MINI PROJECT REPORT

on

Modelling of Pressure Regulator in AMEsim

Undertaken at

Defence Research & Development Laboratory (DRDL), Hyderabad

Under the guidance of

Shri Jagan Mohana Chary

Scientist- E

LPD, DRDL, DRDO.

Submitted by

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1.Introduction

I Thakur Pranav Gopal Singh a 3rd year undergraduate pursuing Mechanical engineering at MIT Manipal have deep interest in the aerospace sector. Internships are a beautiful exposure to students entering and dealing with real world applications. With my keen and specific interest in rocketry, missiles, and defence components, I wanted to get myself involved in the amazing work that DRDO has been doing since a very long time. DRDO and the other governmental organisations are playing a key role in the defence sector. I choose to work in liquid propulsion division because I wanted to specialise in that area in my higher studies and this opportunity would really benefit me. My project guide Shri Jagan Mohana Chary scientist- E, allotted me with a long-term project to design a micro-thruster thrust stand in the range of 0.1 to 15 N and a short-term project to model a pressure regulator and perform the experimental analysis.

2.About DRDL

DRDL is responsible for the design and development of state-of-the-art Missile Systems and technologies required for the deterrence and defence of the country. Systems and Technologies developed by DRDL are deployed on underwater, sea, land as well as air-based platforms.

DRDL is working on several technologies required for the Missiles and Strategic Systems including Aerodynamics and Airframe Design, Computational Fluid Dynamics, Solid, Liquid, Ramjet and Scramjet Propulsion, Precision Fabrication, Systems Analysis, as well as the Command-and-Control systems for missile-based weapon systems.

3.Literature Survey

In the first week of my internship, I had gone through the basics of a thrust stands, how a load cell works, the types of thrust stands - inverted, hanging, torsional, the pros-cons of each one of them. Calibrating the three types to achieve the required accuracy and range was not possible due to various performance metric reasons such as orientation issues, tare, precision etc.

For this research I had gone through the following papers to proceed with my work-

A. Recommended Practices in Thrust Measurement
   IEPC-2013-440, Presented at the 33rd International Electric Propulsion Conference, Washington, DC October 6-10, 2013
   James E. Polk*, Anthony Pancotti†, Thomas Haag‡, Scott King§, Mitchell Walker¶, Joseph Blakelyk, John Ziemer**

B. Thrust Stand Design Principles
   R. B. Runyan, J. P. Rynd, Jr., And J. F. Seely
   Sverdrup Technology, Inc., AEDC Group
   Arnold Air Force Base, Tennessee

C. Review of Thrust Measurement Techniques for Micro-thrusters
   DU Bing-xiao, ZHAO Yong, YAO Wen, CHEN Xiao-qian
   College of Aerospace Science and Engineering, National University of Defence Technology, Changsha 410073, China

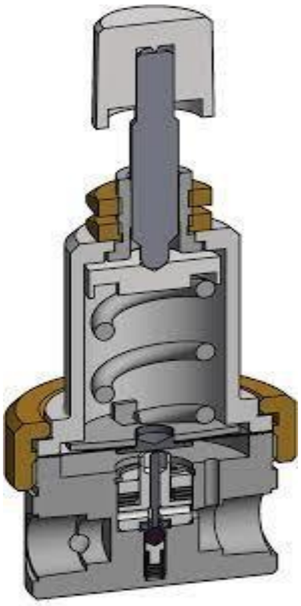
D. Simulation Approach to The Thrust Stand
   Dr Richard A. Kroeger and Dr Paul M. Beckham, Office of the Chief Scientist ARO Inc. Arnold Air Force Station, Tennessee.

After reviewing these papers, I noticed micro-thrusters had been designed by certain modifications to the existing designs by few other organisations and universities. I looked up for those papers and after collecting a few, I reviewed them. So far based on the theoretical information proclaimed I could conclude that electromagnetic method and electrostatic methods have been showcasing good results for our problem statement. A few other methods using weighted pulley and orifice seemed significant, but much data wasn't available on them.

The following two weeks I spent my time learning about pressure regulators, learning AMEsim software to perform my short-term project.

