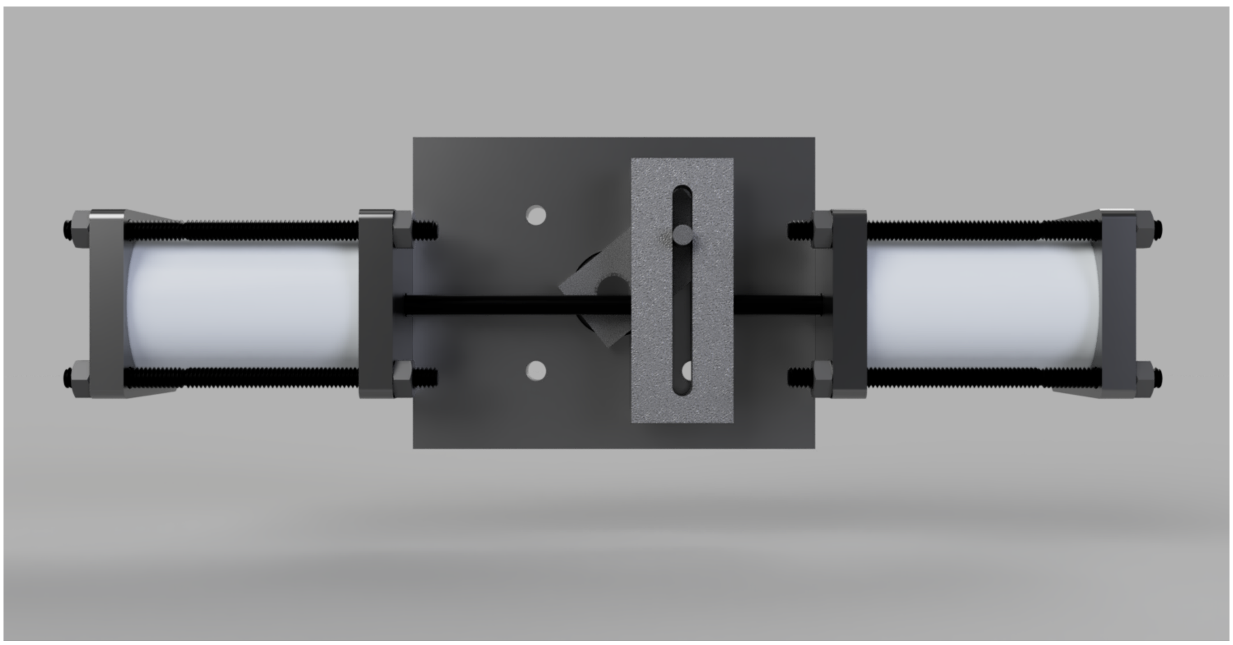
Final Water Pump Report

May 21st, 2021

Thursday Lab Group One



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Description of Design Process

Our design choice process began by comparing each group's A8 designs. The groups of Kean Chastain-Howley/Camille Slattery and Emily Harmon/Gabriella Passarelli had very similar designs. Both groups employed a scotch yoke system that operated two pistons on opposite sides of the drive shaft. Their initial designs are shown below.

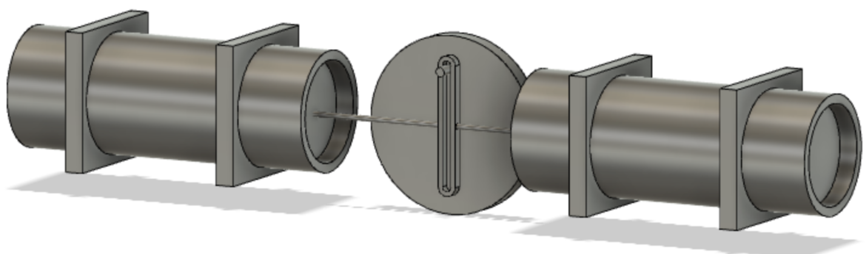

Figure 1: Emily Harmon and Gabriella Passarelli 's initial CAD for A8

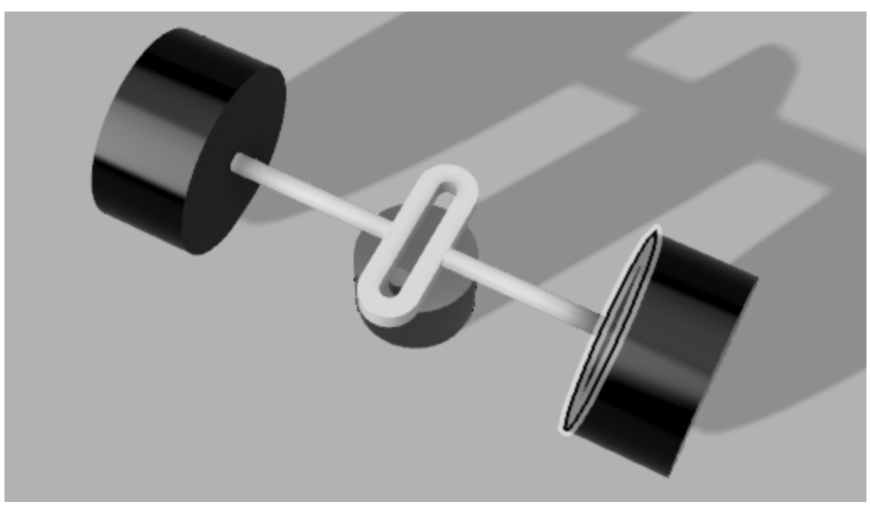

Figure 2: Kean Chastain-Howley and Camille Slattery 's initial CAD for A8

These two group's designs had a few key differences. Emily and Gabriella were planning on using a circular piece of stock for the center of their scotch yolk, while Kean and Camille used a rectangular piece in their design. They were also investigating materials that would allow the pistons to compress. This was intended to create an accordion style pump, that would cause the pistons and the housing to essentially be combined. Rather than having a piston slide through housing, this design would create compressive and depressive motions that sucks in and ejects water. Given the materials available, however, this idea proved to be unfeasible. McMaster did not have materials such as this, and it was impossible to manufacture through Emerson.

The group of Mathias Kohler and Sebastian Torres had a completely different design - a slider-crank powered triple piston pump. The pump worked by having water go in through one piston, then having the slider crank create reverse pressure inside of a PVC connector, leading to the water being pushed in and out through the opposite piston. This mechanism varied greatly from the other two groups mainly in the use of a slider crank instead of a scotch yoke and by having three pistons rather than just two. Their preliminary CAD is shown below.

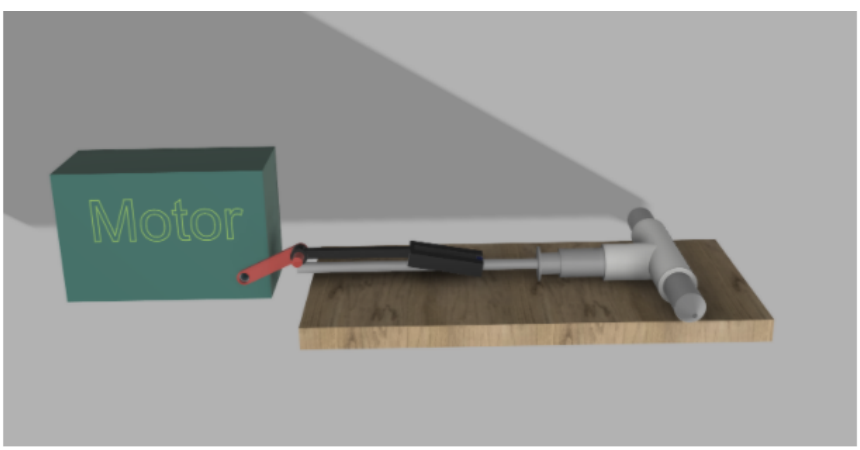

Figure 3: Mathias Kohler and Sebastian Torres' initial CAD for A8

During our deliberation, we considered using this design, but decided it would be difficult to appropriately mount this pump to the testing rig. Additionally, we considered a completely different design - another two piston design, but with a slider crank as opposed to a scotch yoke. The group decided to mirror the designs originally created by Kean/Camille and Emily/Gabriella, as we believed it was the most practical option in terms of manufacturability, easy interface with the test setup and adherence to assignment specifications. The two piston setup would be more cost-effective compared to the triple piston design. The scotch yoke would be easier to design and execute which would save on machining time, which was especially important because the group did not have any machining experience prior to taking 2250. It was imperative to allow for more leeway for necessary design changes and managing errors in manufacturing down the line.

Final Design

Our finalized pump prototype was a double piston scotch yoke design. The scotch yoke moved two pistons backwards and forwards, generating a pumping motion. Each piston had its own housing, which served as the receptacle for water when the prototype was in use. This housing was made of aluminum cylinders and end caps, which were all sealed together to ensure that the water would not leak during operation. The pumps were secured to a backplate using threaded rods. The back plate had four holes drilled so that it could be mounted to the face plate. A drive shaft was attached to a rectangular component which generated the rotational motion for the scotch yoke. Kean recorded the motion of the final assembled pump which can be found in the Water Pump Motion Videos folder. A small pin was also attached to the rectangular component which fit into the slot on the scotch yolk. The circular rotation of the rectangle piece was transformed into linear motion by the slot of the scotch yolk which is what brought the piston arms back and forth, allowing us to pump water.

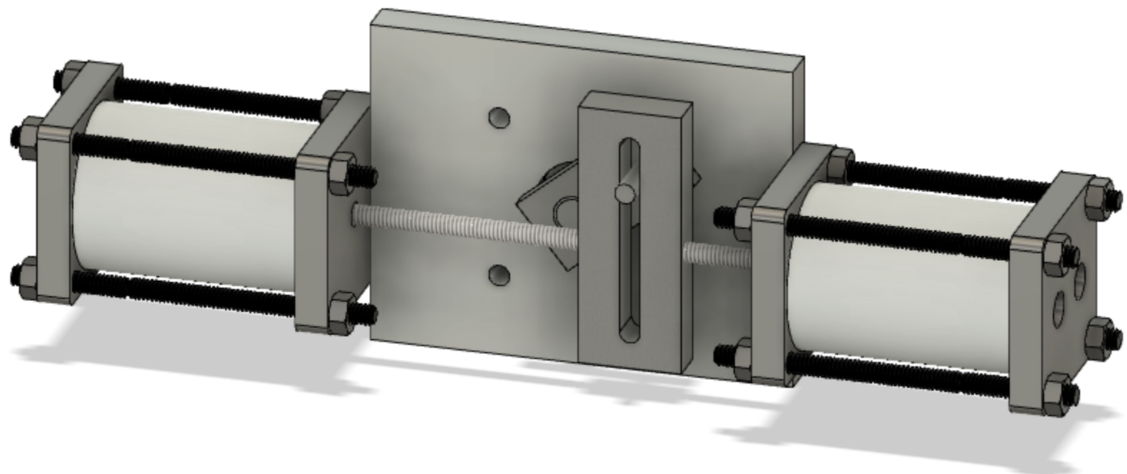

Figure 4: Final Version CAD Assembly

Our final design valued simplicity for ease of manufacturing. We used threaded rods to attach the cylinders to the backplate and for the piston arms. This saved time because a group member would simply have to cut a threaded rod to length instead of needing to manually thread a rod at each end. Originally, the group had planned to add another pair of end caps and drill holes through them for threaded rod to go through to attach to the backplate. Then, the pistons could have been attached to those extra end caps. However, by shifting the pistons slightly to the right and drilling holes in on the sides of the back plate as shown, the group reduced the workload of the machinists, the number of parts needed from Emerson, and the cost of the pump. Additionally, it reduced the dimensions of the pump which was essential because the original design would have been too long. Finally, by choosing to use the rectangular design for the rotating piece instead of the cylinder like Emily Harmon and Gabriella Passarelli's original design, the group was able to avoid ordering large, expensive stock from McMaster.

