GVSU Engineering Senior Project

Engine Dynamometer

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Sponser: GVSU Formula SAE Team

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Problem Statement

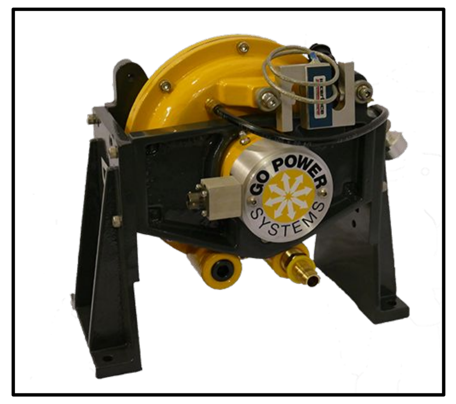
The GVSU Laker Racing Formula SAE team does not have an engine test cell to validate designs and develop engine tuning maps. The current method of testing the engine and vehicle consists of taking the full car and running tests on a chassis dynamometer (dyno). The formula team has procured a D100 Engine Dynamometer Water Brake and control equipment for use in the engine test cell project (pictures of equipment shown to the right). Laker Racing has also acquired simulation software called GT-Suite to simulate horsepower and torque curves for a specified engine configuration.

Objective

The purpose of this project was to design, manufacture and fabricate an engine test cell to advance in-house engine research and development for the GVSU Laker racing team. The engine test cell had to utilize the purchased dynamometer package and be able to accommodate for the testing of various engines common to FSAE. Upon designing, manufacturing, and assembling the test cell, standard operating procedures had to be established. A document specifying how to run the test cell and use the simulation software effectively was final deliverable for the Laker Racing team to be able to tune their engines.

Specifications

Specification	Value or Yes/No	Units
Capable of measuring output shaft torque between	0-44	lb-ft
Must utilize a water brake dynamometer owned by the team	Y/N	
Normal Operating RPM Range (at output shaft of engine)	0 - 12,800	RPM
The test cell must be adequately ventilated for the laboratory air quality not to exceed 50 ppm of CO as an 8-hour time-weighted average (OSHA Spec 1910.1000)	Y/N	
Must operate with available electrical sources	NEMA 5-15 NEMA 5-20	
Measure inlet dynamometer water temperature to validate if systems is safe to start	Min Temp: 60 Max Temp: 220	°F
Must have measurement of sufficient engine coolant water source to determine if the system is safe to start. (Temperature)	Min Temp: 60 Max Temp: 220	°F
Must have engine oil pressure measurement to determine if the system is safe to start	Min Pressure: 0 Max Pressure: 60	psi
Must allow laboratory power shut off to shut off engine test cell	Y/N	
Must incorporate an emergency stop button that turns off power to the test cell	Y/N	
Must cool the engine at full throttle for set time	0 - 30	min
Must have fuel source to run engine	5	gal
System output (Graphs with Torque & Horsepower as function of RPM on a computer connected to the data acquisition module)	Y/N	
Test cell max size (Length x Width x Height)	12x5x9	ft
Required Number of Operators	1	
Max Cost	3,000	USD
Test cell to steel plate mounting method	⅜-16 (0.5" Slot Width)	in.
Must be able to calibrate Dynamometer while on stand		
Mounting and connection Method of the engine is adjustable.	Vert.: 4 / Horiz.: 2	in.
Safety guards - Standard: Based on FSAE Safety Standards (See Appendix B)	Y/N	
Noise Protection - Standard: Based on OSHA Safety Standards (1910.95(a)-(d))	Y/N	



