NFPA

Fluid Power Vehicle Challenge

NFPA Education and Technology Foundation

Final Presentation

Milwaukee School of Engineering

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MSOE UNIVERSITY

The Team

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Problem Statement

Develop a human powered vehicle to:

- Transmit power through hydraulics
- Compete in Sprint, Efficiency, Regeneration, Endurance
- Engage in fluid power and garner interest

2022-2023 Design

Tricycle Downsides

- Low stability at high speed

Chain/Gear Issues

- Proper tensioners are vital

Hydraulic Design

- Small motor = not enough flow and torque; low speed

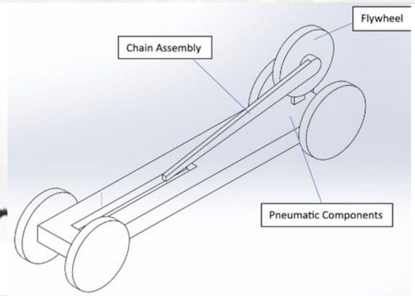
Design Objectives

- Produce an original design
- Tailor our design for speed and simplicity
- Create a reliable and safe vehicle
- Unique pneumatic application

Preliminary Designs

Recumbent Trike

Rower

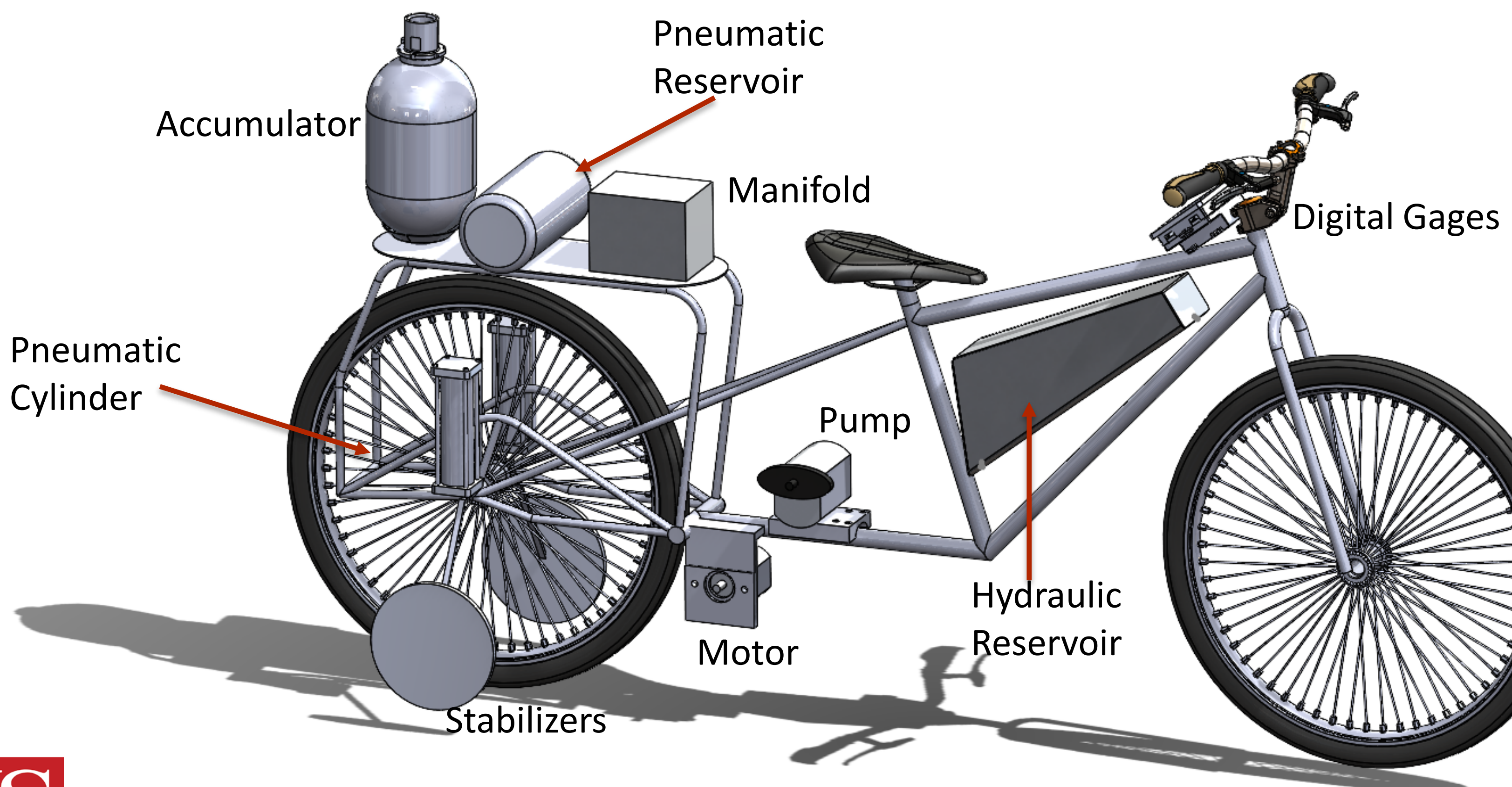


Stepper Scooter

Stabilized Bicycle

Criteria	Weight	Design #1 Recumbent Trike	Design #2 Rower	Design #3 Stepper Scooter	Design #4 Stabilized Bicycle
Cost	5%	2	3	3	4
Ease of Manufacturing	5%	3	1	3	3
Reliability	10%	3	2	3	4
Weight	15%	3	2	5	5
Component Space	5%	4	4	2	2
Stability	10%	4	4	3	2
Safety	10%	3	2	2	3
Sprint	10%	3	2	3	5
Endurance	10%	4	2	3	5
Efficiency	2.5%	3	2	3	4
Regeneration	2.5%	4	3	2	4
Innovation	15%	2	4	5	2
Total	100%	3.075	2.625	3.425	3.6

Selected Vehicle Design



Component Identification: Calculations

Pulling Force:

$F_p = W\frac{\pi}{180}\sin(\theta) = 29.85$ lbf

Rolling Resistance:

$F_R = W\mu_f\cos(\theta) = 5.04$ lbf

Total Pull Required:

$F_{total} = F_R + F_p = 34.89$ lbf

Gear Ratio:

72:9 = 8:1

Torque:

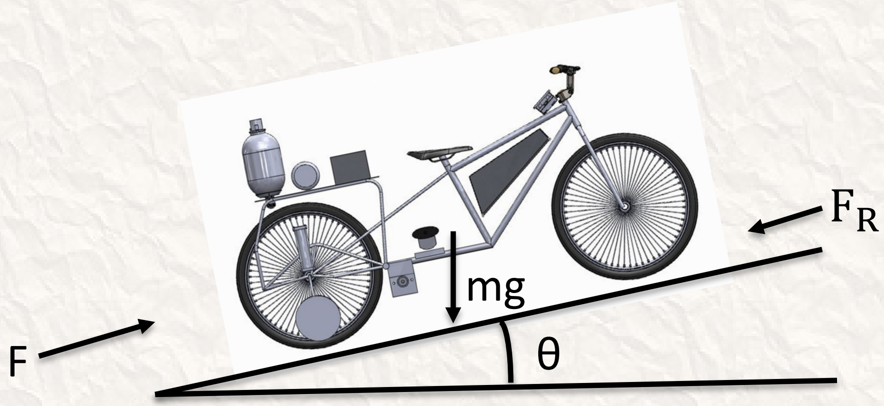
$\tau = F_{total}R = 453.62\ in \cdot lb$

CIR motor:

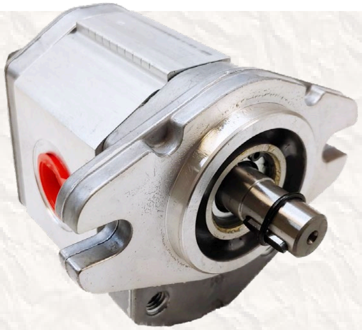
$CIR_{motor} = 2\pi\frac{\tau}{1000} = 0.193\ in^3/rev$

CIR of Pump:

