

University of Cincinnati

NFPA Fluid Vehicle Power Challenge

Final Project Report

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1.0 Abstract

The goal of this challenge was to create a vehicle that operates with human power as the prime mover of the system. The vehicle must also incorporate an energy storage device and fluid power through hydraulic & pneumatic controls. All safety standards set by the NFPA and industry must be met throughout the two semester design process. The vehicle should be designed for one rider to enter, start, stop, and exit unassisted while completing three challenges. This report summarizes the design process, component selection, and cost analysis of the work performed by the 2018-2019 University of Cincinnati team that competed in the NFPA Fluid Power Vehicle Challenge.

2.0 Problem Statement

To design and test a human powered vehicle that operated on hydraulic principles. The vehicle competed in three events with each respective purpose described below.

1. **Sprint:** to showcase the ability of the vehicle to travel 600ft in the fastest amount of time as possible. In this race each team was allotted two tries with the same rider with no assistance from other team members (such as pushing, boosting, etc).
2. **Efficiency:** to exhibit how effectively the vehicle stores and uses energy to propel itself, unassisted, as far as possible proportional to the vehicles total weight (weight of vehicle + rider + safety gear). The vehicle does not have to brake in this challenge and must go at least 100ft. The total distance traveled will be measured from the start until where the riders foot touches the ground.
3. **Endurance:** to demonstrate the safety, reliability, replicability, and durability of the vehicle design and assembly. The vehicle was judged on its ability to travel 1 mile or the greatest distance it travelled in 30 mins, whichever came first. It was required to showcase a regenerative braking system, where the vehicle comes to a complete stop and then travels one full vehicle length forward.

3.0 Project Plan

3.1 Objectives



Our team objectives were determined as a group at one our very first meetings. We believed it was important that all team members were on the same page throughout the duration of the challenge. With a limited amount of knowledge passed down from previous University of Cincinnati teams, we set out with a goal to improve upon last year's school design. Based on notes and feedback we established the following objectives,

1. **Create an efficient hydraulic circuit:** To achieve this goal we had to start at the very beginning when performing calculations to properly size all of the major and minor components. From our course studies and even co-op experience, we learned that it in order to reduce pressure loss it was critical to keep all hydraulic hose length to a minimum, and to be sure to place all fittings in the correct location. In order to compensate for having short hose length, we opted to design a system that was controlled by a PLC. This increased the safety of the bike by locating all electronics at the front of the bike with an easy to use switch panel, mounted conveniently in front of the rider. It was also important that 90 degree fittings were not coming out of the motor or pump.
2. **Have a unique design:** One of the notes we took from lasts years team was that they had trouble balancing on a two wheeled vehicle. To counter this issue we agreed upon on a three wheeled vehicle design that would add additional support and stability.
3. **Grasp new concepts & practice new applications:** Throughout our time at UC, none of our MET courses covered hydraulic fluid power, therefore the majority of this project was foreign for the six of us. Over the course of these past two semesters, we were able to gain knowledge on hydraulic concepts, the fluid power industry, and how it applies to us as future engineers. We also had the opportunity to practice our design skills rather than strictly hands on applications.

3.2 Project Timeline

The timeline of the project was managed in five separate phases that were dictated by design stages and submission deadlines. The Gantt chart that we created reflects what one might see on an industry project.

also used to restrict flow going back in to the pump, as it was a single direction style. The other check valve was to restrict flow of fluid to the motor until in regenerative braking mode. Two pressure relief valves were also implemented for safety in the lines that would see high pressure, this were to ensure no pressure above 3000 psi would occur. The final component of the hydraulic circuit is the two pressure gauges, one to determine the pressure in the accumulator, the other to see the working pressure of the system when in Direct Drive mode.

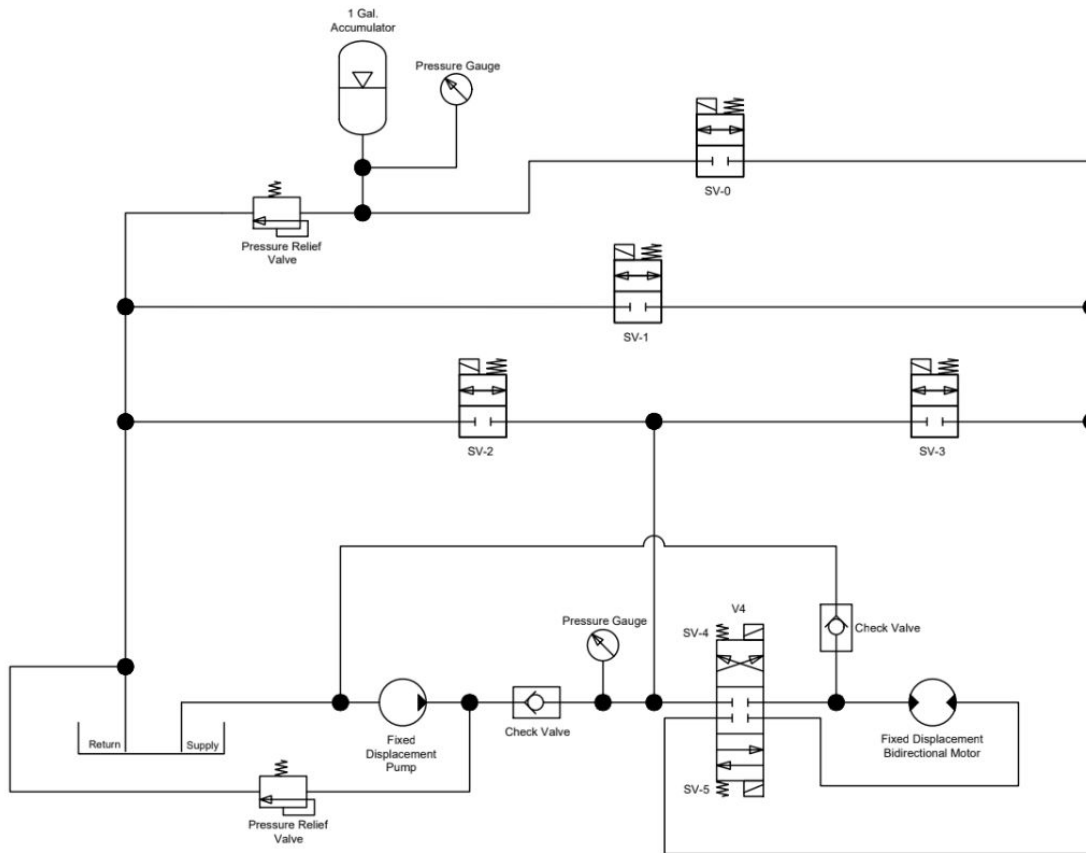


Figure 3: Hydraulic Circuit with valves in their normal state

Direct Drive Mode:

Direct drive was the most commonly used mode to achieve forward motion of the bike. In this mode the fluid would be pulled from the reservoir and into the pump as the rider pedals the bike. As the pump rotates and creates high pressure, the high pressure fluid would then flow through the check valve into the three-position four-way valve labeled V-4 when the SV-5 solenoid was energized. The high pressure fluid passes through the valve and into the motor which causes the motor to rotate, which in turn, rotates the bike wheel, propelling the

rider forward. Once the high pressure fluid passes through the motor, low pressure fluid is returned to the reservoir to begin the process over.