GoPower D100 Dynamometer

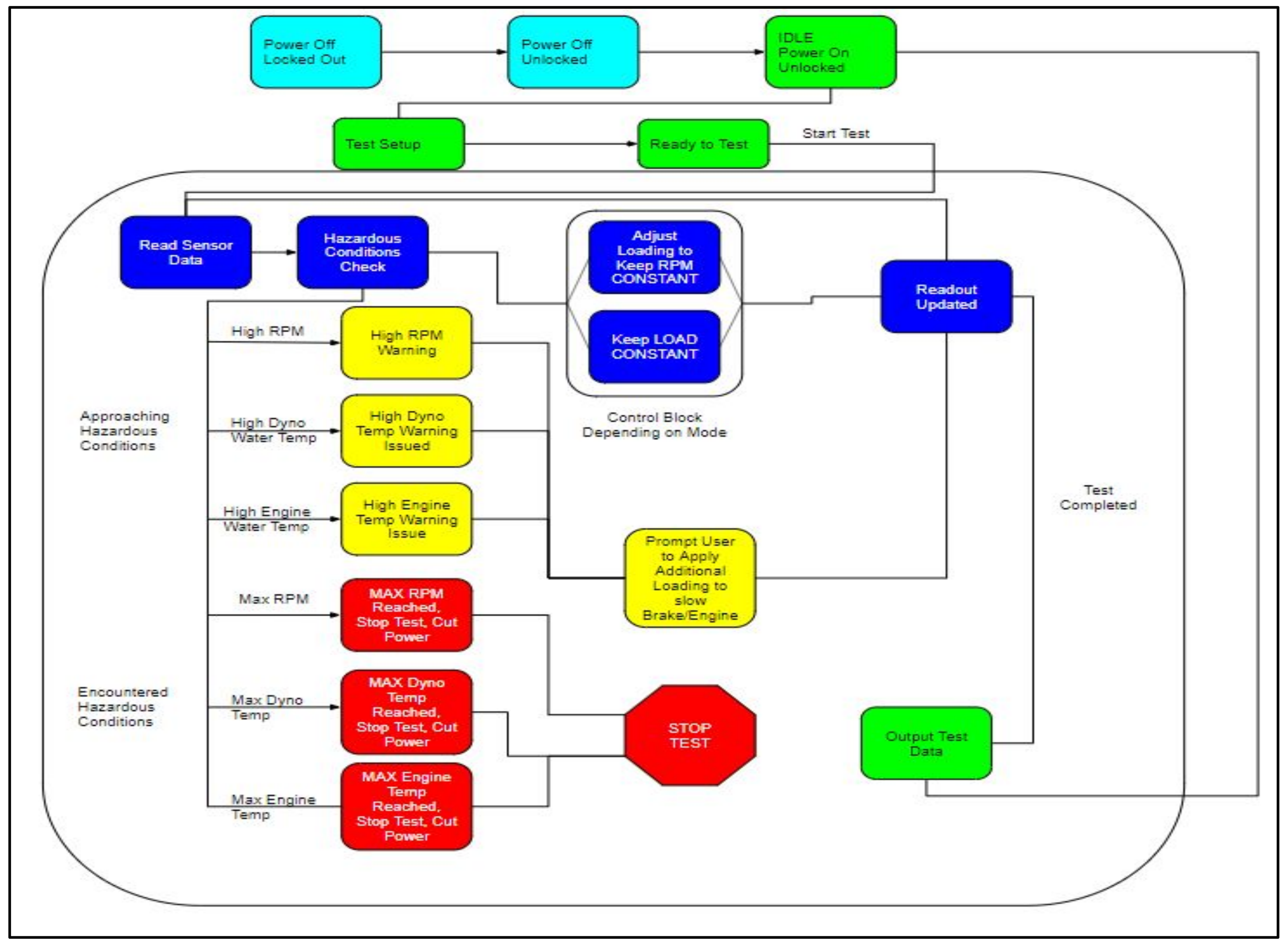
This dyno measures the power output of an engine or motor by using water resistance to absorb power and convert it into heat. Water flow is controlled to simulate different loads, and the power output is determined by measuring torque and rotational speed. This dyno can measure engines between 10-100 hp with a max torque of 66 ft-lbs.

GoPower DC200 Output Console

The display console was included with the GoPower dynamometer package. The RPM, torque, and power values measured by the load cell on the D100 dynamometer are outputted for the user to read while tuning the engine. The values displayed on this console are recorded on the computer and displayed on the monitor as well.

