Regulated Fluidic Pressure System Capable of Harvesting Electrical Energy

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ME 189 – Team 19

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Abstract

The purpose of this project is to design and build a test system capable of autonomous regulation of pressure differentials to a nanofluidic device. The device is to be used to verify the theory of electrokinetic energy conversion by applying a pressure differential which forces an electrolyte solution through a nanoporous membrane. The LabVIEW controlled device exceeds all performance requirements with respect to controller rise time, settling time, and steady state error.

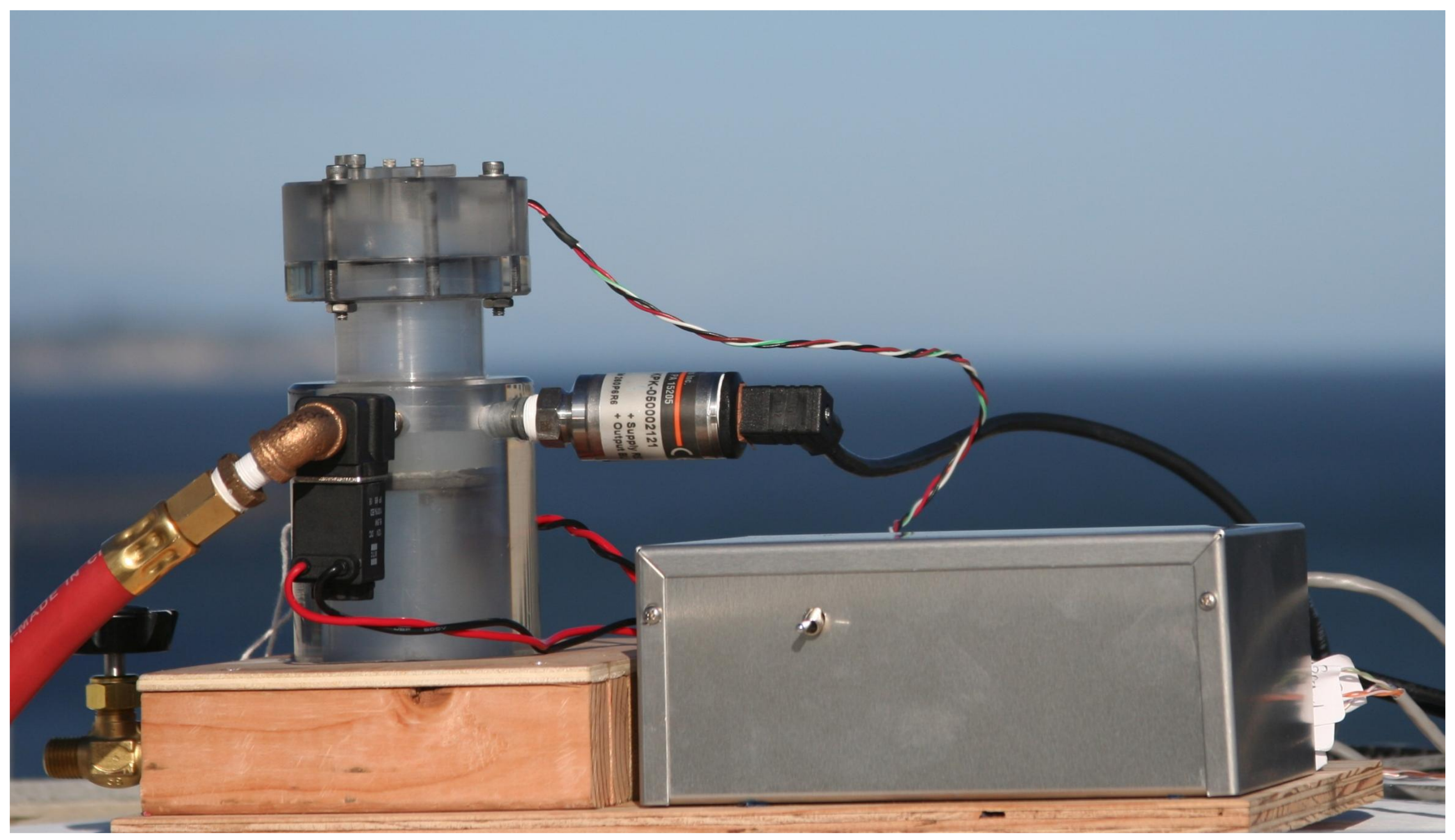

Figure 1. Picture of completed system.