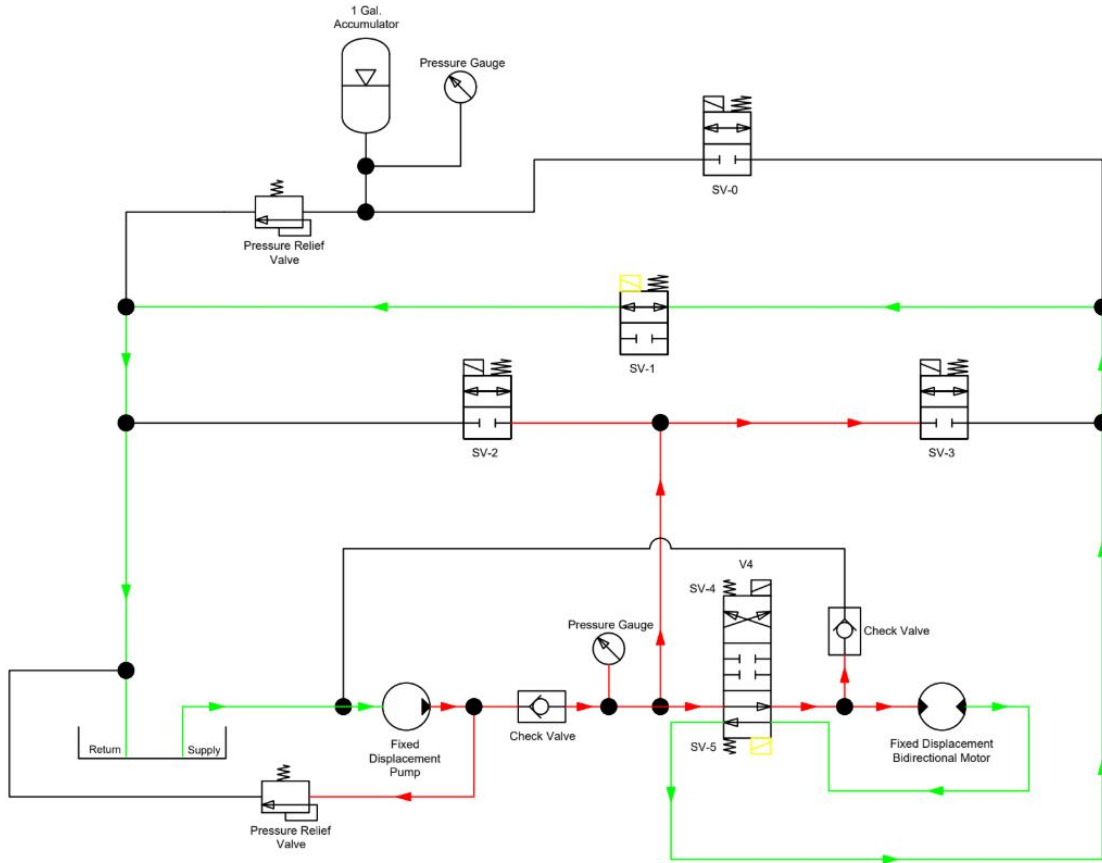


Figure 4: Hydraulic circuit with valves actuated to allow Direct Drive.

Accumulator Charging Mode:

The second mode involves charging of the one gallon accumulator. This was a requirement for the efficiency challenge at the competition. During this mode the rider will again pedal, pulling fluid from reservoir, creating high pressure. This high pressure fluid then flows to the two-position two-way valve labeled SV-3. From there it then flows through another valve labeled SV-0 and into the accumulator. Once the desired pressure is attained in the accumulator, the rider stops pedaling and turns the valves off to store the pressure.

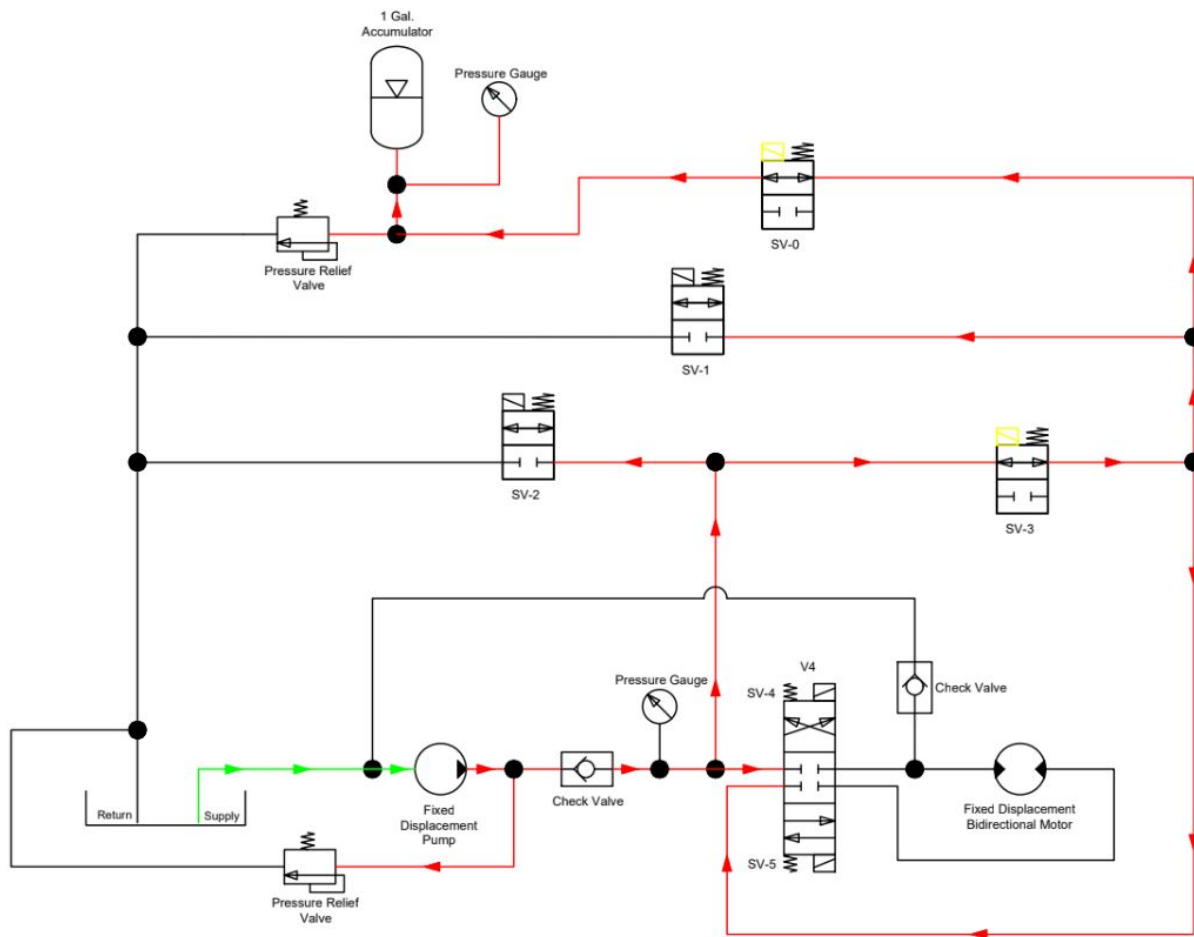


Figure 5: Hydraulic Circuit with valves actuated to allow charging of Accumulator

Accumulator Discharging Mode:

The third required mode is the discharging of the accumulator. In this mode the stored high pressure fluid is released, causing the bike to propel forward without the need for peddling. This is done by the high pressure fluid passing through the two-position two-way valve labeled SV-0 and then to the three-position four-way labeled V-4 when the SV-4 solenoid is energized. After passing through V-4, the high pressure fluid passes through the motor which again turns the wheel enabling the bike to move. Once the fluid passes through the motor the low pressure fluid returns to the reservoir.

