NFPA Fluid Power Vehicle Challenge

NFPA
Education and Technology Foundation

FINAL PRESENTATION
UNIVERSITY OF UTAH
FACULTY ADVISOR: DR. CHEN
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Department of
MECHANICAL ENGINEERING
THE UNIVERSITY OF UTAH

Photo of Vehicle

Team Introduction


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Problem Statement

- Create a vehicle that is human powered, and uses fluid power components to transmit power from user to forward motion.
- To compete in the Fluid Power Vehicle Challenge.
- Gain experience in fluid power systems.
- Create networking opportunity with industry experts.
- Establish a recurring project for the University of Utah Mechanical Engineering Department.

Summary of Midway Review

- Our design objectives were:
  1. Low cost
  2. Reliability
  3. Efficient
  4. User friendly
  5. Meet/exceed competition specifications
- The vehicle was designed around the individual fluid circuit components from our circuit diagram.
  – Vehicle Design had a focus of simplicity.
- Fluid Circuit Design
  – Goal was to minimize the number of valves with a greater emphasis on individual components being able to perform in multiple drive modes.

Summary of Midway Review

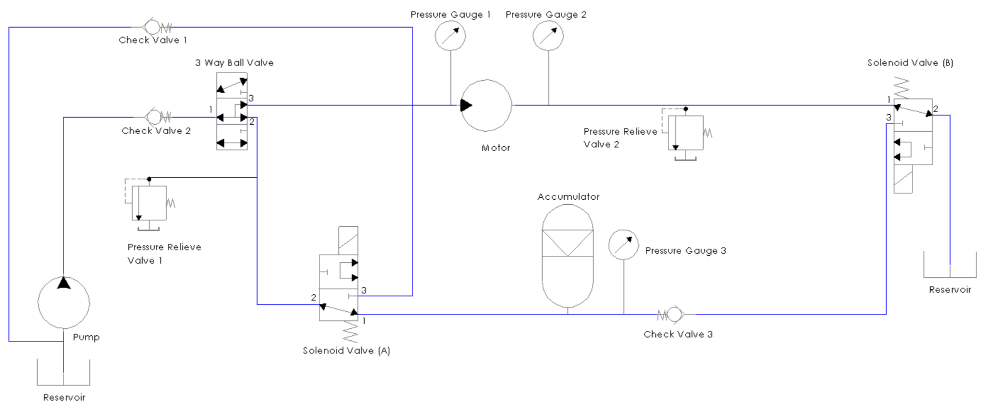
- Hardware Selection from Analysis
  - We selected a .58 CID pump, .62 CID bidirectional motor, and sized our lines based on advice (-6 for pressure/return lines, -12 for the suction line).

Basic Torque Calculations	Equation	Value	Units
Rear Wheel Torque Necessary to Create movement	Tr=Frictional coefficient*rear wheel weight*wheel radius	116	[ft-lb]
Front Wheel Torque Necessary to Create movement	Tf=Frictional coefficient*front wheel weight*wheel radius	97	[ft-lb]
Fluid motor torque	Torque=(PSI*d)/(100*.0628)	247	[in-lb]
Torque conversion from [in-lb] to [ft-lb]	[ft-lb]=[in-lb]/12	21	[ft-lb]