4.Pressure Regulator

A pressure regulator is a valve that controls the pressure of a fluid or gas to a desired value, using negative feedback from the controlled pressure. Regulators are used for gases and liquids and can be an integral device with a pressure setting, a restrictor, and a sensor all in the one body, or consist of a separate pressure sensor, controller, and flow valve.



Types of pressure regulators-

1. Direct operated pressure regulators
2. Pilot operated pressure regulators

Direct-operated regulators

Direct-operated regulators are the simplest form of pressure regulators. They usually operate at lower set pressures, below 0.07 bar (1 psi), and can have greater accuracy. At higher pressures, up to 35 bar (500 psi), they can have 1020% accuracy levels.

Direct-operated regulators are self-contained: they do not require an external sensing line at the output to operate effectively. They consist of a springactuated valve that a diaphragm assembly directly controls. Energy or pressure from the flowing media works to activate the diaphragm. The increasing downstream pressure acts on the diaphragm, which closes the valve plug by compressing the spring. As downstream pressure falls, the spring force becomes greater than the force of the medium, acting on the diaphragm and opening the valve.

Pilot-operated regulators

Pilot-operated regulators provide precise pressure control for conditions associated with gas from cylinders or small storage tanks, such as:

- significant variation in flow rates
- fluctuations in inlet pressure
- decreasing inlet pressure conditions

This type of regulator is generally a one- or two-stage device. A single-stage regulator is ideal for a relatively small reduction in pressure. It is not suitable for systems with large fluctuations in inlet pressure or flow rates.

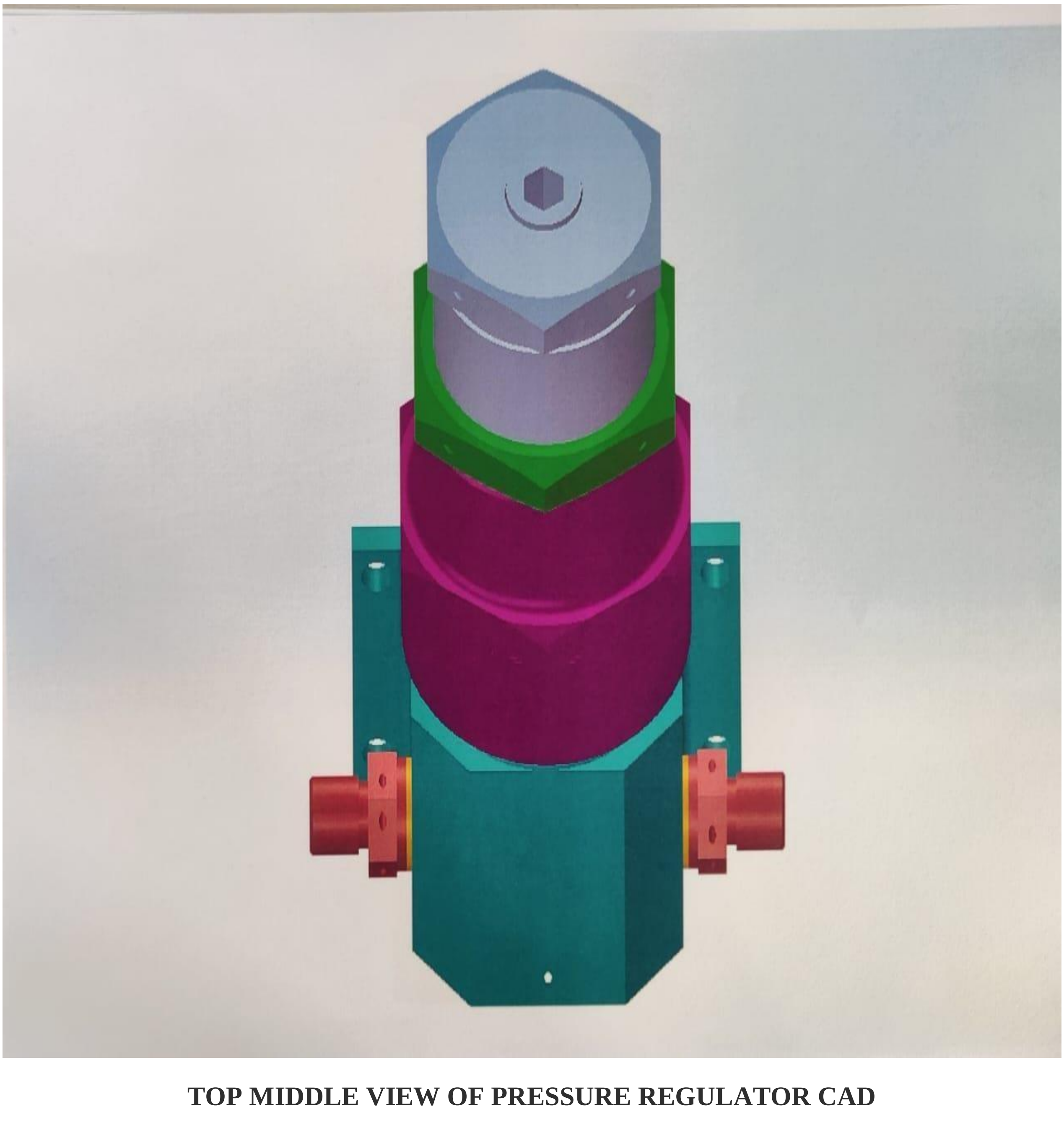
I was directed to work on spring loaded pressure regulators because a following experimental analysis could also be performed to witness a practical experience for what I was going to model in AMEsim software. Working principle of Spring-loaded Pressure Regulators- Components-