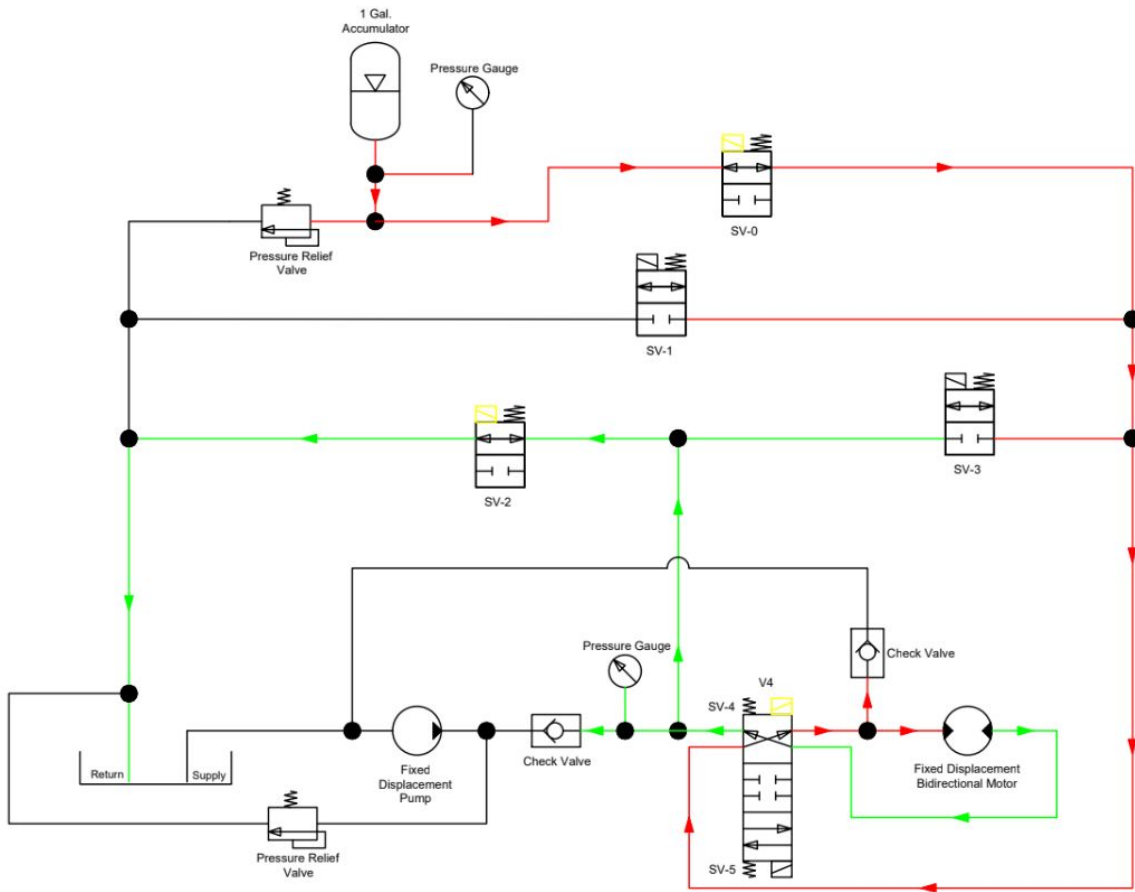


Figure 6: Hydraulic Circuit with valves actuated to allow discharging of Accumulator

Regenerative Braking Mode:

The final mode required was the ability to regenerative brake using the motor as a pump. In this mode whenever the bike is in motion and required to stop, the kinetic energy can be used to pump fluid into the accumulator. This happens when the two-position two-way valve labeled SV-0 and the valve labeled V4 is energized. As the bike is moving the motor is also moving, this in turn makes the motor act as a pump. The motor then draws fluid from the reservoir and creates high pressure. This high pressure is then stored in the accumulator. As the pressure builds the motor sees the resistance from that pressure and slows the bike down. The faster you are traveling the more pressure you will be able to build in the accumulator.

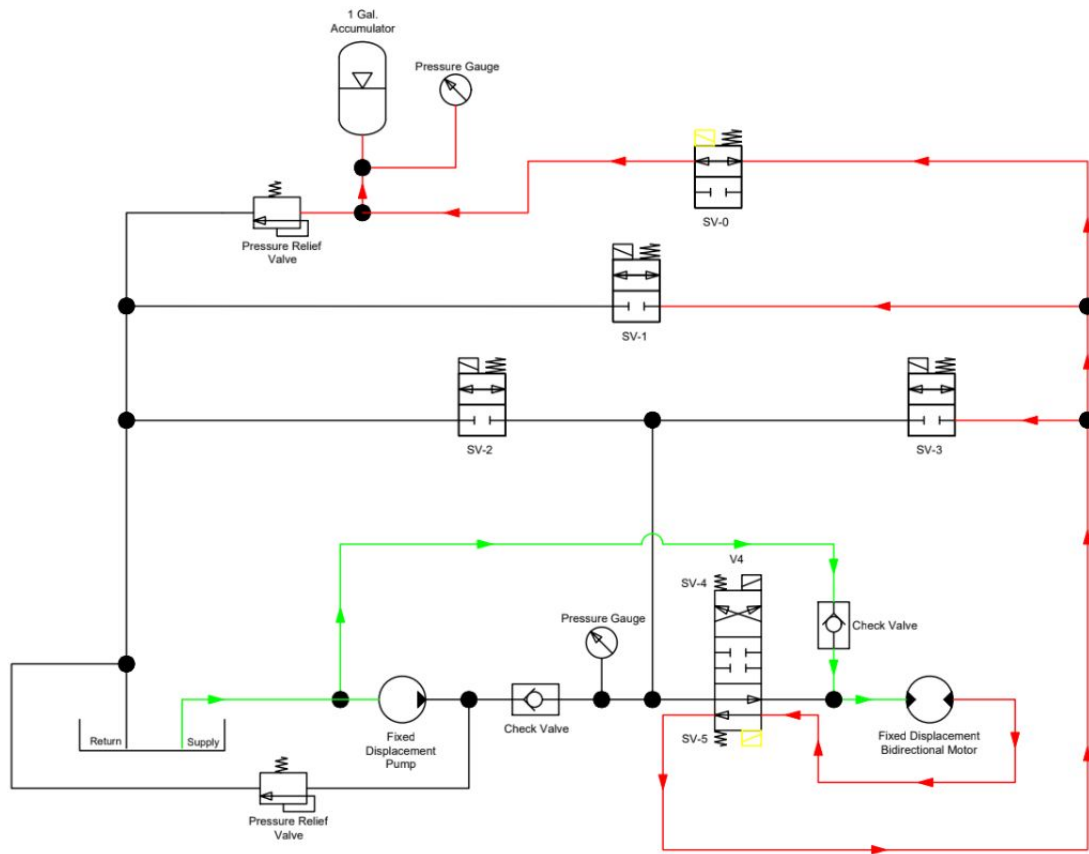
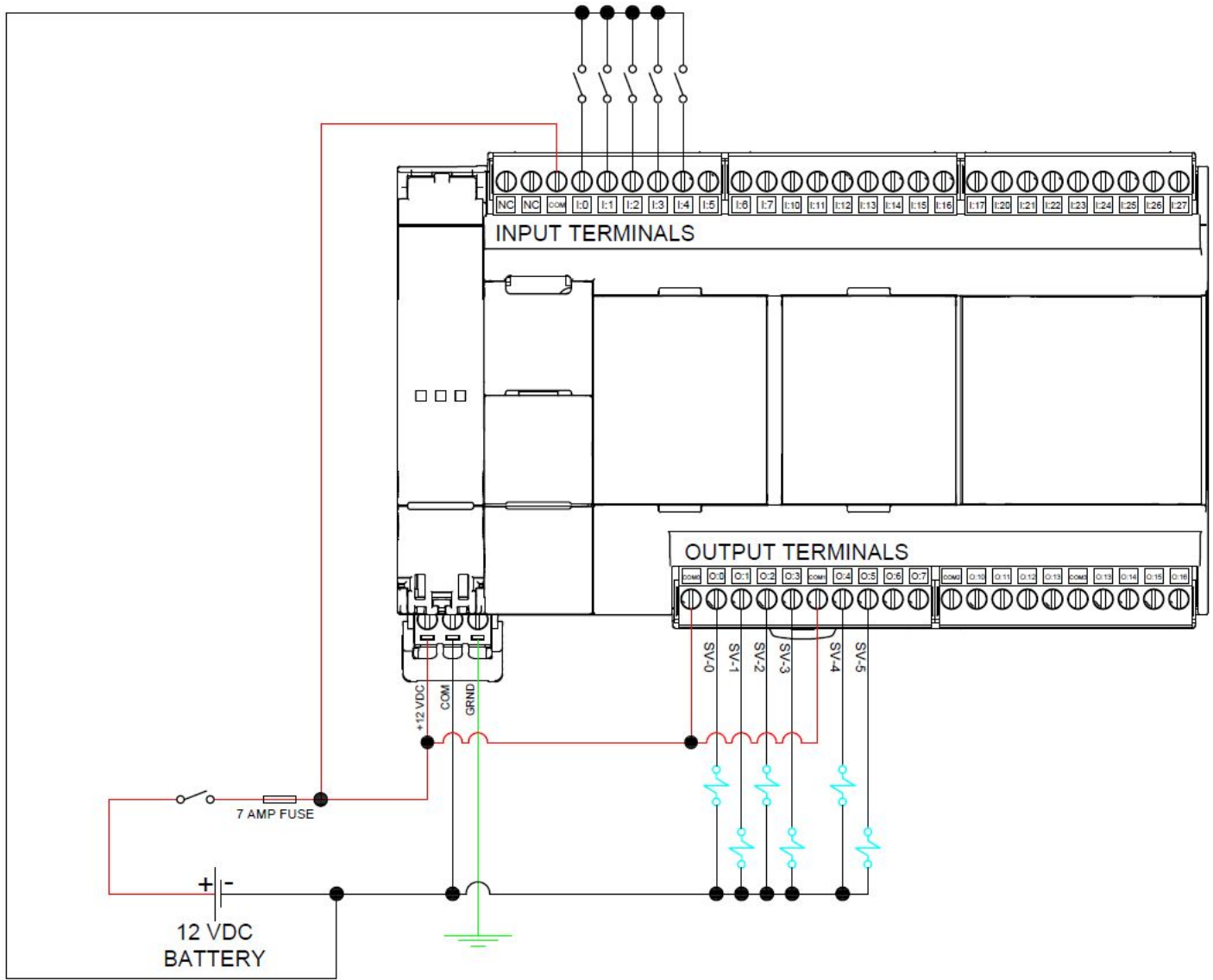


