Water Pump Project

Team 4D
Adam Schreiber
Ethan Kramer
Rayne Milner
Katherine Carroll

Section 404
Patricia Marsa
Xinting Lan

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Section 1: Team Overview

This Section contains a general overview of the Team including contact information and meeting minutes. Within each week we have broken down when each item was completed, and who accomplished each task. We've also provided a summary of each week for quick reference.

Team Members:

Adam Schreiber	sas552@cornell.edu	201-686-0037
Rayne Milner	rmm286@cornell.edu	910-431-2056
Ethan Kramer	esk85@cornell.edu	973-487-8965
Katherine Carroll	kgc39@cornell.edu	484-636-8327

Meeting Minutes:

Week 1:

3/15/15: 1:00-2:10 pm Duffield All

- Looked at Project objectives and information (all)
- Did Research on Water pumps (all)
- Customer engineering Needs and Specs (Adam and Katherine)
- Engineering needs and Specs Rankings (Adam and Katherine)
- Notebook format and PDR needs (Ethan and Rayne)
- Researched Smart Sheets for Gantt chart (Rayne)

Week One Summary: In week one, we familiarized ourselves with the project statement and began researching exactly what needed to be done. This included researching different types of water pumps and determining what needs and specifications must be achieved. Additionally, we set up a shared google document and formatted our notebook correctly, making future updates easy.

Goals for Week Two: In week two we have to do a lot more research on the various pumps and then narrow down the possibilities to three designs. We also have to prepare for the preliminary design review.

Week 2:

3/19/15: 2:00-4:30 pm Taylor Rayne, Katherine, Ethan

- Review research on pumps
- Create Morph charts (Katherine, Rayne, Ethan)
- Review PDR Needs (Katherine, Rayne, Ethan)

3/22/15: 1:00-2:30 pm MechE Lounge Rayne, Katherine, Ethan

- Reviewed progress on designs and talked about possible changes
- Made drawings for Peristaltic and Double Piston pumps(Rayne and Katherine)
- Wrote descriptions for three pump designs (Rayne and Katherine)
- Made the Gantt Chart and critical path (Ethan)

3/24/15: 2:15-4:00 pm MechE Lounge All

- Made slides for presentation (Ethan and Rayne)
- Reviewed notebook and formatted correctly (Katherine and Adam)

Week Two Summary: This week we did the main portion of our research for this project. We thoroughly investigated all of the possible designs, and created morphological charts and drawings for each one. We then used a pugh decision matrix to select our top three pump designs, and created Gantt and critical path charts to plan our time management throughout the remainder of the project. Lastly, we made slides for our PDR presentation.

Goals for Week Three: Next week we have to choose our design for this project, and create an initial CAD model. We also have to start analysis on pump performance and learn how to optimize our design.

<u>Week 3:</u>

4/6/15: 7:00-8:30 pm Upson Lab All

- Reviewed CAD model (designed by Ethan)
- Talked about potential changes of the model and revisions of the model to optimize the performance of pump
    - increase the length of shaft
    - increase the size of the cylinder
    - use bearings to reduce friction in relation to the shaft
- Look into: forces, bending on shaft, etc
- To Do:
    - General Analysis
    - Cost Analysis
    - Drawings and Parts

4/7/15: 2:15-4:15 pm Upson Lab All

- Discussed likely changes for pump to make it more feasible to work
- Cost analysis - Katherine and Adam
- Notebook - Ethan
- Analysis - Rayne

Week Three Summary: In this week we made the transition from brainstorming and researching water pumps to actually designing our own. We chose to make a dual action single piston pump, and made a CAD model of our initial design. After some performance analysis, we made the appropriate changes to our design in order to optimize our efficiency. Lastly, we did cost analysis with regards to our budget, and created drawings of our parts to be ready to machine the following week.

Goals for Week Four: Start Machining.

<u>Week 4:</u>

4/13/15: 2:40-5:00 pm Machine Shop Katherine, Ethan

- Katherine on Mill squared up the top link stock
- Ethan made the piston fit the cylinder and made the cylinder fit the end caps

4/14/15: 2:50-4:30 pm Machine Shop Adam, Ethan

- Adam on Mill squared and machined end caps
- Ethan on Lathe machined piston shaft

4/16/15: 2:30-4:30 pm Taylor, Machine Shop All

- Adam on Mill finished machining end caps
- Ethan and Rayne on Lathe sized piston to fit the cylinder more accurately
- Katherine worked on the notebook

Week Four Summary: In week four we started manufacturing our pump. This week we were able to machine the piston shaft, end caps, cylinder, and piston.
Goals for Week Five: Keep Machining.

Week 5:
4/17/15: 9:00-11:00 am Machine Shop Ethan, Katherine, Rayne

- Rayne sized the threaded rods and squared the mounting plates on the Mill
- Katherine squared the top links and machined the middle link on the Mill
- Ethan sized the cylinder on the Lathe

4/20/15: 3:00-4:30 pm Machine Shop Ethan, Katherine

- Katherine machined mounting plates on the Mill
- Ethan sized and machined input shafts on the Lathe

4/21/15: 9:00-11:00 am Machine Shop Ethan

- Ethan finished input shafts, middle link, and the piston shaft on the Mill

4/21/15: 2:15-4:00 pm Taylor All

- Assembled water pump - looks awesome
- Everyone worked on the notebook in response to Pati's comments

Week Five Summary: In week five we accomplished the majority of our manufacturing. We were able to machine the threaded rods, mounting plates, top and middle links, and input shafts. This meant that we had manufactured all of our parts, and at the end of the week we assembled our pump for the first time.
Goals for Week Six: Make sure our pump works, and optimize it in every way possible. Also, we have to finish the notebook.

Week 6:
4/24/15 :9-11 am Machine Shop Ethan

- Tested Water pump and sanded components. Put in locating spacers. Assembled pump

4/27/15: 1-6 pm Taylor/Machine All

- Machined weight savings on Mill
- Fixed Cylinder to fit in end caps
- Reassembly of water pump and thorough testing and documentations.

4/28/15: 2:15 - 5pm Taylor All

- Final assembly and pictures of assembly.
- Assembly of water pump and testing with drill

4/28/15 8-9:30 pm Bethe House Rayne, Katherine, Ethan

- Rayne: Made FDR Slides
- Katherine: User Manual
- Ethan: Week updates and cost updates

5/1/15: 10:45 - 12:30 am Upson Adam, Ethan

- Finished notebook

Week Six Summary: At the beginning of this week, we had an assembled pump that didn't work at all. We did analysis and created custom spacers to keep the piston shaft concentric to the end caps, as well as sanded and smoothed all of our components. Once the pump was working, we did some final machining to save weight. We took pictures of our pump and each part, created a user manual for the pump, and made a final design review presentation. Lastly, we did a dry run of our pump with a drill, and finalized the notebook.

Who Did What:

Table 0: Member Contributions

	Ethan	Katherine	Rayne	Adam
Pump Research	X	X	X	X
Customer/Engineering Needs and Specifications		X		X
Create Notebook Format	X		X	
Create Morph Charts	X	X	X	
Drawing and Descriptions of Pump Types	X	X	X	
Gantt Chart and Critical Path	X			
PDR Slides	X		X	
Reformat Notebook		X		X
Create CAD Model	X			
Cost Analysis		X		X

Performance Analysis	X		X	
CDR Slides			X	X
Machined Top Links		X	X	X
Machined Piston, Piston Shaft, and Cylinder	X			
Machined End Caps				X
Machined Mounting Plates		X	X	X
Machined Middle Link	X	X		
Machined Input Shafts	X			
Sized Threaded Rods			X	
Assembled Pump	X	X	X	X
Did Further Analysis to Optimize Pump	X		X	
FDR Slides			X	
Finalized Notebook	X	X	X	X

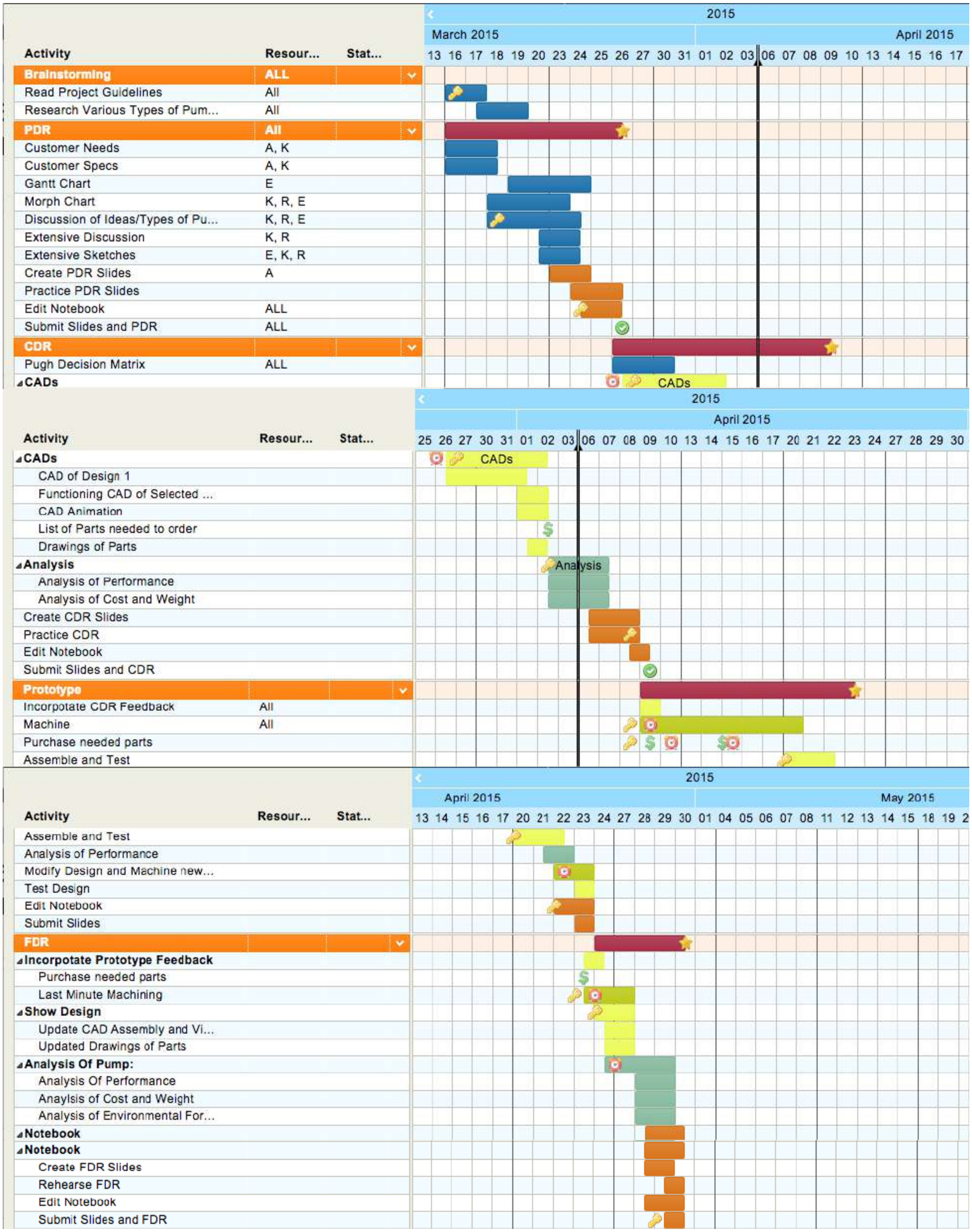
Section 2: Project Planning

This section contains the planning for the duration of the project. Included in this section are the Critical Path and the Gantt Chart. These two items allow us to fully plan out each stage throughout the design of our pump. With these items, we are able to identify any bottlenecks and areas where we need to get a lot of work done.

Table 1: Critical Path

Action Item	Action Name	Team Member Responsible	Depends On	Duration	Time Remaining		Start:	3/16/2015
					44		End:	4/29/2015
1	Read Guidlines	All	-	2	42			
2	Discussion Of Types of Pumps	E, K, R	1	4.5	37.5			
3	PDR Prep	All	1,2	3	34.5			
4	Selection of Ideas	All	2,3	1	33.5			
5	CADS	TBA	4	5	28.5			
6	Analysis of Ideas	TBA	4,5	3.5	25			
7	CDR Prep	All	4,5,6	3	22			
8	Order of Parts	TBA	5,6,7	2	20			
9	Machining	All	5,8	8	12			
10	Assemble and Test	All	9	3	9			
11	Modify CAD Design	TBA	9,10	1	8			
12	Machining New Design	TBA	10,11	2	6			
13	FDR Prep	All	10,11,12	6	0			

Image 1: Gantt Chart


2015
March 2015
April 2015
Activity
Resour...
Stat...
13 16 17 18 19 20 23 24 25 26 27 30 31 01 02 03 06 07 08 09 10 13 14 15 16 17
Brainstorming ALL
Read Project Guidelines All
Research Various Types of Pum... All
PDR All
Customer Needs A, K
Customer Specs A, K
Gantt Chart E
Morph Chart K, R, E
Discussion of Ideas/Types of Pu... K, R, E
Extensive Discussion K, R
Extensive Sketches E, K, R
Create PDR Slides A
Practice PDR Slides
Edit Notebook ALL
Submit Slides and PDR ALL
CDR
Pugh Decision Matrix ALL
CADs
CADs
2015
April 2015
Activity
Resour...
Stat...
25 26 27 30 31 01 02 03 06 07 08 09 10 13 14 15 16 17 20 21 22 23 24 27 28 29 30
CADs
CADs
CAD of Design 1
Functioning CAD of Selected ...
CAD Animation
List of Parts needed to order
Drawings of Parts
Analysis
Analysis
Analysis of Performance
Analysis of Cost and Weight
Create CDR Slides
Practice CDR
Edit Notebook
Submit Slides and CDR
Prototype
Incorpotate CDR Feedback All
Machine All
Purchase needed parts
Assemble and Test
2015
April 2015
May 2015
Activity
Resour...
Stat...
13 14 15 16 17 20 21 22 23 24 27 28 29 30 01 04 05 06 07 08 11 12 13 14 15 18 19 2
Assemble and Test
Analysis of Performance
Modify Design and Machine new...
Test Design
Edit Notebook
Submit Slides
FDR
Incorpotate Prototype Feedback
Purchase needed parts
Last Minute Machining
Show Design
Update CAD Assembly and Vi...
Updated Drawings of Parts
Analysis Of Pump:
Analysis Of Performance
Anaylsis of Cost and Weight
Analysis of Environmental For...
Notebook
Notebook
Create FDR Slides
Rehearse FDR
Edit Notebook
Submit Slides and FDR

Bottlenecks

Bottlenecks were labeled on the gantt chart as clocks which represented points on the schedule where we could expect arrested or slowed progress. Some of the bottlenecks that were listed on the Gantt chart did develop into actual issues, while others passed along smoothly. Also, some unforeseen issues emerged and created stoppages in our progress. One bottleneck that can be seen on the Gantt chart that caused trouble was purchasing our needed parts. Since we continuously modified our design, we were unable to submit a parts order on time, because we did not know exactly what parts we needed. In order to overcome this problem, we submitted multiple smaller parts orders as the project progressed, only ordering what we were certain was necessary at any given time. Another bottleneck that was labeled on the Gantt chart was machining, and this proved to be quite a challenge. Although our drawings were clear and our machining technique was precise, the stock parts we ordered were not as precise as we had expected. Specifically, the cylinder was not perfectly circular, and the circular grooves in the end caps were not centered on the parts. This caused some issues during our first assembly, but we were able to modify the necessary parts in order for the parts to fit together and for the pump to work. However, this problem did cause an increase in water leakage during our final testing. On that note, a bottleneck which arose that we did foresee was the inability for us to test our pump in the testing facility. We ran some dry tests with an electric drill that helped us make some adjustments to the pump, but not being able to test our pump in the proper testing environment inhibited us from producing the best possible pump. Although many bottlenecks arose throughout the course of this project, we were able to maneuver our way to the finish and successfully create an efficient water pump.

Section 3: Product Planning

After devising a roadmap for the course of our project, it was time to start planning our actual product. We decided to go about this in a very systematic manner. First, we looked at the customer needs demanded by the company requesting the water pump as described in the project statement. We then discussed which engineering specifications of our pump would be required in order for the pump to meet the consumers' demands. With a clear idea of what our pump will need to accomplish, we researched various pump designs which we thought would best fulfill these goals. Then, by using morphological charts and Pugh decision matrices to organize our ideas and place values on each design, we narrowed down our ideas to three promising designs.

Table 2: Customer Needs and Engineering specifications:

	Customer needs	Low Cost	Allowable Stress on motor	Efficiency of pump	Weight	Type of Material	Time until max flow rate	Time to Start up	Pump Geometry	# of times it can operate
1	Light Weight		X		X	X				
2	Affordable	X				X				
3	Integrated with testing equipment								X	
4	Good flow rate			X			X	X		
5	Durability		X							X
6	Aesthetically Pleasing					X			X	
7	Easy to Use							X		
8	Safety		X		X	X				X

Table 3: Engineering Specifications

Engineering Specification	Needs Met	Units	Acceptable Range	Importance (1-5)
Low Cost	2	dollars	<$40 (prototype) <$40 (Pump)	4
Allowable Stress on Motor	1,5,8	Pa		5
Efficiency of Pump	4	L/Min Kg	3-6	3
Weight	1,8	kg	2-5	3
Type of Material	1,2,6,8	-	NA	4
Time Until Max Flow Rate	4	sec	5	2
Time to Start Up	4,7	sec	10-15	3
Pump Geometry	3,6	-	Vol<1 c.f. d (drive shaft motor) = 0.5 in d(piston)< 2 in	3
Number of Times it Can Operate	5,8	#	>5	1

First Decisions and Idea Generation:

This First Round Pugh Decision Matrix is a preliminary determination of how we choose to design our water pump. Initially, we independently researched different methods of pumping water. We then met and compiled the designs into the five unique designs below. Once we had these different designs we rated the pump on the below categories to determine the best three candidates moving forward.

Table 4: First Round Pugh Decision Matrix

Type Of Pump	Piston	Rotary	Peristaltic	Diaphragm	Centrifugal
Light Weight	0	0	1	1	-1
Affordable	0	-1	1	0	-1
Good flow rate	1	1	-1	-1	-1
Durability	1	1	0	0	1
Aesthetically Pleasing	0	0	1	1	0
Easy to Use	0	-1	1	-1	-1
Safety	0	1	-1	1	1
Efficiency	1	1	0	-1	-1
Time to Start	0	-1	1	1	-1
Manufacturability	1	0	1	0	-1
Sum	4	1	4	1	-5

Explanations of ratings:

- Piston: A classic pump design that uses fluid displacement in a piston cylinder configuration to move water
    - Light Weight: depends upon design
    - Affordable: not particularly affordable or expensive
    - Good flow rate: a tried and true design that has proven to have good flow rates if designed well
    - Durability: all of the parts and materials are fatigue resistant
    - Aesthetically Pleasing: nothing special about the piston
    - Easy to Use: nothing particularly easy or complicated about the piston pump
    - Safety: could get hurt but nothing makes it especially easy

    - Efficiency: No parts that are especially bulky, minimal unnecessary material
    - Time to start: depends upon design
    - Manufacturability: all the pats to the piston pump are relatively simple to machine.
- Rotary: A design that uses the input power to move water via a rotating mechanism (does not transform the power into linear motion)
    - Light Weight: depends upon design
    - Affordable: many of the parts might need to be made of large pieces of material
    - Good Flow Rate: like the piston pump, rotary pumps have been proven to pump a lot of water
    - Durability: all of the parts and materials are fatigue resistant
    - Aesthetically pleasing: any interesting portions will be enclosed
    - Easy to Use: some of the parts are complicated
    - Safety: moving parts are almost entirely internal
    - Efficiency: no unproductive movement or forces
    - Time to start: might not make a good vacuum to start
    - Manufacturability: parts could be complicated but not particularly so
- Peristaltic: A design that compresses tubing containing water and then moves that point of compression to pump the water through the tube.
    - Light Weight: relatively few parts
    - Affordable: relatively few parts
    - Good Flow Rate: poor flow rate according to research
    - Durability: tubing could wear, but not in the time frame of this project
    - Aesthetically pleasing: one of two pumps with a interesting, visible, feature
    - Easy to Use: relatively simple design
    - Safety: places to easily get your hand caught
    - Efficiency: light weight but also low flow
    - Time to start: pumps online were self starting
    - Manufacturability: relatively few parts
- Diaphragm: A design that uses the same principle of our lungs, bending a flexible membrane and check valves, to move water.
    - Light Weight: relatively few parts
    - Affordable: relatively few parts but membrane might be expensive
    - Good Flow Rate: it seems like the allowable dimensions isn't optimal for the diaphragm
    - Durability: membrane could wear, but not in the time frame of this project
    - Aesthetically pleasing: one of two pumps with a interesting, visible, feature
    - Easy to use: we do not have enough information about the diaphragm pump
    - Safety: no parts that could easily catch a hand
    - Efficiency: flow rates were low from research
    - Time to Start: pumps online were self starting
    - Manufacturability: membrane could be hard to deal with but there are few other parts.
- Centrifugal: Uses a spinning piece that accelerates water and throws it out of the pump

- Light Weight: The central spinning portion is unnecessarily bulky
- Affordable: many of the parts are large and not good uses of expensive material
- Good Flow Rate: flow rates were poor from research
- Durability: the bulky parts are probably durable
- Aesthetically pleasing: the cool part is internal
- Easy to use: we do not have enough information about the centrifugal pump
- Safety: no parts that could easily catch a hand
- Efficiency: the method of pumping is really inefficient
- Time to Start: not self starting
- Manufacturability: strange, complicated parts

From this Preliminary Pugh matrix, we have narrowed our types of pumps down to 3 types:

- Piston (4)
- Peristaltic (4)
- Rotary (1)

Morphological Charts

Once we decided upon three possible types of water pumps, we used morphological charts in order to analyze various designs within the three types of pistons. These morphological charts enabled us to generate ideas and analyze pump function in an organized and systematic manner, and thus helped us come to further conclusions about the feasibility and efficiency of each design. We found it to be most useful if we created a morph chart for each type of pump, and then to reevaluate each design and select the most promising three designs to pursue further.

