SIMPLIFYING MECHANICAL SYSTEMS: PNEUMATIC SEQUENCING VALVE

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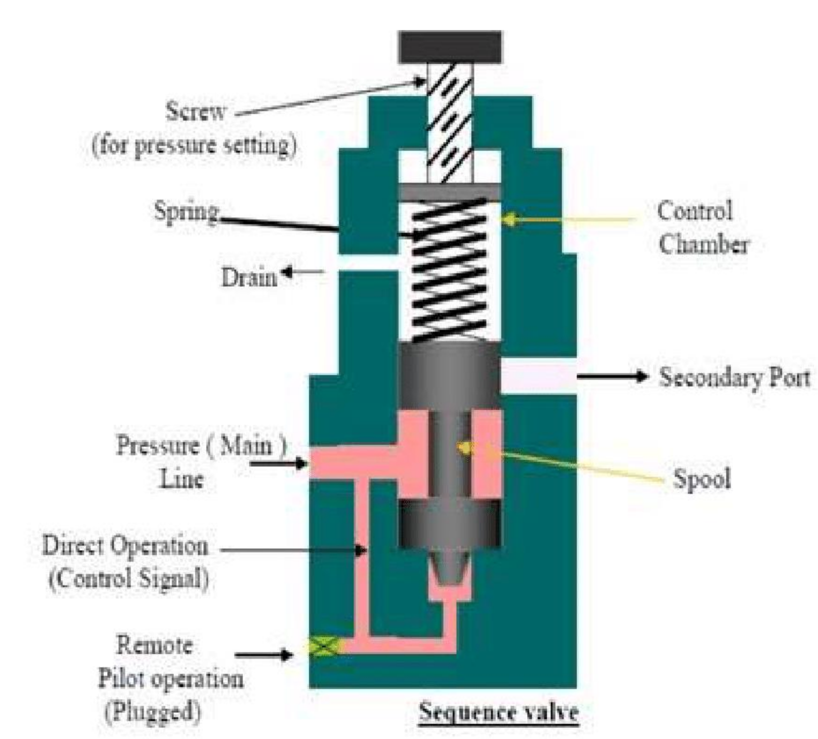
Motivation

- From aerospace to food and beverage to power generation, different types of valves are integral to engineering applications across a variety of industries. The design of valves can be quite complex to precisely and consistently **control the flow** of a fluid (or gas).
- Sequencing valves are one type of valve, used to control the order of operations in systems.
- Sequencing valves are either hydraulically or pneumatically driven and greatly reduce the experimental complexity of different systems by automating the order of operations, reducing error from manual intervention and ensuring consistent timing.
- To reduce the number of valves and controllers and increase storage on the Data Acquisition System (DAQ), I designed and analyzed (FEA) a pneumatic sequencing valve for implementation into a rapid compression machine (RCM) system.
- This system is designed to vacuum the pneumatic chamber of the RCM after compression.

