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Chainless Challenge

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Agenda

- Objectives
- Purpose
- Constraints
- Goals
- Initial Design Concepts
- Final Design
- Bicycle Assembly
- Analysis of the Bicycle
- Future Work/Lessons Learned

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Objectives

- Standard Bicycle
  - Virtually Unchanged
  - Efficient
- Chains to Hydraulics = Challenge
  - Lost Efficiency
  - Weight
  - Many Options

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Purpose

- Hydraulics Knowledge
  - Hands on Experience
  - Real World Application
  - Small to Large Application
- Challenge Students
  - Apply Knowledge
  - Think Outside the Box
  - Teamwork

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Constraints

- Weight
- Leaking Rate
- Number of Riders
- Speed
- Money
- Time

Goals

- Teamwork
- Weight
- Leaking Rate
- Number of Wheels
- Speed
- Coasting
- Money
- Time

Initial Design Concepts

- Implement a pneumatic section
- Use a gearbox to increase and decrease RPM
- Use a worm gear
- Use the bicycle frame as the reservoir
- Use a clutch and pinion assembly
- Use a 3D printed plastic coupler

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Considerations

- Available Space
- Available Parts
- Balance
- Friction Wheel/Back Tire
  - Size
  - Contact
- Back Rack
  - Support/Stability
  - Guide Rollers
- Rotational Power Transfer

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Final Design

- Power Transfer
  - Pedal Input
  - Gear Train
  - Hydraulic Circuit
  - Friction Wheel

- Regenerative Breaking
- Assisted Power

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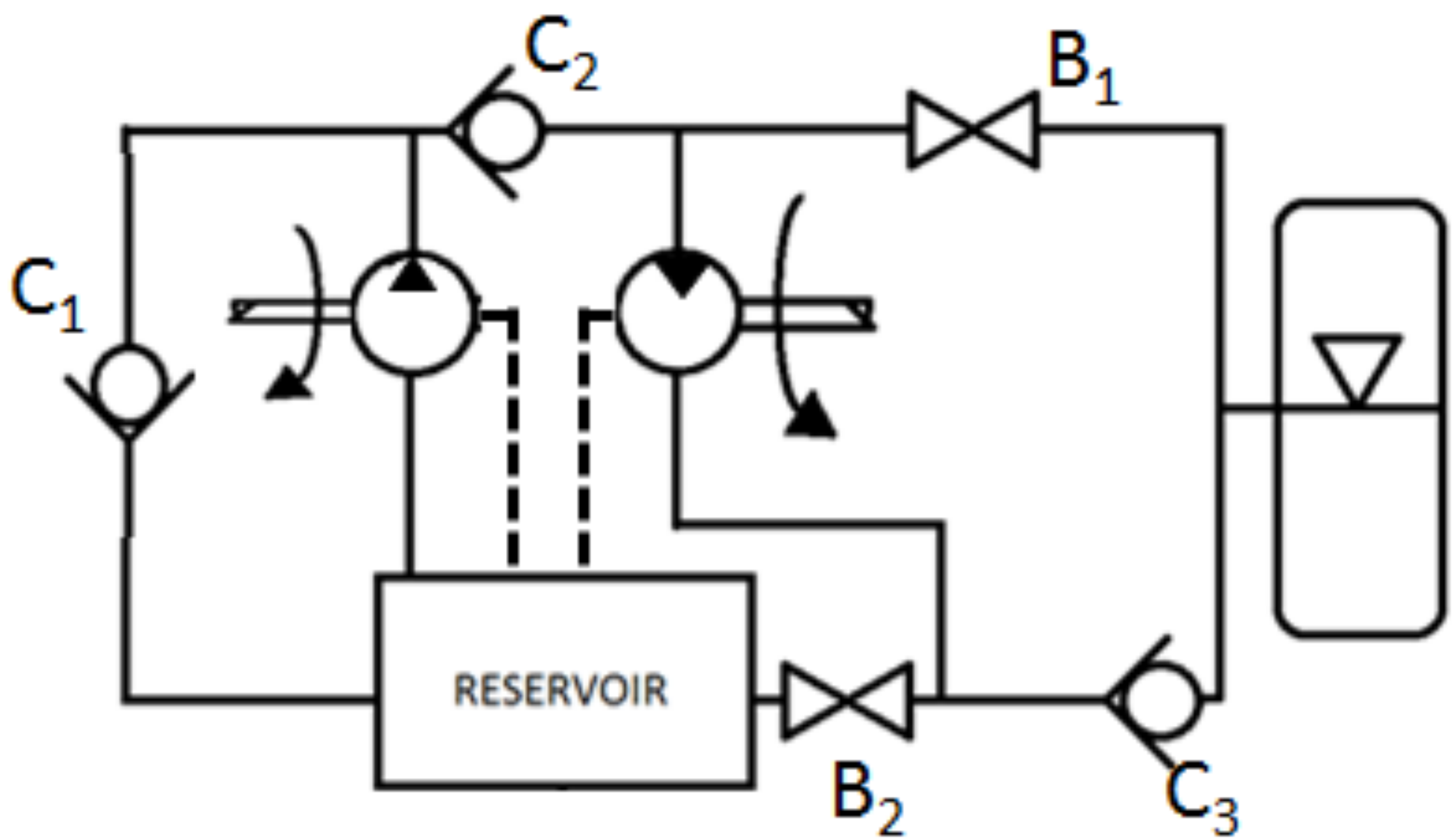
Hydraulic Circuit