Image 2: Peristaltic Pump Morph Chart

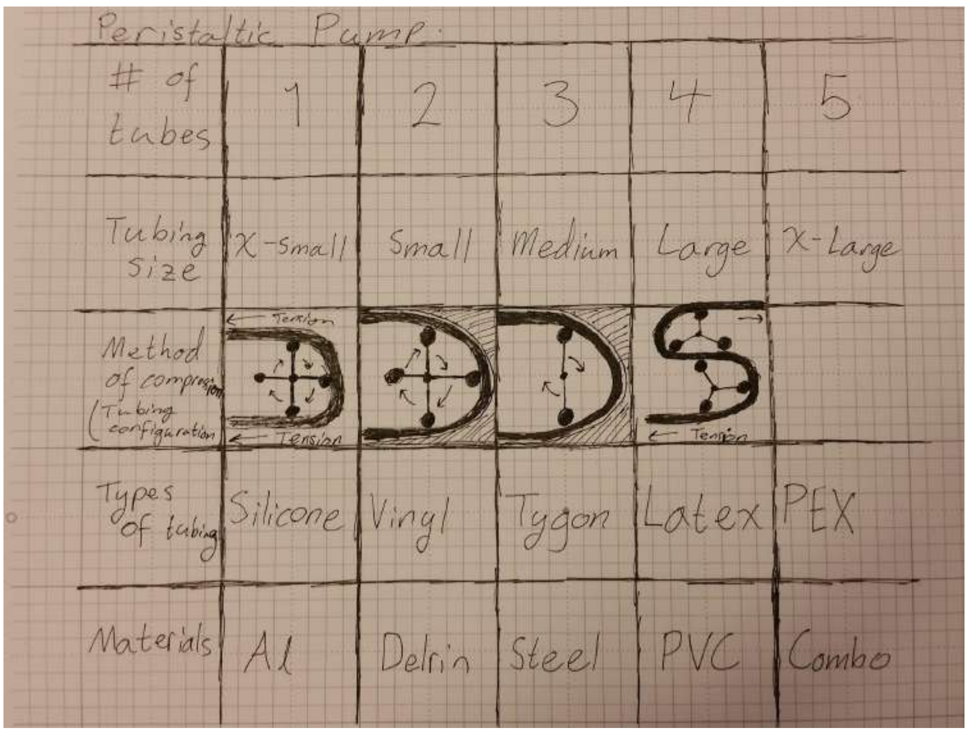


Image 3: Piston Morph Chart

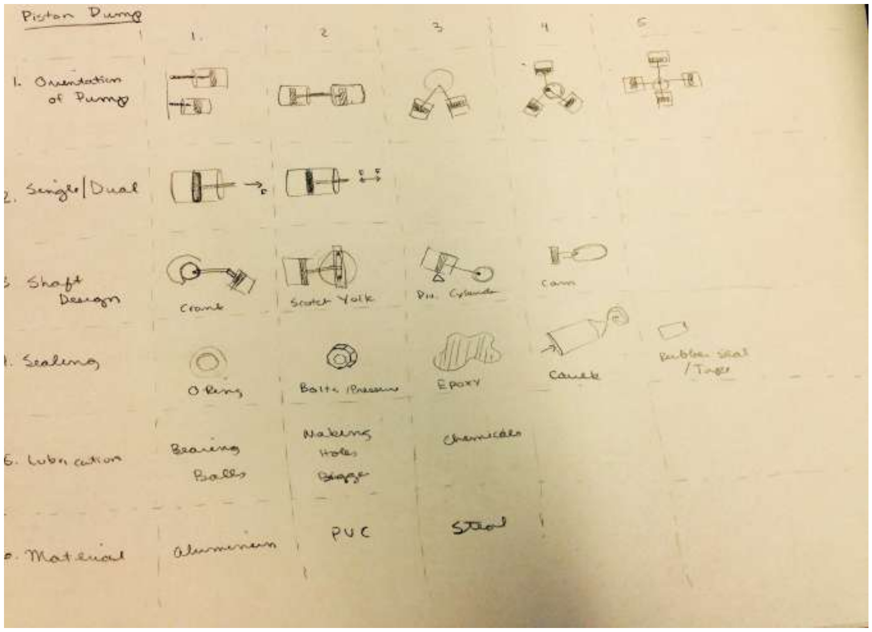
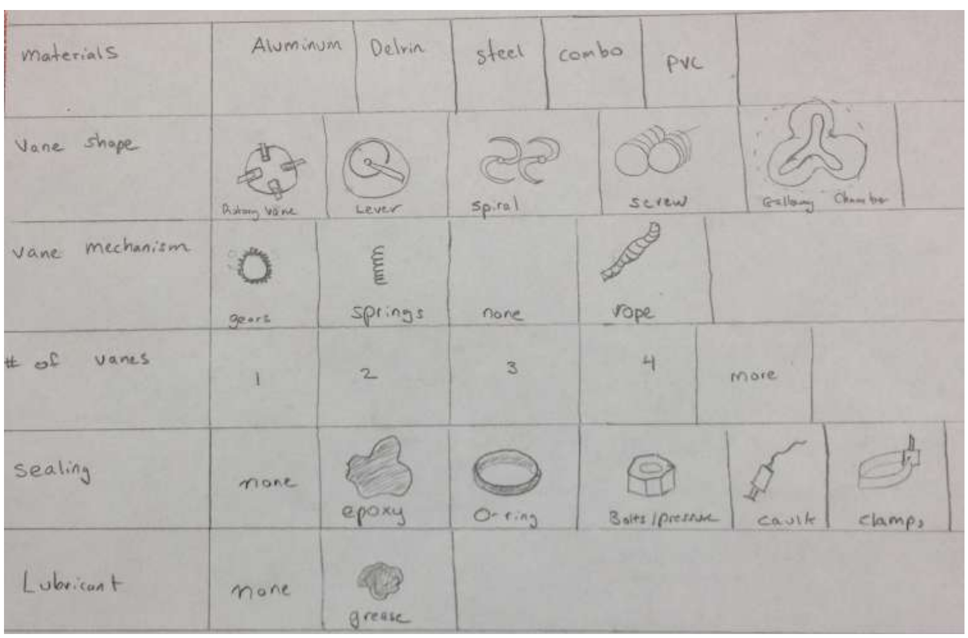


Image 4: Rotary Morph Chart



After looking at the Morphological Charts, we decided to select these three pump designs to explore:

A peristaltic pump: Tension, 3+ tubes, medium tubes, Latex, Aluminum

We decided to explore this design because we believed that this design would be the most functional peristaltic pump that we could design while still maintaining ease of machining and building. The latex tubing would allow for a larger flow rate in comparison to less flexible tubing material.

Single Piston: Single Action, Crank, Stock From emerson, Aluminum and Delrin, Epoxy/Caulk as needed, Bolt and Tension, Ball Bearing

We decided to pursue this design because of its overall ease of machining and simplicity of design. With a single action piston pump, we would able to machine our parts without worrying about issues that may arise with a dual acting pump.

Double Piston: Single Action, linear, scotch yoke, bolts/pressure, epoxy as needed, Ball Bearings, Aluminum and Delrin.

Again, we decided on this pump for its machinability. Using a scotch yoke rather than a crank shaft would allow for stabilization of the pistons as they moved within their cylinder. Ball bearings would be used to prevent friction within the assembly.

Detailed Description of Pumps:

1. **A Peristaltic Pump**: Peristaltic literally means “contracting around”, and that is exactly how this pump works. The drive shaft goes through the center of two triangular plates which constrains three bars in between the plates, each at the vertices of the triangle. A series of tubes are stretched across the bars such that the tubes are held in tension and compressed at the point of contact with the bars. As the tube rotates it moves the position of the seal and pushes the water through the tube.

Image 5: Peristaltic Pump Sketch

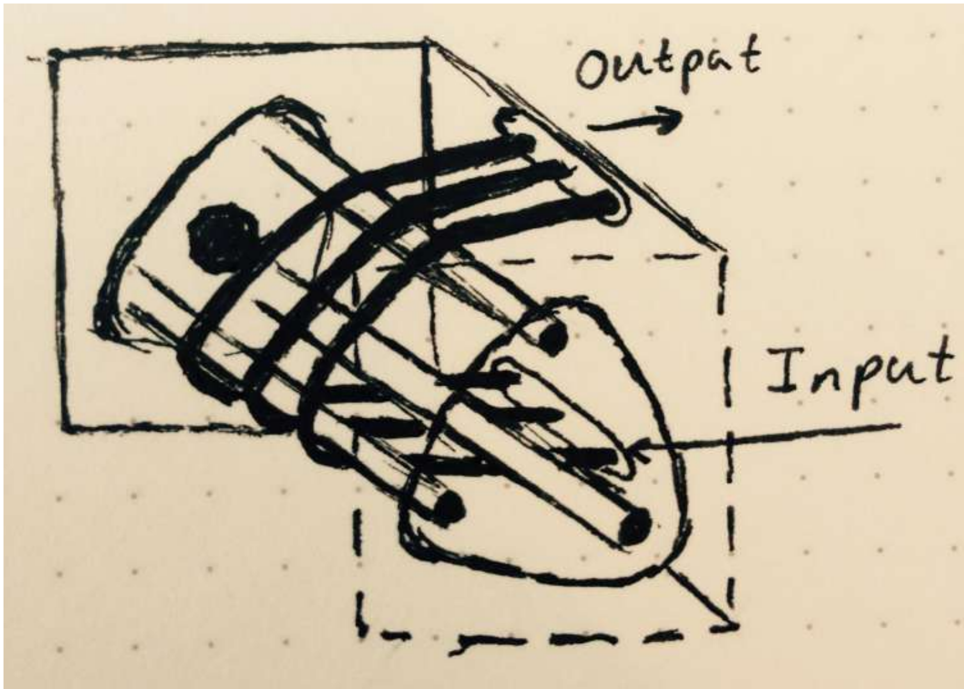
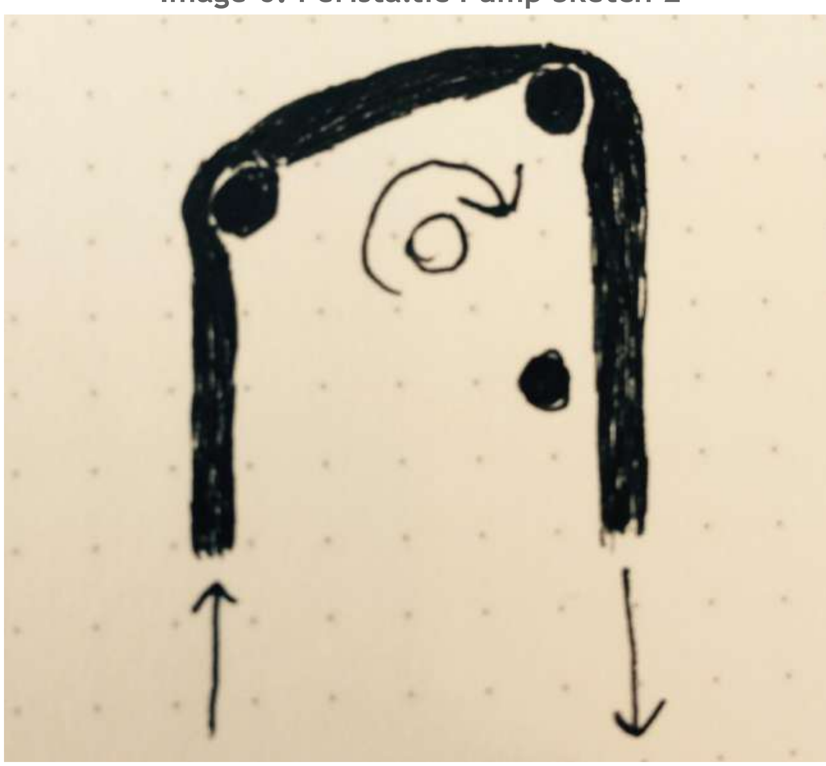
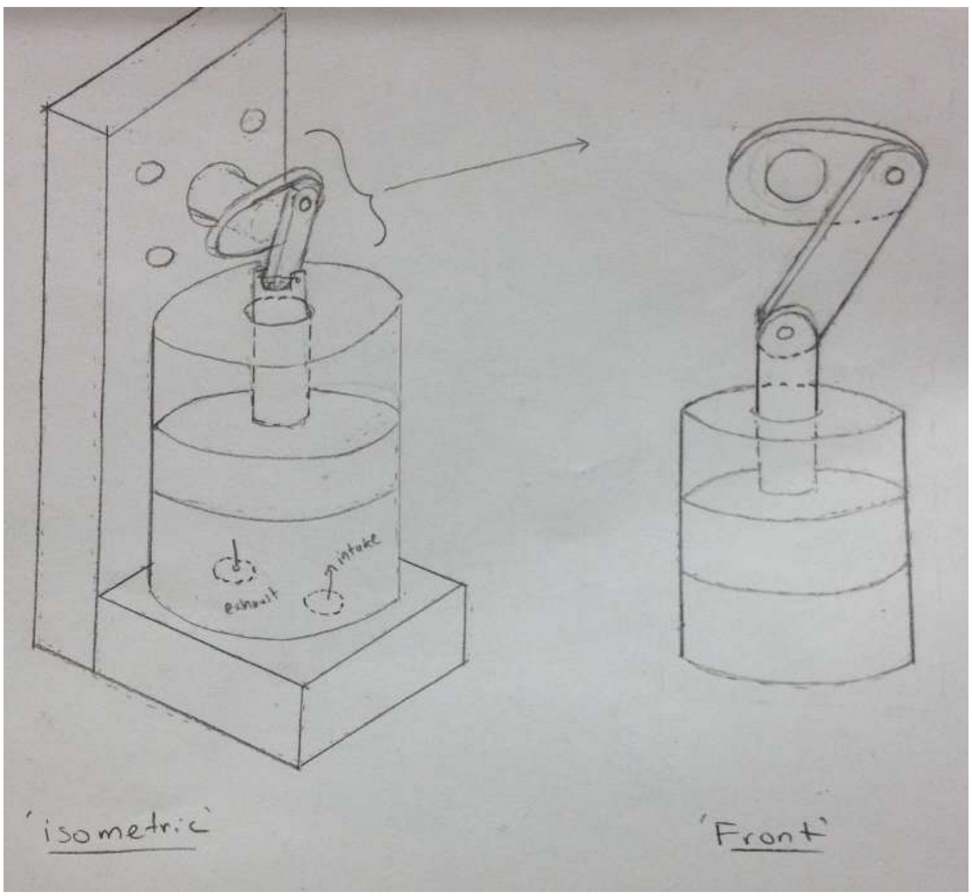


Image 6: Peristaltic Pump Sketch 2



2. **A Single Piston Pump**: The single piston pump is a design with a single piston moving in a linear motion. The motor will be attached by a rod to a crank that will cause rotation about the rod. This rotation will enable the crank to send the lever arm in a circular motion, which will in turn cause the piston to move linearly through the cylinder. Water will be pumped in through the bottom of the cylinder.

Image 7: Single Piston Sketch



3. **A Double Piston Pump**: The design is made with two pistons attached to a scotch in the center of the base. The motor will be attached to a rod that extends from the center of the scotch yoke, through the base, and into the motor. Powered by the motor, the rod will cause the scotch yoke to rotate in a clockwise direction which will cause the scotch yoke to rotate as well. As the scotch yoke turns, the pistons will move in an “out of sync” linear motion inside of its respective cylinder respectively. As the water is pumped

through each cylinder, the motion of the pistons will cause the water to be pumped rapidly through each cylinder.

Image 8: Double Piston Pump Sketch

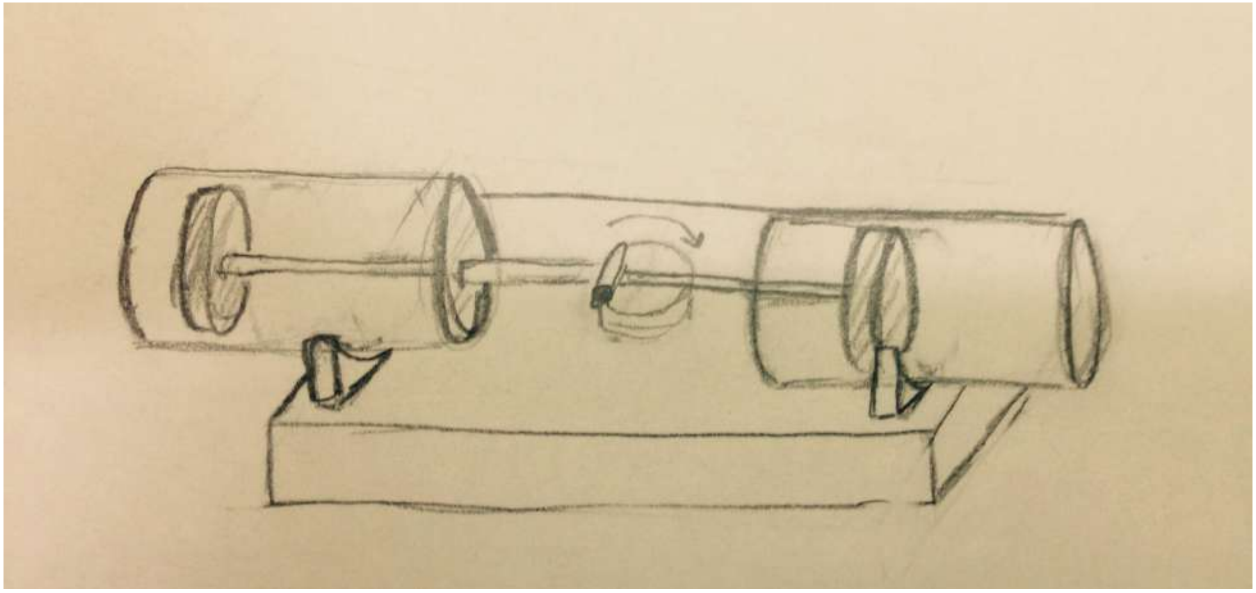
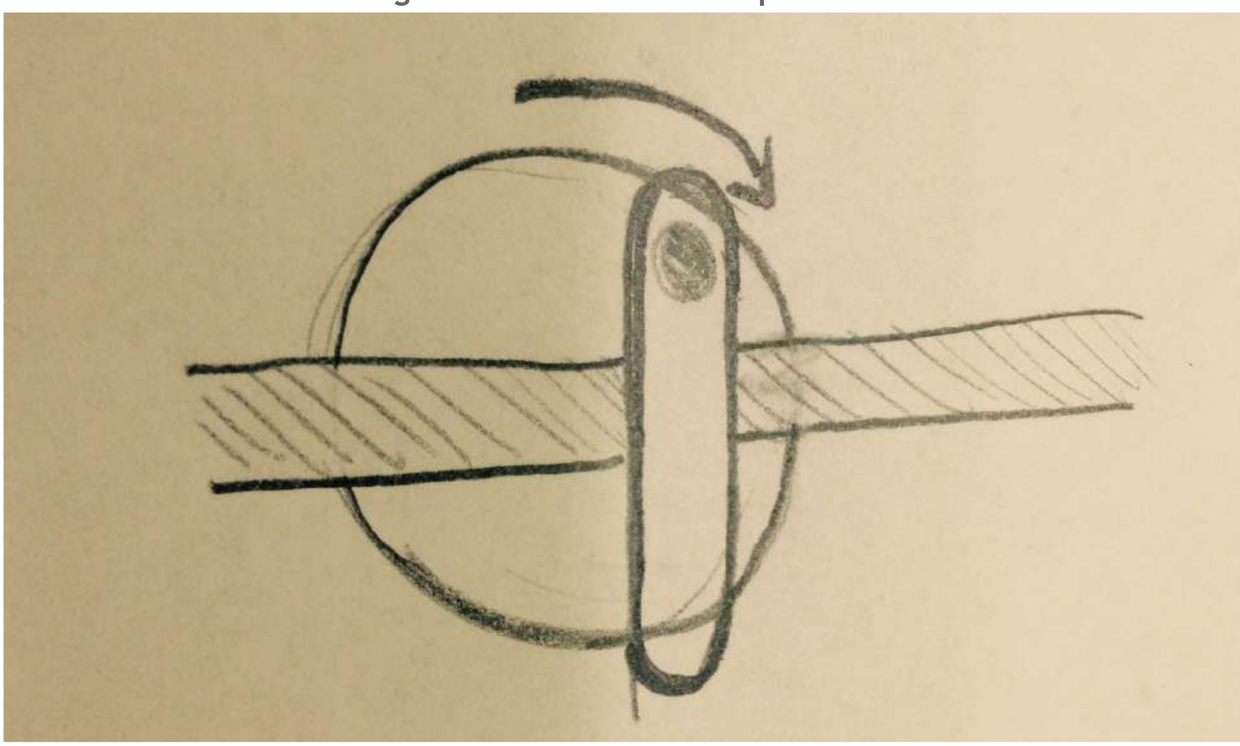


Image 9: Double Piston Pump Sketch 2



Section 4: Design Process

Once we decided upon three promising types of pumps, it was time to choose a final type of pump and begin designing our product. In order to choose a final design, we created a more involved pugh decision matrix of our three pump types included a weighting system representing how we value the various pump criteria.

Table 5: Second Round Pugh Decision Matrix

Criteria	Weight	Piston	Rotary	Peristaltic
Light Weight	3	0	0	1
Affordable	4	0	-1	1
Good flow rate	5	1	1	-1
Durability	1	1	1	0
Aesthetically Pleasing	2	0	0	1
Easy to Use	2	0	-1	1
Safety	3	0	1	-1
Efficiency	5	1	1	0
Time to Start	4	0	-1	1
Manufacturability	5	1	0	1
Sum		**4**	**1**	**4**
Weighted Sum		**16**	**4**	**12**

This second Pugh Decision Matrix confirmed our belief in the piston pump and we decided upon a single, double acting piston as our pump type. We came to this conclusion by heavily valuing a good flow rate, manufacturability of the design, and efficiency of the pump. With these factors in mind, we found that a single piston pump would be the easiest to manufacture, and making it double acting would give us a better flow rate and better efficiency.

Section: Design Iterations

Below are a series of photos of our CAD model designs and respective drawings of individual pieces.

