NFPA Fluid Power Vehicle Challenge

NFPA Education and Technology Foundation

Final Presentation
Cleveland State University
Advisor: Bogdan Kozul
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Meet the Team!

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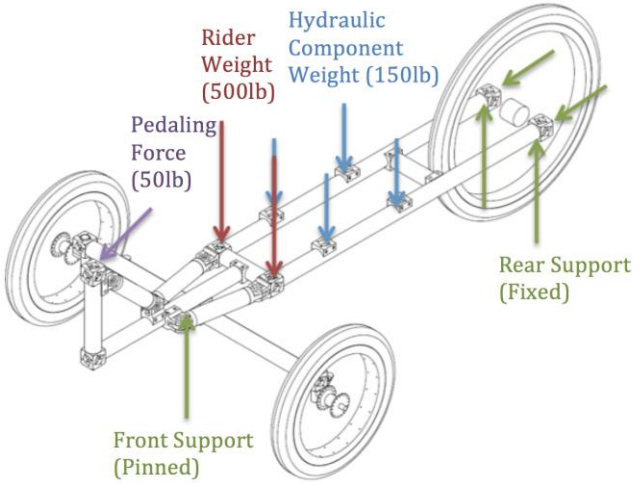
Final Bike

Design Objectives:

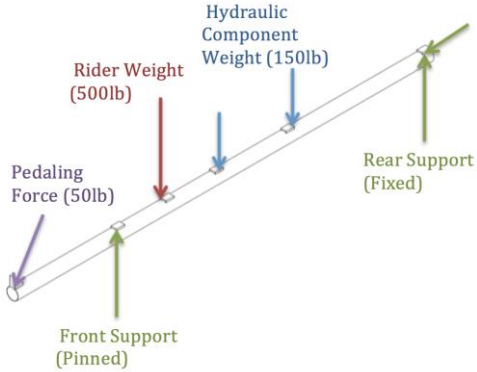
- **Improve Frame Design**
  - Reduce weight
  - Simplify component mounting

- **Improve Hydraulic Circuit**
  - Safe/ user friendly operation
  - Add charging versatility
  - Reduce friction energy loss

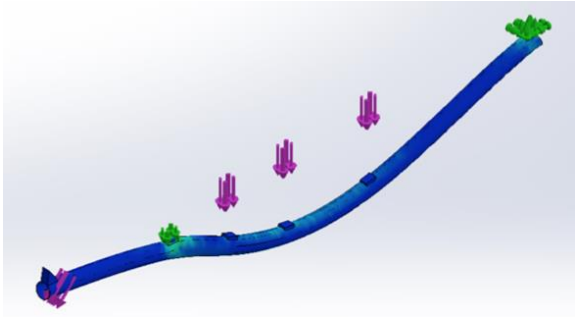
Vehicle Frame: Carbon Fiber



Conservative Simplification:

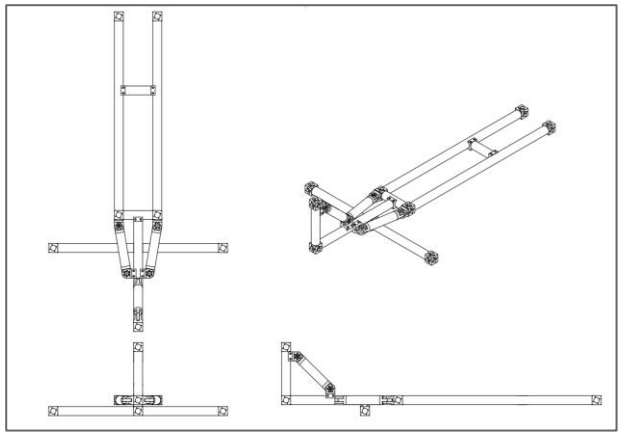


Maximum Stress: 70 MPa

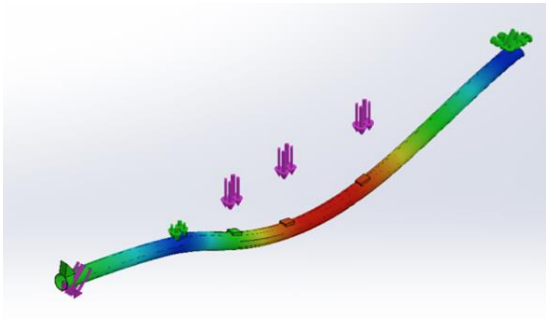


Considerations:

- Weight
- Deflection

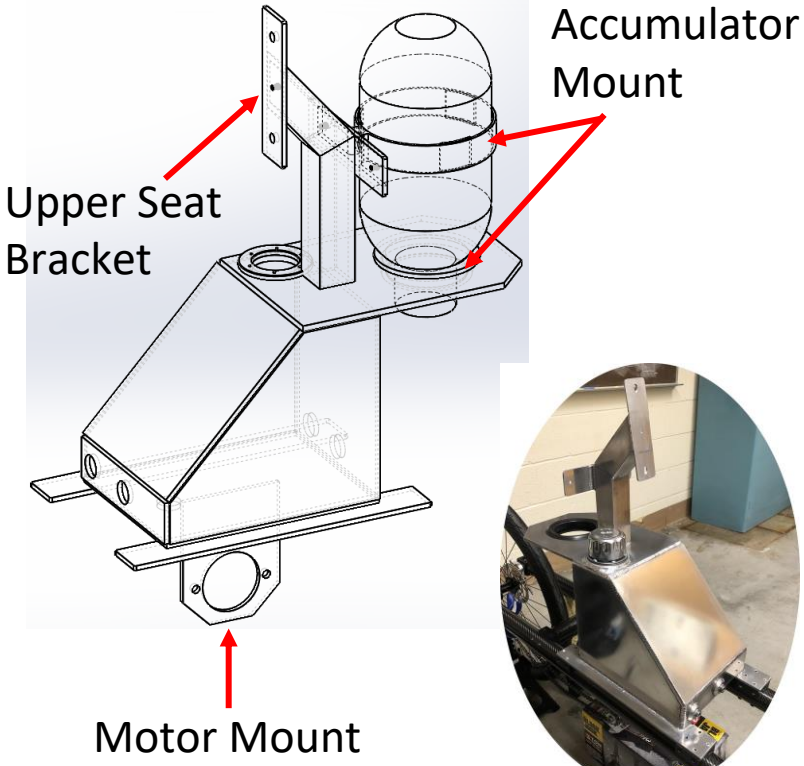


Maximum Deflection: 3mm

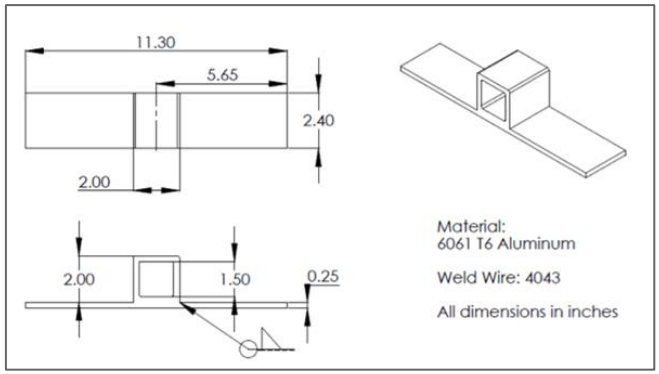


Vehicle Frame: Mounts

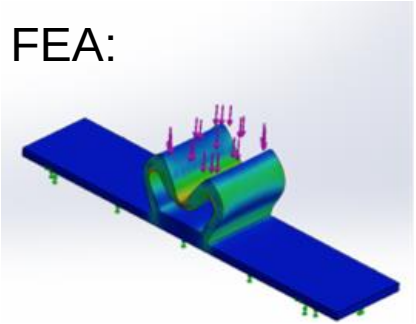
Tank/ Component Bracket:



Lower Seat Bracket:



FEA:

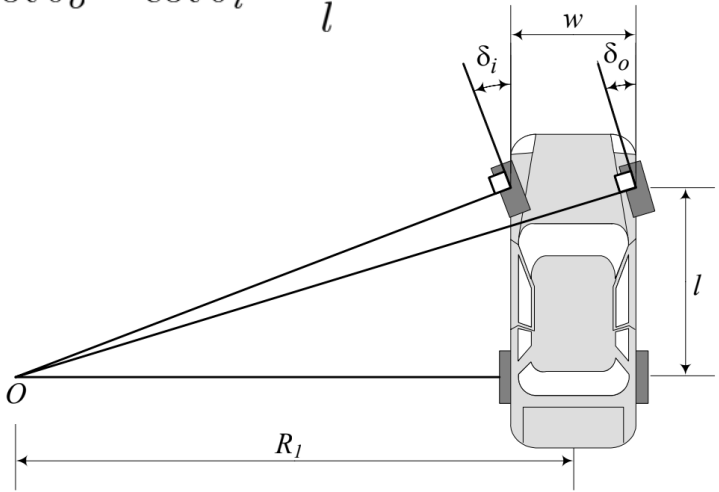


- 6061 T6 Aluminum
- Lower seat bracket sees highest load (500lb)
- Maximum Stress: 15 MPa
- Maximum Deflection: 0.008mm

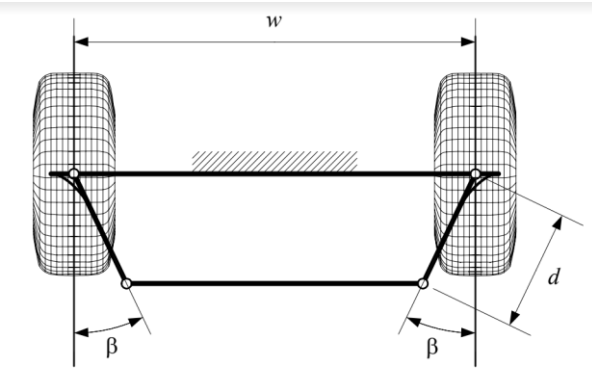
Steering Mechanism

Ackerman Steering Condition (Steering Dynamics):

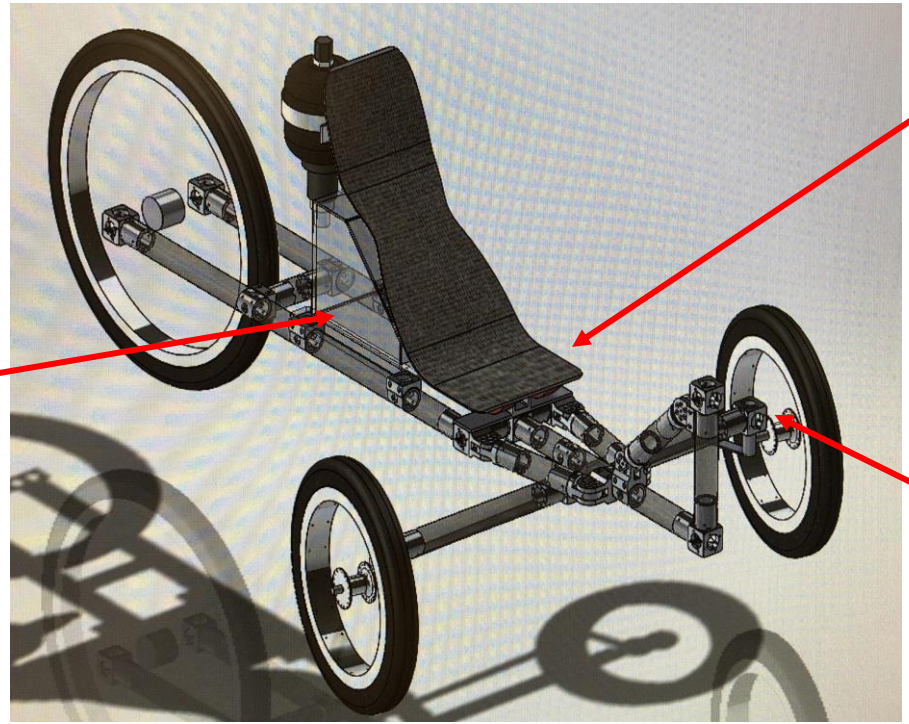
$$\cot \delta_o - \cot \delta_i = \frac{w}{l}$$



