NFPA Fluid Power VEHICLE Challenge

NFPA Education and Technology Foundation

SUNY POLYTECHNIC INSTITUTE

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WILDCAT FLUID POWER SUNY POLY

The Team

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Mechanical Design Lead

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WFP Club Vice President
Hydraulic Design

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WFP Member
Reservoir Design

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Hydraulics Lead

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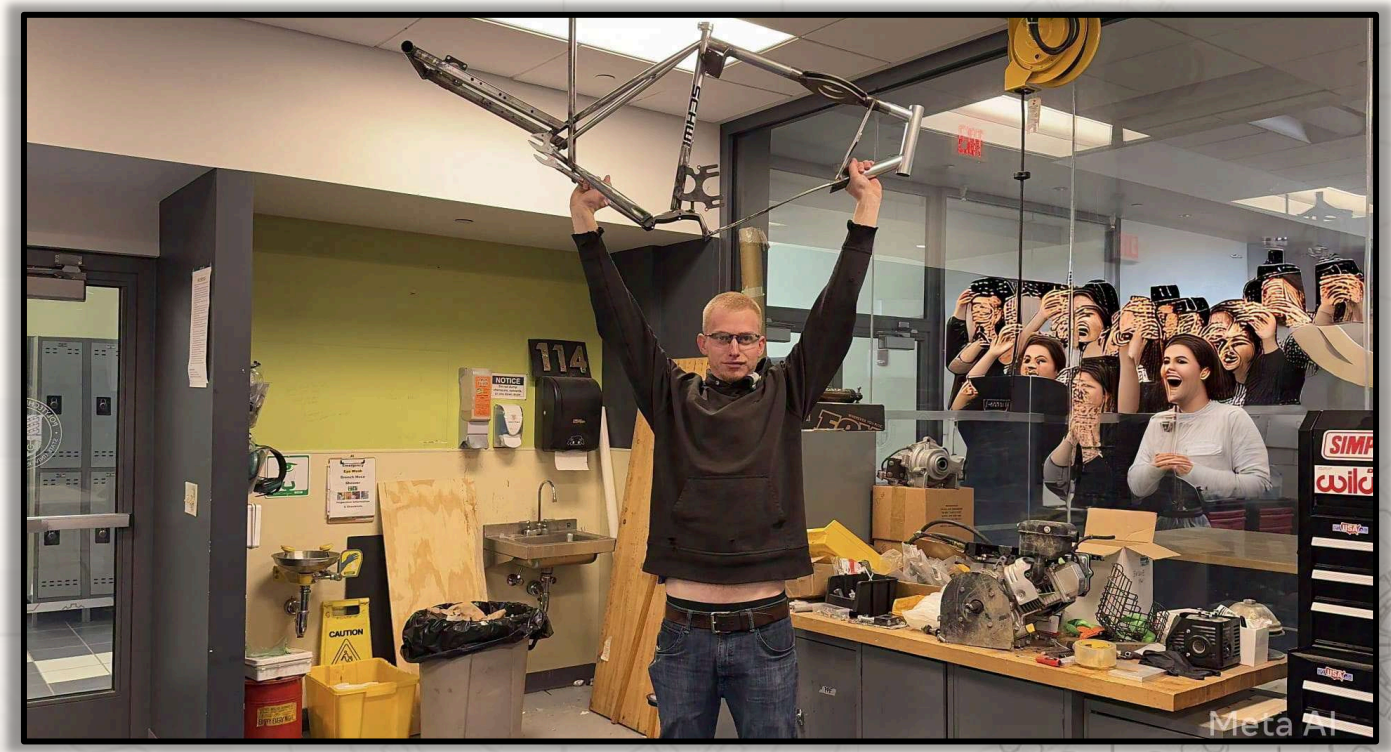
WFP Member
Pneumatic Design Lead

Christopher Lam
WFP Club Secretary
Electrical Design Lead

Robert Dawson
WFP Member
Pneumatic Design

Design and Build



Last Years Circuit

- Pros
  - Simple
  - Reliable

- Cons
  - Electrically Inefficient
  - No Needle Valve Drain for Accumulator

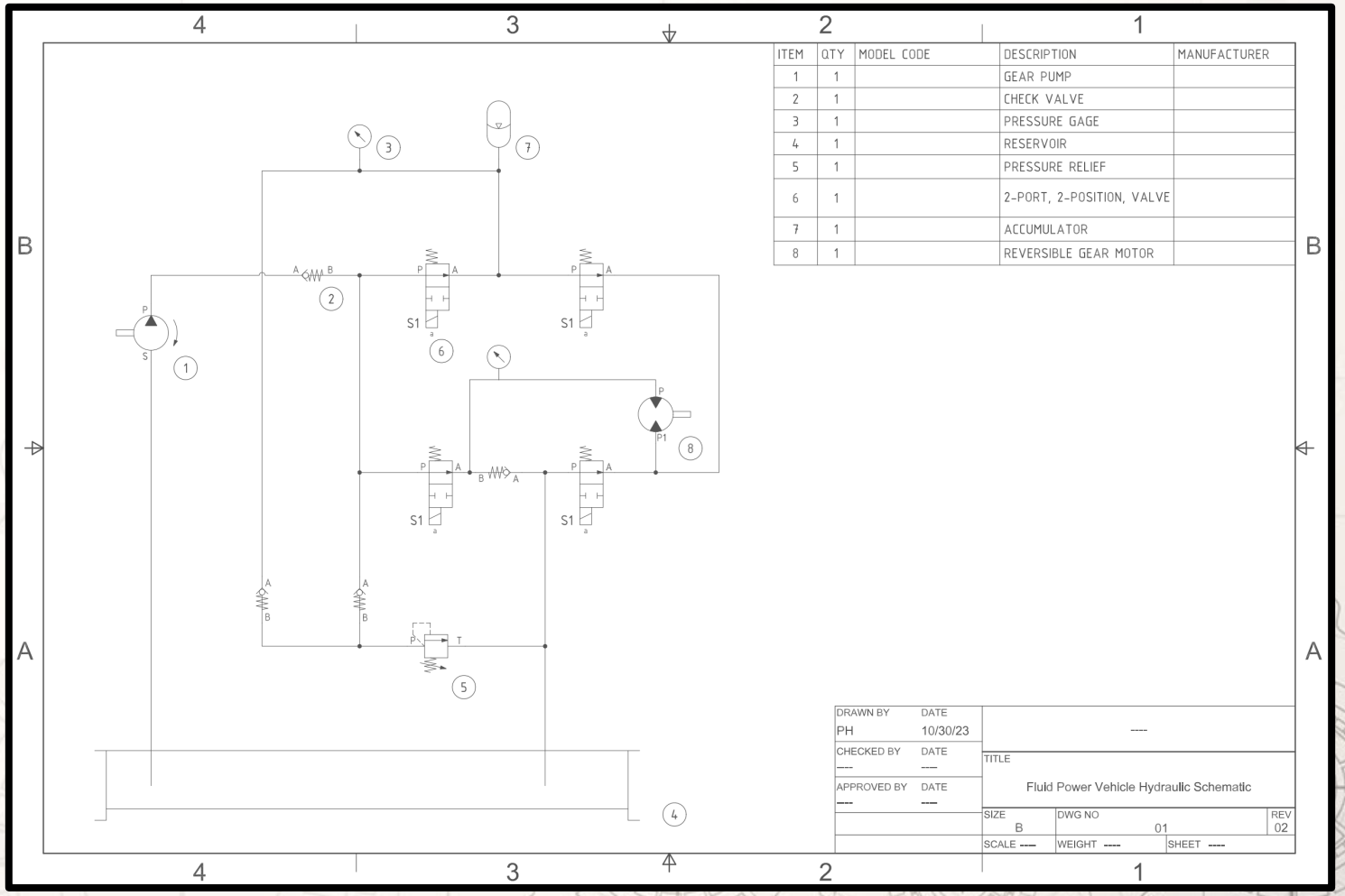


Fig. 1: 2023-2024 Hydraulic Circuit

This Years Circuit

- Dedicated Regen Pump
- One Less Control Valve
- Needle Valve Drain for Accumulator
- Extra Relief Valve