Design One: CDR

Link to animation: https://www.youtube.com/watch?v=BZVz2dSbhgo
Weight: 3.8 lbs

Image 10: CAD Model 1

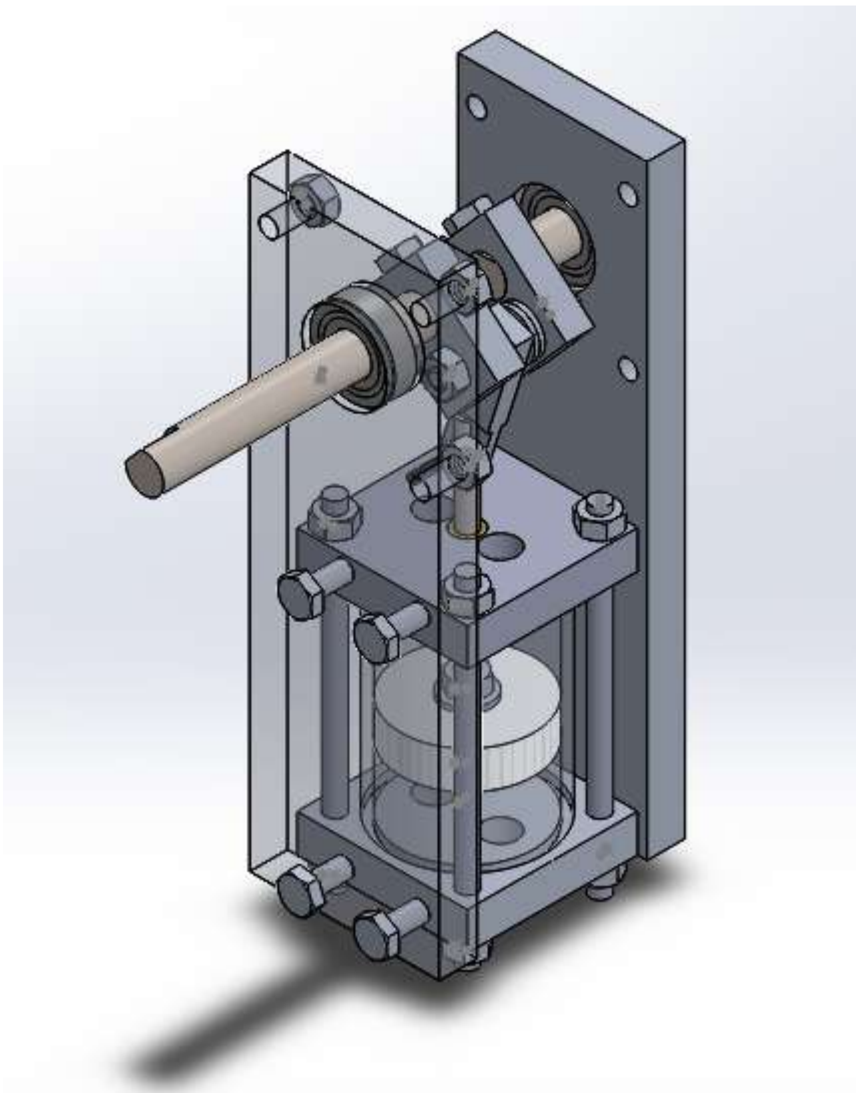


Image 10: A screenshot of our final piston design in an isometric view.

Image 11: CAD Model 2

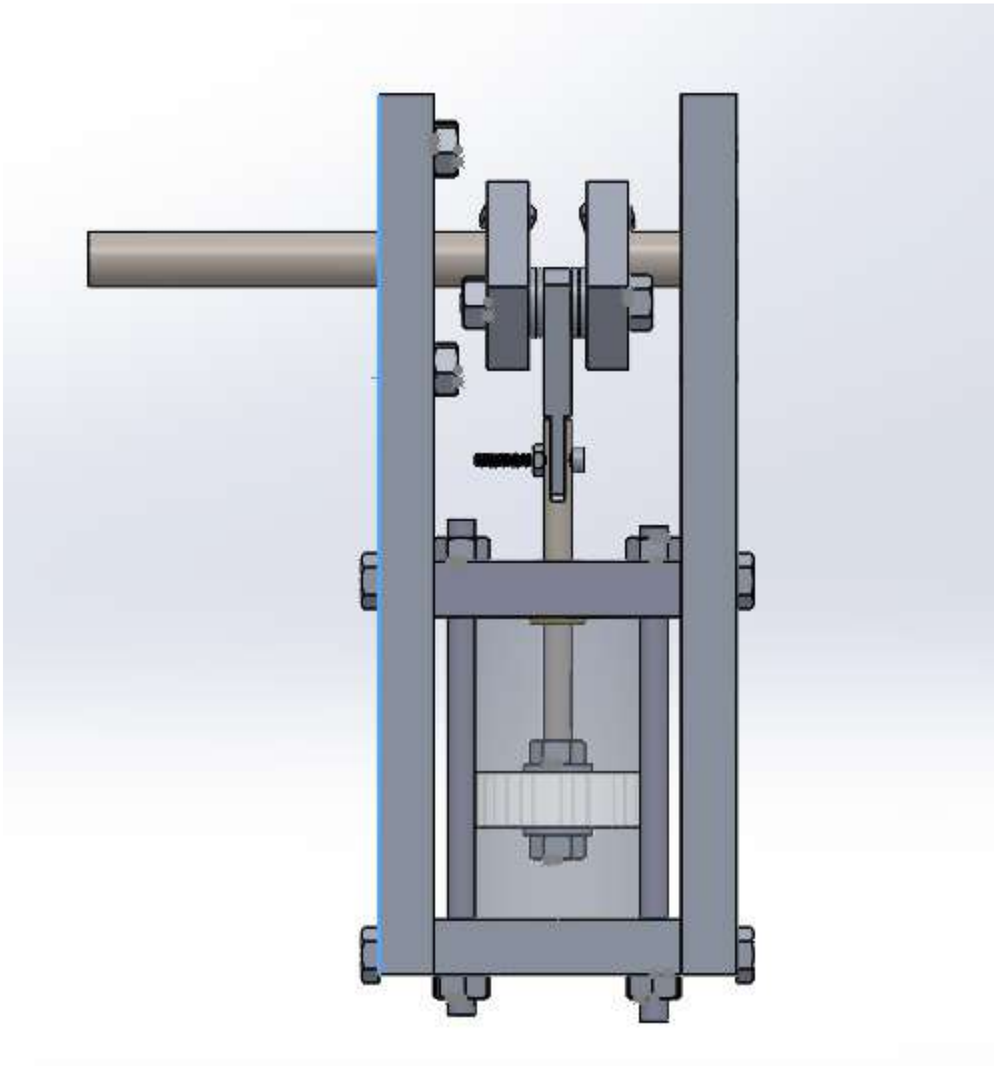
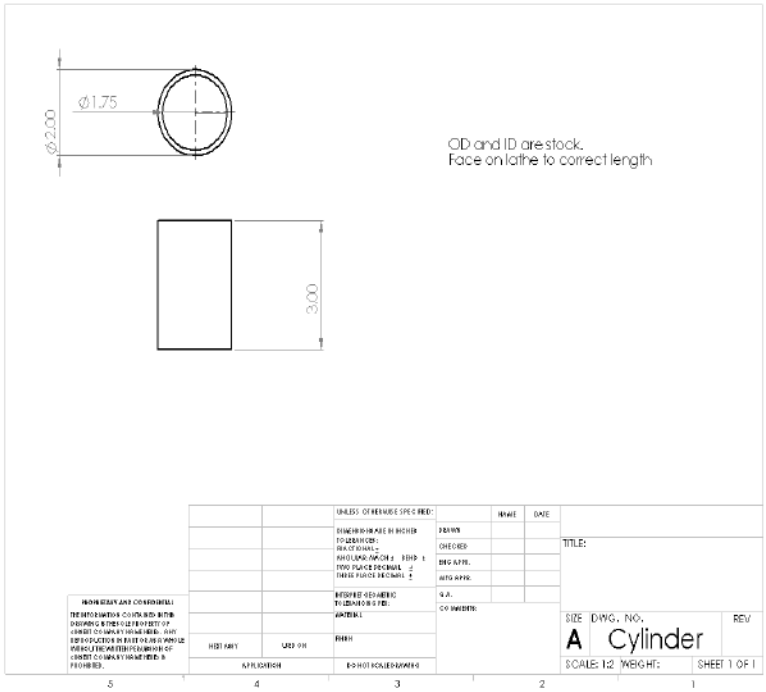


Image 11: screenshot of our design in a side view

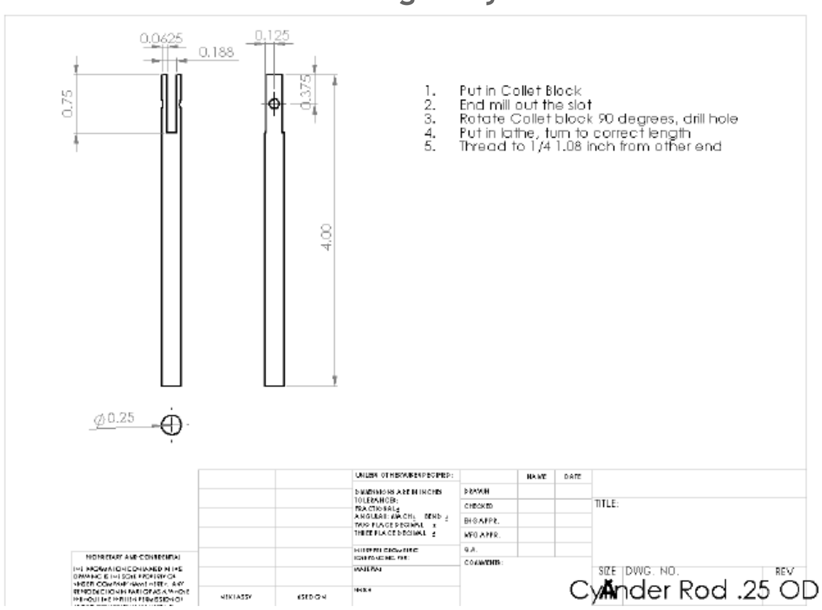
Drawings For Design One:

Drawing 1: Cylinder



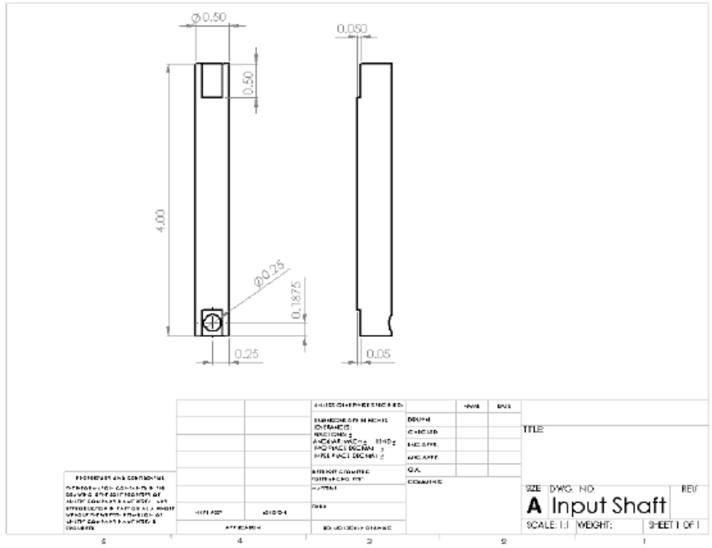
This cylinder is used to contain the water while being pumped. This is where the piston will move up and down to create water flow.

Drawing 2: Cylinder Rod



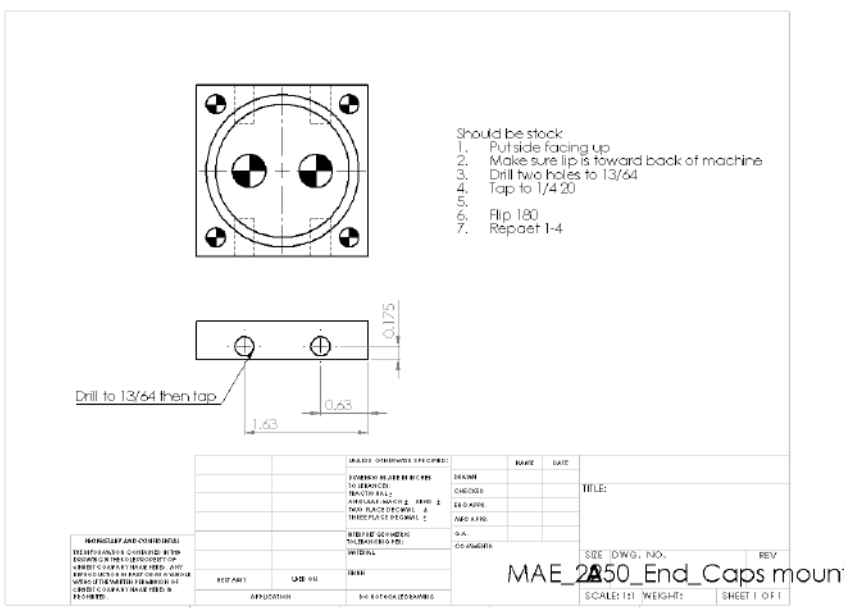
The cylinder rod is attached to the piston and is the final link transferring force from the drive shaft into the water.

Drawing 3: Input Shaft



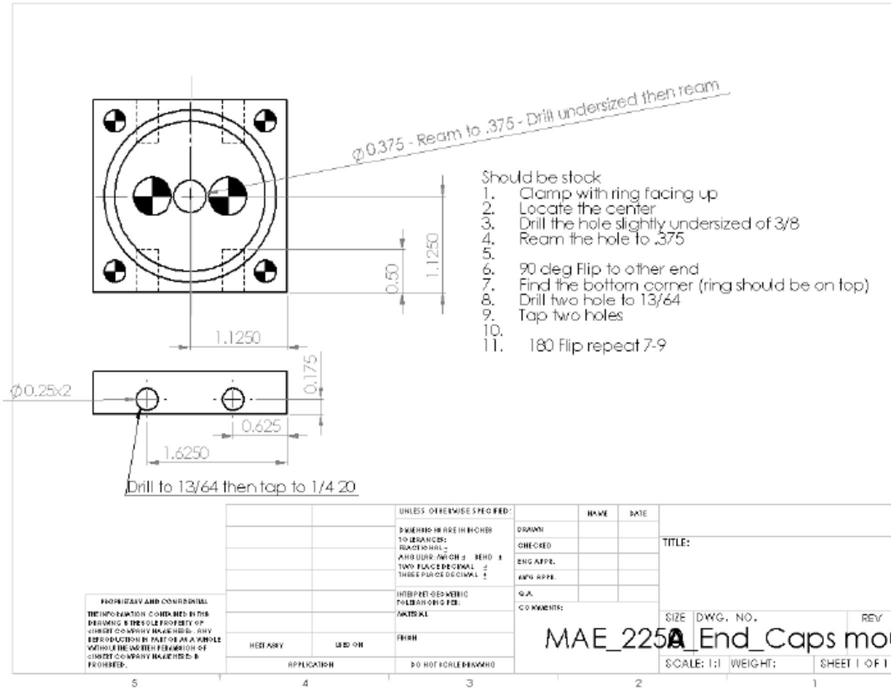
This shaft is attached to the motor that will ultimately cause the piston to move. The other side is attached to the links.

Drawing 4: End Cap Mount



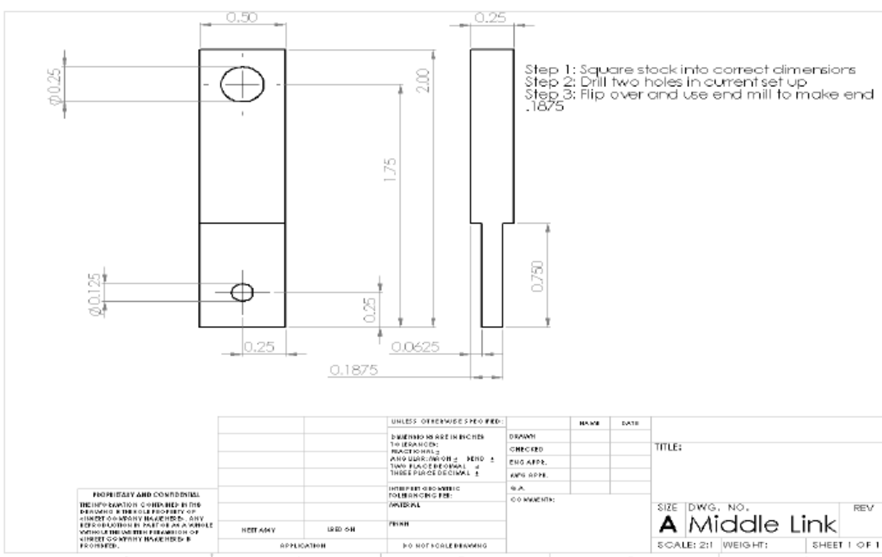
This end cap is attached to the cylinder on the side opposite to the cylinder rod. It directs the water to flow from the input tube and out the output tube.

Drawing 5: End Cap Mount Hole



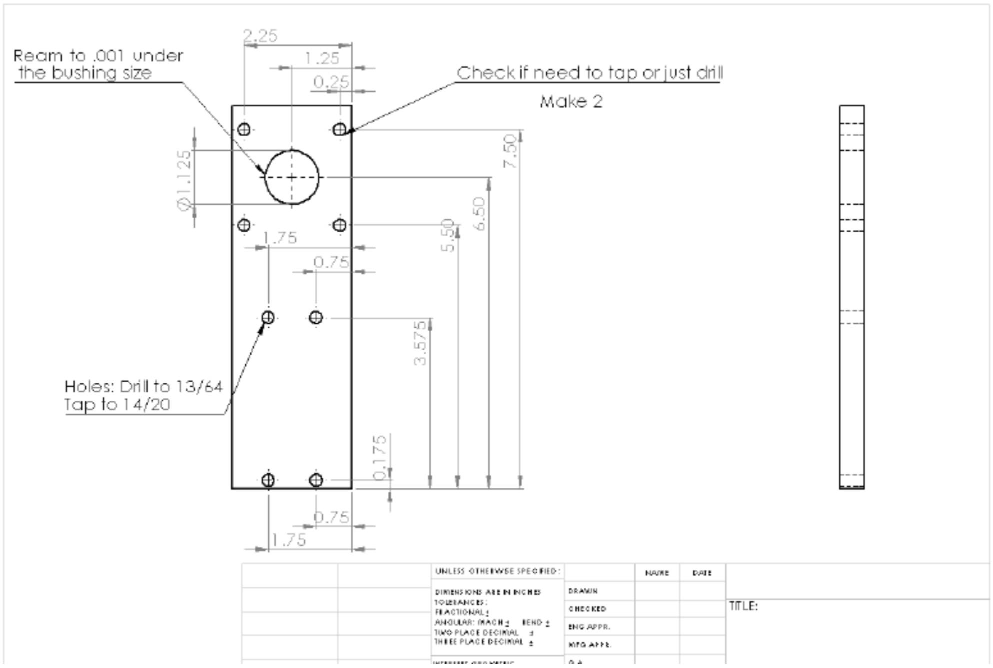
This part is used to hold the piston cylinder and is where the piston rod will be mounted in the center hole. The left and right holes will be where the brass fittings are placed.

Drawing 6: Middle Link



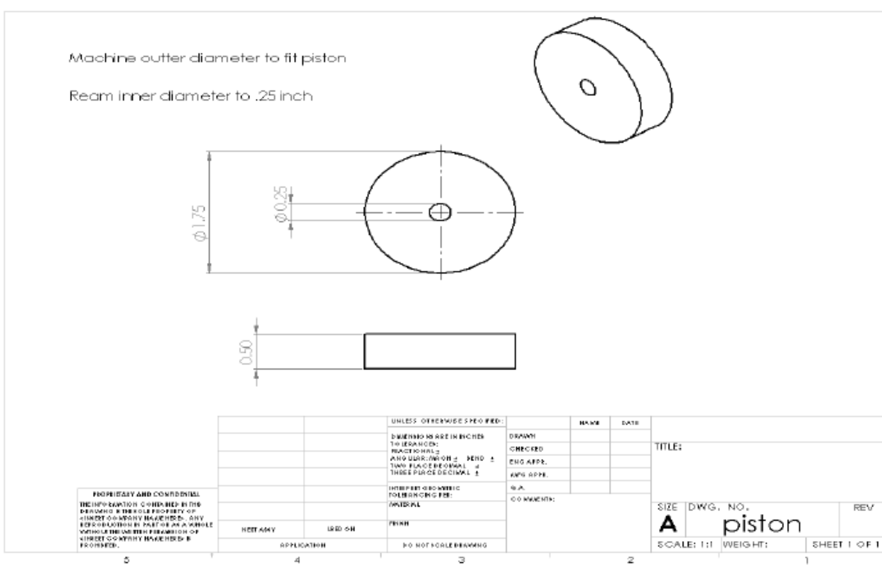
The middle link is an intermediate between the top link (which determines travel length) and the bottom link which attaches to the piston. It’s length determines the direction of force from the top link into the bottom link.

Drawing 7: Mount Plate



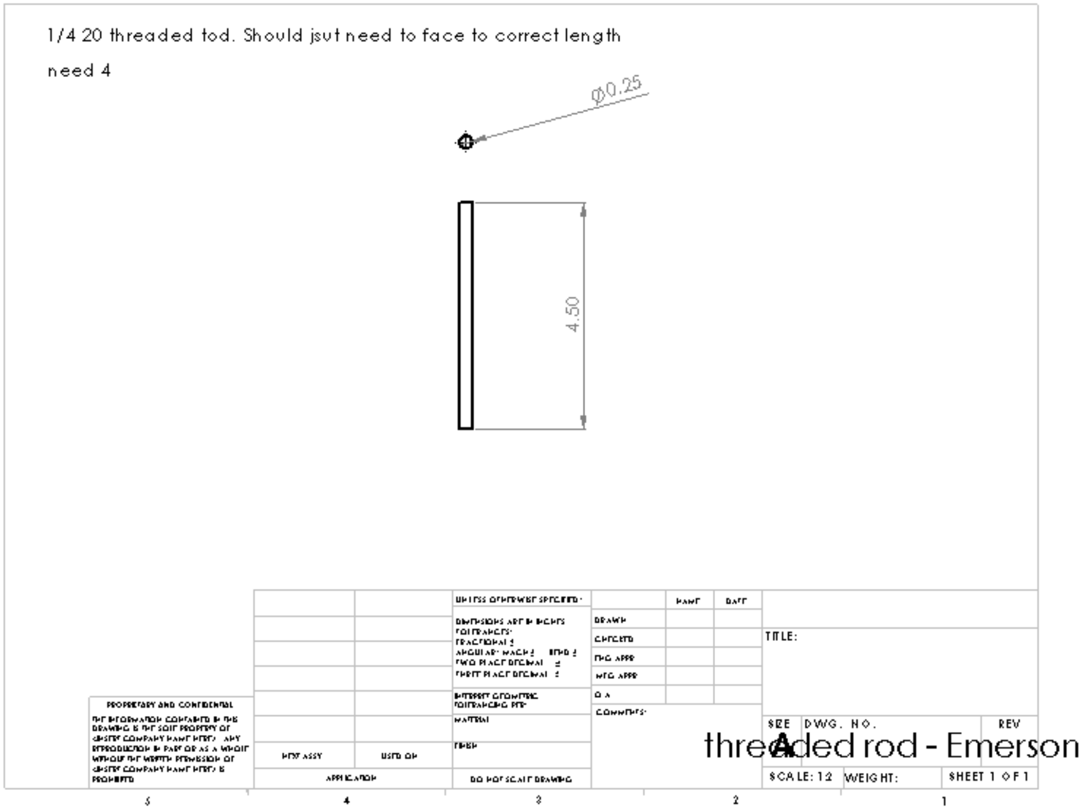
The mount plate will be used to mount the piston assembly to the motor. It will also be used to stabilize the assembly.

