NFPA Fluid Power VEHICLE Challenge

NFPA Education and Technology Foundation

Final Presentation
TENNESSEE STATE UNIVERSITY
DR. MOHAMMAD HABIBI
April 7th, 2025

Tennessee State University

AGENDA

- Team Introductions
- Previous Year Design
- Improvements
- This Year Hydraulic Design
- Vehicle Construction
- Vehicle Testing
- Final Vehicle Brought to Competition
- Regenerative Braking
- Lessons Learned
- Design Choices
- Safety
- Questions?

MEET THE TEAM

Courtney Krechel
Mechanical Engineering
Senior

Luc Lemassi
Mechanical Engineering
Senior

Donovan Davis
Mechanical Engineering
Junior

MEET THE TEAM

Drew Hall
Mechanical Engineering
Senior

Alexander Williams
Mechanical Engineering
Senior

Dr. Mohammad Habibi
Faculty Advisor
Assistant Professor
Mechanical Engineering Dept.

Tennessee State University

MEET THE TEAM

Freshman Team Members

Gregg Moore
Mechanical Engineering

Sa'Mya Quinney
Mechanical Engineering

Maleia Ali
Mechanical Engineering

Justin Collie
Mechanical Engineering

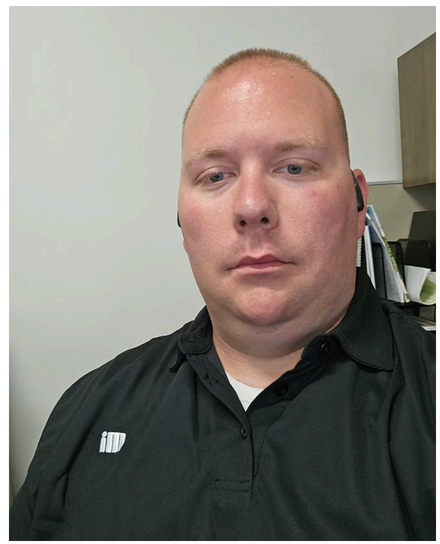
Joe Tunstall
Mechanical Engineering

Marquiles Meadows
Mechanical Engineering

MENTORS & TECHNICAL LIAISON

NFPA Fluid Power Vehicle Challenge

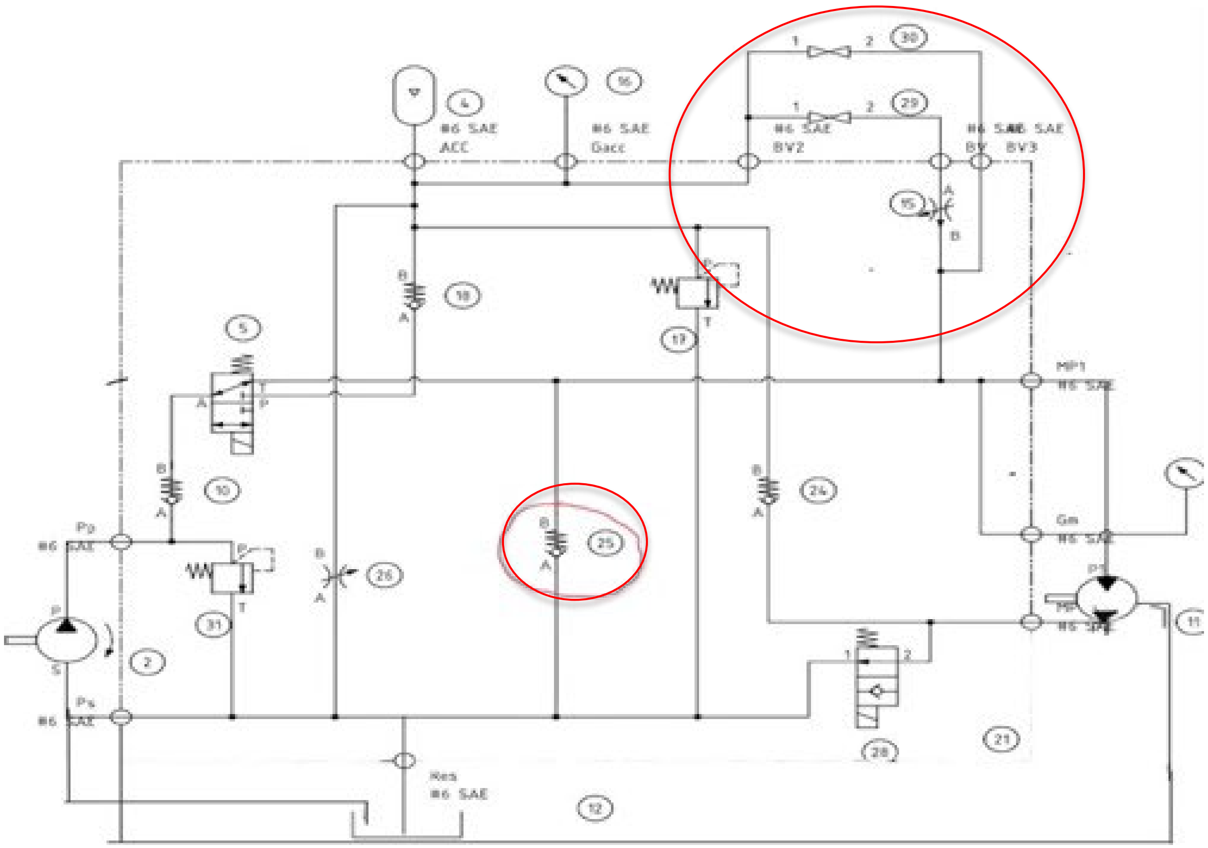
Ernie Parker, CFPA
Technical Liaison
Fluid Power Hall of Fame Inductee