2006 Honda CBR600RR

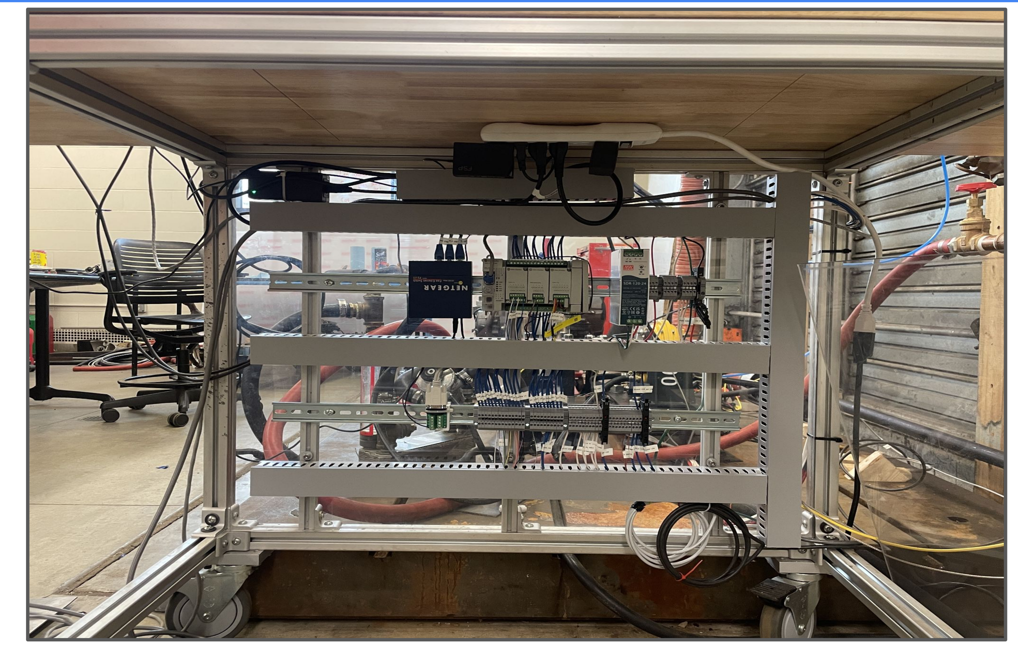
This inline four-cylinder motorcycle engine has been used in Laker Racing cars for the past few years and was utilized for this project. It is a 6-speed manual transmission, maximum power output of 110-120 hp, and 50 ft-lbs of torque at the crankshaft.



State Transition Diagram

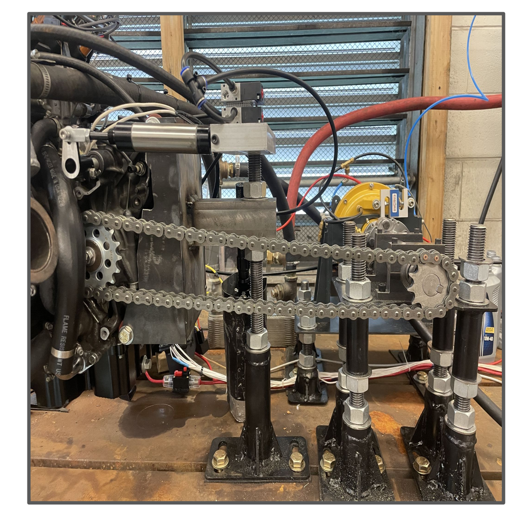
The state transition diagram above shows the flow of operations the dynamometer goes through to meet FSAE specifications and ensure user safety.

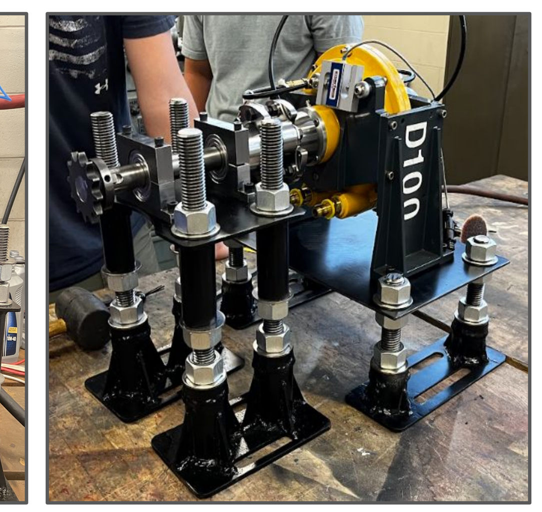
- **Power OFF Locked Out:** The key switch is turned off, and the E-Stop prevents the power from turning the engine on.
- **Power OFF Unlocked:** The key switch and the E-Stop are both responsible for protecting the power from being turned on and both need to be addressed prior to start-up.
- **Idle Power ON Unlocked:** This is the idle state of the dynamometer where the power is on, but no testing has begun.
- **Testing Setup:** In this state, the user will ensure the correct tune is flashed to the engine control unit.
- **Ready to Test:** Following the engine control unit check, the test is ready to be run and the flow will then enter the Testing In-Progress loop.
- **Read Sensor Data:** In this state, the data from all attached sensors is read through the warning system. This information is used to check the system for hazardous conditions and collect data for critical testing values.
- **Check for Hazardous Conditions:** When reading data from sensors, it is important to check data that could be hazardous to the user or destructive to the system. The following blocks are the conditions being observed.
- **Control Block Depending on Mode:** The control block has two options which are based on the type of test being performed. The dynamometer can either keep the RPM constant or keep the load constant.
- **Update Readout:** The update readout state is readouts for all data that is output to the monitor for the user. The programs outputting data will be the Engine Control Unit software, the warning system, and the dynamometer software.
- **Output Test Data:** This state outputs the recorded torque and horsepower by RPM curves. The software will also output the maximum torque and maximum horsepower. These will be used to evaluate the performance of the engine and understand any adjustments made to the engine tune.