$CIR_{motor,act} = \frac{231\ GPM}{RPM}\eta_{pump} = 0.066\ in^3/rev$



Components: Hydraulics



Pump

- *Dynamic* Aluminum Gear Pump
- GP-F10-13-P-C
- 0.0854 in^3/rev

Motor

- *Marzocchi* Bidirectional Gear Motor
- ALM1A-R-5-E2
- 0.2135 in^3/rev

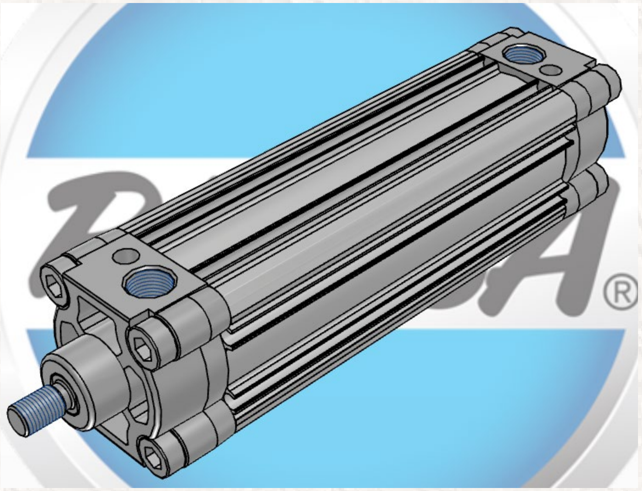
Accumulator

- *SteelHead* Composite Accumulator
- AB30CND10G0N
- 1 gallon

Components: Pneumatics

Cylinder

- NFPA Actuator
- PA-MS4-2.00X6-HC-KK1-MPR
- 2” Bore, 6” Stroke

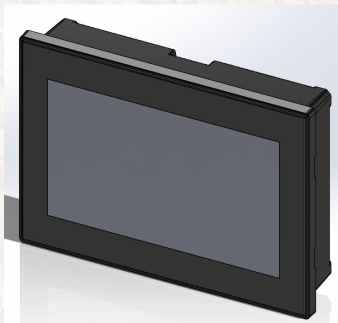


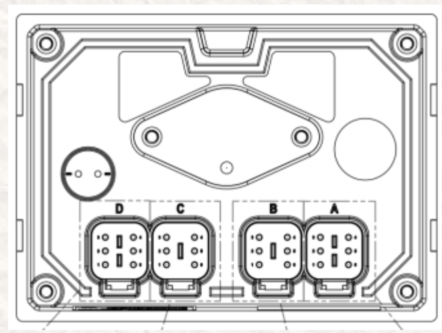
Air Reservoir

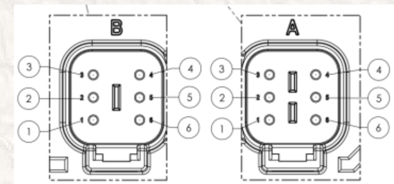
- Steel Compressed Gas Tank
- CRVZS-2
- 2 Liter

Components: Electronics

Interface: Enovation Power Vision 500



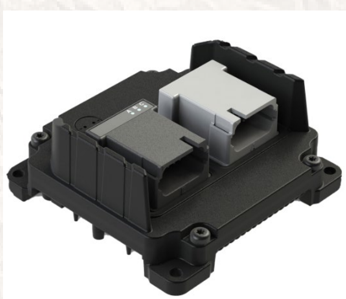




6-POS CONNECTOR-B	
PIN #	FUNCTION
1	BATTERY
2	CAN 1 HIGH
3	CAN 1 LOW
4	DIGITAL OUT 1
5	IGNITION
6	GROUND

6-POS CONNECTOR-A	
PIN #	FUNCTION
1	USB 5V
2	USB D+
3	USB D-
4	NO CONNECT
5	USB SHIELD
6	USB GROUND

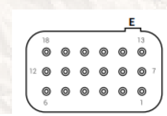
Controller: uControl Module



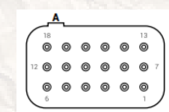
Inputs	MC2-18-6
Universal Analog / High Frequency	4
Universal Analog	14
TOTAL INPUTS	18

Outputs	MC2-18-6
4A PWM (feedback)	2
Dual Range PWM 4A / 0.4 A (feedback)	4
15A PWM (feedback)	0
TOTAL OUTPUTS	6

Other	MC2-18-6
CAN	2
Sensor Supply	1



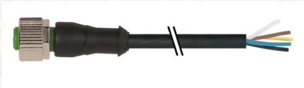
Connector J1 Key E	
Pin	Function
E1	Power Battery (+)
E2	Output PWM 4A With Feedback
E3	Output PWM 4A With Feedback
E4	Input Universal Analog
E5	Load Power (+)
E6	Battery Ground (-)
E7	Sleep Mode
E8	Output PWM Dual Range 4A / 0.5A
E9	Output PWM Dual Range 4A / 0.5A
E10	Input Universal Analog
E11	Load Power (+)
E12	Battery Ground (-)
E13	Output PWM Dual Range 4A / 0.5A
E14	Output PWM Dual Range 4A / 0.5A
E15	Input Universal Analog
E16	Input Universal Analog
E17	Input Universal Analog
E18	Input Universal Analog

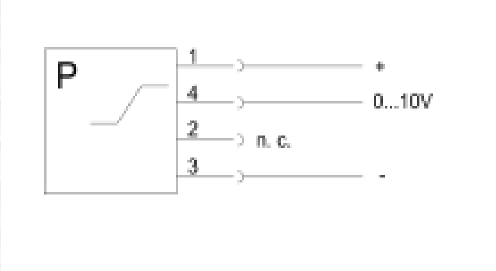


Connector J2 Key A	
Pin	Function
A1	Sensor Supply Output (+10V/+5V)
A2	CAN2 H / RS232 TX
A3	CAN1 H
A4	Input Universal Analog
A5	Input Universal Analog
A6	Input Universal Analog
A7	Input Universal Analog / High Freq.
A8	CAN2 L / RS232 RX
A9	CAN1 L
A10	Input Universal Analog / High Freq.
A11	Input Universal Analog / High Freq.
A12	Input Universal Analog / High Freq.
A13	Sensor Supply Ground (-) / RS232 GND
A14	Input Universal Analog
A15	Input Universal Analog
A16	Input Universal Analog
A17	Input Universal Analog
A18	Input Universal Analog

Electrical Schematic

Pressure Transducer

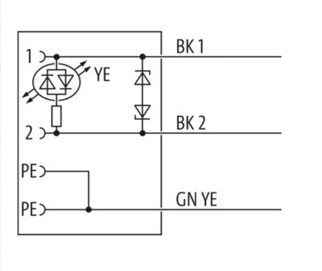




Input Channel:

- Transducer 1 – A15
- Transducer 2 – A16
- Transducer 3 (pneumatic) – A17

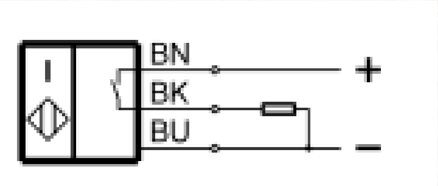
Solenoid Valves



Output Channel:

- DMDA Solenoid – E2
- DTBF Solenoid – E3
- Pneumatic Solenoid (Position 1) – E8
- (Position 2) – E9