Drawing 8: Piston



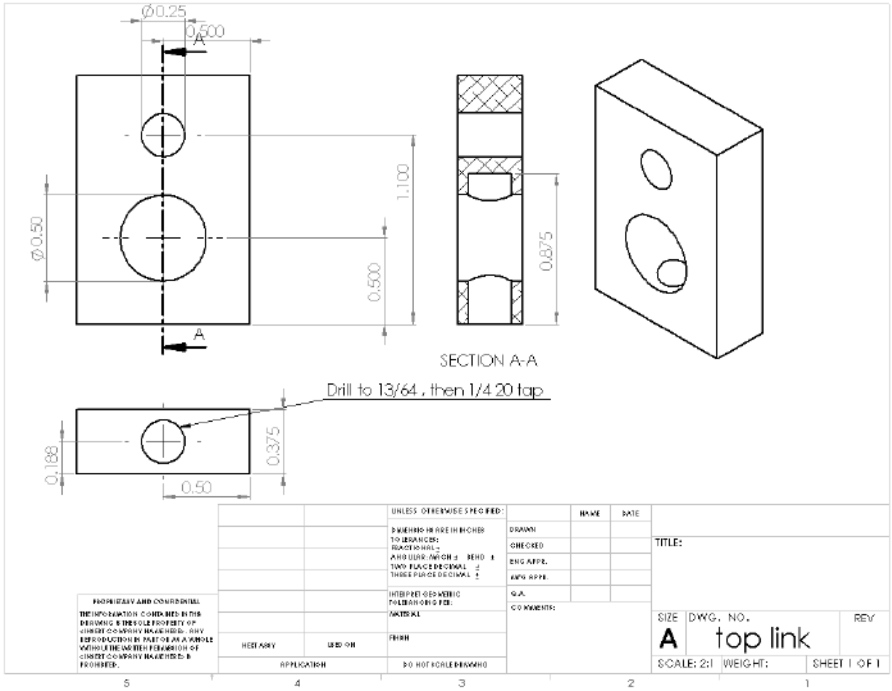
The piston is the part that will push the water through the cylinder to create a dual acting pump. It will be attached to the piston rod, which will induce movement through the piston cylinder.

Drawing 9: Threaded Rod



Four of these surround the main cylinder and apply forces to the endcaps. These provide the force to keep the cylinder pressurized and stop leakage.

Drawing 10: Top Link



The top link is used to connect the middle link to the input shaft which will induce rotation as a result of the motor.

Design One Feedback and Changes:

This section discusses the feedback we received from CDR. It mentions what each item is, and how we addressed that change.

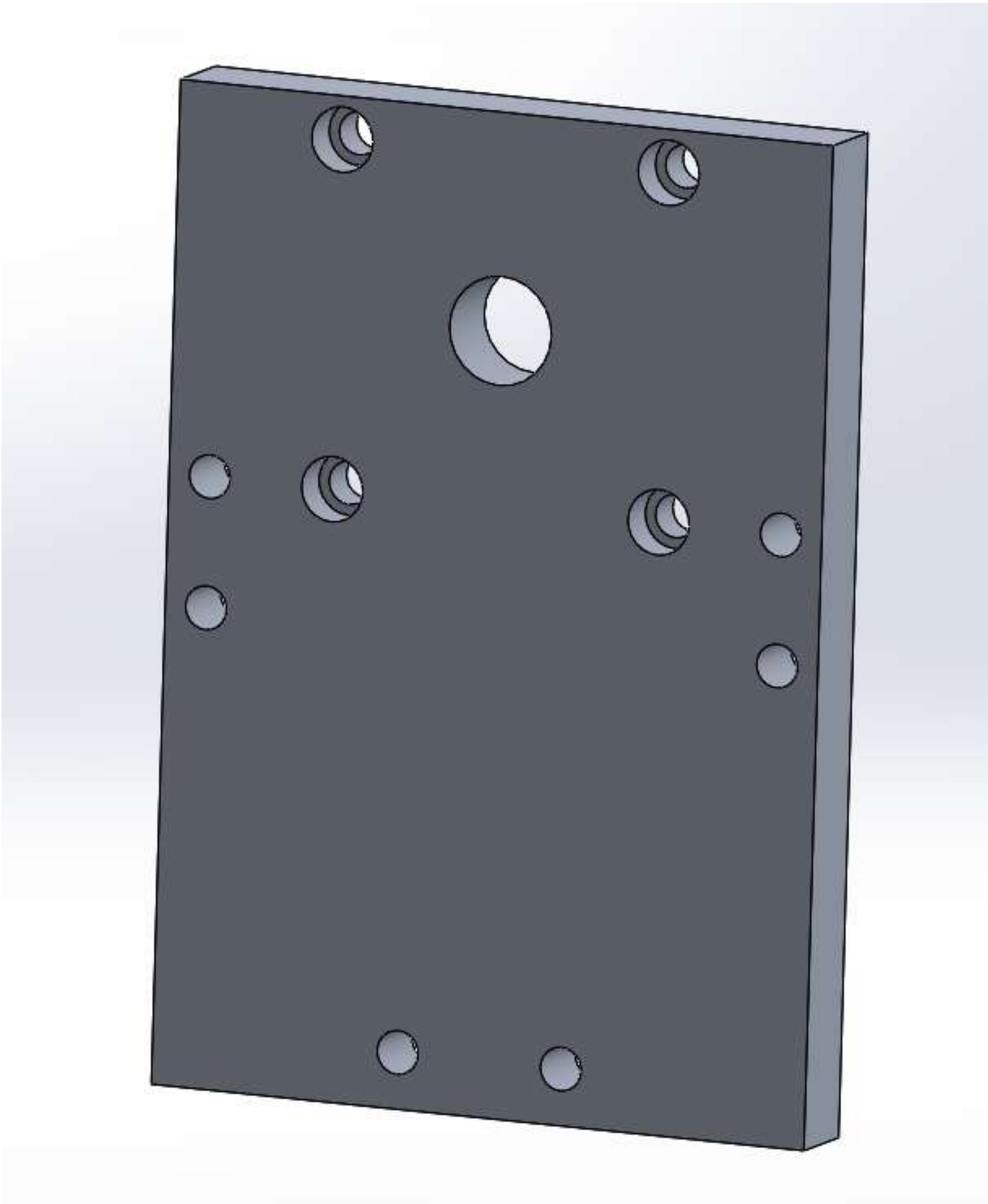
The issues and feedback that were brought up during CDR were:

1. Can the mount holes fit on the mount plate?
2. Can we purchase that much stock and long enough quantities for both plates?
3. Do we need the plates to be that long?
4. Will the piston hit the tubes or the brass fittings?

Feedback 1: Can the mount holes fit on the mount plate?

After looking at the dimensions of the stock and of the hole geometry, we determined we could not fit the holes on the plate. We had to change the back mount plate to be of a wider stock. The below change shows the new mount plate.

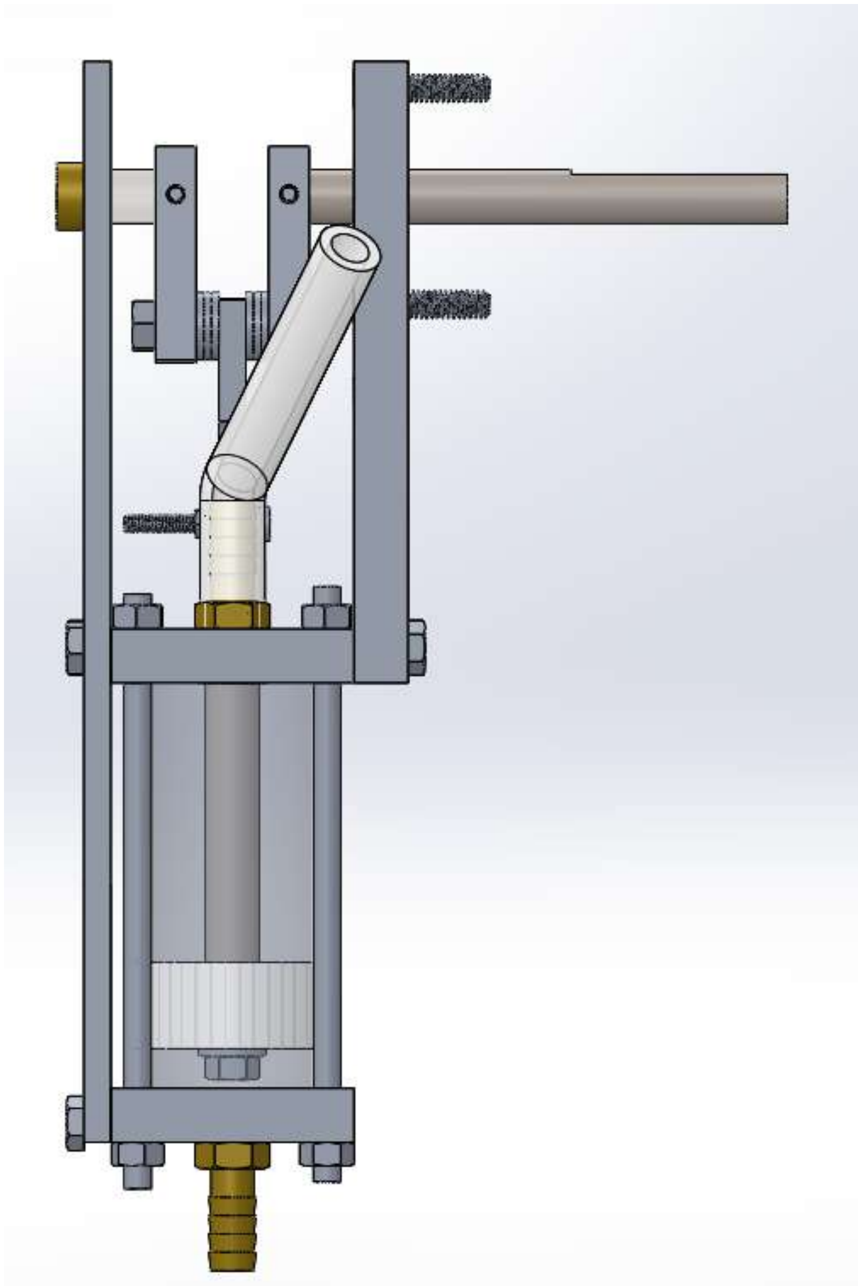
Image: Mount Plate



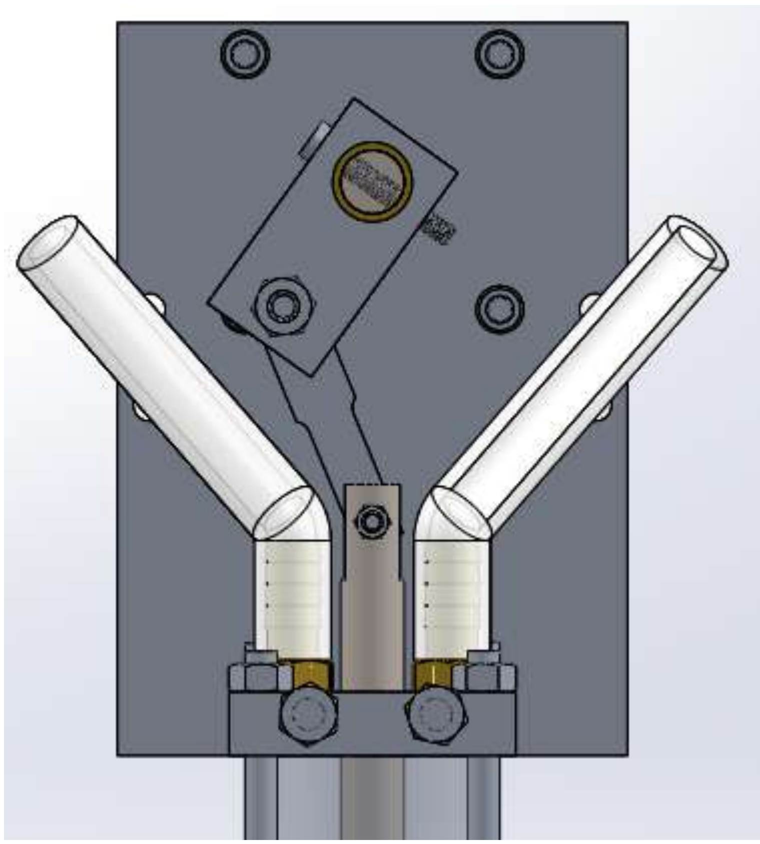
This new mount plate allows for us to mount to the hole geometry, without going over the edge of the stock. This also is much shorter than the previous plate, which addresses the length of stock concern as well.

Feedback 2: Can we purchase that much stock and long enough quantities for both plates?
As shown in the above image, we have reduced the length of the mount plate from 10 inches to 5.5 inches. This allows us to purchase all of the material we need, as well as save weight.

Feedback 3: Do we need the plates to be that long?
As shown and discussed in the addressing of feedback 1 and 2, we have now only mounted the mount plate to the top end cap, instead of both. This greatly shortens the length, cost and weight of our pump.



Feedback 4: Will the piston hit the tubes or the brass fittings?
In order to check to see if tubing would hit piston parts, we checked for interference with the piston assembly. We redesigned our parts in order make sure that there would be complete clearance with all of the parts. Below is a final design of the model with the tubing. Note that there is no interference.



Design Two: Post CDR Model
The below section takes in the above design changes from CDR and shows the full model. Changes from the CDR not mentioned in the above are
1. Stroke length
2. Piston length and Diameter
3. Bronze fittings instead of ball bearings.

Change 1: Stroke Length
In the design section of this report, we decided to optimize the length of our stroke to increase the volume of water pumped, as well as the height to which we pump.

Change 2: Piston length and Diameter
We decided to change the length of the piston head from .5 inches to .8 inches. The reason for this change was because we were afraid of binding up the pump and it breaking. We would

rather it work fairly well, than break and not work at all. Similarly we decided to decrease the diameter of or piston head to be smaller to prevent binding.

Change 3: Bronze fittings instead of ball bearings

We switched our design to have bronze fittings instead of ball bearings in order to minimize cost. We wanted to leave room in our budget for potential machining error. The below model shows the new design with bronze fittings.

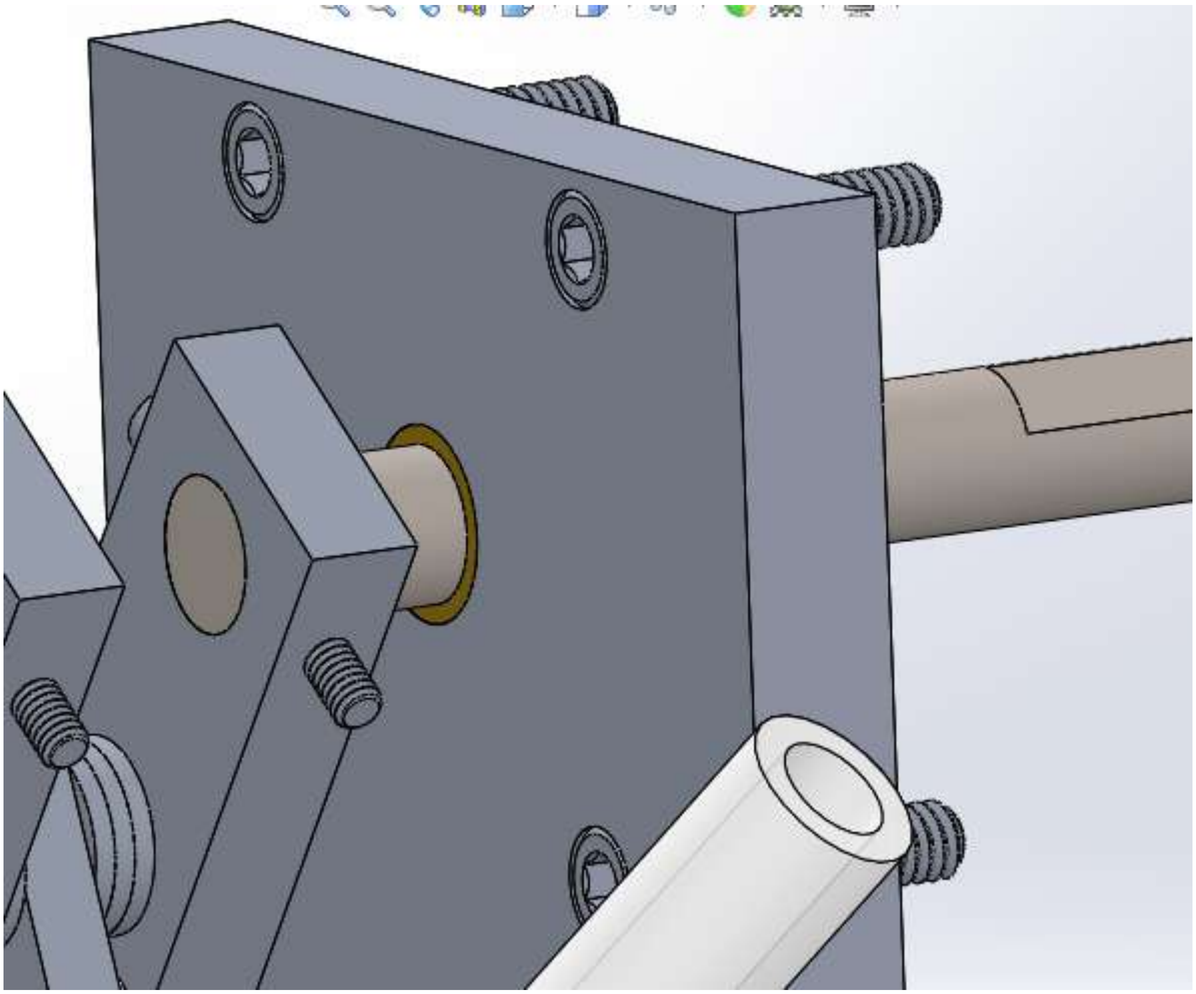


Image 12: Exploded View

Image 13: Exploded Render

Design Three: Prototype Model and More Changes

In the below section, we address the model that we have for the prototype, and several changes from the above Section.
The changes we addressed are:

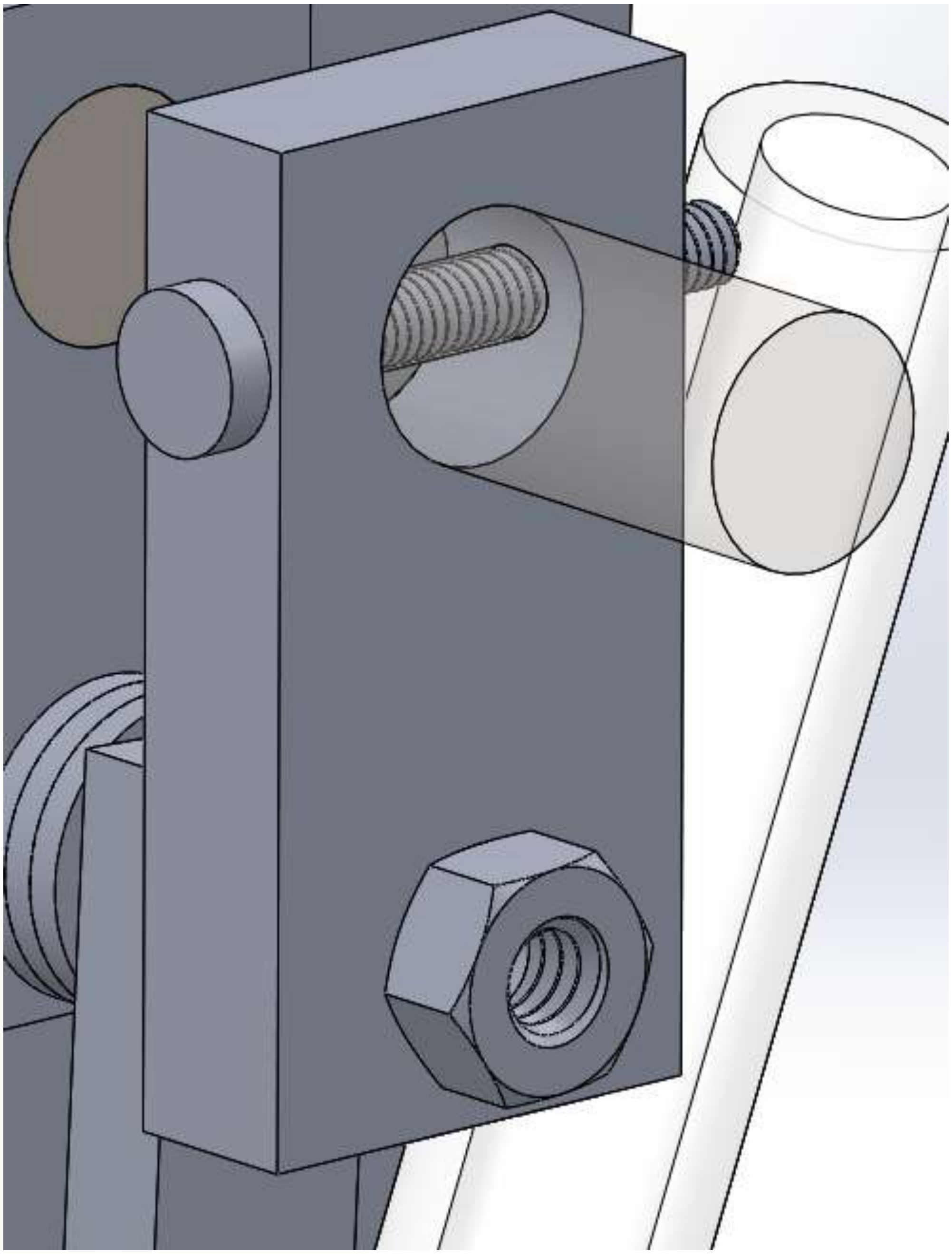
1. New bolt sizes for input shafts, and links
2. New Bolting mechanism for the top links

Change 1: New bolt sizes for input shafts, and links

We spoke to Joe and decided that we should use a new bolt size, 8-32, in our model. This change was in order to reduce issues that may have occurred with our thin top and middle links.