Joshua Rodman
Industry Mentor
Motion Industries

Jonathan Johnson
Industry Mentor
Motion Industries

PREVIOUS YEAR'S FINAL HYDRAULIC CIRCUIT DESIGN

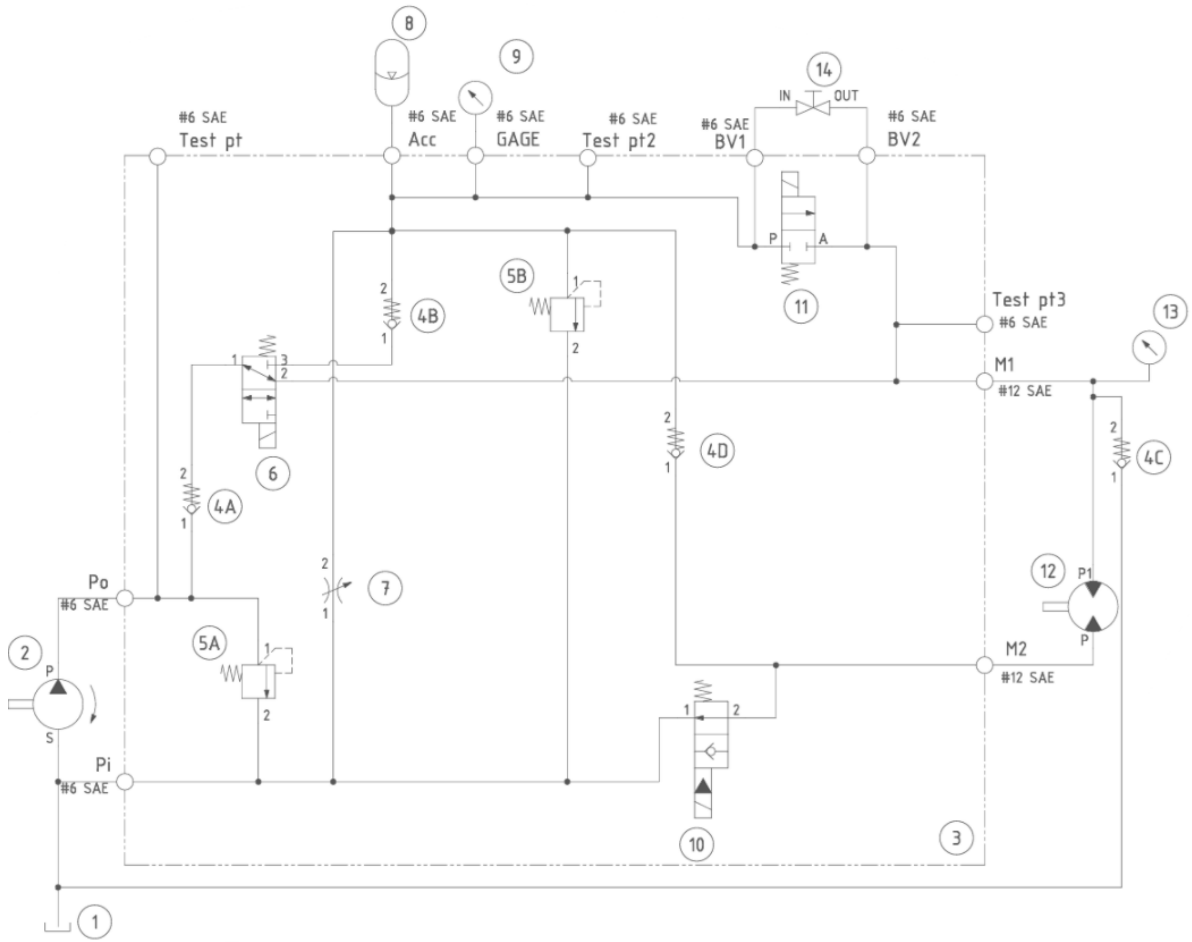


IMPROVEMENTS FROM PRIOR DESIGN

NFPA Fluid Power Vehicle Challenge

- Additional test ports- Ability to check pressure in more locations of the circuit.
- Replaced a manually operated ball valve with a solenoid operated valve- Easier control via electrical switch.
- New mounting platform provides ample space for nearly all components.
- Single speed bike - previous design had issues with a seven speed and being unable to use a smaller wheel sprocket.
- Hose sizing optimized for improved fluid flow with the given components.

HYDRAULIC CIRCUIT DESIGN



NFPA Fluid Power VEHICLE Challenge

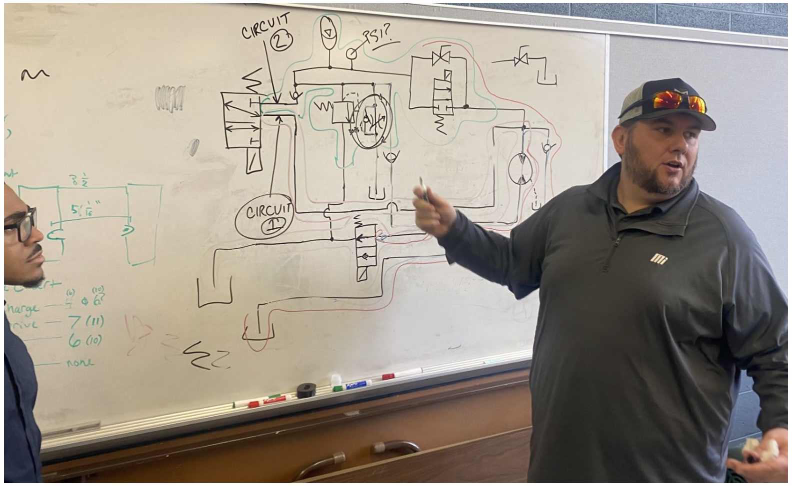
Vehicle Construction

Vehicle construction began in February. Team members worked nearly every day for the next 6 weeks to complete the vehicle. Manufacturing processes utilized by students, with the help of TSU mechanical engineering technician Mr. Lee Isenberg, included welding, drilling, cutting, sanding and deburring.

Tennessee State University

Vehicle Testing

- Initial vehicle testing revealed large problems in our vehicle's performance, including only 1 of 4 driving modes functioning properly.
- With help from one of our mentors, Jonathan, we found the root causes and were able to resolve them to get proper functionality.
- As testing continued, more improvements were made, including increasing the accumulator pre-charge from 140 psi to 700 psi, increasing the pressure in the tires from 25 to 50 psi, and gearing down the motor sprocket for increased torque.



