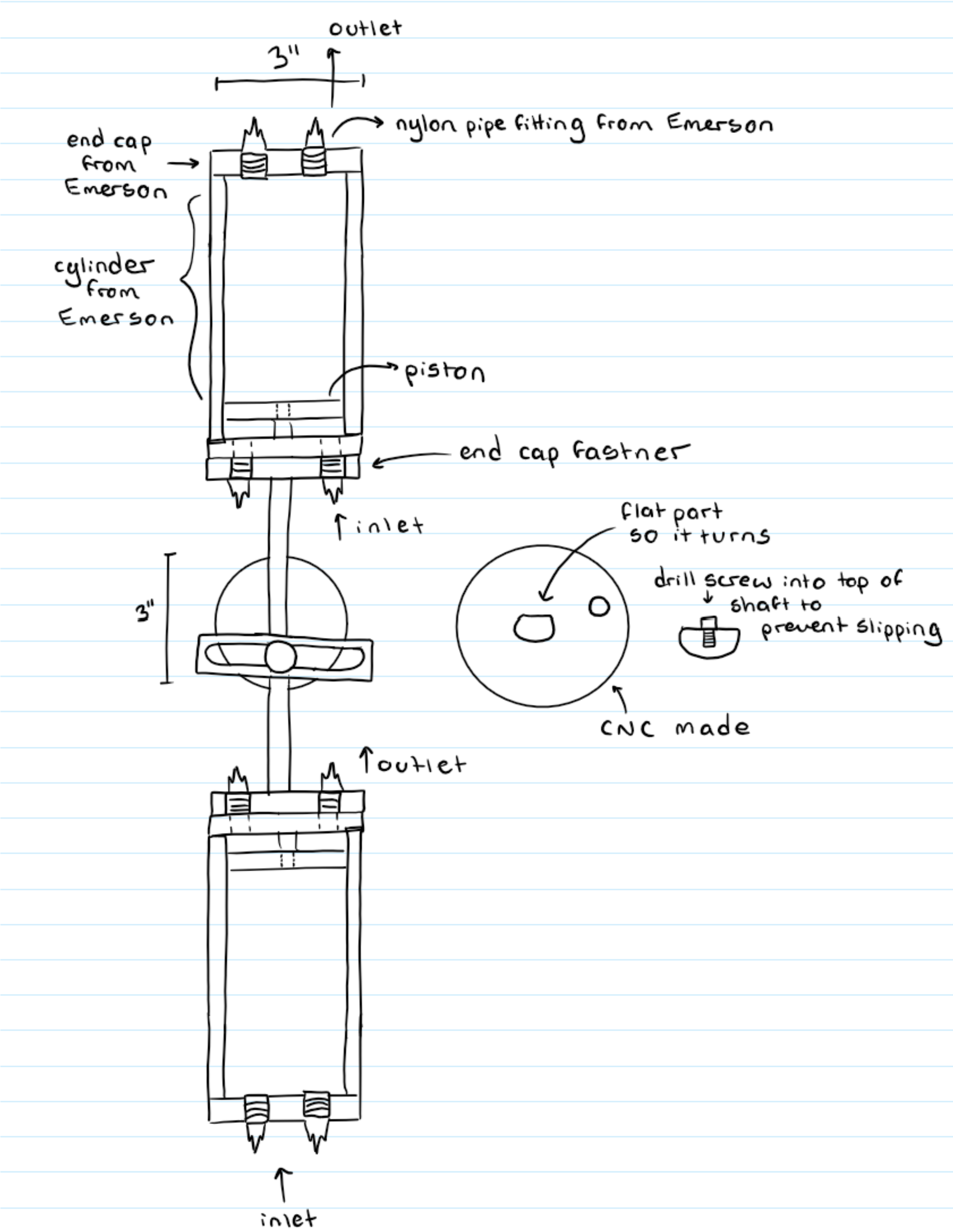
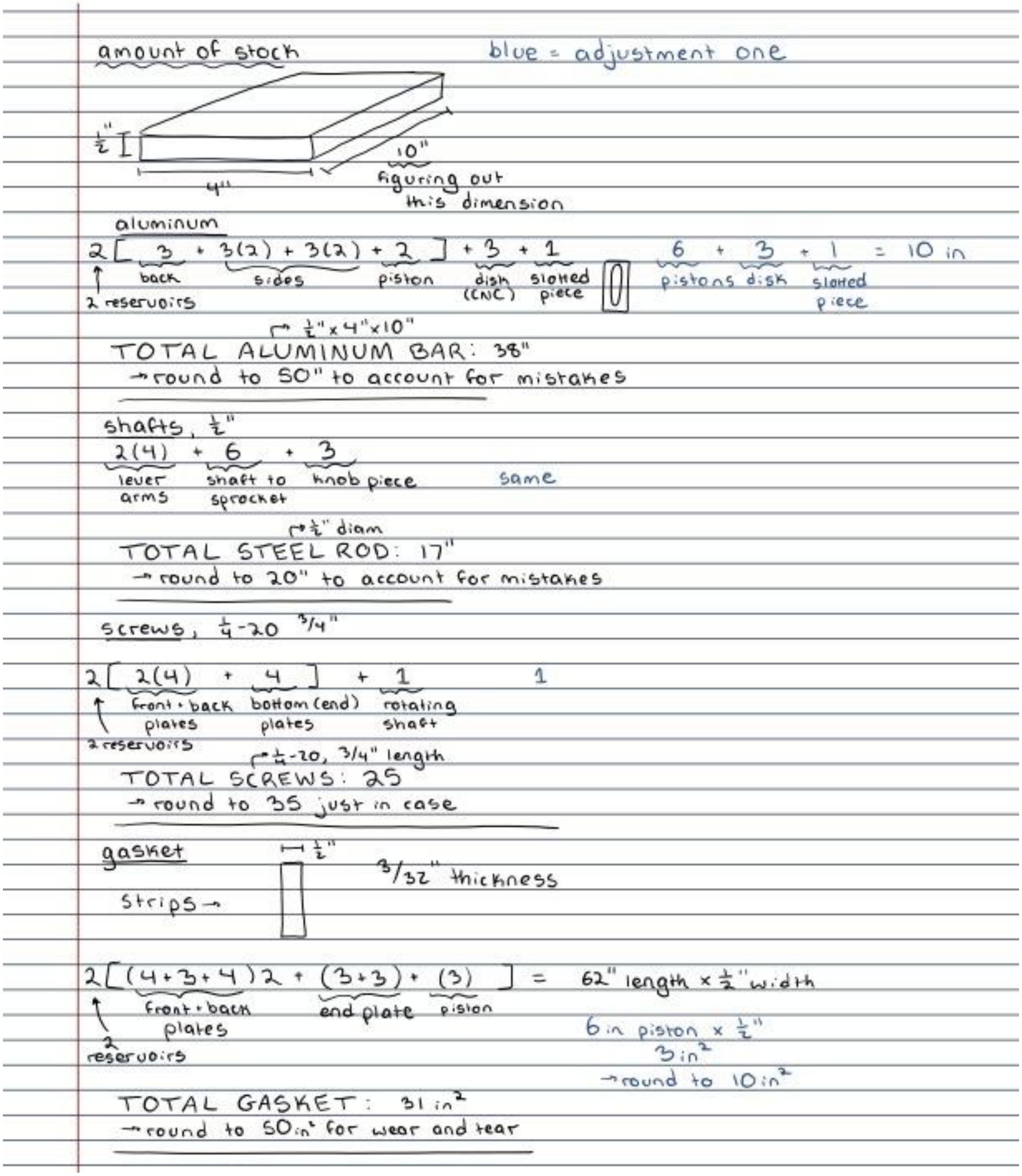