Hydraulics Sequencing Valve



Design Rationale

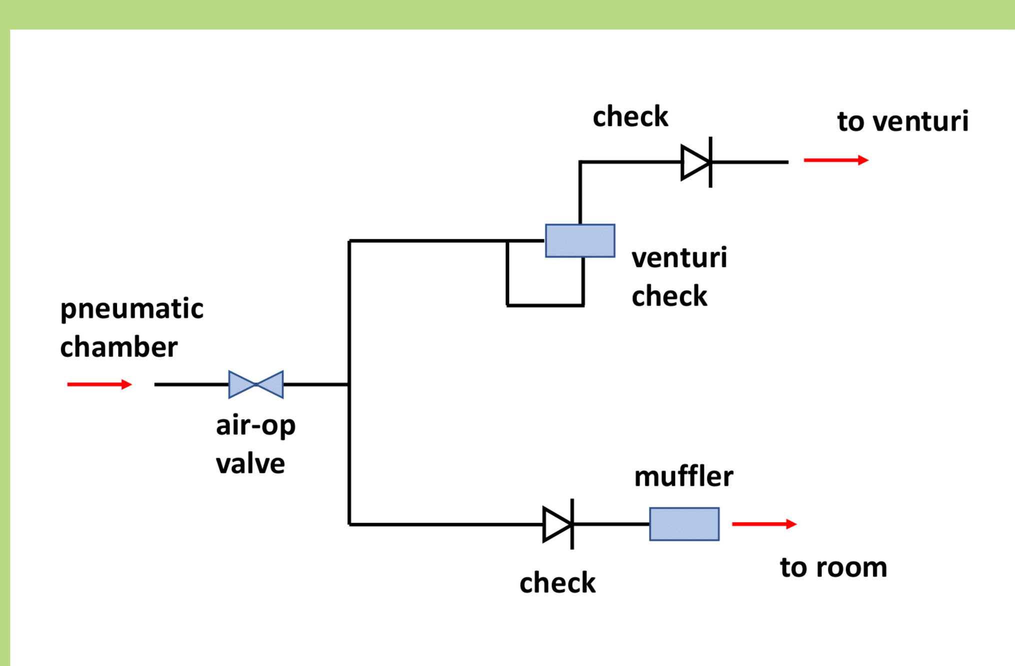


Figure 1: Schematic of current system. Note there are 3 valves among 2 split airlines.

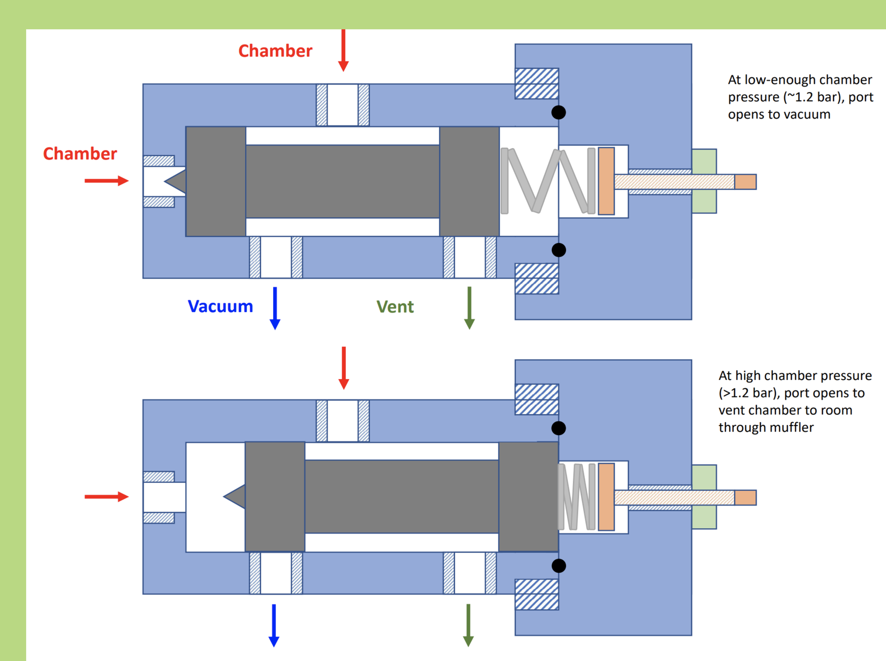


Figure 2: Modified pneumatic sequencing valve schematic.