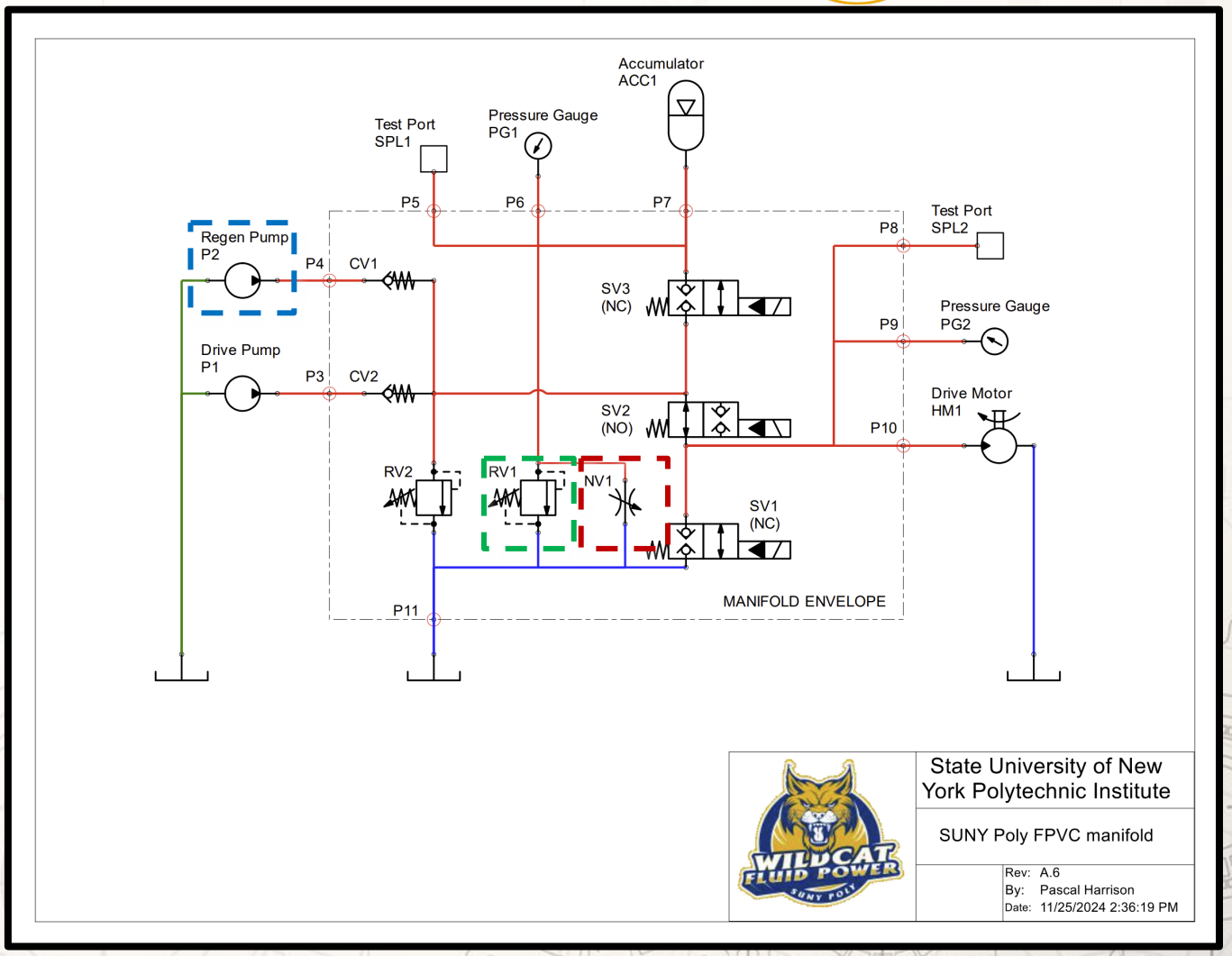
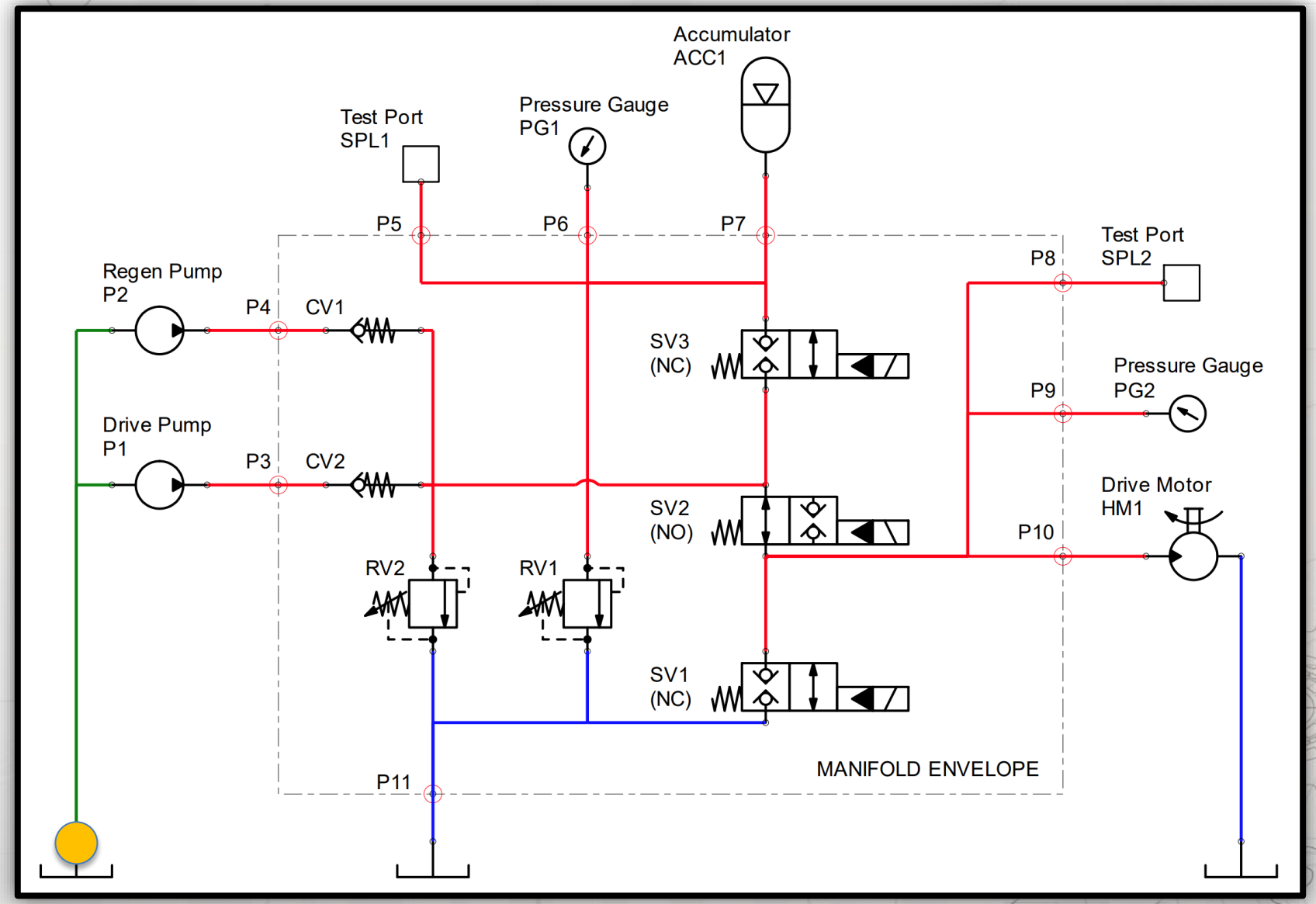
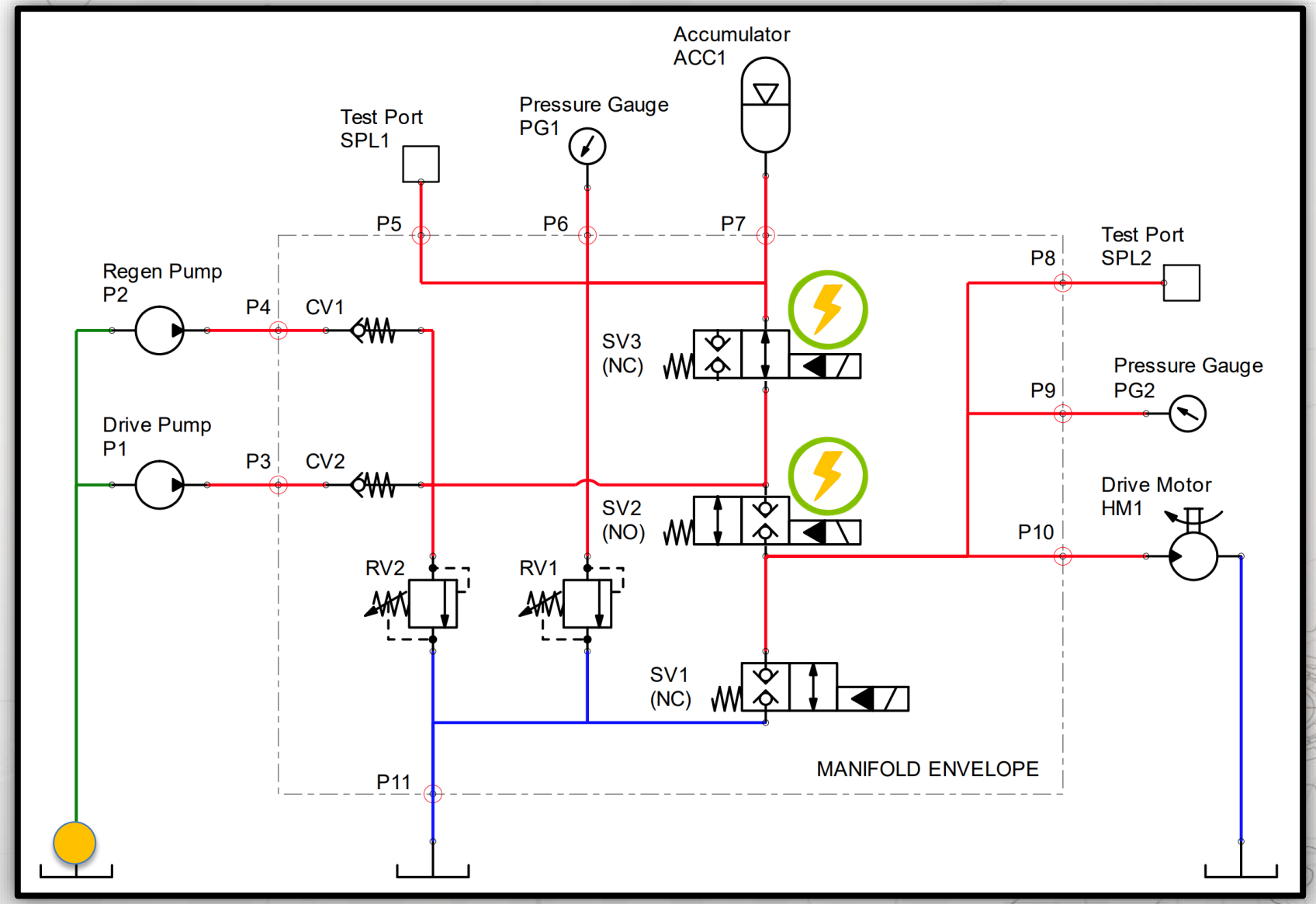


