University of Cincinnati NFPA Fluid Power Vehicle Challenge Project Report

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1.0 ABSTRACT

The purpose of the project is to create a vehicle that is able to participate in the National Fluid Power Association (NFPA) Fluid Power Vehicle Challenge. The challenge requires teams to design and build a vehicle that combines the use of human and hydraulic power. Each vehicle must meet the requirements set by the NFPA. The team will test their design by competing against other schools in a sprint race, efficiency challenge and an endurance challenge. The hydraulic circuit design, component selection fabrication, and cost of the project will be analyzed. The results after testing will be compared to the expected results to evaluate the overall design of the project.

2.0 PROBLEM STATEMENT

Design and build a bicycle that has an efficient hydraulic system and is solely human powered. This vehicle will compete in the following three events determined and defined by NFPA:

1. Sprint Race
    a. This 600 ft. course will demonstrate the ability of the vehicle to move a distance where the weight of the vehicle is proportional to the human propulsion.
2. Efficiency Challenge
    a. With a minimum of 100 ft. this event will demonstrate the ability of the vehicle to effectively store and most efficiently use the smallest amount of stored energy to propel the unassisted vehicle the greatest distance proportional to the vehicle's weight.
3. Endurance Challenge
    a. This 1 mile event will demonstrate the reliability, safety, replicability, and durability of the fluid power system design and assembly.

The following design restrictions must be observed:

- The bike must be able to be operated safely by one person
- Design must comply with all appropriate safety codes
- Vehicle cannot leak any hydraulic fluid
- Vehicle must have multiple, fully active, independent brakes
- The vehicle must have mechanical brakes that can stop in all modes
- Gears and chains are only allowed to power the pump or motor
- Must have a fluid link between pump and motor
- Vehicle must have at least a direct propulsion and a regenerative braking circuit

3.0 PROJECT PLAN

The project timelines are shown in Figures 1 and 2. At the beginning of the project, the team focused on research, design concepts, and team roles. After kickoff, the team continues creating new design concepts and evaluated the current ones. Concepts began to be eliminated after having a greater understanding of the competition's expectations. As a team, the most optimal design concept was chosen. We then performed calculations to determine the minimal requirements of component and hydraulic specifications. First, the hydraulic fluid circuit was designed to be incorporated into our concept design for the bike. The concept of the design is to incorporate all required loops into one circuit. The major factor of consideration during this design phase was space and alignment. With the addition of regenerative braking, the circuit design would take some time. After the completion of a successful fluid circuit design, the available component list needed to be reviewed. Based upon location, alignment, and calculations, the components that complied with our required specification were selected and ordered. During the wait time, the current fluid powered vehicle design was presented to the NFPA staff at the midway review. The competition technical liaisons recommended alterations to the fluid circuit design to improve safety. The recommended alterations were made to the circuit design and the team waited for parts to arrive. Upon the arrival of parts, the fabrication and machining process began. Once all the components were successfully installed and assembled, hose lengths and ending were measured, determined, and manufactured. The assembly of the hydraulic circuit was simple and quick. However, testing showed that there were some faults in our assembly due to some locations that were required for some components for operation. Nevertheless, the team was able to fix all problems discovered during testing and successfully produce an operating fluid powered vehicle in time for the competition.

Fall Semester Plan Execution

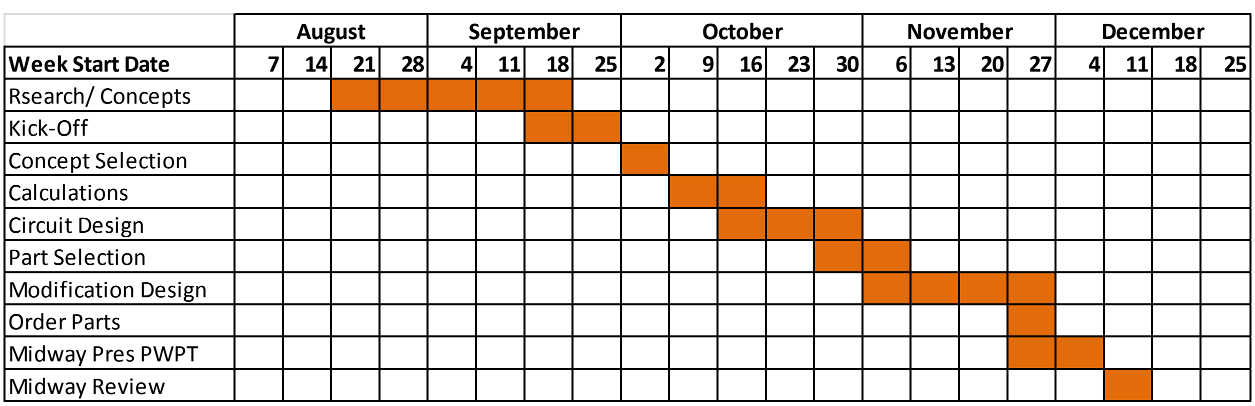

Figure 1

Spring Semester Plan and Execution

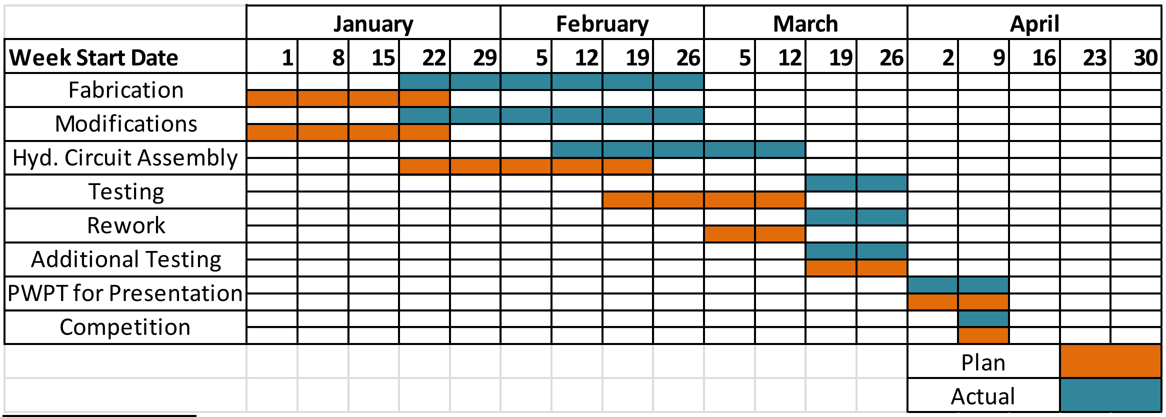

Figure 2

3.1 OBJECTIVES

The vehicle design will use a two wheel bike frame as the base. The main objective for this year's design was to create one circuit that would be able to charge and discharge the accumulator, directly drive the motor, and have regenerative braking. The second main objective was to make sure that the bike would be able to be operated safely by the rider. The number of valves should be reduced and be within reach of the operator. All lines and components should be as compact as possible so that the rider cannot get caught in any lines or moving parts. The weight of the bike should be less than 120lbs so that it can be managed by an average sized adult. Building off of the designed last year our design would remain chainless and require no electrical components. Designing the bike this way will keep it simple and keep the weight down since a battery would not be needed. The bike design will be made so that maintenance can be easily completed and components can be replaced if needed. In summary the objectives for this year's challenge included:

1. Design a hydraulic loop that incorporates all modes in one loop
2. Design a bike that can be easily and safely operated by the rider
3. Include a regenerative braking circuit
4. Design the bike with maintenance and repairs in mind
5. Maintain an advantageous gear ratio leading into the pump
6. Use a two-wheeled bicycle frame and original brakes for safety

4.0 DESIGN
4.1 House of Quality

To help us determine how to go about designing the bike and what factors were the most important to design for we created a house of quality. The house of quality can be seen in figure 3. Based on the house of quality exercise we conducted using weighted values we determined that the acceleration, pedal force, and operating force were the key factors.

	Customer Requirements	Importance wt.	Speed (ft/s)	Acceleration (ft/s^2)	Turn Radius (ft)	Pedal Force (lbf)	Weight (lb)	Alternative Braking Option	Operating Pressure (psi)	Stopping Distance (ft)	Deceleration (ft/s^2)	Volatge Required (V)	Valve Switch Torque (lbf-in)	Hose Length (ft)	Wire Length (ft)	Charge Time (min)	CP	A	B	C
			1	2	3	4	5	6	7	8	9	10	11	12	13	14				
1	High Maintainable Speed	0.15	9	3		9	1		3											
2	High Acceleration	0.15	1	9		1	3		9											
3	Manueverable	0.05	3	3	9		3	1		3	1									
4	Safe	0.10	1	1			1	9	1	9	3	1	3	3	3					
5	Hydraulic Driven	0.20	3	9	3	1			9	3	1	1	1	3						
6	Quick Charge	0.20				3			3							9				
7	Easy to Pedal	0.15				9	3		3							3				
8																				
9																				
10																				
	Total Importance	1.00																		
	Engineering requirement importance		2.4	3.9	1.1	3.7	1.3	1	4.8	1.7	0.6	0.3	0.5	0.9	0.3	2.3				
Performance	Current Product																			
	competitor A																			
	competitor B																			
	competitor C																			
	New Product Targets																			

Engineering Requirements (units); Customer Satisfaction Rating (0.00 - 1.00)