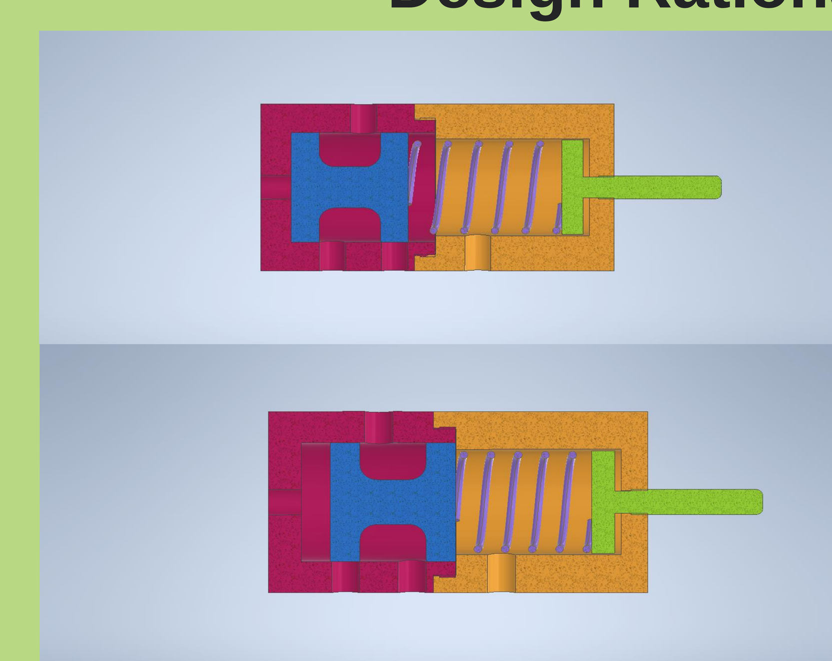
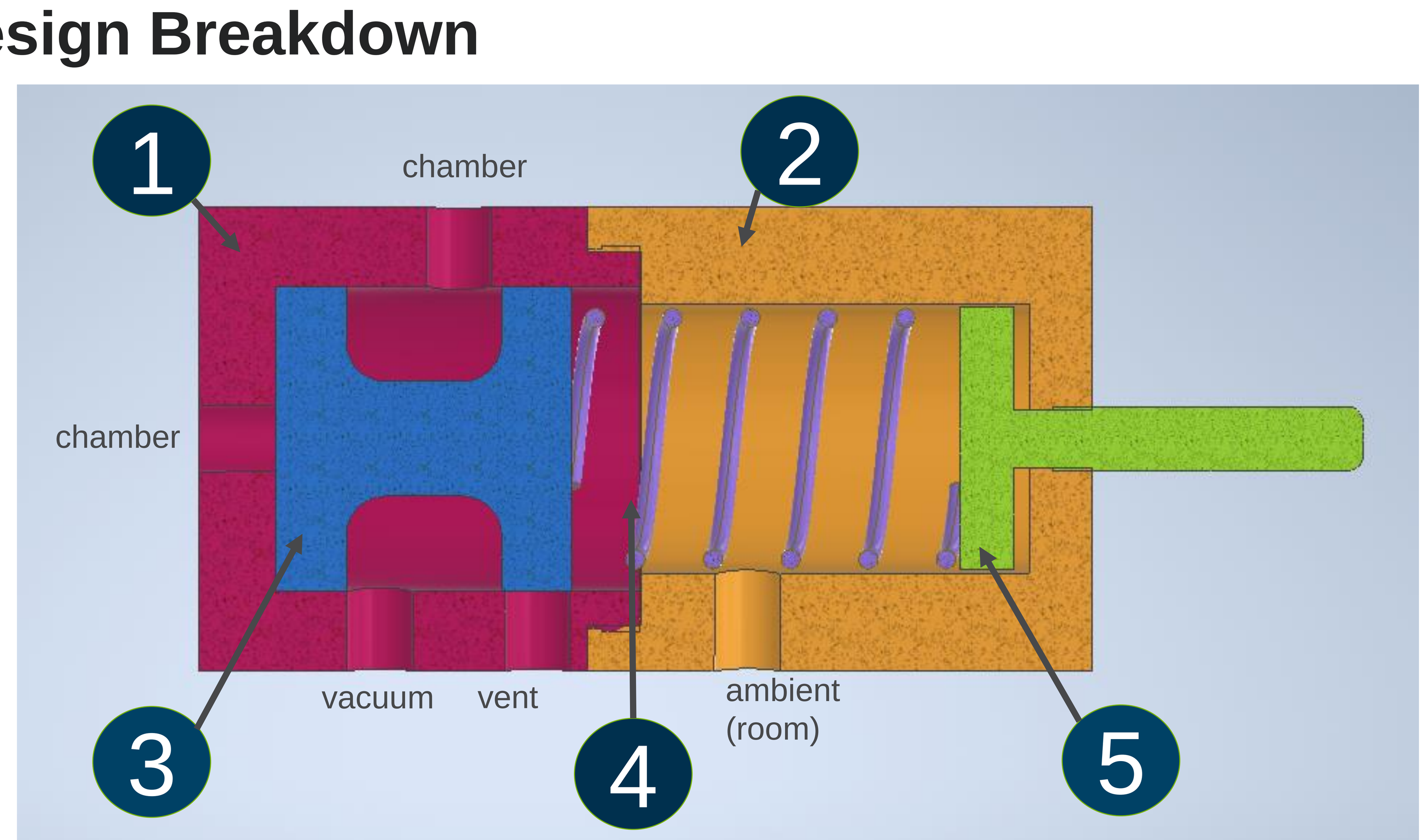


Figure 3: Valve_Configuration_V2. Rated for 450 psi.