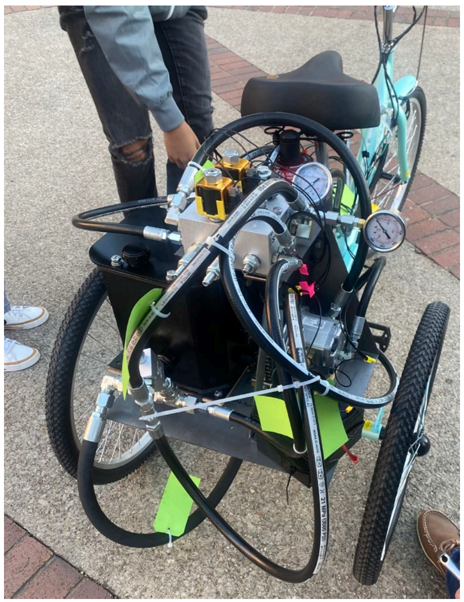
Vehicle Testing

Accumulator drive test

Direct drive test

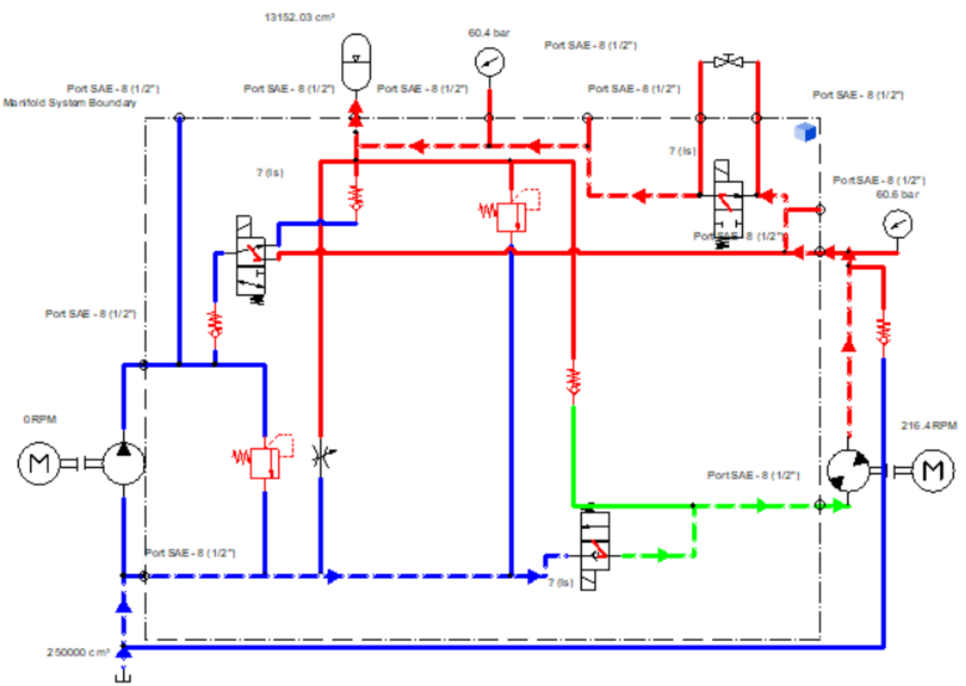
Final Vehicle Brought to Compete

NFPA Fluid Power Vehicle Challenge



Regenerative Braking

- Regenerative braking uses the inertia of the bike as the power source to produce pressure which will charge the accumulator, as a result this will cause the vehicle to slow down.
- Captures kinetic energy during braking and stores it as hydraulic energy instead of wasting it as heat.



TENNESSEE STATE UNIVERSITY

Lessons Learned

- Hydraulic circuit understanding and the role valves play in flow control throughout a manifold.
- Electrical circuit design and building to operate the solenoids.
- Hose sizing and reducing turbulence.
- Hydraulic fittings and how to select mates, fitting designs for complex intersections.
- Selecting the best sprocket ratios and sizing the chain.
- Adaptability of design when unexpected outcomes occur, such as a broken weld.

Design Choices

- Our vehicle was designed to improve weight distribution throughout the bike frame. The pump, rider, and accumulator are concentrated in the center, while the back houses the motor, reservoir, and power source.
- The motor to wheel drive sprocket ratio is 1:1. This allows for improved torque and wheel revolutions.
- The pedal to pump ratio was chosen to make it slightly easier for the rider to pedal when charging the accumulator.
- Adding a third solenoid allows the rider to easily dump the accumulator charge and reach maximum potential distance traveled in a certain amount of time.
- The hose sizing on the pump suction side was increased to SAE 12, matching the inlet of the pump (SAE 12 O-Ring) to increase fluid flow.