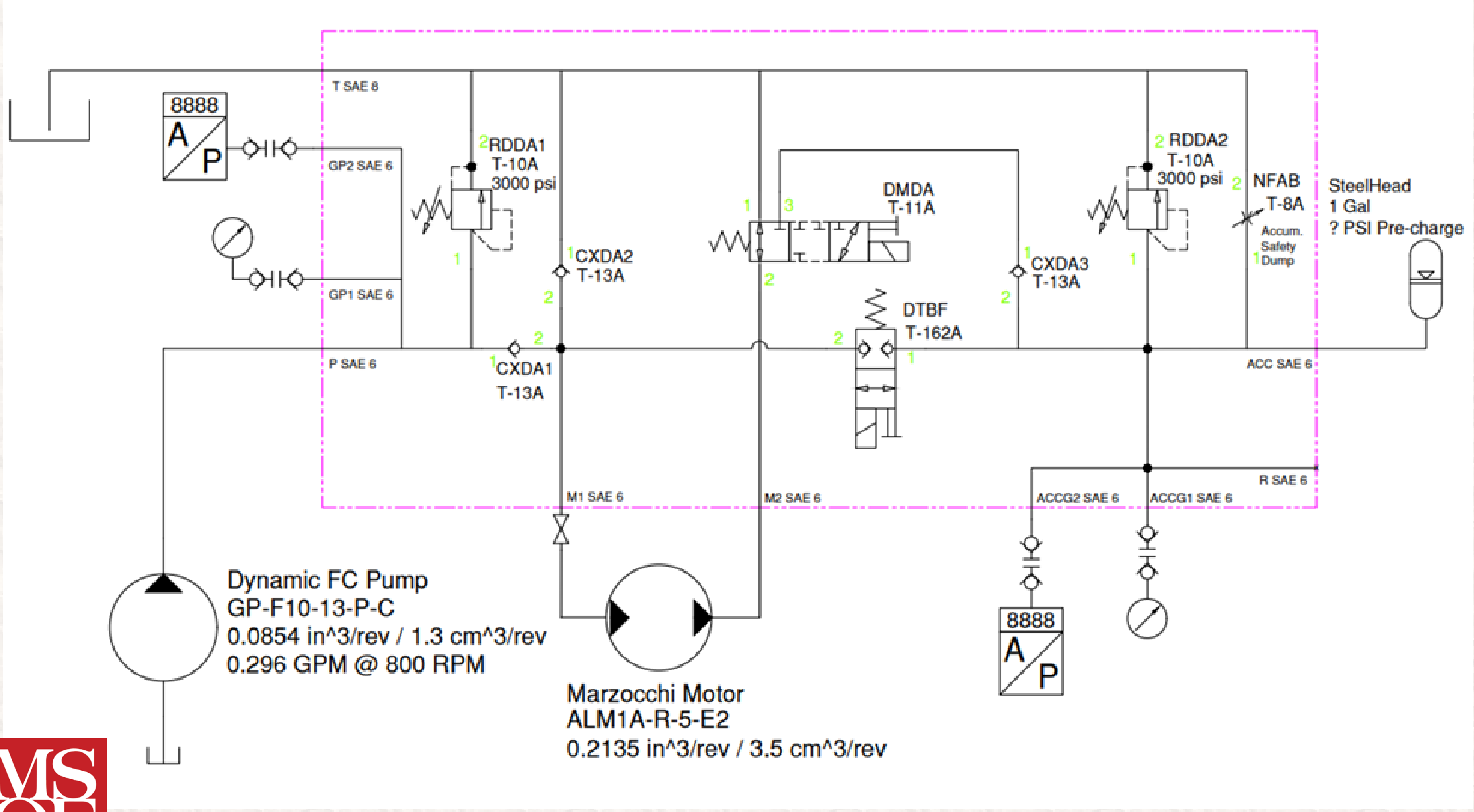
Inductive Sensor (speed)



Input Channel:

- Inductive Sensor – A10

Hydraulic Circuit



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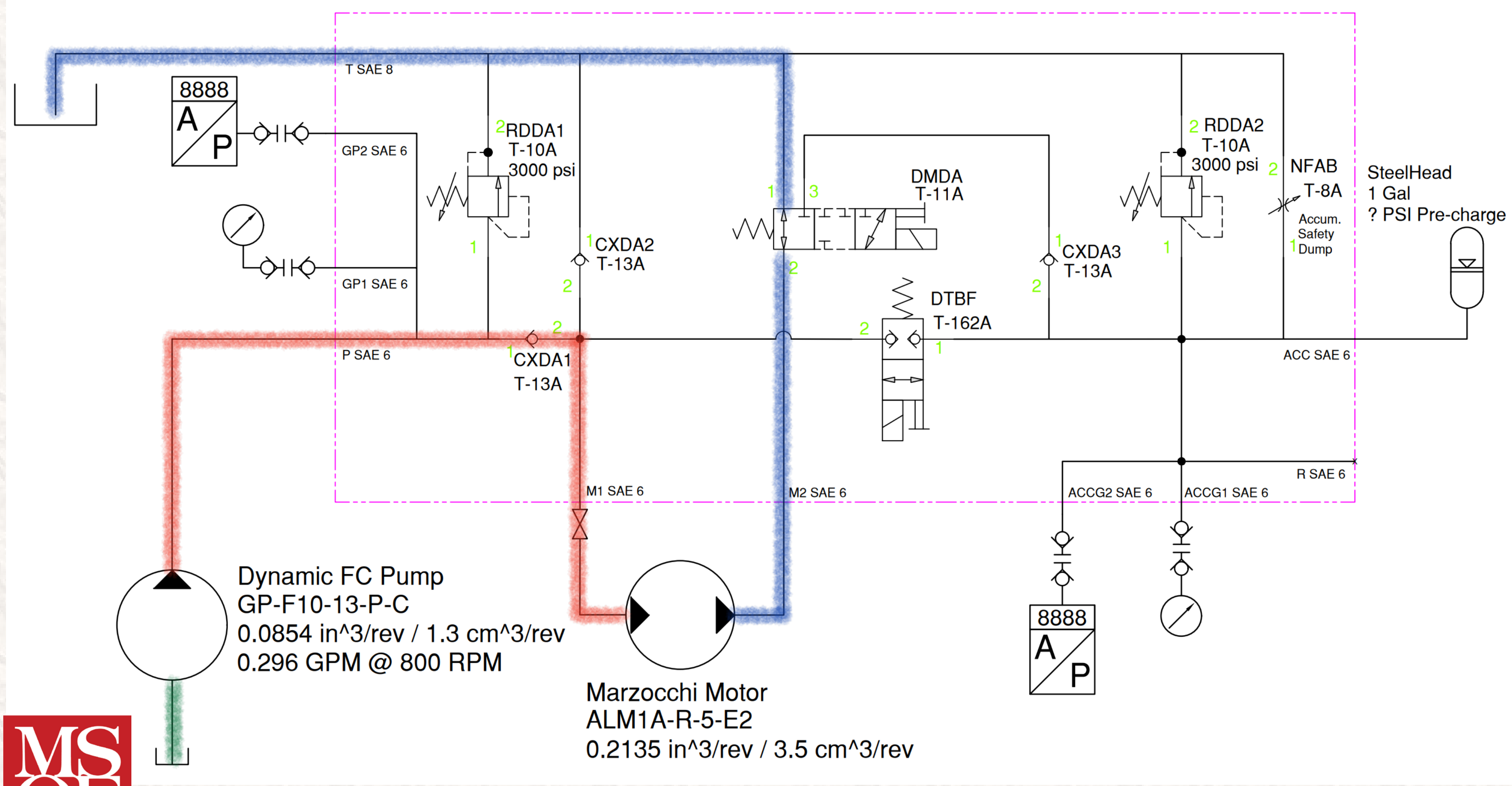
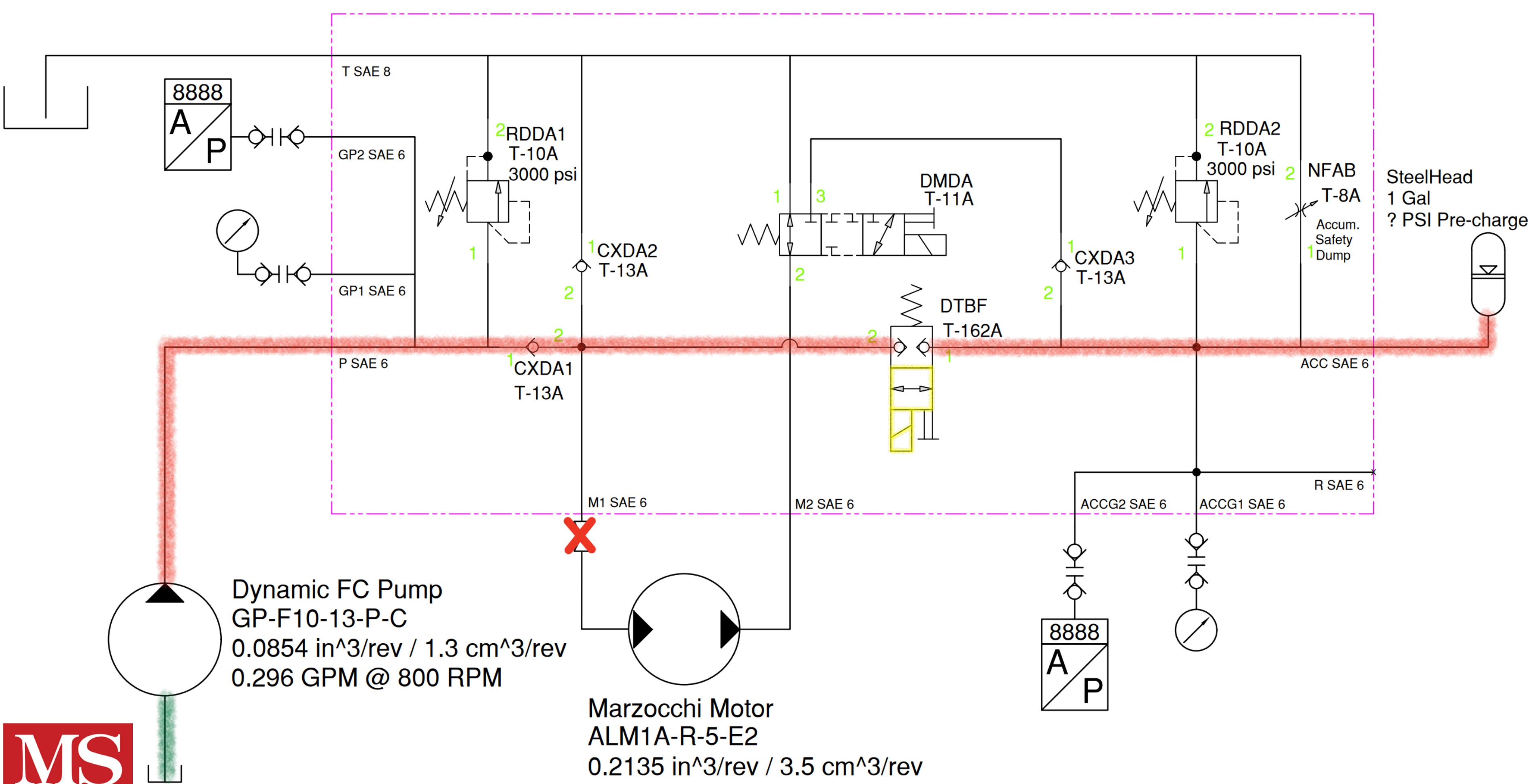
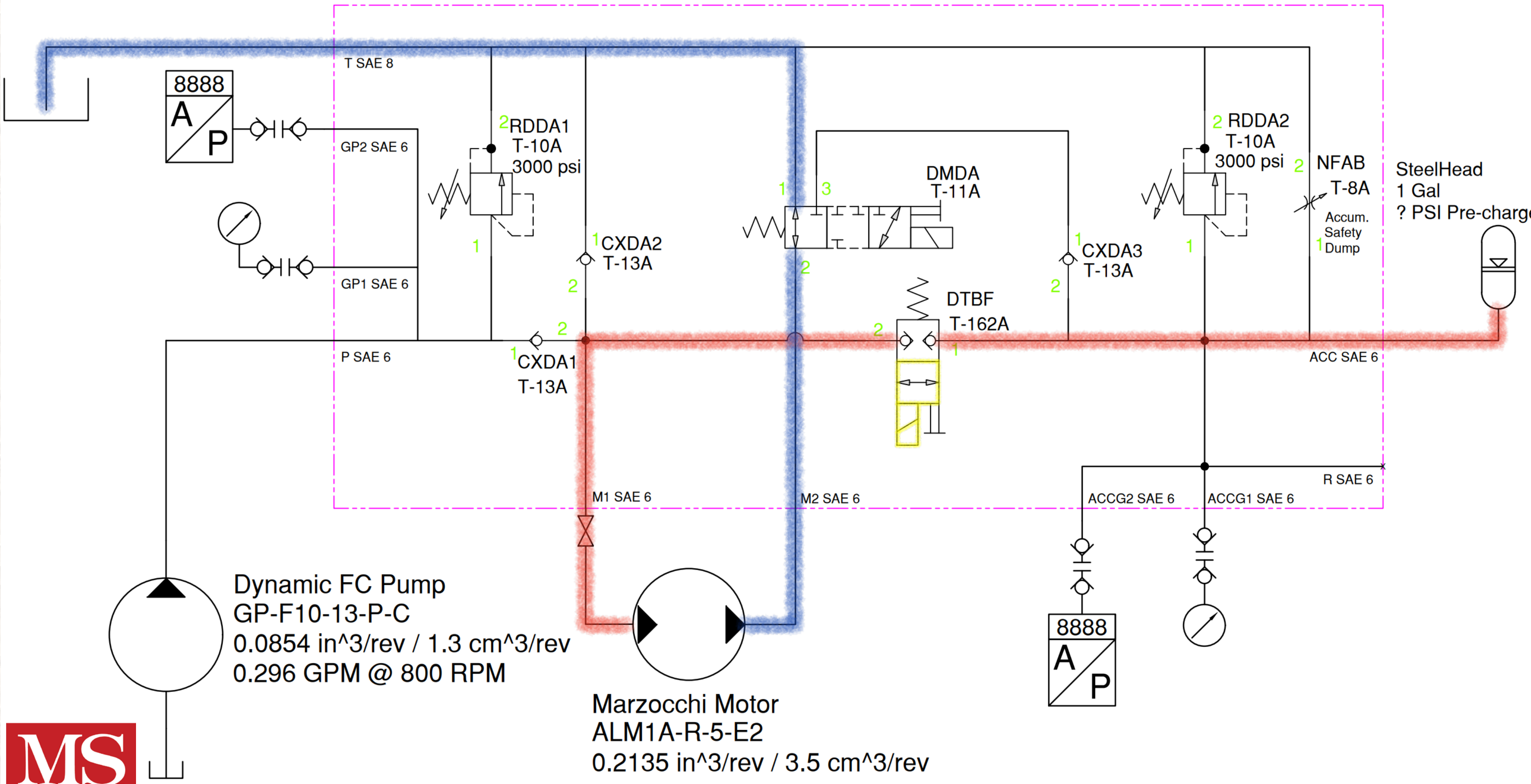
Hydraulic Circuit: Normal Drive



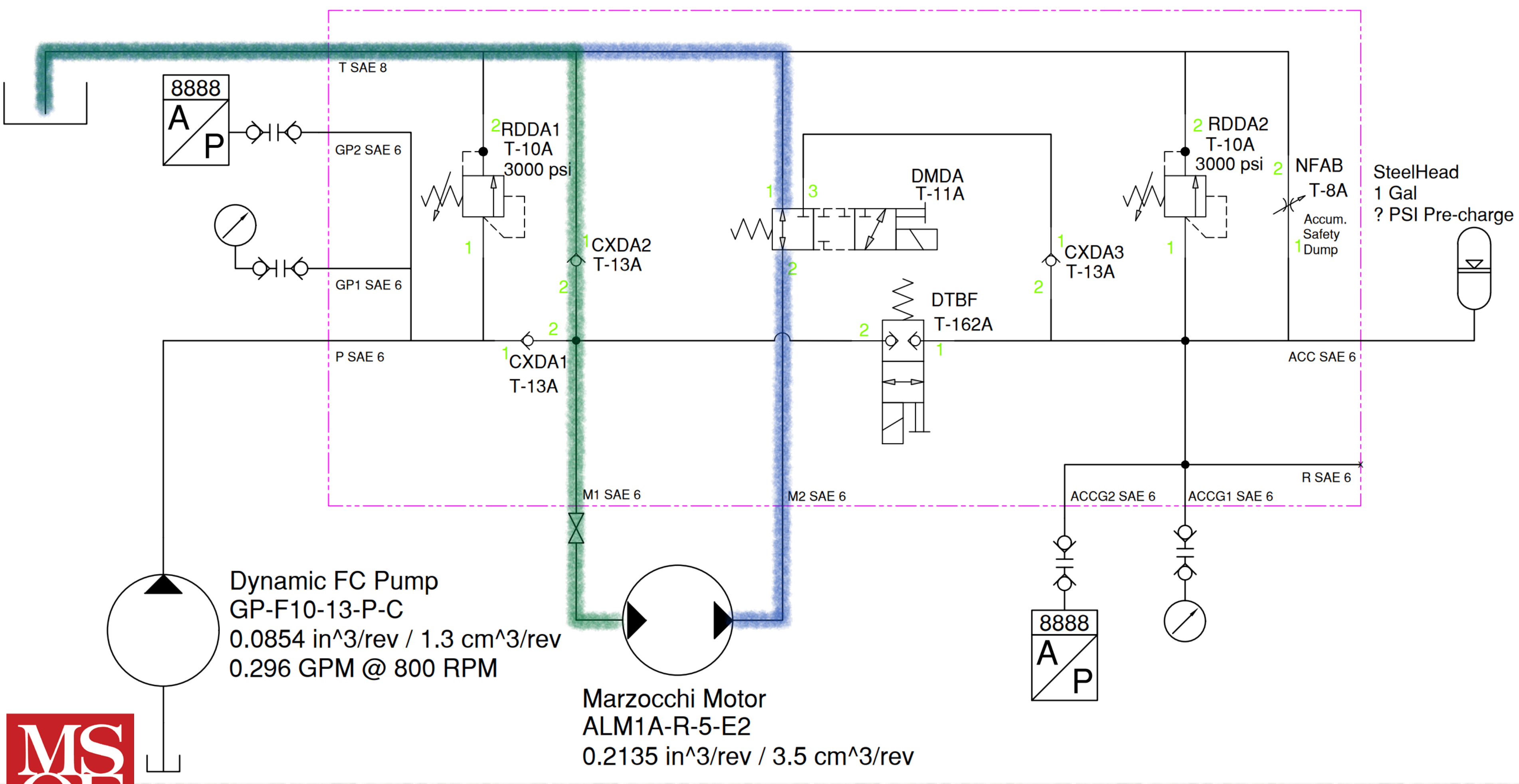
Hydraulic Circuit:
Static Accumulator Charge