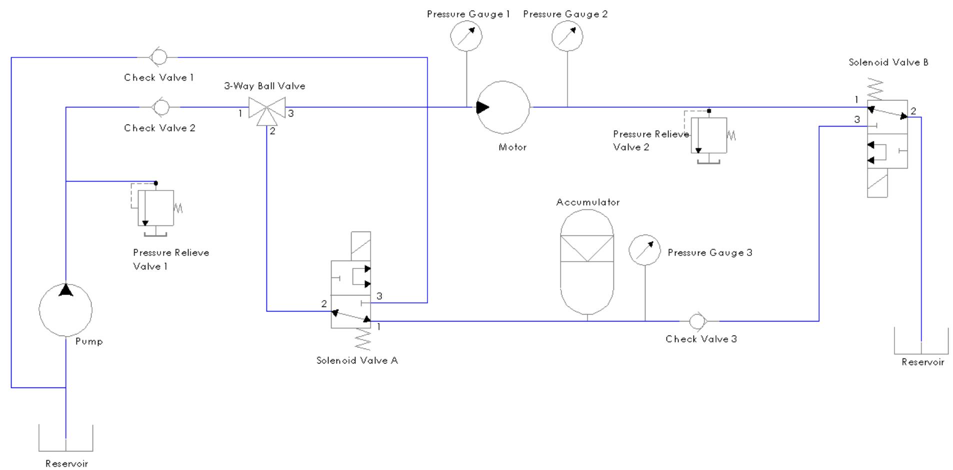
Pump Calculations	Equation	Value	Units
Flow out of pump	Flow out=(Fluid displaced by motor per revolution* pump RPM)/231	3	[GPM]
Flow into pump	Flow in=Flow out/Volumetric efficiency	3.3	[GPM]
Overall efficiency	Overall efficiency= volumetric efficiency*mechanical efficiency	0.89	[ ]
Input horsepower	Input horsepower=(Pump flow rate out [GPM]*pressure[psi])*.0007	6	[hp]
Input power	Input Power=input horsepower*745.7	4718	[W]
Gear ratio needed for pump	Gear ratio=Pump RPM/ input RPM	15	[ ]

Wheel Calculations	Q=GPM, d=CID		
Fluid motor speed	Speed= (231*Q/d)	1123	[RPM]
Gear ratio for wheel	Torque needed/Torque we have	4.7	[ ]
RPM of wheel	Motor Speed/Gear ratio(rounded up)	160.4	[RPM]
Speed of the bike	(RPM*2*π*radius)/60	18.2	[feet/sec]
		12	[MPH]

Summary of Midway Review



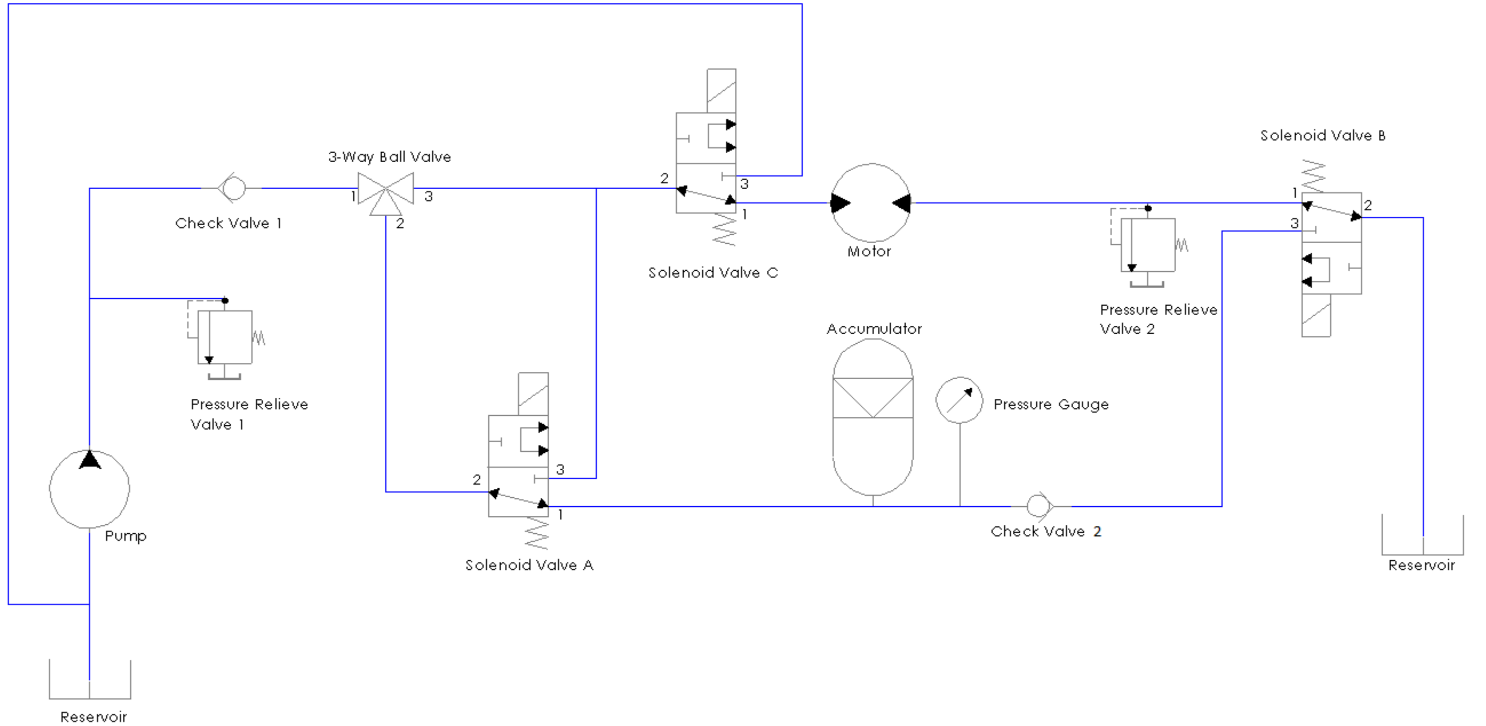
Fluid Circuit Diagram Before Midterm Review