Fig. 2: 2024-2025 Hydraulic Circuit

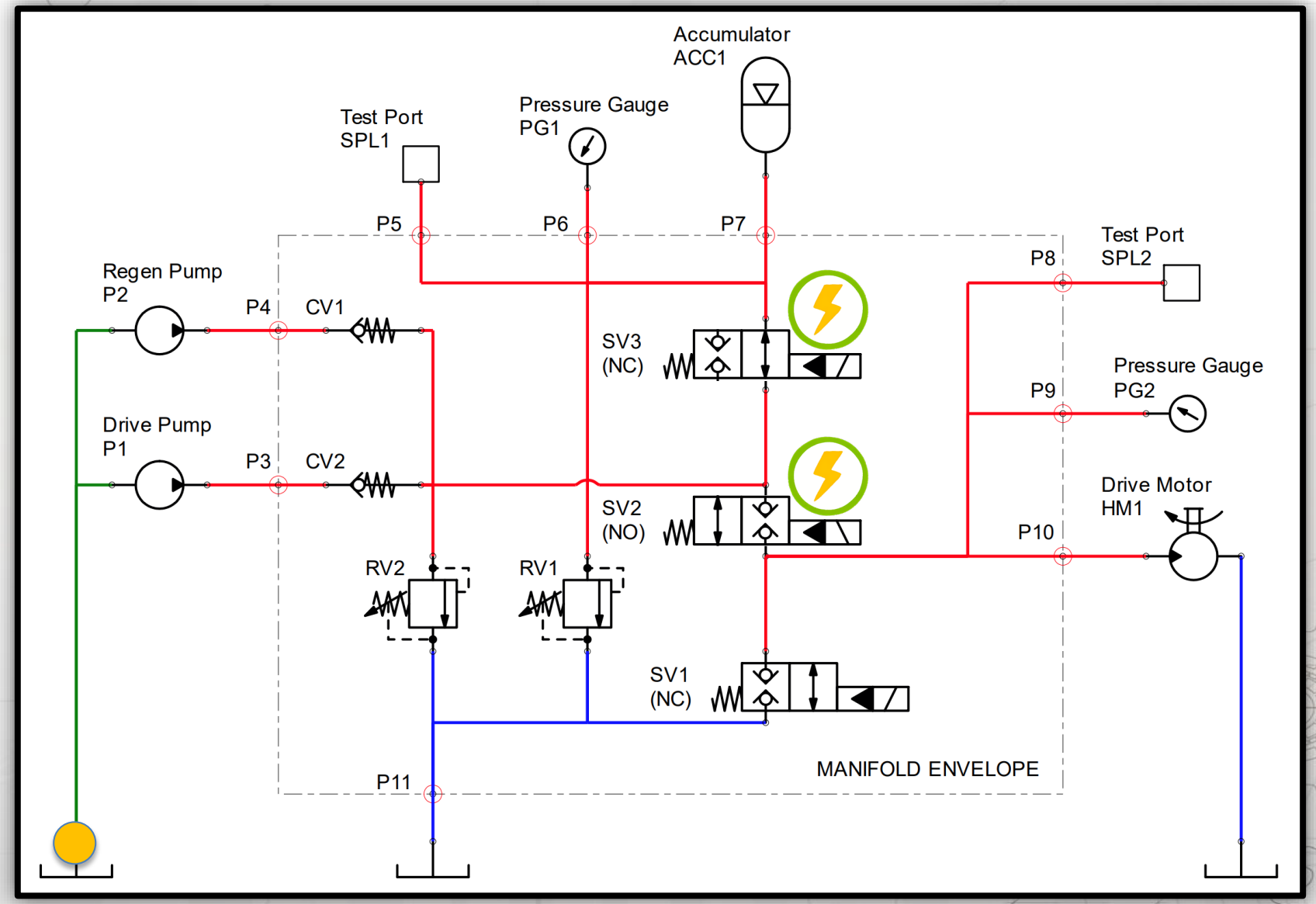
Drive Mode


Accumulator
ACC1
Test Port
SPL1
Pressure Gauge
PG1
P5
P6
P7
Test Port
SPL2
P8
Regen Pump
P2
P4
CV1
SV3
(NC)
Pressure Gauge
PG2
P9
Drive Pump
P1
P3
CV2
Drive Motor
HM1
SV2
(NO)
P10
RV2
RV1
SV1
(NC)
MANIFOLD ENVELOPE
P11

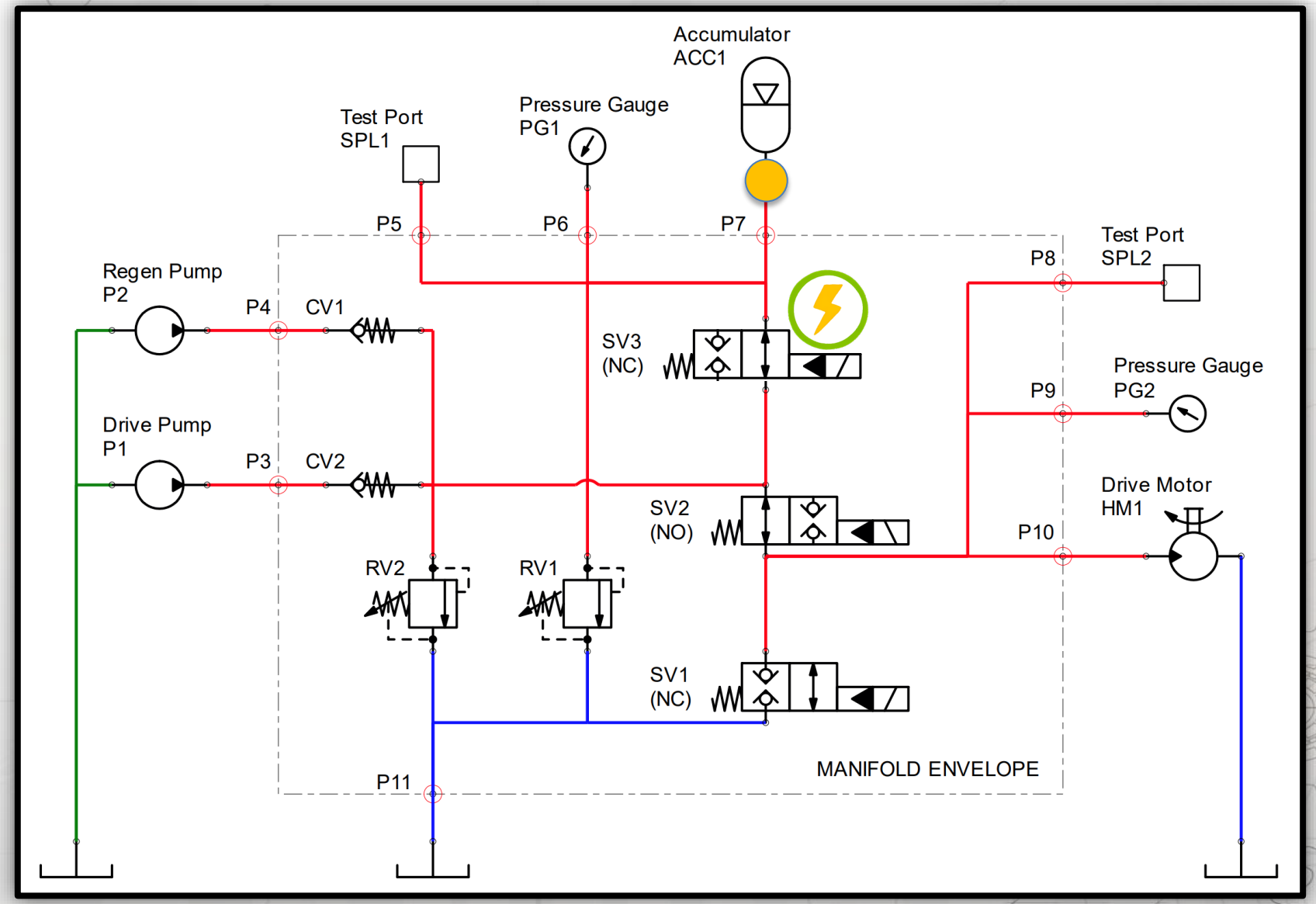
Charge Mode


Accumulator
ACC1
Test Port
SPL1
Pressure Gauge
PG1
P5
P6
P7
Test Port
SPL2
P8
Regen Pump
P2
P4
CV1
SV3
(NC)
Pressure Gauge
PG2
P9
Drive Pump
P1
P3
CV2
SV2
(NO)
Drive Motor
HM1
P10
RV2
RV1
SV1
(NC)
MANIFOLD ENVELOPE
P11

Regen Mode


Accumulator
ACC1
Test Port
SPL1
Pressure Gauge
PG1
P5
P6
P7
Test Port
SPL2
P8
Regen Pump
P2
P4
CV1
SV3
(NC)
Pressure Gauge
PG2
P9
Drive Pump
P1
P3
CV2
SV2
(NO)
Drive Motor
HM1
P10
RV2
RV1
SV1
(NC)
MANIFOLD ENVELOPE
P11

Discharge Mode



Reservoir Design

- Split "Saddlebag" Design
  - Mounted on the rear of the vehicle
  - Fluid and air connections located in the rear