Challenges

Errors in our group's original CAD that was used in the preliminary design presentation presented a challenge for all of us. The original design did not account for the pump to be mounted to the back plate in any way. As you can see in Figure 5, the two pistons were simply resting next to the back plate. There were no screws, adhesives, or additional plates designated to attach the pumps to the back plate. This was a major oversight, because with this design, testing the water pump would be impossible as the design did not even allow for a full assembly. This necessitated a redo of the entire CAD which made it difficult to begin machining parts and placed a lot of additional work on the group members.

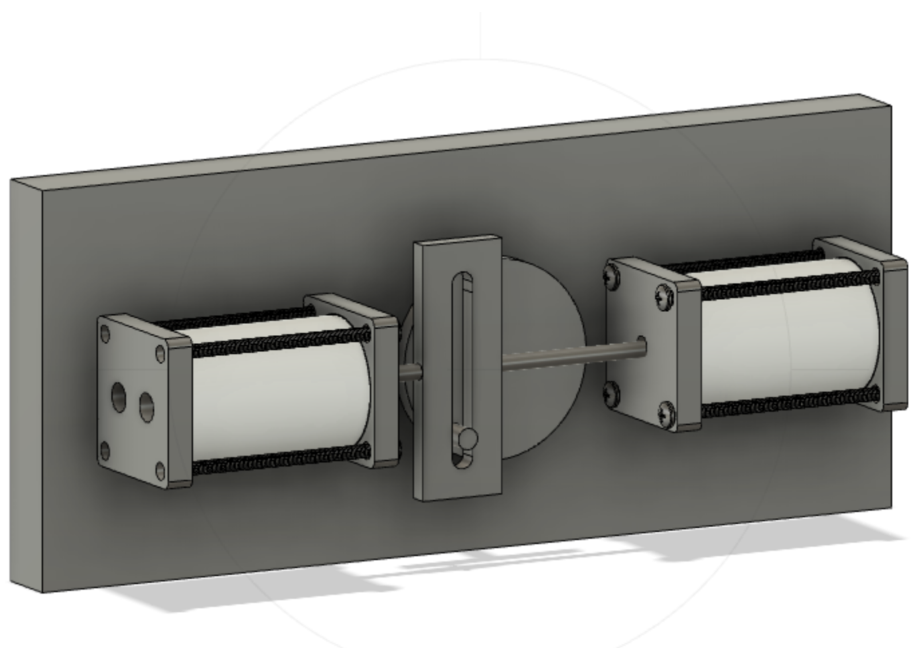

Figure 5: Original Flawed CAD Assembly

Another major difficulty was getting the part drawings to be ready for each group member to machine. In our original CAD, components such as our scotch yolk could not be separated into the appropriate pieces to make part drawings. As you can see in Figure 6, one component included the piston cylinders, the scotch yolk centers, and both of the piston arms. This was a poor design decision because each of those components needed to be machined separately. We had a lot of trouble separating everything while preserving the integrity of the CAD. This was the main reason why the group decided to start entirely from scratch and build a new assembly. After our design overhaul, it was much easier to get part drawings for each separate component as needed.

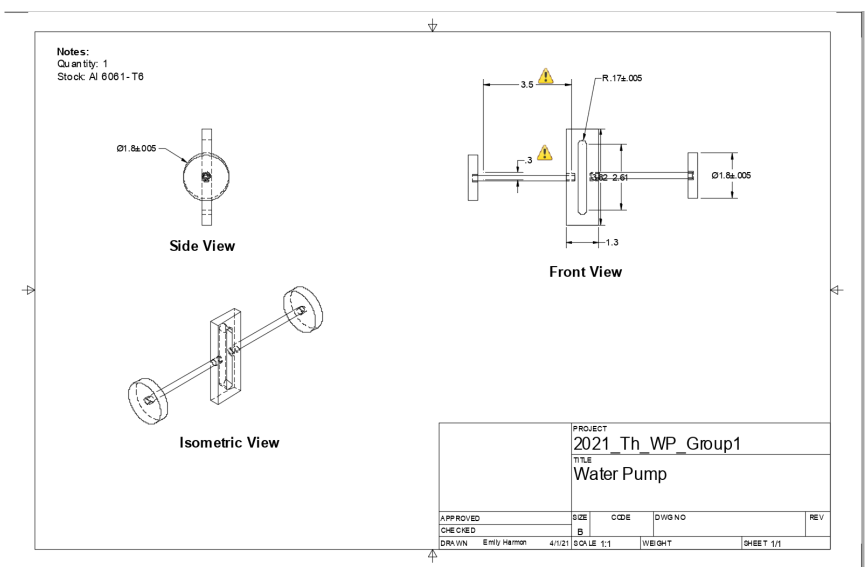

Figure 6: Original, Flawed Part Drawing

Each group member had to catch up on how the CAD changed after the preliminary review. At this point in our manufacturing process, each person had already been given a part to manufacture and part drawings to go with it. However, while making sure that each drawing was appropriately dimensioned, we had to make changes up until the last minute. Some of the changes required thinking about how the parts were going to be machined and where each part would be zeroed. For example, it wouldn't make sense to dimension a feature off of the top of a part and one off of the bottom if the machinist was going to be zeroing the part off of the top face. We also needed to ensure that the depth of thru holes were specified for the parts that required them. This was omitted several times which led to some confusion in the machine shop. Making sure that each member printed out and utilized the newest version of each part drawing was of utmost importance, and proved to be a moderate challenge because of all of the last minute changes. Additionally, Fusion360 requires manual updates to part drawings after an edit has been made to the original CAD, which could result in an outdated version being referenced if a concerted effort was not made to maintain updated part drawings.

Time management was challenging when it came to the manufacturing timeline. Each group member had their own parts to manufacture, and ensuring that each part was made in the necessary order to test their compatibility was a challenge due to each member's busy schedule. Furthermore, several team members underestimated the time it would take to manufacture a part. None of the team members had prior manufacturing experience aside from the lamp training, so getting comfortable with the machines took more time than anticipated. Parts that were originally intended to take only one shift turned out to be a two or three shift process. Some group members who were unable to finish in their designated machine shop shifts and had to coordinate with other members to either take over an unfinished part or schedule another time to finish it.

Passing off parts between members was a logistical challenge because of the fact that most of the team's classes were remote, and team members wouldn't always be on campus to exchange parts. Communication through GroupMe was imperative to make sure each member had the parts that they needed by their shifts. It was also helpful to make sure that each member was clear on what needed to be completed on unfinished parts.

Many of the parts needed to interface with each other in a manner that was essential to the function of the pump. However their fit could not be checked until both parts had been made. Even with the initial fabrication schedule accounting for this, everything was delayed or shifted if one part took longer than expected. Multiple parts had to be brought back into the machine shop for touch ups so that they would interface correctly.

Performance Analysis

Unfortunately, our pump was unable to be operated during the testing period, so we don't have any actual data of our pump performance to compare our analysis to. Our issue was a mounting problem. We did not realize that the screw heads from the screws used to mount the backplate to the face plate would interfere with the rotation of our scotch yolk center. The TAs provided us with Figure 7. It shows that there was not enough clearance for the rectangular piece to make a full rotation. If the pump had been attempted to be operated, it would have violently collided with the screw heads and likely caused a catastrophic failure.

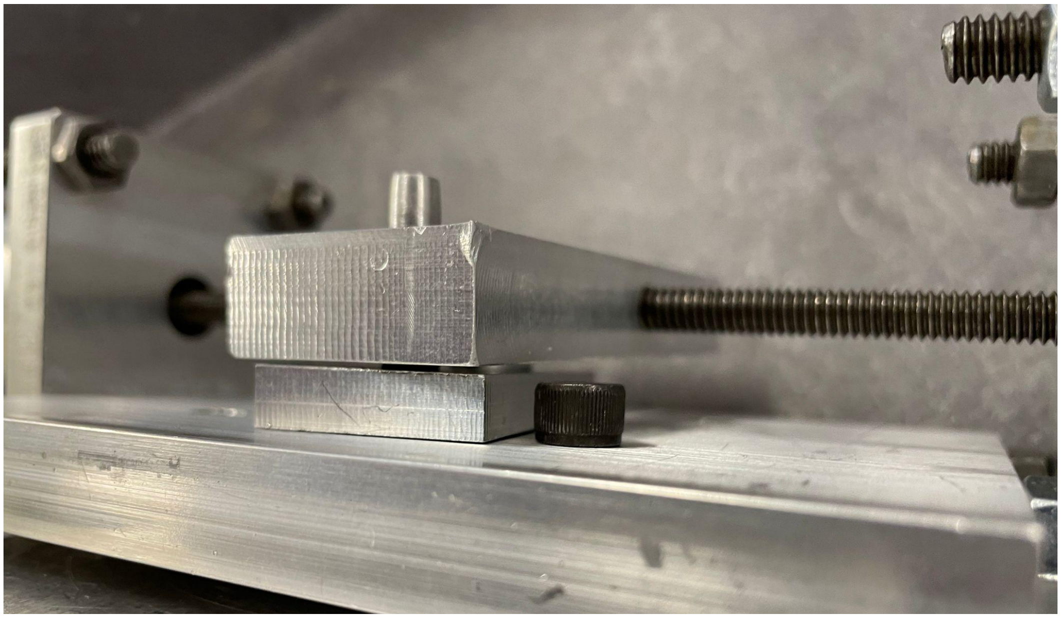

Figure 7: Clearance issue with pump

If the group had tested the pump's motion with these screws, the problem would have been easily identified. The solution would be to counter bore the thru holes on the backplate so that the tops of the screw heads would be flush with the face of the backplate. The group also should have read through the specifications for the project more thoroughly to ensure that something like this wouldn't happen. In hindsight it makes complete sense that if thru holes were needed, there would be a screw head that we would need to account for. Figure 8 shows that this clearance issue was even in the final version of the CAD. The rotating rectangle is directly over the holes with next to no clearance.

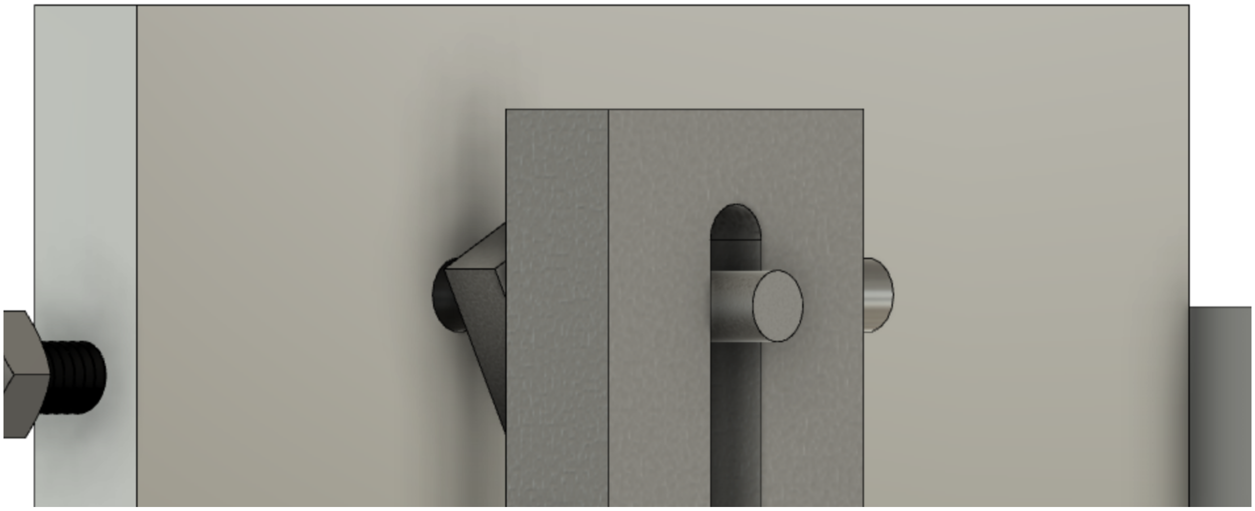

Figure 8: Clearance Issue Demonstrated in CAD Assembly

We should have made modifications to our planning and responsibility allocations as a team in order to foresee the failure of our pump and address it before the final test. Because there were so many specifications for how the pump needed to be mounted onto the test setup, we should have allocated a specific person to be responsible for thoroughly understanding its interface with our assembly in order to ensure that all the components would interact smoothly. After that, we could have worked as a team to support that person in their understanding of the setup and make sure we considered every aspect of our assembly from the beginning. Instead, we mostly took note of specifications individually and modified our assigned CAD parts and machined parts individually. However, this prevented us from thoroughly considering the assembly as a whole, leaving room for the clearance issue to occur.