Fluid Circuit Diagram After Midterm Review

Final Fluid Circuit Diagram

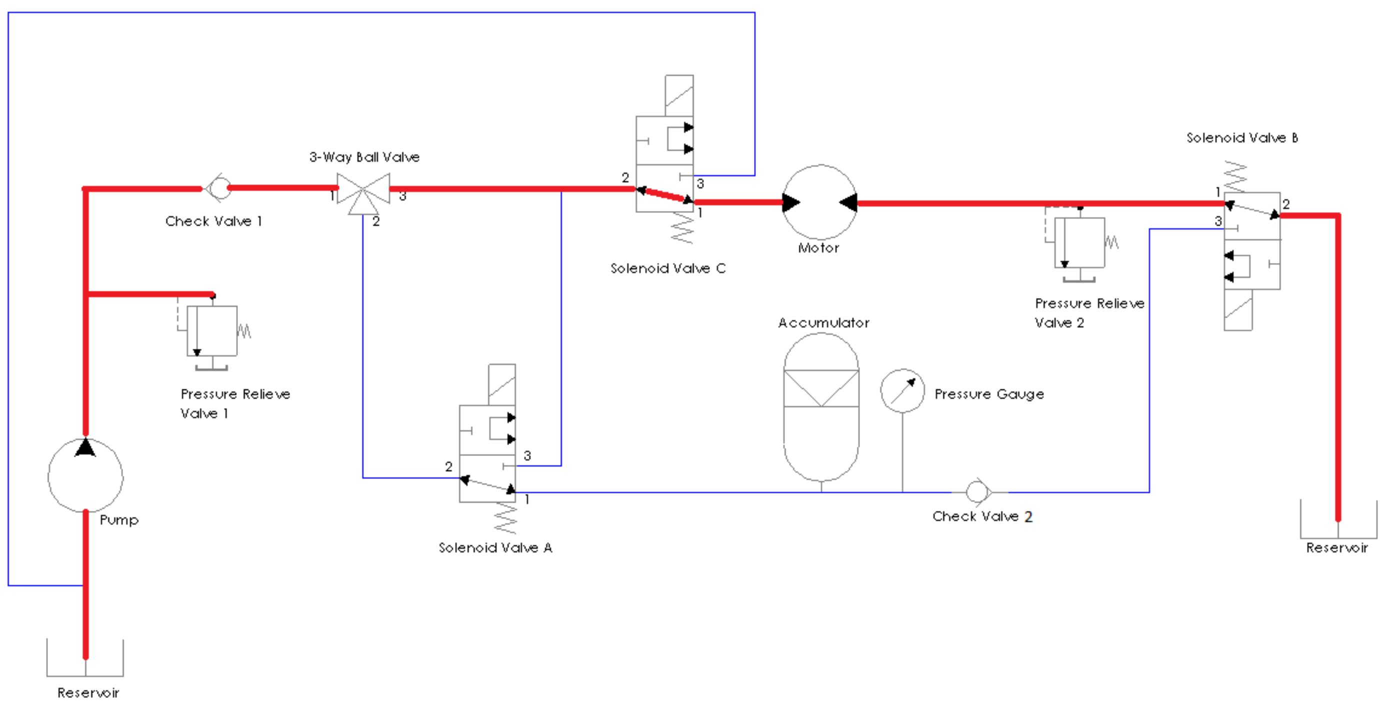
1. Consists of 4 different modes:
   - Direct Drive
   - Charging
   - Discharging
   - Regenerative Braking
2. Control by valves positioning using 2 switches and 1 handle.
3. Safety- Pressure relief valves.