Safety

- To ensure our rider is safe, the vehicle was manufactured with radiused corners and deburred edges to avoid cuts and scrapes.
- The chain from the pedal to the pump is protected with a chain guard to avoid injury to the rider and damage to the chain.
- The rider is equipped with a helmet, steel toed shoes, and optional shin guards, reducing their risk of potential injuries due to falls, drops, and pedals slipping.

THAT YOU

Questions?

Supplementary Slides

PROJECT GOALS & OBJECTIVES

Program Objectives as set by NFPA:

- Stimulate education in fluid power components, circuits, and systems, incorporating them into a systems engineering experience.

- Provide students with experience in real-world engineering under a strict timeline of designing, simulating, ordering, building, testing, and demonstrating their designs.

- Stimulate innovative thinking for designing and testing potential new fluid power technologies or concepts integrated into a vehicle platform.

- Provide an industry recruitment opportunity for high-potential engineering seniors by engaging directly with practitioners in the fluid power industry.

PROJECT GOALS & OBJECTIVES

Team Goals & Objectives

- Vehicle qualifies for all races.
- Vehicle must be under 210 lbs. without the rider.
- Vehicle must meet all safety requirements and safety equipment will always be worn.
- Participating students have learned more about fluid power and will be able to support the next team of students who choose to participate in the next year's FPVC.
- Add HMI controls and additional test points.
- Combines different skills: It brings together physics, fluid mechanics, calculus, thermodynamics, introduction to design, mechanics of materials and computer-aided design, giving a chance to apply what we've learned in different subjects.
- Face real engineering challenges, so that we can think creatively and come up with solutions.
- Work with others that are in the NFPA club, as well as with our mentors to complete the project, building important communication and collaboration skills.