Figure 7: Hydraulic circuit with valves actuated to enable Regenerative Braking.

4.2 PLC Programming

The FC6A-C40R1DE Programmable Logic Controller from IDEC's MicroSmart series was used to control the tricycle's hydraulic circuit. The wiring diagram of the PLC is displayed below.



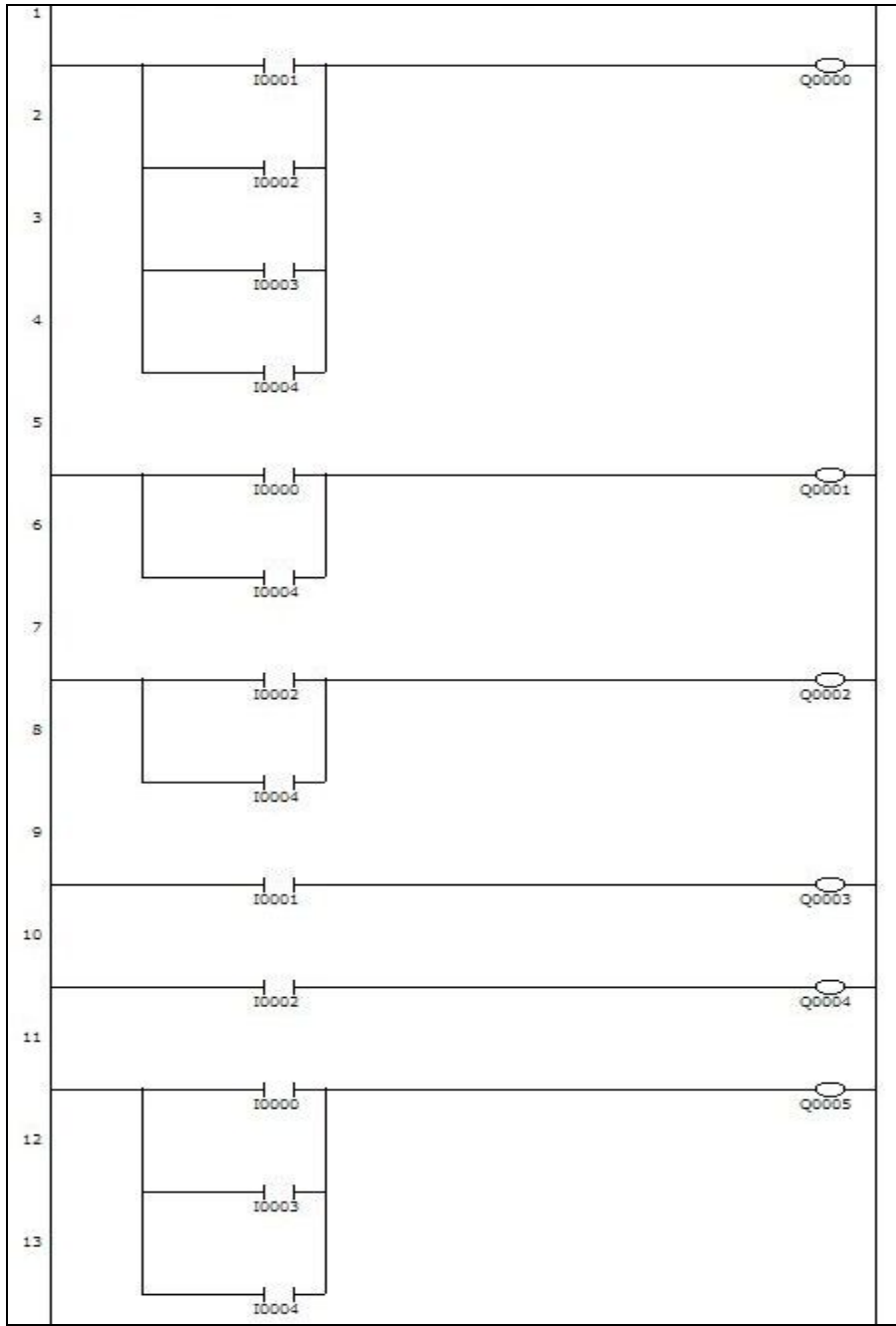


Figure 8: PLC Ladder Logic

The ladder logic used to program the PLC can be seen in the image on the previous page. This program was created in WindLDR Version 8 software and was then uploaded to the IDEC FC6A-C40R1DE PLC.

Each of the six outputs seen on the right side of the rungs corresponds to a solenoid valve in the hydraulic circuit. For example, Q0000 being SV-0 as labeled in the report section 4.1 Hydraulic Circuit Design.

The normally open contacts seen on the left side of the rungs represent the five switches used to switch between modes in the hydraulic circuit.

When Switch I0000 is closed, solenoid valves SV-1 and SV-5 are energized, creating the circuit seen in figure 4, Direct Drive Mode

When Switch I0001 is closed, solenoid valves SV-0 and SV-3 are energized, creating the circuit seen in figure 5, Accumulator Charge Mode

When Switch I0002 is closed, solenoid valves SV-0, SV-2 and SV-4 are energized, creating the circuit seen in figure 6, Accumulator Discharge Mode

When Switch I0003 is closed, solenoid valves SV-0 and SV-5 are energized, creating the circuit seen in figure 7, Regenerative Braking Mode

The last switch, Switch I0004, is an added safety feature to purge the hydraulic circuit of any unwanted pressure. When Switch 10004 is closed, solenoid valves SV-0, SV-1, SV-2, and SV-5 are energized, allowing any fluid in the system to discharge back into the reservoir.

4.3 Hydraulic Component Selection



The hydraulic components were selected based off of our desired design, and then the price and availability of these parts. To start off with the the hydraulic component selection we looked at what parts were offered through the NFPA as they would be free to us and gave us a good baseline of what we thought the other teams would be using as well. When looking at the donated parts list we decided to go with the pump, motor, accumulator, and solenoid valves.

We selected which pump and motor we wanted based off of the calculations that we conducted during the fall semester and found that we wanted a .54 CID motor and then through our gear ratios, we selected the matching pump at .58 CID. When we looked at the accumulator, we knew we wanted to have one that was larger than 1 quart but did not want to opt for the 1.5 gallon accumulator so we went with the 1 gallon one.

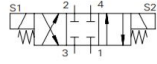
When we looked at what type of valves we wanted to go with, we knew that we were going to do the solenoids from the start so we had to spec out which valves we needed based off of our hydraulic circuit and then selected the following solenoid valves and the corresponding line bodies that worked for our system. The remaining components consisted of fittings and those we just ordered what we thought we would need from the NFPA and then used Grainger for the remaining special fittings that we ended up needing during the fabrication process.