Direct Drive Mode

Task: Pumping the fluid directly from reservoir to the motor
Challenge: Sprint Race
Valves Position:

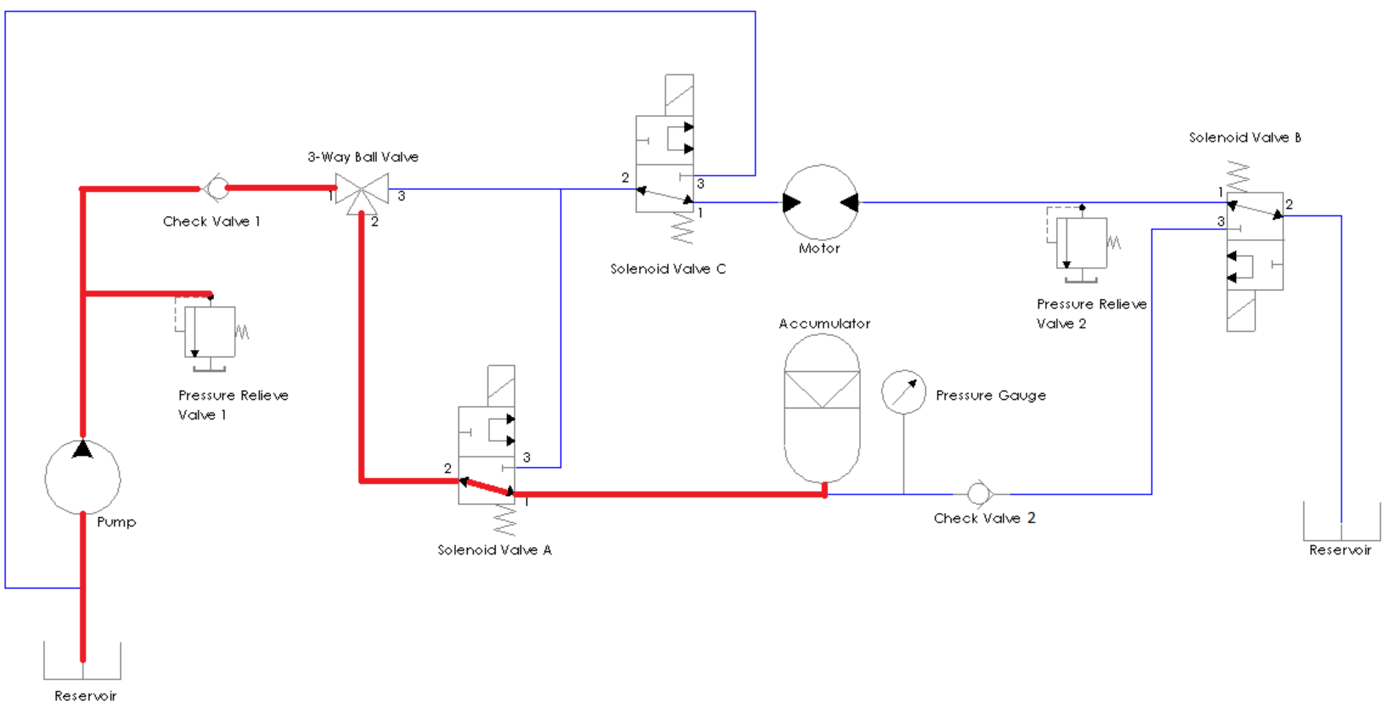
- 3 way ball valve = 90° Angle (allow flow from pump to motor)
- Solenoid Valve (A) = de-energized
- Solenoid Valve (B) = de-energized (allow flow from 2 to 1)
- Solenoid Valve (C) = de-energized (allow flow from 1 to 2)