Figure 1D: A cleaner sketch.



amount of stock

blue = adjustment one

$\frac{1}{2}$"

10"

figuring out this dimension

4"

aluminum

$$2\big[\underbrace{3}_{\text{back}} + \underbrace{3(2) + 3(2)}_{\text{sides}} + \underbrace{2}_{\text{piston}}\big] + \underbrace{3}_{\text{dish (CNC)}} + \underbrace{1}_{\text{slotted piece}}$$

$$\underbrace{6}_{\text{pistons}} + \underbrace{3}_{\text{disk}} + \underbrace{1}_{\text{slotted piece}} = 10 \text{ in}$$

↑ 2 reservoirs

→ $\frac{1}{2}$" x 4" x 10"

TOTAL ALUMINUM BAR: 38"

→ round to 50" to account for mistakes

shafts, $\frac{1}{2}$"

$$\underbrace{2(4)}_{\text{lever arms}} + \underbrace{6}_{\text{shaft to sprocket}} + \underbrace{3}_{\text{knob piece}}$$

same

→ $\frac{1}{2}$" diam

TOTAL STEEL ROD: 17"

→ round to 20" to account for mistakes

screws, $\frac{1}{4}$-20 3/4"

$$2\big[\underbrace{2(4)}_{\text{front + back plates}} + \underbrace{4}_{\text{bottom (end) plates}}\big] + \underbrace{1}_{\text{rotating shaft}}$$

1

↑ 2 reservoirs

→ $\frac{1}{4}$-20, 3/4" length

TOTAL SCREWS: 25

→ round to 35 just in case

gasket

$\frac{1}{2}$"

3/32" thickness

strips →

$$2\big[\underbrace{(4+3+4)2}_{\text{front + back plates}} + \underbrace{(3+3)}_{\text{end plate}} + \underbrace{(3)}_{\text{piston}}\big] = 62\text{" length} \times \tfrac{1}{2}\text{" width}$$

↑ 2 reservoirs

6 in piston x $\frac{1}{2}$"

3 in^2

→ round to 10 in^2

TOTAL GASKET: 31 in^2

→ round to 50 in^2 for wear and tear

Figure 1E: A cost analysis for one of our original designs.

shafts and rods

$\underbrace{\tfrac{1}{2}\text{" diam} \times 4.25\text{ in}}_{\text{shaft}}$ ✓ $\underbrace{1.8\text{" diam} \times \tfrac{1}{4}\text{"}}_{\text{disk}}$ ✓

$\underbrace{\tfrac{1}{2}\text{" diam} \times .906\text{ in}}_{\text{knob}}$ ✓ $(\underbrace{1.777\text{"} \times .3\text{"}}_{\text{piston head}})\,2$ ✓

$(\underbrace{.38\text{" diam} \times 3.25\text{"}}_{\text{lever arm}})\,2$ ✓

bars $\underbrace{.4\text{"} \times 1.5\text{"} \times 2.25\text{"}}_{\text{slotted piece}}$ ✓ emergency: smallest piece they have

fasteners

$(\tfrac{1}{4}\text{-}20 \times 1.5\text{"})\,4$ ✓ $(\tfrac{1}{4}\text{-}20 \times 1\text{"})\,2$ ✓ $\overbrace{(10\text{-}32 \times 1\text{"})\,8}^{\text{McMaster}}$ ✓

hex nuts: 20 ✓ threaded rod: 3 ft ✓

8 pipe fasteners ✓

ball bearing ✓
plumber's putty ✓
loctite ✓

Figure 1F: Cost analysis for our final design.

Category Two: Images, Renders, and Drawings

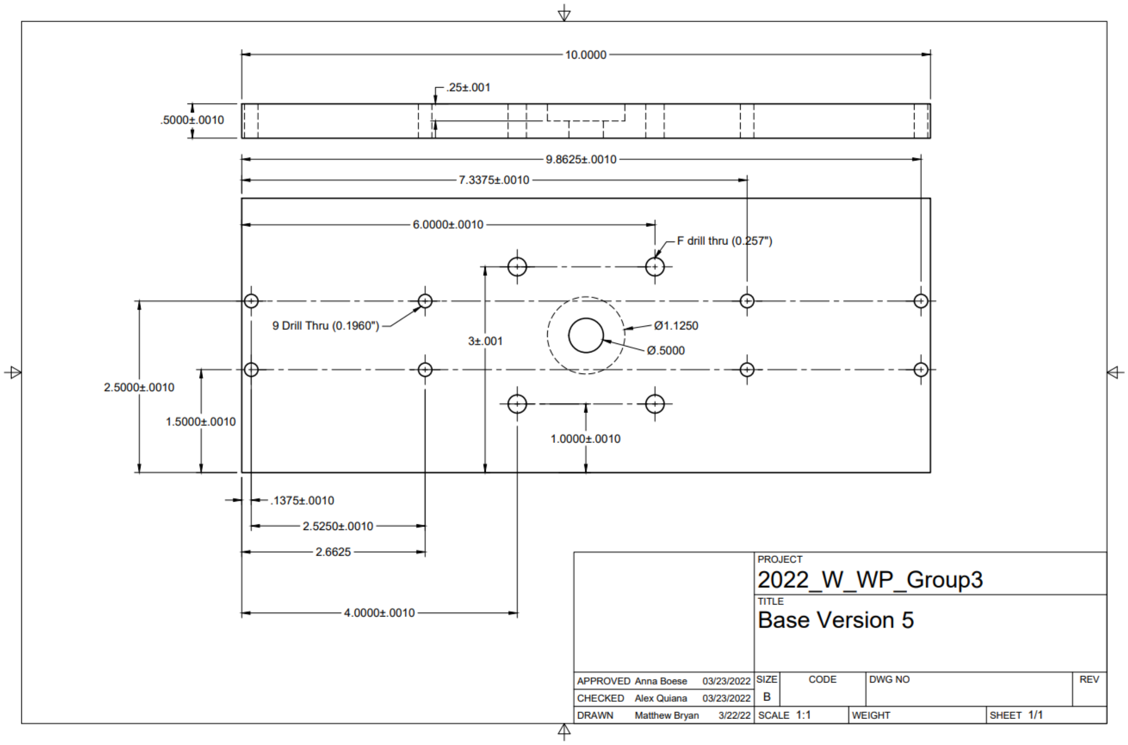


Figure 2A: Part drawing of the base plate.