Order Method	Part	Part No.	Price /unit
NFPA Part List	Check, 1 to 2	CV3-8-P-0-004	\$7.36
NFPA Part List	Coil, 12VDC DIN , J type	300AA00081A	\$12.22
NFPA Part List	Coil Spacer, 10 size	02-179226	\$2.11
NFPA Part List	Fitting, -6 JIC male to -6 JIC female swivel, 45 degree	2070-6-6S	\$1.74
NFPA Part List	Fitting, -6 JIC male to -6 JIC male, 90 degree	2039-6-6S	\$1.35
NFPA Part List	Fitting, -6 JIC male to -6 JIC female swivel, 90 degree	2071-6-6S	\$1.98
NFPA Part List	Fitting, -6 JIC male "T"	2033-6-6S	\$1.84
NFPA Part List	Fitting, -6 JIC, male to female swivel with male branch	203101-6-6S	\$2.59
NFPA Part List	Fitting, -6 SAE male to -6 JIC male, straight	202702-6-6S	\$0.75
NFPA Part List	Line Body, VC08-2, Aluminum SAE -6	02-160731	\$11.29
NFPA Part List	Line Body, VC10-2, Aluminum SAE -6	876700	\$11.98
NFPA Part List	Line Body, VC10-3, Aluminum SAE -6	876704	\$17.46
NFPA Part List	Relief, Direct Acting	RV1-10-S-0-30	\$21.60
NFPA Part List	Solenoid, 2 pos. 2 way Bi-poppet, normally Closed	SBV1-10-C-0-00	\$35.54
NFPA Part List	Solenoid, 2 pos. 3 way Spool 1-2/1-3	SV1-10-3-0-00	\$19.59
NFPA Part List	Solenoid, 3 pos. 4 way, (all ports blocked in neutral)	SV9-10N-E-0-0-00	\$37.42
NFPA Part List	Gear Motor, 0.54 CID, Keyed Shaft .625", Bi-rotation, internal drain ADMAD02AMA01AC0000000A0A	26702-DAB	\$274.69
NFPA Part List	Gear Pump, 0.58 CID, Keyed Shaft .625", CW rotation	26003-RZG	\$178.87
NFPA Part List	Accumulator, 1 gallon, SAE -20 port	A13100-3	\$339.90
Mick - Grainger	Reservoir	na	\$305.29
Mick - Grainger	Hyrdualic Fittings	na	\$133.18
Mick - Grainger	Hyrdualic Fittings	na	\$58.33
Mick - Grainger	Hyrdualic Fittings + check valves	na	\$163.61



SV9-10-E - Solenoid Valve

4-way, 3-position spool type solenoid valve
Up to 23 L/min (6 USgpm) • 210 bar (3000 psi)

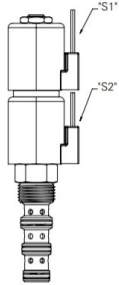


Operation

In the de-energized (center) position, all ports are blocked. When solenoid 1 (S1) is energized, flow is directed from port 3 to port 4 and from port 2 to port 1.

When solenoid 2 (S2) is energized, flow is directed from port 3 to port 2 and from port 4 to port 1.

Sectional View



Performance Data

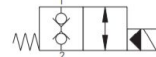
Rating and Specifications

Performance data is typical with fluid at 21.8 cST (105 SUS) and 49°C (120°F)	
Typical application pressure (all ports)	210 bar (3000 psi)
Cartridge fatigue pressure (infinite life)	210 bar (3000 psi)
Fatigue pressure	3,000 psi per NFPA/T2-6-1 R2-2000
Rated burst pressure	(626 bar) 9090 psi per NFPA/T2-6-1 R2-2000
Max flow	6 USgpm
Temperature range	-40° to 120°C (-40° to 248°F)
Coil duty	Continuous from 85% to 110% of nominal voltage
Coil power	26W
Cavity	C-10-2
Fluids	All general purpose hydraulic fluids such as: MIL-H-5606, SAE 10, SAE 20 etc.
Filtration	Cleanliness code 18/16/13
Housing material (standard)	Aluminum
Weight including coil	0.95 Kg (2.1 lbs)
Seal kit	889625 (Buna-N), 566080 (Viton®)
Internal leakage	246 cm ³ /min (15 in ³ /min) max. @ 210 bar (3000 psi)

Viton is a registered trademark of E.I. DuPont
Endurance tested to 1 million cycles at full rated flow and pressure.

SBV1-10-C - Solenoid Valve

2-way, 2-position, normally closed, bi-directional, poppet type solenoid valve
76 L/min (20 USgpm) • 210 bar (3000 psi)



Operation

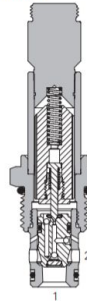
In the de-energized position the valve is blocked in both directions.

When the solenoid is energized the pilot poppet is released from the seat allowing the main poppet to open. A series of internal check valves allows full flow in both directions.

Features

Hardened and ground working parts. Lapped seat for low leakage. IP69K Tough coil compatibility. Continuously rated. Compact design with low pressure drop. 210 bar working pressure.

Sectional View



Performance Data

Rating and Specifications

Performance data is typical with fluid at 21.8 cST (105 SUS) and 49°C (120°F)	
Typical application pressure (all ports)	210 bar (3000 psi)
Cartridge fatigue pressure (infinite life)	210 bar (3000 psi)
Rated flow	76 L/min (20 USgpm)
Internal leakage	5 drops/min, max @ 210 bar (3000 psi)
Temperature range	-40° to 100°C (-40° to 212°F)
Coil duty	Continuous from 85% to 110% of nominal voltage
Cavity	C-10-2
Fluids	All general purpose hydraulic fluids such as: MIL-H-5606, SAE 10, SAE 20 etc.
Filtration	Cleanliness code 18/16/13
Housing material (standard)	Aluminum or steel
Weight cartridge only	0.18 kg (0.39 lbs)
Seal kit	565806 (Buna-N), 889627 (Viton®)

Viton is a registered trademark of E.I. DuPont

Figure 9: The two configurations of solenoid valves used for our hydraulic circuit

4.4 Component Design Layout & Assembly



For ease of design, the frame was made out of spare 80/20 extruded aluminum and lined up perfectly with where the bolts for the original bike rear basket were supposed to go. By using 80/20, parts were able to be adjusted and moved around on the bike to accommodate the various other hydraulic components.

The picture below (Figure 10) shows where the pump was placed on the bike. Not seen in this picture is the adapted pump mount. After testing, the pump appears to wiggle on the mount shown, so a thicker steel mount was installed and a support piece was welded to the frame for additional support. Also seen in the top picture is a clearer view of where the placement is of the reservoir. Holes were made in the 80/20 for the bolts to go through it and mount the reservoir to the 80/20.



Figure 10: Placement of the pump and the reservoir.

In Figure 11 the placement of the motor is shown. It was screwed into the bottom of the 80/20 and secured with L-brackets. However, similarly to the pump, there was wiggling of the motor and an additional steel plate was made to add support. Another problem that occurred was that the chain was rubbing the frame of the bike, so by adding the new steel bracket, the chain no longer was grazing the frame.



Figure 11: Placement of the motor on the underside of the 80/20 frame.

As for the placement of the accumulator, there were plans on placing it on the underside of the bike, however there were concerns of the riders heels knocking the accumulator while pedaling. Due to this concern, the accumulator was mounted on the back of the bike on top of the 80/20 frame and attached using large hose clamps to a metal plate bolted onto the 80/20. Also seen in Figure 12 below, the hoses are seen and where they are attached. In the front of the bike, the battery, PLC, and the switches were all attached on the front of the bike by making use of the the mounting bracket from the original front bracket that the bike

came with. The placement of the battery, PLC, and switches were imperative to be placed on the front of the bike because they made the bike stable. If they were on the back of the bike, the bike would have tipped backwards.



Figure 12: Placement of the accumulator, battery, PLC, switches, and hoses.

The last of the major components to be mounted were the PLC controls. This included the 12V car battery, IDEC PLC, control switches, and respective covers. To protect the battery we decided to go with a lightweight and inexpensive battery cover. The specific cover we chose allowed for easy mounting to the front of the bike using a fabricated bracket. After an unsuccessful search for an off-the-shelf solution to protect the PLC and switches, we decided to design 3D printed covers to hold each of the components. Below are the models of the solutions we came up with. These boxes allowed us to customize how we were going to attach the components to the front of the bicycle, sitting above the battery mount.