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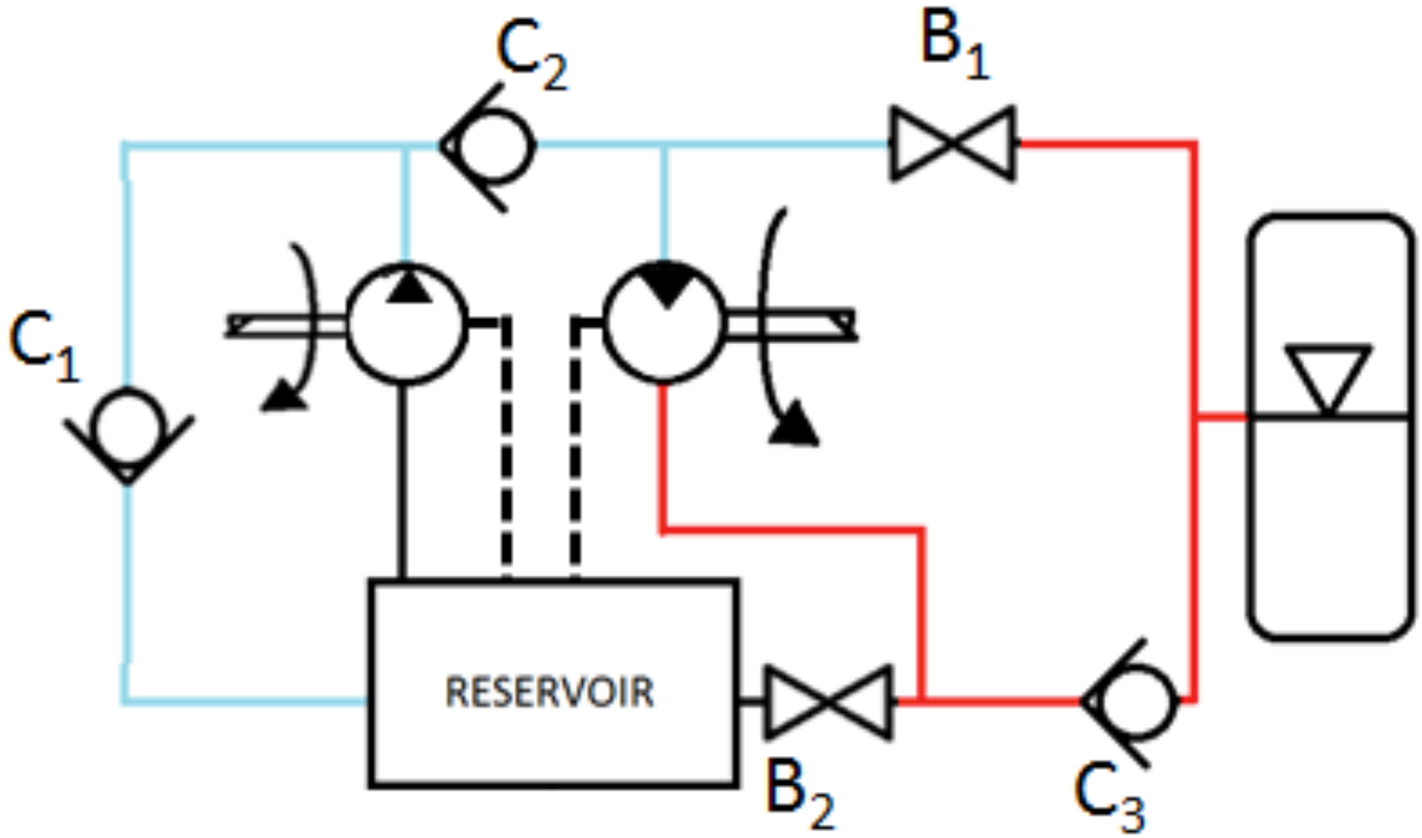
Hydraulic Circuit Charging



