10 YEARS NFPA Fluid Power Vehicle Challenge

Final Review
Cleveland State
Bogdan Kozul
4/23/2026

NFPA
Education and
Technology
Foundation

Meet Our Team

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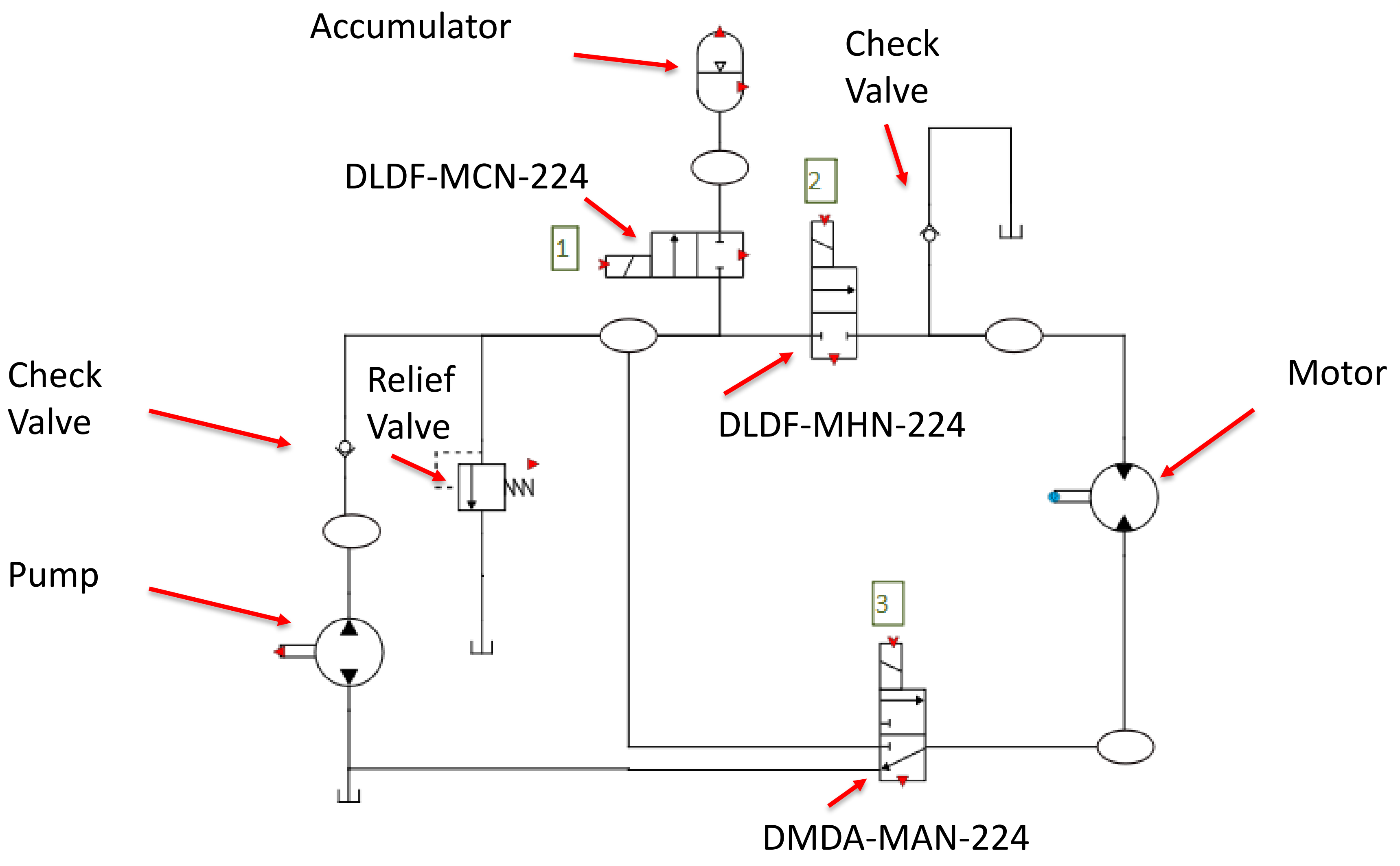
Overview

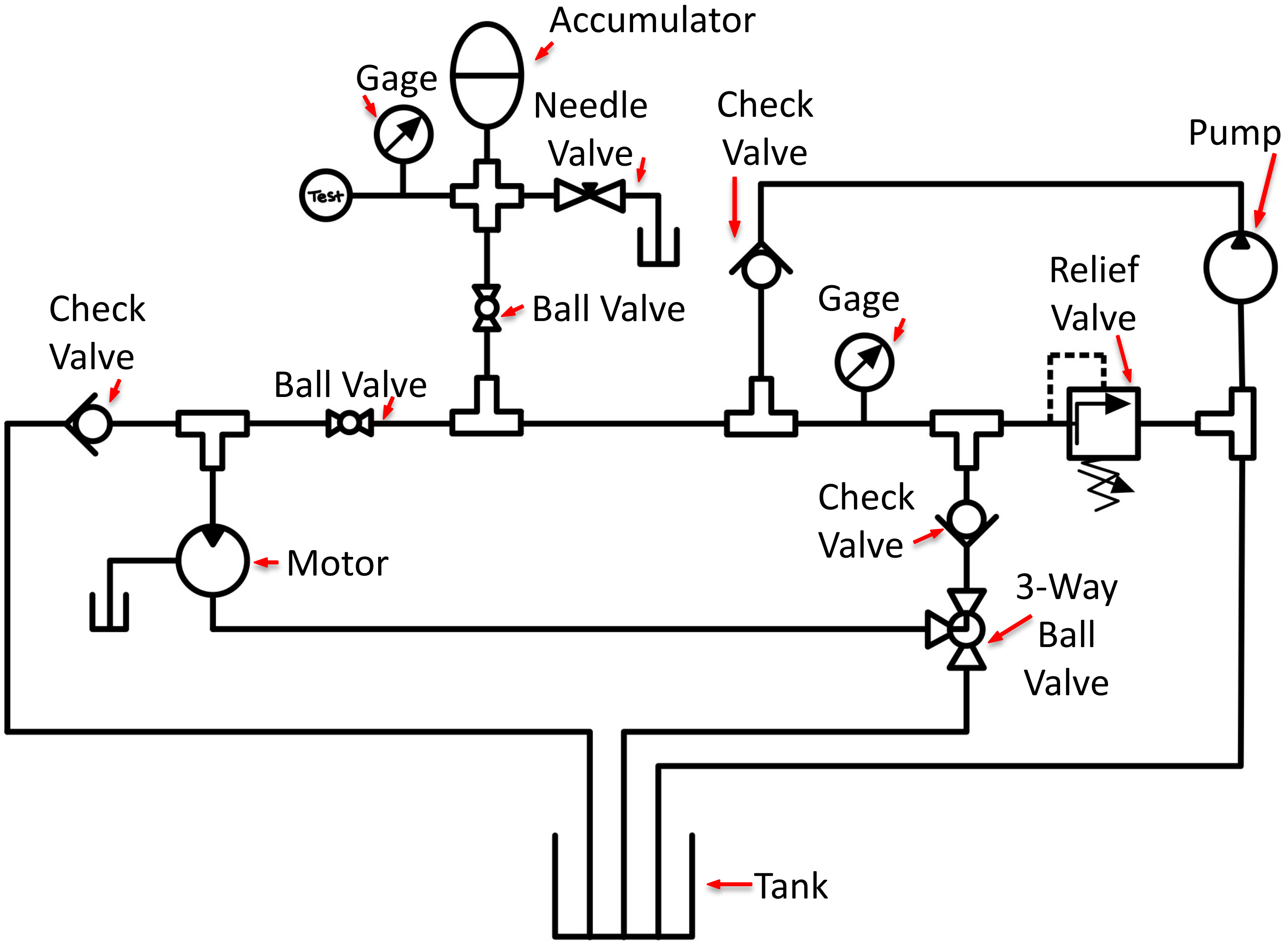
1. Schematic
2. Midway Review Prototype
3. Design Process
   - Construction: Manufacturing, Assembly, Component Testing
   - Design Optimization
   - Safety
   - Performance Testing
4. Over-all Lessons Learned