Trapezoidal Steering Linkage (Steering Dynamics):



Vehicle Frame: CAD

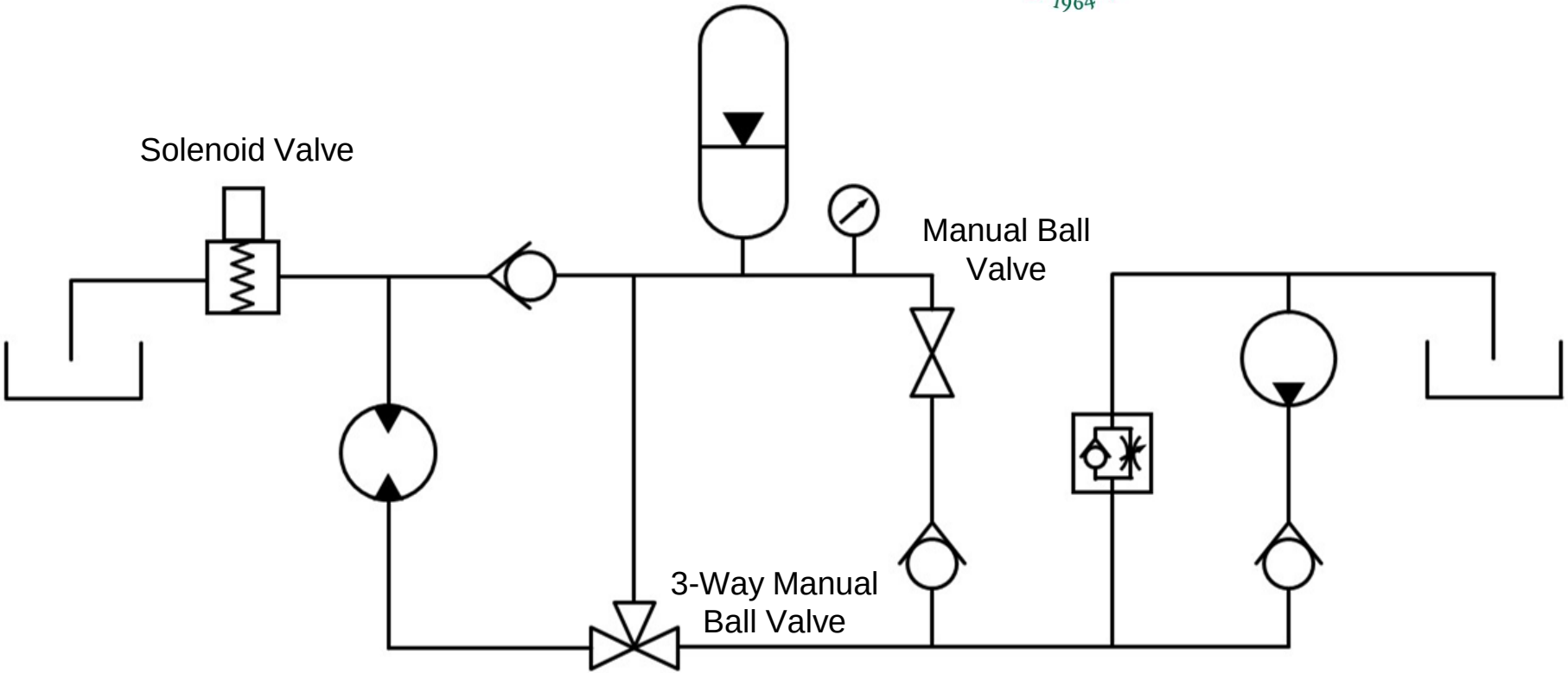


Seat Mounting