- A sensing element such as a diaphragm, piston, or membrane.
- A loading element that applies necessary force to the reducing element, such as a spring, piston actuator, or diaphragm actuator.
- An inlet and an outlet.
- A pressure-reducing element such as a poppet valve.

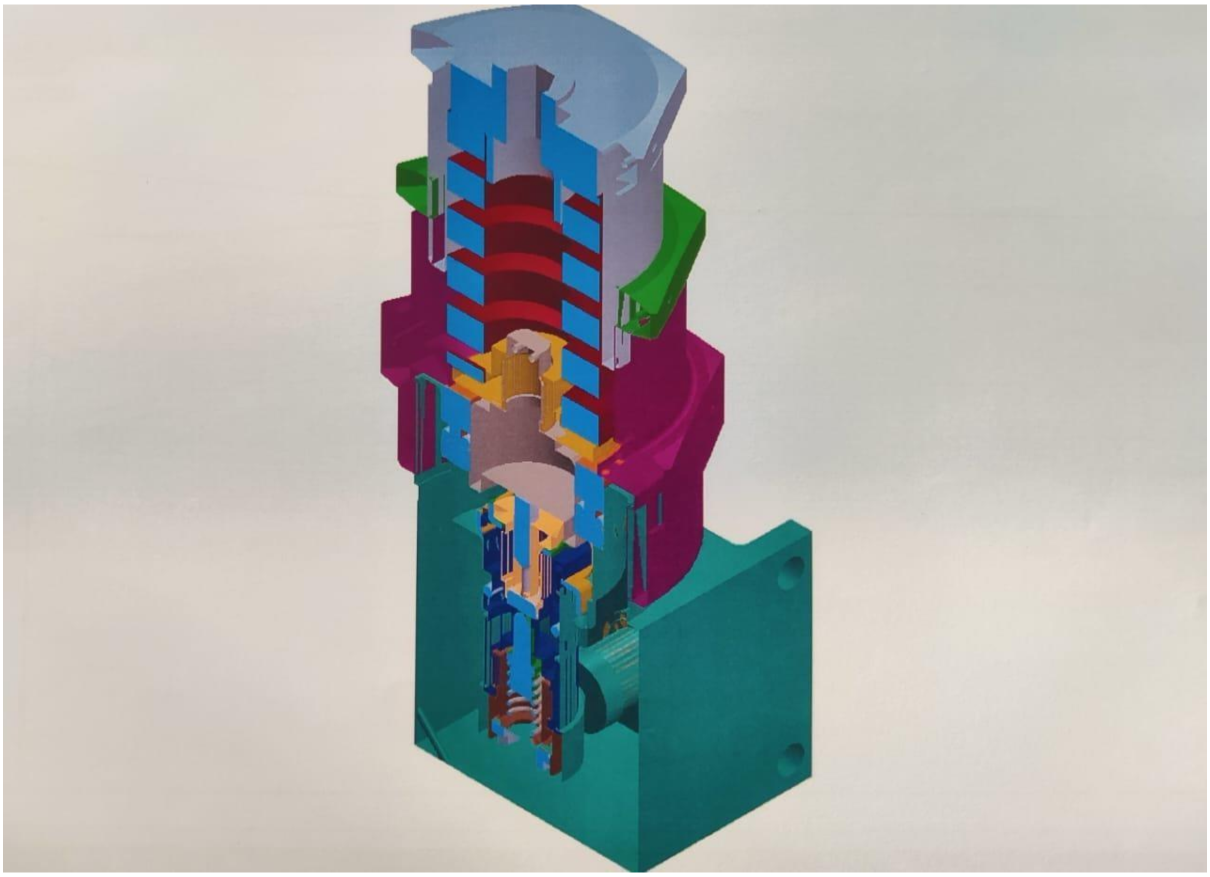
Working principle-

The spring-loaded pressure-reducing valve is commonly used in pneumatic systems. It is often referred to as a pressure regulator. The valve simply uses spring pressure against a diaphragm to open the valve. On the bottom of the diaphragm, the outlet pressure of the valve forces the diaphragm upward to shut the valve. When the outlet pressure drops below the set point of the valve, the spring pressure overcomes