Final Schematic 2024-2025

- 3/8" Line SAE 8 Fittings
- 3/8" Line SAE 8 Fittings



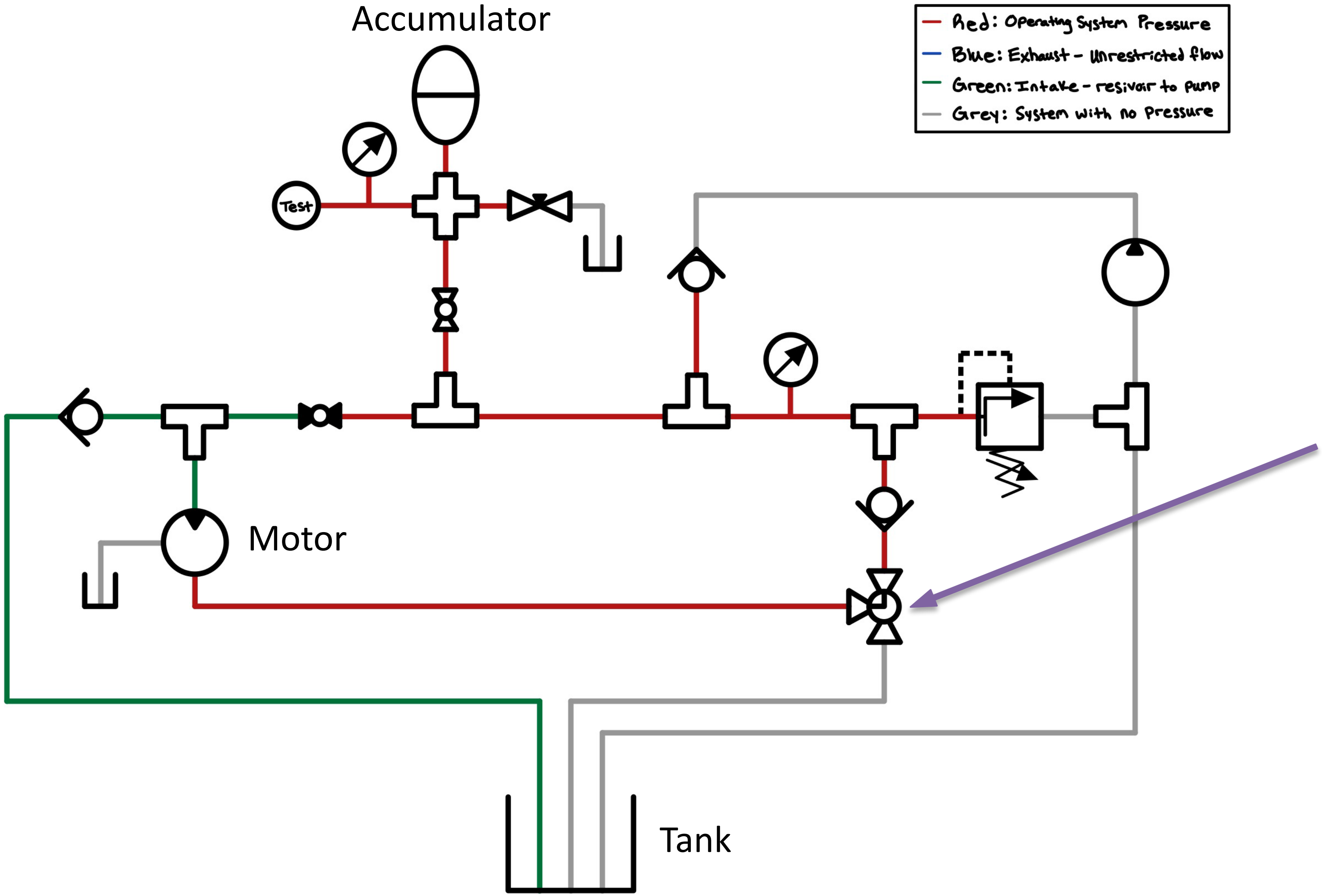
Final Schematic 2025-2026



Key Differences:

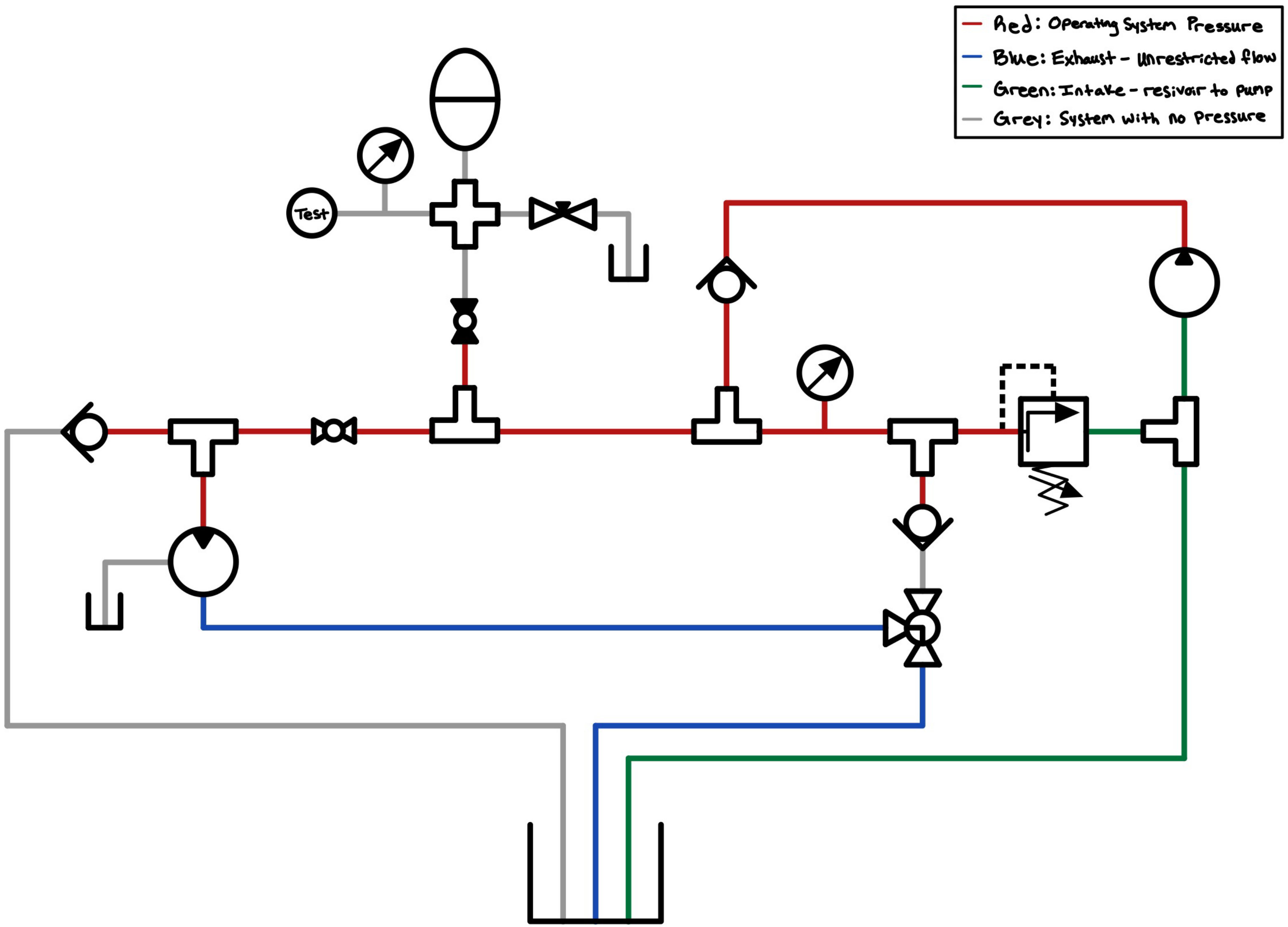
- Ball valves instead of solenoid
- 100% different components except accumulator
- No manifold

Regenerative Braking

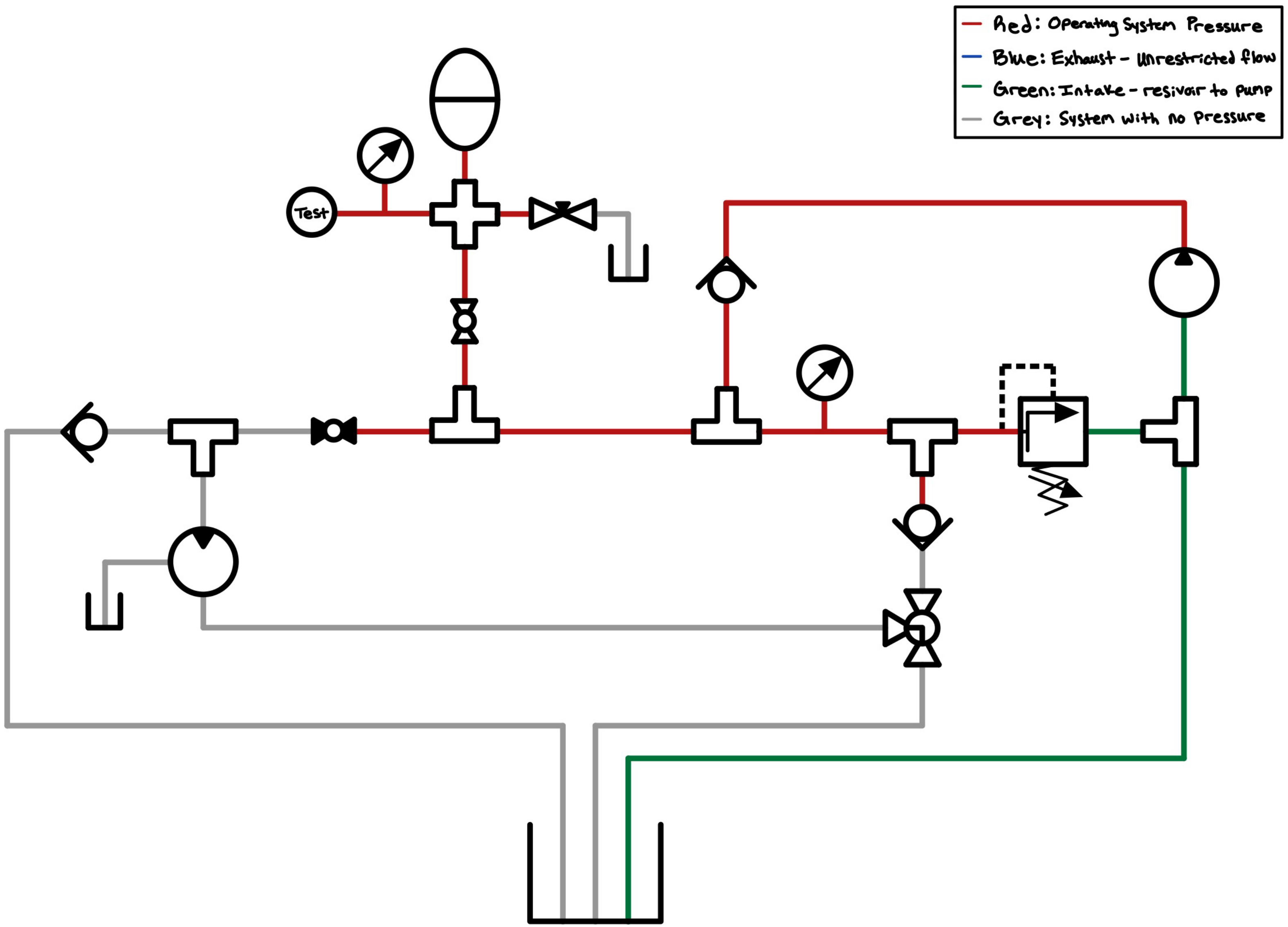


- Fluid flows from tank to motor to accumulator.
- 3-way ball valve is utilized to do this.