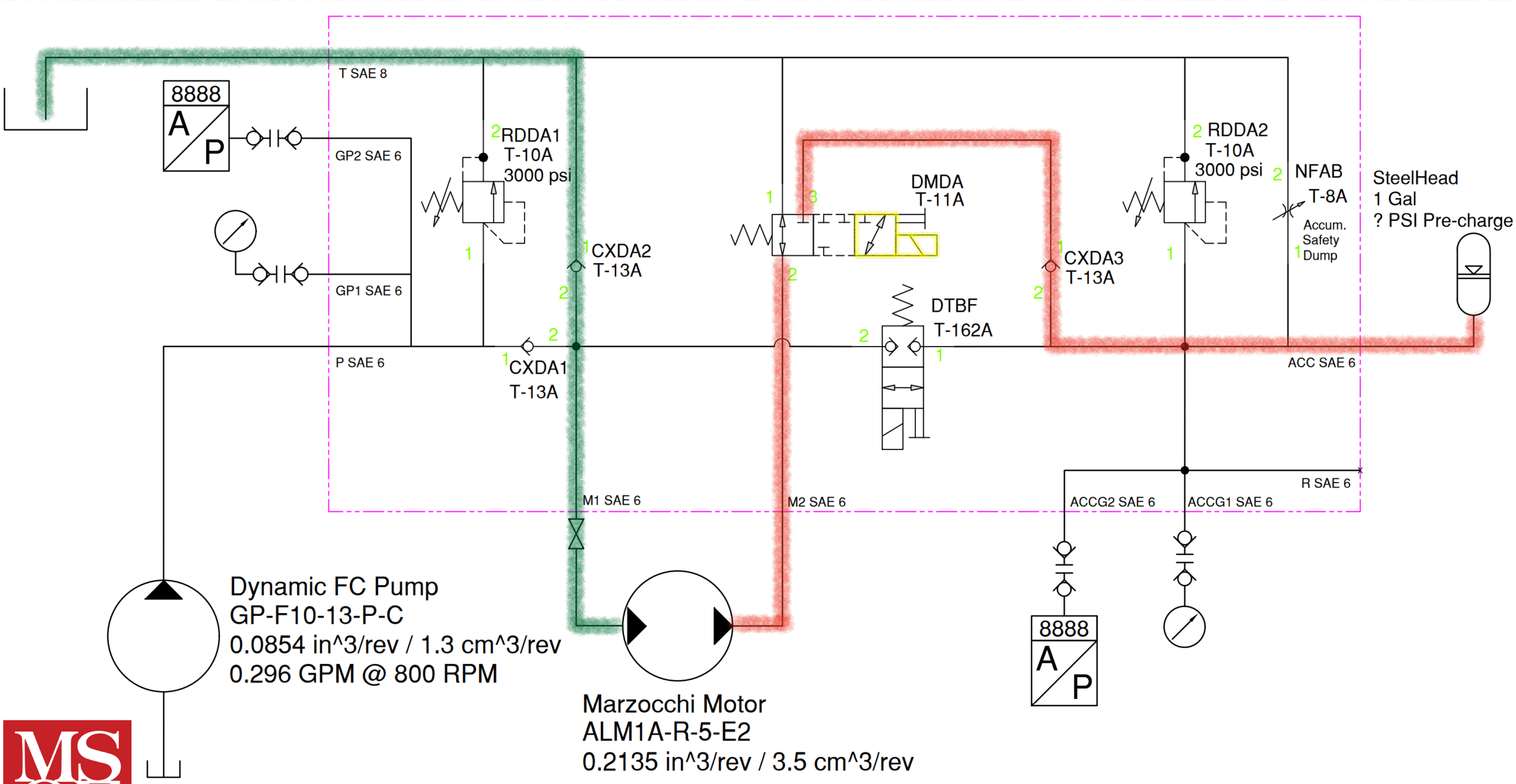
Hydraulic Circuit: Accumulator Discharge



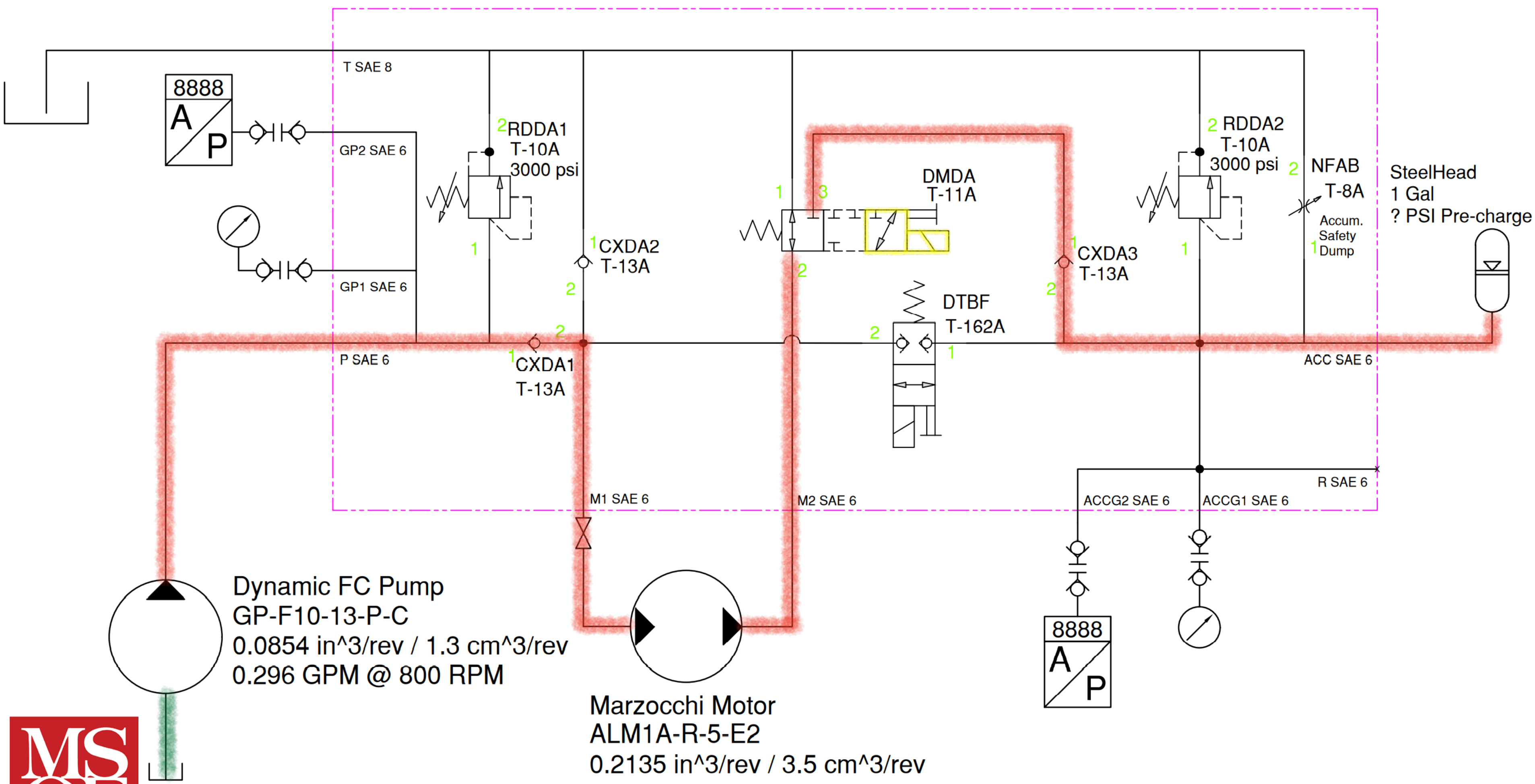
Hydraulic Circuit: Freewheeling (Default)