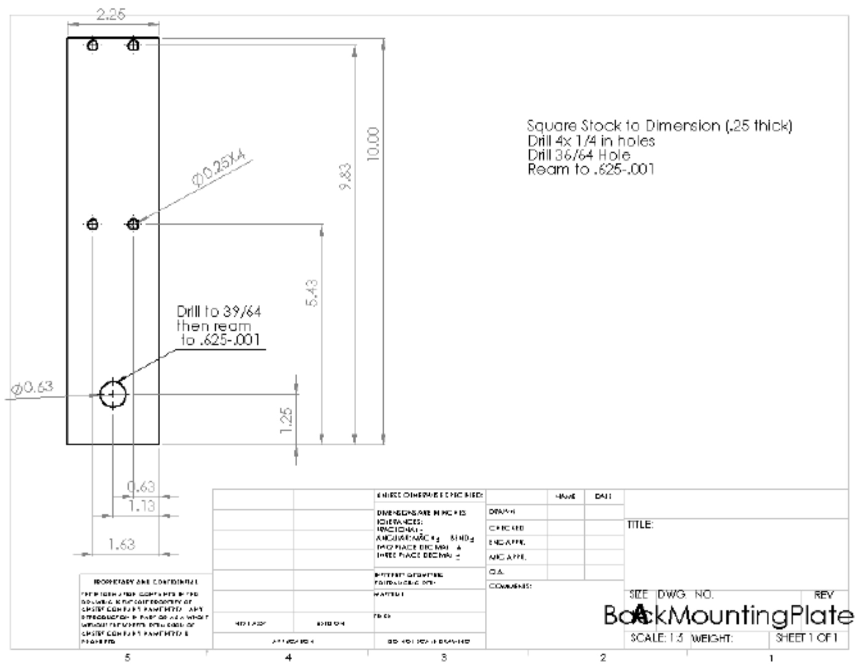
Change 2: New Bolting mechanism for the top links

We decided to change the orientation of the bolts, as reflected in the image below, in order to reduce interference among parts.



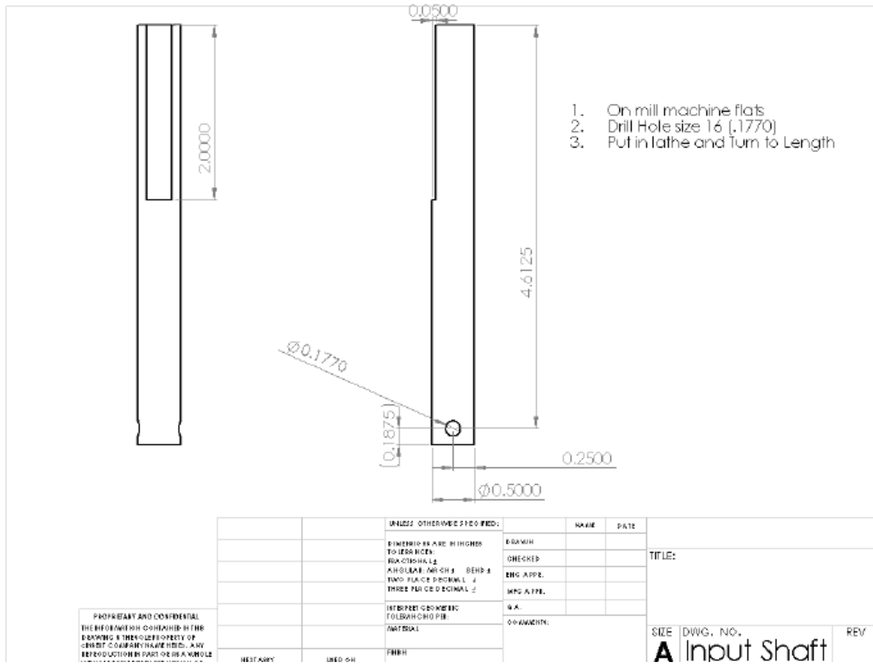
Design 3: Drawings

Image 14: Back Mounting Plate



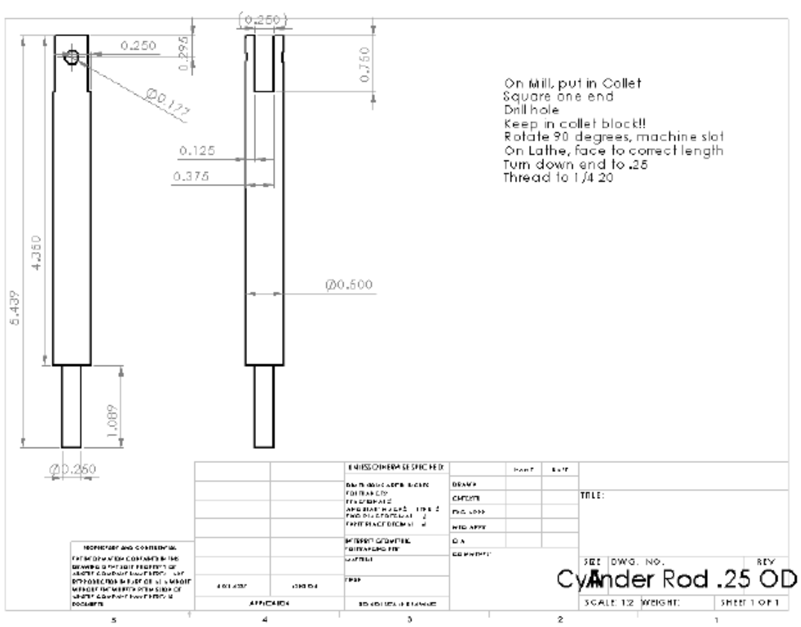
The mount plate will be used to mount the piston assembly to the motor. It will also be used to stabilize the assembly.

Image 15: Input Shaft



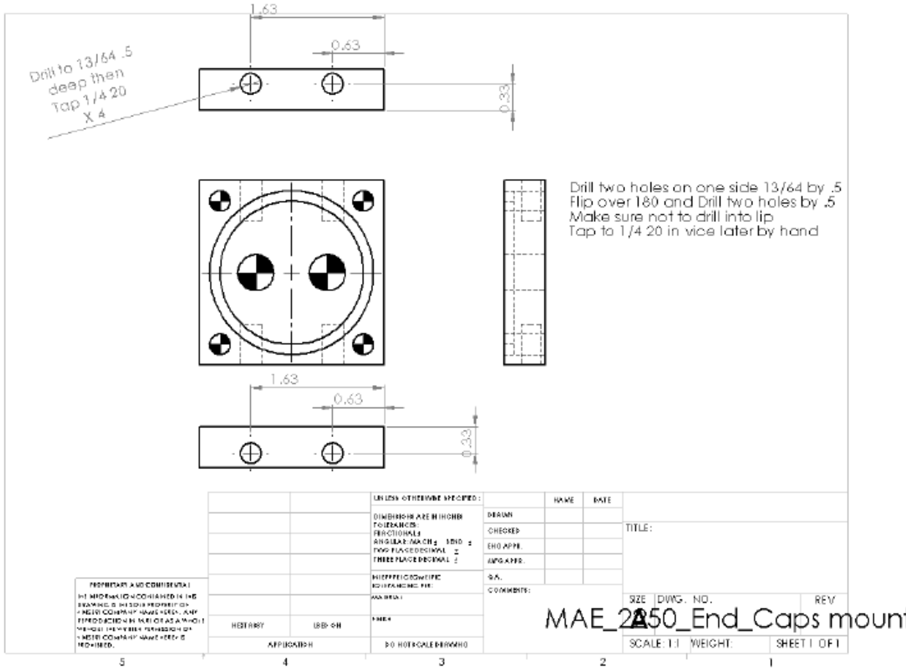
This shaft is attached to the motor that will ultimately cause the piston to move. The other side is attached to the links.

Image 16: Cylinder Rod



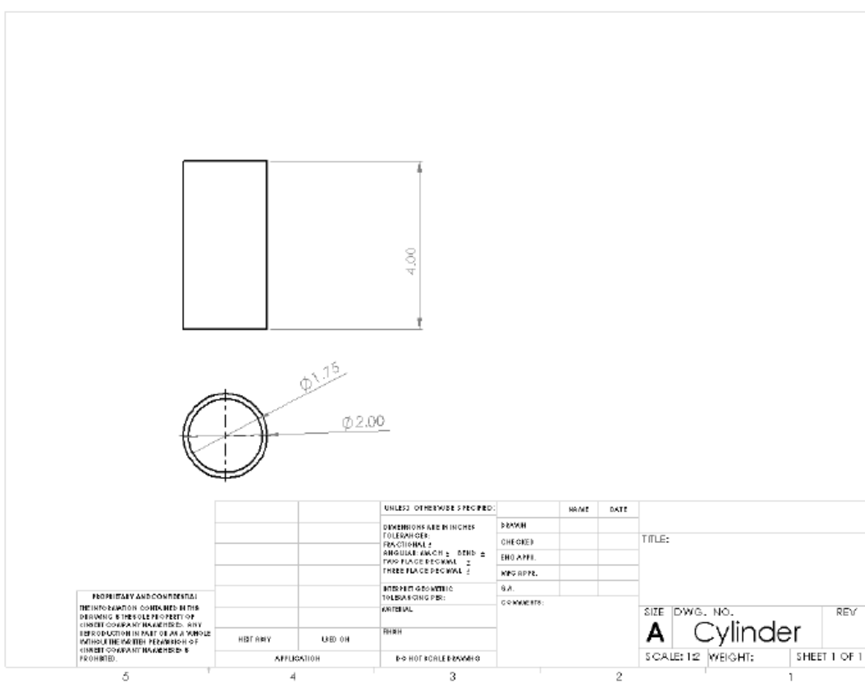
The cylinder rod is attached to the piston and is the final link transferring force from the drive shaft into the water.

Image 17: End Cap



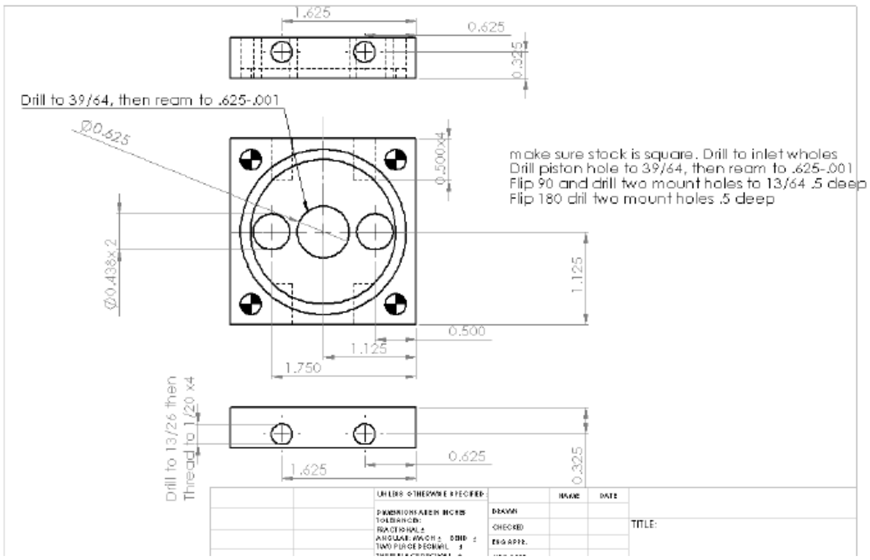
This end cap is attached to the cylinder on the side opposite to the cylinder rod. It directs the water to flow from the input tube and out the output tube.

Image 18: Cylinder



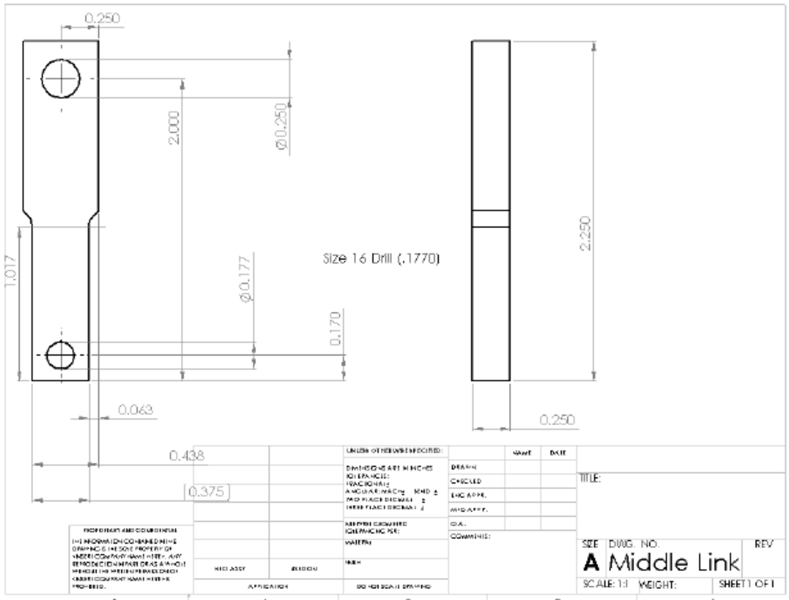
This cylinder is used to contain the water while being pumped. This is where the piston will move up and down to create water flow.

Image 19: Bottom End Cap



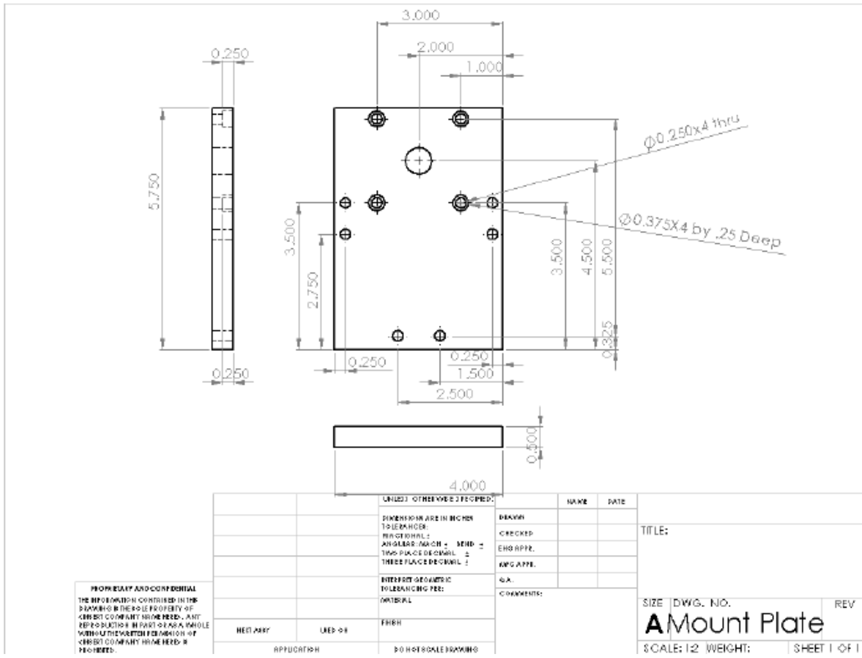
This part is used to hold the piston cylinder and is where the piston rod will be mounted in the center hole. The left and right holes will be where the brass fittings are placed.

Image 20: Middle Link



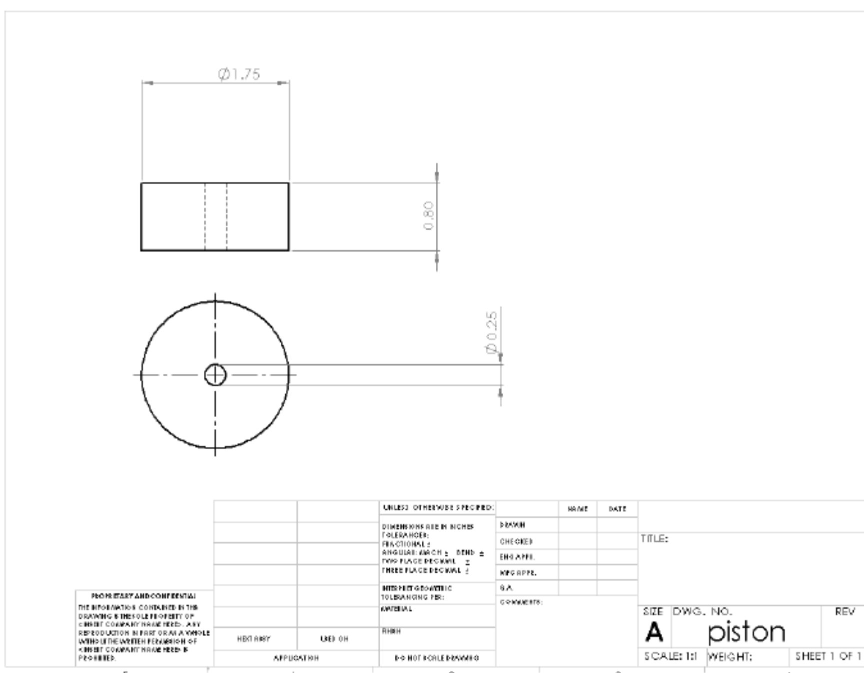
The middle link is an intermediate between the top link (which determines travel length) and the bottom link which attaches to the piston. It's length determines the direction of force from the top link into the bottom link.

Image 21: Mounting Plate



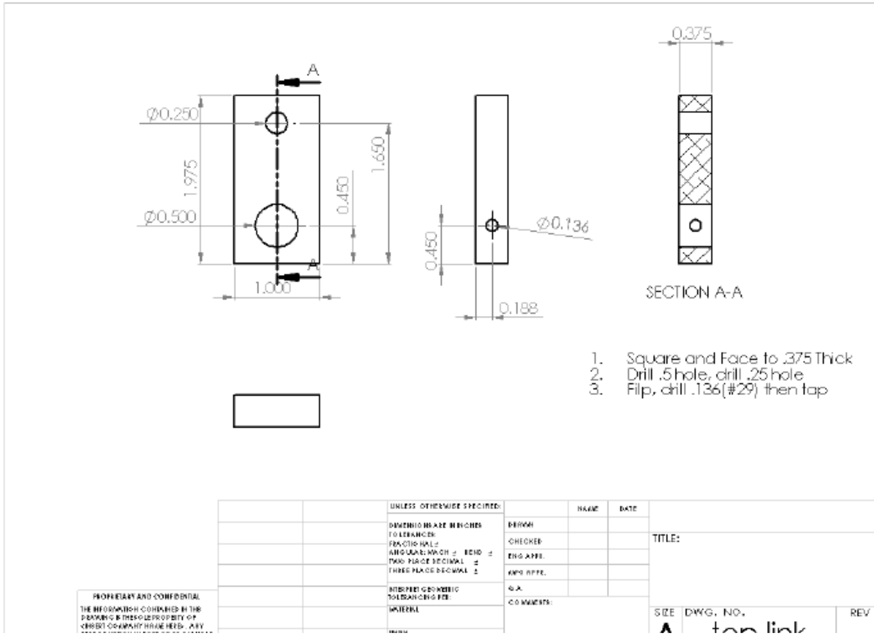
The mount plate will be used to mount the piston assembly to the motor. It will also be used to stabilize the assembly.

Image 22: Piston Head



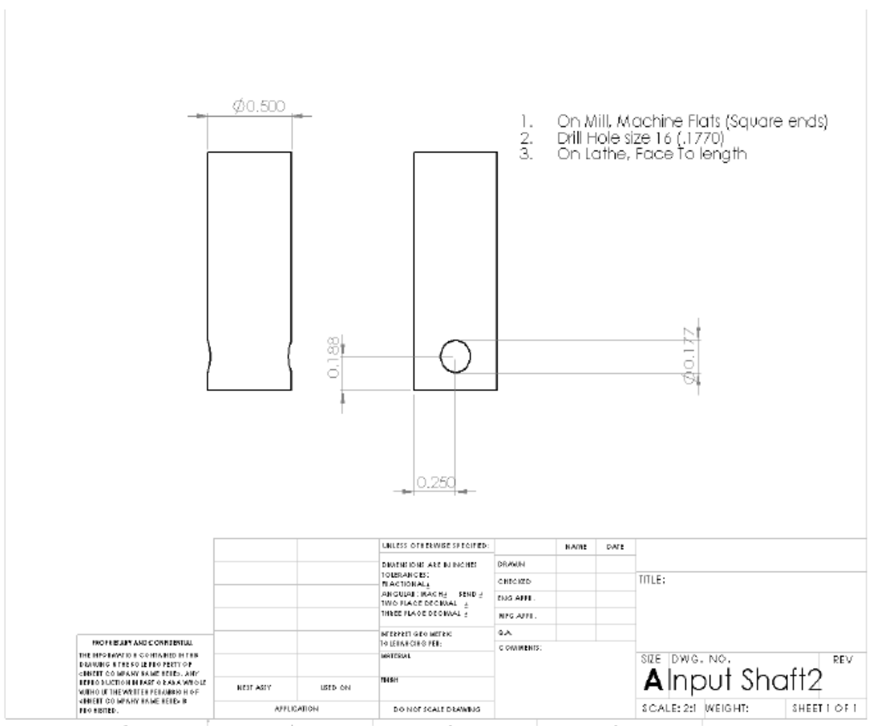
The piston is the part that will push the water through the cylinder to create a dual acting pump. It will be attached to the piston rod, which will induce movement through the piston cylinder.

Image 23: Top Link



The top link is used to connect the middle link to the input shaft which will induce rotation as a result of the motor.