Performance Requirements and Results

Table 1. Tabulated performance requirements.

Requirement	Specification	Achieved
Autonomous control	Controller follows pressure input	No LabVIEW errors
Regulation across pressure range	0 – Max psi	Confirmed, see Figure 3
No air entering fluidic device	Fluid level limit 1/2 in from base	System shuts down when fluid limit reached
Steady state error	< 5 psi	< 0.75 psi
Controller settling time	< 5 sec	< 0.5 sec
Maintain pressure set point for 10 minutes	5 psi/hr pressure loss	1.5 psi/hr
Simulate "black box" flow parameters	< 30 ± 5 mL/min at 90 psi	30 mL/min at 90 psi
Reservoir does not contaminate solution	< 10% change of conductivity	< 5% change of conductivity
Dimensions	< 1ft^3	< 0.75 ft^3

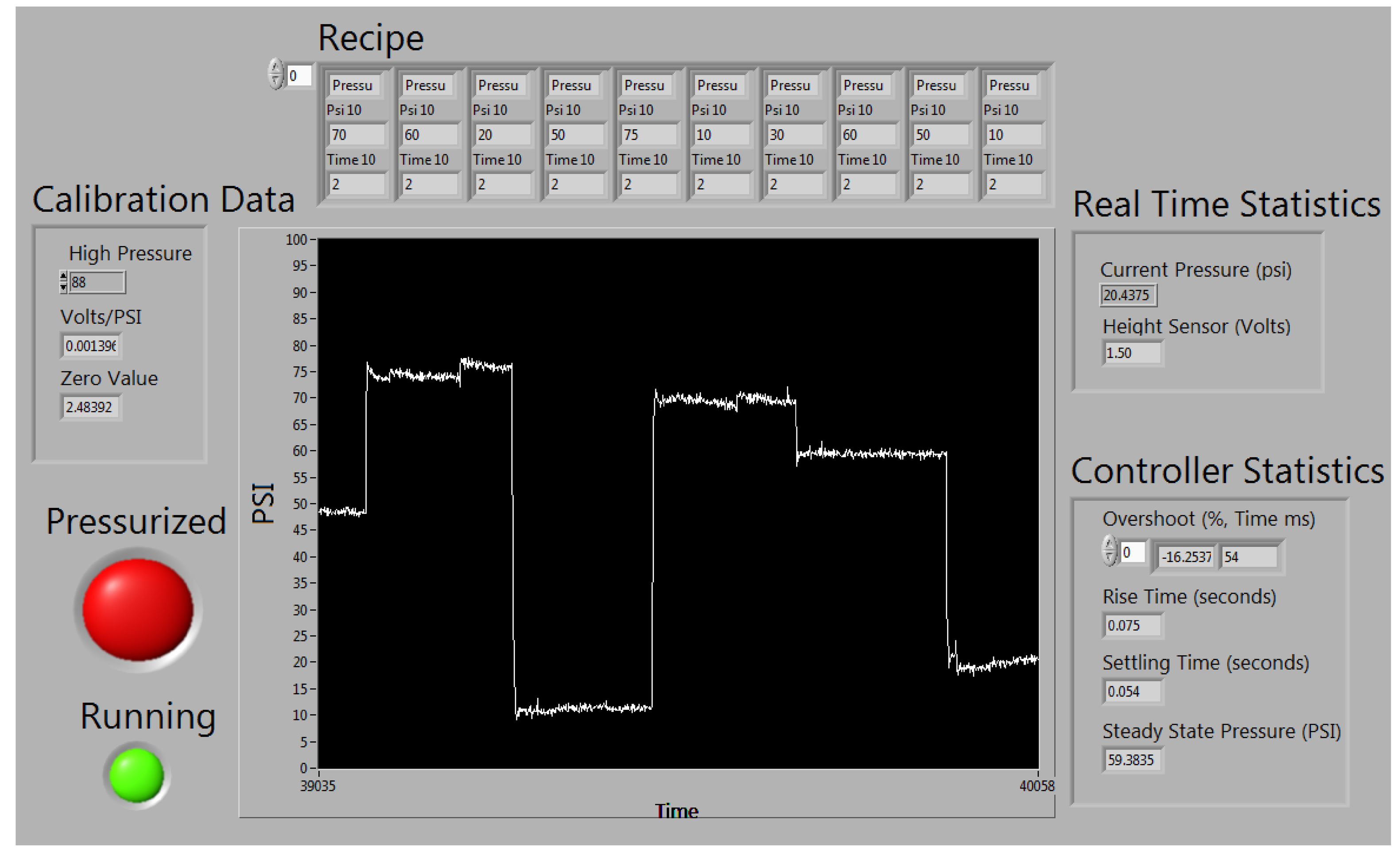

Figure 2. Screen shot of LabVIEW front panel during real time operation showing controller and pressure statistics, calibration data, and pressure recipe.

System Design

Pressure inside of a control volume is regulated through the use of two solenoids. One solenoid is connected to a high pressure source, while the second vents the volume to atmospheric pressure. The controller utilizes feedback from a pressure transducer to determine which valve to open, and for how long. A complex series of internal pressures can be specified by the user in the form of a 'recipe', where each individual pressure goal is entered along with its desired duration. To prevent the device from exhausting the supply of internal electrolyte solution, an infrared sensor monitors the quantity remaining, and shuts the system down when a critical level is reached.