Due to the fact that our pump couldn’t be tested, all of our analysis will have to come from our hand calculations. We calculated the efficiency of the pump by hand. Our calculations are shown in Figure 9.

Motor Specification

- Operating speed = 900 RPM (given on canvas)
- Sprocket Ratio : 9 (motor side) : 70 (pump side)

Find RPM of Drive Shaft

- Motor Side : 900 RPM
- Pump Side : GR · Motor Side

  $= (9/70) \cdot 900 = 116 \text{ RPM}$

*1 rotation of drive shaft = 1 full (in and out) movement of the piston

Calculate Water Pumped By one Pump

> Volume of cylinder = $\pi r^2 h$
> Machined cylinder from Emmerson : ID = 1.78" , h = 3"
> Height of piston head = 0.35"
> Height of groove of endcap = 0.125" } → this will take away from volume of water pumped
> Clearance of piston head and end cap = 0.109"

→ multiplied by two because there are grooves / clearances on both sides

$V = \pi (0.89)^2 (3 - 0.35 - 2 \cdot (0.125 + 0.109))$

$V = 5.43 \text{ in}^3$ water / one full motion / piston

Calculate Total Water Pumped By Entire Pump

> We have two pumps, so twice as much water pumped
*Assume equal amount pumped by each

$V_{tot} = (116 \text{ RPM})(5.43 \text{ in}^3)(2)$

$= 1256 \text{ in}^3/\text{min}$

$= 20.58 \text{ liters/min}$

Figure 9: Hand Calculations for Volume of Water Pumped

Given that the group who pumped the most water, pumped less than half of our calculated amount, with twice as many pistons, this calculation is most likely highly inaccurate. One of the sources of error could be overestimating the RPM of the drive shaft. The motor may not perform as well with the resistance of the water flowing through the pump. A lower RPM would greatly affect our calculation. Additionally the volume of water pumped per motion could be overestimated. By including the height of the piston head and the grooves in the volume calculations, the group tried to account for this, but leakage could also have an effect. By looking at a water pump result video of a double scotch yoke design almost identical to ours, and hand timing the amount of revolutions, Emily Harmon found that the actual RPM of the drive shaft could be closer to 75 PRM. Using that RPM in the current calculation, would yield 13 liters of water pumped per minute. This is still most likely a large overestimate, but closer to the likely actual value.

Some of the design factors that could have an impact on the efficiency and effectiveness of the pump are considered here. The primary cause for efficiency loss would likely be leakage. Water could leak out of the holes in the backplate, or around the edge where the cylindrical bodies interfaced with the backplate. We tried to combat this with sealant, but water still could have found a way through. The tolerance between the piston head and the cylindrical housing also could have been a source of efficiency loss. On our part drawings, we toleranced them to a thousandth of an inch, but it's possible that the diameter could be slightly undersized. This would be an additional source of leakage as the water could go between the edge of the piston and the cylinder. Finally, the drill depth of holes on the sides of the scotch yolk rectangle could also produce inconsistencies with the efficiency. Drilling holes to a specific depth on a mill is somewhat difficult. The hole depth would affect the length of the piston arms and therefore the motion of the pistons. If one rod was shorter than the original design called for, the piston would not travel as far up or down the pump which would affect how much water was pumped. The placement of the pin was also very important to our calculations. If it was closer to the drive shaft at all, it would also affect the distance traveled by the piston and reduce the amount of water it would be able to pump.

Cost Analysis

Total prototype cost = 40 hours x $120/hr + 30 hours x $40/hr + $24.69 **= $6024.69**

The total cost of the prototype was calculated by multiplying the number of non-recurring engineering design hours for the team by the rate of $120 per hour. This was then added to the number of manufacturing hours that the team spent in total which was multiplied by a rate of $40 per hour. These two numbers were added to the material cost to achieve a total prototype cost of $6024.69, which is greater than our initial prototype estimate of $5446.34.

Product cost, single production pump = $6024.69 + (44 x $1.20) **= $6077.49**

To calculate the cost of producing a single pump, every action taken while manufacturing a part had to be added together. For example, we had to sum the number of holes drilled, number of threadings, number of reamings, and all other production processes, which totaled 44. This number was multiplied by $1.20 and added to our total prototype cost, to achieve the cost of producing a single pump.

Product cost per pump = $6077.49/1000 + (44 x $1.20) **= $58.88**

To calculate the product cost per pump if able to sell 1000 pumps, the same process took place as in the previous calculation, but instead of adding the total prototype cost, we added the total prototype cost divided by 1000. This gave us a product cost per pump of $58.88, which is significantly cheaper than our estimated cost of $82.25.

Parts List

Description	**Quantity**	**Cost**
Machined 6061 T6 End Caps	4	$4.00
3” Bored 6061 T6 Cylinder	2	$2.00
1 ⅞” Diameter PVC Type ll Rod	1”	$0.86

⅜" Barbed x ¼" NPT Pipe Fittings	4	$2.20
¼ - 20 Steel Hex Nuts	32	$1.92
¼ - 20 Threaded Steel Rods	40"	$3.40
½" Diameter 1012 Steel Rod	3.5"	$0.81
¼" Diameter 1012 Steel Rod	1"	$0.10
¼" x 1" Aluminum Bar	2.5"	$0.35
½" x 2 ¼" Aluminum Bar	3.5"	$2.56
½" x 4" Aluminum Bar	5.5"	$6.49

Material Costs: $24.69

The total material cost of our water pump was $24.69, which was well within the Emerson Shop budget of $45, giving us room for error or the addition of parts in a future design.

Manufacturing Analysis

- Pistons and Threaded Rods: Sebastian Torres

To manufacture the pistons, Sebastian used the lathe and the 1 ⅞" Diameter PVC Type ll Rod. The first part of this process was to face the rod on the lathe, which allowed it to have a smooth, even finish. Once this was done, the diameter of the rod had to be reduced from 1.875'' to 1.778'' with a tolerance of 0.01''. In order to cut down the diameter, Sebastian first took passes of about 0.03'' to cut it down quickly. After about three to four passes, the autofeed was used to take more finite and smoother passes of 0.001'' to 0.002'' until the ideal diameter of 1.778'' was reached. To accommodate potential errors during the threading, about 1.5'' of the rod was cut down to the 1.778'' diameter. To drill the hole, a 0.201'' drill was used along with a ¼-20'' tap to thread the hole itself. Finally, the dimensions were zeroed to then cut 0.35'' thick pistons. Sebastian cut three because one of them came out to not be within the tolerance of 0.01''.On the other hand, to cut the threaded rods down, Sebastian used a cutting machine that used a stopper to allow for measured cuts. He cut down the 72'' rod into 8 4.25'' pieces and then smoothed out the edges using a belt sander.

- Rotating rectangle: Gabriella Passarelli

To manufacture the rotating rectangle, Gabriella used the ¼" x 1" aluminum bar stock and started by squaring one of the edges on the mill in order to ensure perpendicular sides and proper final dimensions. The stock was then flipped over and the length was reduced by facing off the other side in 1/10" increments, while continuing to check the dimensions. Once the stock was reduced to 2" with .01" tolerance, the part had to be zeroed using the edge finder so that the holes could be drilled in the correct locations. To drill the smaller hole, a .201" drill bit and a ¼-20 tap were used. To drill the larger hole, it was started with the .201" drill bit and then widened with a .328" drill bit, before finishing with the .4219" drill bit. This hole was then chamfered and threaded with a ½-13 tap.

- Scotch Yoke Pin: Camille Slattery

To manufacture the pin that went in the center slot of the Scotch yoke, Camille used the lathe and ¼" diameter steel rod stock. She started off by facing off one edge of the stock then flipped the stock to machine the other side. She used a cutting tool to reduce the length of the part to 1” with .01” tolerance, using .15” increments. She then threaded .25” of one end with .01” tolerance and ¼-20 threads. Finally, she used the belt sander to smooth down the non-threaded edge of the pin.

- Drive Shaft: Camille Slattery

To manufacture the drive shaft, Camille began on the lathe with ½” diameter steel rod stock. She faced off one edge of the stock to start, then on the other side, used a cutting tool to reduce the length of the part to 3” with .01” tolerance, using .15” increments. She then threaded .25” of one end with .01” tolerance and ½-13 threads. Then, Camille switched to the mill to machine a flat on the other end of the shaft. She used a collet block setup to mill a flat that was 1” long with .01” tolerance and .1” deep with .001” tolerance. After testing the clearance of the drive shaft with other parts in our assembly, we realized that the diameter of the drive shaft needed to be reduced by a few thousandths of an inch in order for it to move freely through the backplate and faceplate. Therefore, Camille did one more shift on the lathe, taking passes that reduced the shaft’s diameter by .001” at a time. She did one half of the shaft, then flipped the part over to match the same diameter on the other half of the shaft until they both matched and the shaft could slide through the bearing in the backplate but was still a close fit.

- Scotch Yolk Center: Emily Harmon

Emily began making the scotch yolk center by cutting down a piece of aluminum stock by using the horizontal band saw because there was too much stock to get rid of. Once the piece was much closer to the true dimensions of the part she moved to the mill to face it off. Next she worked on the holes for the threaded rods. She started by flipping the part on its side and using a center drill followed by a 0.201” drill bit up to a depth of 0.35”. Finally she tapped the hole using a ¼-20 tap. Then she repeated the process on the opposite side. The last step was to make the slot in the middle for the pin. First she used a ¼” diameter drill bit to make an initial hole, then she used a ¼” end mill to make the slot because they performed well radially and not axially.

- Back Plate: Gabriella Passarelli, Emily Harmon, and Camille Slattery

To manufacture the backplate, Gabriella began by squaring one edge of the ½” x 4” aluminum stock on the mill. The stock was then flipped over and the length was reduced by facing off the other side in 1/10” increments, while continuing to check the dimensions. Once the stock was reduced to 5.152” with .005” tolerance, the part had to be zeroed using the edge finder so that the holes could be drilled in the correct locations. The four mounting holes were initially drilled using a .201” drill bit, and then were widened with the .257” drill bit, which was their final dimension.

Emily was responsible for making the hole in the backplate for the bearing. She was also planning on making holes in both sides of the backplate for the pumps to mount to. However she was only able to make the holes and tap them in the time side before her shift ran out. Camille helped her to complete them.

The bearing was 1.125” and in order for a good press fit, the hole needed to be almost exactly 1.124”. There is no standard drill bit for a hole of that diameter, so she had to use a boring head. She started by drilling a normal hole and continuously stepped up the diameter, using larger and larger drill bits. Once she reached a 1” diameter hole, she used a boring head to get a diameter of exactly 1.124” with the help of Joe. Finally, she pressed the bearing into the backplate and used an adhesive to make sure that the bearing was secure.

Team Schedule

The team schedule is shown below. Communication was maintained throughout the process via GroupMe and during Zoom meetings.