Reservoir Fabrication

Fig. 4: Tig Welding Reservoir

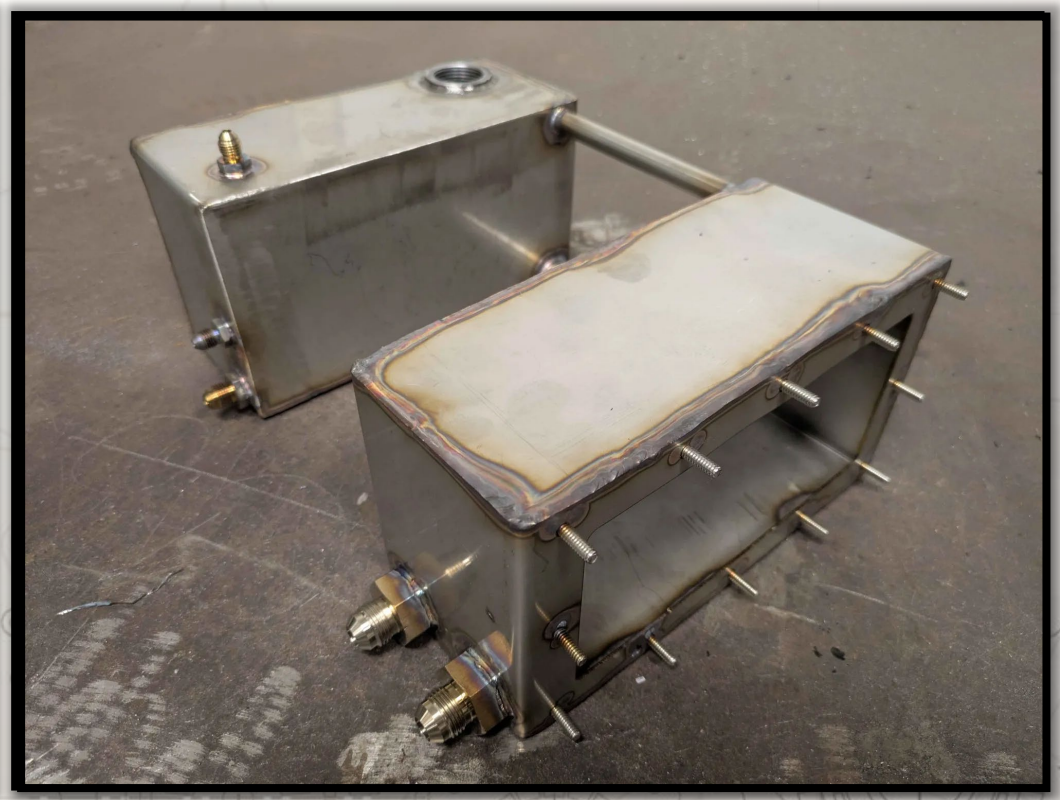
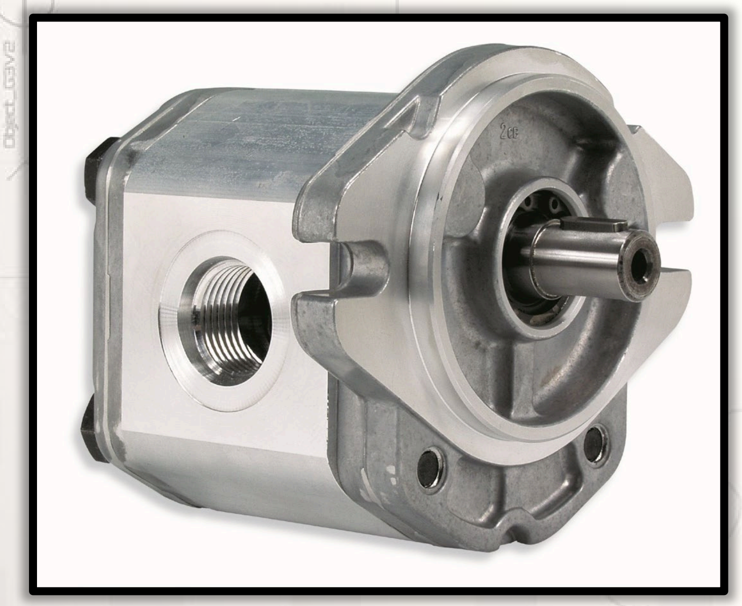


Fig. 5: Unpainted Hydraulic Reservoir

Hydraulic Components



[illegible]