Figure 3: House of Quality

4.2 Hydraulic Circuit Design

The beginning of the development of our hydraulic circuit was researching hydraulic loops. We also evaluated last year's group and their circuit was able to perform direct drive and launching applications. Our circuit required the addition of regenerative breaking that increased the need of more components. Last year only required the need of one ball valve, one check valve, and a relief valve to achieve their two drive loops. In order for us to achieve all of our required drive options; we required one ball valve, one three-way ball valve, one four-way, one check valve, and one relief valve. Last years and our groups avoided the use of solenoid valves due to the need of a battery, which would increase the weight and complexity of our design. Last year's direct drive circuit would start will the fluid moving through the

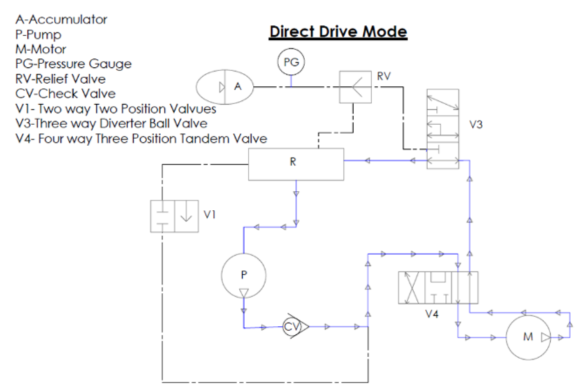

Figure 5: Direct Drive

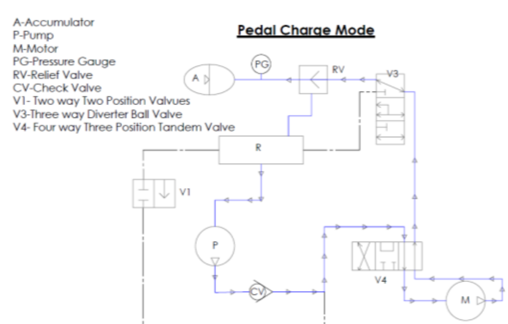

Figure 6: Launch Mode

pump to the pressure relief and then through their in-line check valve. The fluid would then move through a four way junction that led to the pressure gauge and accumulator. This is an issue for this circuit due to the fluid traveling to two unnecessary areas resulting in the loss of operating pressure. The fluid would then travel from the four way junction through the ball valve in the open position to the motor to power the bike. Their charging mode was similar to the direct drive but with the ball valve in the closed position to build pressure between the check valve and the accumulator. Our hydraulic drive loop operated in a similar fashion with some minor alterations. Our original design called for a ball valve after the pump to remove the concern of flow going through the pump causing a safety concern. The technical liaisons said a simple check valve would solve our problem and simplify our operation procedures. Our direct drive is shown in Fig. 5: during this phase our valve one was closed to prevent the loss of flow going to our reservoir. The rider will begin pedaling, which will move fluid with our 3:1 ratio gear set up, that will flow through our check valve. The pressurized fluid would then travel through our four-way valve to the motor. The flow would then exit the motor back through the four way to the three-way that will direct the fluid to the reservoir. In Fig. 6 we should our pedal charging mode: this is similar to our direct drive but with the change in the position of the three-way valve directing the flow to the accumulator to charge. Once the accumulator is charged, the pressure is then released and will travel through our relief, then the three-way to the four-way that is set in the tandem flow location that will direct the flow into the motor correctly. The flow will then travel through the open ball valve that will allow the fluid to enter the reservoir without traveling through our pump due to the check valve as seen in Fig. 7. Our regenerative breaking mode works by the motor acting as a pump by sucking fluid from the reservoir through our open ball valve. The motor would then “pump” the fluid to and through the four-way valve to the three-way that is directed to the accumulator to pressurize as seen in Fig. 8.

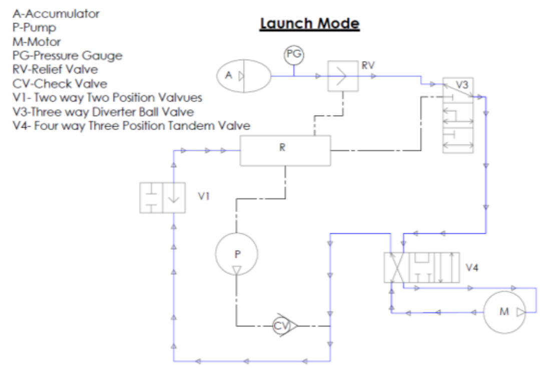

Figure 7: Pedal Charge Mode

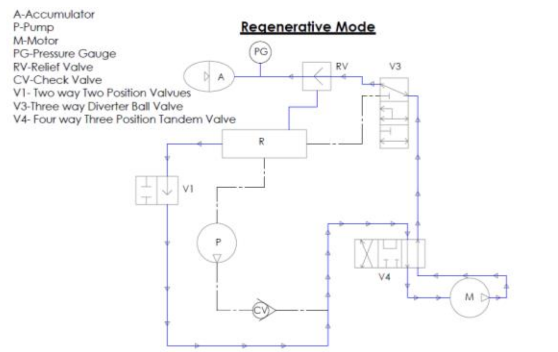

Figure 8: Regenerative Mode

Figure 9: Final Bike Assembly

4.3 Hydraulic and Mechanical Component Selection

The component selection was limited by the parts offered by the NFPA. They offered three different sizes of gear pumps and gear motors (6.6cc, 8.2cc, and 10.2cc) for us to select from. When observing minimum continuous flow it was decided that the 6.6cc pump might not be able to supply enough flow. The 10.2cc pump raised concerns of a high enough operating pressure being unachievable with our gear ratio and pedal RPM. This led to the 8.2cc pump being selected as a middle ground for operating pressure and minimum continuous flow. The 8.2cc motor was selected to maintain a 1:1 ratio with the pump.

When selecting valves we chose based on the needs of our ideal hydraulic system schematics. There was a need for a 3-way two position ball valve and a 4-way three position valve. A 2-way ball valve was also needed once we identified the need of the pump bypass line being able to be controlled. These three valves are crucial to the operation of the system. The applications of the crucial valves were discussed in the hydraulic circuit design portion. A relief valve and check valve were also selected for safety purposes. The check valve is needed to ensure no back flow to the pump, which could have caused the pedals to spin backwards into the operator's legs. The relief valve was selected based on the max pressure of the rest of the system. The max pressure of our lines and accumulator was around 3100 PSI so the relief valve was needed at a maximum of 3000 PSI. The relief valve that was selected had the ability to be adjusted to lower pressures so that it could prevent our system from pushing to its upper limits.

A bevel and a pinion gear (figure 10) were selected to be used as the drive for the pump. A 3:1 gear ratio was selected due to size constraints of the bike. The size of the bevel gear constrained the placement of the pump on the bike. If a larger gear was used the pump inlet and outlet would have been too difficult to get lines in to. The pinion gear was chosen based on companionship to the bevel gear that was selected.

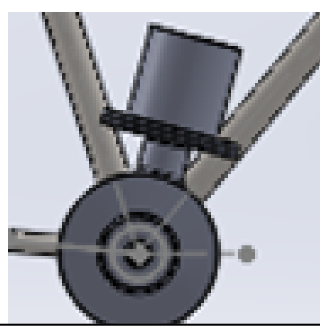

Figure 10: Bevel and Pinion Gears

Figure 11: Final Concept Assembly

The bladder accumulators offered by the NFPA came in sizes of one pint, one quart, and one gallon. The one quart accumulator was selected for our application. In our design the accumulator was to be placed above the reservoir which constrained the size of the accumulator, thus eliminating the one gallon accumulator from being selected. The one pint accumulator would offer less charge for the sprint and efficiency challenges when compared to the one quart accumulator.

4.4 Mechanical Component Design/Assembly

The frame of the bike was a Kent 700 High Roller seen in figure 12. The chain, kickstand, pedal shaft, pedal sprocket, and rear wheel drive sprocket were all removed from the bike because they were not needed for the hydraulic bike. The new design would use a bevel gear on a new pedal shaft that drives a pinion gear connected to the pump. This gearing system provides the rider with a 3:1 mechanical advantage when driving the pump. The new pedal shaft, which can be seen in section 5.0, is able to sit in the existing pedal shaft housing but does require two new 5/8" spherical bearings and a 1" sleeve bearing for a 5/8" diameter shaft. The shaft will have a collar on one end to keep it from sliding out of the housing. The pump is supported by a bracket that is welded to the frame rail going to the seat and the frame rail going to the handle bars. The bracket is aligned so that the pinion gear on the pump meshes up with the bevel gear on the pedal shaft. The reservoir wraps around the top frame rail to save space so the hoses going in and out of the pump. The reservoir has mounting rails for the accumulator to rest on and a mounting bracket for the four-way valve. There are two new plates for the back wheel assembly to fasten to. The back left bracket has three holes in it so the motor can be bolted to it and connect to the axle with a key collar which is fixed to the wheel. The back right plate has only one hole in it with a bearing that holds the end of the axle on the frame. The axle end is threaded so a nut can go on it to make sure the axle cannot come out of the brackets. The bike is designed so that all components can be easily removed from the bike in case there is any need for maintenance or replacement parts. All parts were machined and assembled by members of the team. Lathe turning, boring, drilling, plasma cutting, and MIG welding were the main manufacturing processes used in the fabrication and assembly of the mechanical parts of the bike.