Water Pump Gantt Chart

Task Number	TASK TITLE					PCT OF TASK COMPLETE
1	Class Deadlines	Due Date				
1.1	A8 - Preliminary Design Review	3/25/21				100%
1.1.1	A9 - Final Design Review	4/1/21				100%
1.2	A10 - Team Charter	3/29/21				100%
1.3	A11 - Final Report	5/21/21				100%
1.4	A12 - Water Pump Process Google Form	on own time				100%
1.5	Final Day to Machine	4/21/21				100%
1.6	Assembly Due in Lab	5/3/21				100%
2	Fabrication Timeline	Task Owner	Date	Time	Machine	
2.1	Rotating Rectangle (Drill & Thread)	Gabriella	4/13/21	7:30-9	mill	100%
2.2	Drive Shaft (Thread)	Camille	4/15/21	7:30-9	lathe	100%
2.3	Rotating Rectangle (Cut)	Gabriella	4/12/21	7:30-9	mill	100%
2.4	Pin for rotating rectangle (thread)	Camille	4/12/21	7:30-9	lathe	100%
2.5	Scotch Yoke Rectangle Center (Thread and Cut)	Emily	4/13/21	7:30-9	mill	100%
2.6	Scotch Yoke Rectangle Holes for Arms (drill and thread)	Emily	4/13/21	7:30-9	mill	100%
2.7	Scotch Yoke Arms (Thread and Cut)	Sebastian	4/14/21	6-7:30	lathe	100%
2.8	Scotch Yoke Cylinders (Thread and Cut)	Sebastian	4/20/21	6-7:30	lathe	100%
2.9	Mill Flat on Drive Shaft	Camille	4/19/21	2-3:30	mill	100%
2.1.1	Reduce Drive Shaft Diameter	Camille	4/21/21	7:30-9	lathe	100%
2.1.2	Press-Fit Backplate Bearing	Emily	4/19/21	2-2:30	n/a	100%
2.1.3	Boring Hole in Base Plate	Emily	4/15/21	3:30-5	mill	100%
2.1.4	Base Plate (drill holes)	Gabriella	4/14/21	2-3:30	mill	100%
3	Internal Meetings	Date	Time (hours)			
3.1	Preliminary Design Meeting	3/30/21	2.25			100%
3.2	Design Finalization/Feedback Integration	4/3/21	2.5			100%
3.2.1	Status Update/Design Reevaluation	4/7/21	1.5			100%
3.2.2	Machining Coordination/Scheduling	4/11/21	1.75			100%
3.3	Final Report Organization	5/18/21	2			100%
4	Internal Deadlines	Due Date				
4.1	Integrate Design Feedback into CAD	4/5/21				100%
4.2	Finalize CAD Joints	4/8/21				100%
4.3	Part Drawings	4/9/21				100%
4.4	Assemble Components	4/28/21				100%

3/22-3/26	3/29-4/2	4/5-4/9	4/12-4/16	4/19-4/23	4/26-4/30	5/17-5/21
M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F

Figure 10: Gantt Chart

Graphs, Charts and Tables

Functional Decomposition:

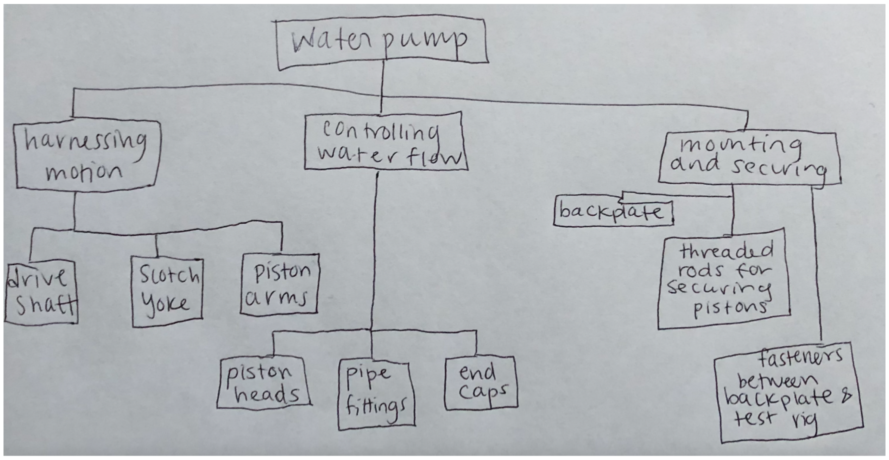

Figure 11: Functional Decomposition

Morphological Chart

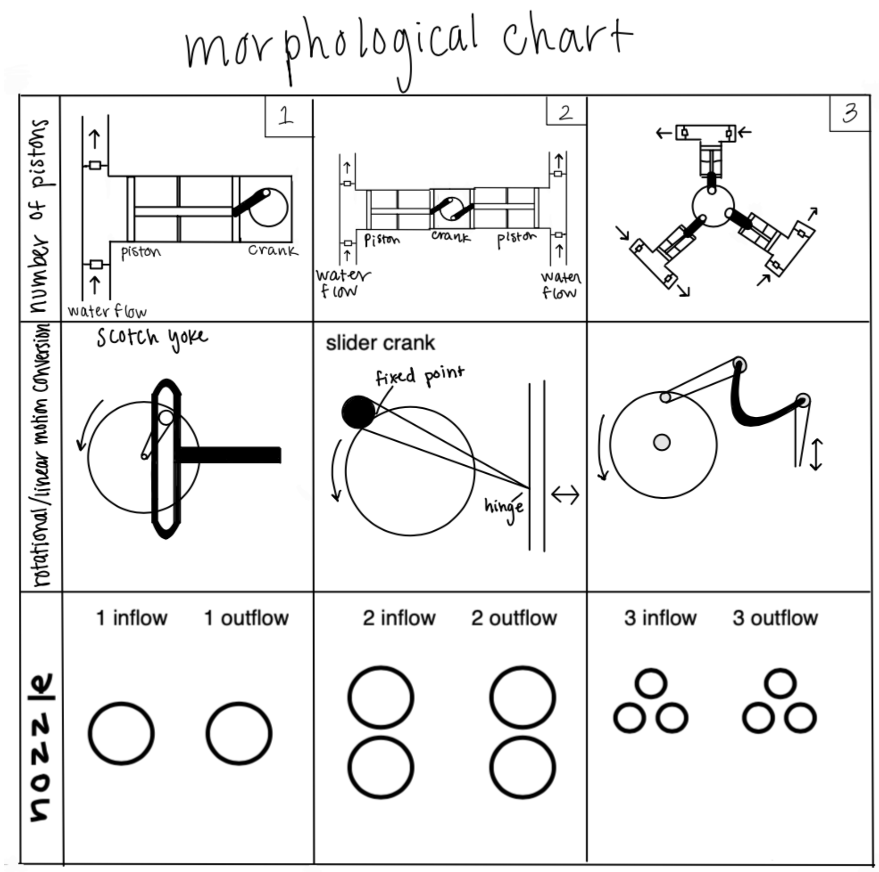

Figure 12: Morphological Chart

For our design, we decided to use two pistons because it would be more efficient than just one, but also more cost effective and easier to assemble than using three. A scotch yoke was our preferred method of conversion from rotational to linear motion due to its ease of manufacturing and intuitive application to a two-piston system. For simplicity's sake, we decided on one inflow and one outflow nozzle.

Appendices

Appendix A: Initial Sketches & CADs …………………………………………………….....23

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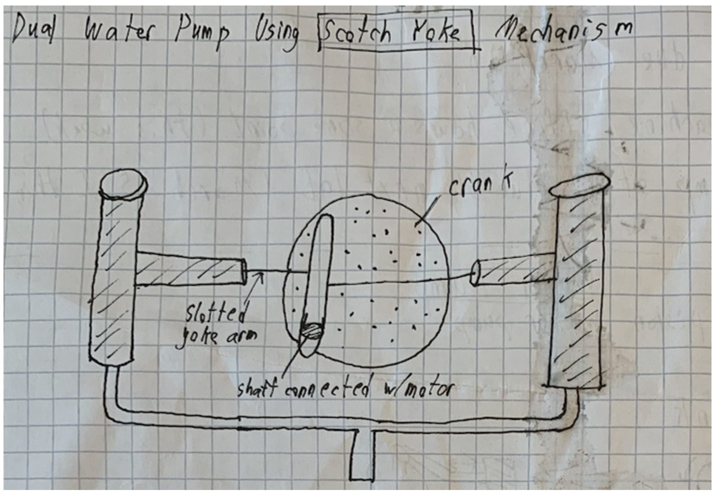
Appendix C: Team Charter…………………………………………………………………..…..33

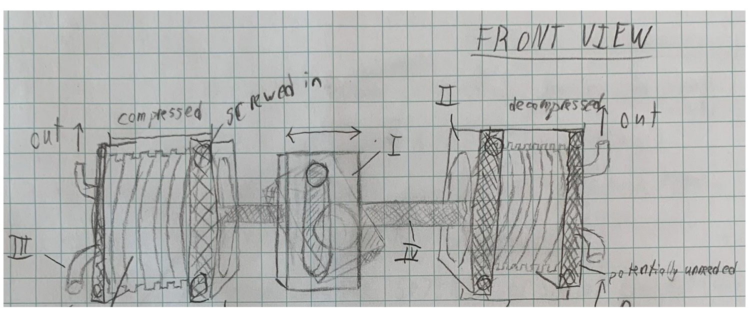
Appendix D: Calendars/Timelines…………………………………………………………..…34

Appendix A

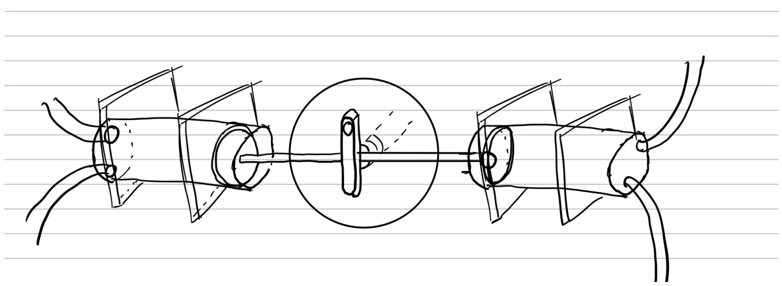
Initial Sketches

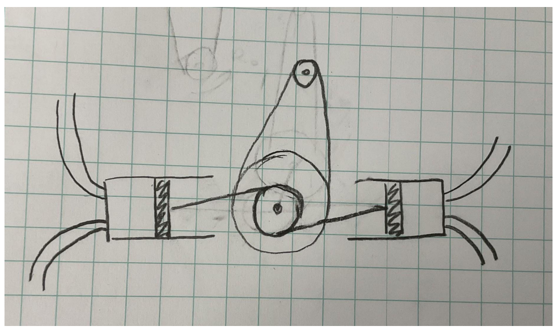
- Kean and Camille's Initial Sketches



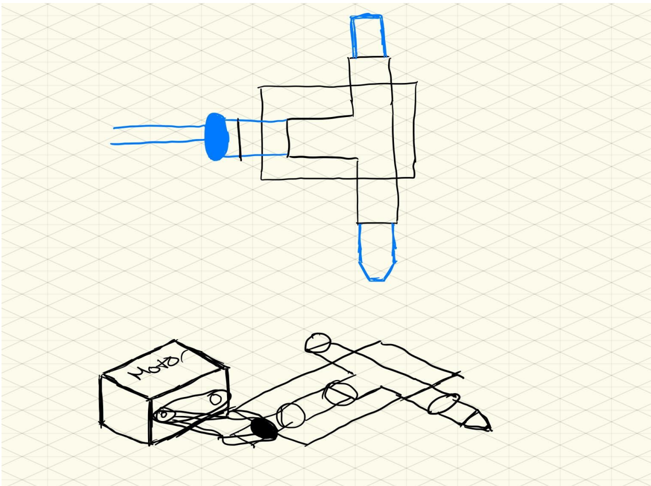


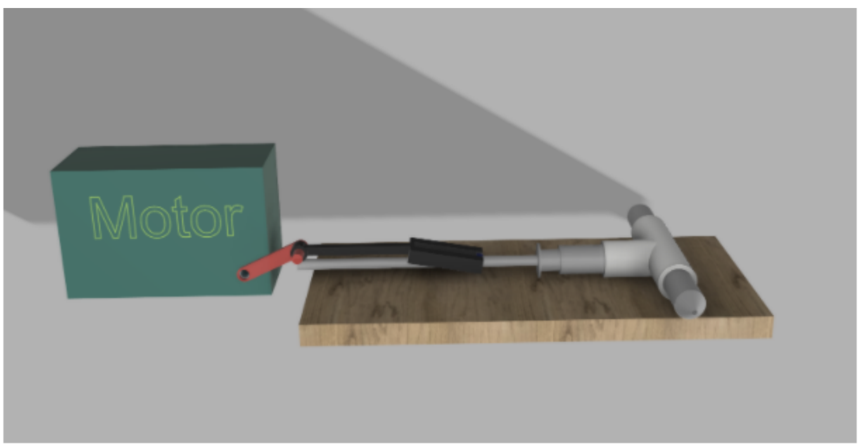
- Emily and Gabriella's Initial Sketches