Fig. 7: Hydac Bladder Accumulator

Fig. 8: Hydraulic Hoses from Local Supplier

Hydraulic Assembly

Optimized Hydraulic Assembly for Efficiency in Drive and Discharge Mode

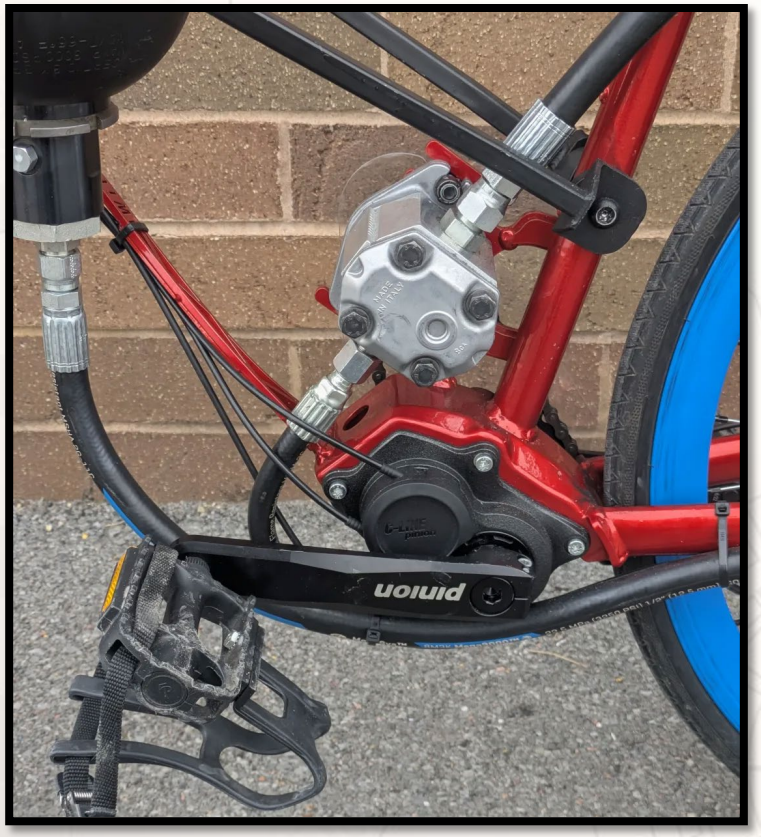


Fig. 9: Pedal Gearbox and Hydraulic Pump

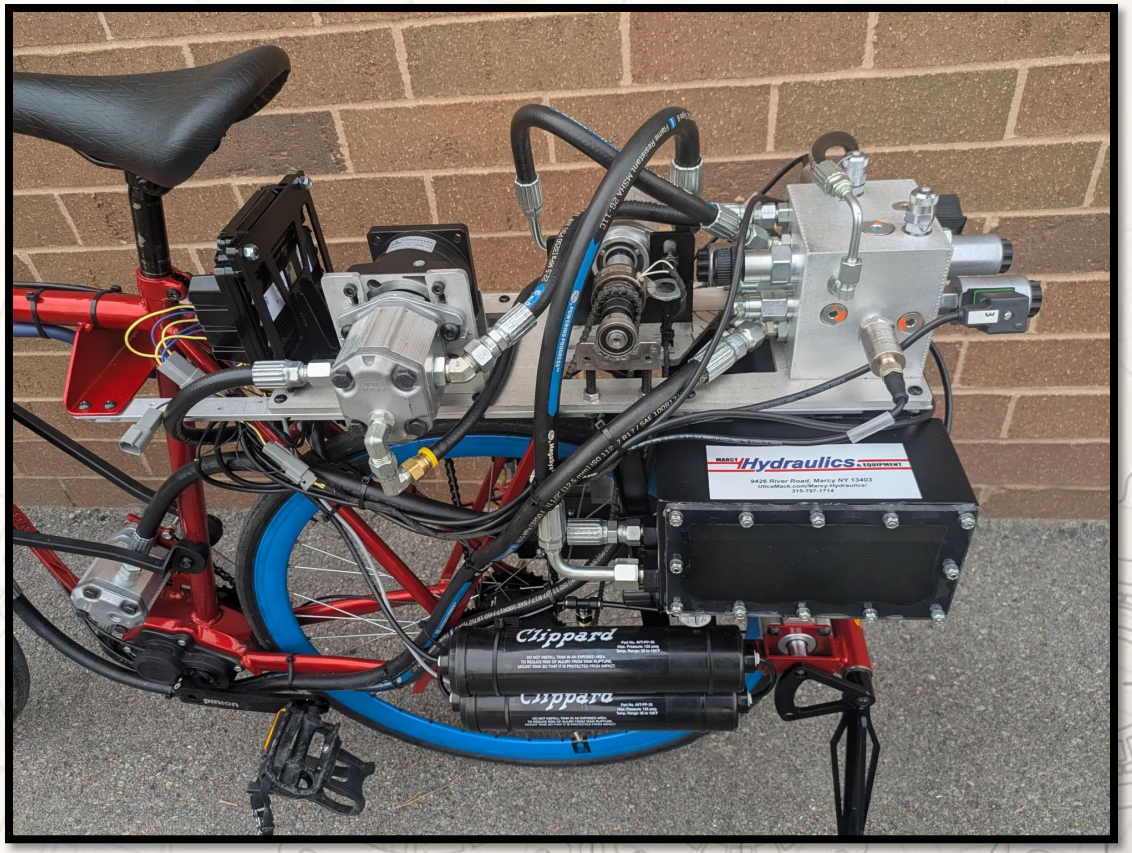


Fig. 10: Back Rack Assembled

Regen Pump with Clutch

Fig. 11: Electro-Magnetic Clutch

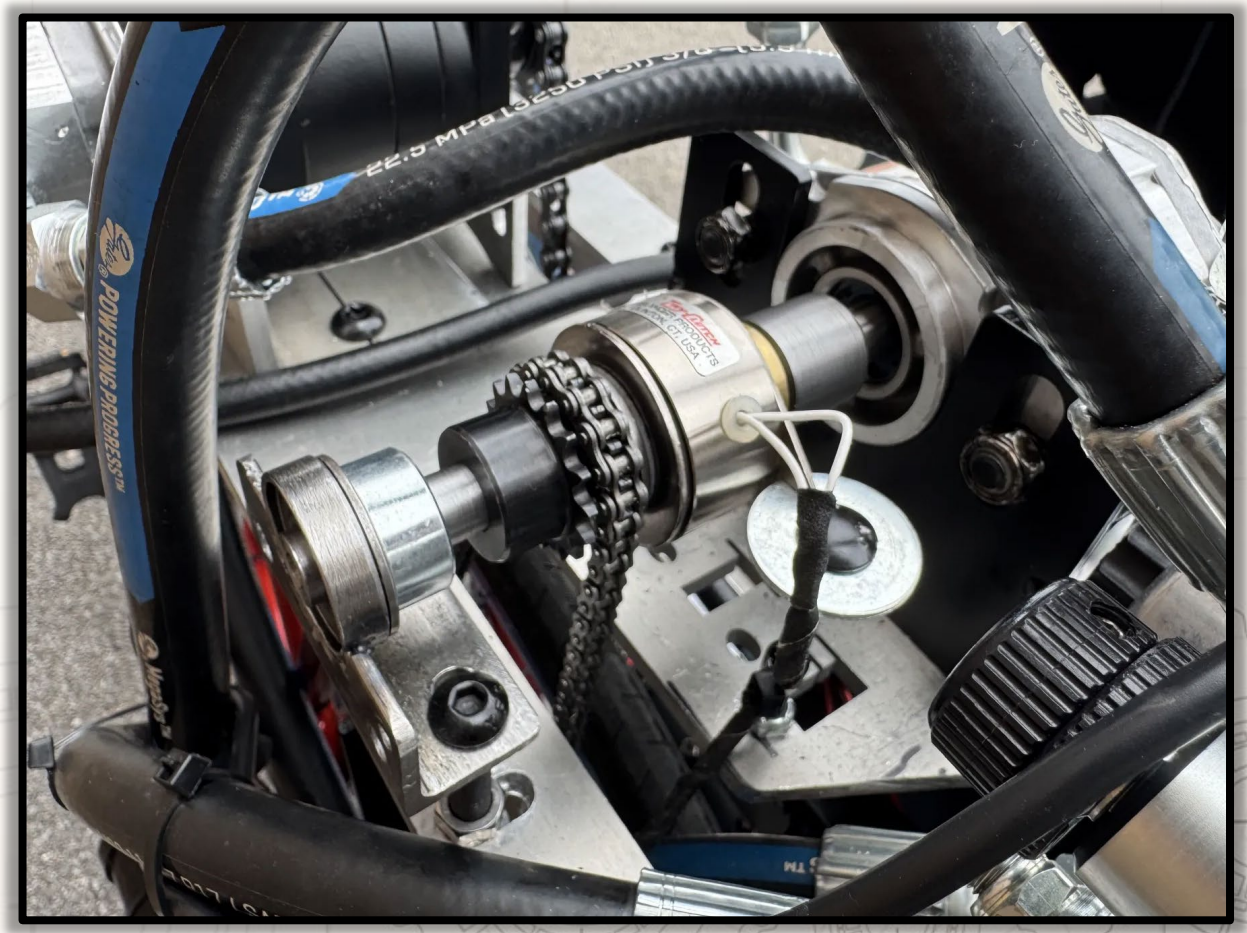


Fig. 12: Clutch Installed on Regen Pump

Hydraulic Calculations

Table 1: Effects of Pedal Gearbox on Fluid Circuit

Pump GPM and psi output based on pedal gearbox								
200W Sustained pedaling								
Gπ†¯	s Ð‡ ı 2 Œı €†Æ‡ π· š˙ - Ⅿ:	s π≥†€z ı ππ≥˙ v s _ :	s π≥†€ÇÁ˜˜ Ðπ ˙ Œ Ґ€˜ Δ	Gπ†¯ v †šŒÁ	s Ð‡ ı z ı ππ≥˙ v s _ :	ÇÁ˜˜ Ðπ Œšás Ð‡ ı ˙ Œ Ґ€˜ Δ	s Ð‡ ı E€Á¾ v †šπ˙ Gs _ :	s Ð‡ ı s ¯π, , Ð¯π˙ ı , Œ
1	0.3172	55	360	5.25	288.75	68.57	0.40	2000
2	0.3172	50	360	6.60	330.00	54.55	0.45	1700
3	0.3172	50	360	8.05	402.50	44.72	0.55	1300
4	0.3172	45	360	10.20	459.00	35.29	0.63	1000
5	0.3172	40	360	12.50	500.00	28.80	0.69	750
6	0.3172	40	360	15.65	626.00	23.00	0.86	500

Table 2: Effects of Rear Hub Gearbox on Wheel Speed and Torque

Motor and wheel torque output based on accumulator parameters											
_ ÁšÁ¯ 2 Œı €†Æ‡ π· š ˙ - Ⅿ:	_ †F €€Á¾†¨ €π s ¯π, , Ð¯π˙ ı , Œ	ÆÆÐ‡ Ð€†šÁ¯ s ¯π†ÆÃ†¯«π ˙ ı , Œ	ï Ãππ€ ≥Œ‡ πšπ¯ Œ:	KÐ¨ «π†¯	Gπ†¯ ¯†šŒÁ	½π¯†«π _ ÁšÁ¯ s ¯π, , Ð¯π˙ ı , Œ	_ †F _ ÁšÁ¯ ÇÁ˜˜ Ðπ ˙ Œ Ґ€˜ Δ	¼„ _ ÁšÁ¯ ÇÁ˜˜ Ðπ ˙ Œ Ґ€˜ Δ	_ †F ¾Ãππ€šÁ˜˜ Ðπ ˙ Œ Ґ€˜ Δ	½π ¾Ãππ€šÁ˜˜ Ðπ ˙ Œ Ґ€˜ Δ	ÆÆÐ‡ Ð€†šÁ¯ Ü, †¨ €π í ÁÆÐ‡ π ˙ Œ˚ я:
0.2502	3000	500	28	1	9.00	1232.5	119.5	49.1	1075.7	441.9	191.6
0.2502	3000	500	28	2	6.62	1232.5	119.5	49.1	791.0	325.0	191.6
0.2502	3000	500	28	3	5.88	1232.5	119.5	49.1	703.1	288.8	191.6
0.2502	3000	500	28	4	4.29	1232.5	119.5	49.1	512.2	210.4	191.6
0.2502	3000	500	28	5	3.46	1232.5	119.5	49.1	413.7	170.0	191.6

Frame Design

- Accumulator Relocation
  - Frame Extension
- New Reservoir Design
- Gearboxes
- Addition of Training Wheels