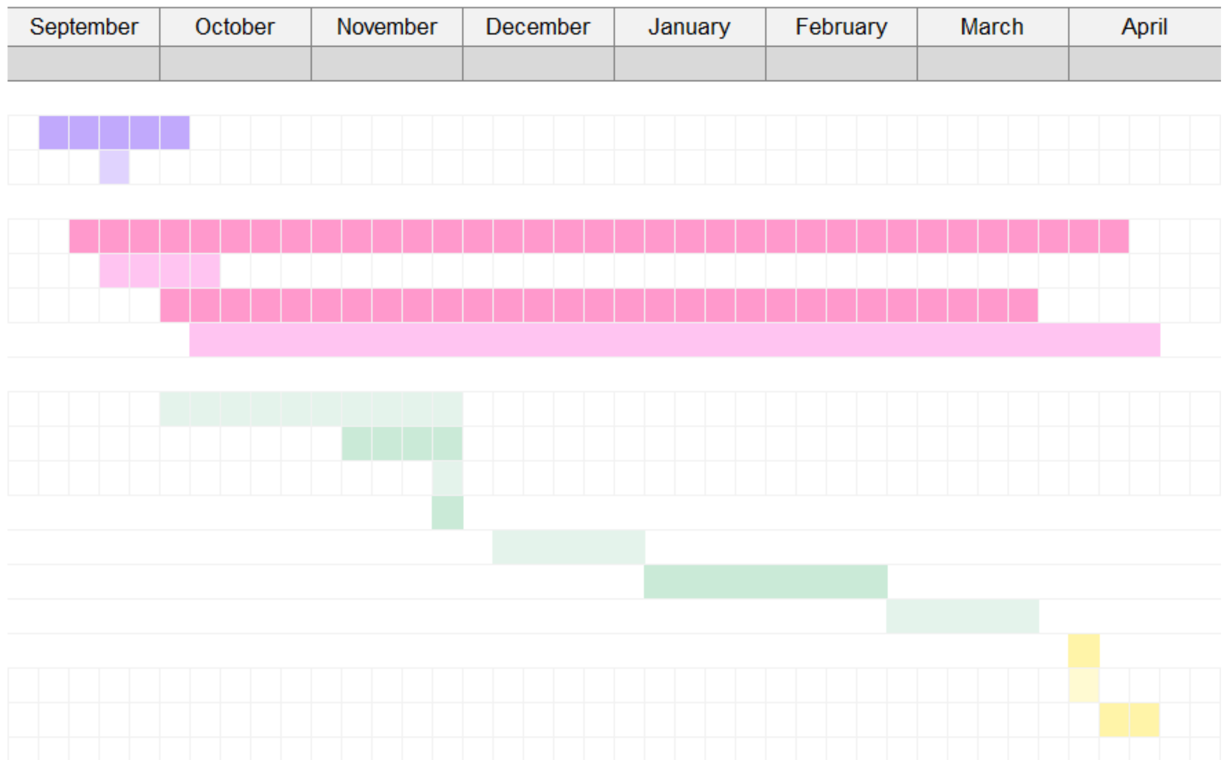
PROJECT TIMELINE

Fluid Power Vehicle

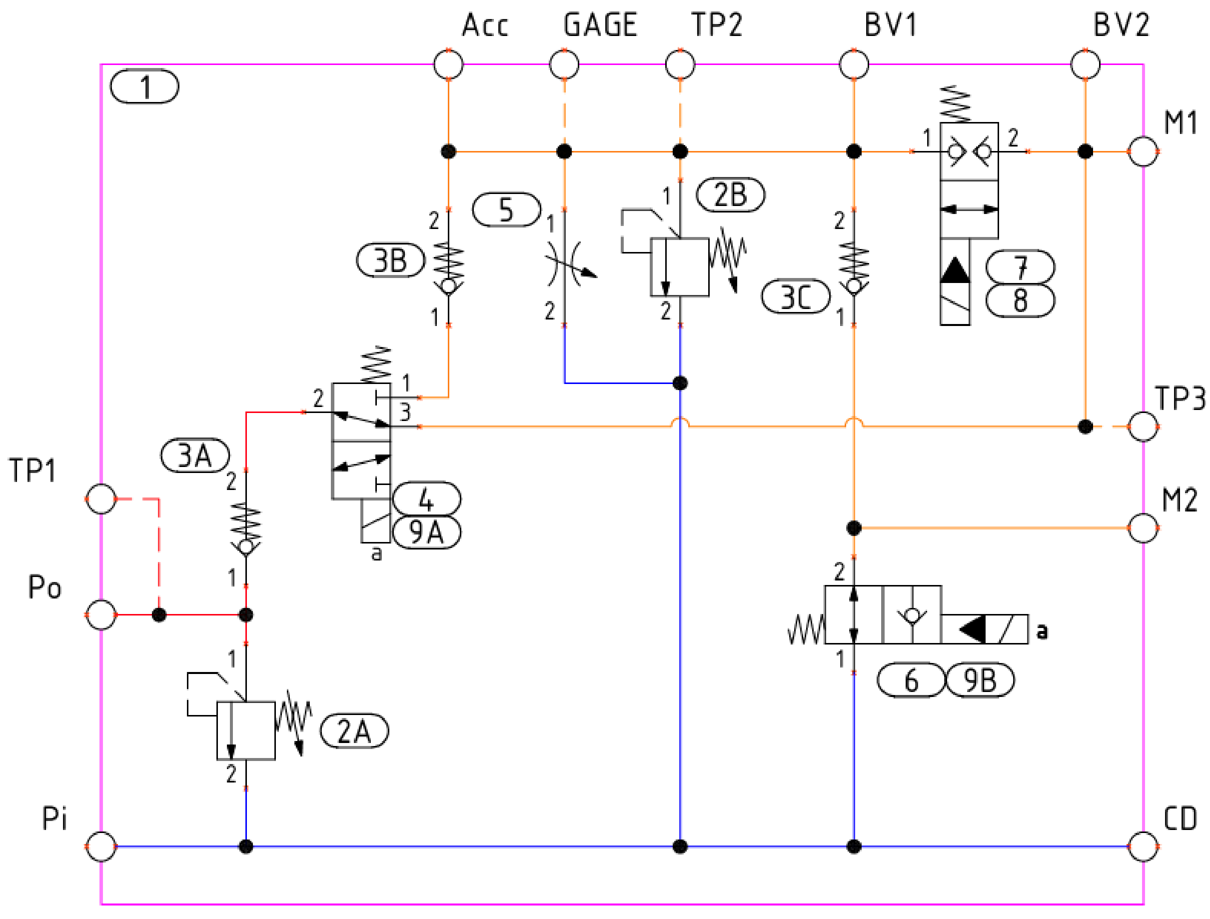
Project start: **Fri, 9/6/2024**

Tennesse State University Team

TASK	START	END
Problem Definition		
Define goals	9/6/24	10/4/24
Kick-off Webinar	9/26/24	9/26/24
Planning and design		
Backround research	9/9/24	
Define scope	9/19/24	10/7/24
Identify safety risks	10/1/24	3/21/25
Meet with mentors	10/11/24	
Execution		
Design Manifold	10/3/24	11/30/24
Simulate manifold design	11/7/24	11/30/24
Choose components	11/25/24	11/30/24
Order components	12/1/24	12/1/24
Source hosing	12/9/24	1/9/25
Assemble bike	1/13/25	2/24/25
Testing	2/25/25	3/21/25
Evaluation		
Competition	4/9/25	4/11/25
Gather feedback	4/9/25	4/11/25
Draw conclusions	4/12/25	4/16/25



FINAL MANIFOLD DESIGN



MAIN COMPONENTS ORDERED

Component	Selected Hardware	Part Number
Accumulator	Bladder Accumulator - 1 Gallon - Carbon Steel Shell	SB330-4A1/112S-210C
Pump	Pump, Gear, 0.39 CID, Keyed Shaft .625", CW rotation	111.20.370.00
Motor	Motor, Gear, 0.659 CID, Keyed Shaft .625", Bi-rotation, external drain	121.20.043.00