Image 24: Input Shaft Small



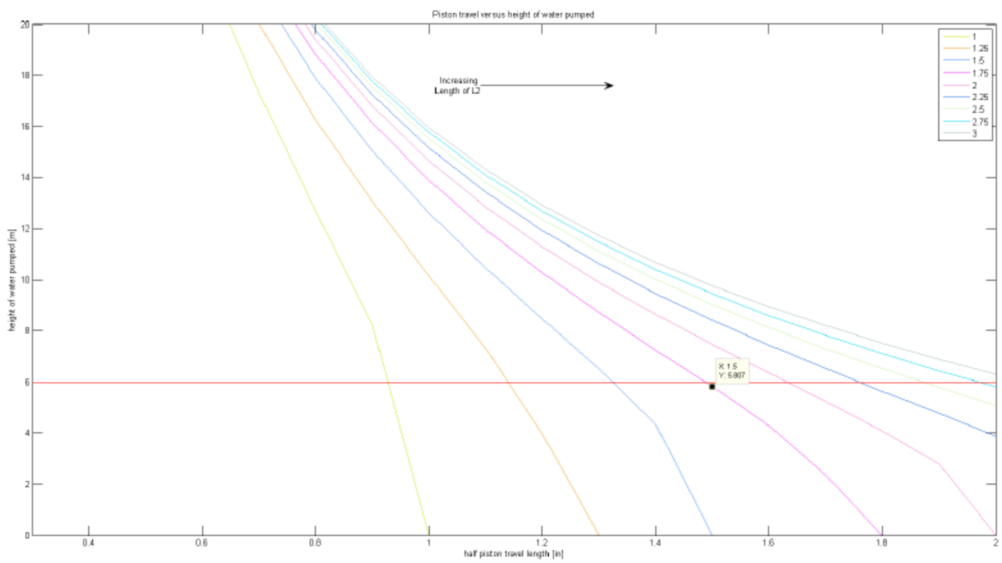
This input shaft is attached to back mount plate in order to stabilize the system as a whole.

Section 5: Analysis of Design

In this section we analyzed the actual pump and its performance. We also looked at ways to optimize the design. The graphs below demonstrate the analysis that we went through in order to find the most functional design for our pump that will output the most water.

Analysis of Height of Water Pumped

Image 25: Pumped Water Height vs. One Half Piston Displacement



The horizontal axes of this graph is the length of the top link, which is half of our travel or displacement length. The vertical axes is the height to which this configuration of link lengths could pump water, this value is derived from analyzing the forces on the pump and the pressure on the water. Each of the colored lines is a function where the middle link length is given a constant value and then plotted over a range of top link lengths. As you can see, increasing the top link length (or travel) always reduces height, but increasing the middle link length allows for a greater range of travel.

Analysis of Force Necessary for Desired Displacement

Image 26: Analysis of Forces and Displacement

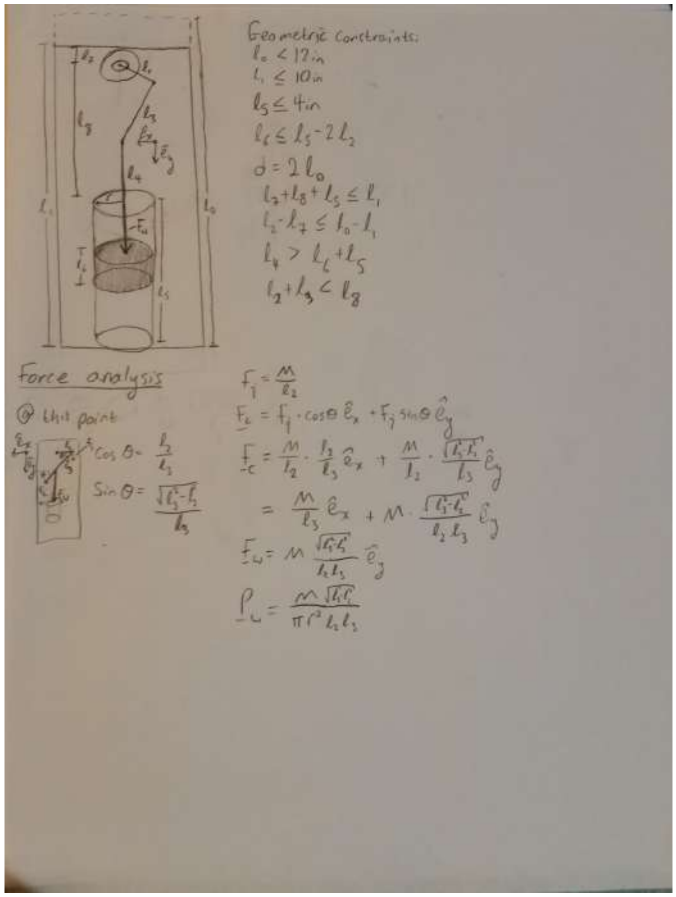
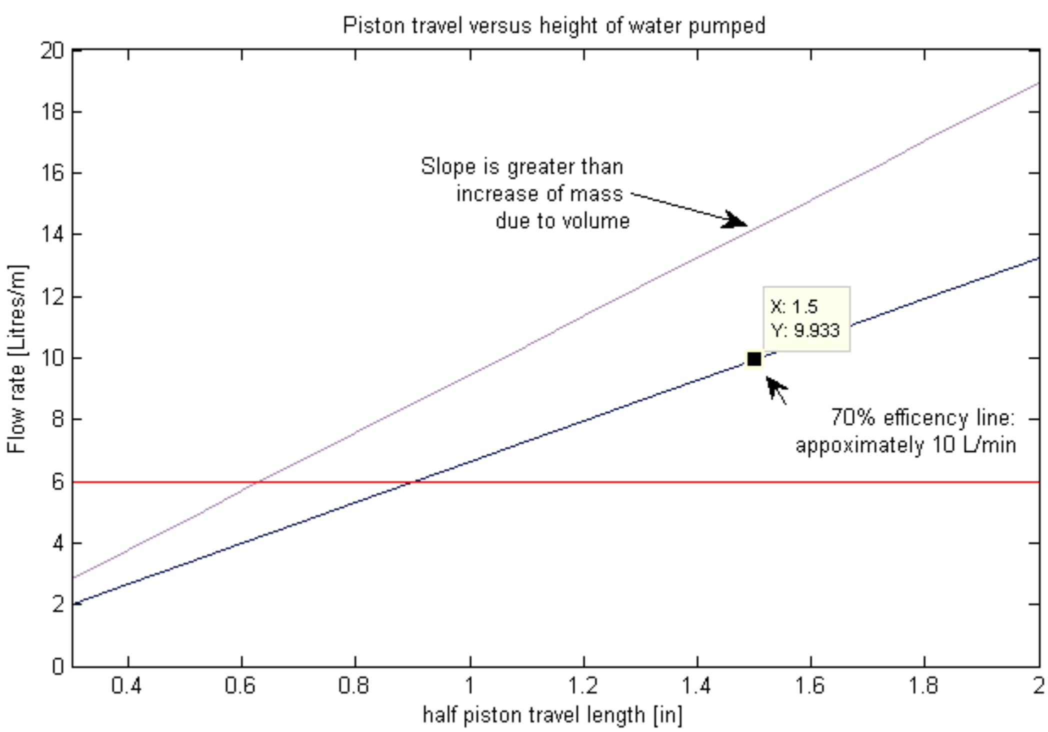


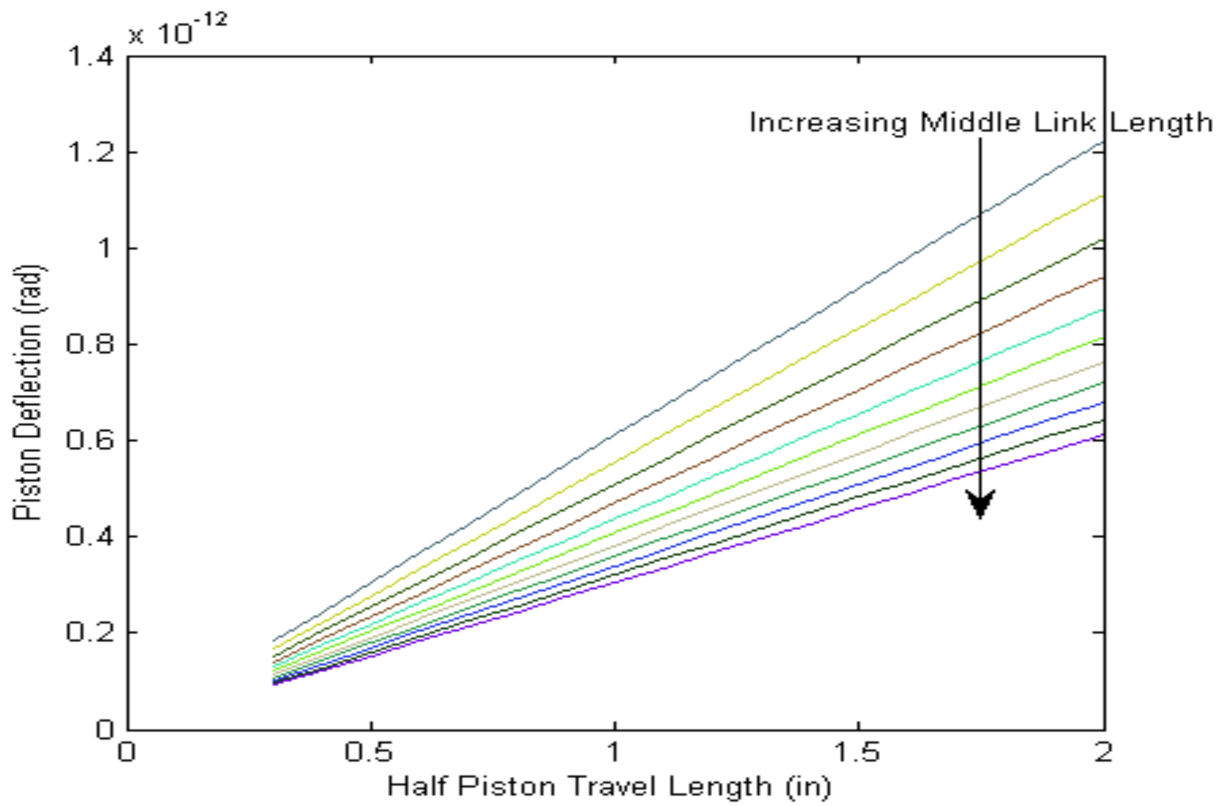
Image 27: Flow Rate vs. One Half Piston Displacement



This graph shows flow rate as function of travel length. The two purple lines represent slopes, they tell us how increasing travel length will increase flow rate at a given efficiency. If the slope of the 70% efficiency line is greater than the slope of weight as a function of travel length then we know that concerns about weight should not factor into our optimization of travel length. We chose a 70% efficiency based off the performance of first section groups that had roughly that efficiency from the predicted to actual.

Analysis of Deflection of the Piston Rod with Respect to the Link Lengths

Image 28: Deflection vs. Link Lengths



This plot is a rough estimation of the deflection angle of the bottom link when it is in the state of highest bending moment (I messed up the constants but the idea is accurate). The plots shows that increasing travel length will increase piston deflection, while increasing middle link length will decrease piston deflection. All of these graphs inform us for prototyping and provide useful information on what might be going wrong with our design.

Analysis of Reynolds Number

Reynolds Number Calculation: Given the values: diameter of the piston is .04445 m, the velocity of the flow is .122 m/s and the properties of water (density, dynamic viscosity), we have reynolds number of 5 which is incredibly low and is not of concern.

Section: Cost Analysis of Design

In this section we discuss our initial cost analysis of our model. Below summarizes the parts and quantities we expect to purchase, the cost of each part, and an overall cost of our design.

Table 7: Prototype Lists of Parts Needed

Quantity	Name of Part	Cost (Individual)	Total Cost
2	End Caps	$1	$2
1	Cylinder	$1	$1
1	Plastic Piston Rod (1.5 in)	$0.86/in	$1.29
4	Threaded Rods (5.5 in)	$1.02/ft	$1.87
11	Hex Nuts	$0.06	$0.66
10	Bolts	$0.17	$1.70
1	Mount Plate (5.75 in) (½ x 4)	$1.18/in	$6.785
1	Back Mount Plate (10 in) (¼ x 2.25)	$0.36	$3.60
2	Top Link (1 in) (½ x 2 ¼)	$0.73	$1.46
1	Middle Link (2.25 in x ¼) (1 in)	$0.36	$0.36
1	½ in Steel Rod (6 in) (Piston)	$0.23/in	$1.38
1	½ in Steel Rod (6 in) (Input Shaft)	$0.23/in	$1.38
7	Washers	$0.02	$0.14
3	Piston Screw	$0.6	$0.18
3	Bronze Sleeve Bearing (1677K3)	$0.60	$1.80
1	Piston Nut	$0.06 (guess)	$0.06
1	Threaded Rod (3 in)	$1.02/ft	$0.26
4	Brass Pipe Fitting	$1.43 each	$5.72
1	Aluminum Rod 1’’ OD 1in	$2.07	$2.07

4	Plastic Tee Connector	$.95	$3.80
2	Plastic Tubing (ft)	$.37	$.74
TOTAL	**SUM**		$37.64

Table 8: Final Design

Quantity	Name of Part	Cost (Individual)	Total Cost
2	End Caps	$1	$2
1	Cylinder	$1	$1
1	Plastic Piston Rod (.8 in)	$0.86/in	$.688
4	Threaded Rods (5 in)	$1.02/ft	$1.70
3	Hex Nuts	$0.06	$0.18
6	Bolts	$0.17	$1.02
1	Mount Plate (5.75 in) (½ x 4)	$1.18/in	$6.785
1	Back Mount Plate (10 in) (¼ x 2.25)	$0.36	$3.60
2	Top Link (1 in) (½ x 2 ¼)	$0.73	$1.46
1	Middle Link (2.25 in x ¼) (1 in)	$0.36	$0.36
1	½ in Steel Rod (5.5 in) (Piston)	$0.23/in	$1.27
1	½ in Steel Rod (5 in) (Input Shaft)	$0.23/in	$1.13
3	Piston Screw	$0.6	$0.18
3	Bronze Sleeve Bearing (1677K3)	$0.60	$1.80
3	Piston Nut	$0.06	$0.06
1	Threaded Rod (1.8 in)	$1.02/ft	$0.26
4	Brass Pipe Fitting	$1.43 each	$5.72
1	Aluminum Rod 1’’ OD 1in	$2.07	$2.07
TOTAL	**SUM**		$30.543

In the final design we chose to forgo the use of Tee connectors of additional tubing. We determined during testing that the tee connectors did not increase our flow rate. Therefore, our final design is a total cost of $30.54, much less than the prototype.

Section 6: Manufacturing of Water pump

The below section describes the manufacturing of the water pump including a schedule, and a brief restatement of changes. We've also included a bit of the machining ways that we went about making the parts.

Machining Schedule

The below Schedule outlines the parts we need to machine, who is responsible, as well as priority and dependencies. Priority of 1 Is most important, 3 is the least.

Table 9: Machining Schedule

Part Name	Person To machine	Machine Needed	Priority	Depends on
Mount plate	Katherine, Adam	Mill	3	
Support Mount Plate	Katherine, Rayne, Adam	Mill	2	
Piston Case	Ethan	Lathe	1	
Piston	Ethan, Rayne	Lathe	1	Piston Case
Piston Rod	Ethan, Katherine	Lathe, Mill	1	Piston
Top Links	Rayne	Mill	3	

End Cap Full	Adam	Mill	1	
End Cap	Adam	Mill	1	
Input Shaft Long	Rayne, Ethan	Lathe, Mill	2	
Input Shaft Short	Rayne, Ethan	Lathe, Mill	2	

Bolt Selection

This section includes a bolt selection table which helped us pick hole sizes for out parts for tapping, drilling, and different types of fits. To tap to ¼ -20, we used a size 7 drill. For out bolts that did not need to be threaded (8-32 hole), we used a size 18 drill. This provided a close fit but allowed the bolt to rotate freely.

Table 10: Bolt Selection and Hole Size

Screw	O.D.	Tap		Close Fit		Free Fit	
Size/Thread	Decimal	Size *	Decimal	Size	Decimal	Size	Decimal
000-120	0.0340"	71	0.0260"	65	0.0350"	62	0.0380"
00-90	0.0440	65	0.0350	3/64"	0.0469	55	0.0520
0-80	0.0600	3/64" (56)	0.0469	52	0.0635	50	0.0700
1-72	0.0730	53	0.0595	48	0.0760	46	0.0810
2-56	0.0860	50	0.0700	43	0.0890	41	0.0960
3-48	0.099	47	0.0790	37	0.1040	36	0.1065
4-40	0.1120	43	0.0890	32	0.1160	30	0.1285
5-40	0.125	38	0.102	29	0.1360	28 (9/64)	0.1405
6-32	0.1380	36	0.1065	27	0.1440	25	0.1495
8-32	0.1640	29	0.1360	18 (11/64)	0.1695	16	0.1770
10-24	0.190	25	0.150	9	0.196	7 (13/64)	0.2010
10-32	0.1900	21	0.1590	9	0.1960	7 (13/64)	0.2010
1/4-20	0.2500	7	0.2010	F	0.2570	H (17/64)	0.2660
1/4-28	0.2500	3	0.2130	F	0.2570	H (17/64)	0.2660
5/16-18	0.3125	F	0.2570	P	0.3230	Q	0.3320
3/8-16	0.3750	5/16"	0.3125	W	0.3860	X	0.3970
1/2-13	0.5000	27/64"	0.4219	33/64"	0.5156	17/32"	0.5312

* For copper, aluminum, cast iron, bakelite, or very thin materials, use one drill size larger (i.e. a slightly smaller diameter).

Design Refinements:

After the CDR, the team decided to rework the design due to several possible issues when pumping. First, there was concern that the brass fittings and the tubing would interfere with the motion of the piston and links. This interference could cause several issues such as the piston system binding due to unintentional friction. In order to fix the potential issue, we changed the thickness and width of the links. Now there should be no overlap. Second, the team decided that we would need to change the original mount plate design in order to attach it to the motor; with this change, it was necessary to change the stock (now 5.76” of 1/2" x 4" Aluminum Bar). The change of stock would also create a potential weight and cost issue, so the front mount plate was decreased in height which would significantly help.

Machining and Assembly Plan:

Top Links

For the top links, both pieces needed to be sized to the correct dimensions. In order to do this, the mill was used to shorten the stock’s thickness and length. Four holes will be drilled using the mill to attach each to the mount plate and the middle link.

Middle Link

The middle link, like the top links, needed to fit to the proper dimensions of the design. In order to do this piece, the mill was used to fit the material to proper dimensions and then holes were cut so the middle link would be able to be attached to the top links as well as the piston itself.

Plastic Piston Rod

The piston rod was machined down to the proper diameter using the lathe.

Section: Images of Parts

Image 29: Pump Assembly to Check hole geometry

Image 30: Back Mount Plate

Image 31: Front Mount Plate

Image 32: End Caps (Left we machined the holes, right was pre machined)

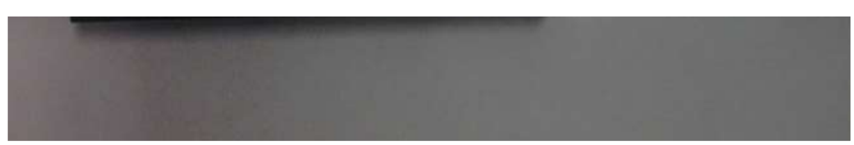


Image 33: Piston Cylinder

Image 34: Input Shaft

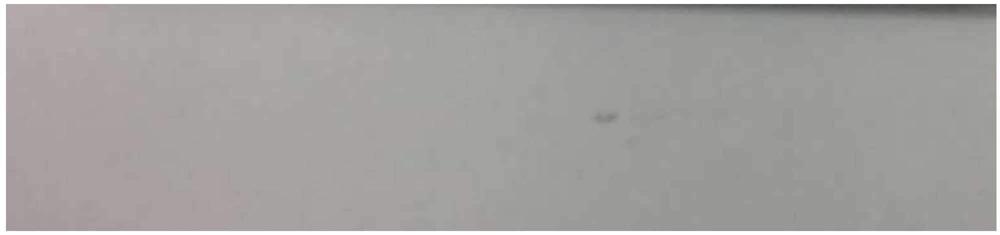


Image 35: Piston Assembly

Image 36: Piston Assembly “Exploded View”

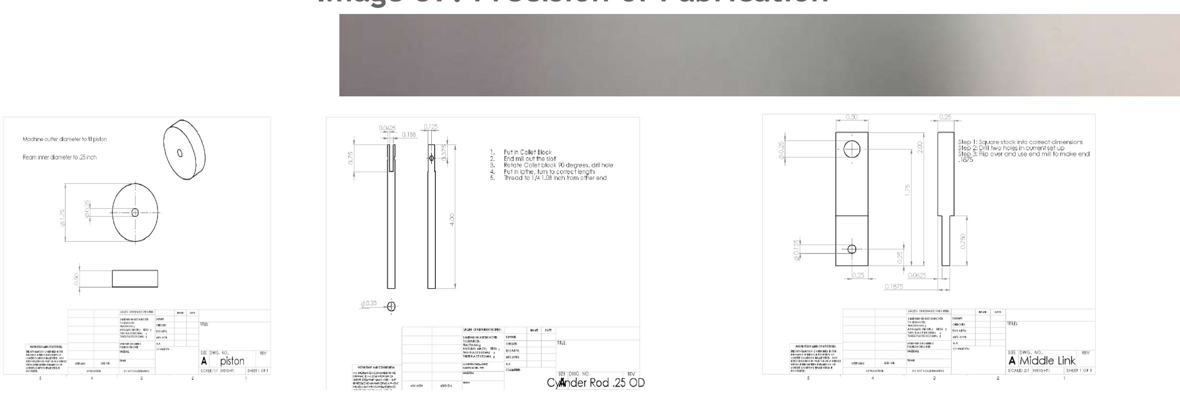
Section 7: Fabrication

This section provides a brief overview of our fabrication methods and processes.

Fabrication:

To create a quality product, one must have a great attention to detail throughout the design and manufacturing processes. Often times, a product is designed with too much complexity to be accurately manufactured, or a simple part is manufactured in an overly complex manner. To avoid these complications and enable an easy transition from the design stage of our project to the manufacturing stage, we designed our product using basic geometries and printed clear fabrication instructions on the drawings of each part. Additionally, we prioritized our machining schedule in order to manufacture the most important elements of our pump as early as possible, which allowed us to precisely fabricate and finish all of the other subsequent parts accordingly. Lastly, as with any project, we constantly checked and measured the accuracy of our manufactured parts against our design to make sure that everything was finished in a precise, quality, manner.

Image 37: Precision of Fabrication



As you can see from the above image, the clarity and foresight of our design process made the manufacturing process much easier. However, even with these preparations, our pump was still having trouble reciprocating smoothly upon first assembly. We realized that although our manufacturing techniques were as precise as we could manage, there were many flaws in the stock end caps and cylinder that we purchased which caused discrepancies in the spacing of our parts. We had planned on using washers to create uniform spacing, but we found that manufacturing our own aluminum spacers of the exact lengths needed was much more accurate and kept the piston rod concentric to the brass bushing in the top end cap.