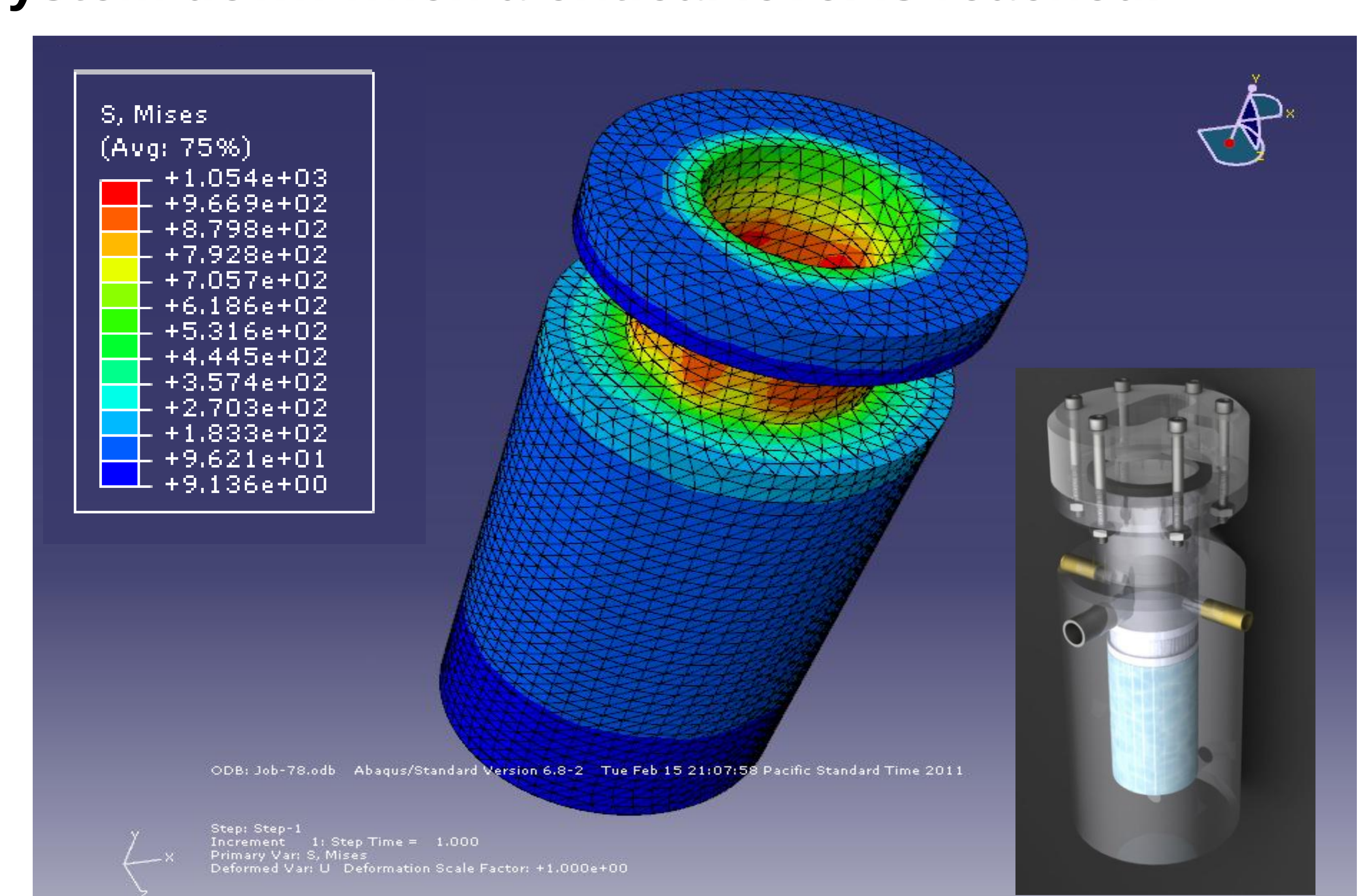

Figure 4. FEA of reservoir (CAD model inset).

Design Development

Initial design efforts were focused on demonstrating pressure control inside an appropriate volume with solenoid valves. Reservoir development was based around providing a housing which would withstand pressures far in excess of our operating range, while not contaminating the solution. Completion of overall system design incorporates a power supply and solution level monitor.