Fig. 13:
Last Year's Vehicle
2023-2024

Fig. 14:
This Year's Vehicle
2024-2025

Frame and Hub

Fig. 15: Purchased Bike Frame

Fig. 16: Rear Hub Gearbox

Early Frame Modification

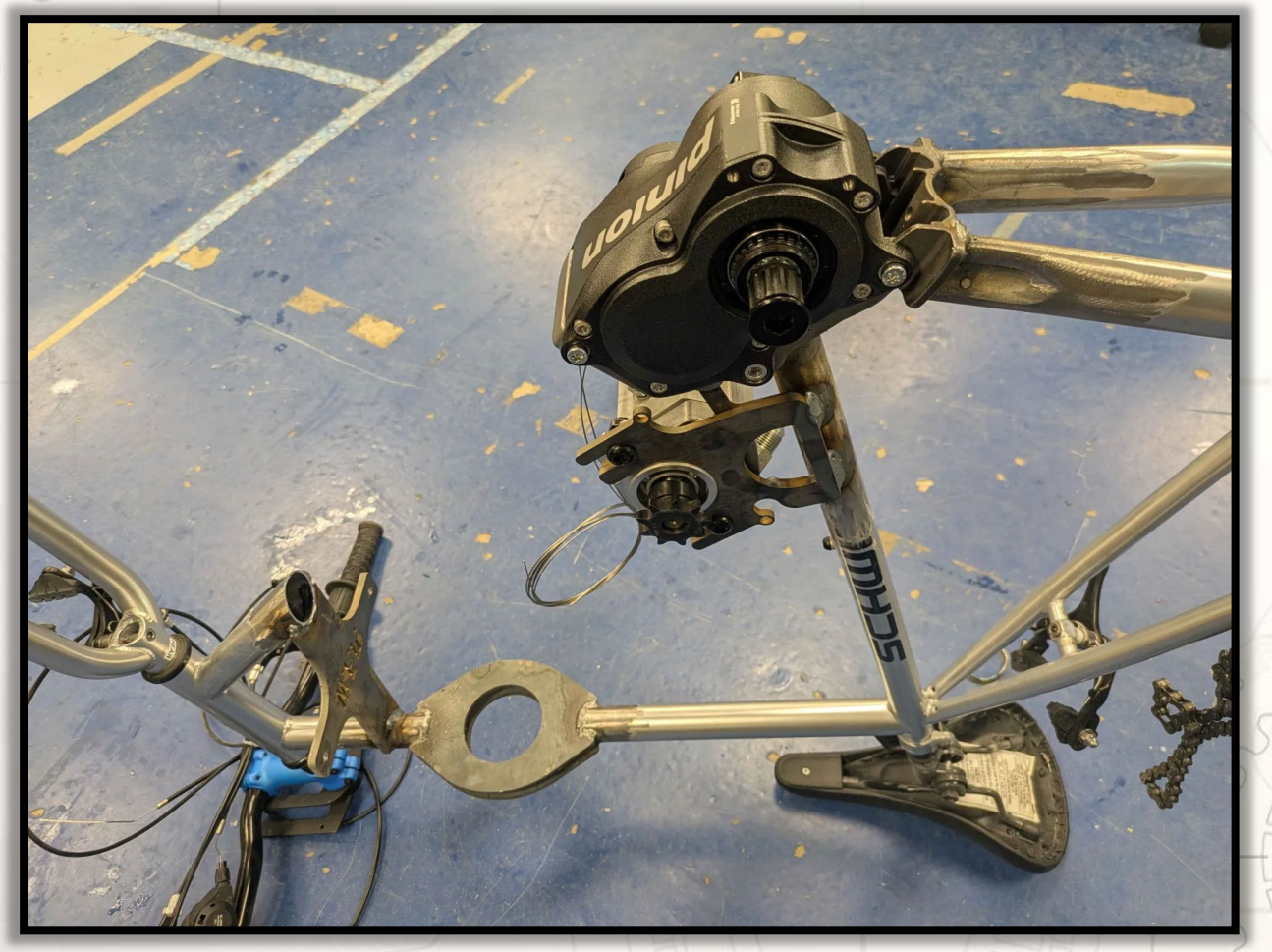


Fig. 17: Frame Accommodations for Accumulator and Pedal Gearbox

Fig. 18: Custom Lower Member

Component Mounts

Fig. 19: Hydraulic Motor Mount Fabrication

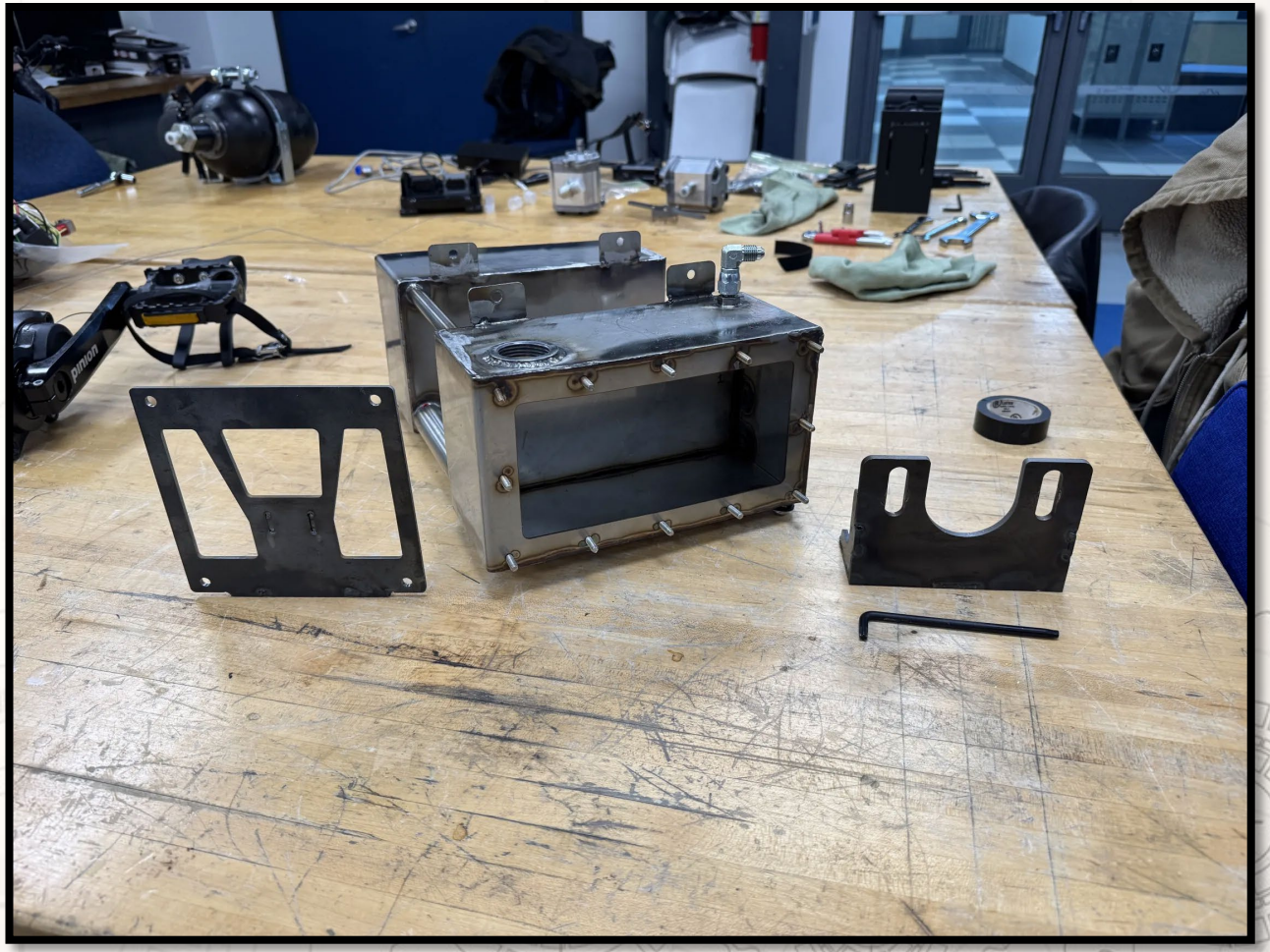


Fig. 20: PLC Mount (left), Hydraulic Reservoir, Regen Pump Mount

Painting

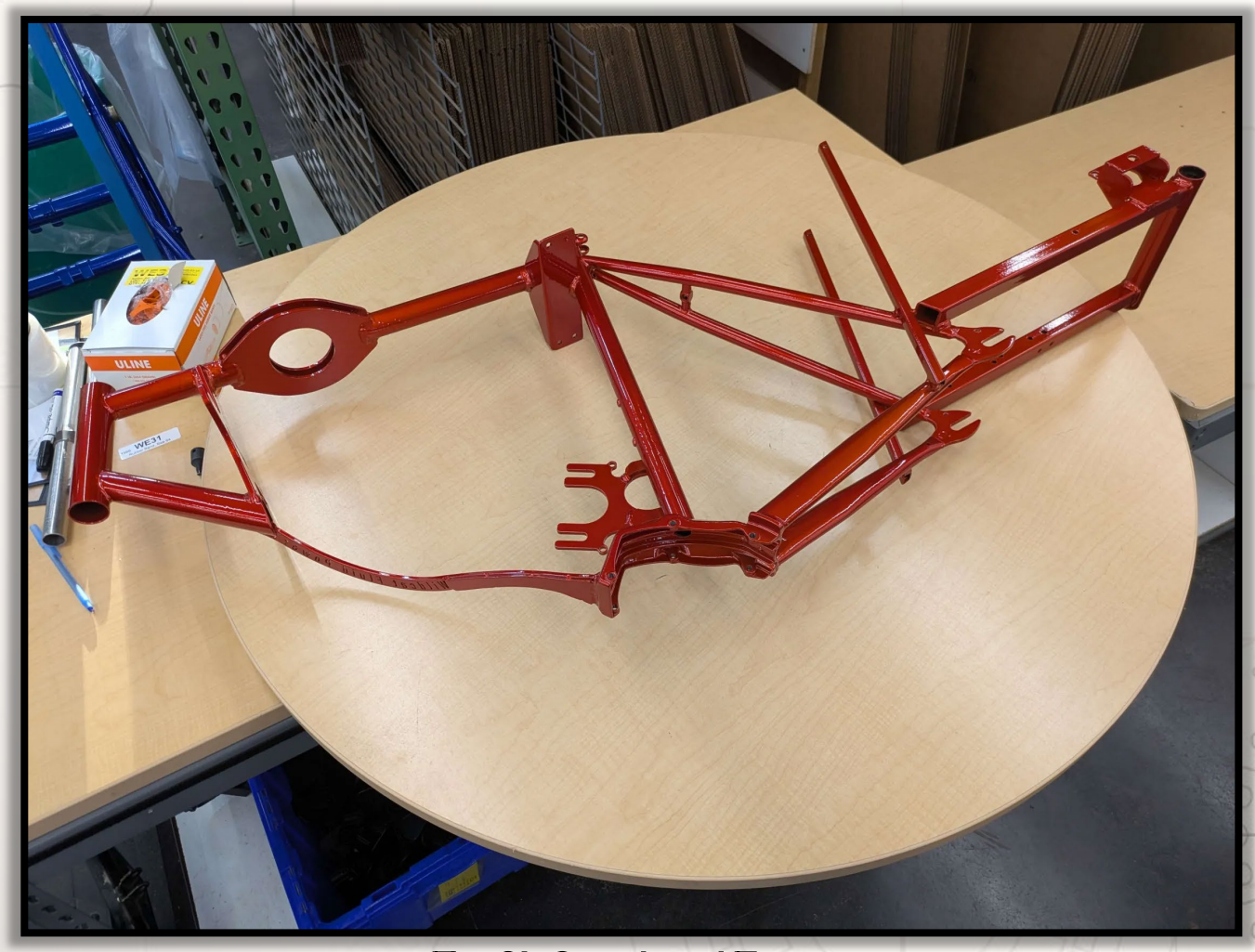


Fig. 21: Completed Frame

Fig. 22: Regen Sprocket Mounting

Final Assembly

Fig. 23 Complete Vehicle Before Paint

Fig. 24: Team Inspecting Vehicle After First Ride

Pneumatics

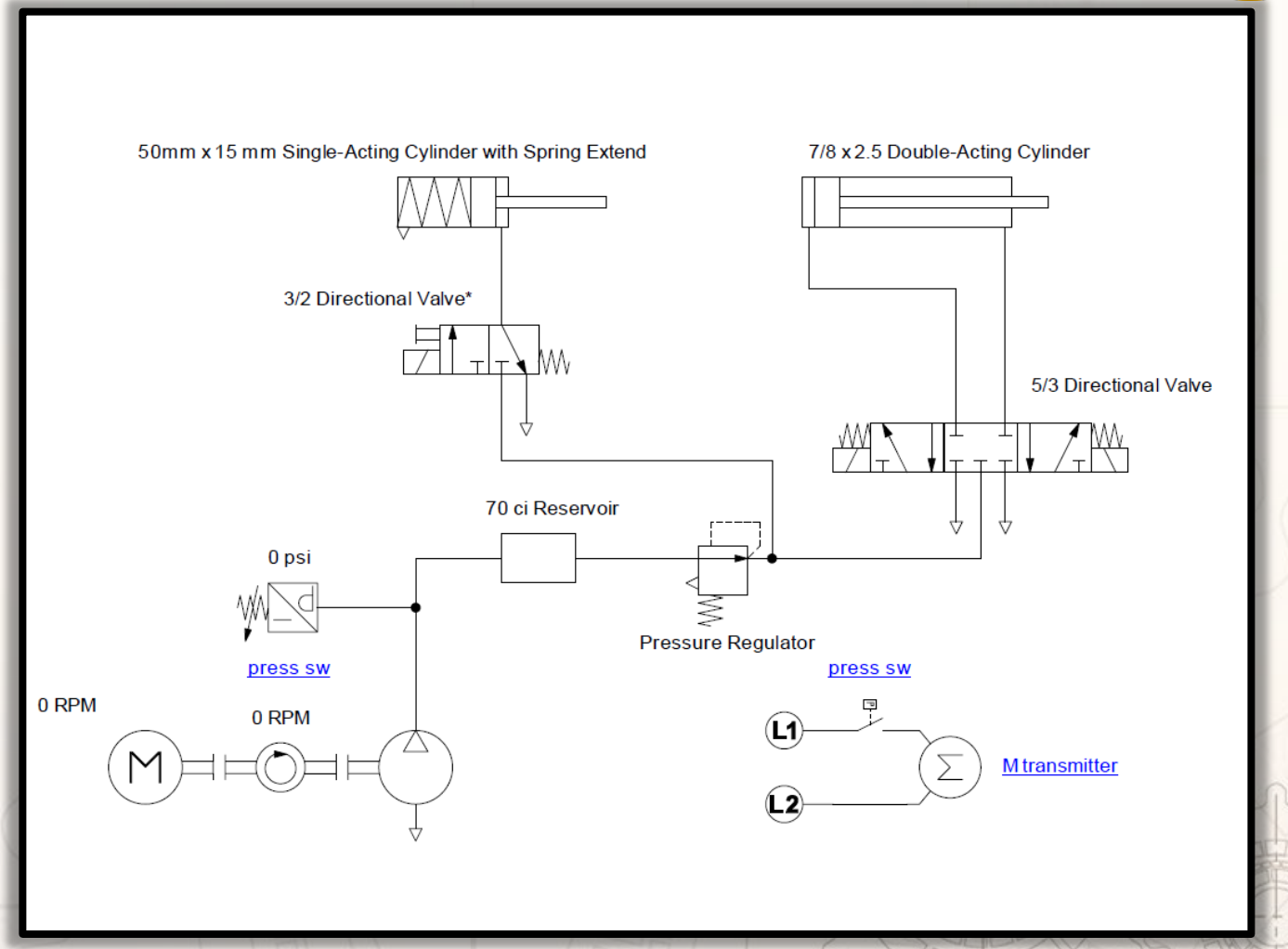


Fig. 25: Pneumatic Circuit and Compressor Power Circuit

Pneumatic Components

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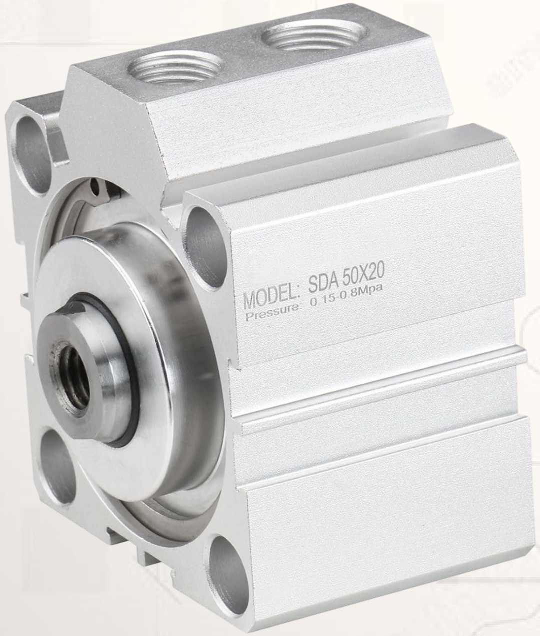