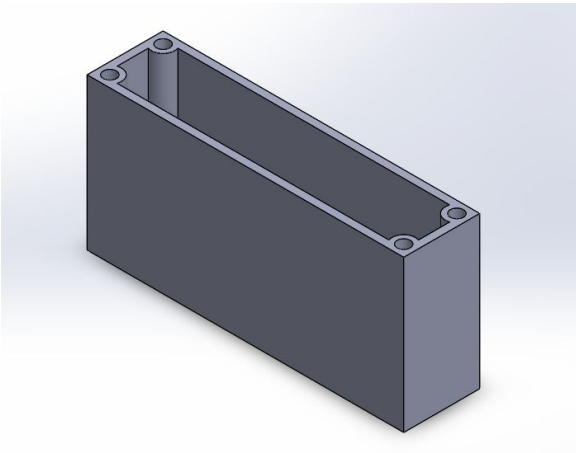


Figure 12: Each of the switches were bolted into a thin piece of metal that acted as the lid on the switch box seen above.

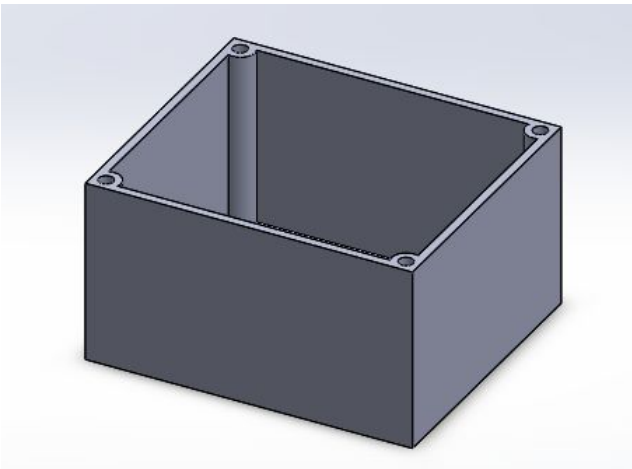


Figure 13: The PLC box needed to be simple and have enough room to hold the necessary wiring.

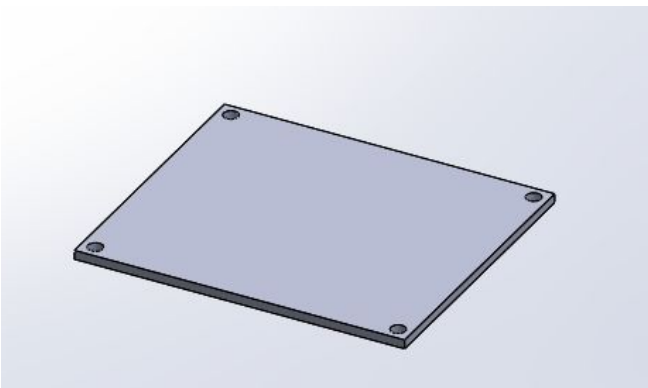


Figure 14: The PLC box cover matched the box is thickness, with its purpose to seal off the box in order to keep water, dust, and debris away from the PLC.

4.5 FEA Analysis

A FEA analysis was performed to determine if the main frame of the tricycle would be strong enough to hold the load of the components. Since the main components were localized on the back of the tricycle, the strength of the frame was a concern. Once the FEA analysis was run, it confirmed that the structure of the frame would be able to handle the load of the main components. Since the results were positive, it was unnecessary to add structure to the back of the tricycle frame.

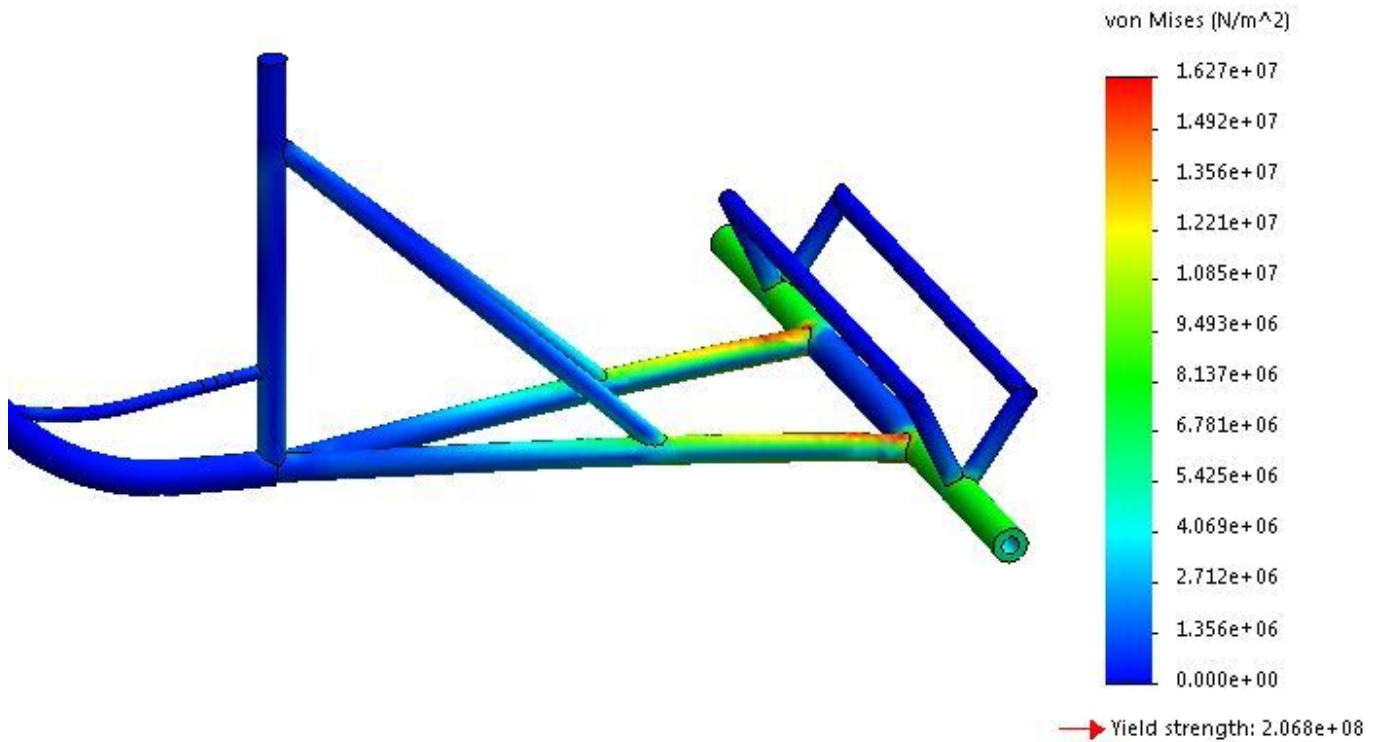
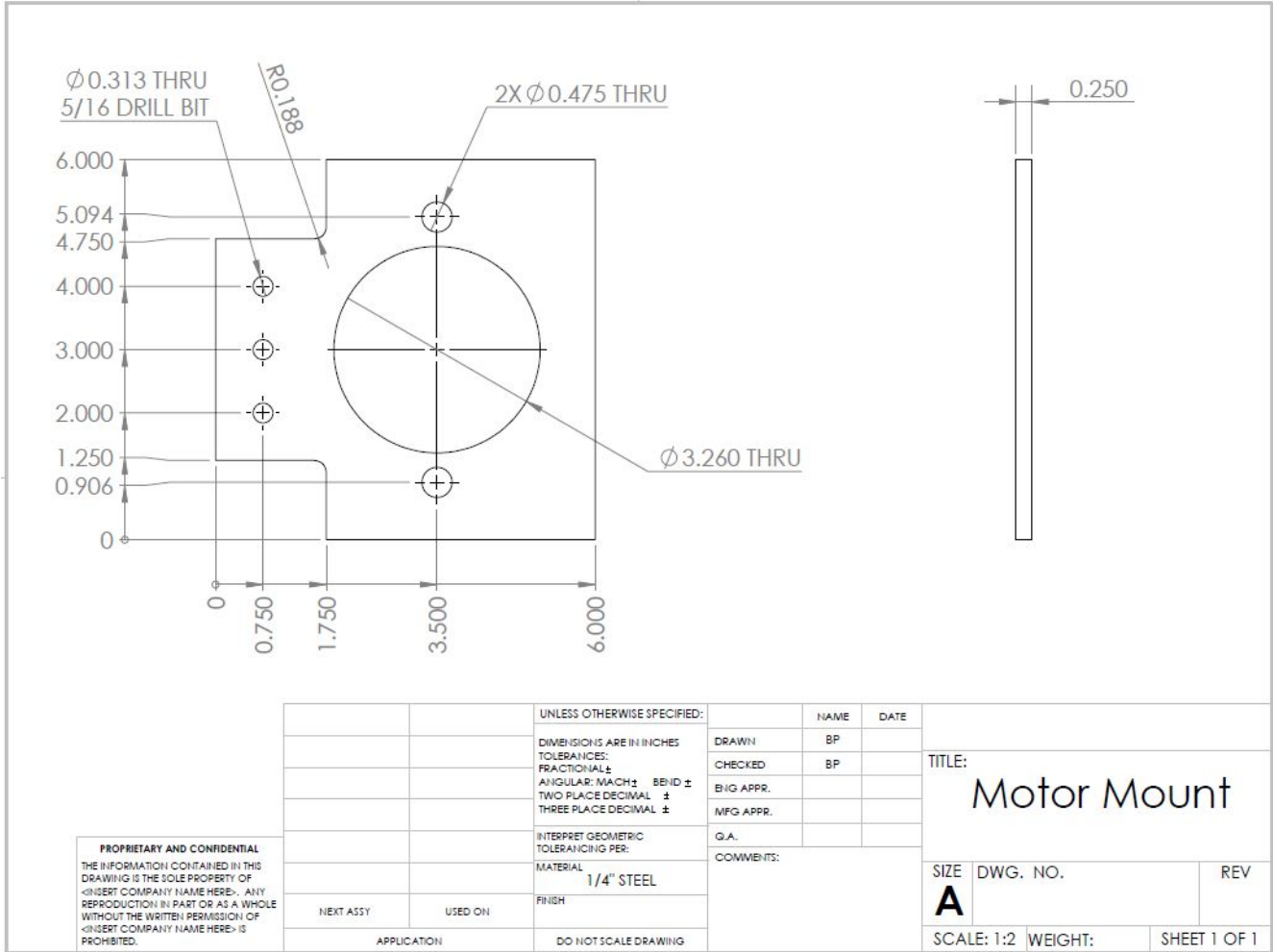
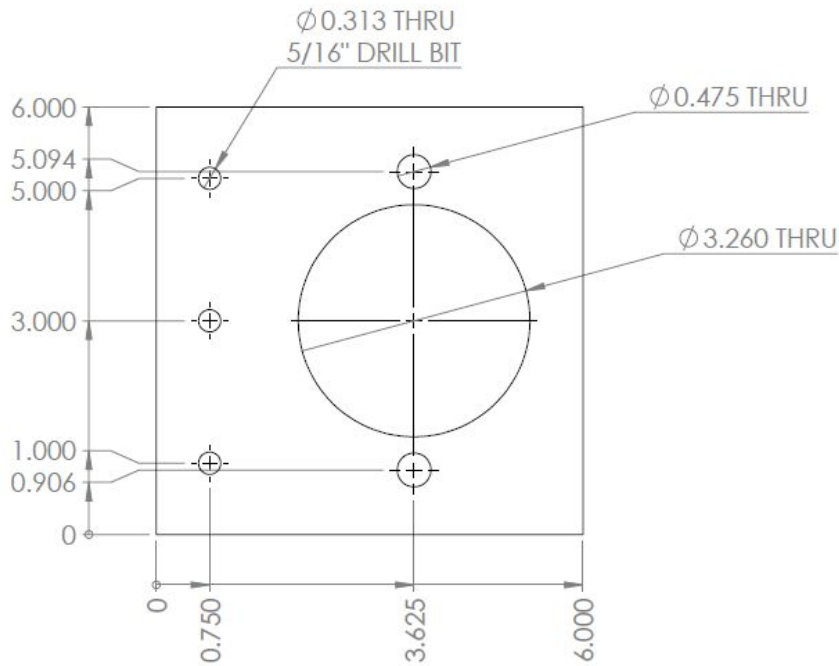