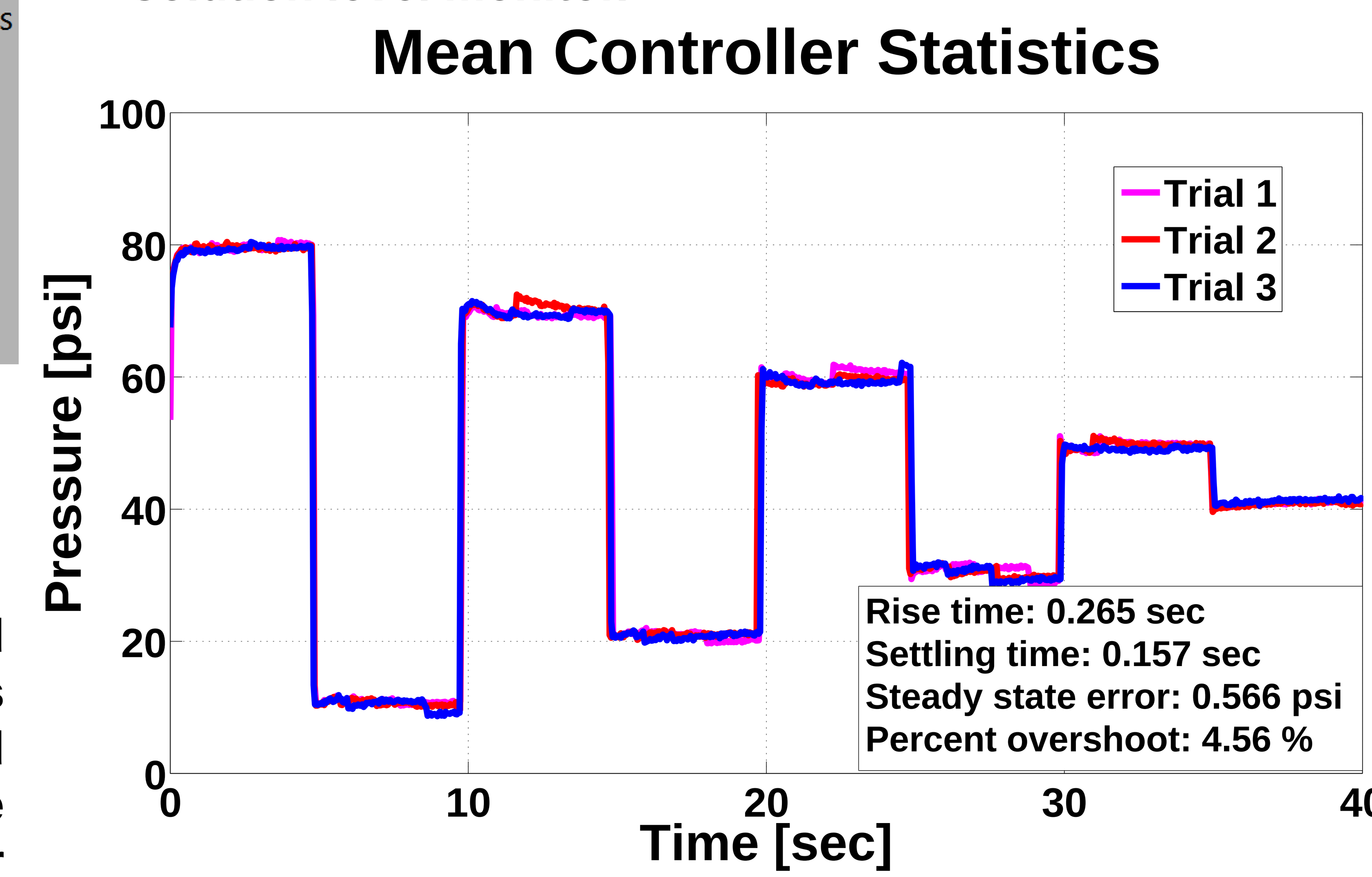

Figure 3. Graph of controller statistics for three pressure tests.

Conclusion

Our automated pressure regulation device met or exceeded all of the designated performance requirements. We conclude that our method of pressure regulation is sufficient for the proposed application as a testing platform for electrokinetic energy conversion. The next step is to use this device as a benchmark to build a more robust device capable of handling pressure differentials on the order of 1500 psi.

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Additional Controller Information

The controller presented in our poster is a reflection of our preliminary pressure regulation efforts. The controller design utilizes only proportional feedback, which means it runs without knowledge of the dynamics of the system (ie. Flow rates, solenoid actuation, and latency in the electronics).