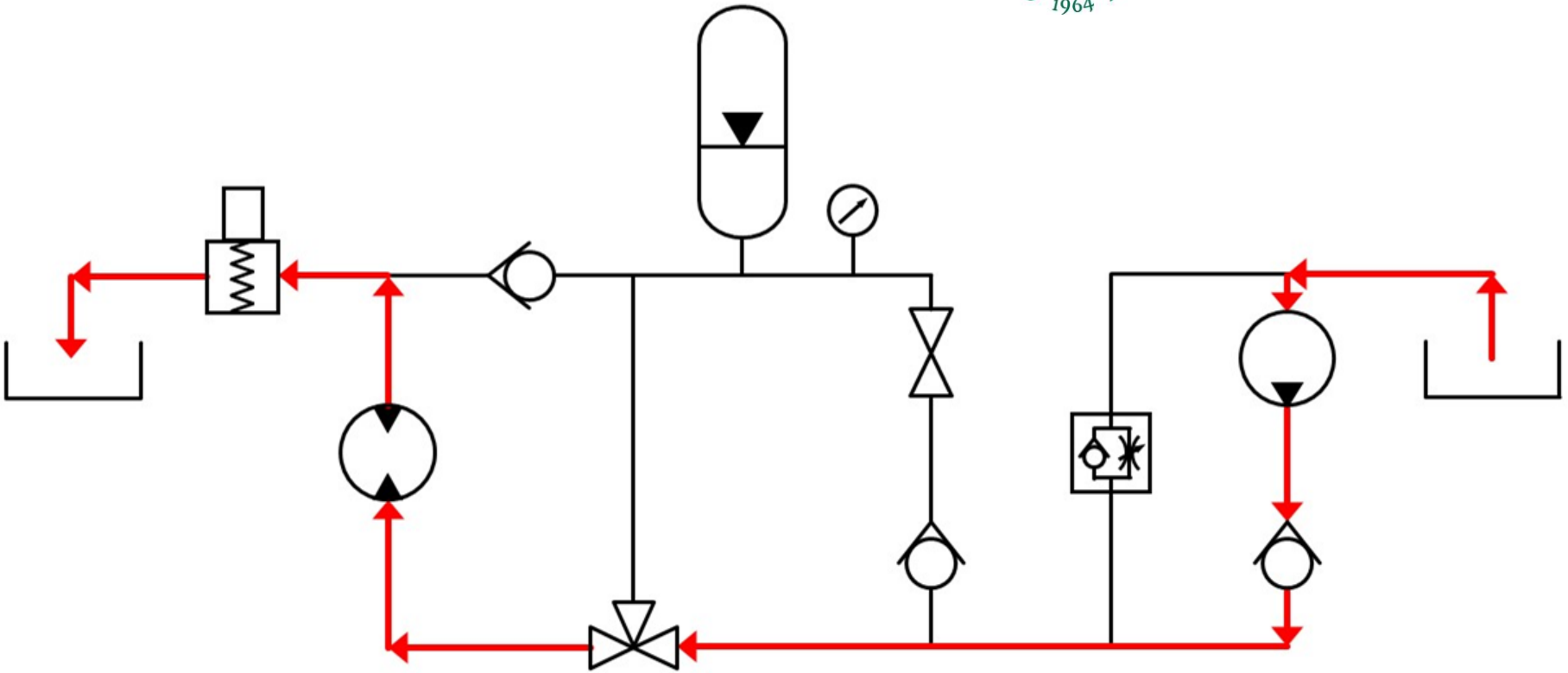
Tank Integration

Steering Mechanism

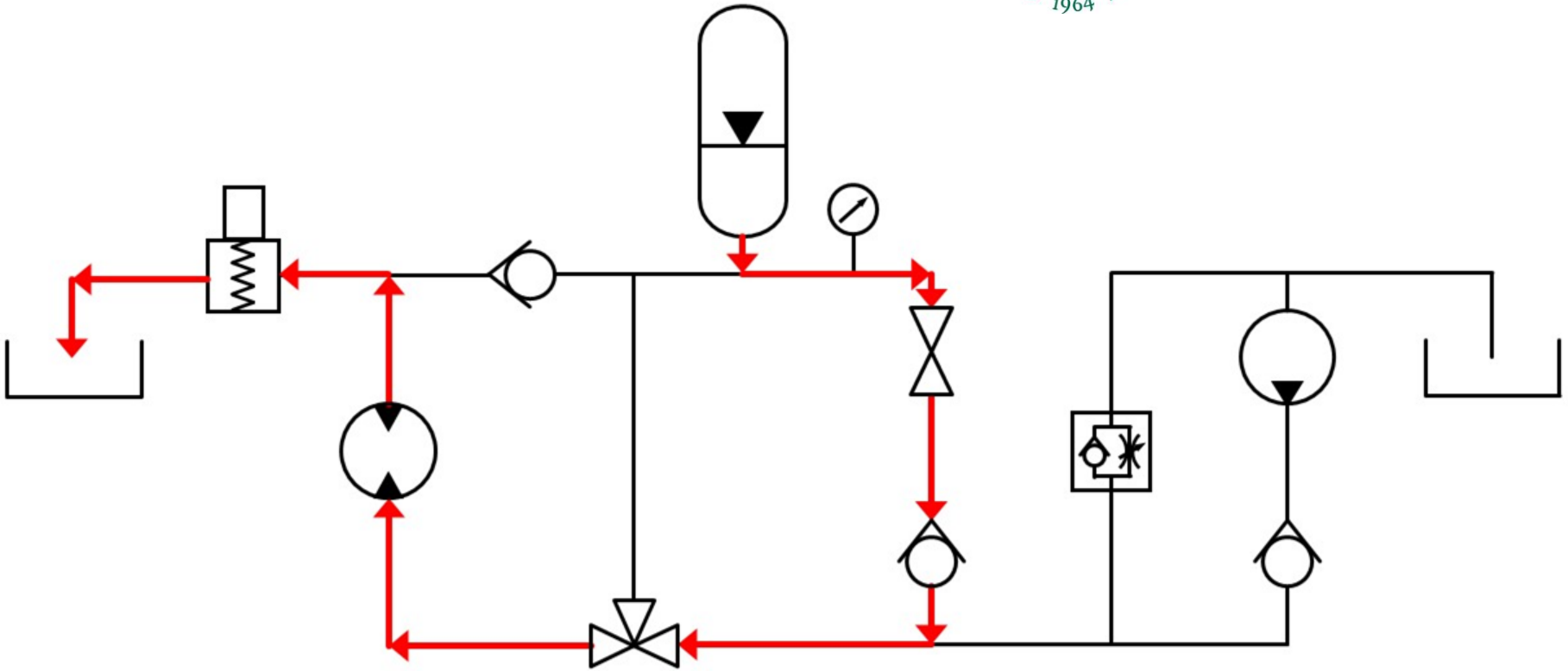
Hydraulic Circuit:



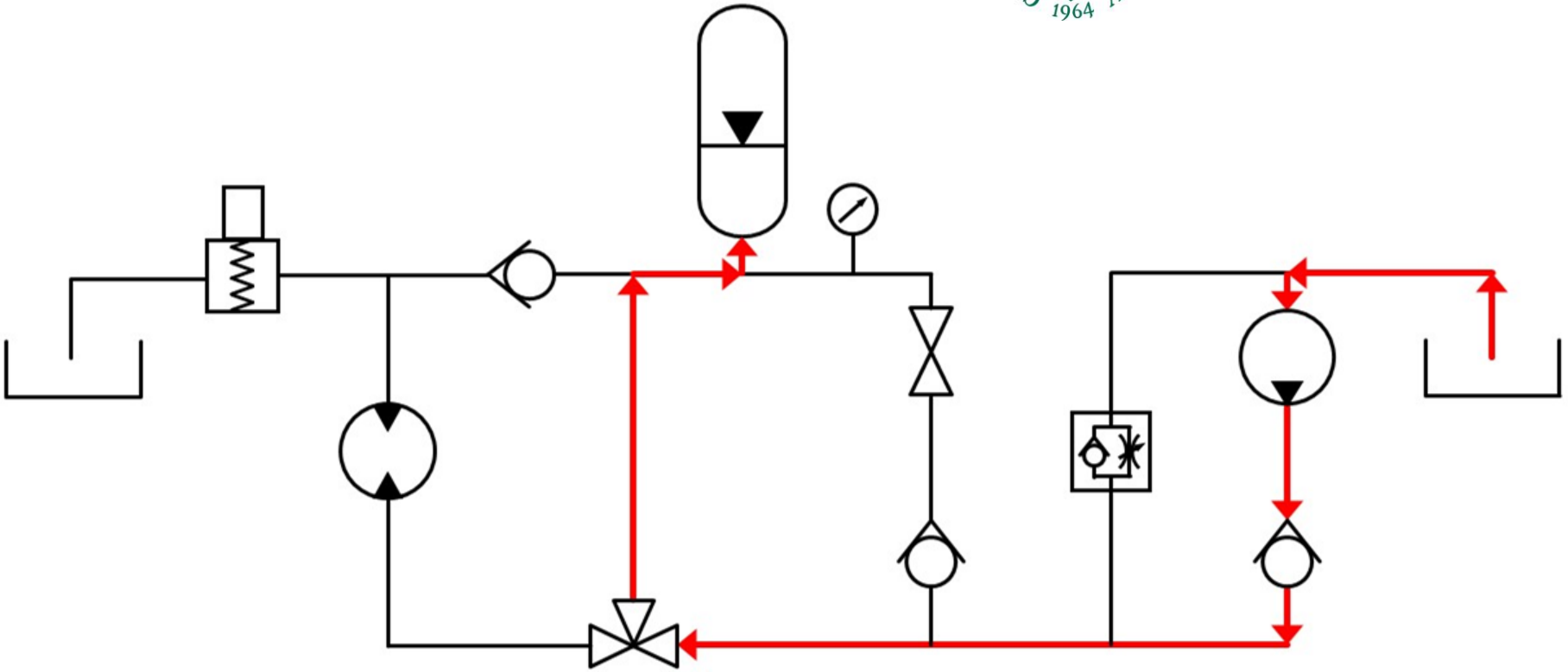
Pedaling Drive:



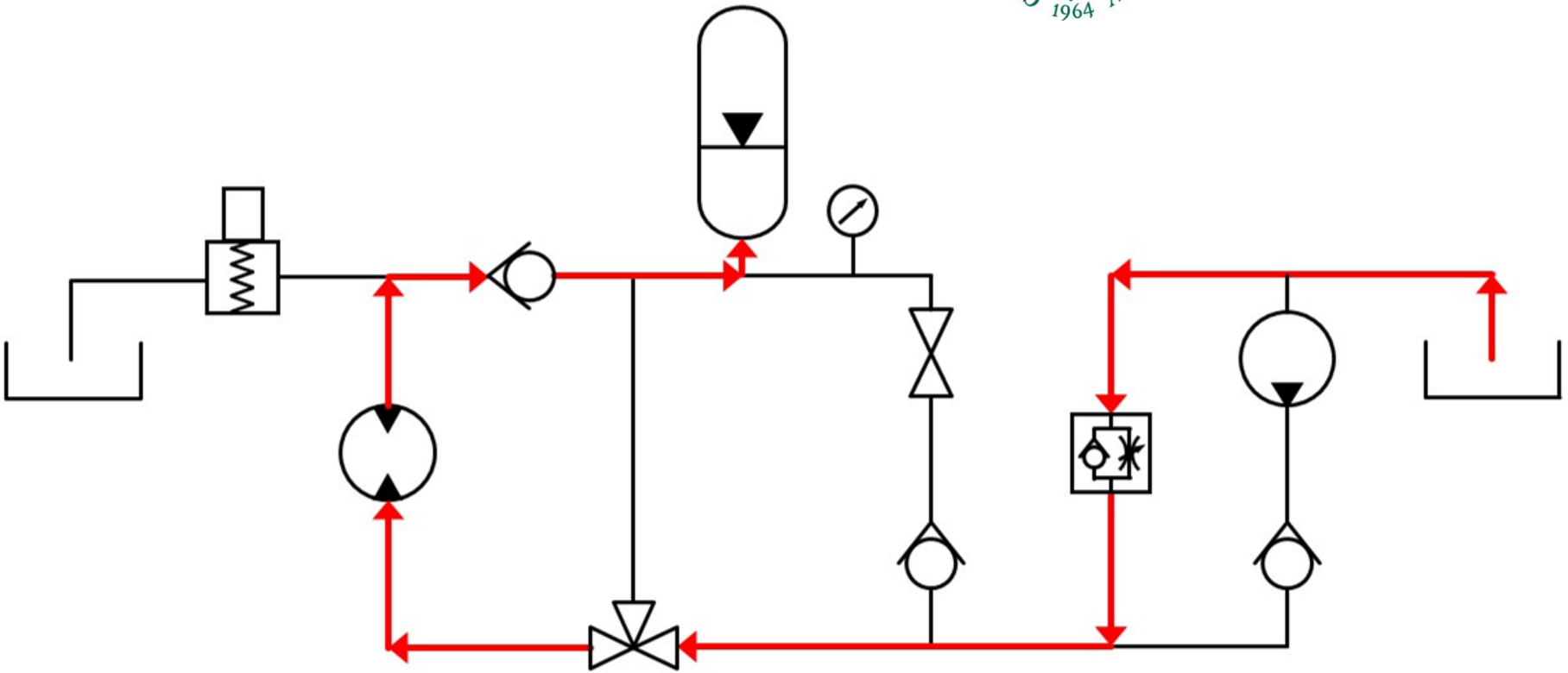
Accumulator Drive:



Charge By Pedaling:



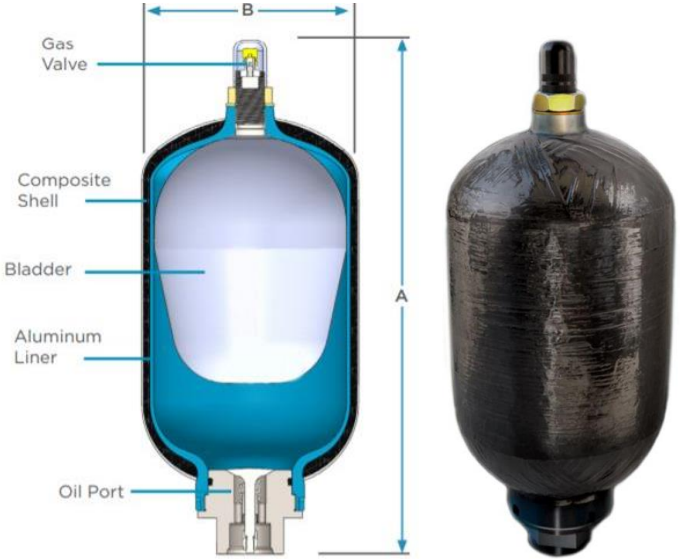
Regenerative Braking:



Component Selection

Bladder Accumulator

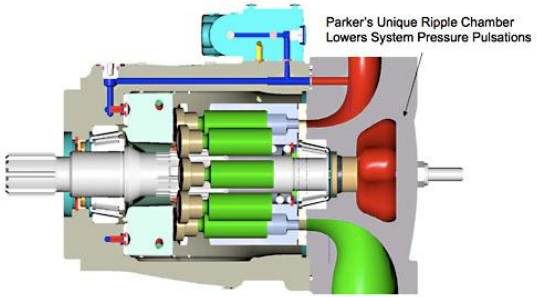
- High Efficiency
- Requires Recharging



(Steelhead Composites)

Piston Pump:

- High speed and efficiency
- Fixed displacement

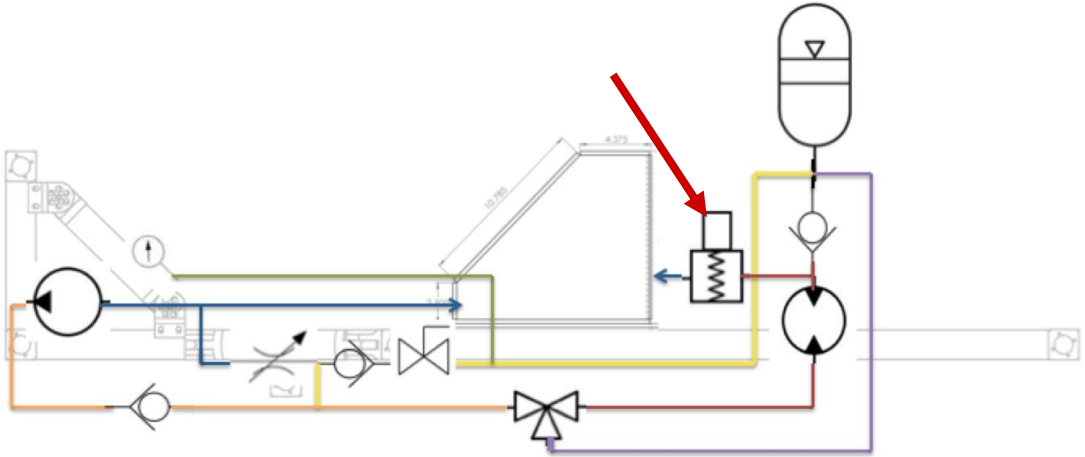


(Parker)

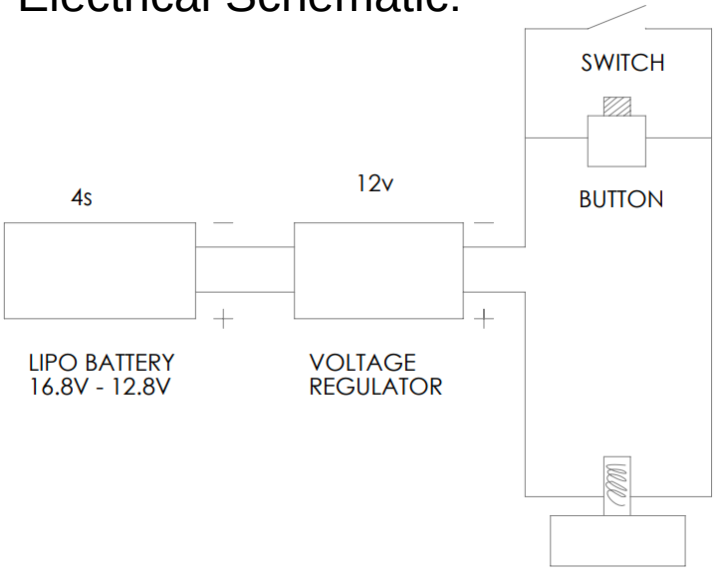
Component Selection

Solenoid Valve:

- Safety
- Regen Braking
- Normally Open
- Reduce Pressure Drop



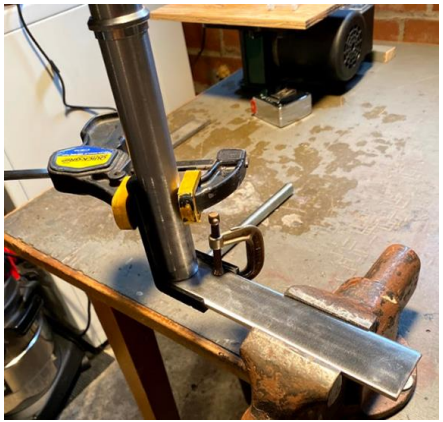
Electrical Schematic:



Vehicle Build:
Frame and Steering

Building Carbon Tubing Frame

Putting Spokes on the Wheels

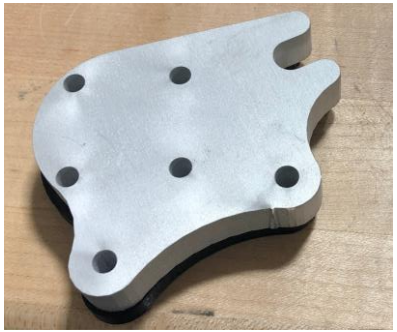


Welding the Kingpins

Aluminum Frame Support

Vehicle Build: Components

Waterjetting Aluminum for Mounts



Rear Axle/ Disc Brake Mount

Cutting Handlebars to Size

Vehicle Build:
Tank and Hydraulics

Fabricating the Tank

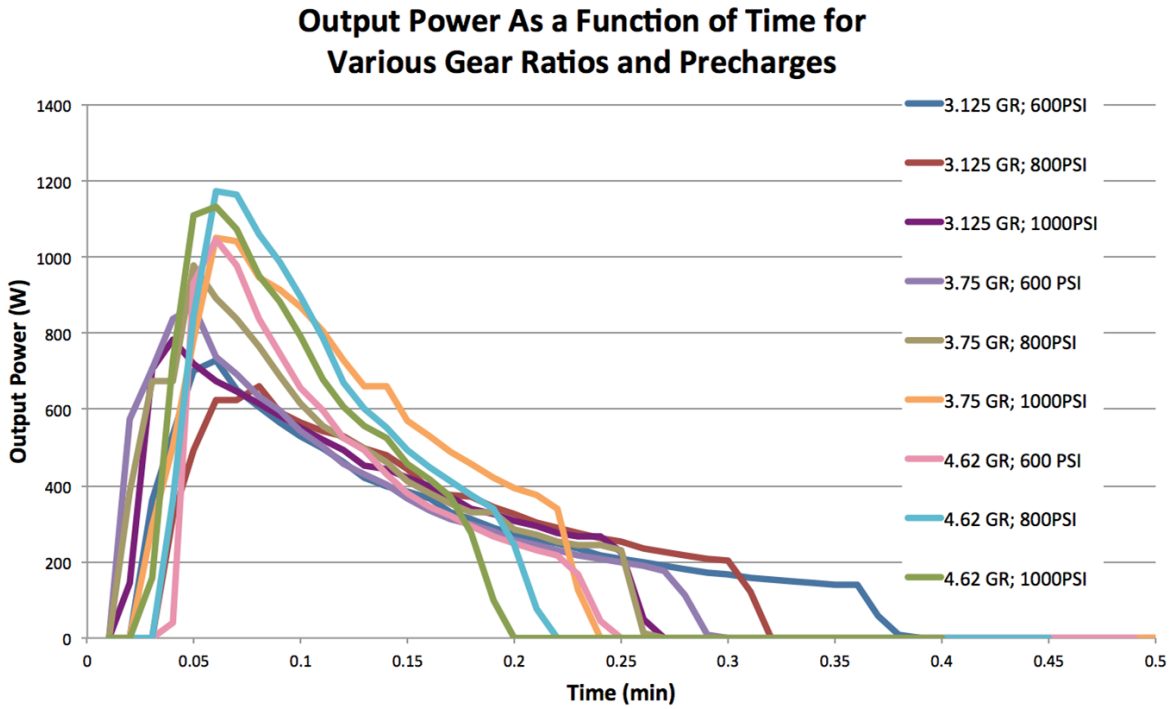
Working out the Hydraulics

Bi-directional Valve Mount

Testing

- Rear Wheel Gearing
- Accumulator Precharge

Power Output



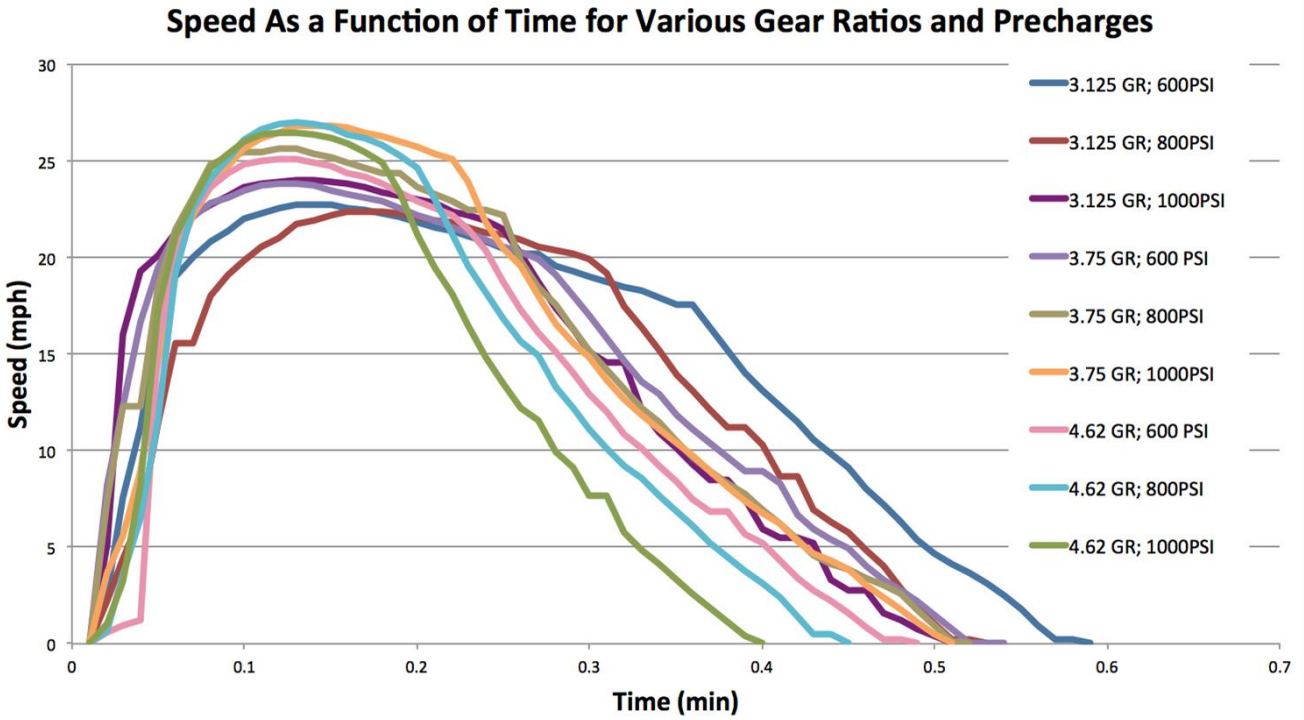
- Increased gear ratio:
  - Torque
  - Required Motor Flow
- Increased precharge:
  - Energy
  - Accumulator Pressure
  - Oil Volume