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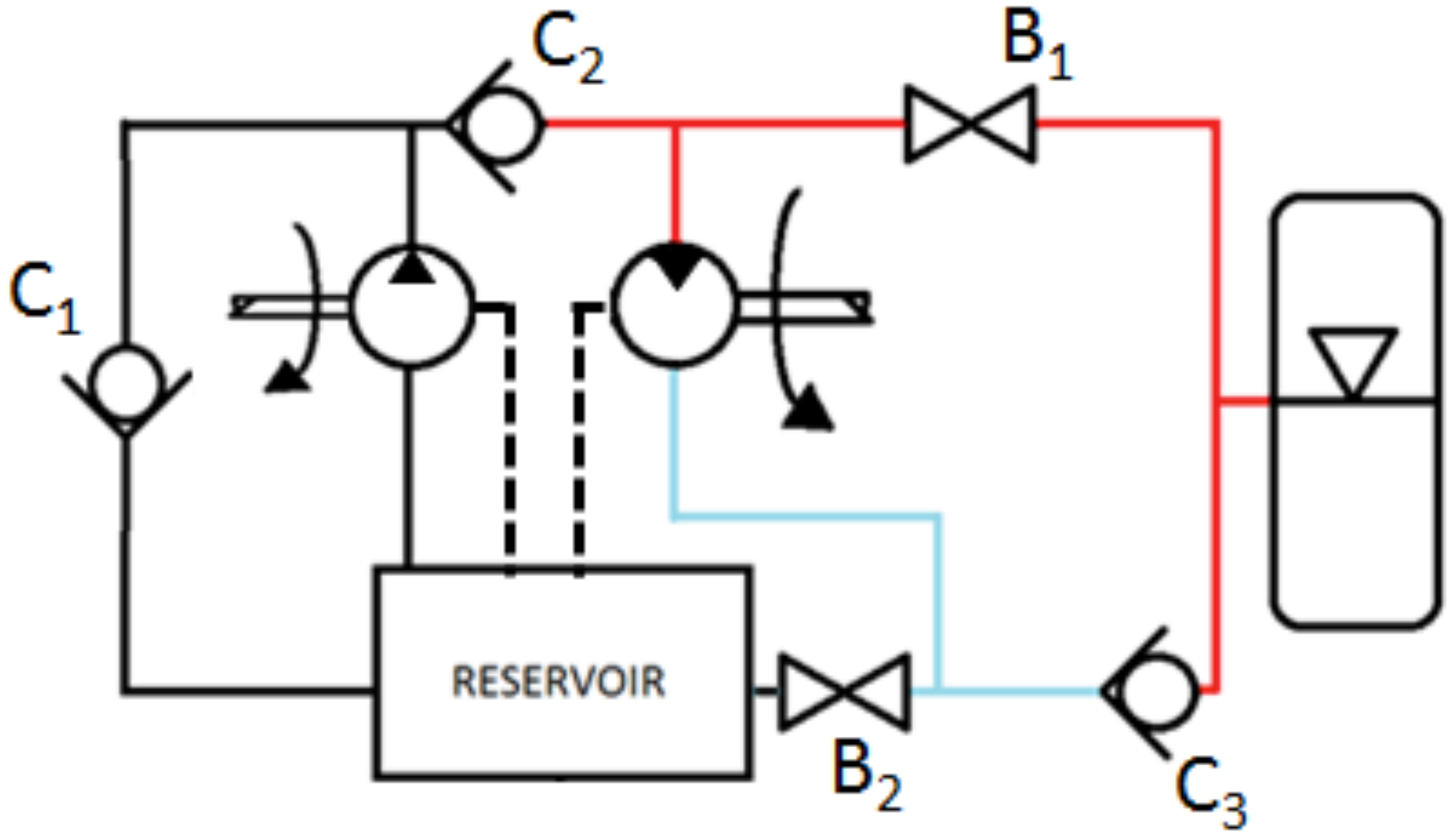
Hydraulic Circuit Assist



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Selection of Hardware

- Bicycle
- Motor/Pump
- Accumulator
- Gear Train
- Friction Wheel/Coupler
- Flexible Tubing/Fittings
- Reservoir
- Check Valves/Ball Valves
- Motor Mount

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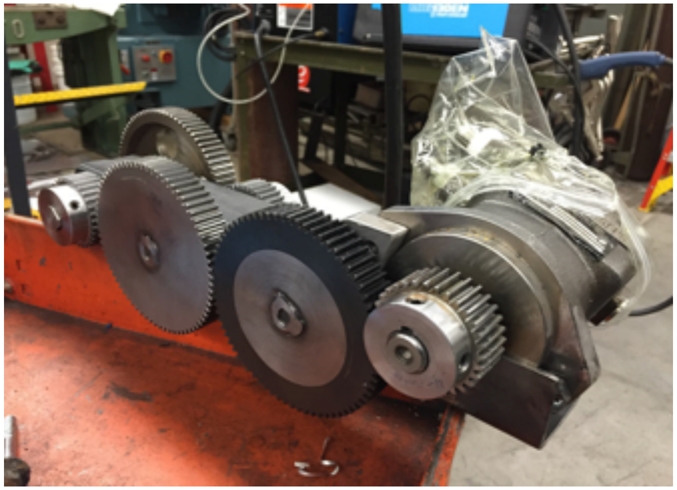
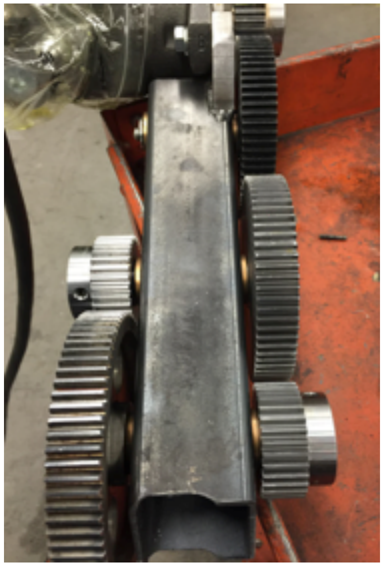
Selection of Bicycle