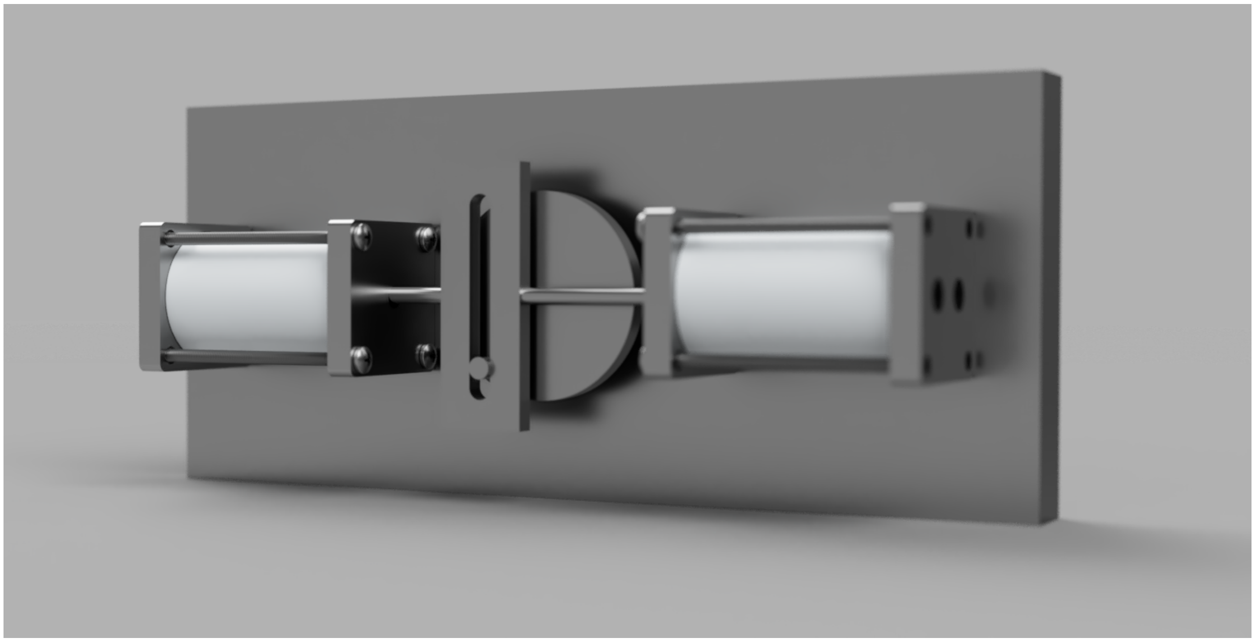


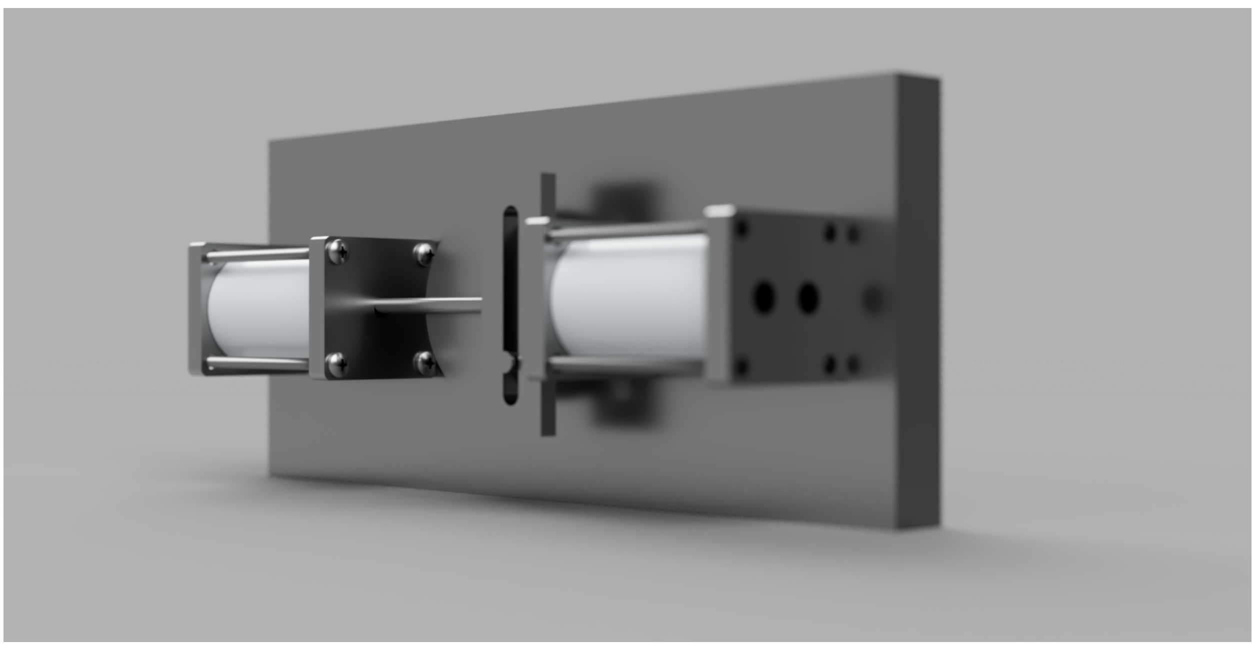
- Mathias and Sebastian's Initial Sketches