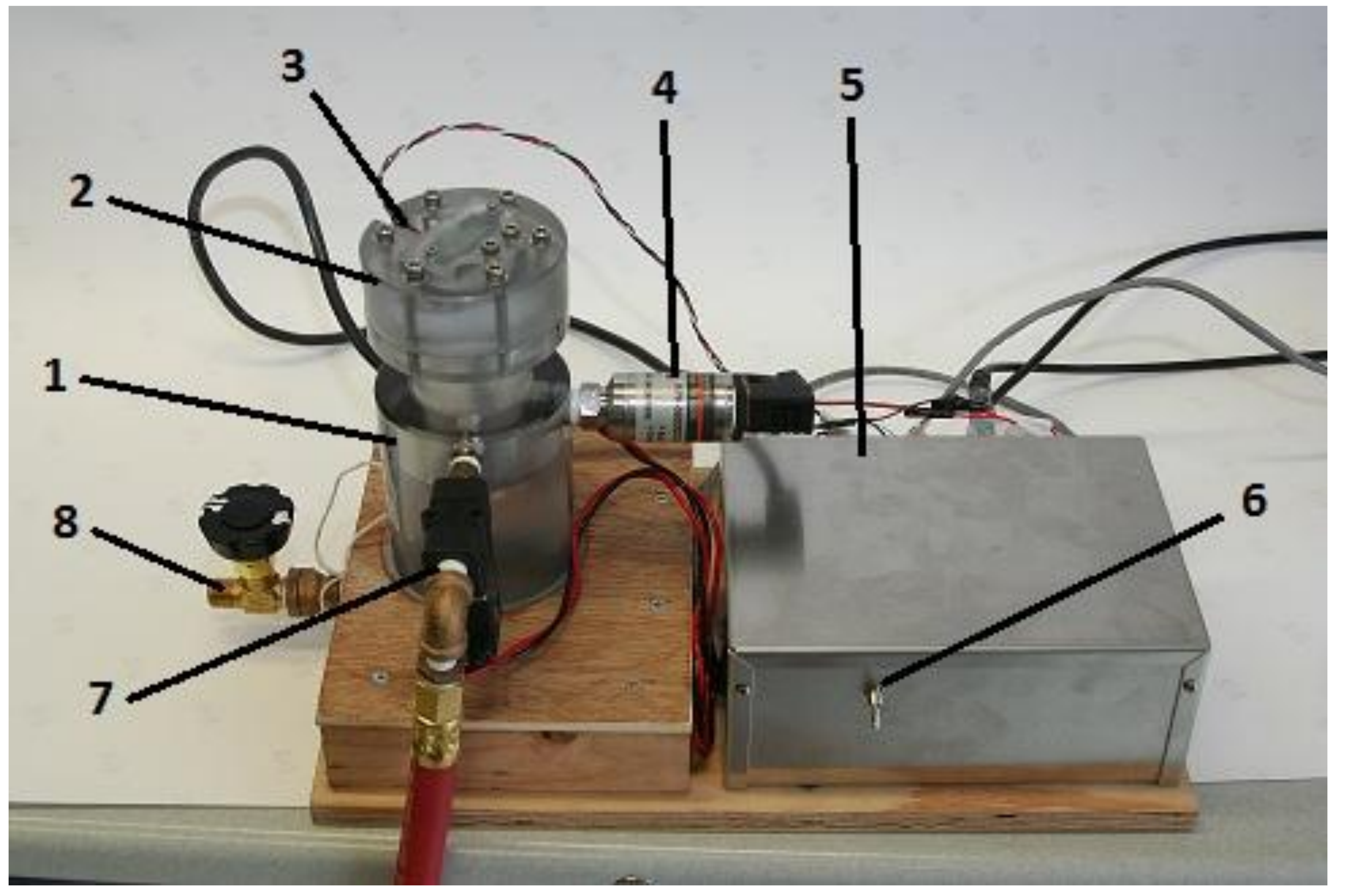
After achieving the Project Completion Requirements, we began to explore more elegant methods of control with the goal of achieving pressure regulation in a minimal number of valve operations. Specifically two models were developed:

1. Nonlinear Control
2. Lead Control

We developed the nonlinear controller by describing the flow dynamics of the system in a set of differential equations and performing a linearization around the setpoint. This method had a significant steady state error due to the appearance of second order dynamics due to electronic latency and was discarded.