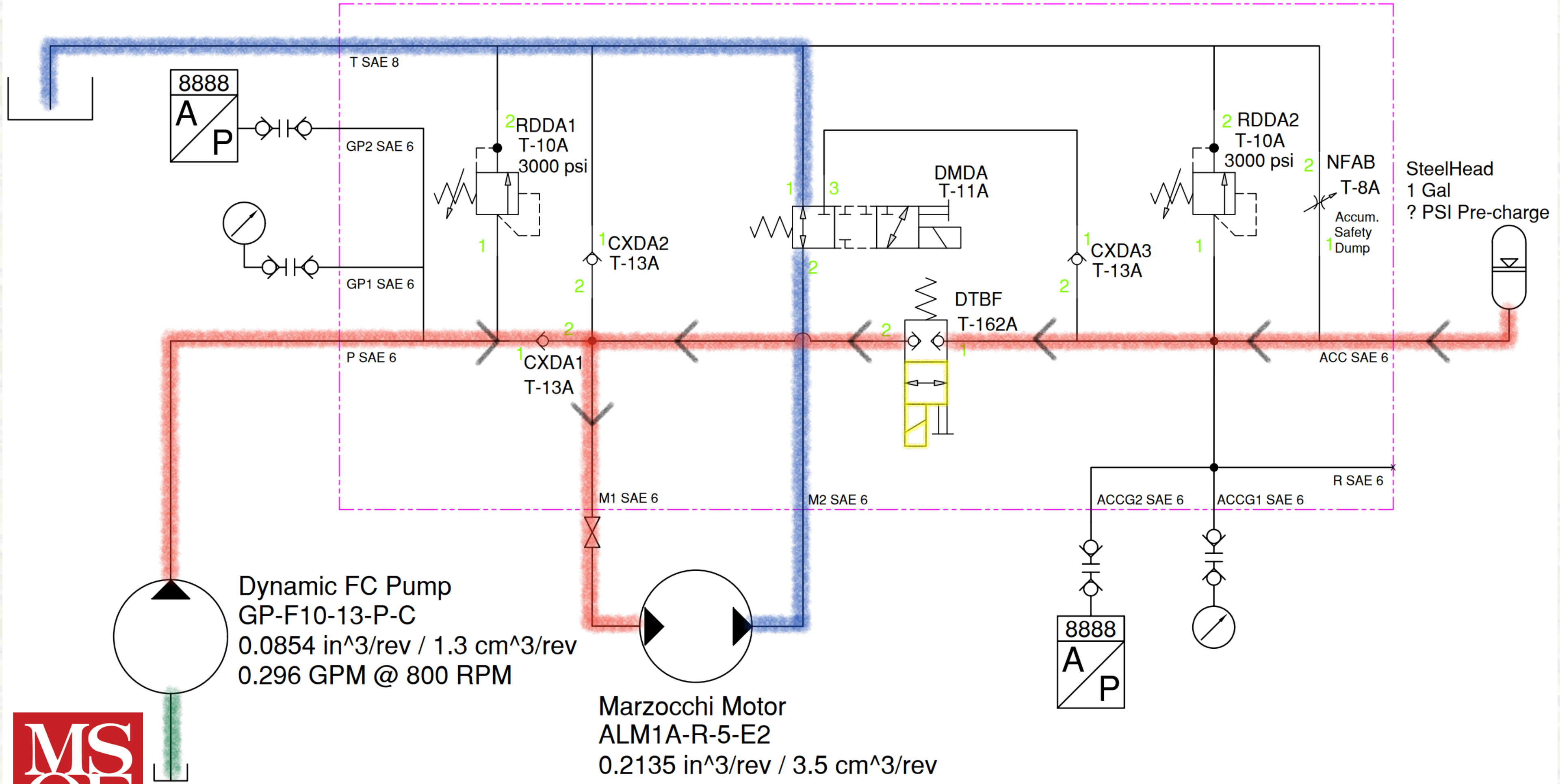
Hydraulic Circuit: Regen Brake Engaged (Freewheeling)



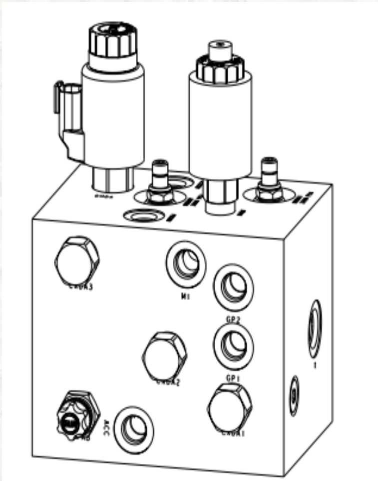
Hydraulic Circuit:
Regen Brake Engaged (Pedaling)

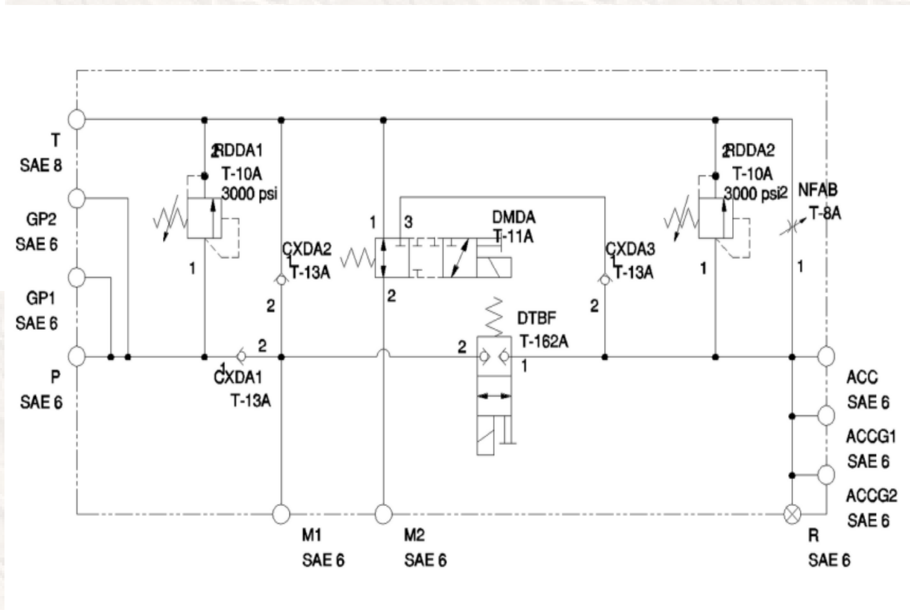


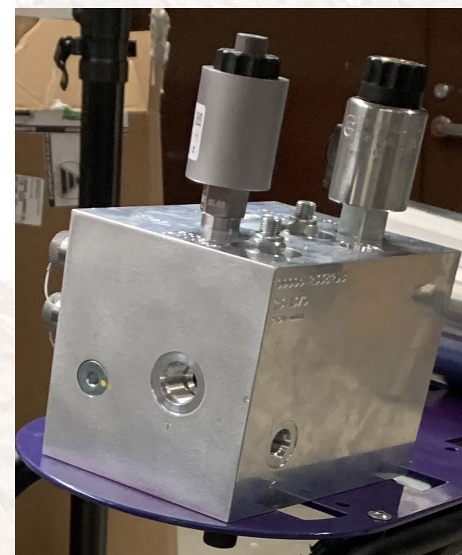
Hydraulic Circuit: Supplemented Pump Flow