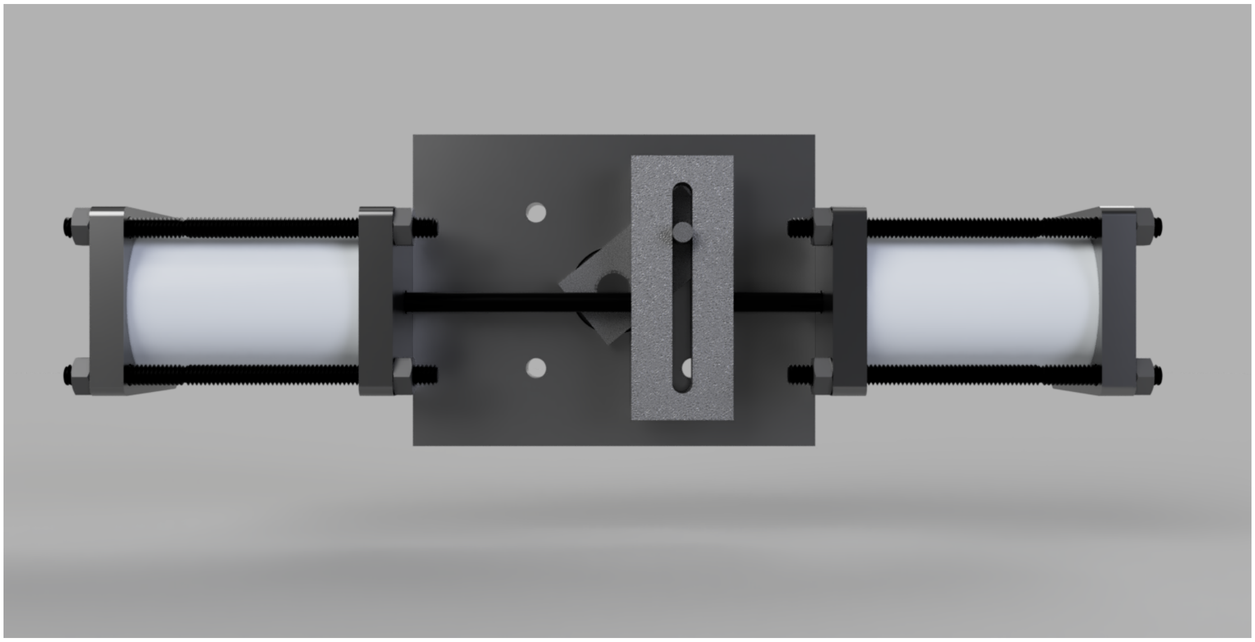
<u>Original CAD</u>



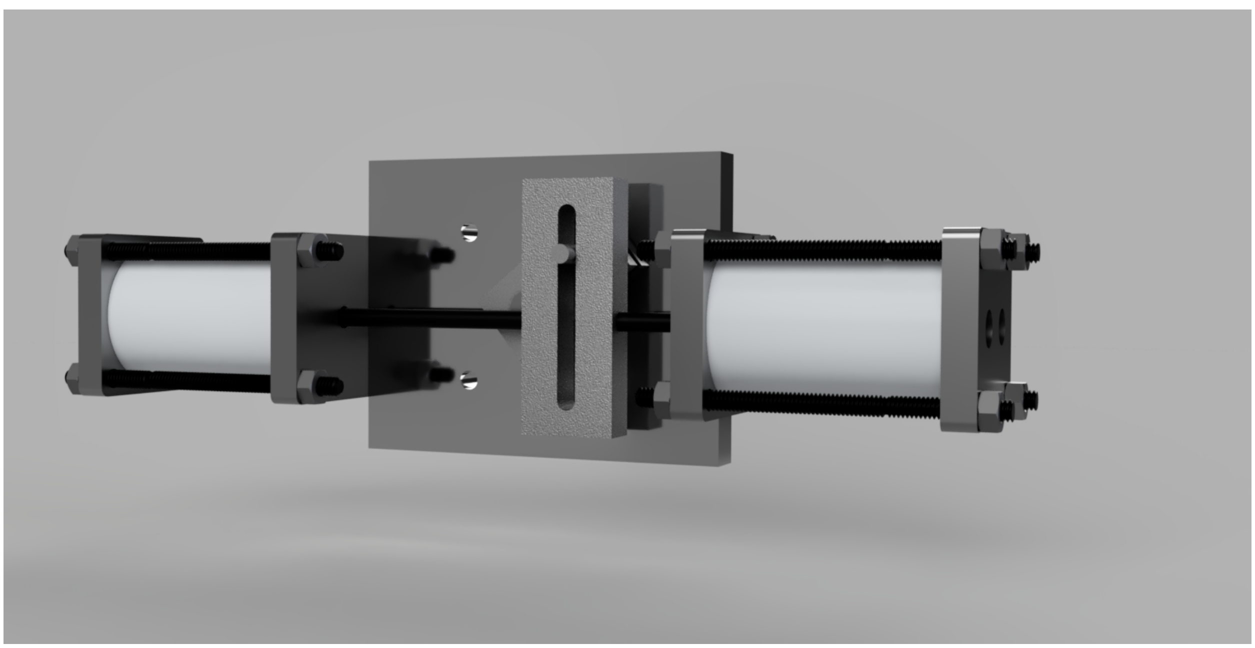


<u>Final updated CAD</u>

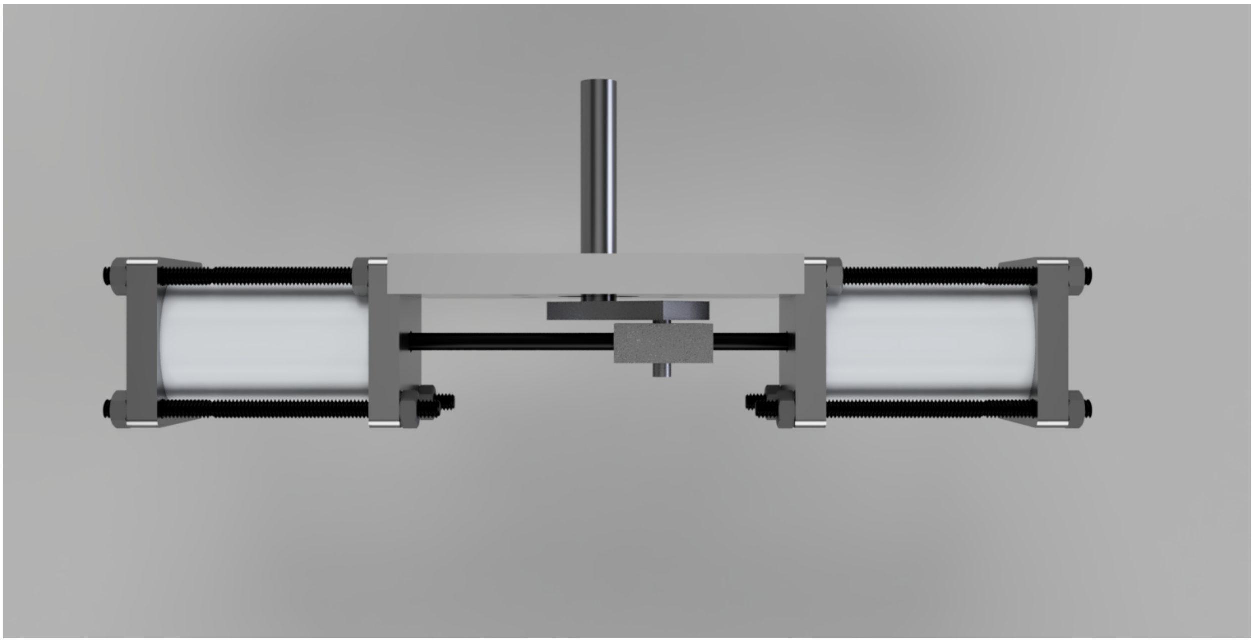
Front View



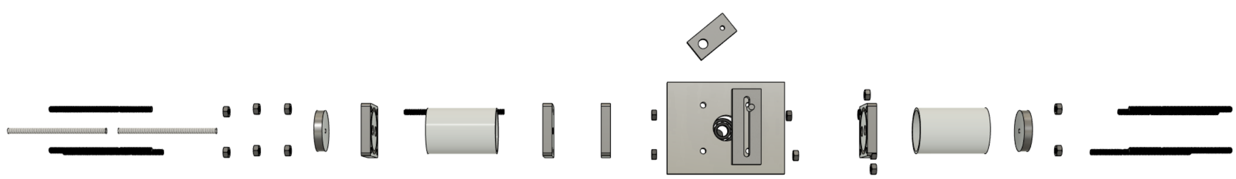
Front-Right View



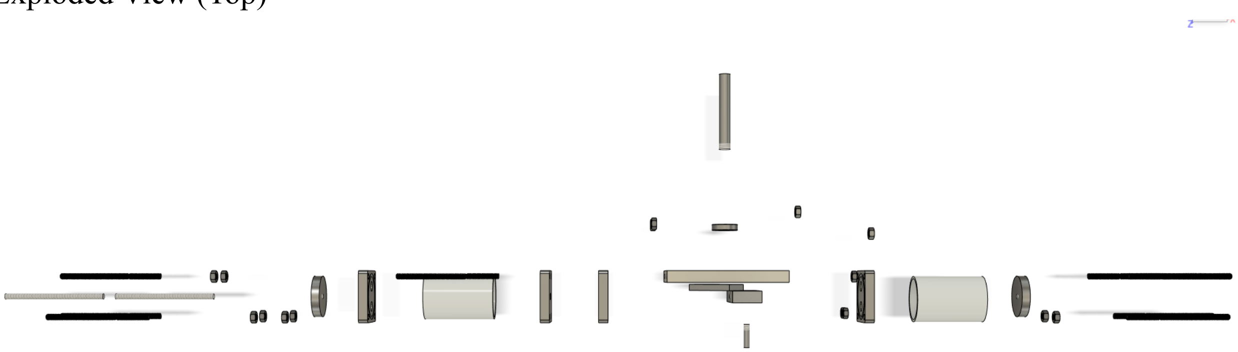
Top View



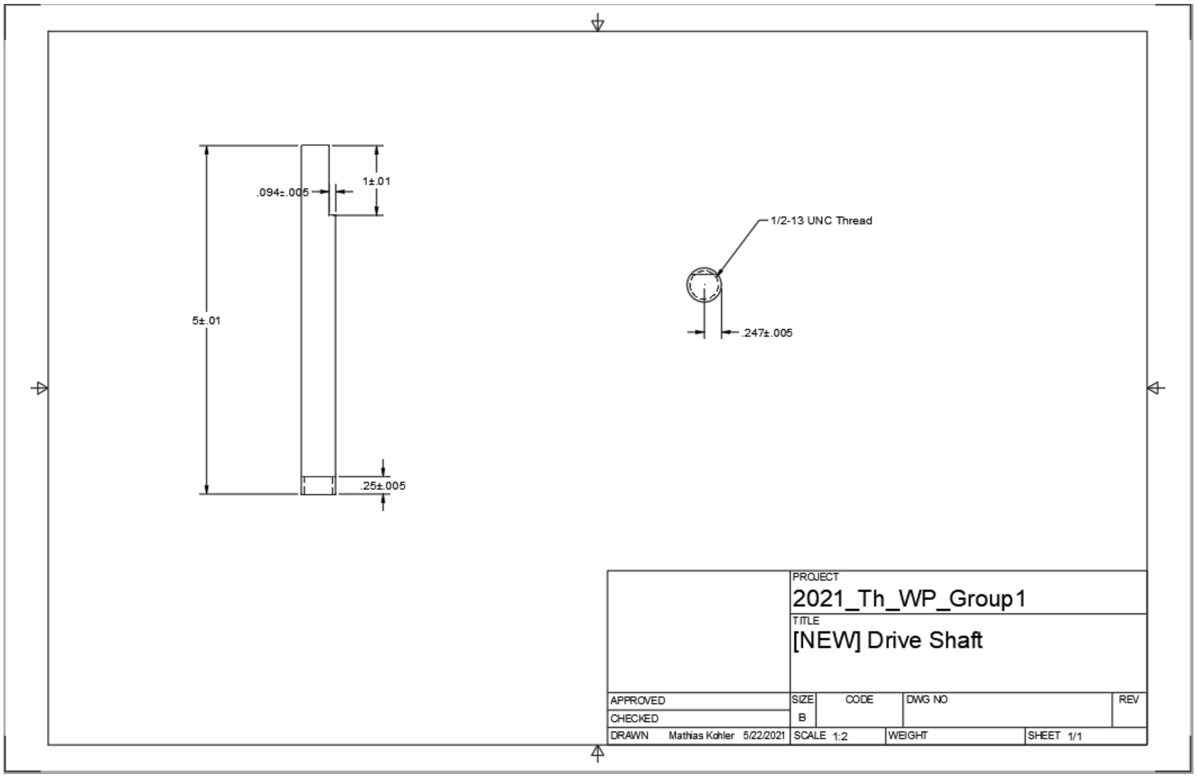
Exploded View (Front)