Figure 12: Kent High Roller

Design Variables	Values	Units
Weight Rider	220	lb.
Weight Bike	112	lb.
Weight Total	332	lb.
Incline Grade	3	%
Incline	1.718	Degree
Rolling Resistance Factor	0.002	Concrete
Total Resistance	12.193	lb.
Tire Diameter	27.5	in
Tire Radius	2.292	ft
Torque	167.654	in*lb.
Pressure	1000	Psi

Displacement Motor (90% Eff)	**0.9477**	**in^3/rev**
RPM	122.182	Rev/min
Flow Rate (95% Eff)	0.586	gal/min
Power	**0.342**	**hp**
Size Hose	0.375	in
Velocity of Oil	1.184	ft/s
Pedal RPM	250	Rev/min
Displacement Pump (95% Eff Pump & Motor)	**0.504274**	**in^3/rev**
Pump Displacement (cc)	3.699	cc/rev
Motor Displacement (cc)	15.53	cc/rev

Table 1: Calculation Table

4.5 FEA Analysis

FEA was conducted on both the frame of the bike and the new pedal shaft for the bike. Analysis was completed on these parts because the frame is the entire structure of the bike and the pedal shaft will have a decent amount of stress applied to it especially during the pedal charging mode. The Analysis for the frame can be seen in figure 13. In the analysis a stress load of 220lb was applied. The max stress is 2,546.4 PSI with the max stress being near the back axle. We determined that the frame would still be safe even though the stress was lower than the yield strength because we would not be anywhere near the max stress with our application.

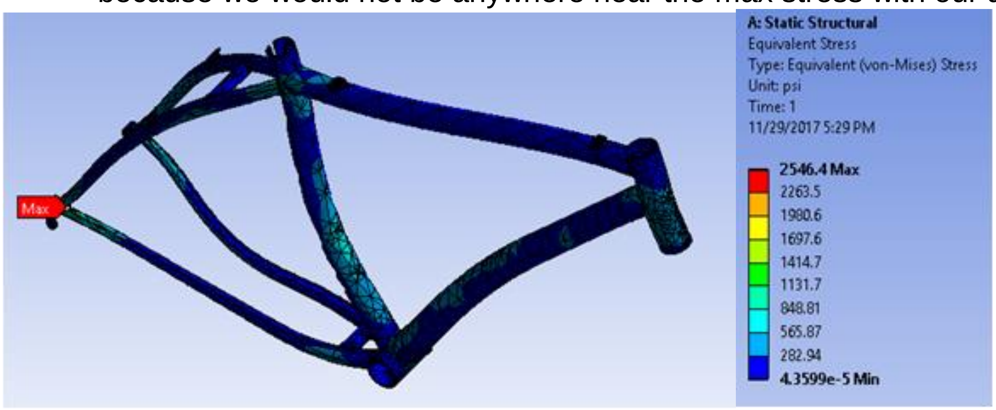

Figure 13: Frame FEA

The second FEA analysis was completed on the pedal shaft which can be seen in figure 13. A load of 220lbs was applied to the shaft. After running the analysis we found that the max stress was 4,216 PSI. This is significantly lower than the yield strength which is around 50,000 PSI. The pedal shaft will be able to withstand the forces applied by the rider.