- FreeSpirit Woman's Brittany
  - Ease of Mounting

Selection of Gears

- Diameter of the gears
  - 2 – 5 inch
  - 2 – 2 inch
  - 2 – 4.5 inch
  - 1 – 1.875 inch





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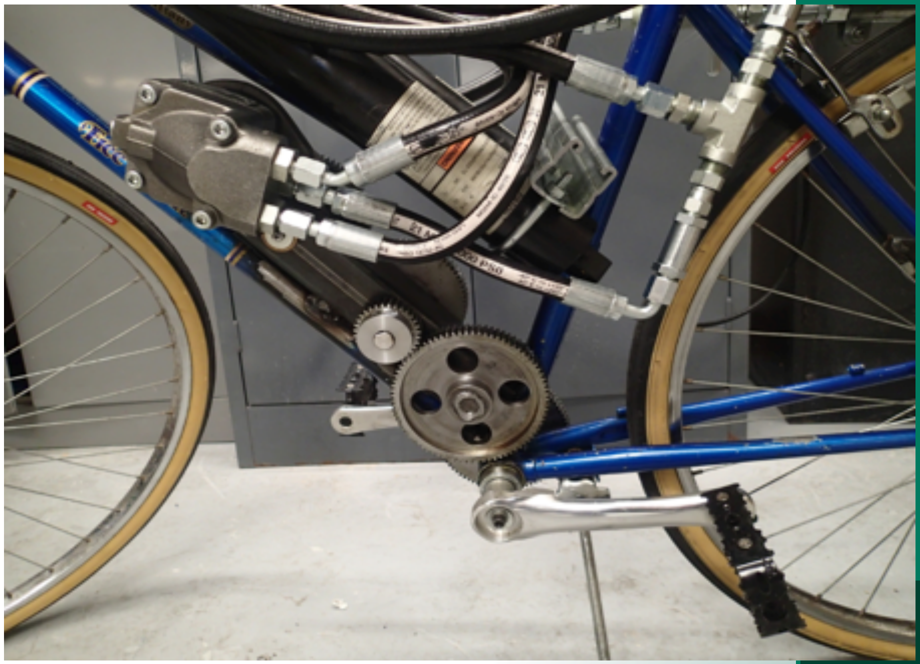
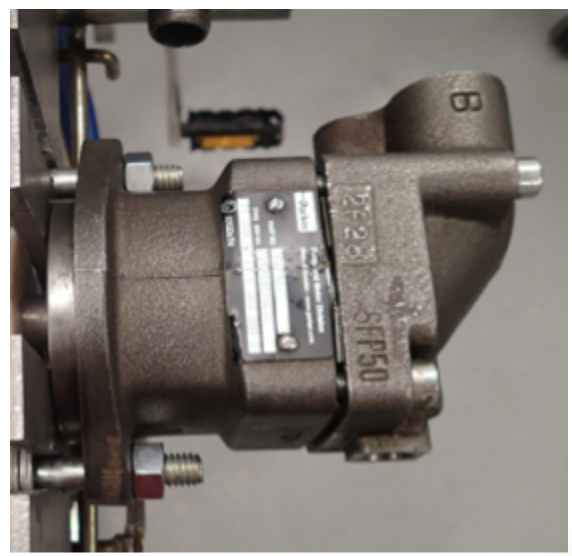
Selection of Gears