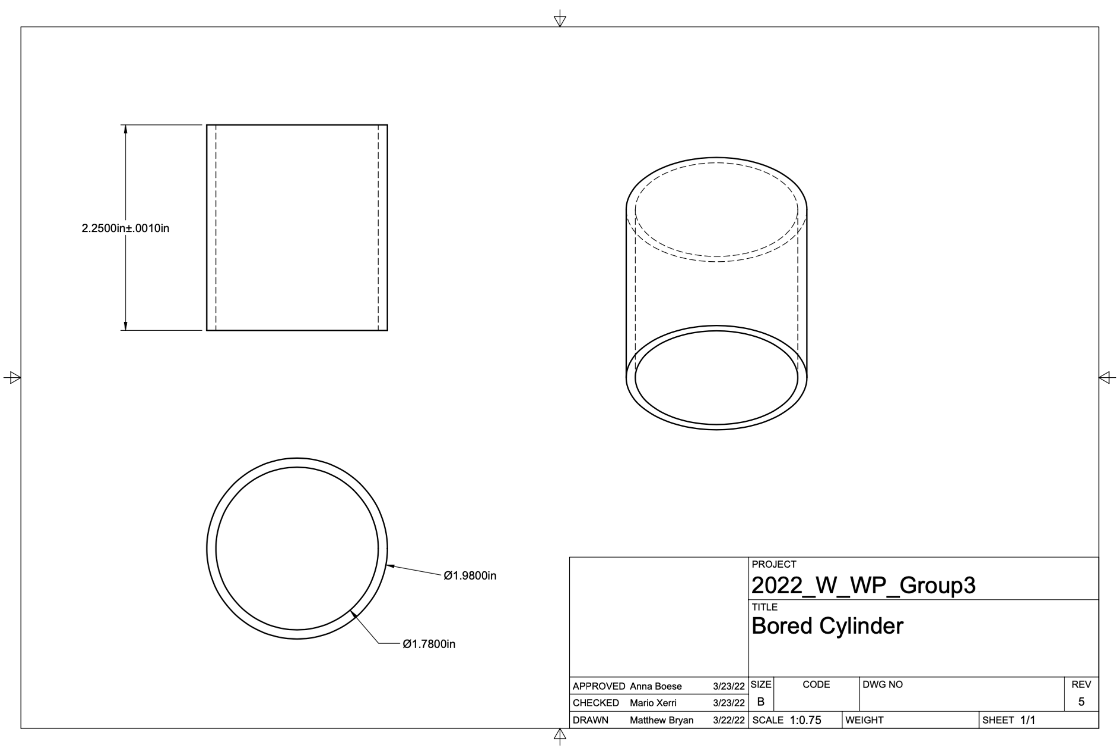


Figure 2B: Part drawing of the Emerson cylinder.

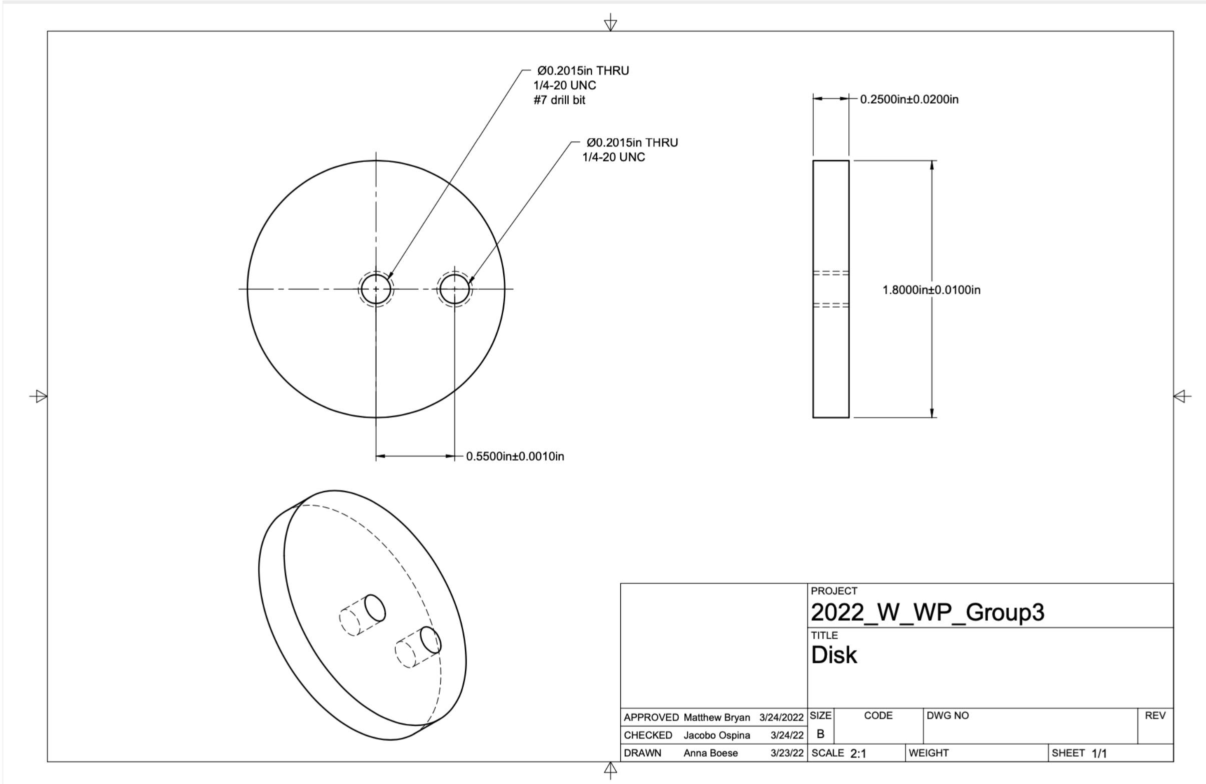


Figure 2C: Part drawing of the rotating disk in the scotch-yoke.

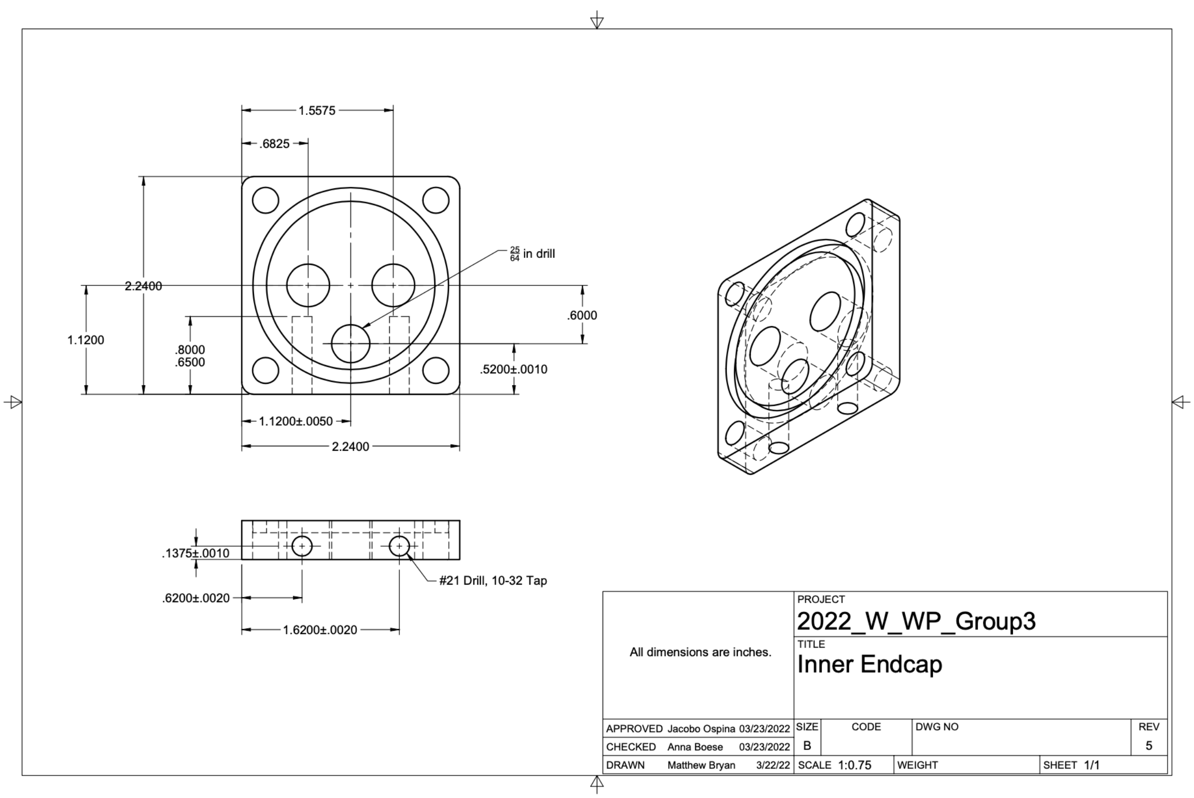


Figure 2D: Part drawing of one of the inner end caps.