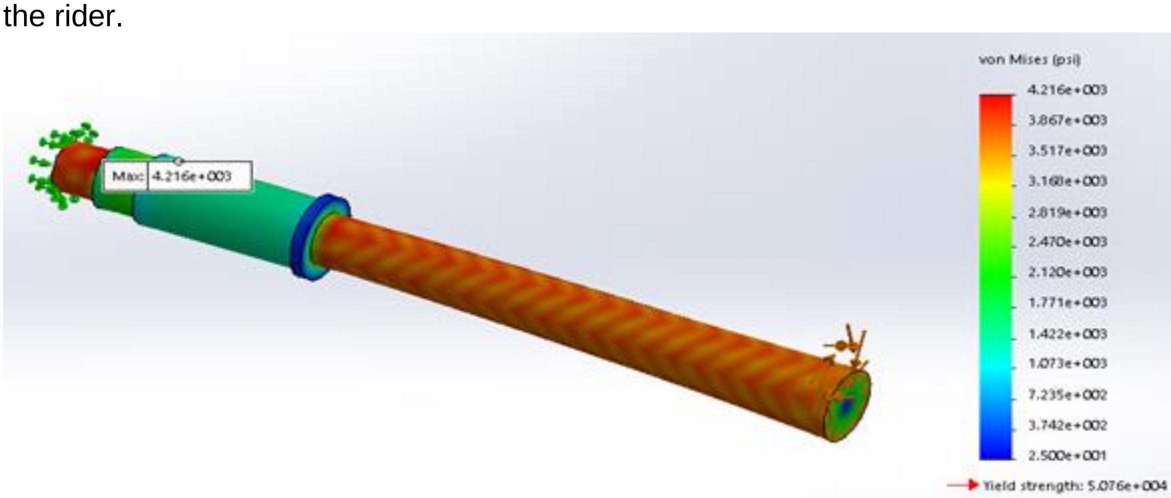

Figure 14: Pedal Shaft FEA

5.0 DESIGN DRAWINGS

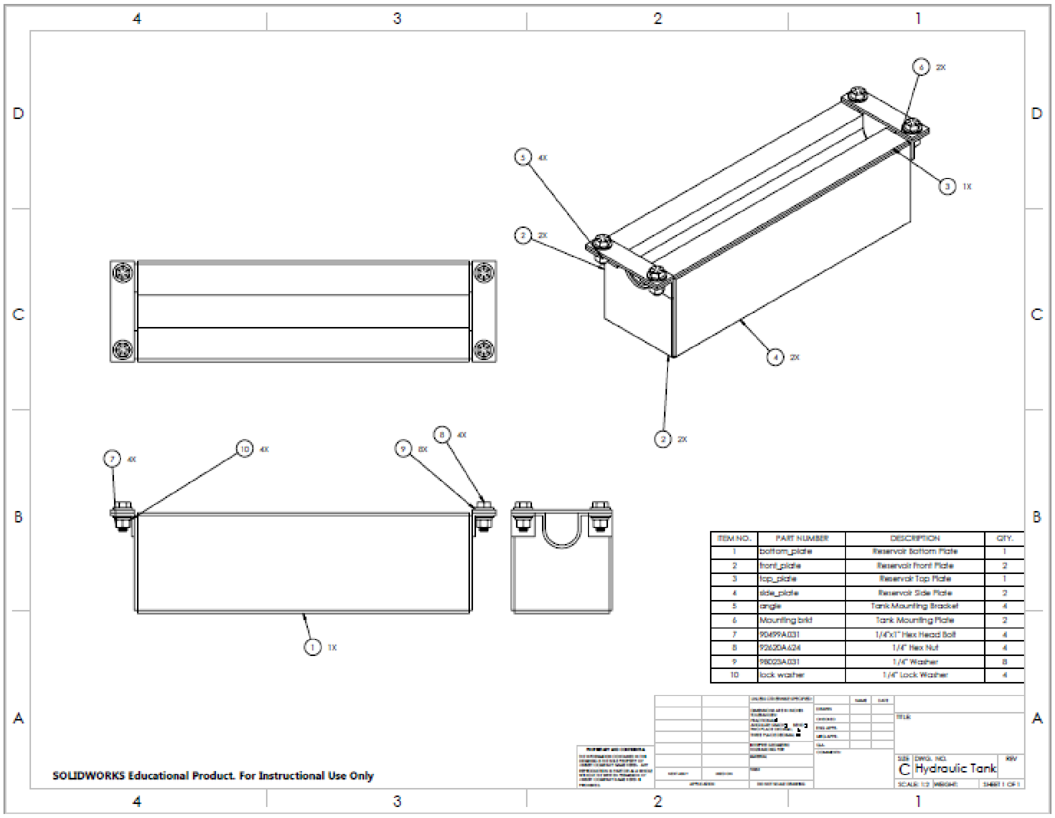

Figure 15: Hydraulic Reservoir Assy

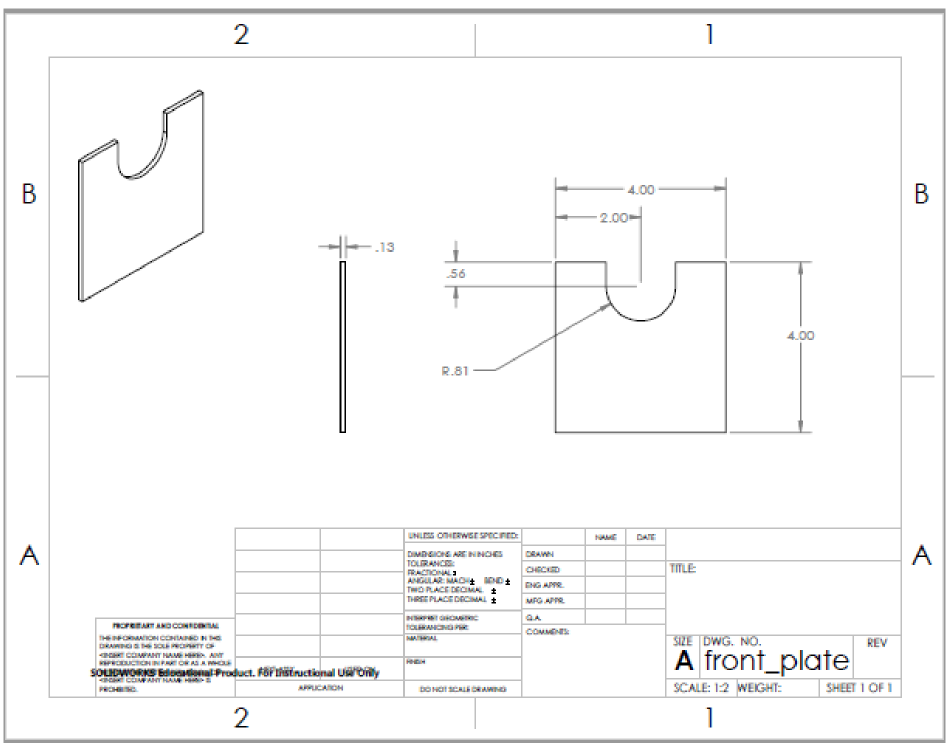

Figure 16: Reservoir Front Plate

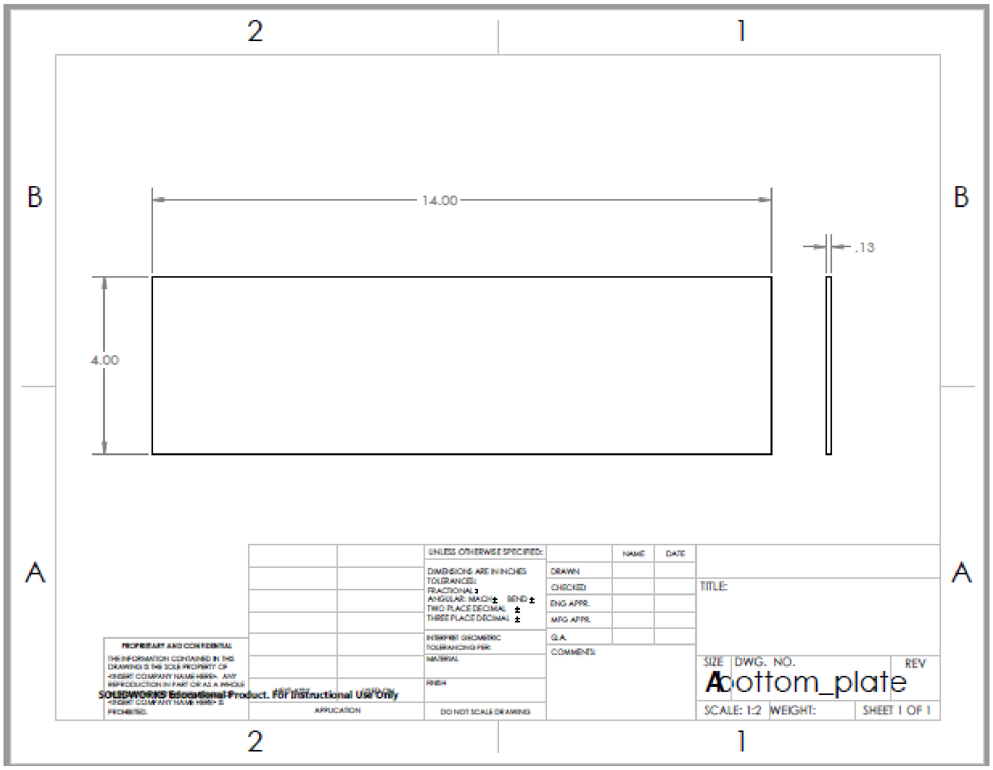

Figure 17: Reservoir Bottom Plate

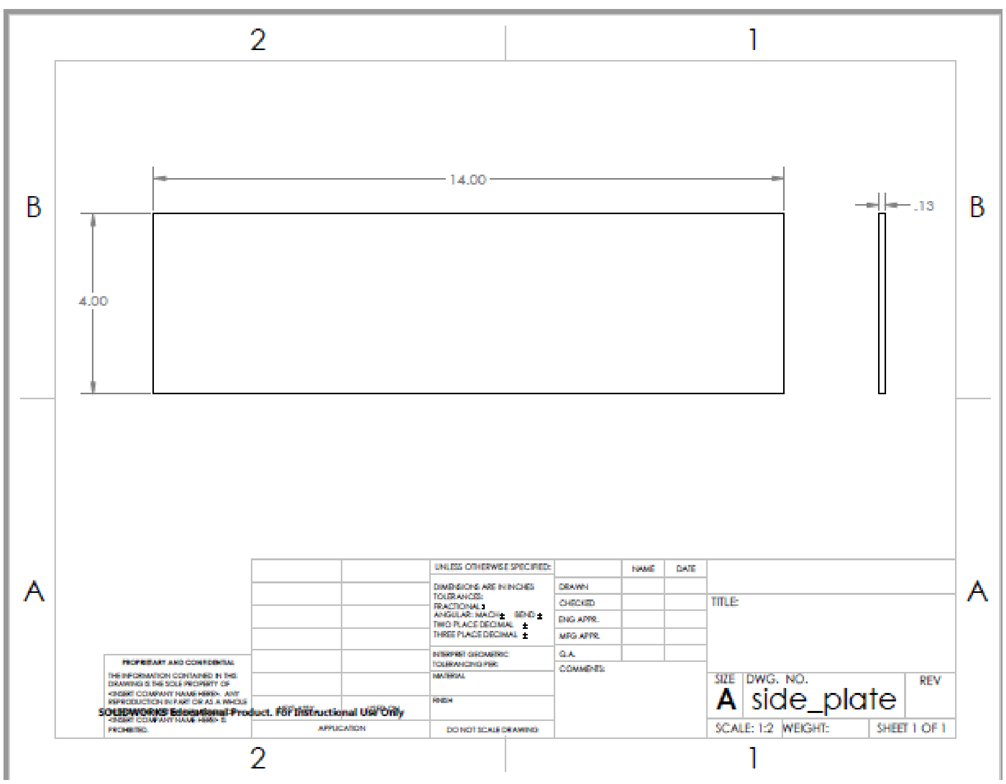

Figure 18: Reservoir Side Plate

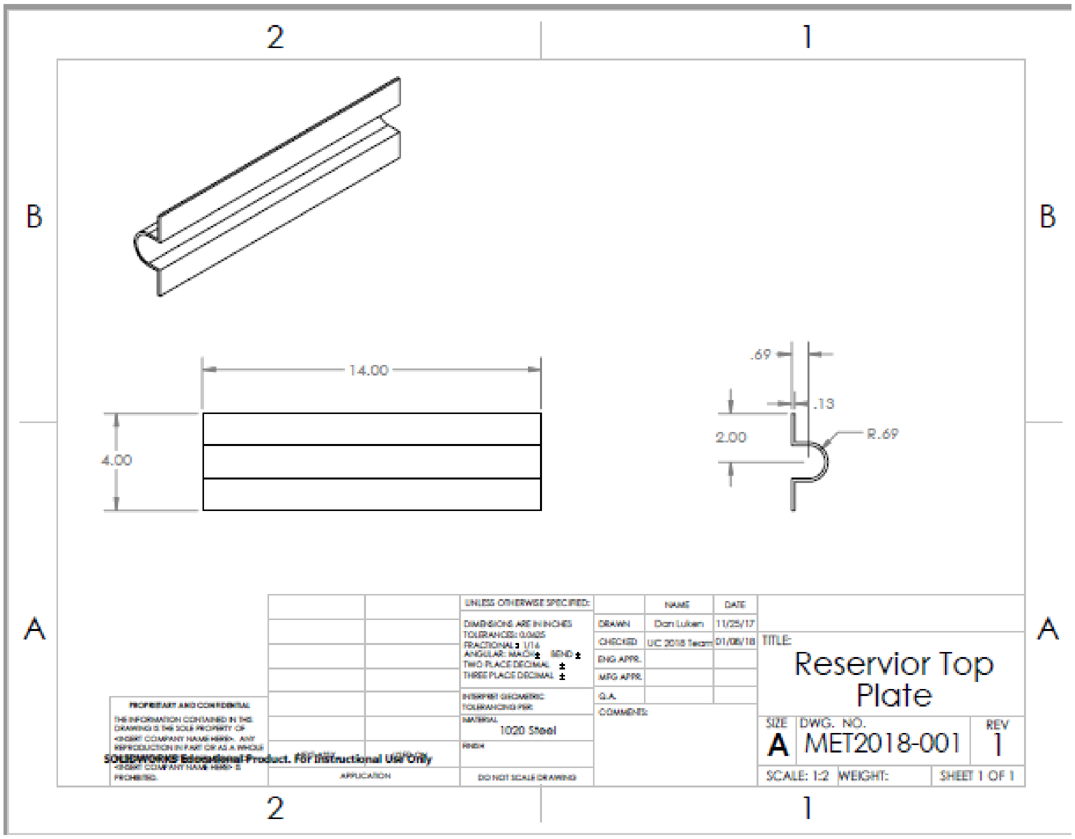

Figure 19: Reservoir Top Plate

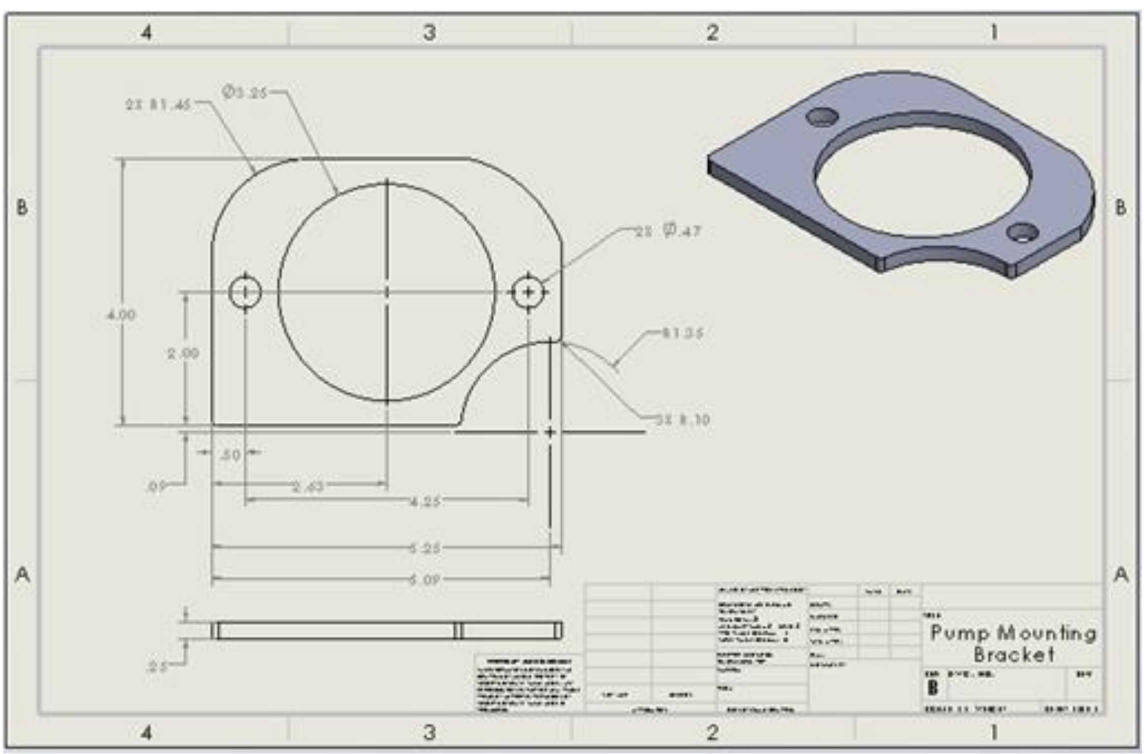

Figure 20: Pump Mounting Bracket

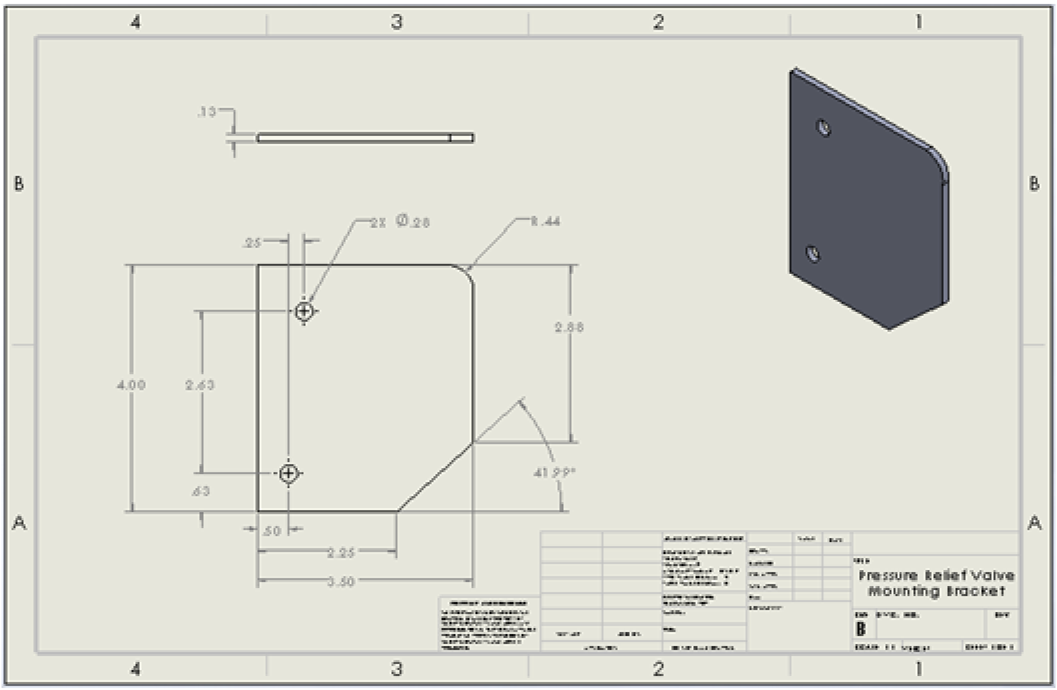

Figure 21: Pressure Relief Valve Mtg Bracket

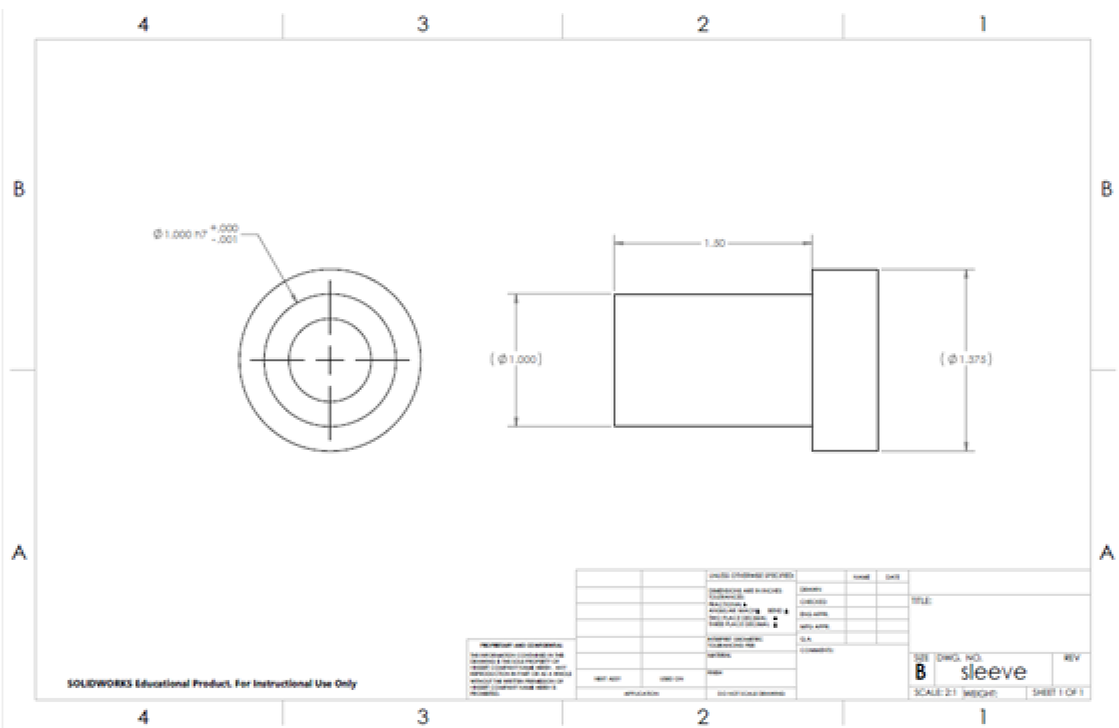