- Gear Ratios
  - 2.67:1, 2.5:1, 1:1, 2.25:1
- Overall: 15:1



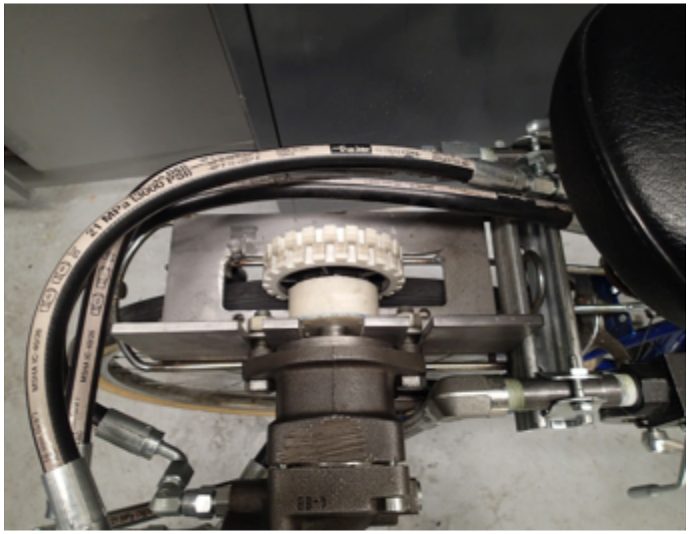
Selection of Motor/Pump

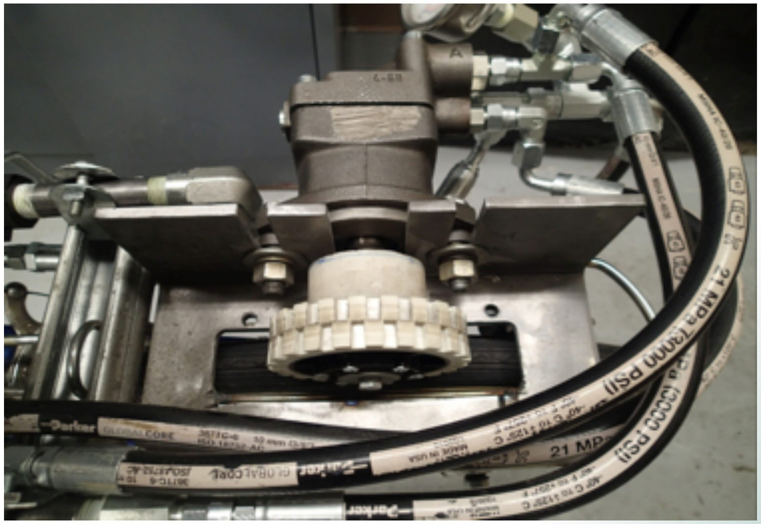
- Two F11-05 Motor/Pump
  - 11 Pounds
  - Displacement: 4.9 cm^3/rev



Selection of Motor Mount

- Steel Plate
  - ¼ Inch
- Slots for Adjustment





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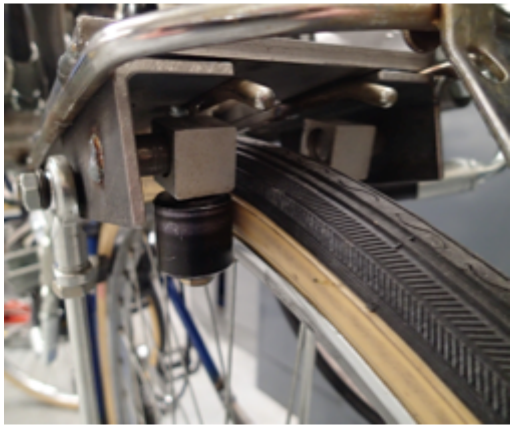
Selection of Motor Mount

- Adjustable Rod
- Guide Wheels
- Reinforcement Plates



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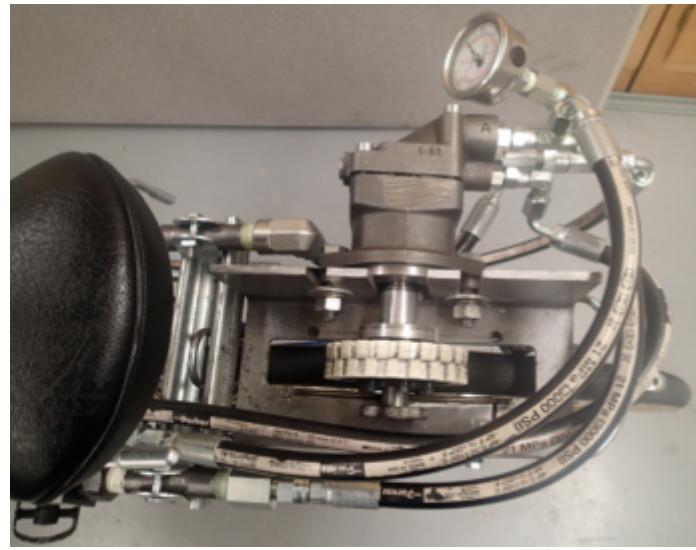
Selection of Friction Wheel and Coupler



- Friction Wheel
  - Rubber 4 and 6 Inch
  - Mated to the Back Tire
- Coupler
  - Aircraft Aluminum

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Selection of Accumulator

- Two Piston Accumulators

Specifications	Dimensions
Weight (lb)	10
Length (in)	24
Diameter (in)	2.38
Volume (in^3)	58
Pre - Charging Pressure (PSI)	400
Max Operating Pressure (PSI)	3000