Charging Mode

Task: Charging the accumulator
Challenge: Efficiency test
Valves Position:

- 3 way ball valve = 0° Angle (allow flow from pump to accumulator)
- Solenoid Valve (A) = de-energized (allow flow from 2 to 1)
- Solenoid Valve (B) = de-energized
- Solenoid Valve (C) = de-energized



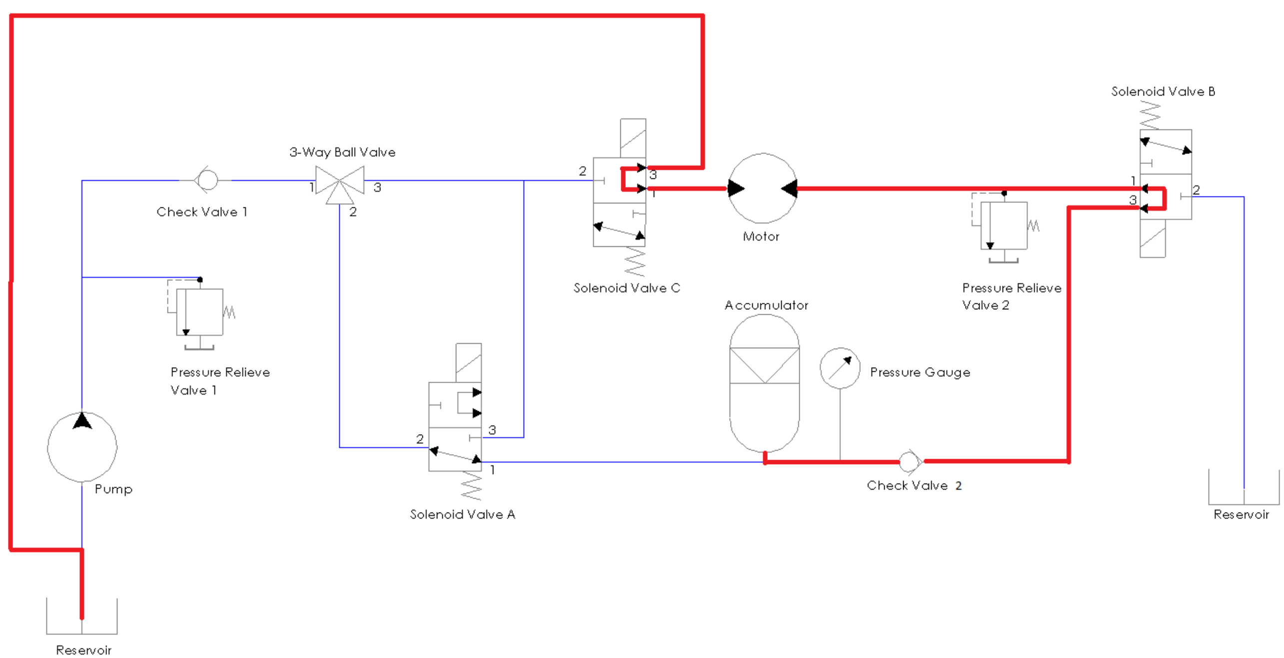
Regenerative Braking Mode

Task: Use the momentum from the bike to turn the motor to pressurize fluid back into accumulator

Challenge: Endurance test

Valves Position:

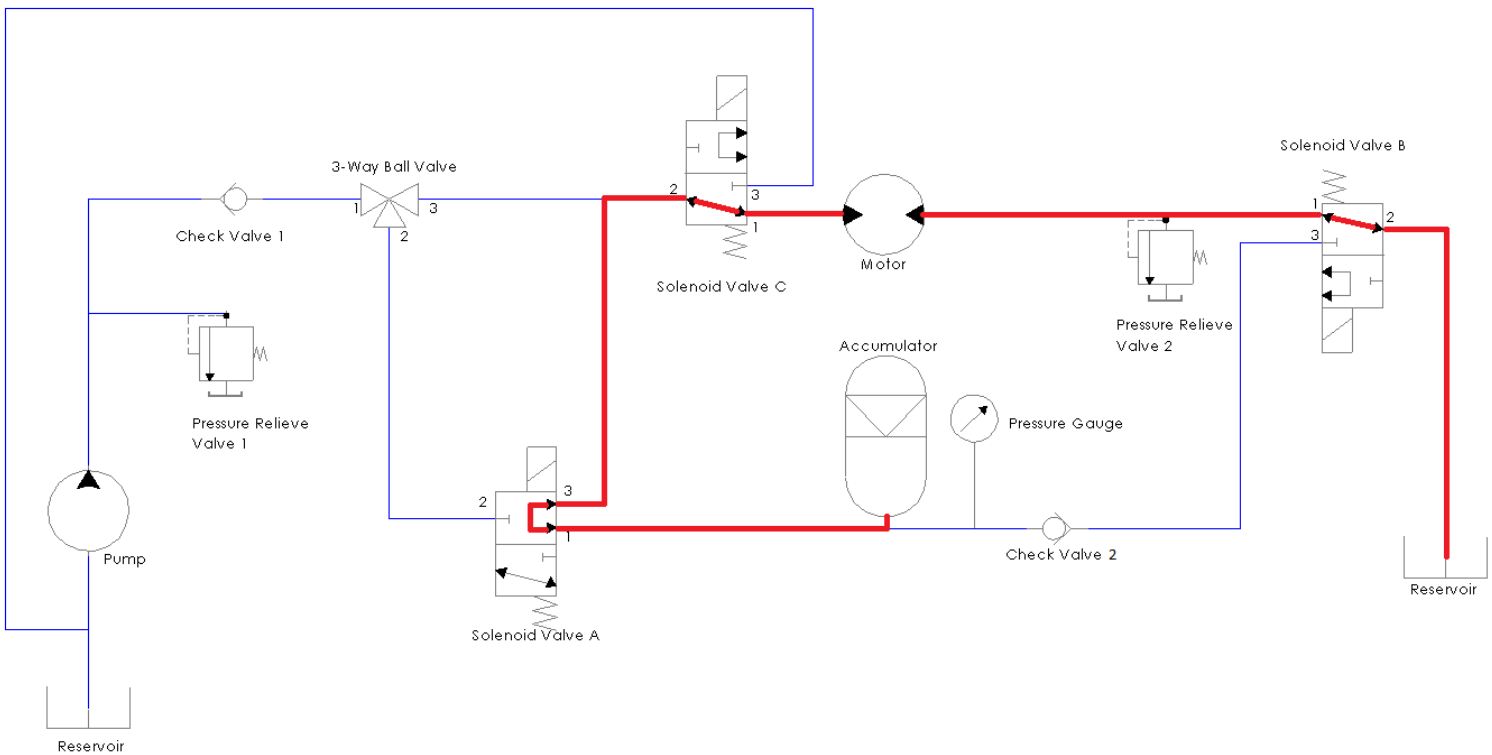
- 3 way ball valve = any
- Solenoid Valve (A) = de-energized
- Solenoid Valve (B) = energized (allow flow from 1 to 3)
- Solenoid Valve (C) = energized (allow flow from 3 to 1)



Discharging Mode

Task: Discharge the accumulator
Challenge: Efficiency and endurance test
Valves Position:

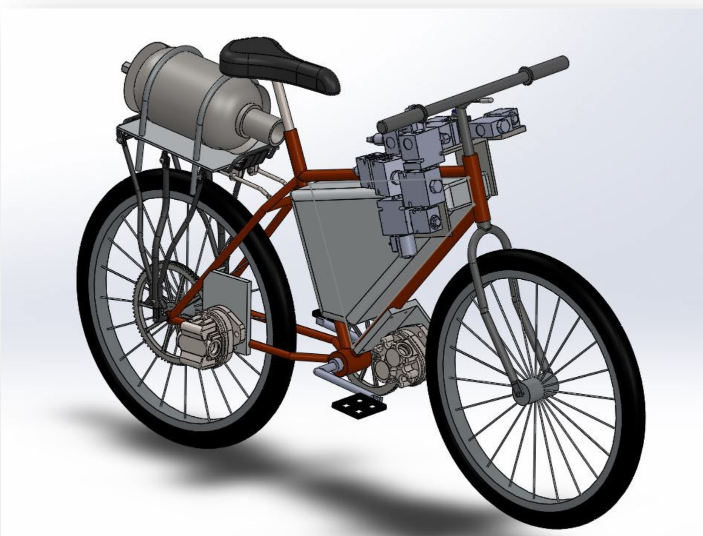
- 3 way ball valve = Any
- Solenoid Valve (A) = energized (allow flow from 1 to 3)
- Solenoid Valve (B) = de-energized
- Solenoid Valve (C) = de-energized



Vehicle Construction

- Initial Design and layout were modeled in Solidworks, in order to help with fitment and design of bracketry and layout of vehicle
- From this model, work was divided up by systems
  - Pump and Motor
  - Accumulator
  - Valve Assembly
  - Reservoir
  - Electrical Circuitry

SolidWorks Model



Final Fluid Power Vehicle

Vehicle Construction

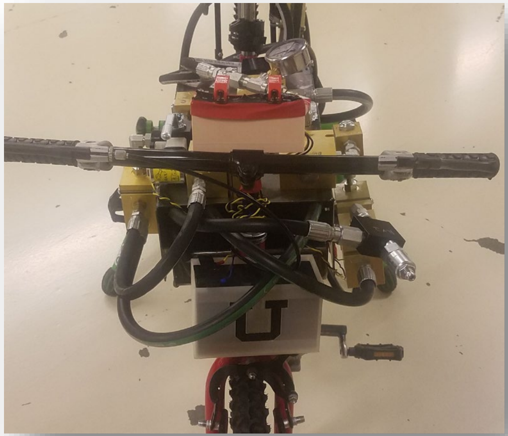
- Pump and Pump Gearing
  - Designed to fit under bottom tube of bike, the pump is turned by a chain attached to a gear on the pedals
  - Due to interference and chain binding issues, the intermediate gear was removed, lowering the overall gear ratio

- Motor and Motor Gearing
  - The motor was designed to mount on the back tire support frame
  - The gear was bolted directly to the hub of the wheel

- Accumulator
  - The Accumulator was mounted on a bicycle rack behind the rider

Vehicle Construction

- Valve Assembly
  - Due to size of connection pieces, the final valve assembly was broken up into parts, allowing for different bodies to be mounted in different locations
- Reservoir
  - Based off of the design in the SolidWorks model, the reservoir was welded out of steel plates. Several port connections were cut and welded into the reservoir body.
- Electrical Circuitry
  - An Arduino controlling the solenoid switches was mounted on the handlebars, with the battery situated in front of the handlebars