Figure 22: Gear Spline Shaft Adapter Sleeve

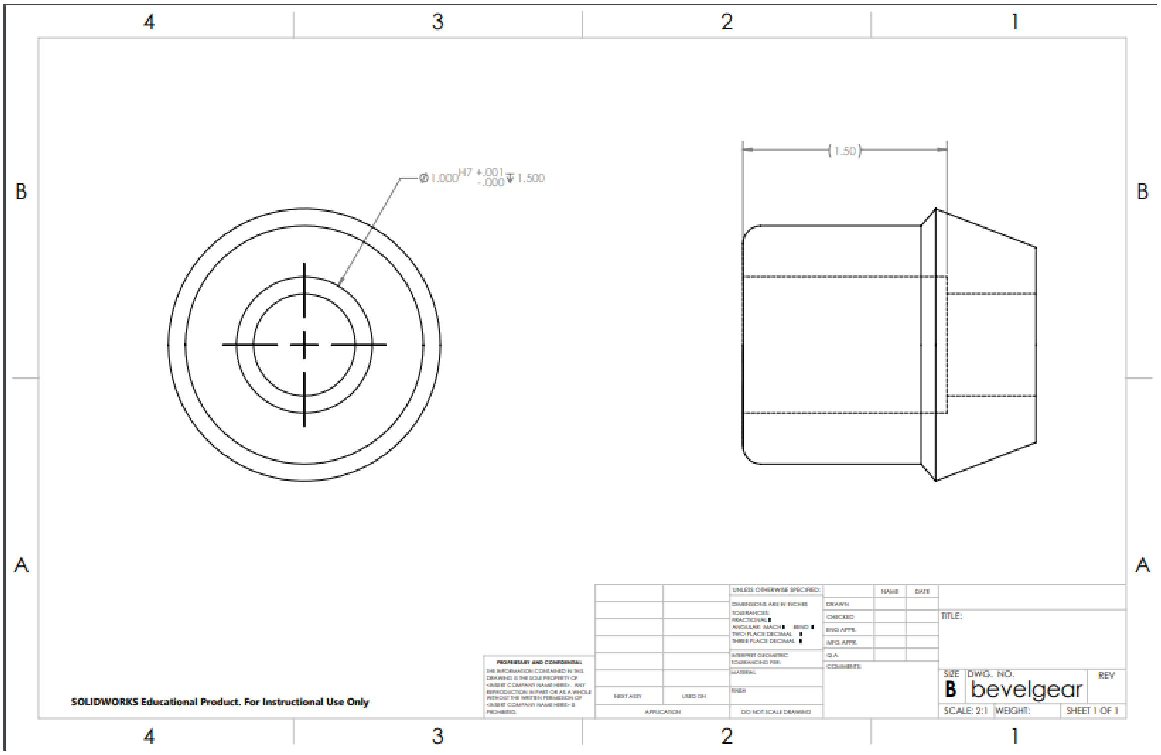

Figure 23: Bevel Gear Machining Drawing

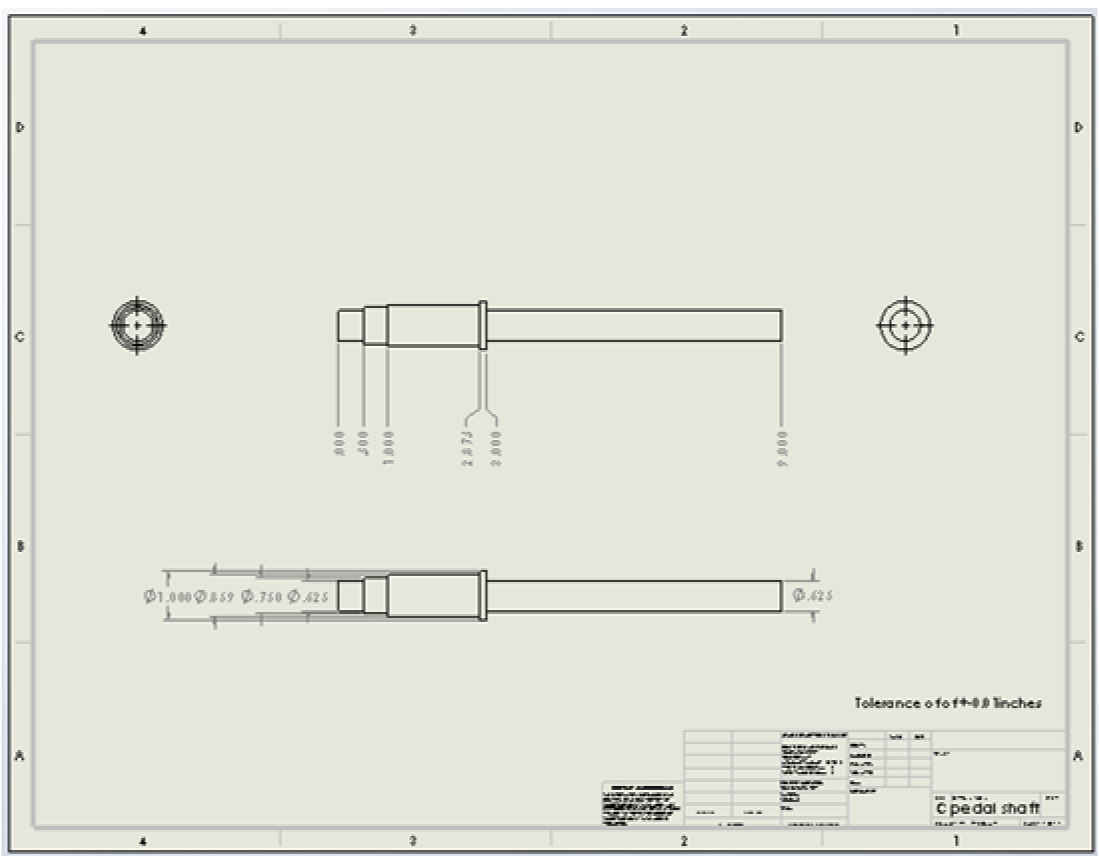

Figure 24: Pedal Shaft

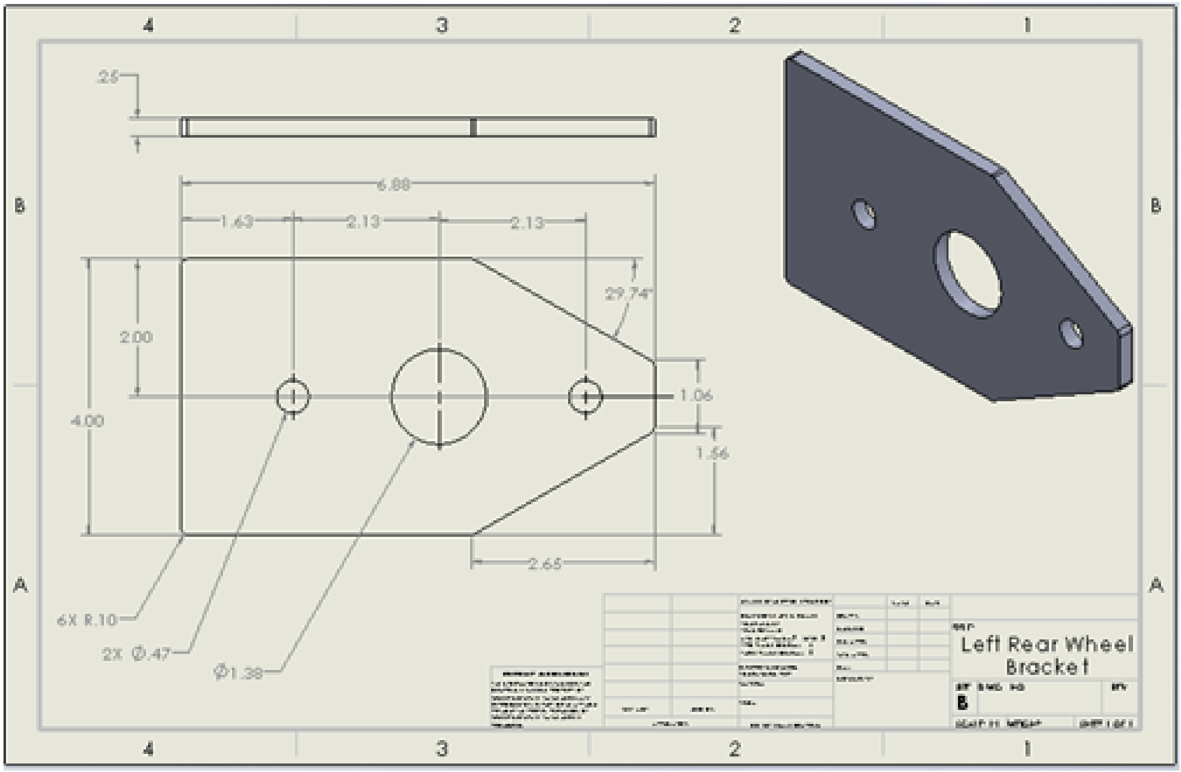

Figure 25: Left Rear Wheel and Motor Bracket

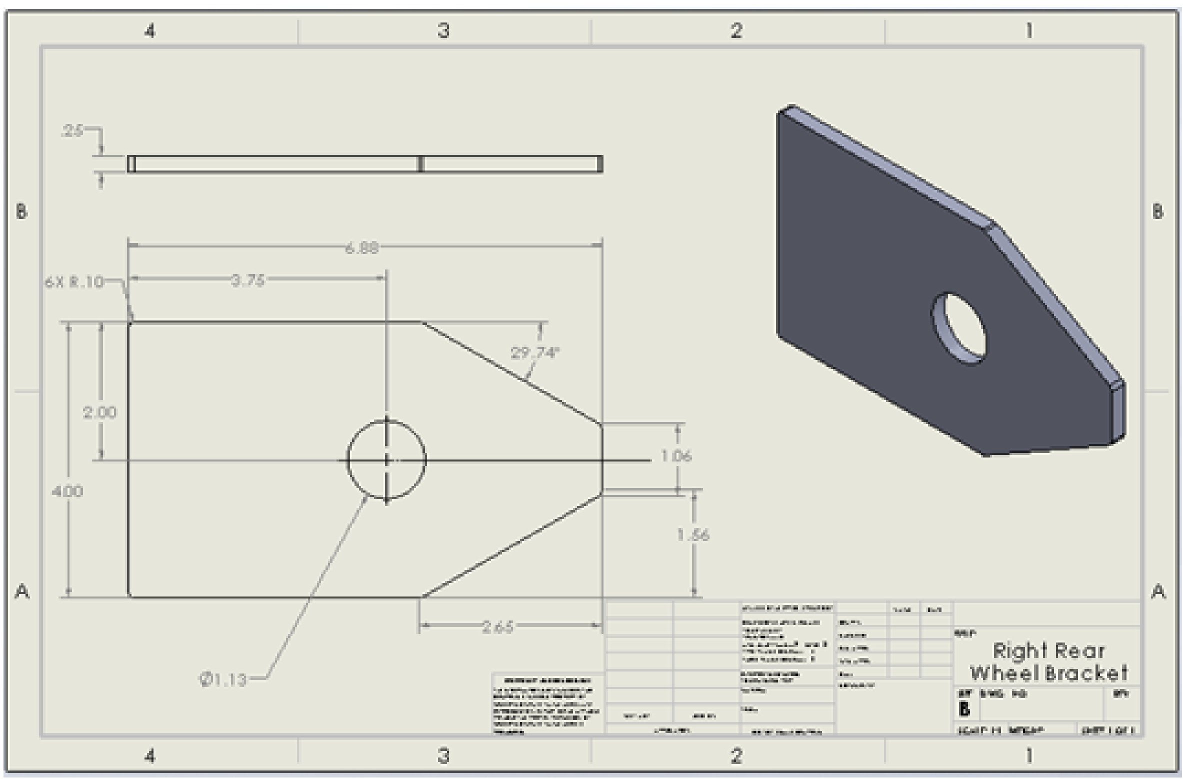

Figure 26: Right Rear Wheel Bracket

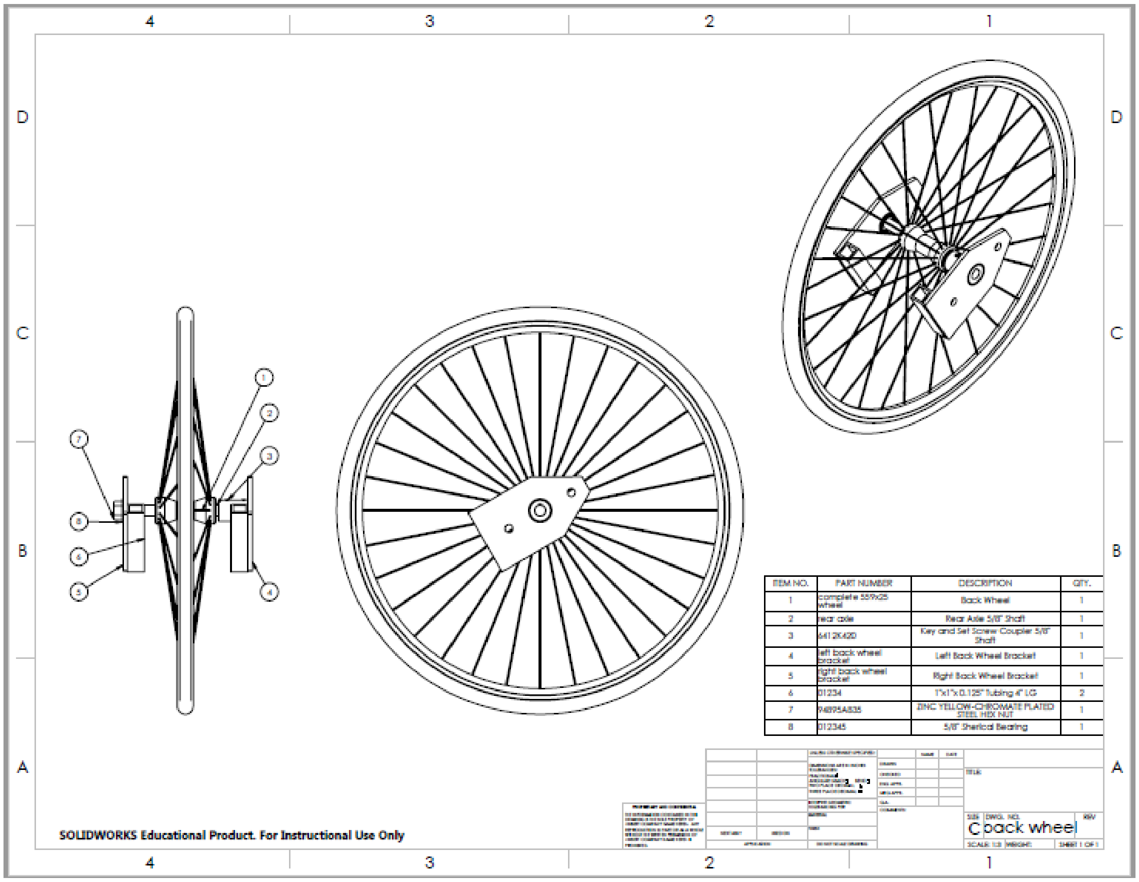

Figure 27: Back Wheel Assembly

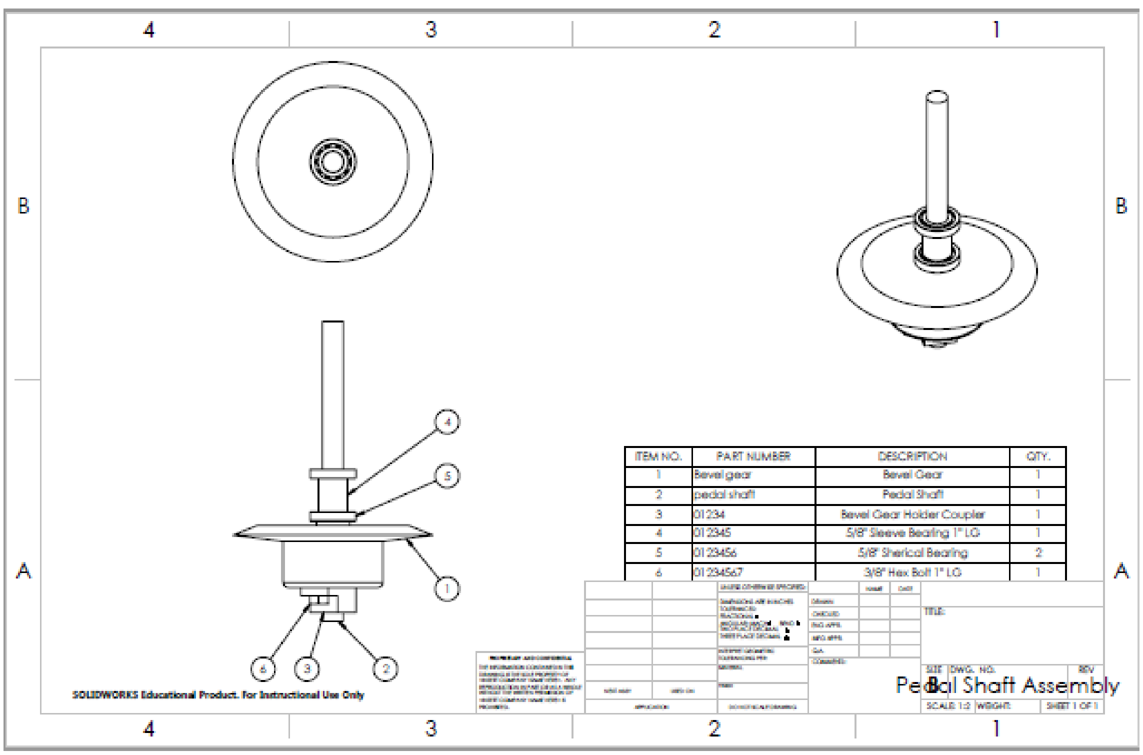

Figure 28: Pedal Shaft Assembly

6.0 COMPONENT LIST

Hydraulic Bike BOM			
Item	**P/N**	**Discription**	**QTY**
Hydraulic Components			
1	26002-RZJ	8.2cc RH Gear Pump	1
2	26703-DAA	10.2cc Gear Motor	1