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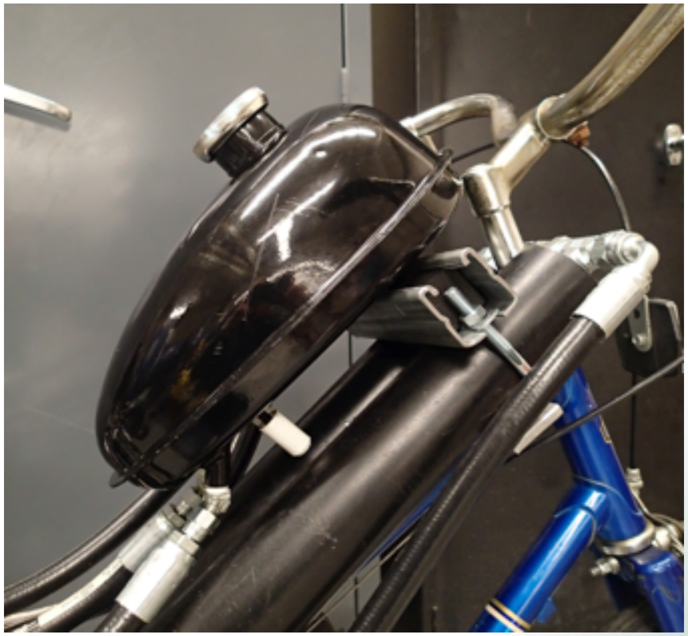
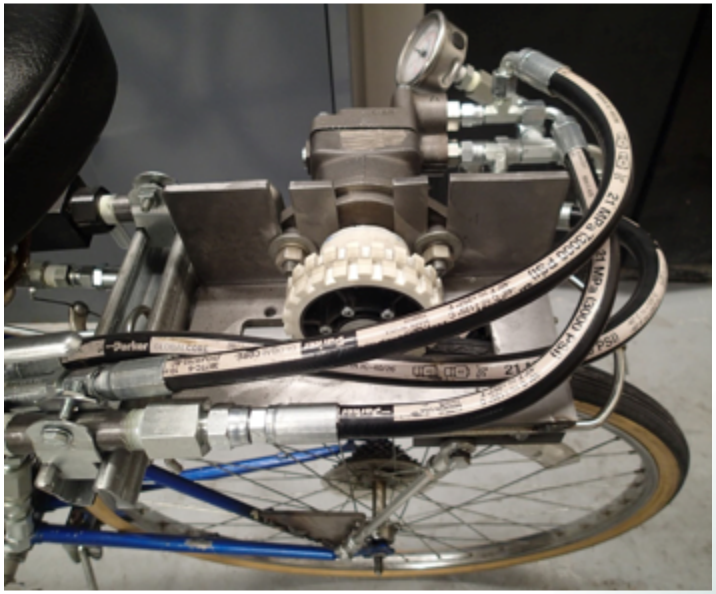
Selection of Reservoir

- 2.5 Liter
- Steel
- Modifications
- Vent Cap



Selection of Hoses

- Flexible Tubing
  - 3/8 Inch Diameter
- Adjustable



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Selection of Valves

- Three Check Valves
- Two Ball Valves
  - Mechanical

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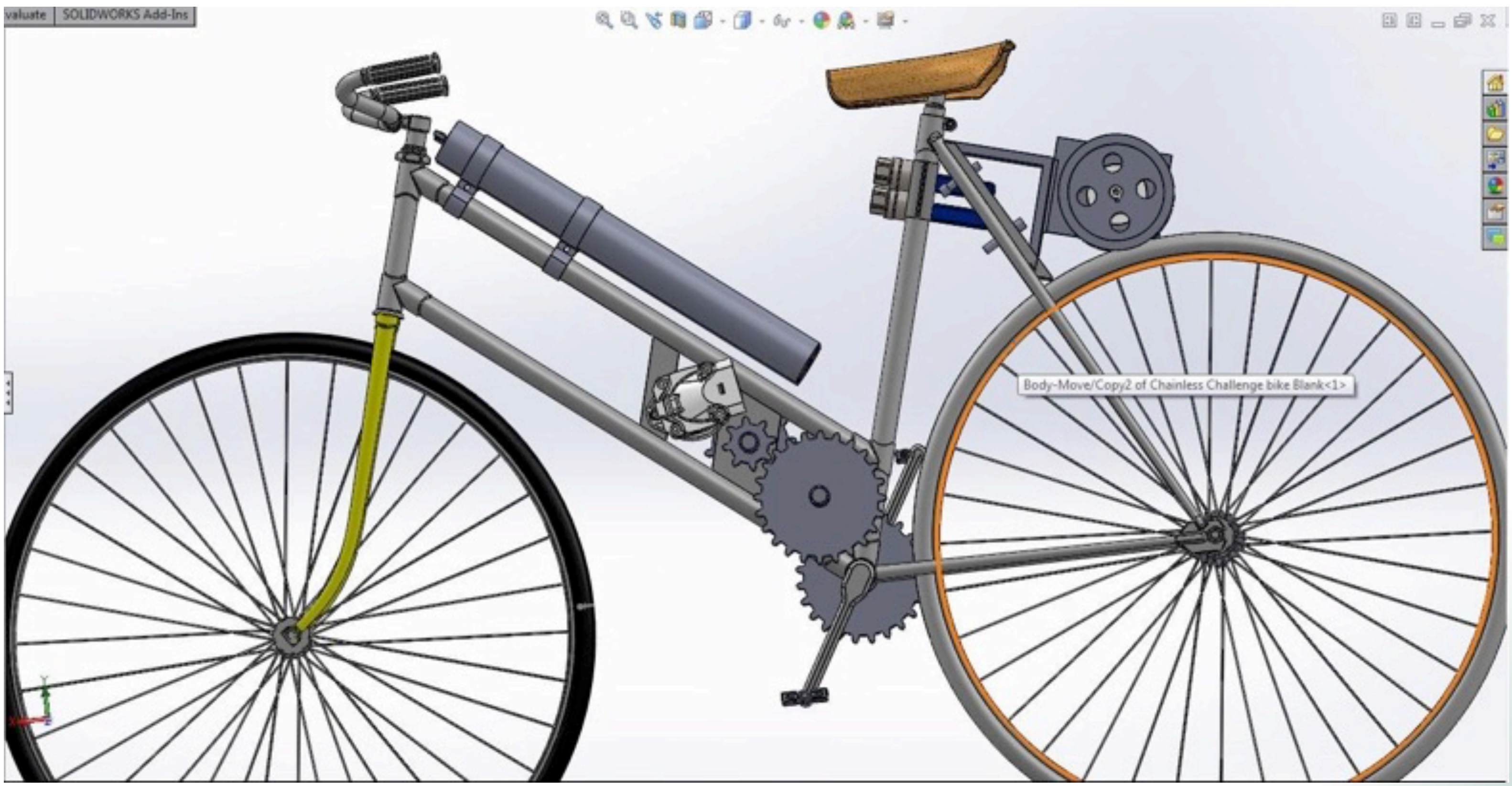
Bicycle Assembly