PLC Wiring/Control Center

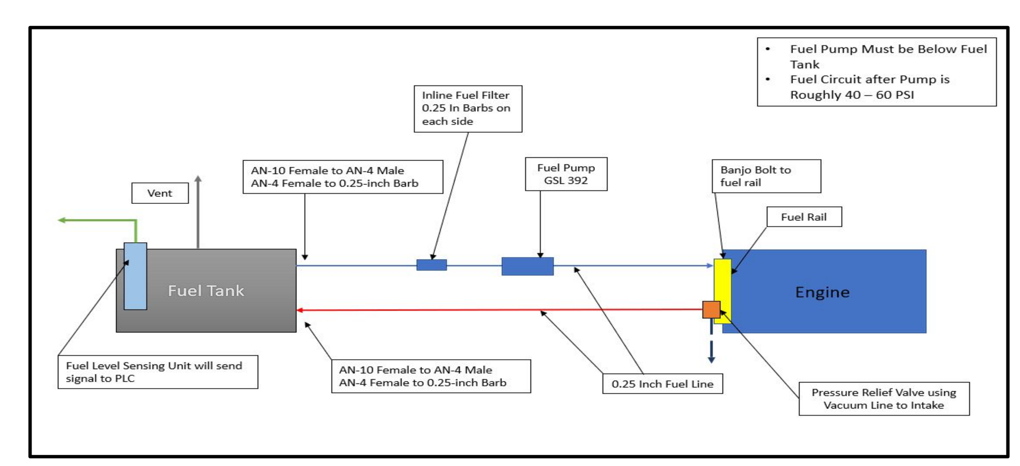
The test cell uses a PLC system (Allen Bradley Micro850) to support the engine ECU tuning software and dynamometer control console to further monitor the status of different components operating inside the test cell. The controller interfaces with different I/O modules and monitors other conditions in the test cell to maintain safety of the operators and equipment in the room. Input signals that are interfaced with the PLC consist of temperature sensors, pushbuttons, limit switches, serial communication, and signals passed through relays.





Engine to Dynamometer Interface

To safely transfer power from the engine's output shaft to the dyno, a chain and sprocket configuration was used. To accomplish this an auxiliary shaft had to be used, which was supported by two pillow blocks which housed bearings for the shaft to freely spin. On one end of the auxiliary shaft sat a 15 tooth sprocket, while the other end was connected to a flexible coupling. The flexible coupling connected the auxiliary shaft to the shaft of the dyno, while allowing for some shaft misalignment.