3	A1QT31003	1 QT Accumulator, 3000 PSI 1-1/16" SAE Fluid Connection	1
4.1	DG17V38C60	4W 3P Directional Control Valve	1
4.2	DGMS31E1OS	Subplate and Bolt Kit	1
5	BV3D-0375SA-1111	3/8" 3000psi 3 way diverter ball value	1
6	BVH-0375S-1111	3/8" 2000psi ball valve	1
7	203101-6-6S	3/8" 37' tee one female swivel and two male	2
8	2071-6-6S	3/8" 37' male to female swivel - 90'	5
9	T3000-6D	ISOBARIC 3100 psi hose	12 ft
10	T203-0609	3/8" male JIC hose ends	5
11	T204-0609	3/8" female JIC hose ends	8
12	T224-0609	3/8 female JIC 90 degree	7
13	C5305-6	3/8" JIC union	3
14	T5000-6D	ISOBARIC 5100 psi hose	1 ft
15	B3HFC	3/4 X 3/8" hex bushing	4
16	6 D5OX-S	Straight tread fitting	3
17	6 F65OX-S	Straight tread swivel 37 d fitting	2
18	6-8 F5OX-S	Straight tread fitting	4
19	6-12 F5OX-S	JIC fitting	1
20	6-6 F6X-S	Straight Swivel	3
21	6-8 C5OX-S	Straight tread	3
22	12-8 F5OG5-S	Reducer-expande	3
23	6-6 F6X-S	Straight Swivel	1
24	10-3/8 F5OG-S	Female adapter	1
25	6 G6X-S	Adapter	1
26	6 HX6-S	Tube fitting	2
27	6 HTX-S	Union	2
28	6-6 FTX-S	Male connector	2
29	19RT59	Spherical Bearing, bore diam 0.625"	3
30	15V660	Involute splined coupling, 9 spline x 2" length	1
31	L1567Y-P	Bevel pinion gear, 3:1 ratio, 0.875" bore, 10 pitch, 20 teeth	1
32	L157Y-G	Bevel gear, 3:1 ratiuo, 1.00" bore, 10 pitch, 60 teeth	1
33	RV-2H	Differential poppet relief valve, cast iron, 3000 psi, 30 gpm, 3/4" NPTF	1
34	-	Reservior	1