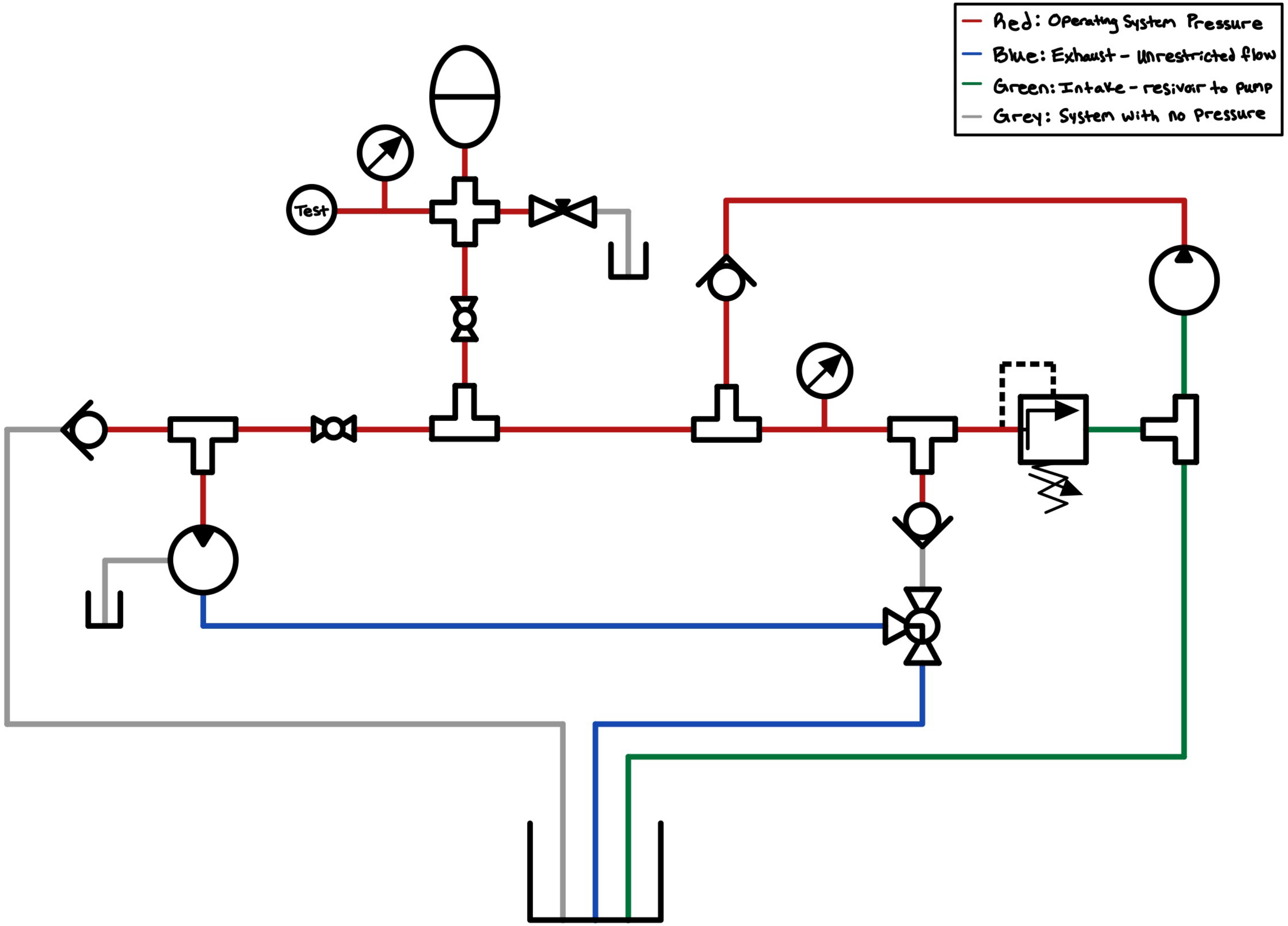
Direct Drive



Sprint Charge



Sprint


Red: Operating System Pressure
Blue: Exhaust - Unrestricted flow
Green: Intake - resivoir to pump
Grey: System with no Pressure
Test

Vehicle Construction: Where We Left Off

- Fully functioning prototype constructed on November 13th
- Schematic tested
- Gear ratios were not finalized
- Testing with gear pumps
- Using 30 lb. accumulator

Vehicle Construction Timeline

November

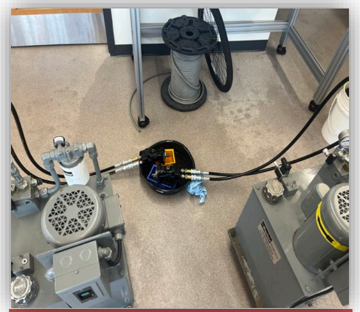
Prototype

Began constructing initial bike design with laboratory components and ordering new parts

January

Braking Components

The team installed Brake Line and Calipers for enhancing braking reliability and hear dissipation during operation



February

Component Testing

Testing motors and accumulators for proper pre-charging and optimizing acceleration and get-off

February

Hardlines and Sprockets

Bending tubes and optimizing gear ratios

March

Sprockets & Safety

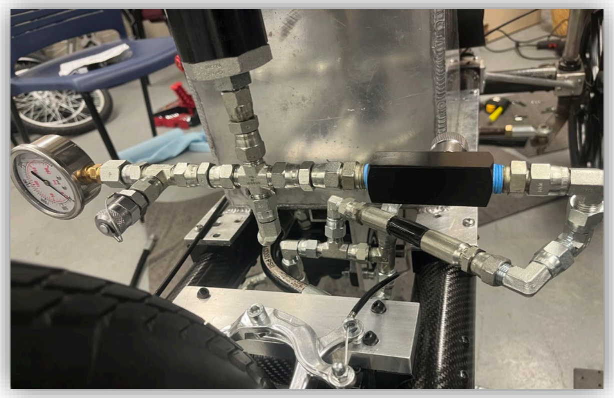
Optimizing gear ratios and manufacturing guard