Solenoid Valve #6	Cartridge Valve, Solenoid, 2 pos. 3 way Spool 1-2/1-3	SV10-23-04-R00-00-B-00
Solenoid Valve #10	Cartridge Valve, Solenoid, 2 pos. 2 way Uni-poppet Normally Open	SVP10-NOR-R00-00-B-00
Solenoid Valve #11	Cartridge Valve, Solenoid, 2 pos. 2 way Bi-poppet, normally Closed	SBV11-8-C-0-00
Check Valve	Free flow nose to side check valve (1 PSI to open)	CXBAXZN
Relief Valve	Cartridge Valve, Relief, Direct Acting	RV1-10-S-0-36
Needle Valve	Cartridge Valve, Flow Control, Needle Valve	FCV7-10-S-0-NV

Hose Lengths

HOSE LENGTHS					
From	To	Length (Inches)	Connection	M/F	Shape
CD (motor)	Reservoir return	33.5	JIC 6	Female	Straight
CD (manifold)	Reservoir return	10.5	JIC 6	Female	Straight
Reservoir outlet	Pump suction (inlet)	36	JIC 12	Female	Straight
Pump outlet (pressure)	Po (manifold)	42.5	JIC 6	Female	Straight
Accumulator	ACC (manifold)	49	JIC 6	Female	Straight
PI (manifold)	Reservoir outlet	29	JIC 6	Female	Straight
Motor inlet (motor)	Reservoir outlet	32	JIC 6 & JIC 8	Female	Straight
M1 (manifold)	Reservoir outlet	27	JIC 8	Female	Straight
M2 (manifold)	Motor outlet	29	JIC 8	Female	Straight
BV1		42	JIC 6	Female	Straight
BV2		42	JIC 6	Female	Straight