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Bicycle Assembly

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Bicycle Assembly

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Stress Calculations

Rider's Weight (lbs)	Length of Pedal Arm (in)	Max Torque (in-lb)	Shaft Diameter (in)	Shear Stress (ksi)	Factor of Safety
140	6	840	0.625	17.5	1.8
145	6	870	0.625	18.1	1.7
150	6	900	0.625	18.8	1.7
155	6	930	0.625	19.4	1.6
160	6	960	0.625	20.0	1.5
165	6	990	0.625	20.7	1.5

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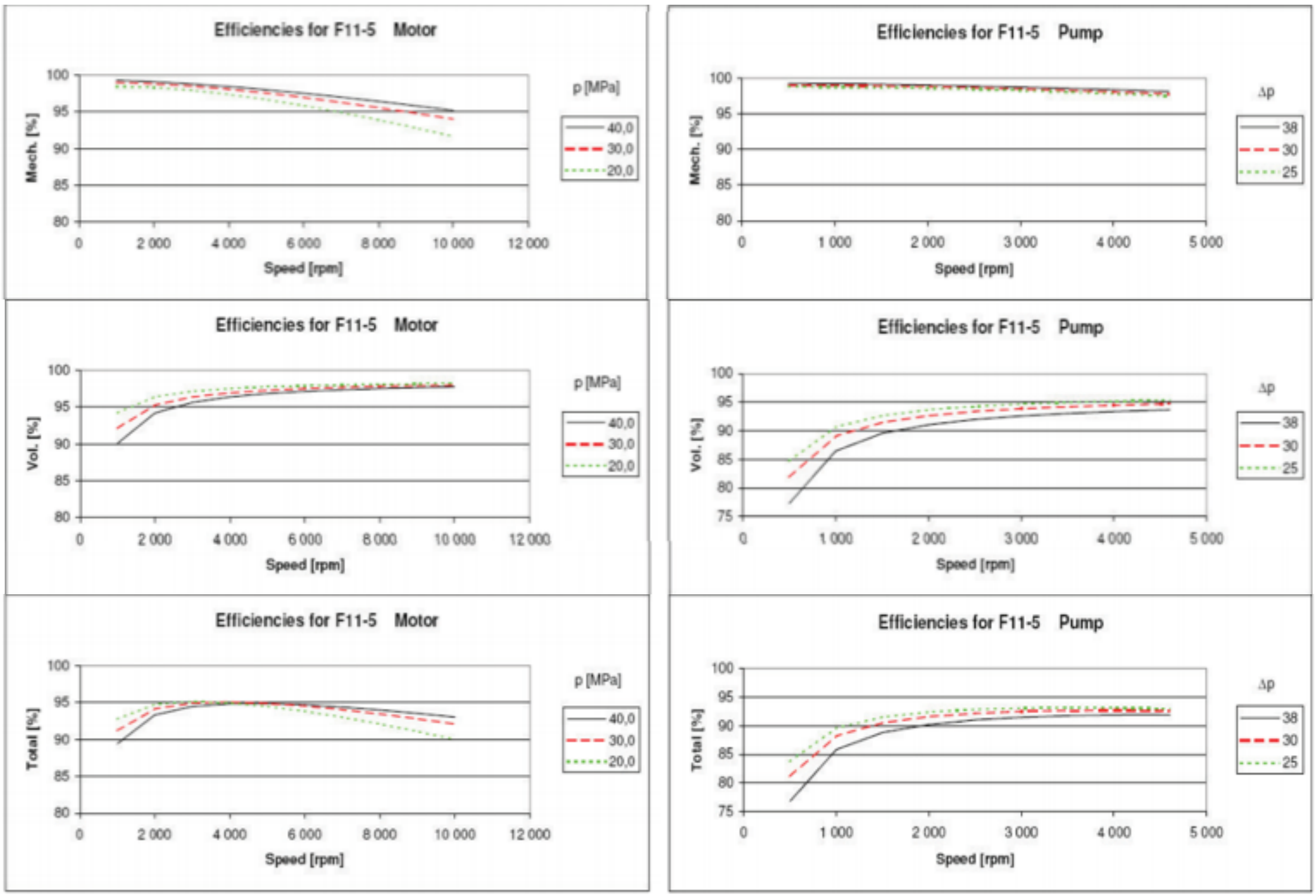
Gear Ratios