Mechanical Components			
35	001	Bike Frame	1
36	002	Pressure Relieve Valve Mounting Bracket	1
37	003	1/4" x 1.5" Hex Bolts	2
38	004	1/4" hex nuts	6
39	005	1/4" x 1" Hex Bolts	4
40	006	1/4" Washer	8
41	007	1/4" Lock Washer	4
42	008	7/16" x 1.5" Hex Bolts	4
43	009	7/16" Lock Washer	4
44	010	7/16" Hex Nut	4
45	011	Pump Mounting Bracket	1
46	012	Right Back Wheel Bracket	1
47	013	Left Back Wheel Bracket	1
48	014	Rear Wheel Shaft	1
49	015	5/8" Hex Nut	1
50	016	Pedal Shaft	1
51	017	5" Hose Clamps	2
52	018	Front Wheel	1
53	019	Front Wheel Axle Assembly	1
54	020	Back Wheel	1
55	021	Bike Stand	1
56	022	5/8" Washers	4
57	023	Pedal Shaft Bearing Housing Assembly	1
58	9414T13	Set Screw Shaft Collar 5/8" Diam	1
59	2868T157	High Load Sleeve Bearing 5/8" Shaft 7/8" OD 1" Long	1
60	6412K42	Set Screw Shaft Coupling	1
61	24	Bevel Gear Locking Colar	1

Table 2: Hydraulic Bike Bill of Materials

7.0 ACTUAL PERFORMANCE ANALYSIS

Testing began shortly after the completion of the bike. The first test performed was the direct drive mode of the hydraulic circuit. It was a little difficult for the rider to get used to the heavier bike but once they got the hang of things the bike worked. As we continued testing some of the teeth on the bike actually broke and the gear started skipping teeth making it hard to pedal and keep the bike going. A new gear was ordered and was put on when it came in. The wait time on the new gear severely limited the amount of time left for testing. With the new gear on testing resumed and the bike worked fairly well. The accumulator was the next part of the circuit that needed to be tested. Before the competition the accumulator was charged to 1200 PSI. This was too high and made it difficult to charge the accumulator. The pressure was dropped to 750 PSI but that was still too high to charge. Finally the accumulator was dropped down to 575 PSI which made charging possible and produced a decent test launch.

During the competition the bike did not perform as well as expected. During the sprint race we were not able to build up enough pressure to get a good torque output in the motor to get started. The start of the race was facing directly into a strong wind of somewhere near 20 to 25 miles per hour. When we were doing our initial calculations we did not take into account the drag force when we were calculating the forces we would need to overcome with the torque output of the motor. Another reason for the lower actual torque output is we had to have fairly long lines from the pump to the motor because of how our circuit was designed and the placement of the valves. The long lines made it difficult to quickly build up pressure and keep where it needed to be. This could have also been addressed in better ratios between the pump and motor. During the competition the gears started slipping because the gears must not have been lined up perfectly when the bike was assembled. Since we used a pinion and bevel gear we were limited on the ratio between them. The biggest ratio we were able to use was a 3:1. If we were able to start the project over we would have used a sprocket and chain to drive the pump. This would have solved the gear slipping issue and would have allowed us to get a better gear ratio and generate a higher working pressure.

8.0 COST ANALYSIS

Our cost analysis consisted of compiling receipts of components and materials used. We added cost for research and development at the rate of $60/hr with a total of 350 hours. The total fabrication process took 125 hours to complete at a rate of $60/hr as well. The cost for our raw steel was only $80. Our analysis shows that our circuit and mechanical components come out to a total of $2,689.71 without the addition of labor. With the addition of our labor, our total cost for our bike is totaled at $31,189.71.

	Labor Rates	Costs
Hydraulic Circuit		$2,387.03
Mechanical Components		$302.68
R&D	Rate of $60/hr for 350 hrs	$21,000.00
Labor Cost Fabrication	Rate of $60/hr for 125 hrs	$7,500.00
Without Labor		$2,689.71
With Labor		$31,189.71

Table 3: Hydraulic Bike Cost Analysis

9.0 LESSONS LEARNED

The following are personal perspectives offered by the University of Cincinnati team members, relaying their own experiences, lessons, and knowledge taken away from the FPVC competition design process.

Mateo Oquendo-Chandler

"At first, I was definitely nervous about being on the team. I had no hydraulic knowledge or prior experiences dealing with it. However, I know can say that I have learned so much after participating in this challenge. By taking lead, dealing with calculations, and communication, I was in the middle of all the action. This forced me to learn quick and understand everything that was going on. I was also given the opportunity to talk one-on-one with hydraulic experts who were so willing to share their knowledge and wisdom. After all was said in done, I realized that a fluid powered vehicle isn't all about how small or light weight you can make it, but how efficient your circuit is. I also learned that crimping a hose isn't just as easy as pinching a piece of metal to the hose. Overall, I enjoyed the experience and believe it was well worth my time and effort!"

Daniel Luken

"One of the biggest things I learned from doing this project is the importance of focusing on detail. There were a couple times during the completion of the project where we had to change and rework some things because we didn't pay close enough attention to the details. Paying attention to detail can save time and make the assembly process easier. I also learned the importance of being flexible and having the ability to overcome adversity. When working on a big project things will change or go wrong and you have to be able to adjust and adapt to the situation so you can get back on track and finish what you need to do. The final thing I learned is the power of hydraulics and how useful they can be in the right application. Hydraulics are very complex and the component selection is a major key to how the hydraulic loop actually works. Overall I learned what it takes to complete a complex project and how you can use fluid power in vehicles."

Chelsie King

"With this project I first had to learn what hydraulic power is. Hydraulic powered vehicles with the use pipes and hoses is not something I have thought much about. The size of the pipes and hoses chosen can juristically change the amount of pressure. This goes for diameter and length. I also learned how much better chains work than meshing gears in this project. It is much easier to get the chain moving than it is for the gears. Having a chain drive system also allows more room for the motor because it gives more design options."

Brandon Kohli

"Going into this project with no experience with hydraulics proved to be more of a challenge than expected. When Jon and I first started researching circuit designs we started to learn a lot about it though. It didn't take us to long to come up with a circuit design but part selection was challenging as well. We weren't sure how exactly the lines would be ran so it was hard to figure out what hose ends we would need, but valve selection wasn't too hard. After attending the NFPA event we learned a lot of stuff about how the valves, hose, and other components really interacted with one another. We never accounted for so many things that can happen in a real life build of a circuit. These were things we did not find research on when designing our circuit because all the research focused on the theory of the circuits. The issues we end up learning about were things like pressure drop in long hoses, ninety degree elbows into outlets causing flow issues, and more flow isn't always better compared to higher pressure flow.

The project was a huge learning experience. Being able to work on a team and problem solve together taught me a lot about teamwork as well. It was nice being able to take some of our coop experience and apply it to our own project and use that to learn how to better run a project in the future."

Jon Von Hoene

"I never dealt with hydraulics or hydraulic circuits. The logic behind the development of the circuit itself was not that difficult, but to determine how to pull it off was different. The locations that were available to mount our valves and pump were limited due to our design. We should have looked at better alternatives to manual valves. Using the manual valves left little areas that were reachable for our operators and extended the overall hose lengths that lowered our operating pressure in the system. We also learned that you do not want to elbow into the pump and motor due to lowering the flow rate due to the fluid being unable to reach terminal velocity. Overall, the project was relatively successful due to our groups willingness to work together to solve issues that we encountered."

Evan Stathis

"Working on any project can teach one many lessons. Regarding this hydraulic bicycle, a few things I learned were more hands on skills, a basic overview in the concept of hydraulics, thinking outside the box when it came to design, and just communication overall. The hands-on skills came when Dan and I were fabricating parts for the bike. I had a hand in fabricating the reservoir and in doing so I refreshed myself on the welding that I already knew and continued learning more techniques that made my welds stronger and cleaner. I also gained some more knowledge in machining when it came to machining a coupler that would couple the pinion gear to the pump. The basic overview of hydraulics came from mild research as well as discussions in our meetings on how the drive loop and regenerative braking loop would work, and what I got out of those discussions is that hydraulics for the most part is using pressurized fluid as energy for a system. This project also taught me to always try to think outside the box when designing because in doing so, one learns to make do with what is placed in front of them and it teaches one how to problem solve with limited space given to them, in this case a limited amount of space on a bike frame. Finally, this project taught me that communication is key because that is how we were able to complete the bike. The communication kept us all organized, on top of what we needed to do, and aided in minimal miscommunication of ideas. Without communication, nothing gets done because of the lack of organization and miscommunication of ideas leads to delays in the design process. Overall, this project was a great learning experience."

10.0 CONCLUSION

Hydraulic fluid power is a versatile field that has many different applications such as lifting, controlling power tools, and driving machinery and equipment. Starting this project no one in the group had much experience with hydraulics or how the work. This project taught us about hydraulics and how they can be used to power vehicles and equipment. One of the biggest things learned from the project was what regenerative braking is and how you can use hydraulics and fluid power to conserve energy. There are a lot of applications that are beginning to use hydraulic regenerative braking to save energy. On application is in semi-trucks where engineers are implementing it in the designs to help improve fuel efficiency. There are a lot of small details to pay attention to while designing and working with hydraulics. Factors such as the size, orientation and location of pump and motor inlets can reduce the efficiency of the system and make it not perform as well. When designing hydraulic systems it is important to try to reduce hose length and achieve the best ratios between the pump and motor so the circuit operates at the optimal working pressure and has the highest efficiency.

11.0 References

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