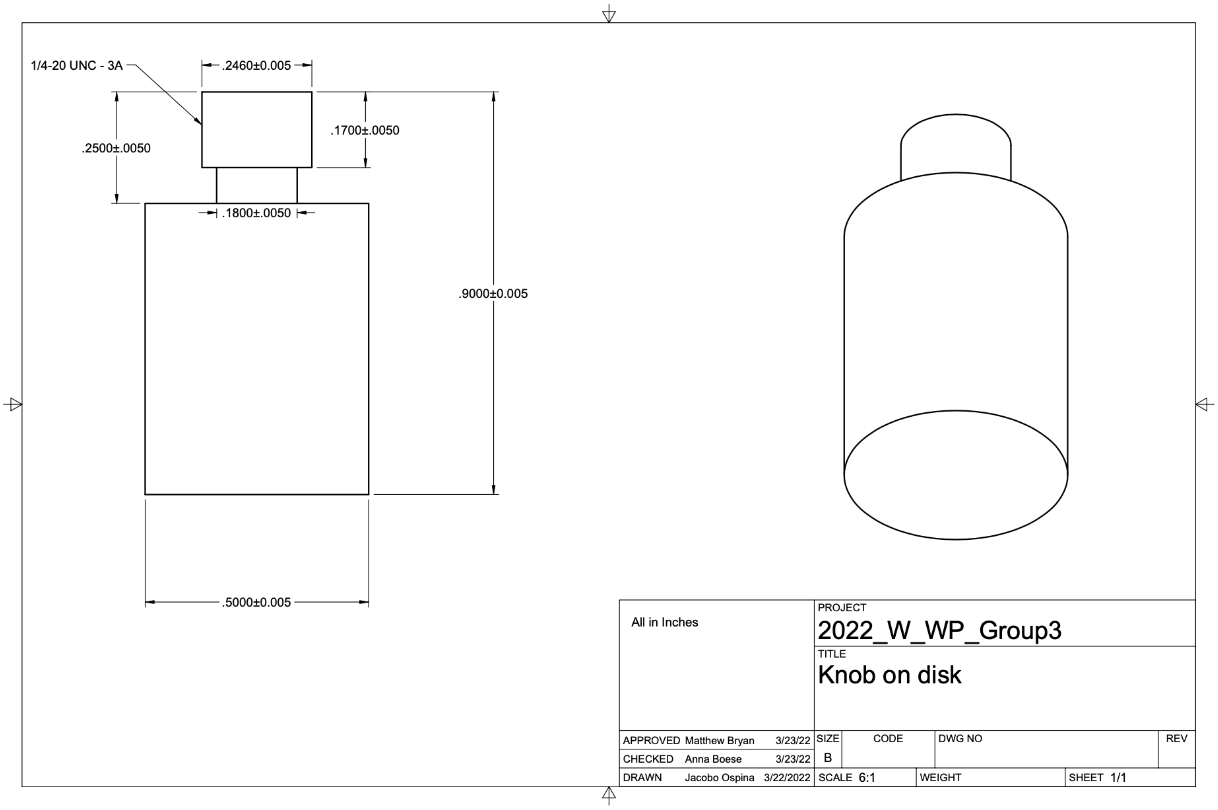


Figure 2E: Part drawing of one of the knob.

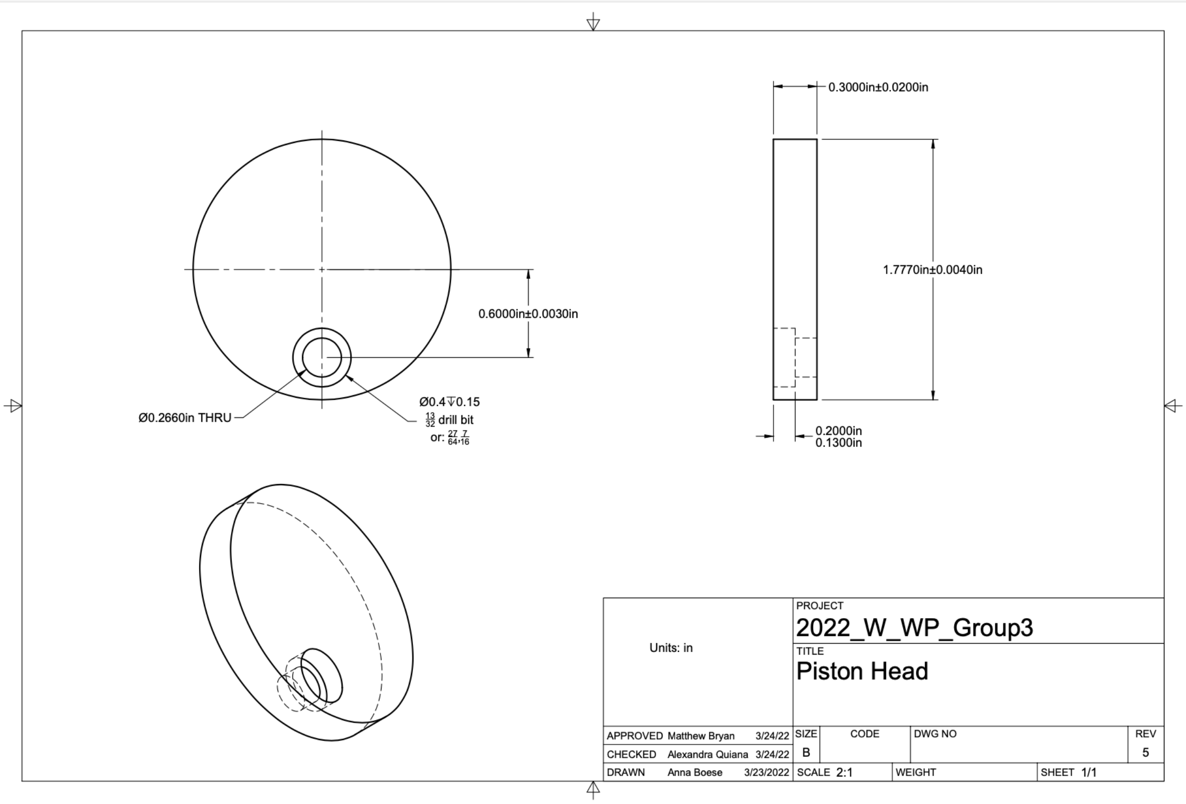


Figure 2F: Part drawing of one of the piston heads.