Image 38: Crankshaft Assembly with Aluminum Spacers

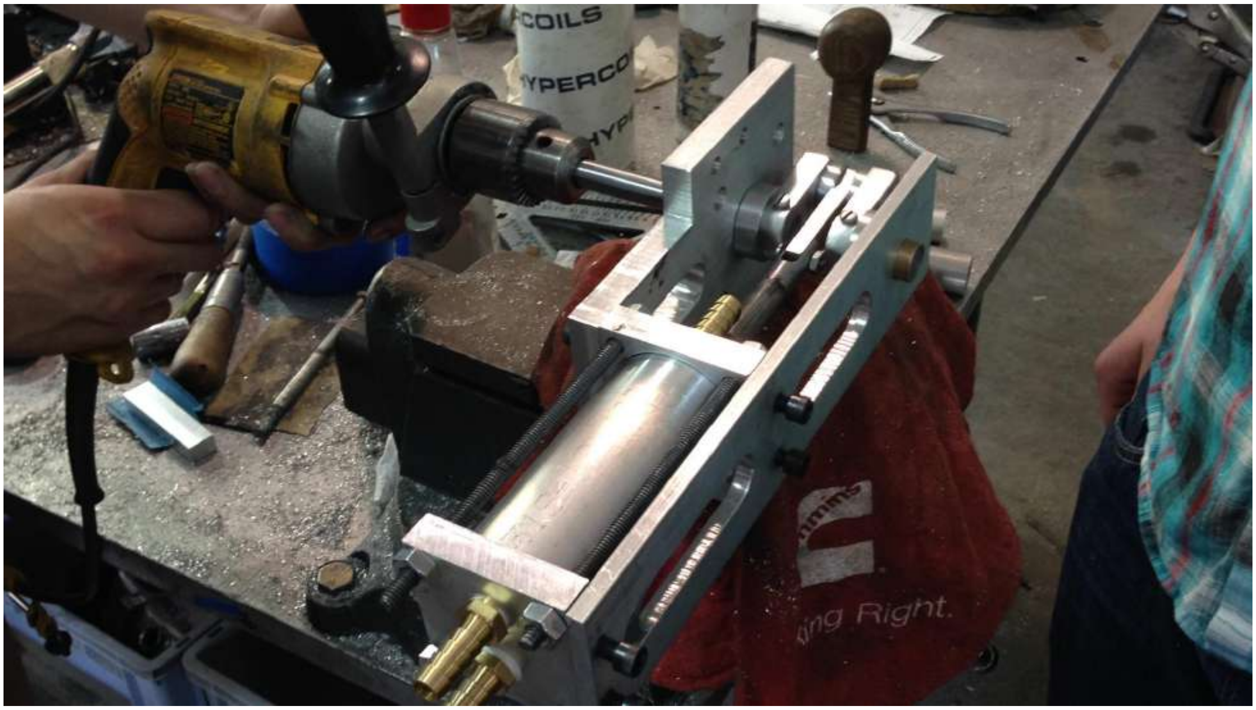
After manufacturing, assembling, adjusting, testing, refining, and polishing each part, we successfully produced the product which we had designed earlier in the project. The pump worked as planned, looked as planned, and after removing unnecessary material from the mounting and back plates, our pump was even lighter than we had predicted. Our care and effort throughout the fabrication process allowed us to produce a high quality product in a small time frame, all while staying safely under our budget.

Section 8: Testing and Possible Improvements

This section contains photos and videos of the testing of the final design, and feedback of the final design from testing. This section also includes results and possible future improvements.

Preliminary Testing

Image 39: Dry Run Testing Set Up



This image shows the testing set up of our water pump which used a drill and a vice. This testing was done the see if our pump would run to the needed specifications without water.

The below links are videos of the testing:
https://www.youtube.com/watch?v=E_DYqWK3Jkw
https://www.youtube.com/watch?v=qJ4vRS2o3TQ
https://www.youtube.com/watch?v=y1rAy_T7aF8

As shown, are design works very well with a power drill. We also identified several problems with the design such as fit due to testing. We solved the fit problem by tightening our threaded rods as well as getting shorter bolts to provide a clamping force on the back plate. This allowed the cylinder to sit in one spot exactly where the piston would run.

Final Testing

The below videos show the results from trial 1 and 2, as well as comments on performance from each.

Trial 1 Analysis:

As shown in the above video, we had a lot of leakage. This was as a result of the lack of sealing between the cylinder and the end caps, as well as at the brass fitting for the piston. At the time, we only had an external ring of hot glue that tried to seal the end caps to the cylinder. The effects of leakage were two fold: we not only pumped less water because it leaked, but also out pressure was less so it was more difficult to pump water.
The result from this test was 4.0 L/m with a weight of 3.3 Lbs.

Changes from Trial 1:

After noticing we had leakage problem, we decided to disassemble the cylinder portion of our water pump and fix the seal problem. We used a ring of hot glue on the top end cap ring and forced the cylinder in the groove. We then held it there tightly and let it dry. Next, we put a ring of electrical tape around the hot glue in an attempt the hold it even more. After that was completed we moved to the other side of the cylinder. We put a ring of a few layers of teflon tape around the other side of the cylinder and forced it into the other end cap. We then reassembled the pump with the new seals and prepared to test. We noticed that our pump did not turn as smoothly as before, and would lock up near top dead center. To see if it would still work, we tested it again with a power drill and saw that it still spun. Therefore, we decided to test.

Another change between trial 1 and 2 was that we decided to not use plastic T connectors. We felt that they did not add anything to our pump, but they did cost a fair amount. We decided to just run one inlet and one outlet per side.

The below link is from the first testing of our pump:
https://www.youtube.com/watch?v=tYcZmZ5D948&feature=youtu.be

Trial 2 Analysis:

Trial two was much more successful. We solved our leakage problem from the end caps, and seemed to reduce overall leakage while increasing pressure. Despite earlier concerns of it binding up, our pump is built very sturdily and was able to easily pump once started. As a result, we had a flow rate of 7.5 L/min with a weight of 3.3 Lbs with slight leakage around the piston. This is a 2.273 Flow Rate to mass ratio. We were very happy with these results but still feel we can improve.

The below link is from the second test:
https://www.youtube.com/watch?v=cWsxCPUh_aI&feature=youtu.be

Comparison of Actual versus predicted:

As shown in our analysis section of the notebook, we predicted an ideal flow rate of roughly 11.4 L/min and an adjusted 70% rate of 8 L/min. In actual performance we pumped 7.5 L/min. Our percent error from predicted to actual is:

$$Percent\ Error: \frac{7.5\ -\ 8}{8} *\ 100\%\ =\ -6.25\%\ error$$

This is a very low percent error, which we are very happy with. We attribute this low percent error because of our precise machining, and easily machinable design. Moreover, our estimate of 70% was determined through data gathered in the first section. The cause of our percent error is most likely due to the slight leakage around the piston shaft. Had this not leaked, we feel we would have pumped over 8 L/m, and resulted in an accurate performance. Nonetheless, we feel that we hit upon our predicted results quite well.

Future Improvements:

After seeing our performance and predicted performance, we were happy with the results. Future improvements would be mainly concerned with two categories - weight savings, and leakage reduction.

Weight Savings:

Because this is scored on flow rate divided by mass, our objective is to reduce our mass. One was to do that would be to instead of a .5in mount plate, we would purchase ⅜ in. This would save roughly .2 lbs. Additionally, we would add larger pockets and reduce more mass on both mount plates. We feel that we could reduce .2 additional lbs on each mount plate by rounding edges and removing more material inside. After that, we feel that we could add pockets in each of the link, reducing .05 lbs total among the 3 links. We could then use an aluminum shaft instead of steel, which has ⅓ the density. This would reduce our mass by .2 lbs. We would next swap out or aluminum locating bushing for delrin, which would save roughly .05 lbs total.

Therefore we feel our total mass potentially saved would be:

$$Total\ mass\ reduced = .2\ +\ .2 * 2\ + .05\ +\ .2\ +\ .05\ =\ .9\ Lbs$$

As a result, assuming we pump the same volume of water, our flowrate to mass ratio would be

$$Flow\ rate/Mass\ = 7.5L/2.4Lbs\ =\ 3.125\ L/\ Lbs$$

Leakage Reduction:

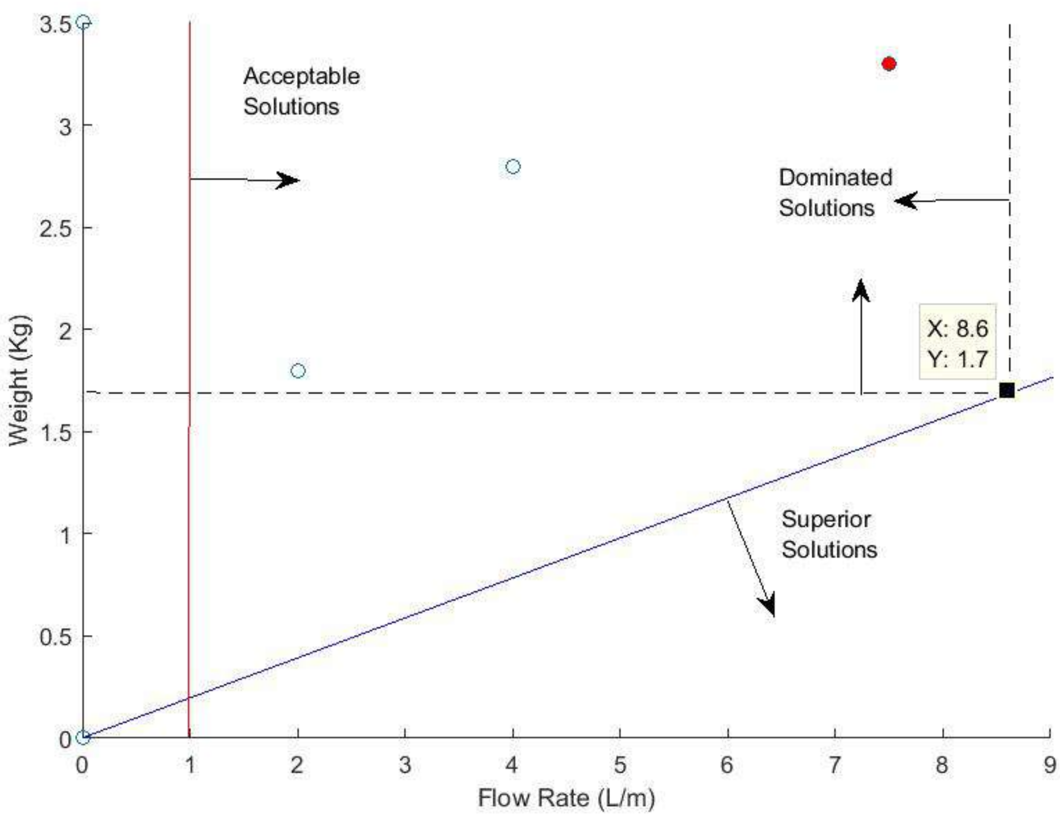
We are currently roughly 10 dollars under budget, so we feel we can spend more money to purchase better sealing mechanism. Around the piston shaft, we would either purchase the same sealing mechanism as Group 4A, or we would replace the brass sleeve bushing with two o-rings in the end cap. This would prevent leakage out of piston connection, although slightly increasing friction.

We would also put an oring on our piston to maximize volume of water displaced per stroke. Our position did not fit perfectly in the cylinder for two reasons. Firstly, the cylinder we purchased was crushed, and was no longer circular. This made it very difficult to machine a proper piston head. Secondly, we were worried about binding, so we undersized the piston head. With an oring, we would be able to reduce both of these sources of error.

Comparison to Class:

Through both testing and general analysis, we were able to see the effectiveness and overall selling points of our product. Our design, as compared to the other teams was very machinable, extremely sturdy, affordable, and maintains large factors of safety. This being said, our water pump design was a huge success when it came to its manufacturability. It is a product that can be easily mass produced for any scale or need. Not only did our pump perform well under analytical comparison, but it also outperformed most pumps in actual testing. In comparison to the class, we came in second both flow rate in L/min as well as in a flow to weight ratio. With 7.5 L/min and 2.272 L/(min lbs), we proved that our pump was highly effective in the given situation. We feel that our pump was a very sound design that proved to do well.

Image 40: Pareto Front



This optimization analysis shows flow rate v. weight for each design where our design is shown in red. The black point dominates all other points in both weight and flow rate thus singularly defining the pareto front. Gratefully, our point lies above the acceptable solutions line, but it also lies within the dominated solutions which indicates we can improve on both flow rate and weight.

Environmental Impact:

Our water pump had minimal negative impact on the environment due to several factors:

- Our water pump is easily machinable, and was machined without the use of all the slots. The resulted in less pollution and less electricity by not needing the machines.
- We purchased all of our stock from emerson (on site). This meant that we did not have to worry about the shipping and the pollution caused by shipping. By building our pump out of material on site, we were able to reduce our carbon footprint.
- Our sturdy, durable and long lasting design results in long life of our component. Additionally, because out pump won't break, we know that it will not damage what it is required to operate. Therefore, life of all parts will increase which will reduce manufacturing and repair of newer components.

Section 9: User Documentation

User Manual

Image 41: End Caps

Step One: Place barbed fitting in end caps.

Image 42: End Caps (Internal View)

Step Two: Prepare end caps to attach to mount plates and cylinder.

Image 43: Piston Rod

Step Three: Check the piston rod to be inserted into top machined end cap and assembly to piston cylinder.

Image 44: Piston Assembly (Exploded View)

Step Three: Assemble the piston rod with the piston head, washer, and nut.

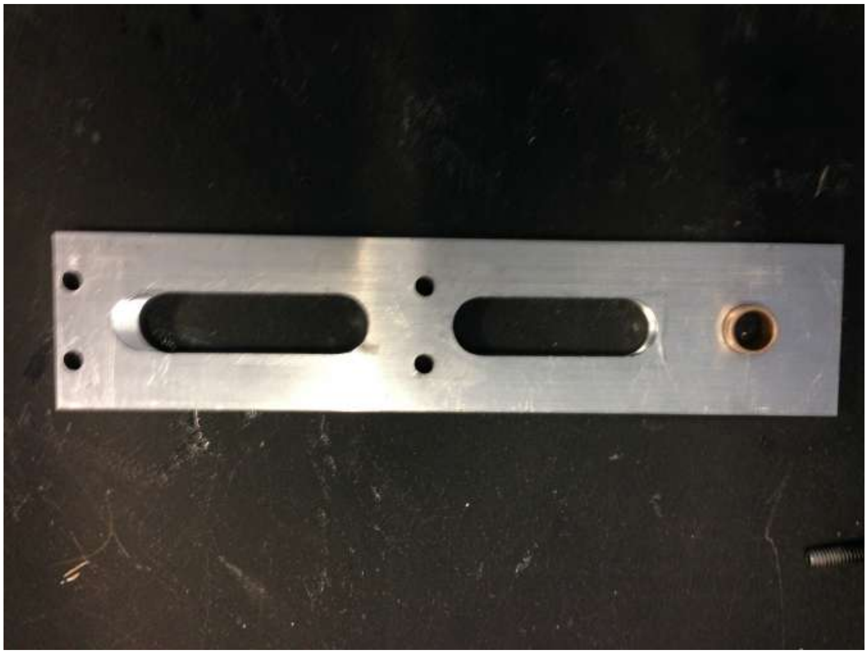
Image 45: Piston Assembly

Step Four: Make sure the piston assembly is tightly fit so there will be no leakage and no disassembly while pumping.

Image 46: Piston Cylinder Assembly

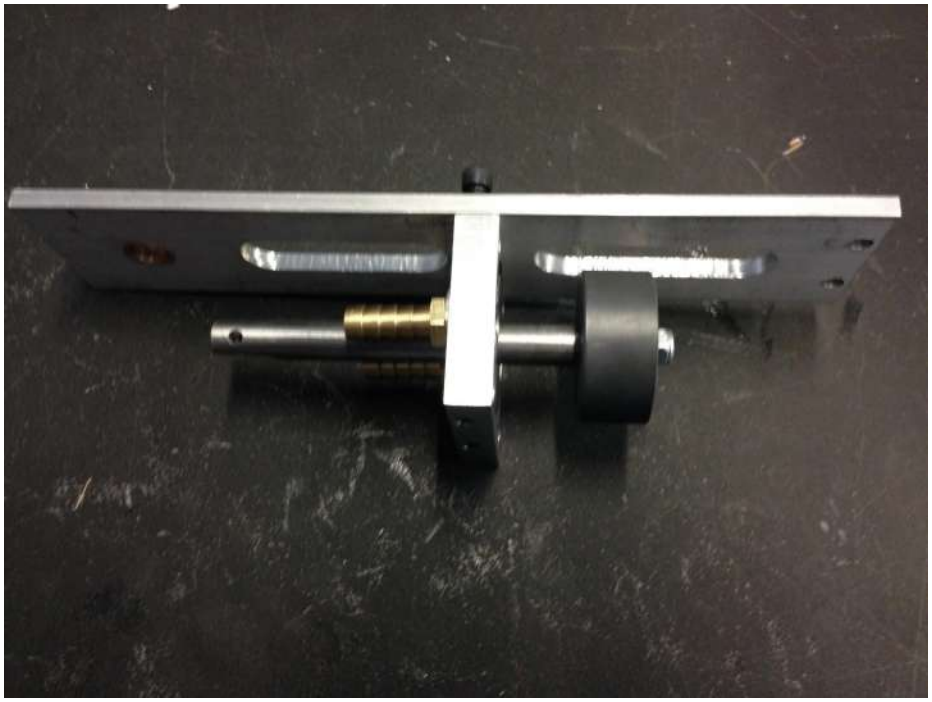
Step Five: Insert piston rod assembly into cylinder. Lubricate the cylinder and move the piston up and down to spread the lubricant.

Image 47: Back Mount Plate



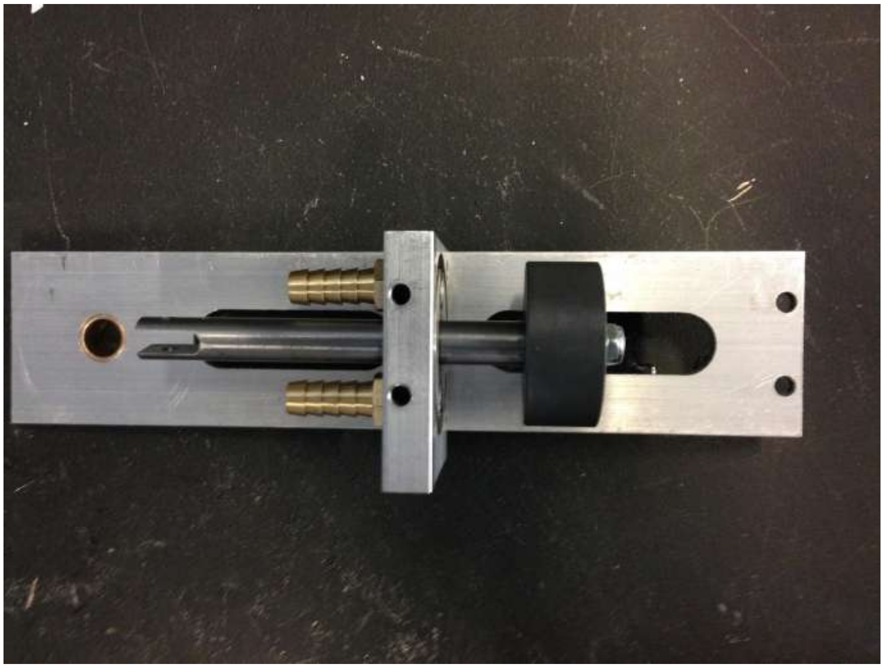
Step Six: Align back mount plate bolt holes with the end caps.

Image 48: Back Mount Plate, Top Endcap, Piston Assembly



Step Seven: Bolt the top end cap with the piston assembly to the back mount plate. Make sure that bolts are securely inserted into back mount plate to assume that the assembly stays together while testing.

Image 49: Back Mount Plate, Top End Cap, and Piston Assembly

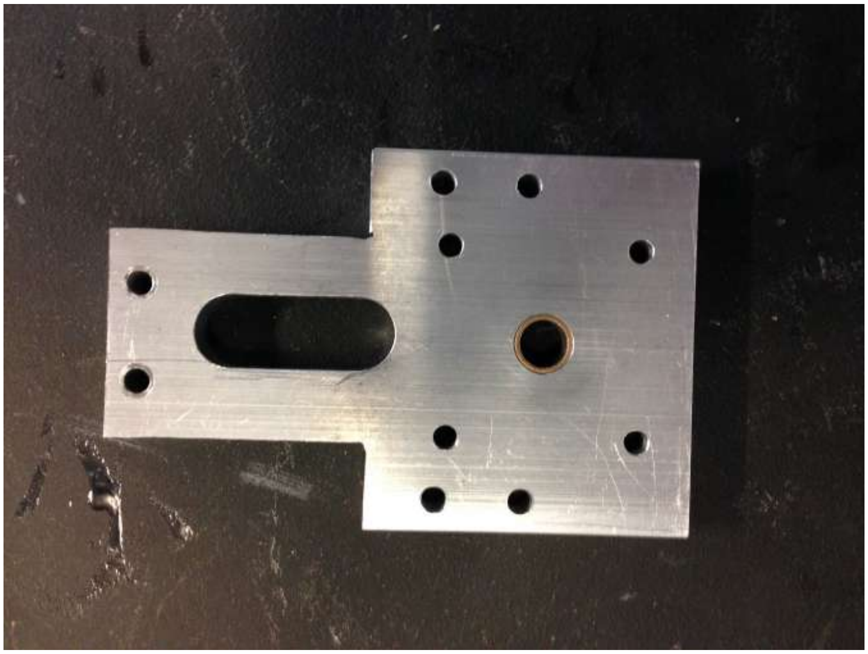


Step Eight: Align cylinder and bottom end cap with the piston assembly.