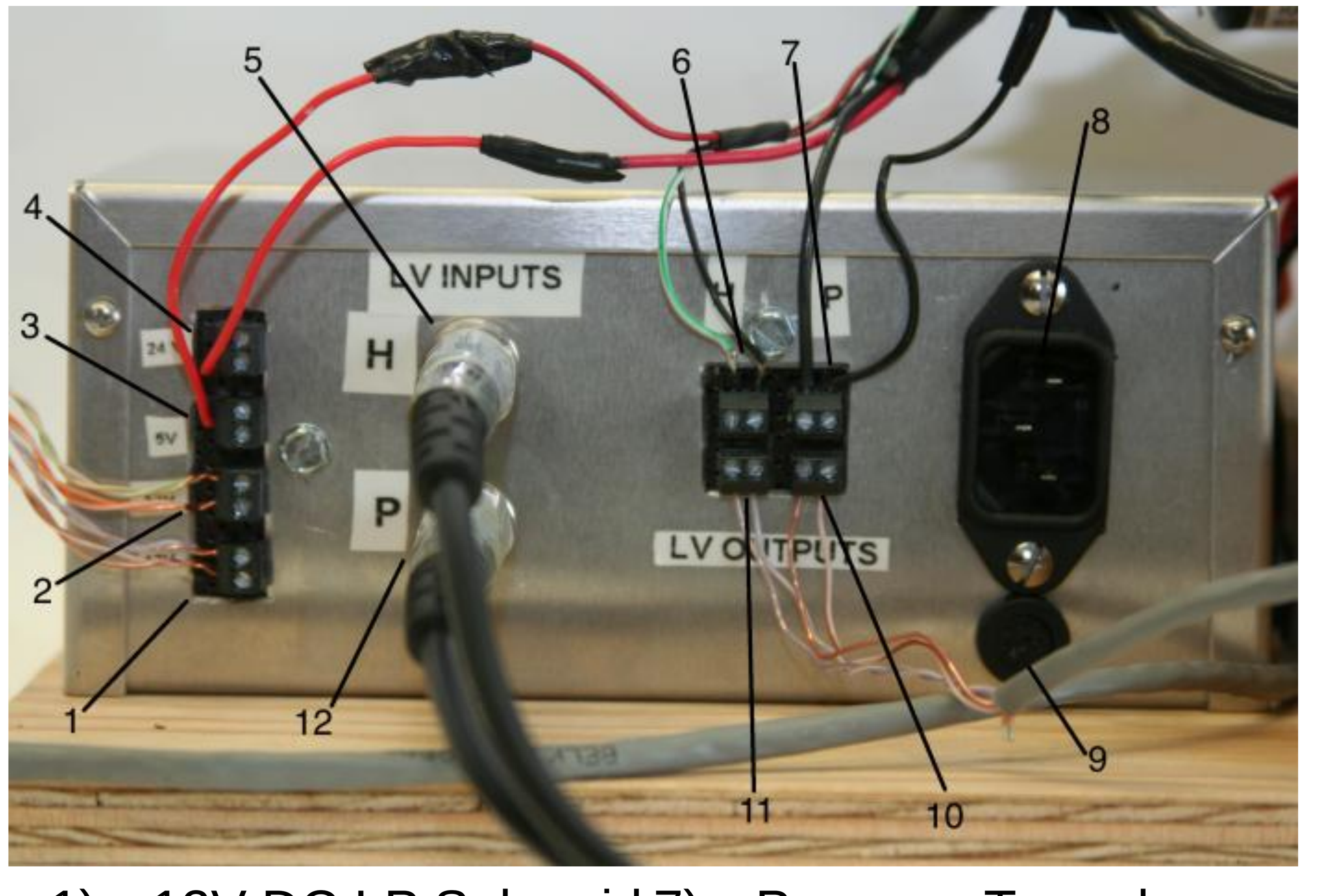
The lead controller was developed through ARX model identification with a forced integrator and the use of RL tools in MATLAB to obtain the linear transfer function. This controller is the *capstone* of our pressure regulation device. Due to time constraints, results are not shown.

Completed Device



1) Reservoir
2) Reservoir Cap
3) Infrared Sensor
4) Pressure Transducer
5) Power Supply Unit
6) Power Switch

Power Supply Unit



1) 12V DC LP Solenoid
2) 12V DC HP Solenoid
3) 5V DC Infrared Sensor
4) 24V DC Pressure Transducer
5) Height Sensor Data Output
6) Height Sensor Data Input
7) Pressure Transducer Data Input
8) 120V AC Supply
9) Fuse
10) HP Solenoid Control Input
11) LP Solenoid Control Input
12) Pressure Transducer Data Output

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