Vehicle Testing

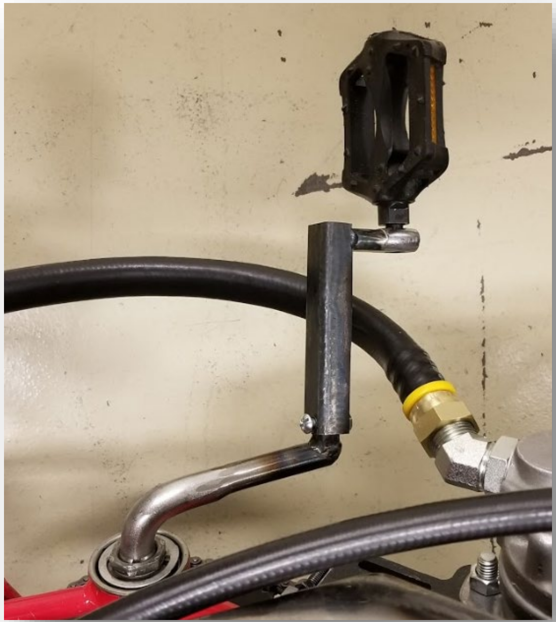
Direct Drive Mode

- Gear Ratio = 7:1

Test 1

Parameter	Value
Distance Traveled	270 ft
Time Elapsed	60 seconds
Average Speed	3 mph

Identified loose pedal extensions causing difficult pedaling



Vehicle Testing

Direct Drive Mode

- Gear Ratio = 7:1

Secured pedal extensions
to remove play

Test 2

Parameter	Value
Distance Traveled	120 ft
Time Elapsed	16 seconds
Average Speed	5 mph
Avg Speed from Test 1	3 mph
Improvement	2 mph

Vehicle Testing

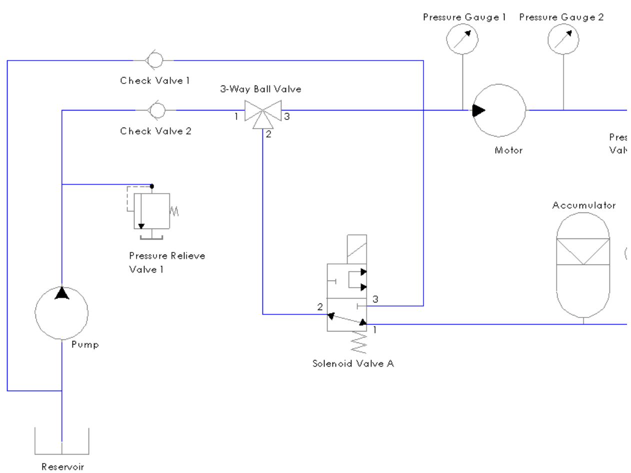
Accumulator Drive Distance Analysis:

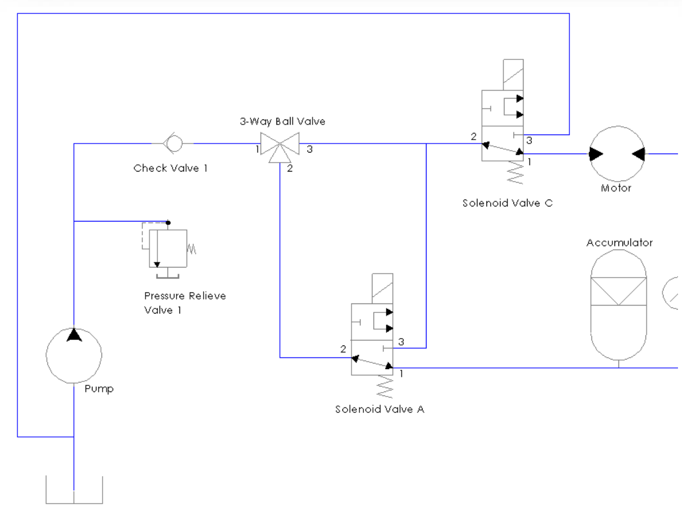
Parameter	Value
Pre-charged Pressure	900 psi
Fluid Pressure	1100 psi
Distance Traveled	100 ft

Vehicle Testing

Regenerative Braking

- In our initial test, the regenerative braking didn’t work due to difficulty of overcoming the check valve in the circuit
- The Check valve was replaced by a Solenoid valve





Lessons Learned

- A manifold would reduce the number of fittings and valve bodies required
- Suction lines should be short and direct, and not have a check valve on low pressure side
- Can save money on suction hoses by not buying 3000 psi rated hoses
- Beware of current draw through a transistor for solenoid control

Thank you to the NFPA and industry sponsors!