the outlet pressure and forces the valve stem downward, opening the valve. As the outlet pressure increases, approaching the desired pressure, the pressure under the diaphragm begins to overcome spring pressure, forcing the valve stem upward and closing the valve. You can adjust the downstream pressure by turning the adjusting screw, which varies the spring pressure against the diaphragm. This spring-loaded valve will fail in the open position if a diaphragm rupture occurs.

A pressure regulator cad was developed in DRDL is modelled in AMEsim software and result was compared with the experimental data.



TOP MIDDLE VIEW OF PRESSURE REGULATOR CAD



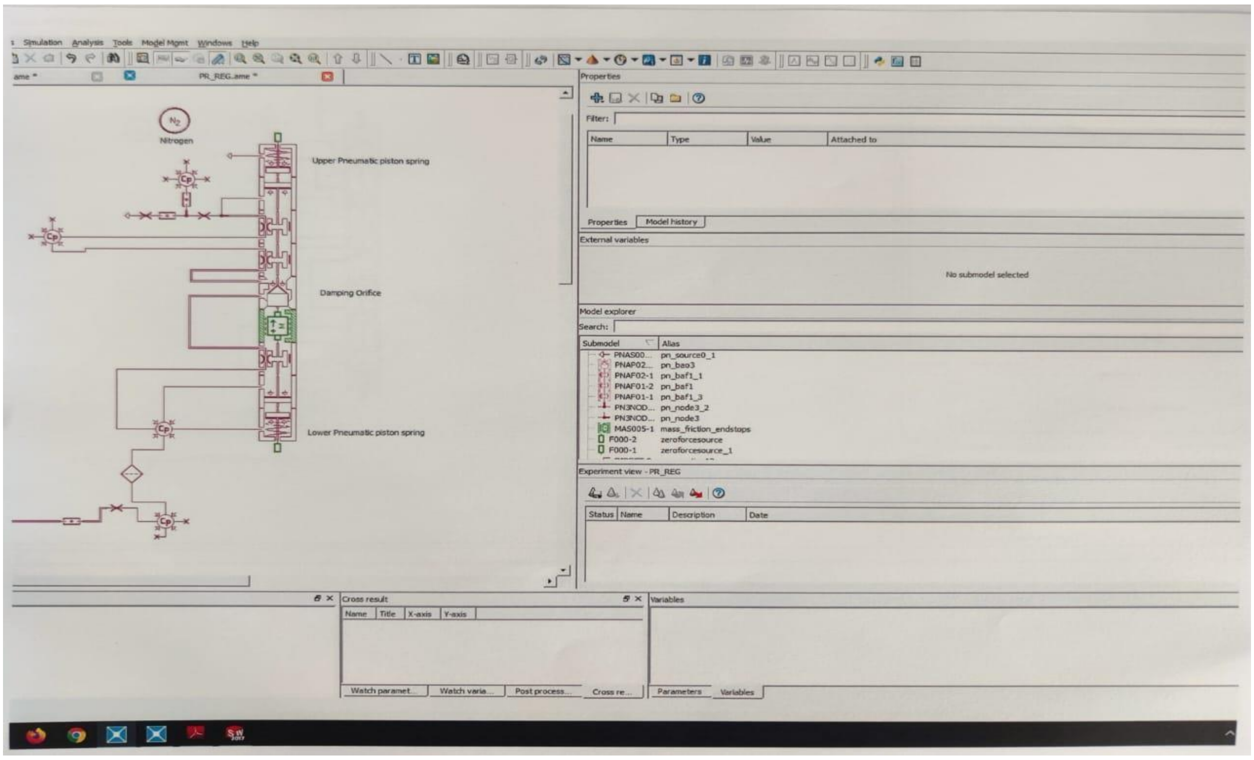
SECTIONAL VIEW OF THE PRESSURE REGULATOR CAD