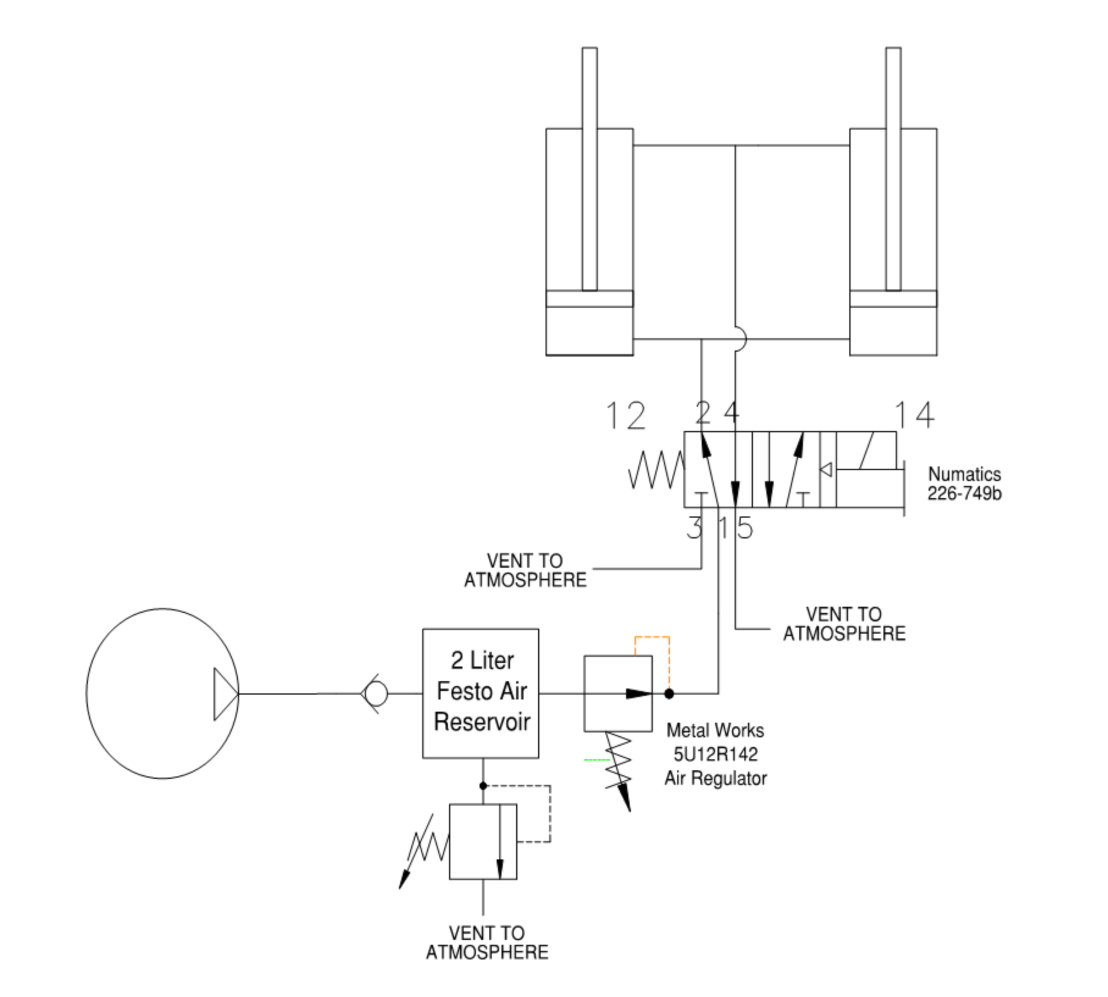
Manifold Design



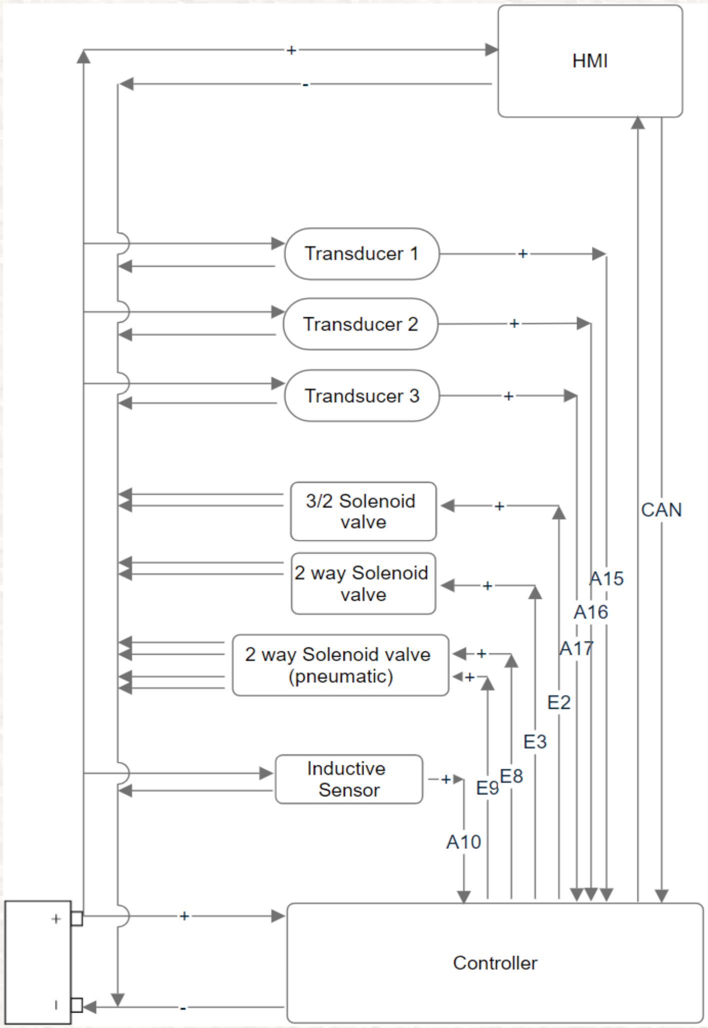




Pneumatic Circuit

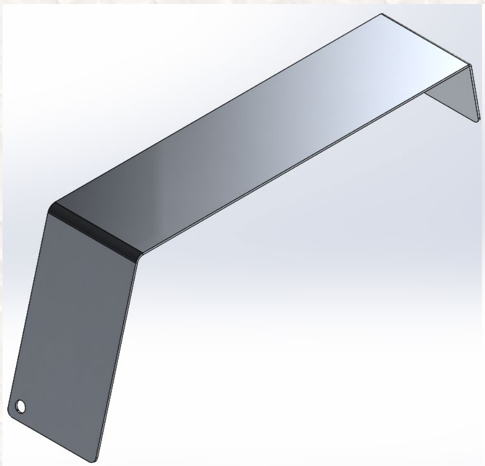


Electric Circuit

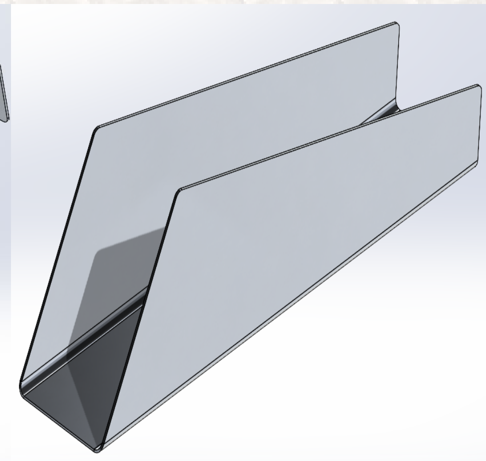


Fabrication - Reservoir

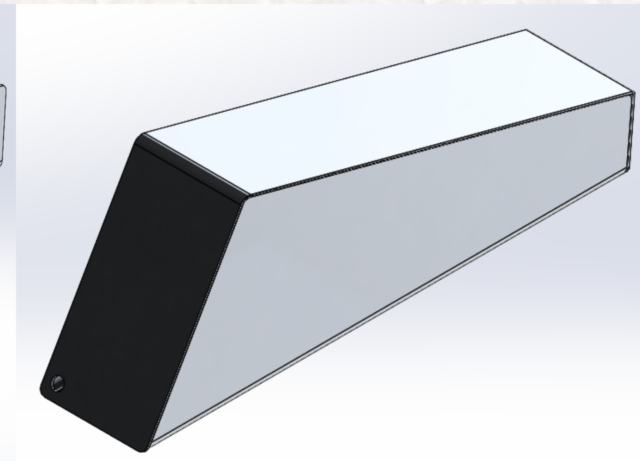
Top



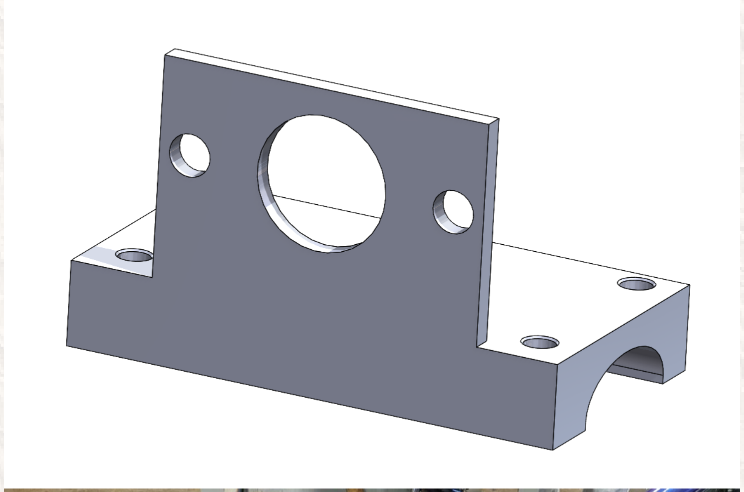
Bottom



Assembly



Fabrication – Mounts

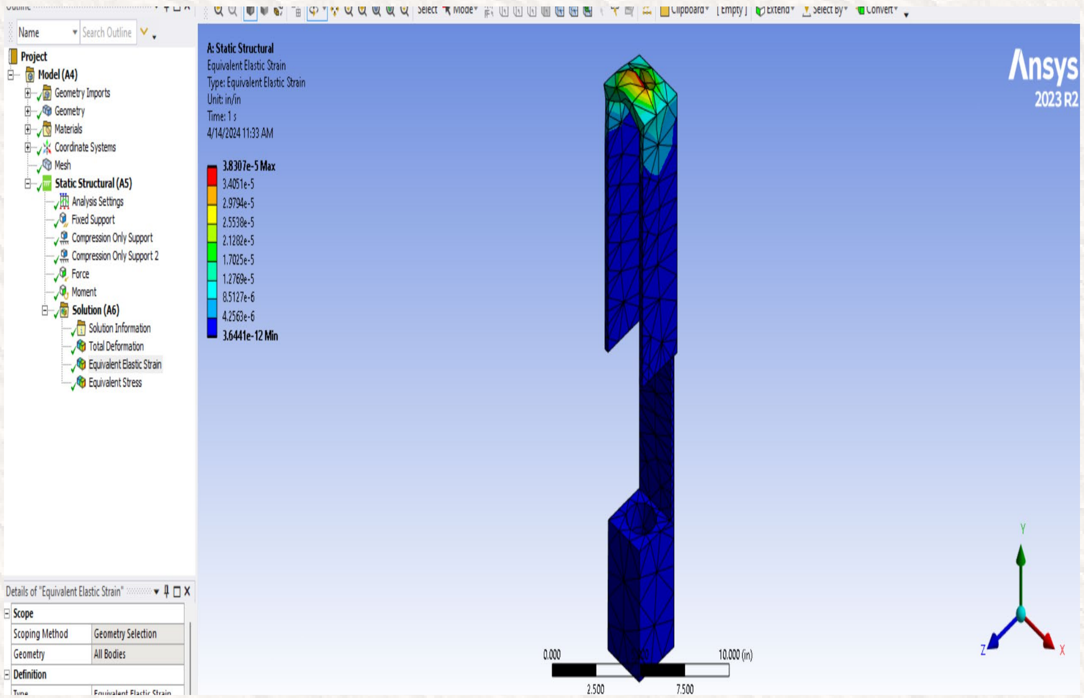


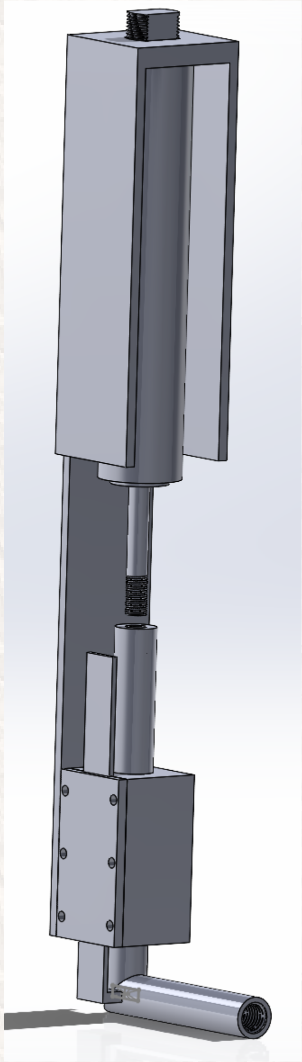
Fabrication – Sprockets

Fabrication – Bracket

Fabrication - Stabilizers

- Finite Element Analysis
- SolidWorks planning