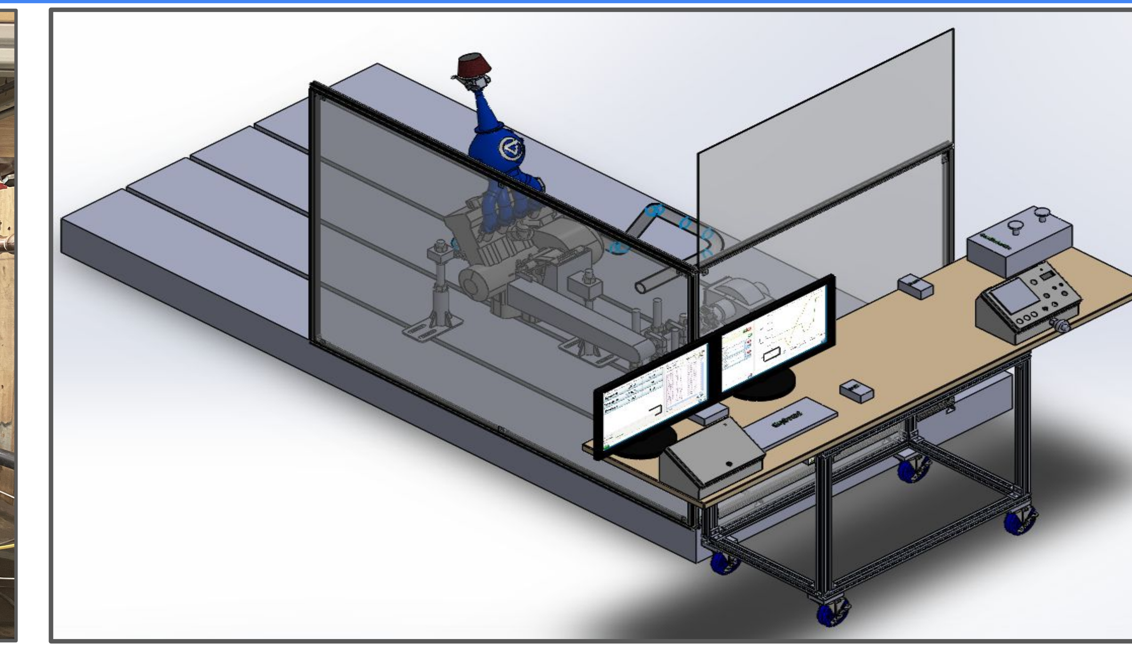


Engine Fueling

The fuel system used for the test cell was similar to what has been used on the Laker Racing cars. The 5 gallon fuel tank used for the test cell features a supply, return, and vent port. The same fuel pump used on the car was used for the test cell.