5.AMEsim Software

The pressure regulator model had to be developed and I started learning the AMEsim software with the help of the demos and libraries available in it. I learnt about various libraries available for each small specific operations, some handy pre-defined models and operate its easy user-friendly interface. I was domain specific to pneumatic, but before I could make such a model, I practised making a normal flow with a few orifices and different ports. Make a model of Joule-Thompson effect. Finally, after learning about different components, I started to develop the model.

Basic process:

1. Sketching
2. Sub modelling
3. Feeding parameters
4. Run simulation
5. Analysis the results.

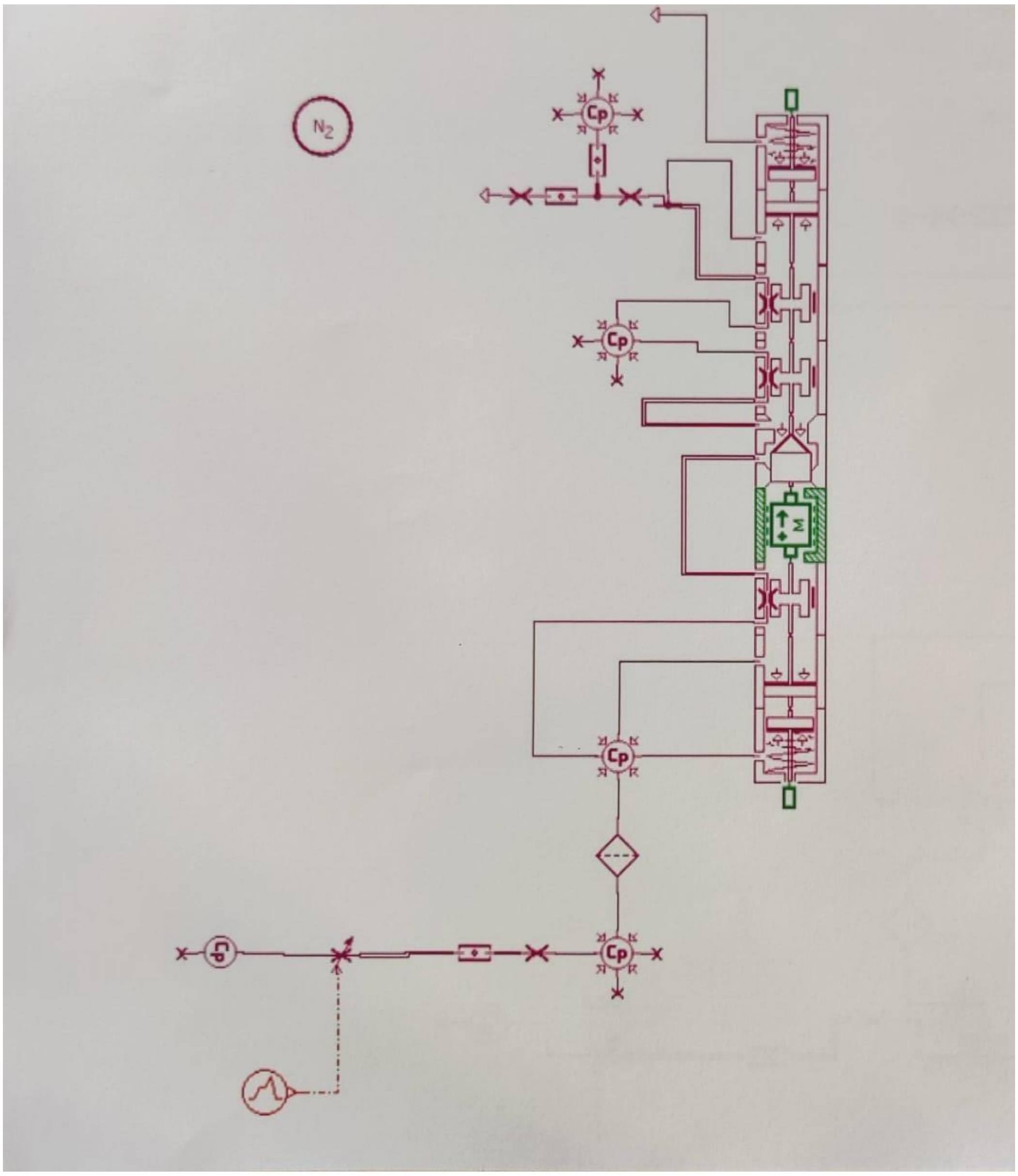


AMEsim Software, Modelling of Pneumatic Pressure Regulator.