This valve design consists of two key components which determined the geometry of this system: the spring and the O-rings. The spring's relevant parameters are its spring rate, *k*, outer-diameter (OD), and free length (L). As for the O-ring, it was important to use a material with a low coefficient of friction, but a high enough Shore A durometer measurement to prevent extrusion.

Design Breakdown

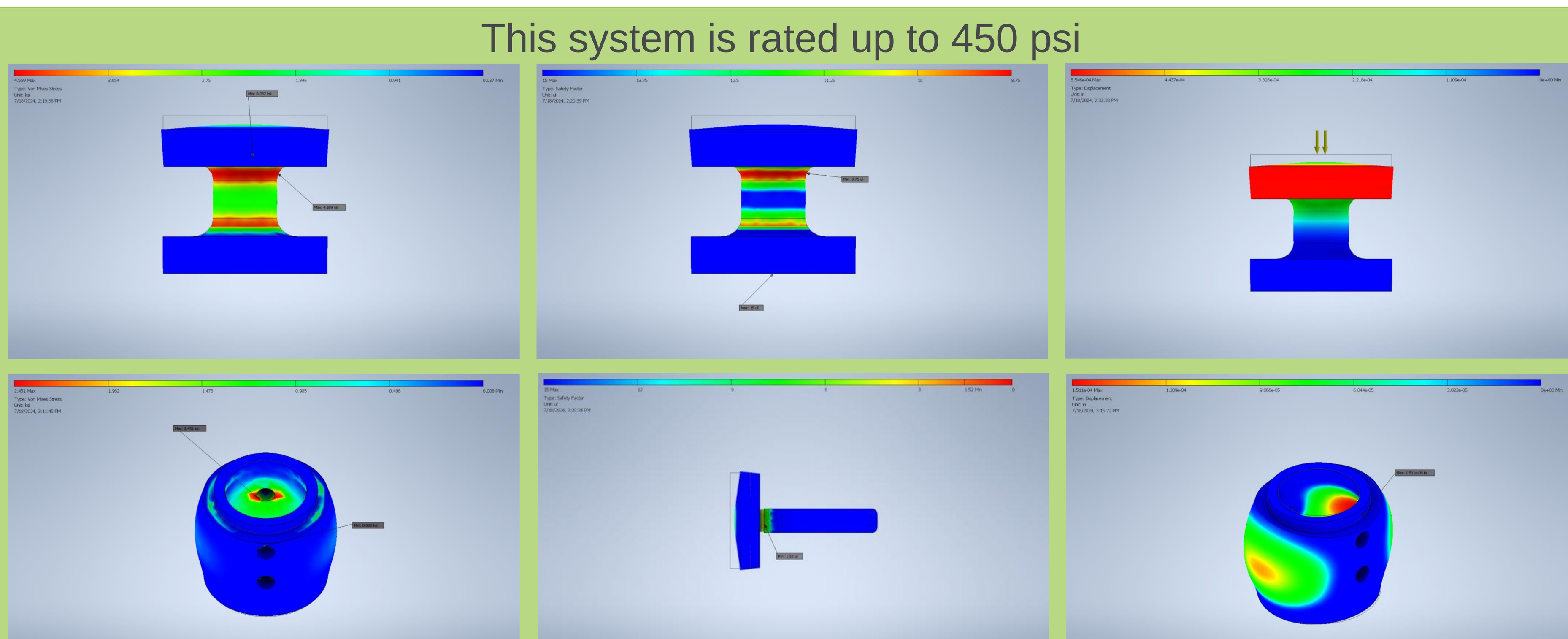


1. Plunger shell: Houses the pneumatically actuated plunger. Tight seal between O-ring and walls. Functions as volume for fluid passage from chamber to vacuum or vent.
2. Spring shell: Houses the spring and tensioning rod for adjusting the compression (spring) rate of the spring. Opens to room pressure to calibrate system against pressure differential.
3. Plunger: Actuates linearly, allowing for multi-directional flow. Cannot displace further than the wall of the plunger shell, so flow is always directed to an outlet.
4. Spring: The spring rate is measured in pounds-force to compress the spring 1". This stainless-steel spring has a rate of 18.85 lbs/in, an OD of 1.687", and a length of 2.5".
5. Tensioner: Externally threaded to adjust the spring tension as needed. **Additionally, there is a bolt on the outside of the spring shell to prevent the tensioner from shifting.**