April

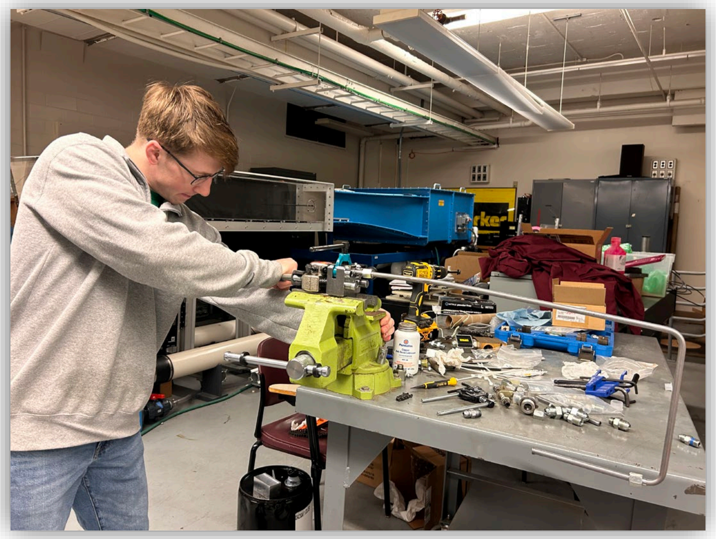
Finishing Touches and Final Testing

Full construction of bike completed, wrapped up, and event tested

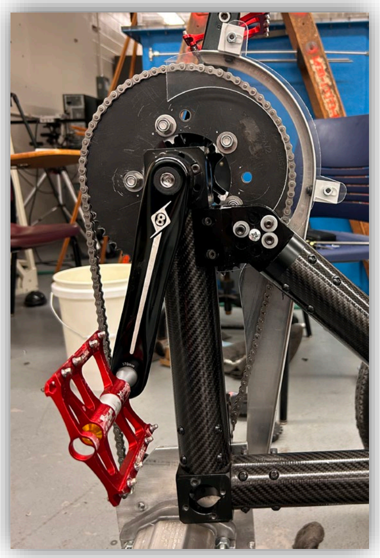
Manufacturing & Assembly



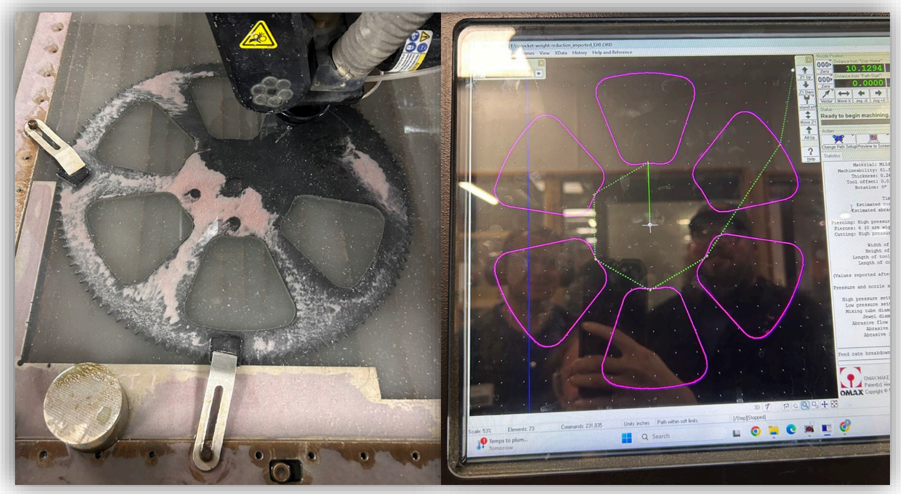
Arranging Hardline Tubing and Fittings



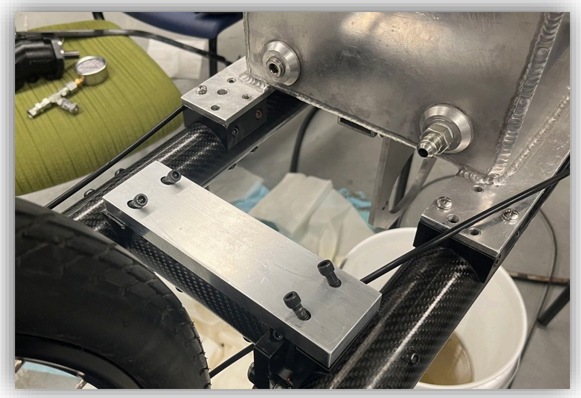
Hard Line Bending Tubing Flaring



Waterjet Polycarbonate Chain Guard Design

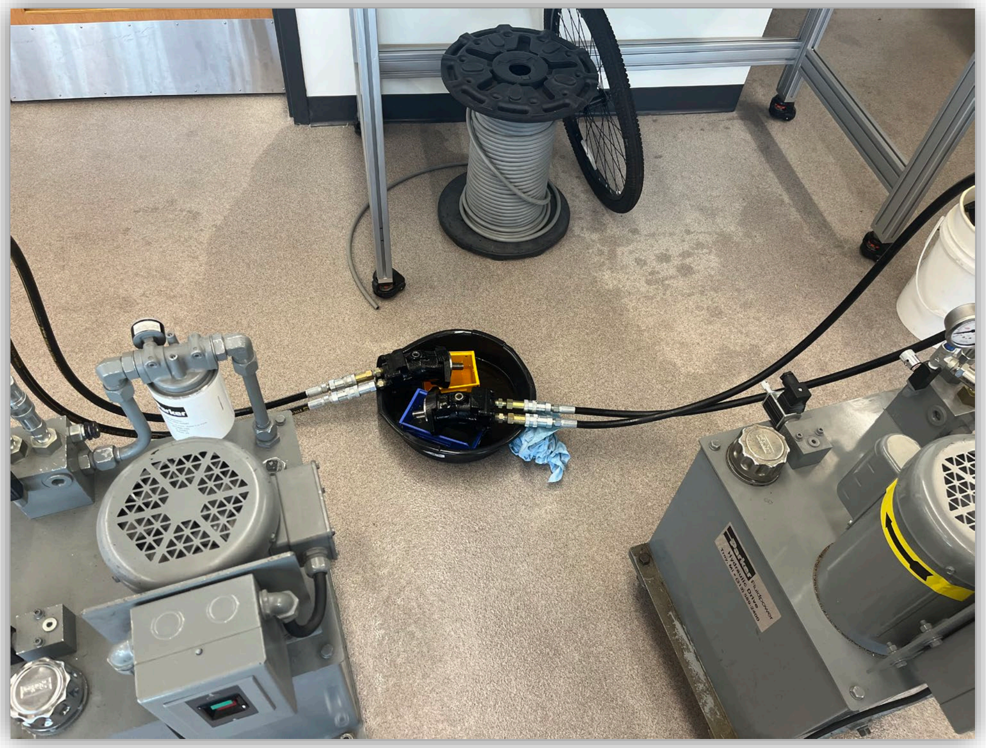


Waterjet Gear Weight Reduction



Milled Brake Caliper Mount

Component Testing: Biggest Struggle



- The biggest obstacle in our bike design was trying to use bent axis piston motors
- Spent multiple days trying to break in the motors
- Had to pedal to 2000 psi for motor to break free

Lessons Learned from Construction

Technical Skills:

- How to properly match fittings
- Proper bending and flaring technique
- How to use manufacturing equipment: Waterjet, Lathes, Mills, Band Saws
- How to properly pre-charge accumulators

Industry:

- Having the right equipment for chains is really important
- Keep fitting manufacturers consistent

Bent Axis Pumps:

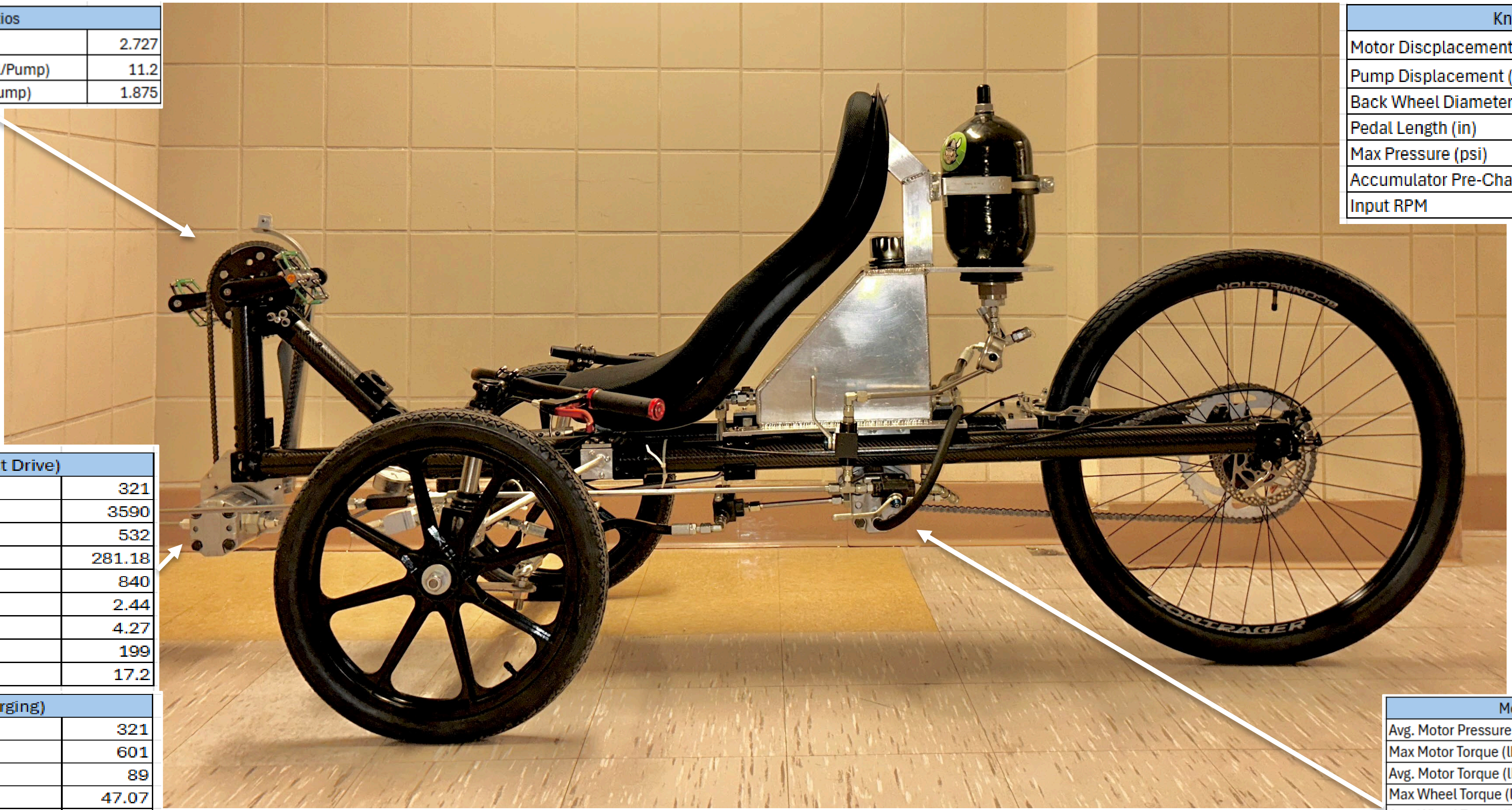
- Extremely delicate
- Have a higher hydraulic efficiency, but the mechanical efficiency is lower

Overall System Specifications

10 YEARS NFPA Fluid Power Vehicle Challenge

Gear Ratios	
Speed Ratio (Wheel/Motor)	2.727
Direct Drive Gear Ratio (Pedal/Pump)	11.2
Charging Gear Ratio (Pedal/Pump)	1.875

Known Variables	
Motor Discplacement (in^3/rev)	1.037
Pump Displacement (in^3/rev)	0.671
Back Wheel Diameter (in)	29
Pedal Length (in)	6.75
Max Pressure (psi)	3000
Accumulator Pre-Charge Pressure (psi)	1000
Input RPM	75



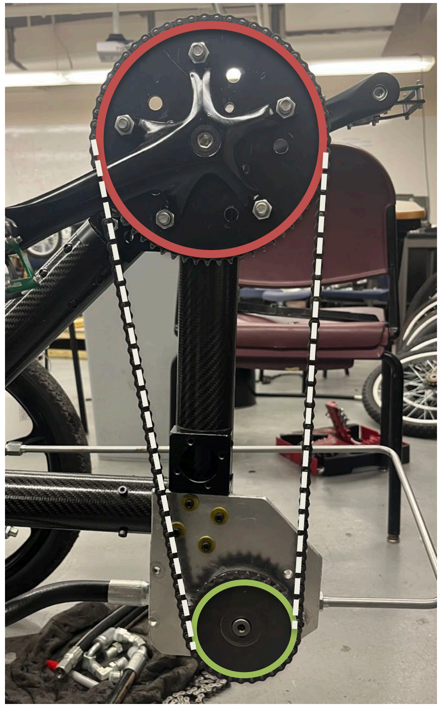
Pump Information (Direct Drive)	
Max Pump Torque(lb-in)	321
Pedal Torque (lb-in)	3590
Force on Pedal (lbs)	532
Avg. Force on Pedal (lbs)	281.18
Pump RPM	840
Pump Flowrate (GPM)	2.44
Input Horsepower	4.27
Max Pedaling Wheel RPM	199
Max Pedaling Velocity (mph)	17.2

Pump Information (Charging)	
Max Pump Torque(lb-in)	321
Pedal Torque (lb-in)	601
Force on Pedal (lbs)	89
Avg. Force on Pedal (lbs)	47.07
Pump RPM	140.625
Pump Flowrate (GPM)	0.41
Input Horsepower	0.71
Max Pedaling Wheel RPM	33
Max Pedaling Velocity (mph)	2.88

Motor Information	
Avg. Motor Pressure (psi)	1586
Max Motor Torque (lb-in)	495
Avg. Motor Torque (lb-in)	262
Max Wheel Torque (lb-in)	1351
Avg. Wheel Torque(lb-in)	714
Max Pull (lbs)	93
Avg. Pull (lbs)	49
Accumulator Usable Volume (in^3)	153
Distance Traveled Under Power (ft)	411

Different Sprocket Ratios

Charging Ratio



60 t

32 t

1.875 : 1

Smaller

Optimizes:

Top Speed

Efficiency

Direct Drive Ratio

112 t

10 t

11.2 : 1

Aggressive

Optimizes:

Torque

Acceleration

Speed Ratio

60 t

22 t

2.727 : 1

Fixed

Design Optimization

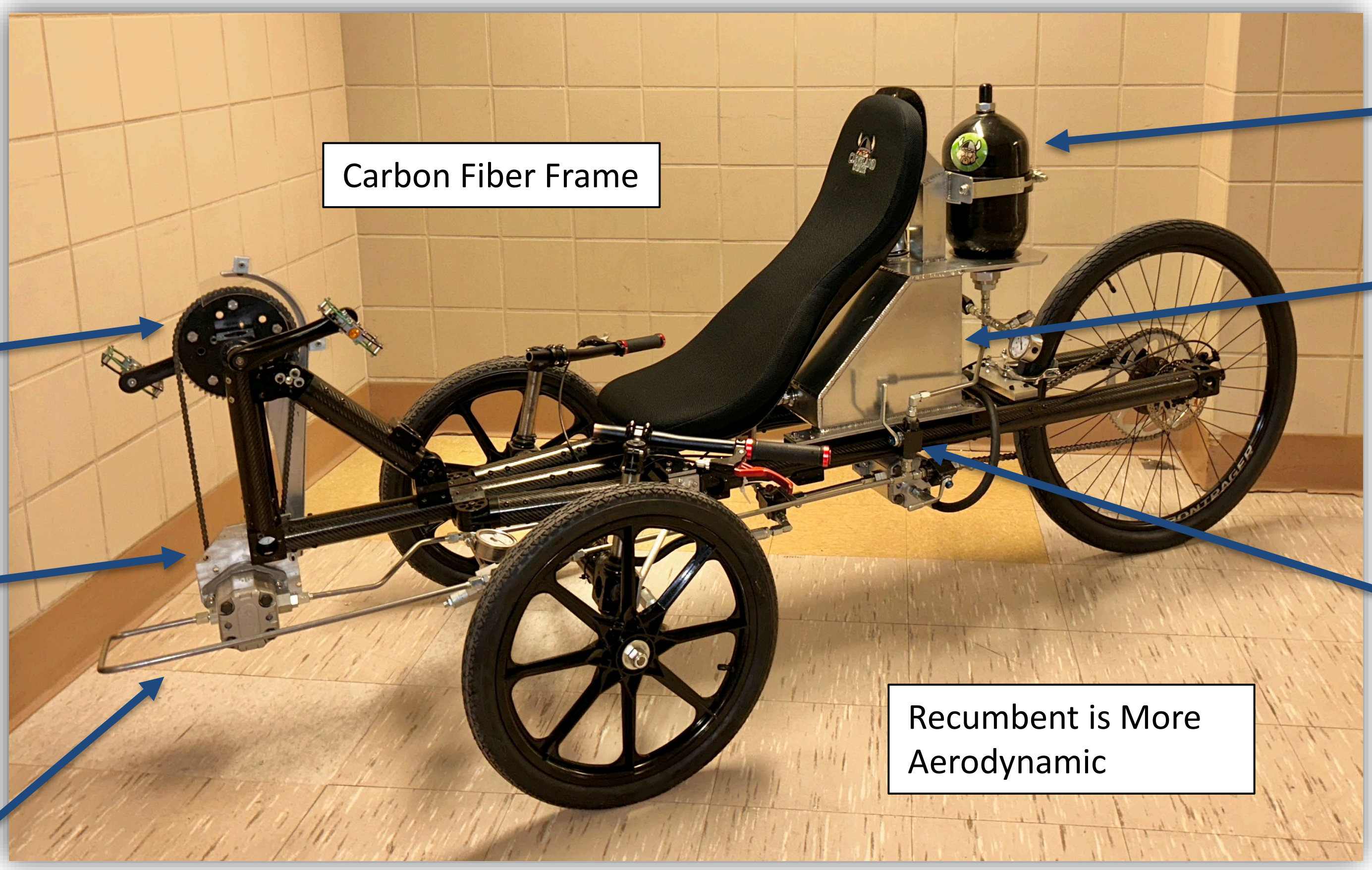
Designed for Sprint Race:

Focused on Weight Reduction and Aggressive Gear Ratios to Optimize Speed, Used Ball Valves

Weight reduction by 50% on Endurance Race Sprocket

All Aluminum Mounting, Aluminum and Polycarbonate guard

Hard lining has Better Pressure Resistance and Heat Dissipation, More Compact



Carbon Fiber Accumulator

Aluminum Tank and Compact Frame to Seat

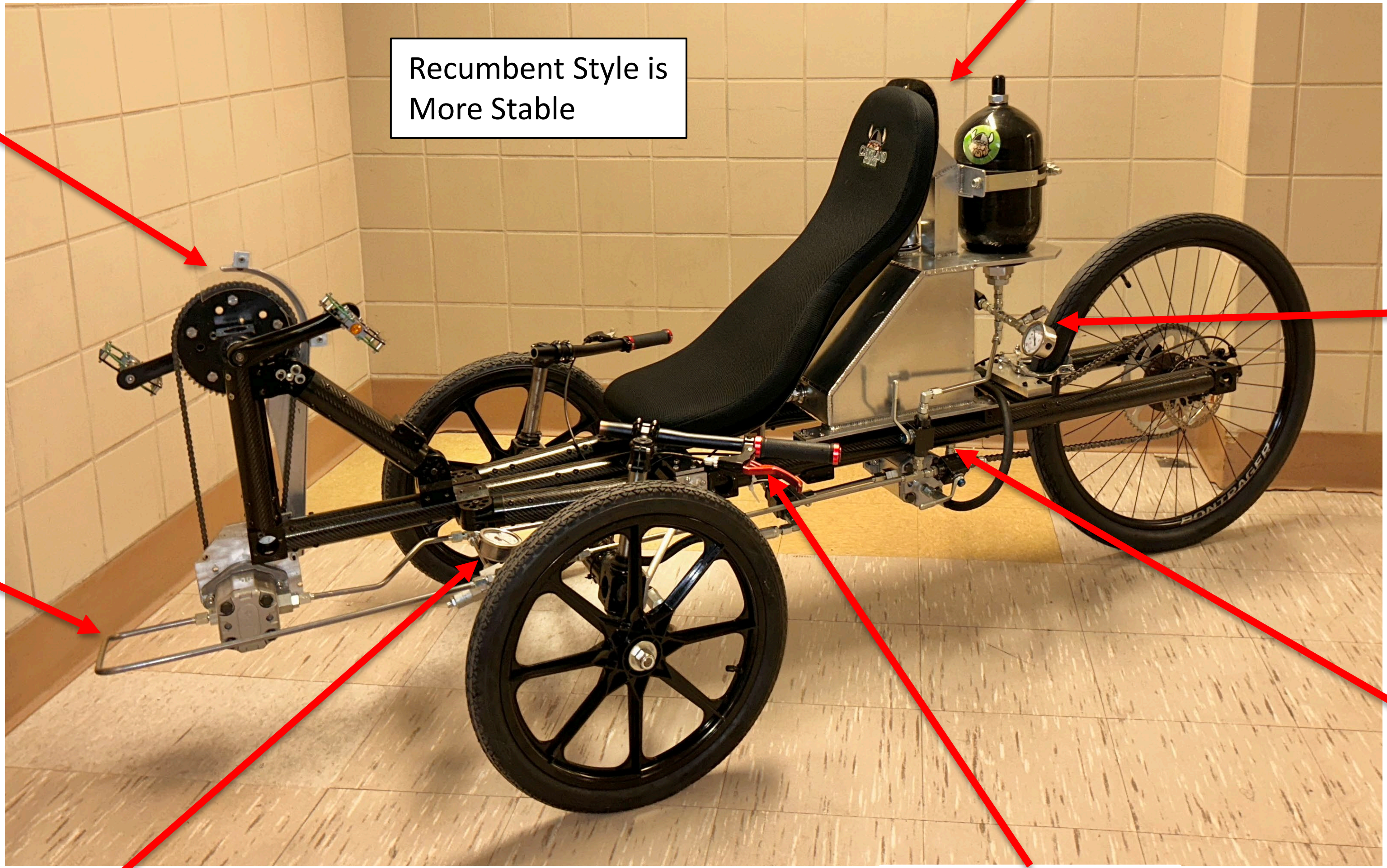
Ball Valves Used for Better Efficiency: Less inertia, Less Friction