Figure 13: FEA of bike frame with specified load

5.0 Design Drawings

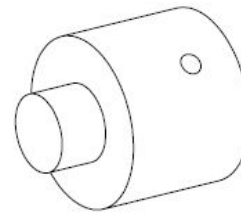
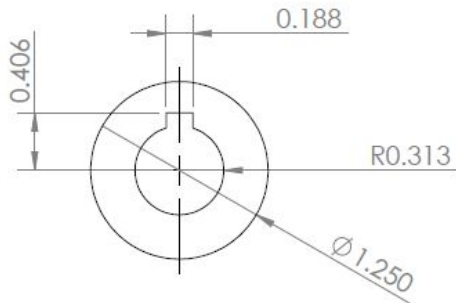
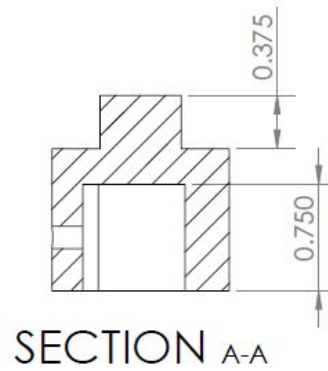
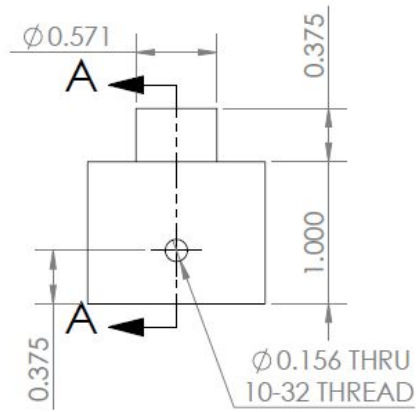




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		TWO PLACE DECIMAL \pm	Q.A.			DWG. NO.
		THREE PLACE DECIMAL \pm	COMMENTS:			REV
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		MATERIAL				
NEXT ASSY	USED ON	FINISH				
		1/8" STEEL				
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						SHEET 1 OF 1





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TITLE:		
SPROCKET TO SHAFT ADAPTER		
SIZE	DWG. NO.	REV
A		
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6.0 Component List

1	Order Method	Part	Part No.	Price / unit	Quantity	Total Cost
2	NFPA Part List	Check, 1 to 2	CV3-8-P-0-004	\$ 7.36	3	\$ 22.08
3	NFPA Part List	Coil, 12VDC DIN , J type	300AA00081A	\$ 12.22	8	\$ 97.76
4	NFPA Part List	Coil Spacer, 10 size	02-179226	\$ 2.11	1	\$ 2.11
5	NFPA Part List	Fitting, -6 JIC male to -6 JIC female swivel, 45 degree	2070-6-6S	\$ 1.74	15	\$ 26.10
6	NFPA Part List	Fitting, -6 JIC male to -6 JIC male, 90 degree	2039-6-6S	\$ 1.35	15	\$ 20.25
7	NFPA Part List	Fitting, -6 JIC male to -6 JIC female swivel, 90 degree	2071-6-6S	\$ 1.98	20	\$ 39.60
8	NFPA Part List	Fitting, -6 JIC male "T"	2033-6-6S	\$ 1.84	15	\$ 27.60
9	NFPA Part List	Fitting, -6 JIC, male to female swivel with male branch	203101-6-6S	\$ 2.59	10	\$ 25.90
10	NFPA Part List	Fitting, -6 SAE male to -6 JIC male, straight	202702-6-6S	\$ 0.75	5	\$ 3.75
11	NFPA Part List	Line Body, VC08-2, Aluminum SAE -6	02-160731	\$ 11.29	3	\$ 33.87
12	NFPA Part List	Line Body, VC10-2, Aluminum SAE -6	876700	\$ 11.98	7	\$ 83.86
13	NFPA Part List	Line Body, VC10-3, Aluminum SAE -6	876704	\$ 17.46	1	\$ 17.46
14	NFPA Part List	Relief, Direct Acting	RV1-10-S-0-30	\$ 21.60	2	\$ 43.20
15	NFPA Part List	Solenoid, 2 pos. 2 way Bi-poppet, normally Closed	SBV1-10-C-0-00	\$ 35.54	5	\$ 177.70
16	NFPA Part List	Solenoid, 2 pos. 3 way Spool 1-2/1-3	SV1-10-3-0-00	\$ 19.59	1	\$ 19.59
17	NFPA Part List	Solenoid, 3 pos. 4 way, (all ports blocked in neutral)	SV9-10N-E-0-0-00	\$ 37.42	1	\$ 37.42
18	NFPA Part List	Gear Motor, 0.54 CID, Keyed Shaft .625", Bi-rotation, internal drain ADMAD02AMA01AC0000000A0A	26702-DAB	\$ 274.69	1	\$ 274.69
19	NFPA Part List	Gear Pump, 0.58 CID, Keyed Shaft .625", CW rotation	26003-RZG	\$ 178.87	1	\$ 178.87
20	NFPA Part List	Accumulator, 1 gallon, SAE -20 port	A13100-3	\$ 339.90	1	\$ 339.90
21	er.com/Brands/Surplus-Center/5-Gallon-	5 Gallon Hydraulic Reservoir / Tank	9-8416-5	\$ 101.95	1	\$ 101.95
22	Mick - grainger	80/20 hardware	na	na	na	\$ 228.16