6.Model Development

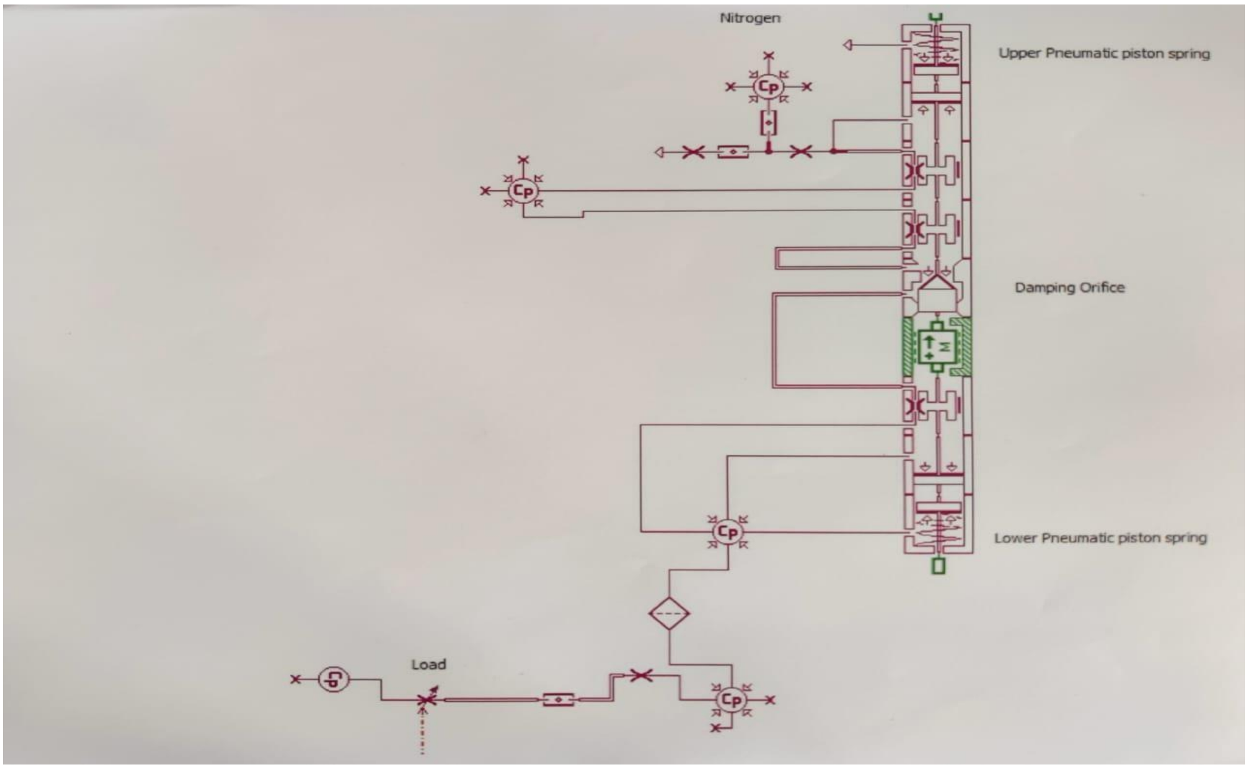
The basic components required-

a. Piston Cylinder system
b. Spring mass system
c. Mass flow system
d. Compression pressure chamber with heat exchanger
e. Valve
f. Orifices
g. Pneumatic ports
h. Gas data – Nitrogen (N2)



SKETCH OF PRESSURE REGULATOR IN AMEsim

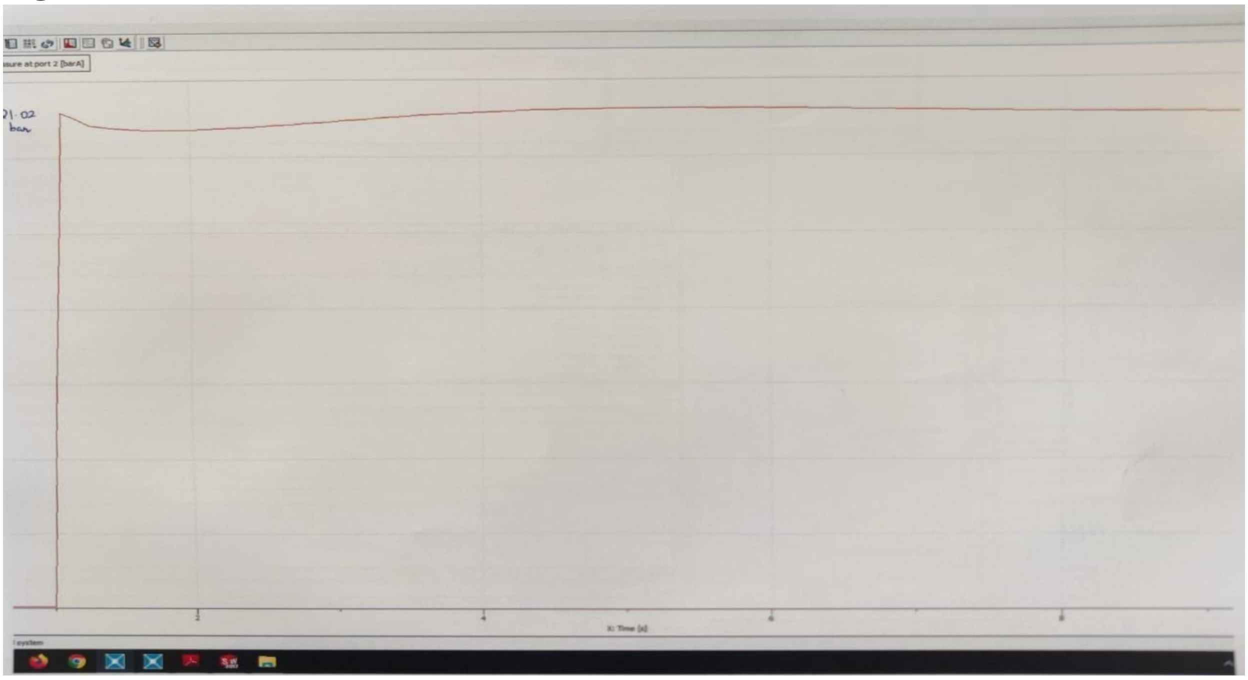
Sketch all the components with appropriate links and ports. Run to check if the whole system is closed. Now, set the parameters to each of the components. I compared the cad model made in solid works software and defined each of the parameters. Finally run the simulation, thereafter, compare and analyse the graphs of pressure vs time and other required details.