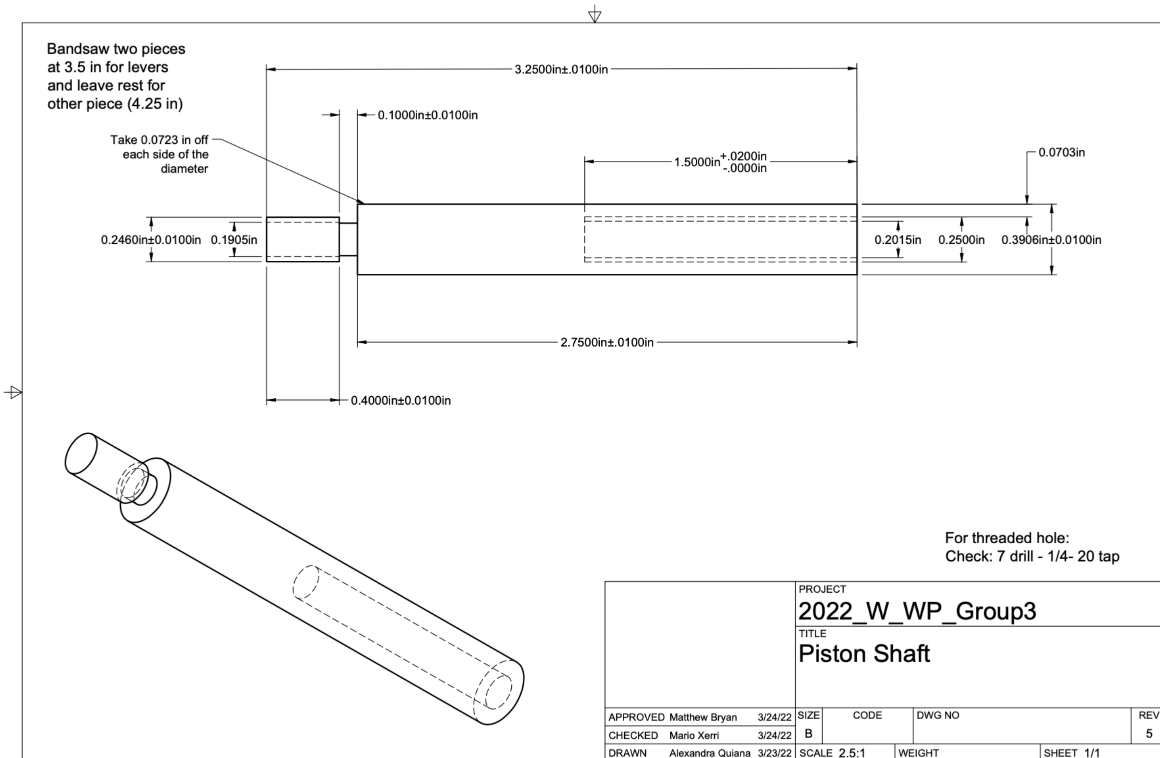


Figure 2G: Part drawing of one of the piston shafts.

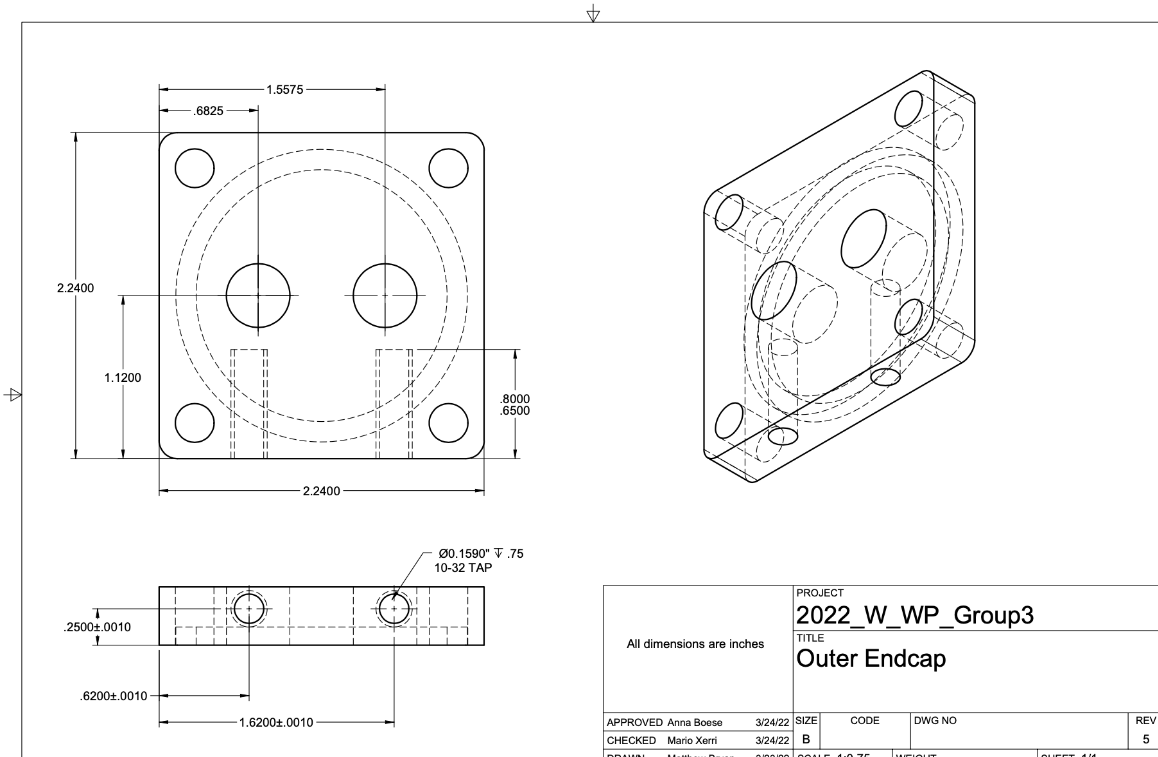


Figure 2H: Part drawing of one of the outer end caps.