Image 50: Back Mount Plate and Piston Cylinder Assembly

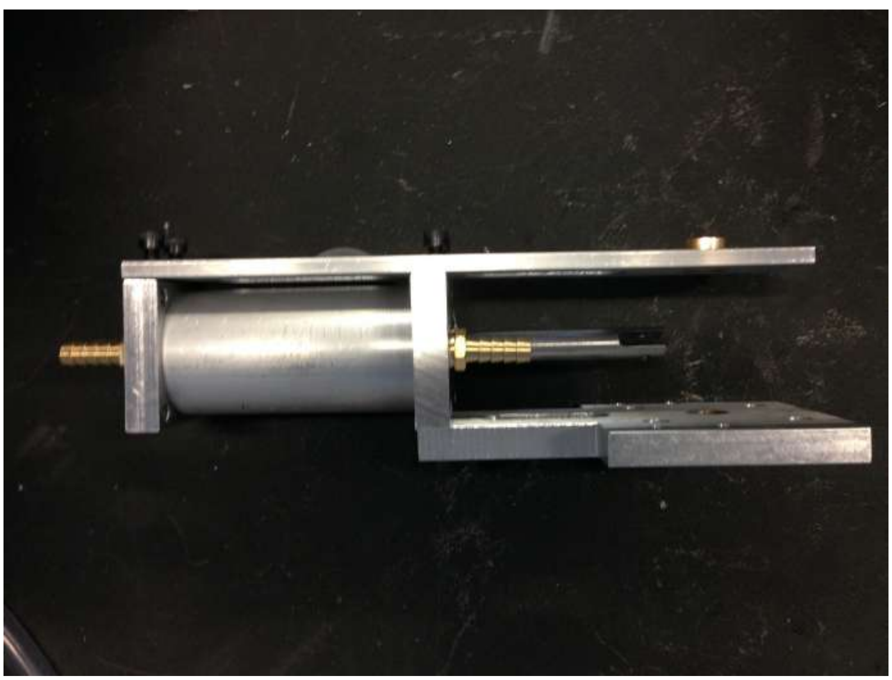
Step Nine: Securely bolt the the bottom end cap to the back mount plate. Make sure that the piston cylinder is rigidly attached between the two end caps.

Image 51: Front Mount Plate



Step Ten: Align the front mount plate to the piston cylinder assembly and top end cap.

Image 52: Piston Assembly

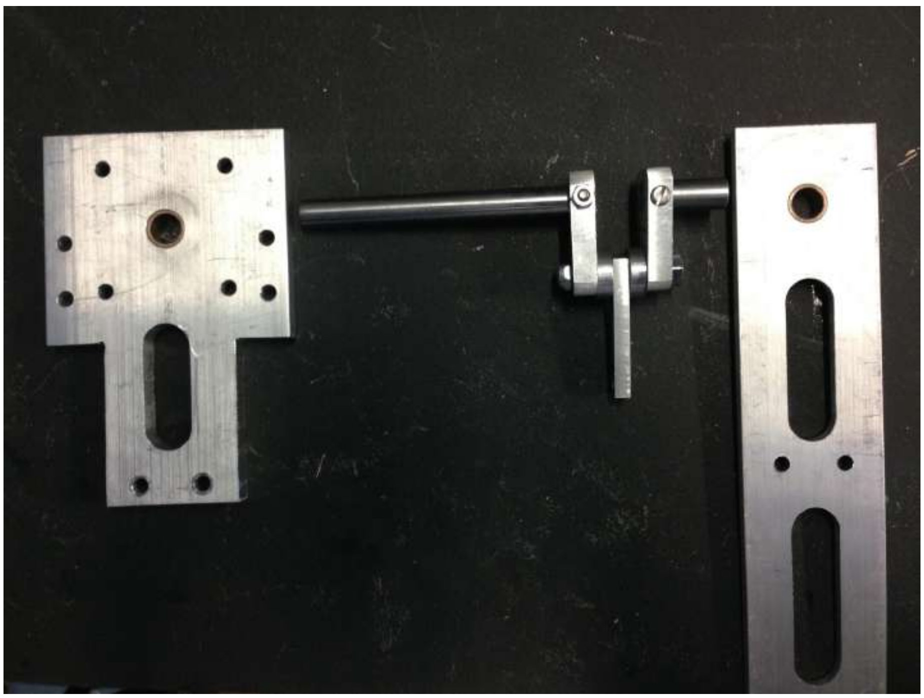


Step Eleven: Bolt the front mount plate to the piston assembly. Make sure bolts are securely inserted into the assembly.

Image 53: Crankshaft Exploded assembly

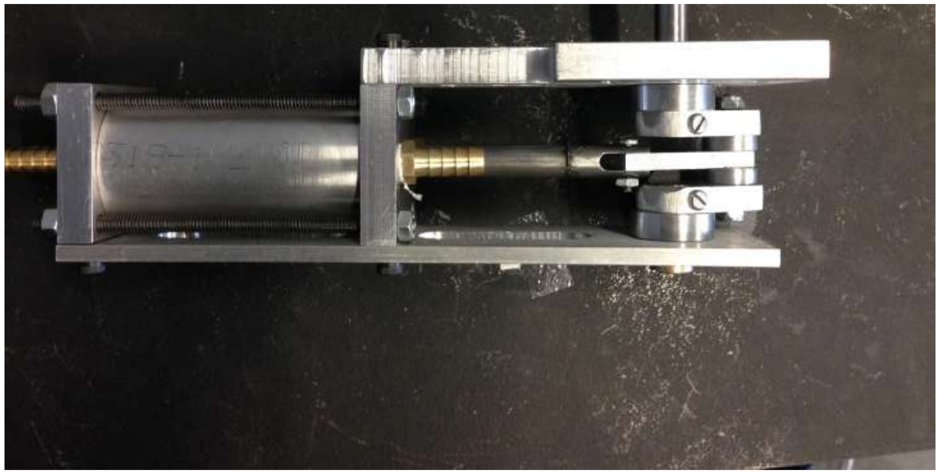
Step Twelve: Assemble the crankshaft with the parts shown above.

Image 54: Crankshaft, Front and Back Mount Plates



Step Thirteen: Insert the crankshaft into the brass bearings on the front and back plates. Assure that the assembly is attached correctly for proper results.

Image 55: Full Piston Assembly



Step Fourteen: Check that the assembly is fully functional by rotating the input shaft. Put lubricant on the piston rod in order to minimize friction.

Safety Instructions

- Wear safety glasses while testing to reduce chance of injury.
- Keep hair, loose clothing, and fingers away from machine.

Troubleshooting

In case the assembly binds up while testing, stop immediately. Add lubricant to reduce friction and manually ease the piston back into the cylinder. Once the piston can move through the cylinder, attach a drill to input shaft and slowly apply torque to assembly to test again.

If any part of assembly breaks, stop immediately. Fix broken parts. If not easily fixable, re-machine parts or weld broken piece together.

Section 10: Bibliography

This section contains the sources used in the fabrication of the pump and the report.

"Tap Drill Chart." Tap Drill Chart. Web. 2 May 2015. <http://www.physics.ncsu.edu/pearl/Tap_Drill_Chart.html>.

Section 10: Presentation Slides

This section contains the Presentation slides from PDR, CDR, and FDR

Water Pump PDR

Group 4D: Adam, Ethan, Katherine, and Rayne

Content:

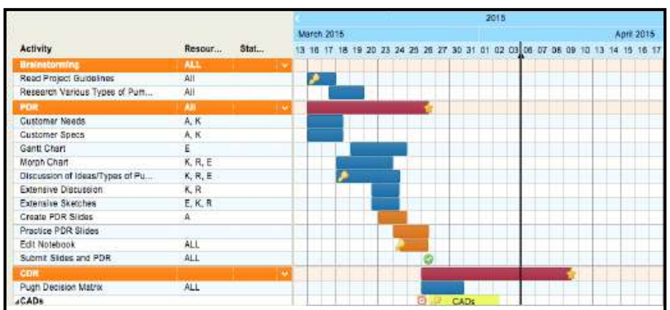
1. Identifying the Problem
2. Planning our approach
3. Generating Potential Solutions
4. Developing Effective Solutions
5. Selecting Potential Solutions

	Customer needs	Low Cost	Allowable Stress on motor	Efficiency of pump	Weight	Type of Material	Time until max flow rate	Time to Start up	Pump Geometry	Number of times it can operate
1	Light Weight		X		X	X				
2	Affordable	X				X				
3	Integrated with testing equipment								X	
4	Good flow rate			X			X	X		
5	Durability		X							X
6	Aesthetically Pleasing					X			X	
7	Easy to Use							X		
8	Safety		X		X	X				X

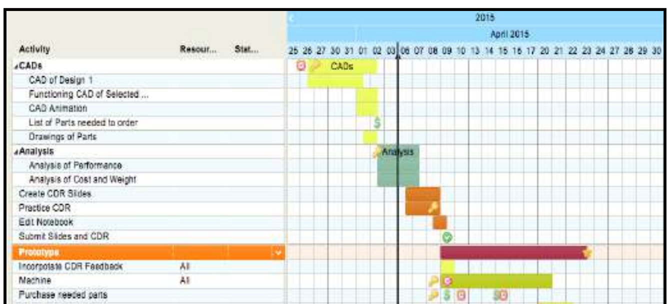
Customer Needs and Specifications

Engineering Specification	Needs Met	Units	Acceptable Range	Importance (1-5)
Low Cost	2	dollars	<$40 (prototype) <$40 (Pump)	4
Allowable Stress on Motor	1,5,8	Pa		5
Efficiency of Pump	4	L/MinKg		3
Weight	1,8	kg		3
Type of Material	1,2,6,8	-		4
Time Until Max Flow Rate	4	sec		2
Time to Start Up	4,7	sec		3
Pump Geometry	3,6	-	Vol<1 c.f. d (drive shaft motor) = 0.5 in d(piston)< 2 in	3
Number of Times it Can Operate	5,8	#	>5	1

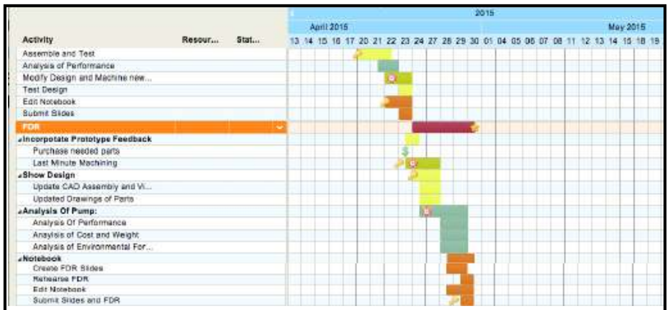
Engineering Specifications



Gantt Chart: Brainstorming - PDR



Gantt Chart: CDR - Prototype



Gantt Chart: Prototype - FDR

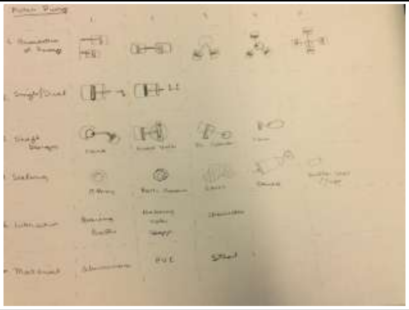
Current Progress along with Legend

Action Item	Action Name	Team Member Responsible	Depends On	Duration	Time Remaining			
					44		Start:	3/16/2015
							End:	4/29/2015
1	Read Guidlines	All	-	2	42			
2	Discussion Of Types of Pumps	E, K, R	1	4.5	37.5			
3	PDR Prep	All	1,2	3	34.5			
4	Selection of Ideas	All	2,3	1	33.5			
5	CADS	TBA	4	5	28.5			
6	Analysis of Ideas	TBA	4,5	3.5	25			
7	CDR Prep	All	4,5,6	3	22			
8	Order of Parts	TBA	5,6,7	2	20			
9	Machining	All	5,8	8	12			
10	Assemble and Test	All	9	3	9			
11	Modify CAD Design	TBA	9,10	1	8			
12	Machining New Design	TBA	10,11	2	6			
13	FDR Prep	All	10,11,12	6	0			

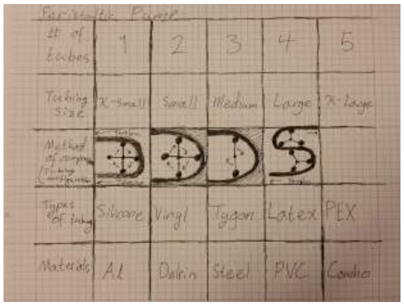
Critical Path

Type Of Pump	Piston	Rotory	Peristaltic	Diaphragm	Centrifugal
Light Weight	0	0	1	1	-1
Affordable	0	-1	1	0	-1
Good flow rate	1	1	-1	-1	-1
Durability	1	1	0	0	1
Aesthetically Pleasing	0	0	1	1	0
Easy to Use	0	-1	1	-1	-1
Safety	0	1	-1	1	1
Efficiency	1	1	0	-1	-1
Time to Start	0	-1	1	1	-1
Manufacturability	1	0	1	0	-1
Sum	4	1	4	1	-5

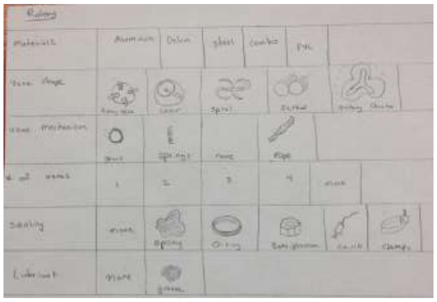
Preliminary Pugh Decision Matrix



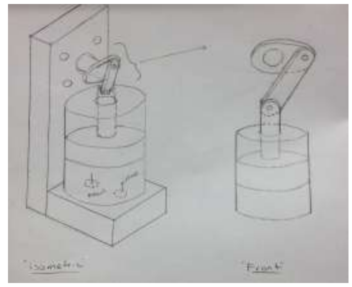
Morph Chart - Piston Pump



Morph Chart - Peristaltic Pump



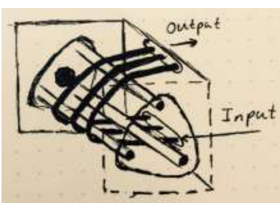
Morph Chart - Rotary Pump



Design: Single Piston

Materials:
- Aluminum (Case, Crank)
- Delrin (Piston)
- Epoxy/Caulk (Seal)
- Steel (Bolts, Drive Shaft)

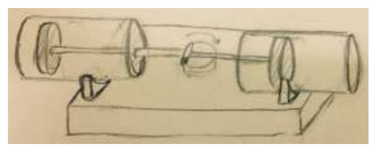
In Depth Design - Piston Pump

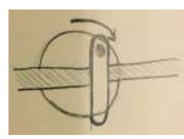


Design: Peristaltic

Materials:
- Latex (Tubes)
- Aluminum (Plates and Bars)
- Steel (Bolts, Drive Shaft)

In Depth Design - Peristaltic Pump





Design: Double Piston

Materials:
- Aluminum (Case, Crank)
- Delrin (Piston)
- Epoxy/Caulk (Seal)
- Steel (Bolts, Drive Shaft)

In Depth Design - Double Piston

Thank You!

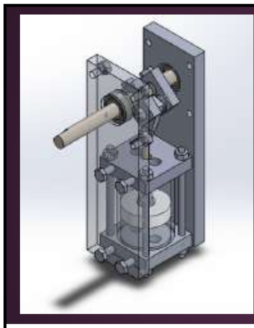
Any Questions?

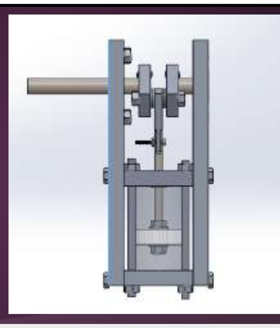
CDR: 4D

Katherine Carroll
Ethan Kramer
Rayne Milner
Samuel Schreiber

Criteria	Weight	Piston	Rotary	Peristaltic
Light Weight	3	0	0	1
Affordable	4	0	-1	1
Good flow rate	5	1	1	-1
Durability	1	1	1	0
Aesthetically Pleasing	2	0	0	1
Easy to Use	2	0	-1	1
Safety	3	0	1	-1
Efficiency	5	1	1	0
Time to Start	4	0	-1	1
Manufacturability	5	1	0	1
Sum		**4**	**1**	**4**
Weighted Sum		**16**	**4**	**12**

Pugh Decision Matrix





CAD Model

CAD Animation

Quantity	Name of Part	Cost (Individual)	Total Cost
2	End Caps	$1	$2
1	Cylinder	$1	$1
1	Plastic Piston Rod (½ in)	$0.86/in	$0.43
4	Threaded Rods (4.5 in)	$1.02/ft	$1.53
16	Hex Nuts	$0.06	$0.96
10	Bolts	$0.17	$1.70
2	Mount Plate (8 in) (½ x 2 ¼)	$0.73/in	$11.68
2	Top Link (1 in) (½ x 2 ¼)	$0.73	$1.46
1	Middle Link (2 in) (¼ x 1)	$0.14	$0.28

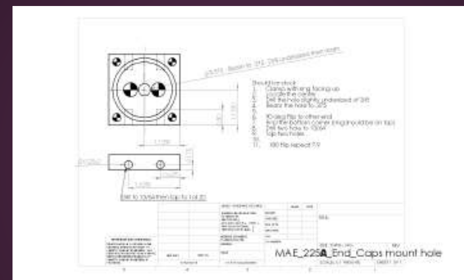
Parts

1	¼ in Steel Rod (6 in) (Piston)	$0.10/in	$0.60
1	½ in Steel Rod (6 in) (Input Shaft)	$0.23/in	$1.38
6	Washers	$0.02	$0.12
1	Piston Screw	$0.17 (guess)	$0.17
1	Bronze Sleeve Bearing (1677K3)	$1.13	$1.13
1	Piston Nut	$0.06 (guess)	$0.06
1	½ in Steel Rod Input Shaft (other side) (2 in)	$0.23/in	$0.46
2	Sleeve Bearings (⅝ th in)***	$1.68	$3.36
1	Threaded Rod (3 in)	$1.02/ft	$0.26
TOTAL	**SUM**		$28.58

Parts

Part Name	Person To machine	Machine Needed	Priority	Depends on
Mount plate	Katherine	Mill	3	
Piston Case	Adam	Lathe	1	
Piston	Ethan	Lathe	1	Piston Case
Piston Rod	Ethan, Katherine	Lathe, Mill	1	Piston
Top Links	Rayne	Mill	2	

Compressed Machining Schedule

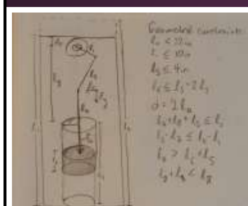


Example Drawing

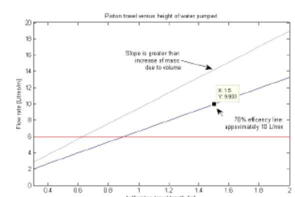
Total Weight	Final Design	Potential SP Design
	2.2Lbs	1.84

Weight Analysis:

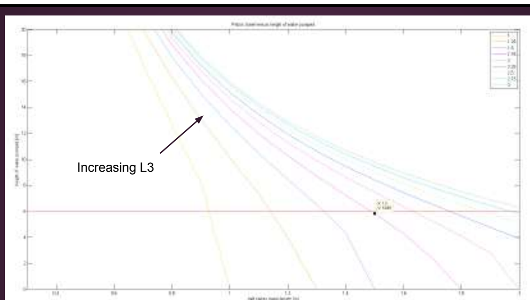
Analysis - Link Lengths



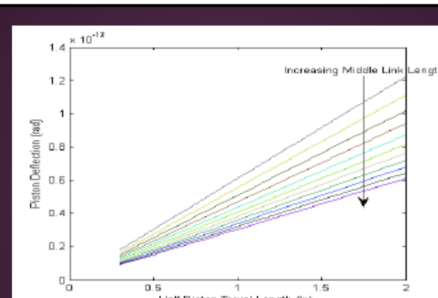
- Worst case for double piston is we don't use it



Want Piston Volume to be a max



Link Length Optimization



Force analysis

Thank You!

Questions?

FDR 4D

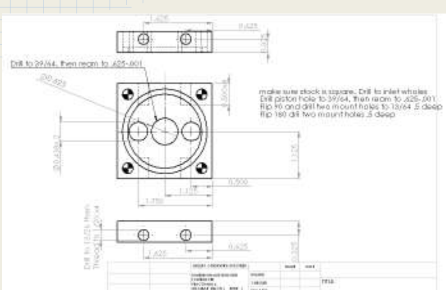
Ethan Kramer
Adam Schreiber
Rayne Milner
Katherine Carroll

Engineering Specifications

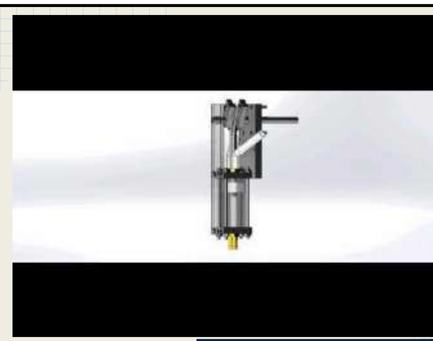
Engineering Specification	Units	Acceptable Range
Cost	Dollars	<$40
Flow Rate	L/min	>1
Weight	lbs	<4
Height Pumped	m	>2
Pump Geometry	-	Vol< 1 c.f. d(drive shaft motor) = .5in d(piston)< 2in

Design

Exploded View



Crucial Drawing



CAD animation

Performance Overview

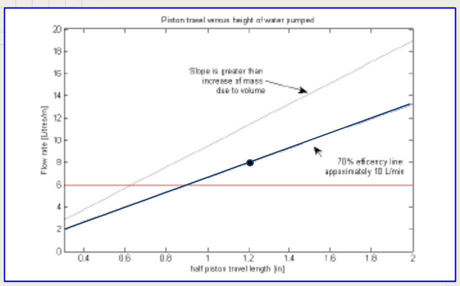
Engineering Specification	Units	Acceptable Range	Our Performance
Cost	Dollars	<40	35.08
Flow Rate	L/min	>1	8
Weight	lbs	<4	3.3
Height Pumped	m	>2	8
Pump Geometry	-	Vol< 1 c.f. d(drive shaft motor) = .5in d(piston)< 2in	Vol< 1 c.f. d(drive shaft motor) = .5in d(piston)< 2in

Predicted Prototype Cost: $37.64

Final Prototype Cost: $35.08

Percent Under Budget: 12.3%

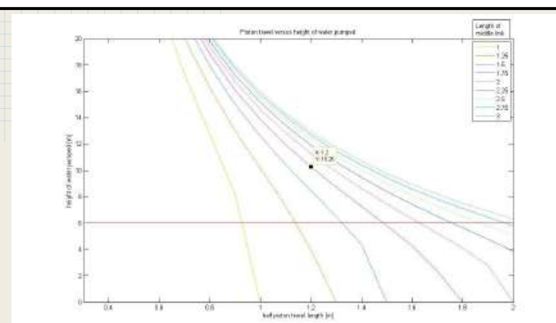
Cost Analysis



Flow Rate

Testing

Weight



Height Pumped

Geometry

Performance - Summary

- Sturdy
- Easily Machinable
- Large factors of safety
- Affordability

Thank you!

Any Questions?