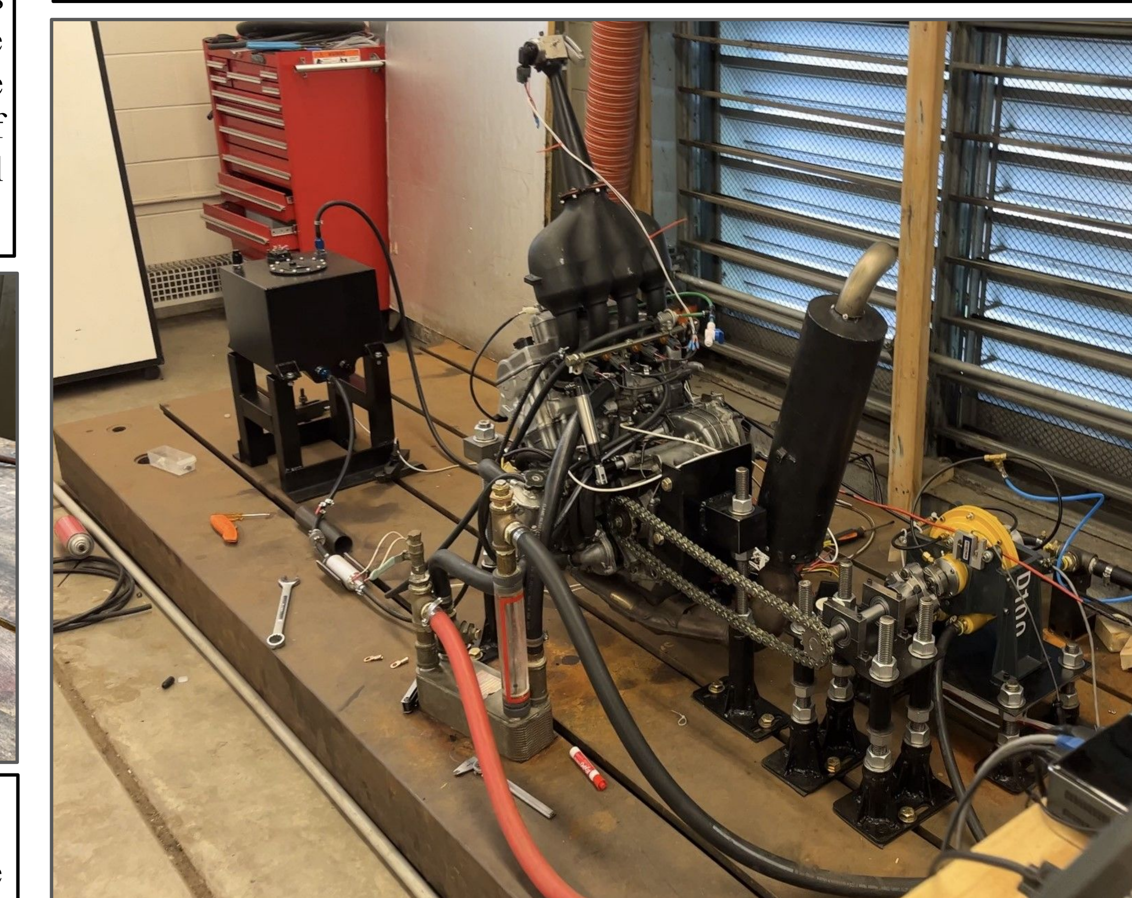
Water Systems

The engine cooling and dyno load are dependent on the 2 inch water supply line that was available in the Keller Laboratory. Using a Tee-fitting, both systems were adequately supplied with the necessary flow rates for maintaining operating temperatures of both systems. Distilled water was used to extract heat from the engine, from there the distilled water ran through a heat exchanger where city water from the 2-inch pipe extracted the heat from the distilled water. The cooled distilled water was then returned back to its original reservoir and the hot city water was fed to a drain in the room.



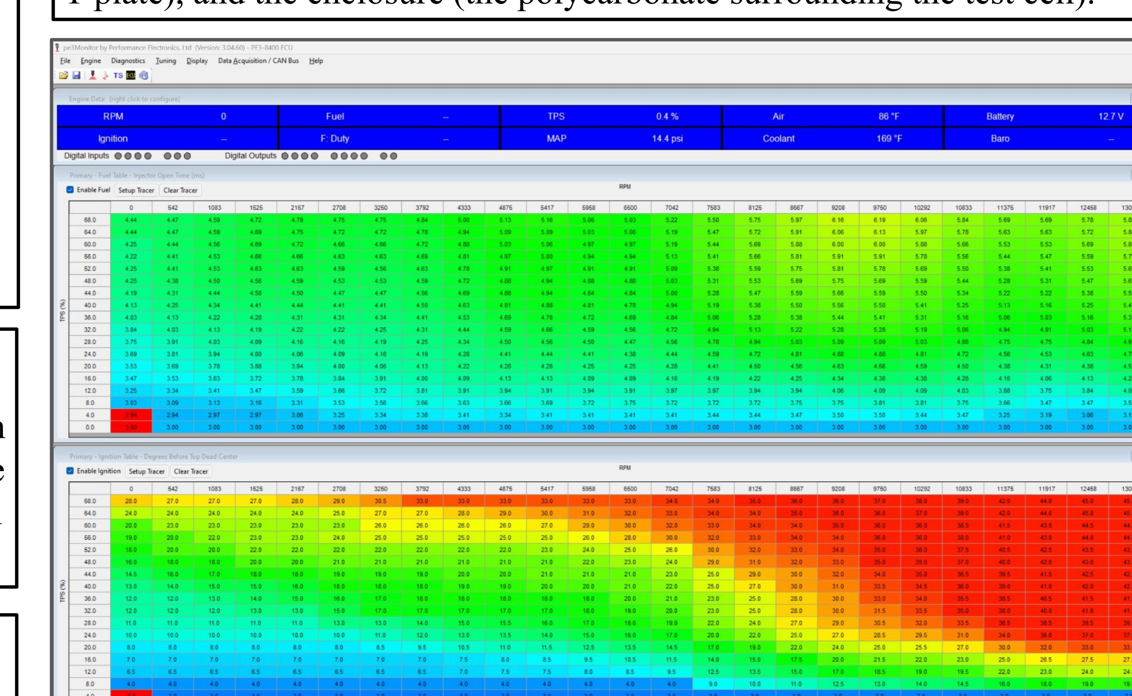
Adjustable Engine Test Cell CAD Assembly

The assembly above includes the major components of the engine test cell. Any tubing, wiring, and some components such as the fuel pump and heat exchanger were omitted from the CAD assembly



Assembled Engine Test Cell

The picture above shows the completed engine test cell, which can be found in the Keller Engineering Laboratory (room 101 in Keller). As seen in the pictures above, all of the stands that were designed, manufactured, and assembled were mounted to a large metal T-plate which allowed for minimal vibration of the various components. The main subassemblies in the test cell are the control center (the cart and table which housed the equipment the operator will be using during the tune), the test cell (everything on the T-plate), and the enclosure (the polycarbonate surrounding the test cell).



ECU Tuning

The screenshot above was taken from the engine tuning software that interfaces with the engine's ECU. The software used was PE3 Monitor by Performance Electronics, which gives the user the ability to change numerous engine variables (i.e. fuel injector parameters, ignition timing, idle speed, throttle response, or rev limit). By modifying these variables, the engine that is being tested can be optimized.