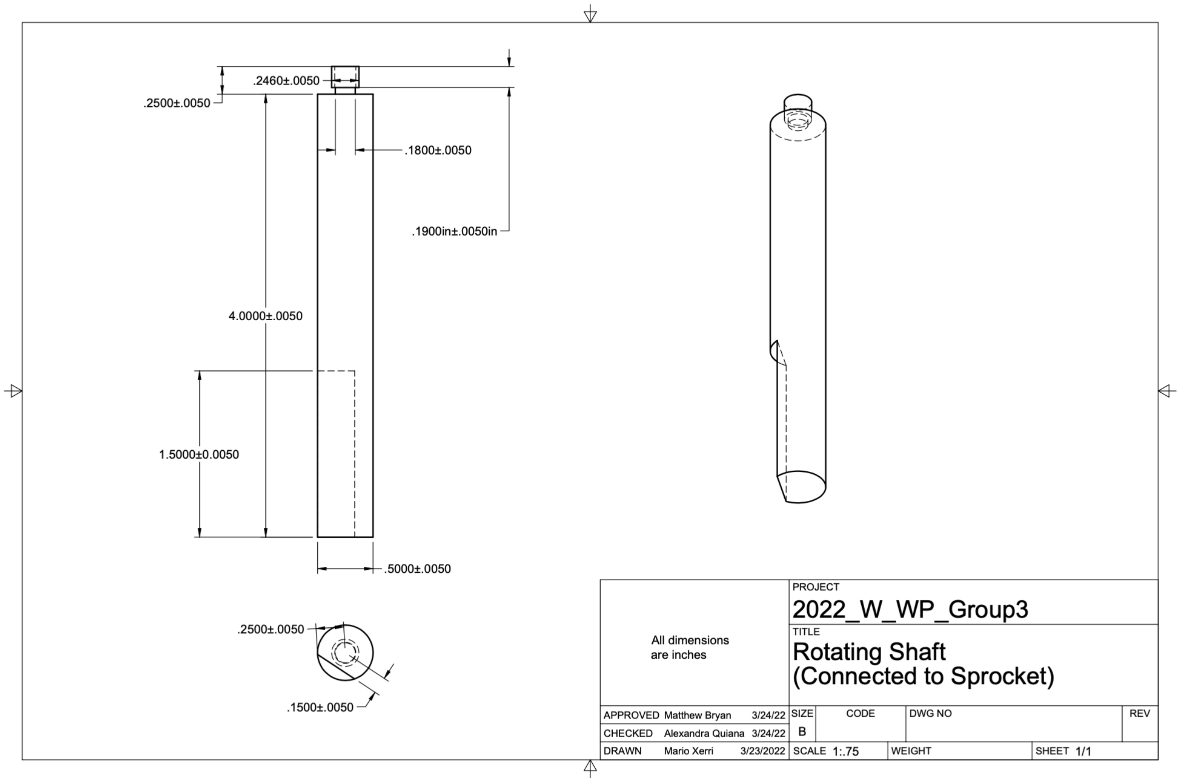


Figure 2I: Part drawing of the rotating shaft.

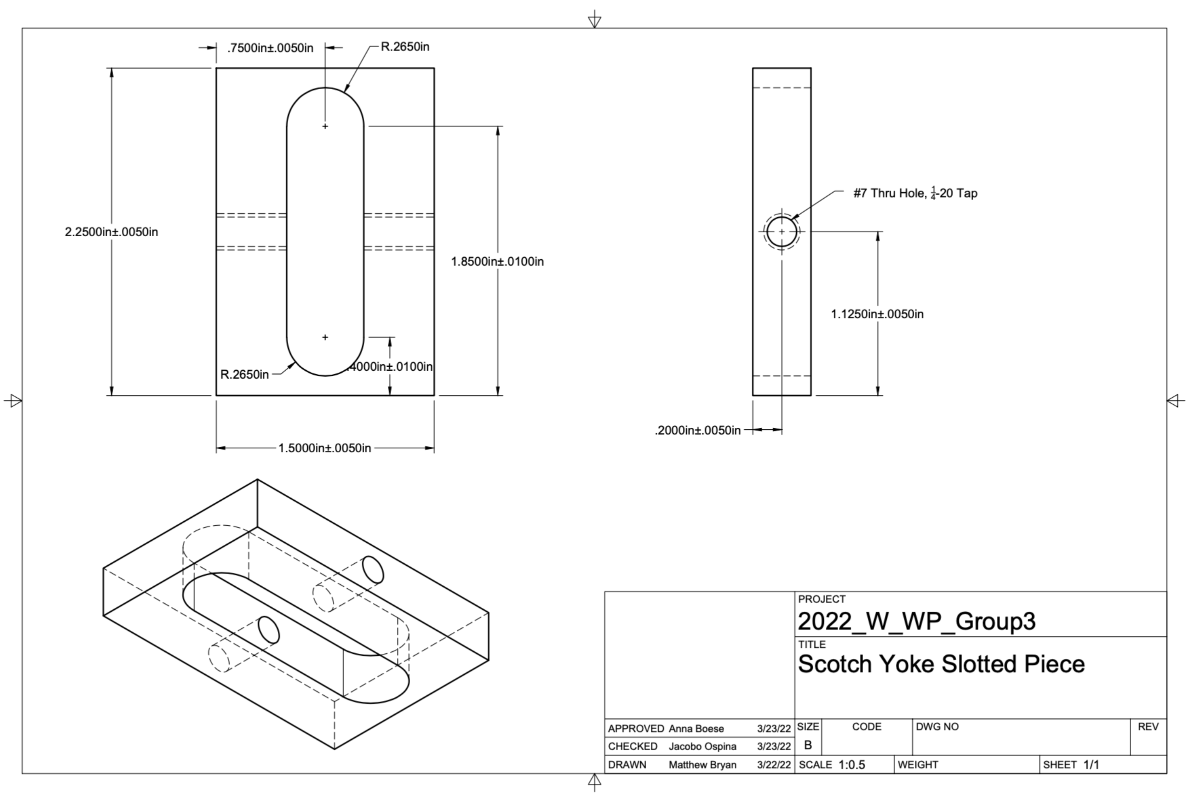


Figure 2J: Part drawing of the scotch yoke.

Category Three: Fabrication Plan

Emerson Parts					
Part Name	**Description**	**Quantity**	**Unit Cost**	**Total Cost**	**Status**
Aluminum Bar 1/2" x 4"	Mounting plate	10	1.18	11.8	Received
Aluminum Bar 1/2" x 2.25"	Slotted piece on scotch-yoke	2	0.73	1.46	Received
Steel Rod 1/2" Diameter	For lever arms, rotating shaft, knob on disk	14	0.23	3.22	Received
Aluminum Rod 2" Diameter x 3"	Piston heads and rotating disk in scotch-yoke	1	3	3	Received
Socket Head Cap Screws 1/4-20 1.5" length	To attach the mounting plate	4	0.23	0.92	Received
Socket Head Cap Screws 1/4-20 1" length	To hold piston head	2	0.17	0.34	Received
Nylon Pipe Fittings 3/8" barbed x 1/4" NPT	Connect tubing from reservoir to check valves	8	0.55	4.4	Received
Threaded Rod 1/4-20	Connect end caps of reservoir	3	1.02	3.06	Received
Machined End Caps	For the end of each reservoir	5	1	5	Received
Tee Connector 3/8" barbed	To combine tubes from each pump	3	0.95	2.85	Received
Bored Cylinder 3"diam	Reservoir body	2	1	2	Received
Plastic Tubing	For water flow	10	0.31	3.1	Received
Steel Hex Nut 1/4-20	To attach threaded rods	20	0.06	1.2	Received
Aluminum Bar 1/4"x1"	Emergency top and bottom caps	3	0.14	0.42	Received
				42.77	

Figure 3A: Bill of materials for the parts ordered from Emerson.

McMaster Parts						
Part Name with Link	**Description**	**Quantity**	**Number of Extra**	**Unit Cost**	**Total Cost**	**Status**
Ball Bearing for 1/2" Shaft	For easy rotation of shaft	1	0	6.65	6.65	Received
Socket Head Screw 10-32 1" length	For attaching end caps	1	42	11.6	11.6	Received
Loctite	To make threads more secure	2	1	2.75	5.5	Received
Washer for #10 Screws	To make warped parts fit together evenly	1	92	5.11	5.11	Received
					28.86	

Figure 3B: Bill of materials for the parts ordered from McMaster.