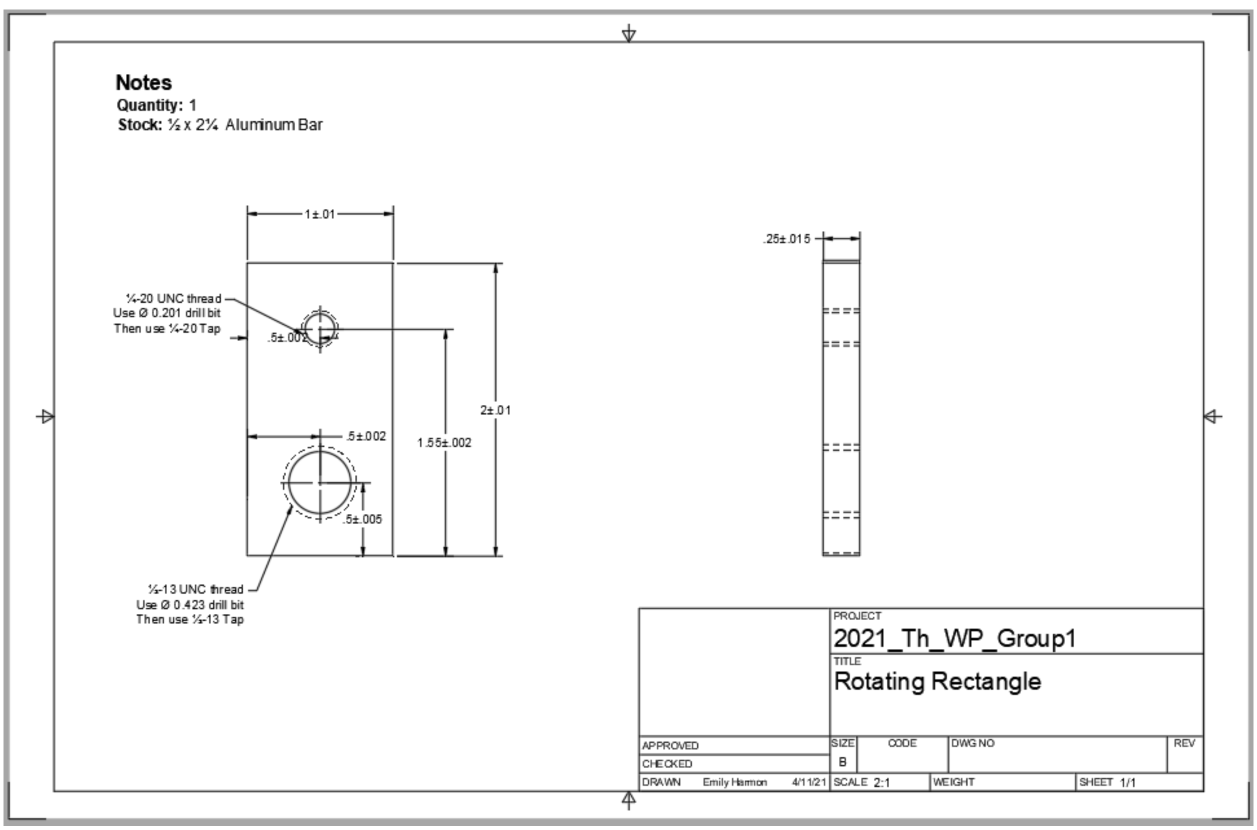


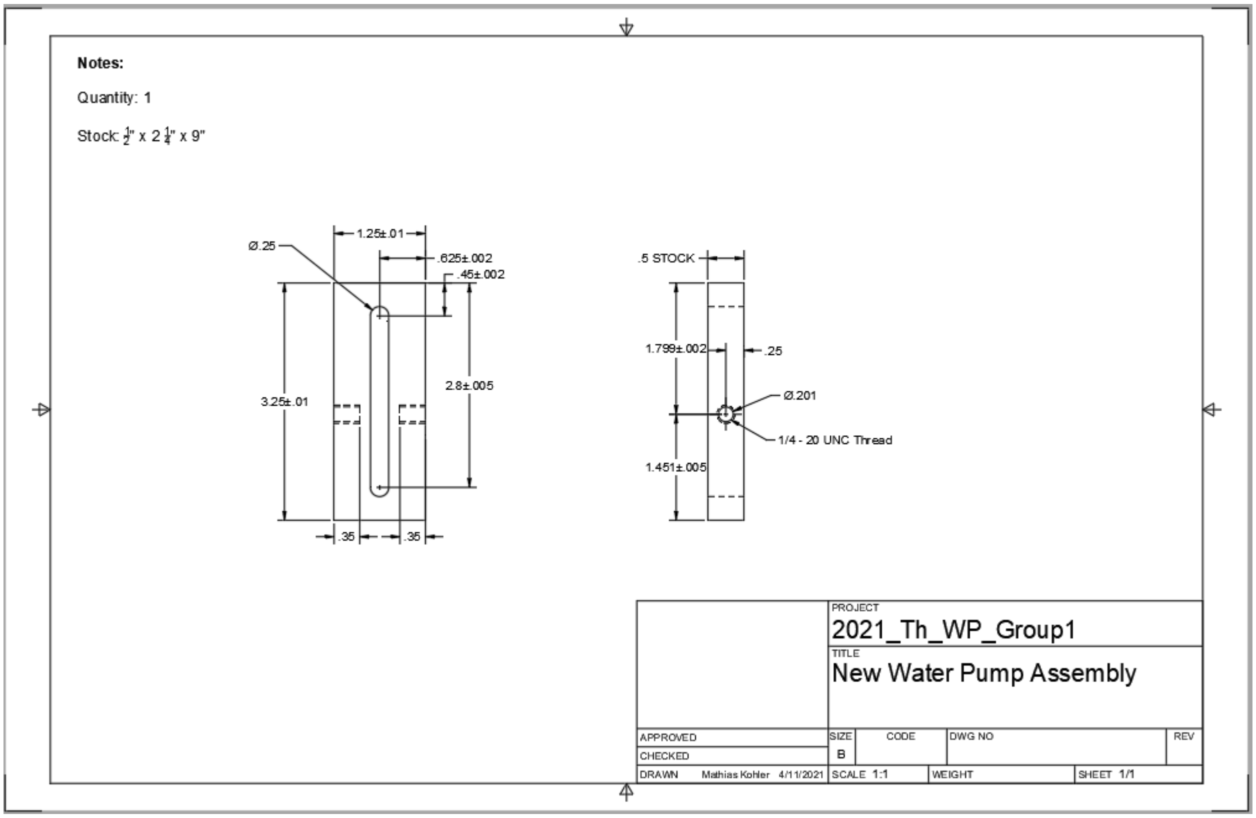
Exploded View (Top)

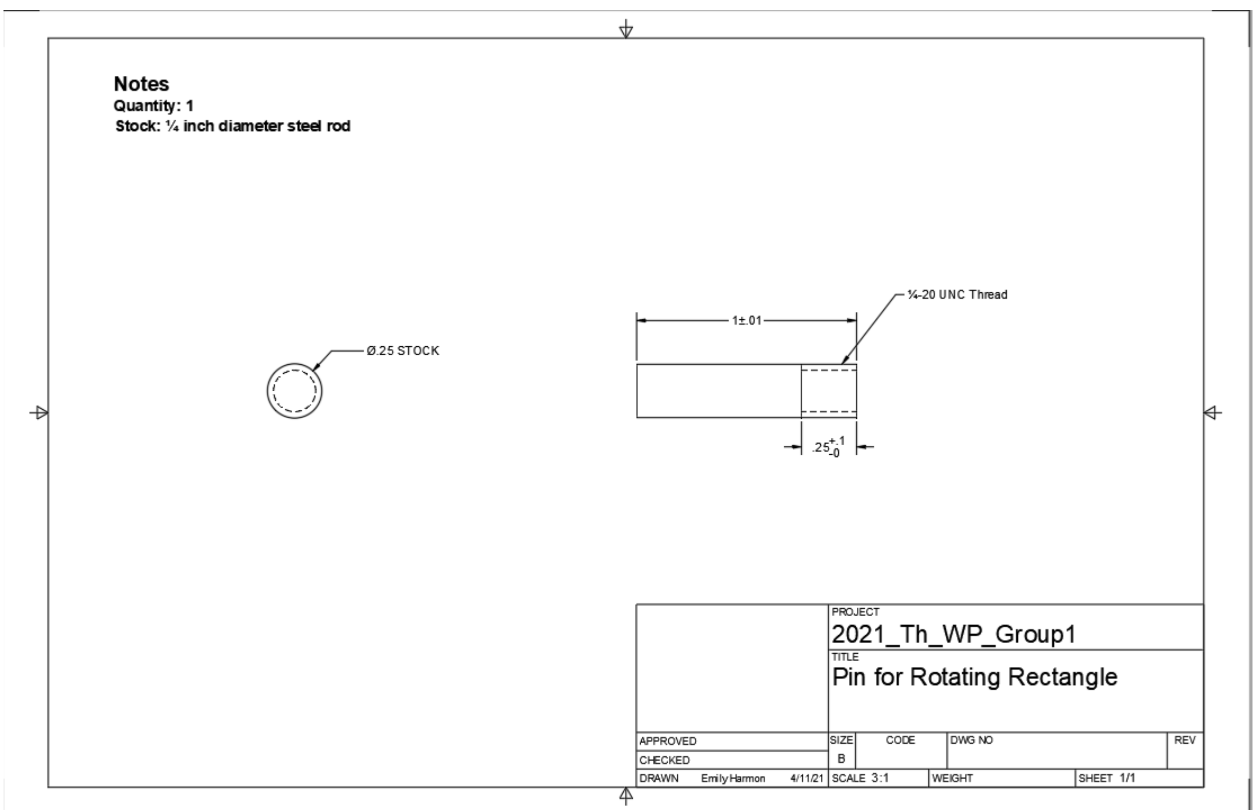


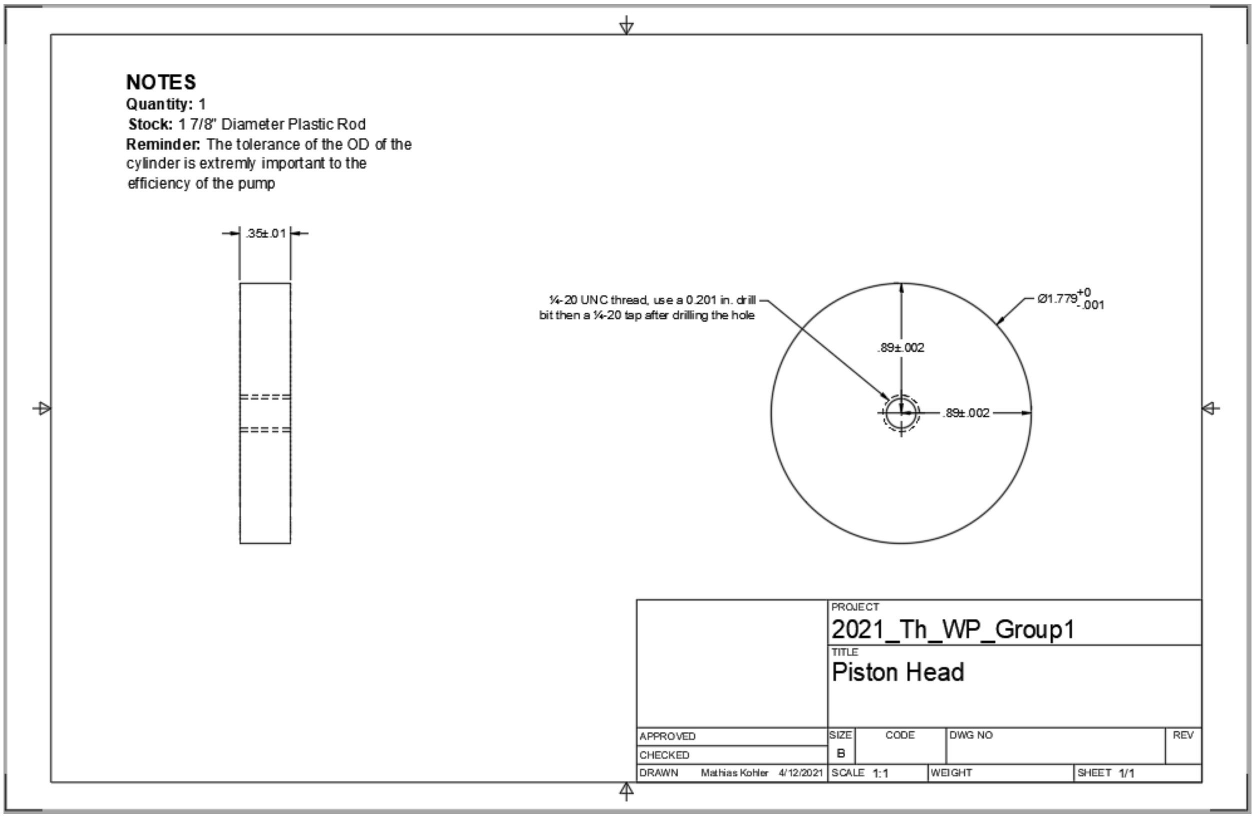
Appendix B

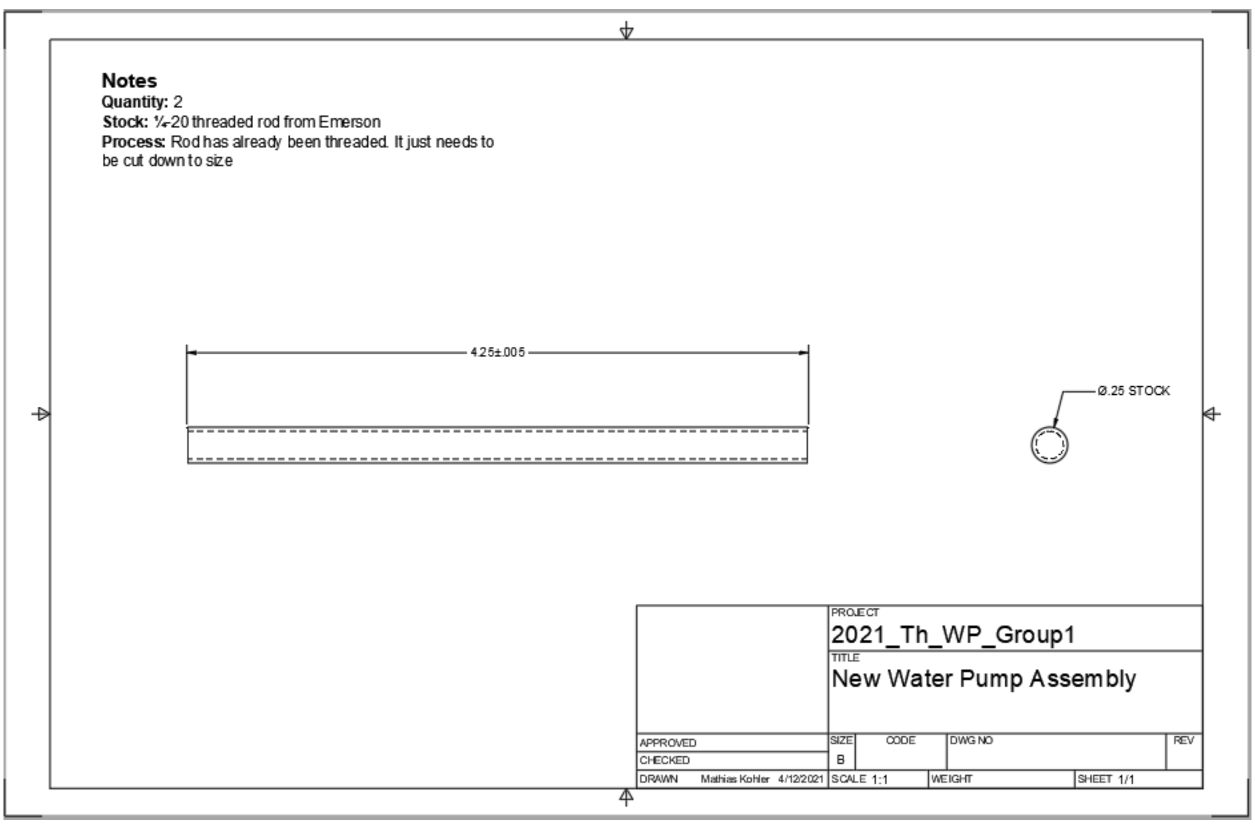

.094±.005
1±.01
5±.01
.25±.005
1/2-13 UNC Thread
.247±.005
PROJECT
2021_Th_WP_Group1
TITLE
[NEW] Drive Shaft
APPROVED
CHECKED
DRAWN Mathias Kohler 5/22/2021
SIZE B
CODE
DWG NO
REV
SCALE 1:2
WEIGHT
SHEET 1/1