Fig. 27: 50mm x 15mm SA Spring Extend Cylinder

Fig. 28: 3/2 and 5/3 Pneumatic Solenoids on Manifold

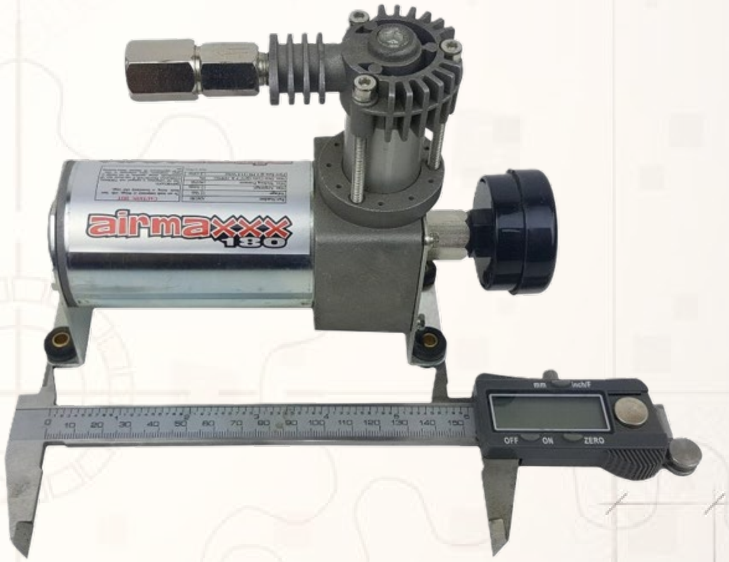


Fig. 29: 1.2 CFM Compressor

Fig. 30: Bimba 062.5-DXP

Training Wheels

Fig. 31: Training Wheels CAD Model

Fig. 32: Training Wheels During Fabrication

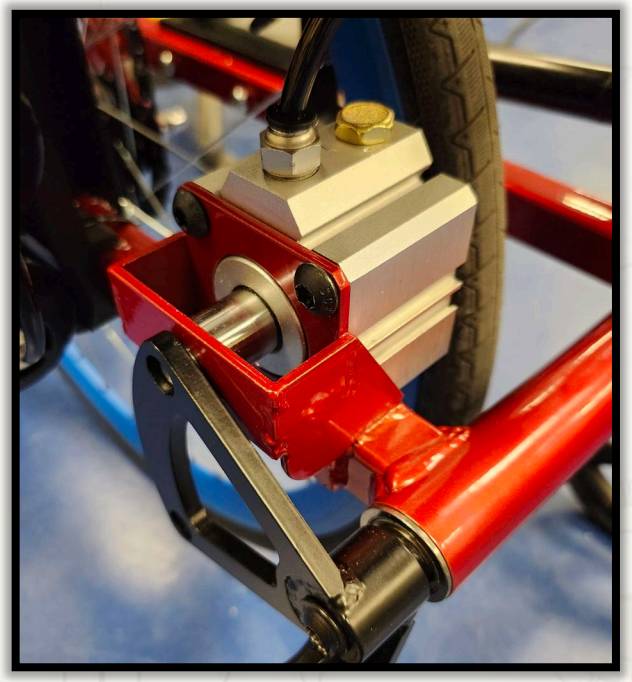


Fig. 33: Pin Locking Cylinder

Fig. 34: Completed Training Wheels

Electrical Components

Fig. 35: uControl MC 2-18-6 PLC

Fig. 36: Talentcell 12V/24V Battery

Fig. 37: PowerView 500 Screen

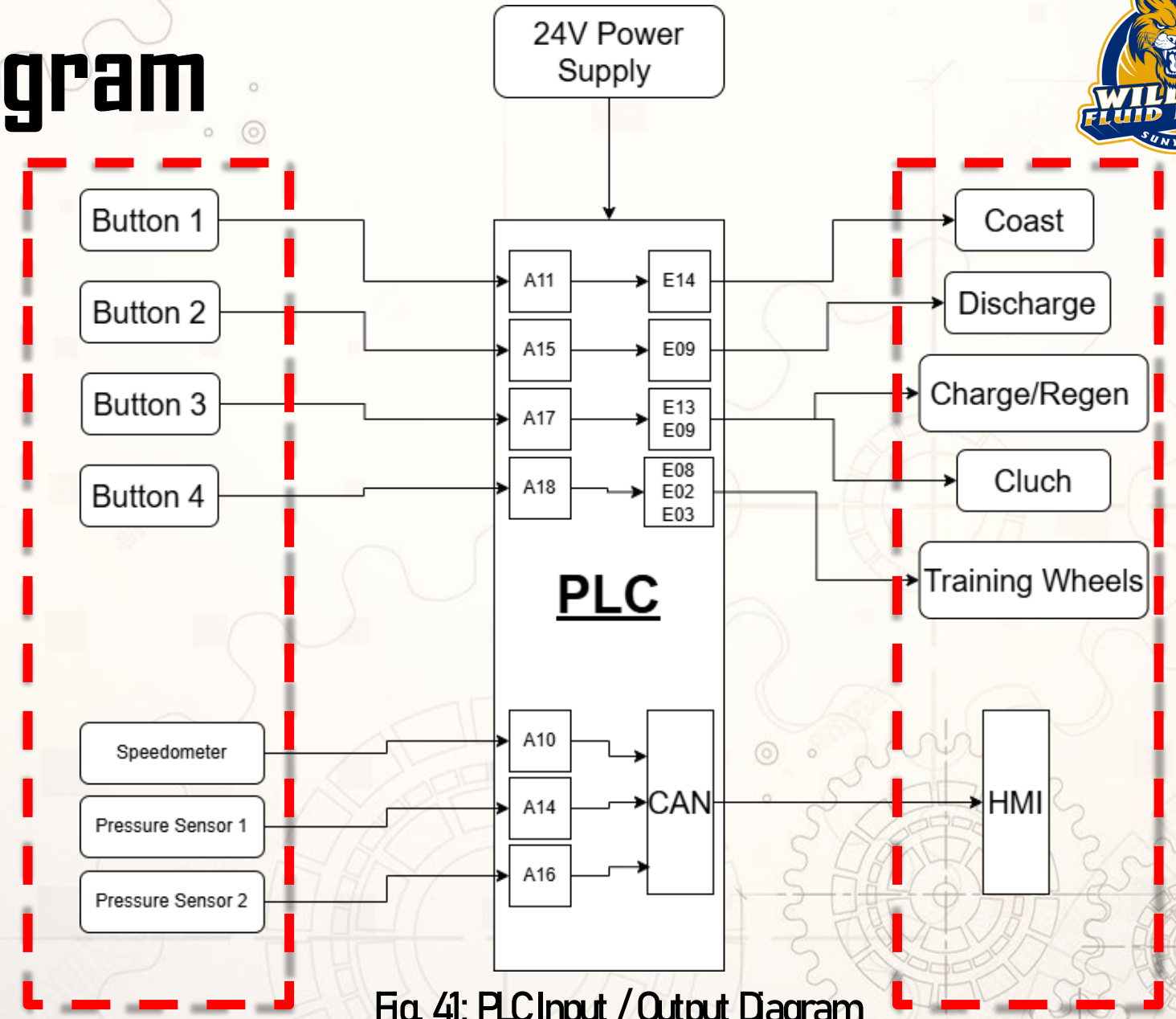
Fig. 38: Balluf Digital Pressor Sensor

Fig. 39: Sun Hydraulics Solenoid

Fig. 40: M8 Inductive Hall Effect Sensor

PLC Diagram

Input



Output

Fig. 41: PLC Input / Output Diagram

Screen

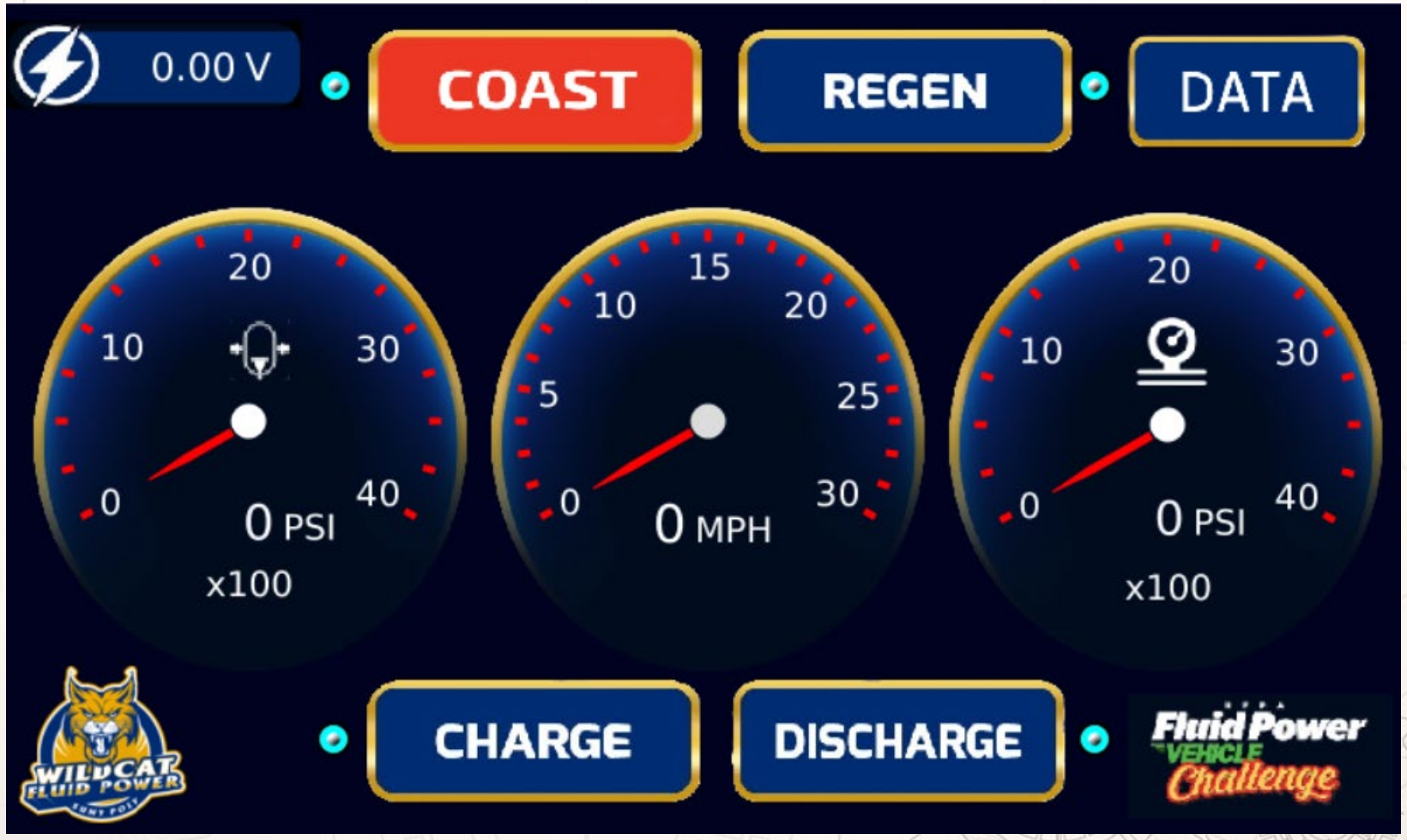


Fig. 42: HMI Home Screen

Data logging

Fig. 43: HMI Data Screen

Testing

Fig. 44: Initial Circuit Function Test

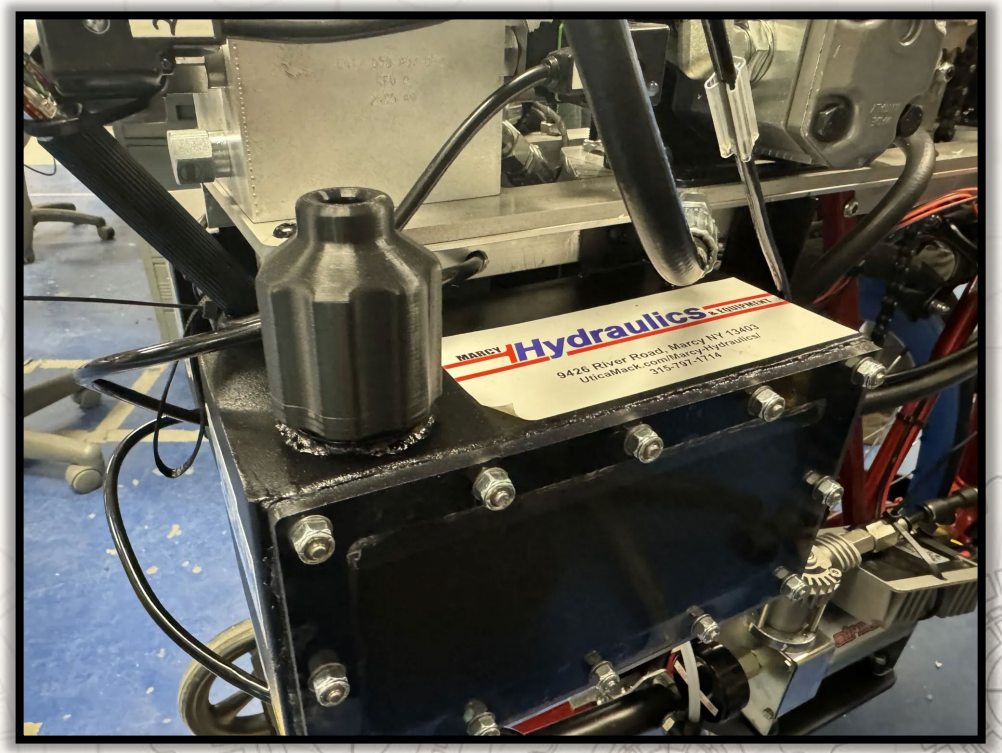


Fig. 45: Reservoir Vented Cap Shroud

Field Testing

In theory, there is no difference between theory and practice. In practice, *there is*. –Richard P. Feynman

Fig. 46: Henry Riding Bike

Fig. 47: Collecting Efficiency Data

Testing

- 1 ½ Weeks of testing
- Reduced the sprocket size on the motor to from a 15t to a 12t
- 600 psi was chosen as an arbitrary starting value
- Precharge Adjustment: 600psi *adjusted to* → 900 psi
- We found the sweet spot to be in the range of 750-900 psi
- Confirmed Via Real World Testing