Machined Parts			
Part	**Machined By (subject to change)**	**Status**	**Notes**
Rotating shaft (connected to sprocket)	Mario Xerri	Done!	
Base plate	Matt Bryan	Done!	Need to make counterbore bigger
Lever arm x2	Alex Quiana	Done!	
Piston head x2	Anna Boese	Done!	
Rotating disk for scotch yoke	Anna Boese	Done!	
Knob for scotch-yoke	Jacobo Ospina	Done!	
Hole in endcaps from Emerson x2	Matt Bryan	Done!	Gotta fix one
Shave off cylinders	Matt Bryan	Done!	
Slotted piece on scotch-yoke	Anna Boese	Done!	Finish cutting down, then do slots and holes

Figure 3C: List of parts to be machined with assignments as of the Final Design Review.

Date	Part(s)	Person	Machine	Shift
Tuesday 3/22	End caps (x2)	Matthew Bryan	Mill	3:30-5:00
Wednesday 3/23	Base Plate	Anna Boese	Mill	Lab
	Bored Cylinders (x2)	Jacobo Ospina	Lathe	Lab
	Scotch Yoke	Anna Boese	Mill	7:30-9:00
Thursday 3/24	End caps (x2)	Matthew Bryan	Mill	6:00-7:30
	Piston Heads (x2)	Matthew Bryan	Lathe	7:30-9:00
	Knob	Jacobo Ospina	Lathe	7:30-9:00
	Piston Shafts (x2)	Alexandra Quiana	Lathe	7:30-9:00
Saturday 3/26	Scotch Yoke, Endcap	Anna Boese	Mill	8:00-10:00
	Piston Heads (x2), Disk	Matthew Bryan	Lathe	8:00-10:00
	Piston Shafts (x2)	Alexandra Quiana	Lathe	10:00-12:00
	Rotating Shaft	Mario Xerri	Lathe	1:00-3:00
Monday 3/28	Base Plate	Anna Boese	Mill	7:30-9:00
Tuesday 3/29	Disk, Piston Heads	Matthew Bryan	Mill	3:30-5:00
Wednesday 3/30	Knob	Jacobo Ospina	Lathe	Lab
	Piston Shafts (x2)	Alexandra Quiana	Lathe	Lab

Figure 3D: Machining timeline with finalized assignments, including individual machine slot times.

Category Four: Graphs, Charts, and Tables

Piston Area, Knob Radius, Angular Vel.

$$\dot{Q} = \frac{AR\dot{\theta}}{\pi} = \frac{\pi(.045)^2}{4} \times \frac{(.013) \times 117 \times 2\pi}{\pi} = .0085\ m^3/min$$

$$\boxed{.0085 \times 4\ m^3/min \approx 33\ L/min}$$

$$P = \rho g h \dot{Q} = \left(997\ \frac{kg}{m^3}\right)(9.81)(1)(.0085\ m^3/min) = 83\ W$$

$$\frac{83W \times 4}{746} = \boxed{.45\ hp}$$

Figure 4A: Figure 1G: Power Calculations for our original design

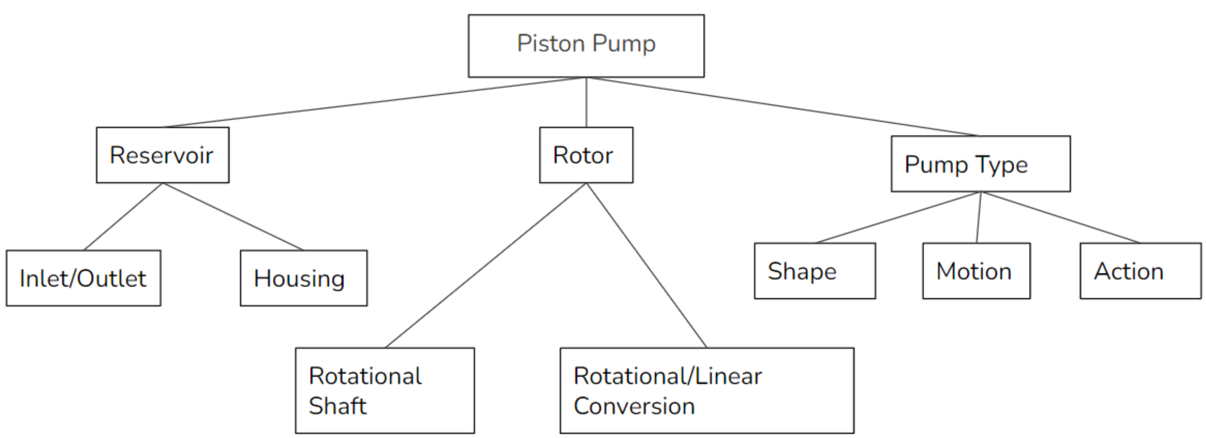


Figure 4A: Functional Decomposition Chart

Morphological Chart

#	Option 1	Option 2	Option 3
Inlet/Outlet	Ball Check	Normal	Modified Ball Check
Piston Head	Square	Circle	Ovular
Reservoir	Cylindrical	Rectangular	Gigantic
Motion	2 bar Linkage	3 bar linkage	Scotch Yoke
Pistons	Alternating 2	Alternating 4	
Piston Rod	Threaded Rod	Machined Cylindrical Rod	Rectangular Rod