Stored Energy in Accumulator (NFPA):

Usable Volume — Weighted Average Pressure

$$E_{stored} = \left[V_{total}\left(1 - \frac{\boldsymbol{P_{precharge}}}{P_{max}}\right)\right] \times \left[0.29P_{max} + (1 - .29)\boldsymbol{P_{precharge}}\right]$$

Speed

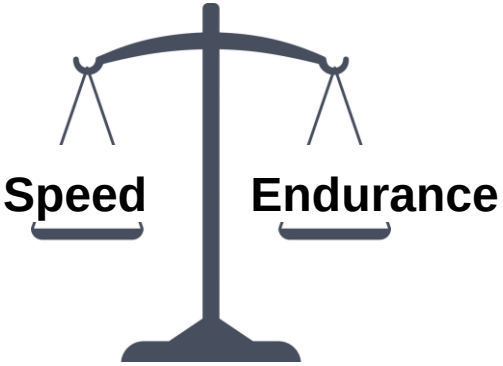


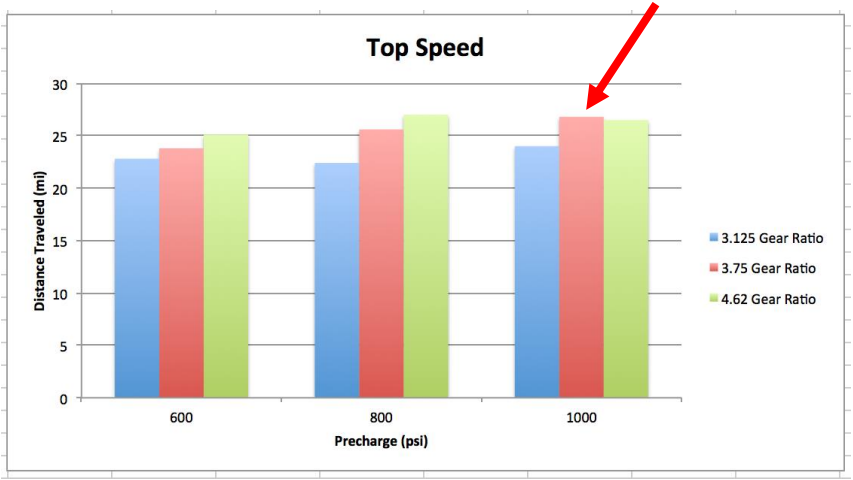
- Increased gear ratio:
  - Acceleration
  - Flow Rate
- Increased Precharge:
  - Volume and Pressure balance

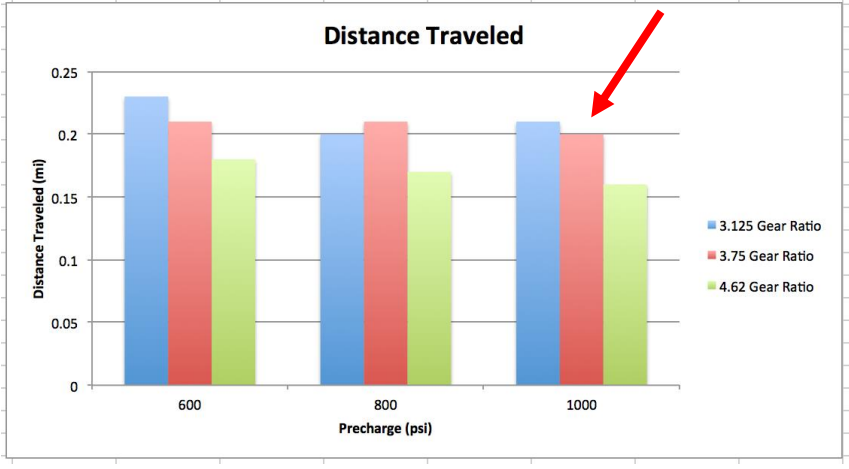
Gear Ratio and Precharge

Gear Ratio: 3.75

Precharge: 1000 psi







Final Vehicle

- Top Speed: 27mph
- Curb Weight: 171 lb
- Full Throttle Efficiency: 8%

Summary

- Carbon Fiber Tadpole Recumbent Frame
- Custom Fabrication:
  - Tank/ Seat Bracket
  - Trapezoidal Steering Linkage
- Modified Hydraulic Circuit
  - Solenoid Valve
- Testing for Gear Ratio and Precharge

Resources

- Jazar, R. N. (2017). *Vehicle dynamics: theory and application*. New York: Springer.
- Norton, R. L. (2020). *Design of machinery: an introduction to the synthesis and analysis of mechanisms and machines*. New York, NY: McGraw-Hill Education.
- Joseph, A. (2013, March 26). Hydraulic Pump Noise Reduction. Retrieved December 13, 2019, from https://www.designworldonline.com/hydraulic-pump-noise-reduction/.
- Cosford, J. (2014, February 28). Accumulators add functionality to hydraulic circuits. Retrieved December 13, 2019, from https://www.hydraulicspneumatics.com/technologies/accumulators/article/21883813/accumulators-add-functionality-to-hydraulic-circuits.