Fittings

Component		Part number (Brennan)	Connection type	Connection Shape	Price
Accumulator	Accumulator	6801-12-20-NWO-FG	12Male JIC, 20Male ORB adjustable	90 elbow	75
		2406-12-06	12Female JIC, 06Male JIC	straight	13.55
Pump	pressure side	6400-06-10-O	06Male JIC, 10Male ORB	straight	14.17
		6801-06-10-NWO-FG	06Male JIC, 10Male ORB adjustable	90 elbow	15
	suction side	6400-12-12-O	12Male JIC, 12Male ORB	straight	72
		6801-12-12-NWO-FG	12Male JIC, 12Male ORB adjustable	90 elbow	16.55
Motor	inlet	6801-06-10-NWO-FG	06Male JIC, 10Male ORB adjustable	90 elbow	14.9
		6400-06-10-O	06Male JIC, 10Male ORB	straight	14.17
		6801-08-10-NWO-FG	08Male JIC, 10Male ORB adjustable	90 elbow	9.86
		6400-08-10-O	08Male JIC, 10Male ORB	straight	7.45
	outlet	6801-06-10-NWO-FG	06Male JIC, 10Male ORB adjustable	90 elbow	14.9
		6400-06-10-O	06Male JIC, 10Male ORB	straight	14.17
	drain	6400-06-06-O	06Male JIC, 06Male ORB	straight	2.72
		6801-06-06-NWO-FG	06Male JIC, 06Male ORB adjustable	90 elbow	5.34
Reservoir	Top (return) port	6505-08-06	08Male NPT (NPT 1/2"), 06Female	straight	21.76
		2601-06-06-08-FG	06Male JIC, 06Male JIC, 08Male NPT (NPT 1/2")	TEE	26.28
	Bottom (suction) port	6505-16-16	16Male NPT (NPT 1"),16Female JIC	straight	21.14
		2403-16-12	16Male JIC, 12Male JIC	straight (reducer)	22
	Bottom TEE OPTION	2601-12-12-16-FG	12Male JIC, 12Male JIC, 16Male NPT (NPT 1")	TEE	65.24
		6602-12-12-12-FG	12Male JIC, 12Female JIC swivel, 12Male JIC	TEE	25.24
		2406-12-06	12Female JIC rigid, 06Male JIC	straight (reducer)	13.55
Set up similar to Ben Quaid's way (but with updated sizing for SAE 12 line for pump)		2404-12-16	12Male JIC, 16Male NPT	converter/reducer	14.69
		2406-16-12	16Female JIC, 12Male JIC	reducer	18.1
		6600-12-12-12-FG	12Female JIC, 12Male JIC, 12Male JIC	TEE	25.72
		6504-08-12	08Male JIC, 12Female JIC swivel	straight (reducer)	31.45
		6402-08-08-O	08Male ORB, 08Female JIC swivel	straight (converter)	10.69

Fittings (continued)

Manifold	M1	6400-08-08-O	08Male JIC, 08Male ORB	straight	3.93	
		6801-08-08-NWO-FG	08Male JIC, 08Male ORB	90 elbow	8.45	
		~~6400-06-08-O~~	~~06Male JIC, 08Male ORB~~	~~straight (reducer)~~	~~3.51~~	(Just in case we used SAE 06 hose here)
	M1	6804-08-08-04-NWO-FG	08Male JIC, 08Male ORB adjustable, 04Male JIC	TEE	15.69	
		6506-04-04	04Female JIC, 04Female NPT	straight (converter)	7.52	
	M2	6400-08-08-O	08Male JIC, 08Male ORB	straight	3.93	
		6801-08-08-NWO-FG	08Male JIC, 08Male ORB	90 elbow	8.45	
		~~6400-06-08-O~~	~~06Male JIC, 08Male ORB~~	~~straight (reducer)~~	~~3.51~~	(Just in case we used SAE 06 hose here)
	Po	6400-06-06-O	06Male JIC, 06Male ORB	straight	2.72	
		6801-06-06-NWO-FG	06Male JIC, 06Male ORB adjustable	90 elbow	5.34	
	Pi	6804-06-06-06-NWO-FG	06Male JIC, 06Male ORB adjustable, 06Male JIC	TEE	7.86	
	ACC	6400-06-06-O	06Male JIC, 06Male ORB	straight	2.72	
		6801-06-06-NWO-FG	06Male JIC, 06Male ORB adjustable	90 elbow	5.34	
	CD	6400-06-06-O	06Male JIC, 06Male ORB	straight	2.72	
		6801-06-06-NWO-FG	06Male JIC, 06Male ORB adjustable	90 elbow	5.34	
	BV1	6400-06-06-O	06Male JIC, 06Male ORB	straight	2.72	
		6801-06-06-NWO-FG	06Male JIC, 06Male ORB adjustable	90 elbow	5.34	
	BV2	6400-06-06-O	06Male JIC, 06Male ORB	straight	2.72	
		6801-06-06-NWO-FG	06Male JIC, 06Male ORB adjustable	90 elbow	5.34	
	GAGE	6405-06-04-O	06Male ORB, 04Female NPT (NPT 1/4")	straight (converter/reducer)	3.76	
		6805-06-04-NWO-FG	06Male ORB, 04Female NPT (NPT 1/4")	90 elbow	13.17	
EXTRAS (to play it safe)		2603-06-06-06	06Male JIC, 06Male JIC, 06Male JIC	TEE	7.17	quantity: 3