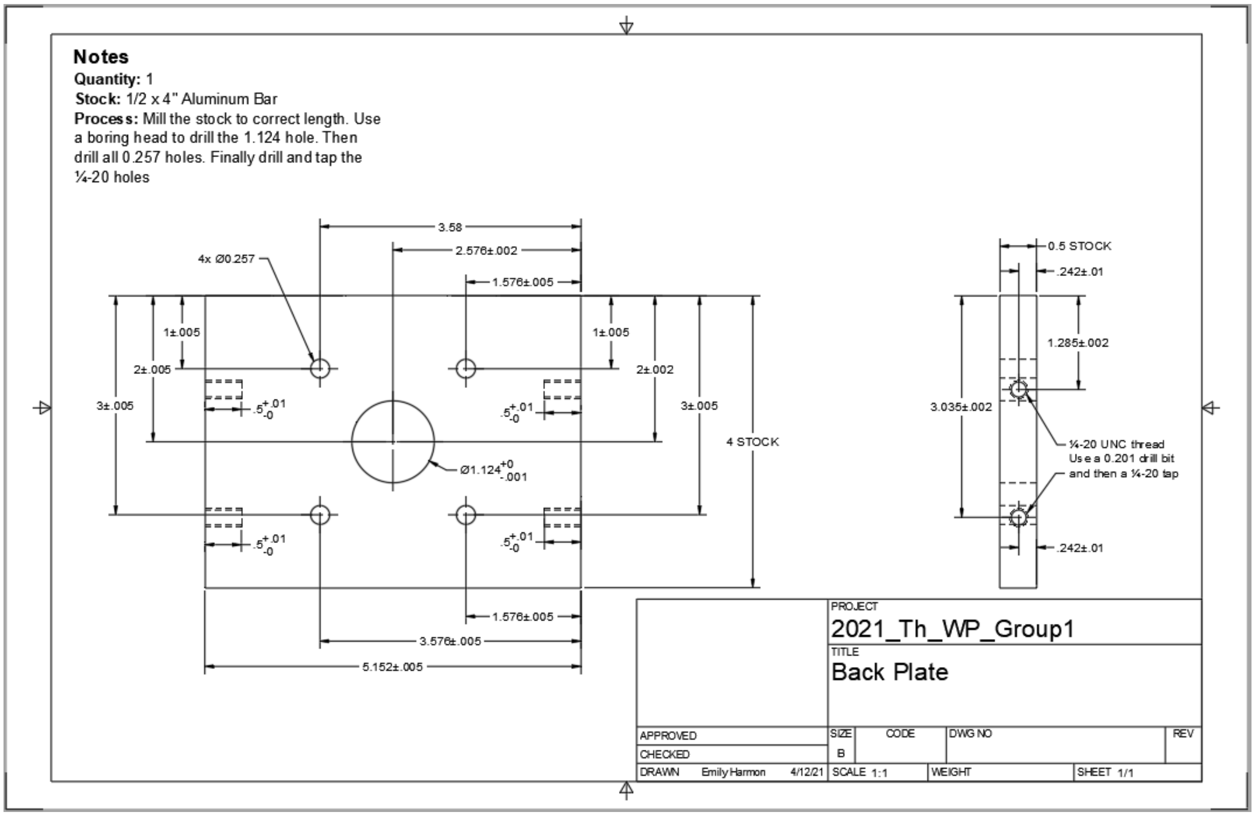

Notes
Quantity: 1
Stock: ½ x 2¼ Aluminum Bar
1±.01
¼-20 UNC thread
Use Ø 0.201 drill bit
Then use ¼-20 Tap
.5±.002
2±.01
.5±.002
1.55±.002
.5±.005
½-13 UNC thread
Use Ø 0.423 drill bit
Then use ½-13 Tap
.25±.015
PROJECT
2021_Th_WP_Group1
TITLE
Rotating Rectangle
APPROVED
CHECKED
DRAWN Emily Harmon 4/11/21
SIZE B
CODE
DWG NO
REV
SCALE 2:1
WEIGHT
SHEET 1/1


Notes:
Quantity: 1
Stock: ½" x 2 ¼" x 9"
Ø.25
1.25±.01
.625±.002
.45±.002
3.25±.01
2.8±.005
.35
.35
.5 STOCK
1.799±.002
.25
Ø.201
1/4 - 20 UNC Thread
1.451±.005
PROJECT
2021_Th_WP_Group1
TITLE
New Water Pump Assembly
APPROVED
CHECKED
DRAWN Mathias Kohler 4/11/2021
SIZE B
CODE
DWG NO
REV
SCALE 1:1
WEIGHT
SHEET 1/1


Notes
Quantity: 1
Stock: ¼ inch diameter steel rod
Ø.25 STOCK
1±.01
¼-20 UNC Thread
.25 +.1 -0
PROJECT
2021_Th_WP_Group1
TITLE
Pin for Rotating Rectangle
APPROVED
CHECKED
DRAWN Emily Harmon 4/11/21
SIZE B
CODE
DWG NO
REV
SCALE 3:1
WEIGHT
SHEET 1/1


NOTES
Quantity: 1
Stock: 1 7/8" Diameter Plastic Rod
Reminder: The tolerance of the OD of the cylinder is extremly important to the efficiency of the pump
.35±.01
¼-20 UNC thread, use a 0.201 in. drill bit then a ¼-20 tap after drilling the hole
Ø1.779 +0 -.001
.89±.002
.89±.002
PROJECT
2021_Th_WP_Group1
TITLE
Piston Head
APPROVED
CHECKED
DRAWN Mathias Kohler 4/12/2021
SIZE B
CODE
DWG NO
REV
SCALE 1:1
WEIGHT
SHEET 1/1


Notes
Quantity: 2
Stock: ¼-20 threaded rod from Emerson
Process: Rod has already been threaded. It just needs to be cut down to size
4.25±.005
Ø.25 STOCK
PROJECT
2021_Th_WP_Group1
TITLE
New Water Pump Assembly
APPROVED
CHECKED
DRAWN Mathias Kohler 4/12/2021
SIZE B
CODE
DWG NO
REV
SCALE 1:1
WEIGHT
SHEET 1/1



Notes
Quantity: 1
Stock: 1/2 x 4" Aluminum Bar
Process: Mill the stock to correct length. Use a boring head to drill the 1.124 hole. Then drill all 0.257 holes. Finally drill and tap the ¼-20 holes
3.58
2.576±.002
1.576±.005
4x Ø0.257
1±.005
2±.005
3±.005
2±.002
4 STOCK
Ø1.124 +0 -.001
.5 +.01 -0
3.576±.005
5.152±.005
0.5 STOCK
.242±.01
1.285±.002
3.035±.002
¼-20 UNC thread
Use a 0.201 drill bit
and then a ¼-20 tap
PROJECT
2021_Th_WP_Group1
TITLE
Back Plate
APPROVED
CHECKED
DRAWN Emily Harmon 4/12/21
SIZE B
CODE
DWG NO
REV
SCALE 1:1
WEIGHT
SHEET 1/1

Appendix C

Team Charter Summary:

Our group communicated through GroupMe messages and weekly Zoom meetings. We shared project materials through our Google Drive folder titled "2250_S21_TH_1." Though our team members had limited machining and design experience, we possess a variety of soft skills and related technical skills that we applied to the project. Matias Kohler was the scheduling and co-design coordinator, responsible for managing deadlines, group meetings and updating the CAD. Kean Chastain-Howley was the other design coordinator, responsible for updating the CAD and managing the physical assembly. Emily Harmon, Gabriella Passarelli, Sebastian Torres and Camille Slattery were design and manufacturing team members, responsible for machining parts, shop drawings and contributing to CAD designs.

To access our full Team Charter, please click here.

Appendix D

The following spreadsheets are from earlier on in our organization process and have been provided for reference. Updated information from both can be found in Figure 9, the Gantt Chart.

Initial Meeting/Deadline Schedule:

Date	Action	Lab Dates:
March 29	Submit Team Charter	
March 30	Meeting to finalize design and divide up	April 1
		April 8
April 1 - April 15	Finish CADs and sketches, Go into sho	April 15
		April 22
April 6	Meeting	April 29
April 13	Meeting	
April 16 - April 23	Assemble parts and test functionality (if parts aren't to specifications, we will remanufacture during this window)	
April 20	Meeting	
April 23 - 28	Finalizing the report	
April 29	Submit the report	

Fabrication Schedule:

Part to Manufacture	Machine	What we're doing	Stock Needed	Date	Time	Person
Base Plate (Drill Holes)	mill	Drilling holes	1/2 x 4" Aluminum Bar	4/14/21	2-3:30	Gabriella
Base Plate (Boring Hole)	Mill	Boring the hole for the bearing	1/2 x 4" Aluminum Bar	4/15/21	3:30-5	Emily
Base Plate (Press Fit)		Press fitting the bearing into the back plate	1/2 x 4" Aluminum Bar and M	4/19/21	2-2:30	Emily
Base Plate (Drill Holes)	Mill	Finishing the holes on the side for the pump to mount to	1/2 x 4" Aluminum Bar			Camille
Drive Shaft (Thread)	lathe	Cutting stock down to the size, milling flat on end	1/2" diameter rod	4/15/21	7:30-9	Camille
Rotating Rectangle (cut)	mill	Reduced stock to size	1/2" x 2 1/4" Aluminum Bar	4/12/21	7:30-9	Gabriella
Rotating Rectangle (drill and thread)	mill	Drilled and threaded holes	1/2" x 2 1/4" Aluminum Bar	4/13/21	7:30-9	Gabriella
Pin for rotating rectangle (thread)	lathe	reduce diameter, thread end	1/4" diameter rod	4/12/21	7:30-9	Camille
Scotch Yoke Rectangle Center (Thread and (	mill	Cut hole for pin in recuangular stock with end mill	1/2" x 2 1/4" Aluminum Bar	4/13/21	7:30-9	Emily
Scotch Yoke Rectangle Holes for Arms (drill a	mill	Thread holes in side to connect arms	N/A	4/13/21	7:30-9	Emily
Scotch Yoke Arms (Thread and Cut)	lathe	Cutting stock down to size and then threading both arms	1/4" diameter rod	4/14/21	6-7:30	Sebastian
Scotch Yoke Cylinders (Thread and Cut)	lathe	reduce length/diameter and thread hole for arms	cylindrical stock			Sebastian
Assembly						Kean
		Shop Drawings to Finish:	Issue:			
		Scotch Yoke Rectangle	Show thread			
		All Shop Drawings	Update/double check			
		To Order:				
		Base Plate	1/2" x 4" aluminum bar			
		Silicone Sealant	McMasterrcar			
		Bearing	McMasterrcar	1/2"		
		2" Diameter x 3" length Rods	quantity 2			