23	Mick - grainger	pump shaft collar	na	na	na	\$ 10.26
24	Mick - amazon	pump 9 tooth gear	na	na	na	\$ 9.99
25	Mick - Allied Electronics	Connectors for solenoids	na	na	na	\$ 32.41
26	Mick - Home Depot	Switches	na	na	na	\$ 33.60
27	Mick - Grainger	Reservoir	na	na	na	\$ 305.29
28	Jordan - Lowes	Rear modification mounting hardware	na	na	na	\$ 23.22
29	Mick - grainger	Motor shaft collar	na	na	na	\$ 10.26
30	Mick - Home Depot	Reservoir hardware	na	na	na	\$ 9.81
31	Mick - Grainger	5/8" Shaft	na	na	na	\$ 12.07
32	Mick - Grainger	Hyrdualic Fittings	na	na	na	\$ 133.18
33	Mick - Grainger	Hyrdualic Fittings	na	na	na	\$ 58.33
34	Mick - Grainger	Hyrdualic Fittings + check valves	na	na	na	\$ 163.61
35	Mick - amazon	pump 10 tooth gear	na	na	na	\$ 5.99
36	Mick - HD	Solenoid mounting hardware	na	na	na	\$ 16.75
37	Mick - Walmart	spare parts / chain break	na	na	na	\$ 77.08
38	Luree- hoses	hoses from Triad tech	na	na	na	\$ 436.02
39	Mick - Harbor Freight	Battery	na	an	na	\$ 59.35
40	Jordan - Lowes	moutning hardware, misc hardware	na	na	na	\$ 70.17
41	Jordan - grainger	battery box	na	\$ 9.87	1	\$ 9.87
42	Jordan - ULINE	crate	na	\$ 536.51	1	\$ 536.51
43	Digital Fab Lab VPC	3D printed parts	na	na	na	\$ 103.51
44	Mick - Amazon	Additional gears	na	na	na	\$ 32.97
45	Mick - Wright Bros	Nitrogen Gas refill	na	na	na	\$ 18.76
46	Mick - HD	Misc bolts for battery / electrical coverings	na	na	na	\$ 29.40
47	Mick - Walmart	Chain	na	na	na	\$ 10.56

7.0 Test Data Compared to Analysis

After the build phase was completed, we tested the bike in direct drive mode. While doing this we ran into a few unexpected problems.



The first problem we noticed was that while the rider was pedaling, the pressure would cause the pump to pull inwards towards the pedals. This caused slack in the chain resulting in the chain falling off of the gear pump. We quickly realized that our pump bracket needed additional support to be held in place. We cut two pieces of stainless steel and welded them into a T-joint. The flat bottom was then welded to the frame of the bike and the top was welded to the pump bracket. This gave the pump extra support while pedaling and allowed the pump to remain stable in direct drive mode.

The second problem we encountered pertained to our gear ratios. While pedaling the bike we were unable to build up the necessary pressure to move the bike forward. Originally, we had 4:1 gear ratio on the front of the bike between the pedals and pump. On the back of the bike, we had a 2:1 gear ratio between axle and motor. The front gears were changed to a 2:1 gear ratio and the back gears were changed to a 5:1 gear ratio. This made the bike much easier to pedal and helped make it easy to get the bike started initially. However, these ratios were still not ideal and did not allow us to get our speed up to what we had expected. We would have like to test out more gear combinations, but the lack of time before the competition prohibited us from doing so.

8.0 Cost Analysis

This cost analysis is composed of three different sections; donated parts, purchased parts, and labor. Under the purchased parts category, any line item that cost more than \$100 is called out by itself and then a sum of all the smaller items is called out. The design and fabrication hours is composed of all hours that any individual worked on the project this semester at a rate of \$15/hour as that is our median co-op pay in our degree program. The final costs for the bike the team actually spent was \$2539 but if we include the parts that were donated and the amount of time we spent on the project, the bike would have cost \$9034.



Cost Analysis NFPA Spring 2019	
Donated Parts:	\$ 1,471.71
80/20 hardware	\$ 228.16
5 gal Reservoir	\$ 101.95
2.8 gal Reservoir	\$ 305.29
Hydraulic Fittings	\$ 355.12
Hoses	\$ 436.02
Crate	\$ 536.51
3D printed Parts	\$ 103.51
Misc. (Under \$100 each)	\$ 472.52
Design and Fabrication Labor (\$15 hour *433hrs)	\$ 6,495.00
Total W/O Labor or Donated Parts	\$ 2,539.08
Total W Labor	\$ 9,034.08

9.0 Lessons Learned

Jordan Holmes

Throughout the past two semesters, I have learned how important clear and objective communication is on a dynamic project. Especially when taking on concepts and skills that are new, it is important that all team members are on board and on the same page. I think there is a fine line between over communicating and not communicating enough. Although I still have ample room to grow in this area, working on the UC FPVC team has helped me gain much needed perspective in regards to managing a team and project. From this project I also gained basic knowledge of hydraulic circuits. I hope to dig deeper into this topic to better understand it in the future.

Mick Morris

Through this project I learned a lot more than I was expecting about hydraulic systems and project management. Coming into this project I had little to no experience working with hydraulic systems and



understanding how the components operate as well as how to make them all connect was a challenge but though the help of our team mentor as well as various textbooks we successfully created a circuit composed of parts that worked well together. As the team lead for this project I also learned a lot about project management to include ensuring clear communication and holding people accountable for their actions are the two most important aspects when managing a project.

Gabriele Tisch

Over the course of my senior year, I have grown and learned more than I thought possible. This project helped me refine my technical and communication skills while also allowing me to fully immerse myself in new topics that weren't covered through previous classwork. Prior to working on this project, I had zero experience with fluid power. Through the project research and application, I now have a basic understanding of hydraulic circuits and hydraulic component selection. I also gained a refresher in PLC programming, component design, and fabrication. Additionally, this project allowed me to enhance some of my soft skills such as critical thinking, adaptability, and effective communication.

Taylor Gelhausen

During this project, I was able learn about fluid power. As of now, our coursework does not cover this topic. Throughout the process of this project, I was able to learn and understand the basics of fluid power. Being able to design, fabricate, and test this tricycle with the help of my teammates was the best way for us to all gain an understanding of fluid power. This project also helped me in realizing how to go about a project. Looking back, there are some things that I think we could have done better, but overall I think we fabricated a great hydraulic tricycle.

Brandon Potter

Doing this project was a great learning experience to understand the basics of hydraulic fluid power. Having prior experience in pneumatics it was interesting to see the similarities and differences regarding the two types of fluid power.

10.0 Conclusions

From August to April our team objectives stayed the same, but there were a few design aspects changed along the way. The preplanned design consideration of various gear sizes allowed us to keep a clean and safe hydraulic design with all major components behind the rider. Although the gear ratios were not perfected, our vehicle was able to store ample amount of energy to propel a rider over 1000ft. Using a PLC and solenoid valves allowed us to create a very simple user experience directly in front of the rider. Areas of improvement could come from more detailed calculations and testing.



Figure 14: Final bike construction



2018/2019 UC NFPA Hydraulic Powered Bicycle Team