Figure 4B: Morphological Chart

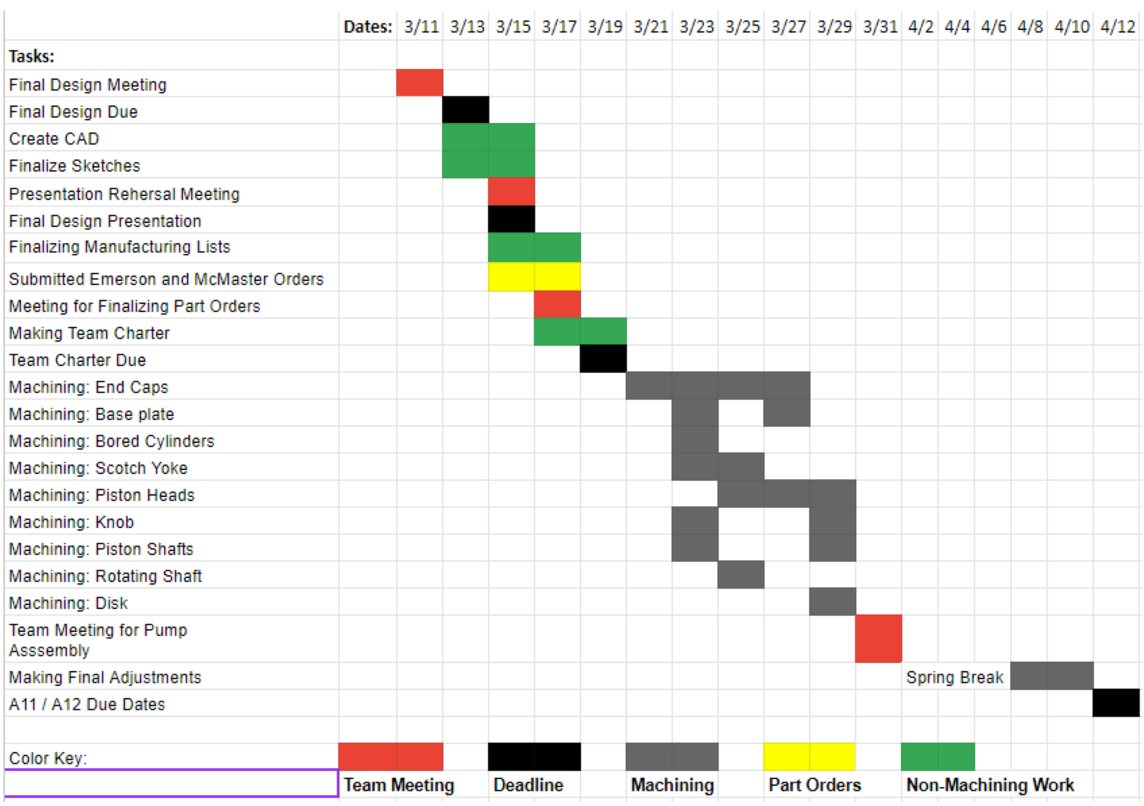


Figure 4C: Gantt Chart

Category Five: Team Charter

From: Team 3W

Anna Boese
Matthew Bryan
Alexandra Quiana
Jacobo Ospina
Mario Xerri

To: Mike Liao, Kevin Liu

Re: Team Charter

Date: 03/09/2022

Team Name	Team Member Names	Team Member Emails	Team Member Numbers
Team 3W	Anna Boese	aeb293@cornell.edu	(845) 545-3735
	Matthew Bryan	mjb535@cornell.edu	(786) 514-1291
	Alexandra Quiana	asq5@cornell.edu	(201) 419 - 4963
	Mario Xerri	max3@cornell.edu	(631) 561-8310
	Jacobo Ospina	jo338@cornell.edu	(973) 477-7239

Team Logistics and Coordination:

A. Our team decided to use Google Drive and a group chat to communicate and move documents and ideas back and forth. Our expectations for this system is to check group chat notifications and answer the group chat as often as possible. The group chat will also be a place where we provide updates on progress and notify other group members to look over adjustments made to the Google Drive. We agree that updates on Google Drive should be reviewed at least every two days if not more often. The team will notify each other when a document is uploaded. Team members will CC all other team members when emailing Professor Hoffman or the teacher's assistants. This will ensure that everyone is on the same page regarding the status of the water pump project.

B. Outside sources will be stored on a shared Google Document in our Google Drive. Links to websites and any other sources that we use for research will be stored in a list on the document. At the end of this project we will use an automated citation formatting service to cite our sources and format it correctly. A team member will physically review all citations to ensure that the website is correct and accurate. If an error were to arise, they will use a separate website and update the citation accordingly.

C. We agreed that our team will meet Thursday at 7:30 pm every week until the project is finished. This is a time that works for all of us and should have minimal conflict. At each meeting we will provide updates of what we have done during the previous week and plan our course of action for the upcoming week. If any extra meetings are needed they will be planned in our group chat. These meetings will take place in Upson Hall. If someone cannot attend in person, they will take part in the meeting via Zoom. If an emergency arises for a team member, they must communicate with the team and make sure they are caught up with the meeting topics and can work on their assigned task.

Teamwork and Collaboration

A. Specialized skills

a. Machining: Anna Boese, Matthew Bryan

Anna Boese and Matthew Bryan have a specialized skill in machining that they can bring to this project. Both of them have an interest in working in the Emerson Manufacturing Lab to fabricate our water pump design. This is a very important skill to have in this project. Matthew Bryan has experience using a manual mill on his project team, so he will take the lead in manufacturing parts that require this machine. Anna Boese will have the same role for parts that require lathes. Both machining specialists will help other team members develop manufacturing plans for their shop shifts.

b. Sketching and Design: Alexandra Quiana

Alexandra Quiana has a specialized skill in sketching and design. She hopes to be at the forefront of the creative design process and help sketch out our team's water pump design. Her sketches will be used as the foundation for our full CAD.

c. CAD and Drawings: Jacobo Ospina , Matthew Bryan

Jacobo Ospina and Matthew Bryan are well-versed in Fusion 360. This project requires us to create a CAD render of our water pump design. We will utilize their specialized skills during this part of the project to create an accurate and functional CAD render. During the design process, they will create parts that minimize costs and are easy to machine. They will also make drawings of their parts that will be utilized for manufacturing. Their drawings will follow the guidelines described in the drawing tutorials found on Canvas. Jacobo Ospina and Matthew Bryan will communicate with each other to ensure that deadlines are met and that all models are fully constrained.

d. Calculations and Finances: Mario Xerri

Mario Xerri has a special skill in calculations and financing. This is an integral part of the water pump project and we will employ his skills to make sure our water pump operates correctly. Also, he will also ensure that the group stays on budget for the project. This entails ensuring that a sufficient amount of stock is bought to make the pump, while not having too much extra material. Also, he has to make decisions on whether it is more cost effective to self manufacture parts or buy them elsewhere. With a small budget it is important to keep on top of how much we are spending on material and costs using equipment such as the CNC machine.

   e. Product testing: Mario Xerri, Matthew Bryan, Alexandra Quiana

Mario Xerri, Matthew Bryan, and Alexandra Quiana have specialized skills in product testing. After our water pump is designed and fabricated, we will use their product testing skills to make sure our water pump functions properly. If it does not work properly, they will need to locate the source of the problem and correct it. They will thoroughly test the water pump until it maximizes the amount of water output to the reservoir. If a major error were to occur in the testing, they will immediately text the group with the preferred method of communication.

B. Leader: Anna Boese
   Co-leader: Alexandra Quiana
   The leader and co-leader will have very important responsibilities. Their duties will be including but not limited to making sure deadlines are met, assigning tasks and following up on their results, and scheduling extra meetings when necessary.

C. Design integrator/coordinator: Mario Xerri
   The design integrator and coordinator will be responsible for putting all the ordered and manufactured parts together to obtain the desired result, recording necessary adjustments, and performing product testing.

D. Other responsibilities: Every team member excluding the leader, co-leader, and design integrator/coordinator will design and machine one or two parts for the water pump and deliver them to the integrator.
   a. Sketching our water pump design
   b. Modeling our water pump design
   c. Using CAD to render each part of the water pump
   d. Ordering needed parts
   e. Fabricating parts in the Emerson Manufacturing Lab

E. Consequences for Missing Deadlines:
   If a team member misses a deadline, they are responsible for the work they missed and must buy every team member a cookie from Mattin's Cafe in Duffield. This rule also applies if a team member completes work not up to par with the quality of work we agreed to submit.

Date	**Event**	**Time**
03/12/22	Final Design Meeting	1:00 pm
03/12/22	Finalized Design DUE	11:59 pm
3/13-3/15	Create CAD design, finalize sketches and begin compiling	

	buy list and machining list	
3/15/22	Presentation Rehearsal Meeting	9:00 pm
03/16/22	**A9 Final Design Presentation**	**2:40 pm**
03/17/22	Part Order and Manufacturing Meeting	7:30 pm
03/18/22	**A10 Team Charter**	**11:55 pm**
03/18/22-03/23/22	Begin manufacturing and continue waiting for ordered parts to arrive. Begin anticipating the assembly process.	
03/24/22	Team Meeting: Manufactured parts DUE	7:30 pm
03/25/22-03/30/22	Assemble the pump and begin the testing phase. Make adjustments to the parts and/or assembly as needed.	
03/31/22	Team Meeting: Fully assembled and tested pump DUE	7:30 pm
04/01/22-04/12/22	Finalize testing procedure and make and final adjustments.	
04/13/22	**A11 Finished Pump / A12 WP Reflection**	

F. The group's desired grade has been discussed and decided upon.