$RPM_{Pump}/RPM_{Pedal} = G/R$ $G/R = D_1/D_2 \times D_3/D_4 \times D_5/D_6$

- Max Pump Efficiency: ~1000-2000 RPM
- Rider Pedaling: Estimated 60 RPM
- Overall Gear Ratio: 15:1

Analysis of Efficiency



Analysis of Efficiency

Efficiency	Pump	Motor
Mechanical	99%	98%
Volumetric	88%	93%
Total	86%	92%

- Overall Efficiency: 77%

Calculations for Motor/Pump

Flow (q)

$$q = \frac{D \times n}{1000 \times \eta_v} \; [l/min]$$

Torque (M)

$$M = \frac{D \times \Delta p \times \eta_{hm}}{63} \; [Nm]$$

Power (P)

$$P = \frac{q \times \Delta p \times \eta_t}{600} \; [kW]$$

D - displacement [cm^3/rev]

n - shaft speed [rpm]

η_v - volumetric efficiency

Δp - differential pressure [bar] (between inlet and outlet)

η_{hm} - mechanical efficiency

η_t - overall efficiency ($\eta_t = \eta_v \times \eta_{hm}$)

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Calculations for Motor

Motor	750 RPM 34.48 bar	750 RPM 206.9 bar	900 RPM 34.48 bar	900 RPM 206.9 bar
Flow (l/min)	3.95	3.95	4.74	4.74
Torque (Nm)	2.63	2.63	15.77	15.77
Power (kW)	0.21	1.25	0.25	1.50

Calculations for Pump

Pump	750 RPM 34.48 bar	750 RPM 206.9 bar	900 RPM 34.48 bar	900 RPM 206.9 bar
Flow (l/min)	4.18	4.18	5.01	5.01
Torque (Nm)	2.65	2.65	15.93	15.93
Power (kW)	0.21	1.24	0.25	1.49

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Analysis of Performance

Pedal RPM	Gear Ratio	Motor/Pump/Friction Wheel RPM	Tire RPM	Speed (mph)
50	15	750	115	8.9
60	15	900	138	10.7
70	15	1050	162	12.5
80	15	1200	185	14.3
90	15	1350	208	16.1
100	15	1500	231	17.8
110	15	1650	254	19.6

Theoretical Speed Calculations

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Analysis of Performance

Pedal RPM	Gear Ratio	Pump RPM	Motor/Friction Wheel RPM	Tire RPM	Speed (mph)
50	15	750	581	89	6.9
60	15	900	698	107	8.3
70	15	1050	814	125	9.7
80	15	1200	930	143	11.1
90	15	1350	1046	161	12.5
100	15	1500	1163	179	13.8
110	15	1650	1279	197	15.2

Speed Calculations with inefficiencies in the hydraulic circuit

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Analysis of Performance

Friction Wheel Size (inch)	Pedal RPM	Speed (mph)	Calculated Speed with inefficiencies (mph)	Calculated Speed no inefficiencies (mph)
4	83	11.56	11.5	14.8
4	62	8.66	8.6	11.1
4	52	7.23	7.2	9.3

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Analysis of Performance

Friction Wheel Size (inch)	Distance (feet)	Coasting/No Coasting	PSI
6	587.27	No Coasting	2200
6	839.90	Coasting	2200
4	546.26	No Coasting	2200
4	623.36	Coasting	2200

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Price of a Bicycle in a 500 unit Order

Item	Cost
Labor	$570,000.00
Parts	$1,317,105.00
Profit Markup(5%)	$94,355.25
Total	**$1,981,460.25**
Price Per Unit	**$3,962.92**

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Future Work

- Gear Shifting
  - Gear Train
  - Friction Wheels
- Optimize Gear Ratio
- Reduce Weight
- Enhance Hydraulic Circuit
- Bike Aesthetics

Lessons Learned

- Project Management
  - Time
  - Money
  - Role Delegation
- Applying Engineering Theories
- Overcoming Obstacles
- Teamwork

Thank you