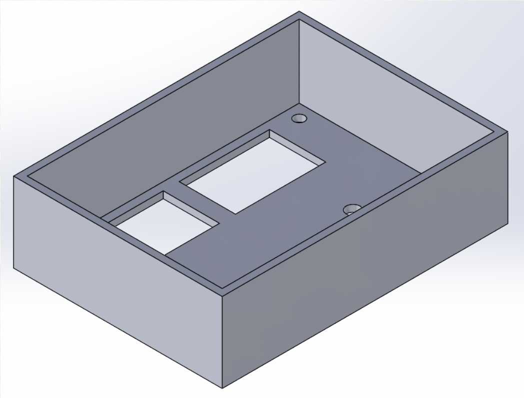


Fabrication - Stabilizers

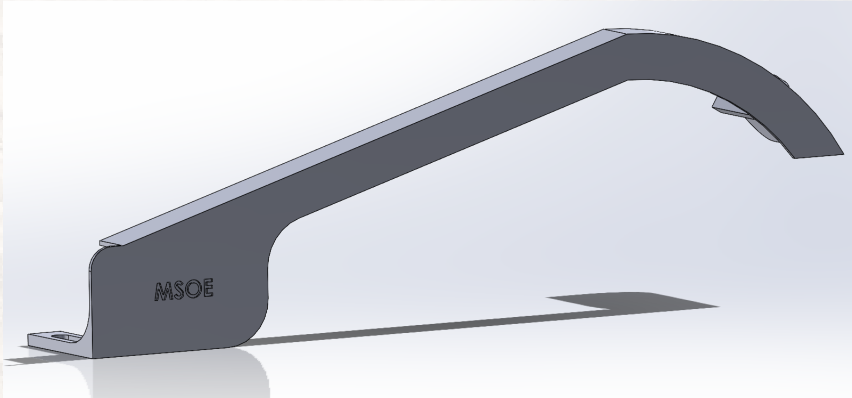
- Stability for low speeds
- Linear movement

Fabrication – 3D Prints

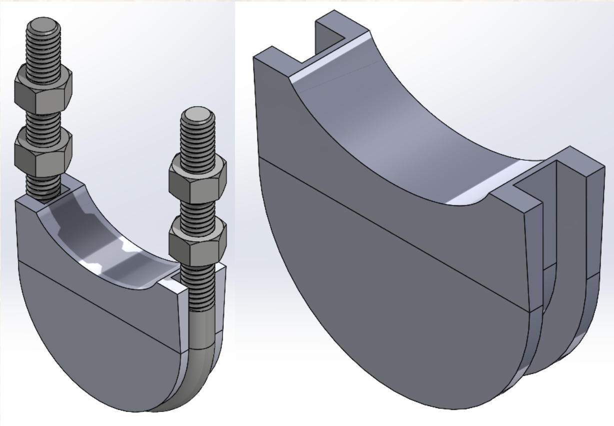
Interface Box



Chain Guard



Pump Mount Spacer



Testing Problems

- Chain issues
- Leaking connections
- Pneumatic regulator pressure

Lessons Learned

- Experience drives problem solving
- Persistence is key
- Learning is continuous

Acknowledgements

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NFPA Fluid Power VEHICLE Challenge

Questions?