- Sprint Precharge: 900 psi
- Efficiency Precharge: 750 psi

Table 3: Efficiency Test Data at 600 psi Pre-charge

Ç†¸ šŒ« 2 †š† †š Ír ьь 1 ¸ Œs ¯π·ÆÃ†¯«π			
8· π¯«Ğf Ðš¨€¸ Eš¸: [Weight x Cf (.005) x Dis. (Ft)]	¼«¸ s¯π¸¸Ð¯π [PSI]	Mı Ðš 8· π¯«Ğ¨M¸ Eš¸: [Avg. PSI x in³ of useable oil /12]	Eff.(%) [Uneven parking lot]
659	741	5,949	11.07
1,099	847	9,278	11.94
1,428	955	12,006	11.90

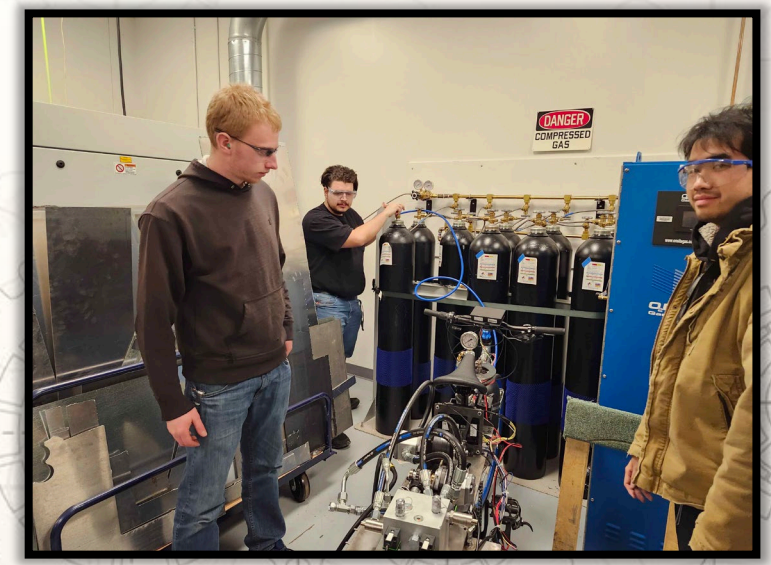


Fig. 48: Adjusting Accumulator Pre-charge

Lessons Learned

Lessons Learned

Expect the unexpected

- We learned to start a plan B *before plan A has had a chance to fail.*
- Lost shipments, Prolonged delays
- Component failures
- Increased frame rigidity
- Redesigned clutch shaft
- Swapped electric solenoid for pneumatic locking pin

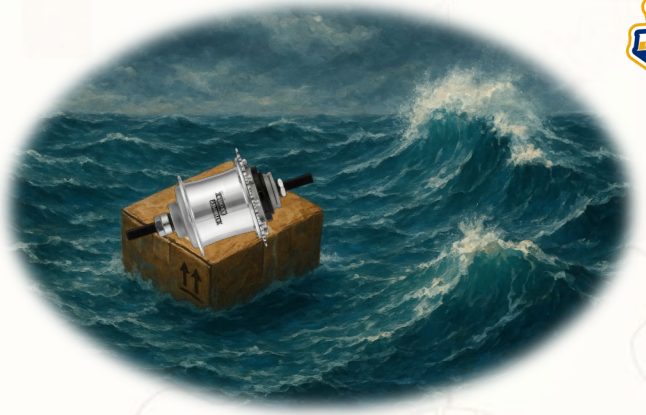


Fig. 49: Lost Sturmey-Archer Hub Gearbox

Fig. 50: Frame Stiffening Braces

Acknowledgements

- We would like to extend our heartfelt appreciation to the NFPA for making this competition possible
- We thank all our mentors and sponsors for your invaluable contributions, it goes without saying, but we could never have done it without you.
- There are those to whom we owe a particular debt of gratitude
  - Jonathan Lerner and Michael Budda for your exemplary and ever-ready assistance and expertise.
  - Dr. Ahmed Abdelaal, our team advisor, biggest fan, and unwavering supporter through the highs and the lows of this challenge.

Dr. Ahmed Abdelaal
Faculty Advisor

Questions?

No 90 degree fittings?