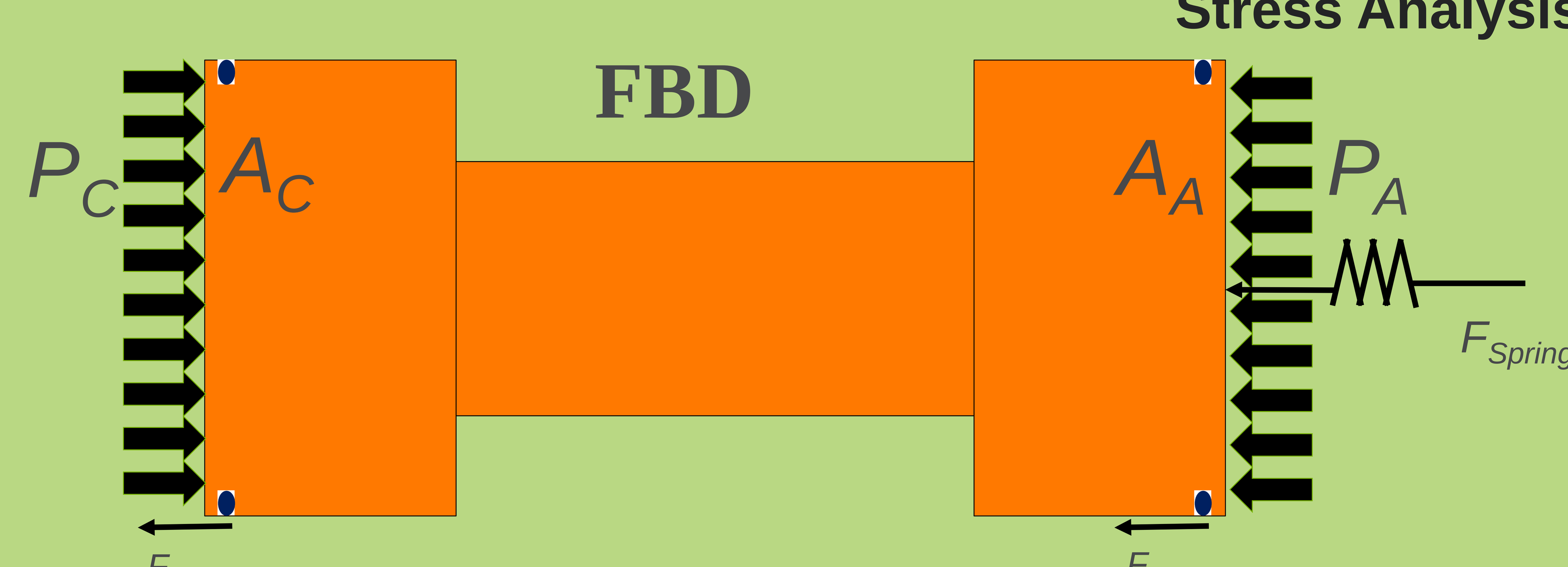
*** O-ring: Two EPDM O-rings are crucial to this system to ensure a gas-tight seal between the piston and the cylinder walls, thus maintaining the pressure differential.

Safety Note: A check valve must be installed in series with the vent outlet to prevent backflow and avoid system over-pressurization.

This system is rated up to 450 psi



Stress Analysis



$$\Sigma F_X = 0: P_C A_C - P_A A_A - F_{Spring} - 2 * F_{O\text{-}ring} = 0$$

$F_{spring} = kx$, where k is the spring rate and x is its displacement

$F_{O\text{-}ring} = F_C + F_H$, where F_C is the total friction due to seal compression and F_H is due to hydraulic pressure on the seal: can be determined from Parker O-ring manual

References

1. *Parker Hannifin O-ring Handbook & Material Offering Guide*
2. *MW Component: About Compression Springs*

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