LABELLED SKETCH OF PRESSURE REGULATOR

The results obtained

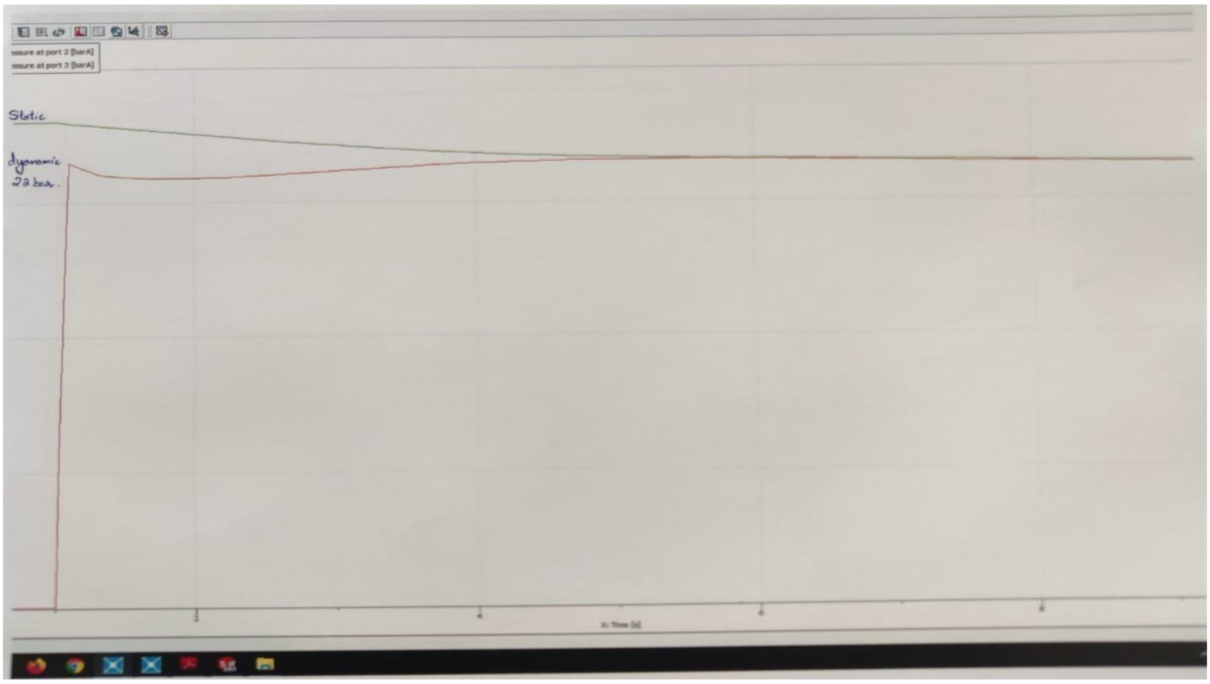
The obtained pressure vs time curve showed increase initially and thereafter regulated itself and settled at 20.48 bar.



PRESSURE VS TIME CURVE AT THE OUTLET ORIFICE

7.Experimental data

The experiment performed on the pressure regulator showed similar results to the one that had been modelled. The orifice diameter used for the experiment was 1.6mm and mass flow rate of 12g/s.



STATIC VS DYNAMIC, PRESSURE VS TIME CURVE

PRESSURE AT INLET (BAR)	PRESSURE AT OUTLET (BAR)
360	21.27
300	21.04
240	20.88
180	20.44
120	20.001
60	19.98

TABLE OF PRESSURE REGULATED, INLET VS OUTLET.

8.Conclusion

It was a wonderful experience performing a couple of projects under the guidance of Shri Jagan Mohana chary Scientist- E. I learnt and witnessed a lot of new things. I was fortunate enough to work with similar minded people and get an opportunity to involve and learn from their work. I would work on my long-term project and keep doing such amazing scientific work. I would also sincerely thank Shri Ambadas Scientist- F, Technology Director DOLP, Shri Murli Krishna SSO-1 for providing me this opportunity.

THANKYOU