Design Safety and Ergonomics

Ergonomic Seat and Tank mount

Chainguard Applied for Rider Safety

Recumbent Style is More Stable



Tubing Rated for Max 3400 psi with a Wall Thickness of t= 0.065’’

All Valves Rated for 3000 psi or Higher

Pressure Relief Valve Set to 3000 psi

Ball Valves Easy to Reach

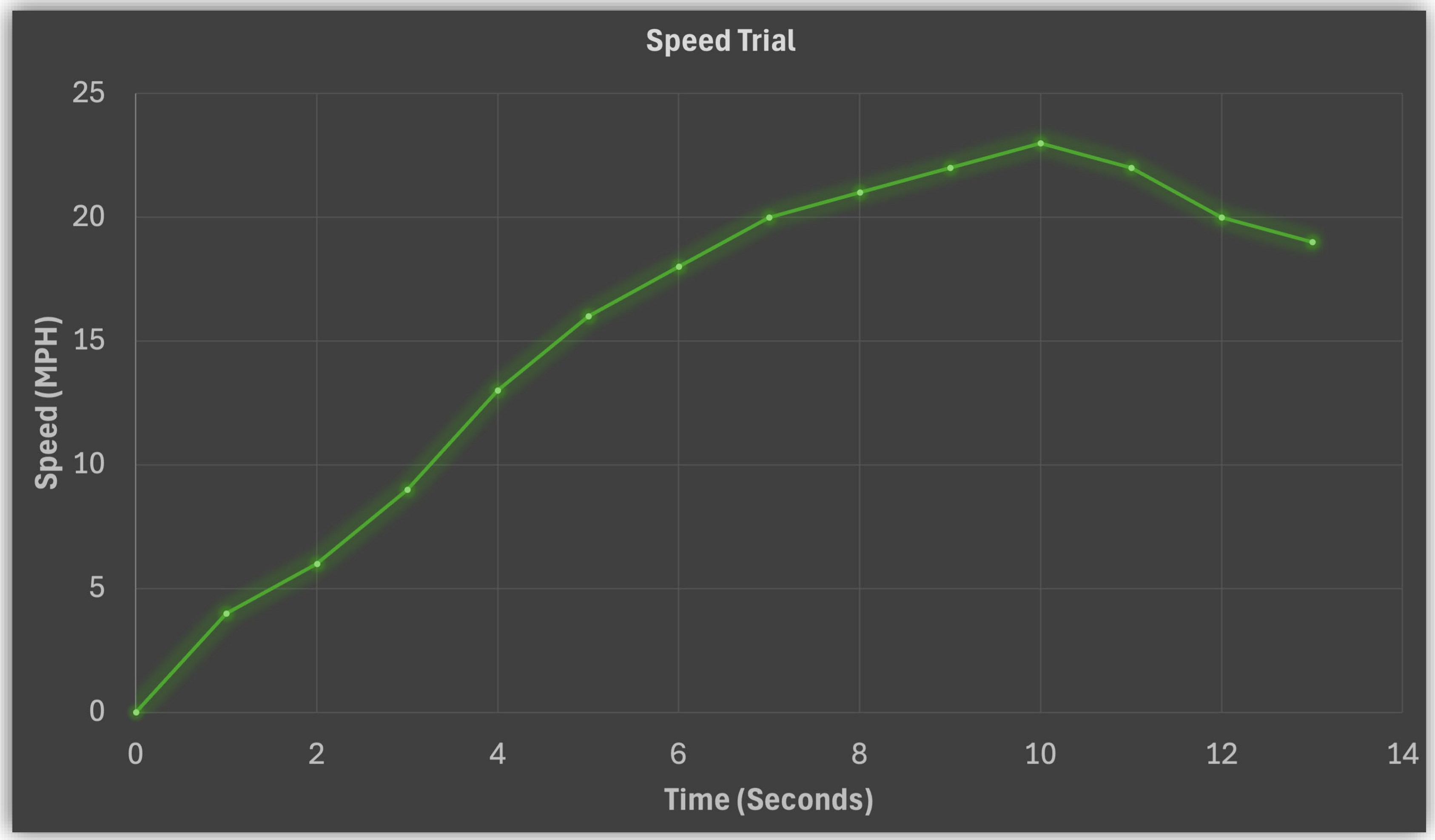
Pressure Gage Visible

Dual Brake Line Caliper Setup for Braking Efficiency

Performance Testing

Testing Type	Results	Modifications/Improvements
Sprint Race	Challenge Distance: 300ft Elapsed Time: 12.5 seconds Average Speed: 16.4 mph Maximum Speed: 22 mph	○ Lowered Charging Gear Ratio
Endurance Race	Challenge Time: 15 min Elapsed Distance: 1.6 mi Average Speed: 7.4 mph	○ Swapped 3/8th line for ½'' for better flow ○ 10 lb. Weight Reduction

Performance Data



Where We Started

Final Product

10 YEARS
NFPA
Fluid Power
=VEHICLE
Challenge

Over-all Lessons Learned

- Sometimes having a working prototype faster is more valuable than a perfect design
- If something doesn't make sense don't keep putting time and effort into it
- We learned to use all our resources – asking companies for help
- Read the product specifications - suppliers can have faulty info, always read the product data sheet
- Choose an aspect of your design to build around.

Questions?