Custom Poppet Valve PDR

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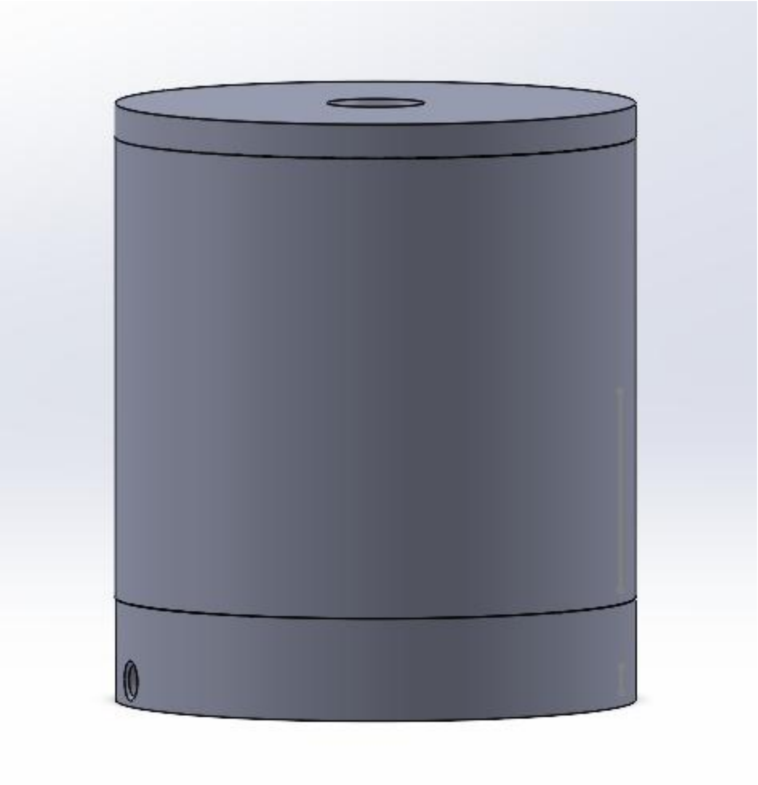
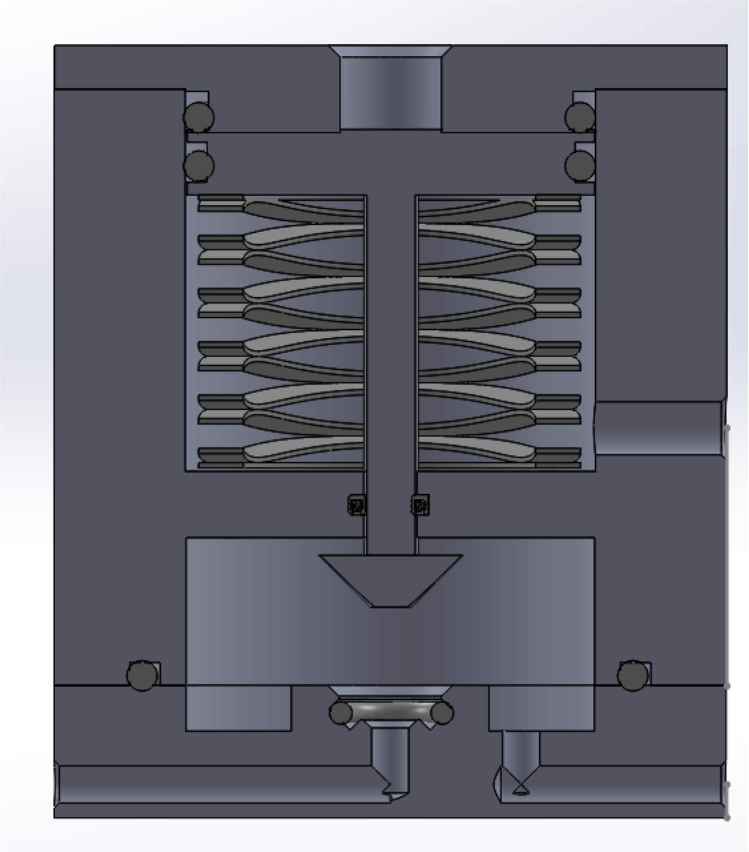
Outline

- Requirements
- Trade Studies
- Design & CAD
- Analysis
- Interface
- Schedule
- Risks
- BOM





Requirements

- Requirements
  - 1.1 All custom valves must be analyzed at ambient conditions and be shown to have remaining margin using a Factor of Safety (FOS) of 2 to yield and 2.5 to ultimate.
  - 1.2 Must use pneumatics pressure of 200 psig with opening FoS of at least 2
  - 1.3 6000 psig MEOP
  - 1.4 CdA of 1/4” tube, approx. 0.029 in^2, similar to CdA of CAV
  - 1.5 Able to function at 32 degrees Fahrenheit (mitigate Joule Thompson effect)
  - 1.6 Only one way flow needed
  - 1.7 Normally Open valve

- Assumptions
  - **Pneumatics Pressure: 200 psig (Req. 1.3.5)**

Trade Study

Method of Sealing is a Challenge for this Valve!

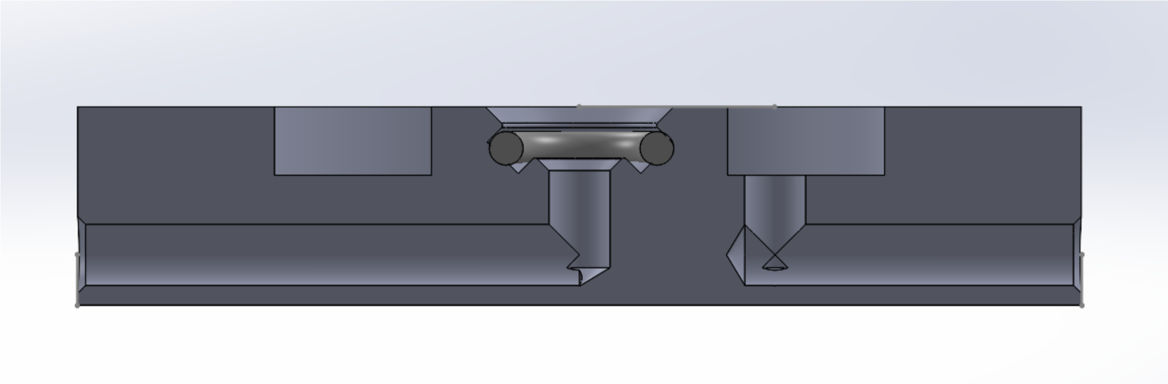
- **Face seal vs using force to seal poppet in valve seat**
  - Force balance for high pressure working fluid scales horribly with low pressure pneumatics if relying on force on poppet alone to seal
  - General rule of thumb says at least 3x working pressure must be exerted on poppet to seal
  - What poppet material won't permanently deform at 18 ksi?
  - After doing force balance, results in piston diameter of ~4 in for 3/8 in flow path (bc of such low actuation pressure)
- **Using face seal to seal:**
  - Force balance is much friendlier
  - Piston diameter of ~1 in now
  - Much smaller force needed on poppet to seal

2 Design Options

2 possible designs: will machine/test in parallel

- **Design 1: 45° rotated face seal**
  - Just a face seal rotated 45° with 45° poppet
  - More difficult to machine
  - Made of aluminum to give highest chance of machining success
  - Waiting for protolabs quote to see if bottom piece can be

    done out of house
- **Design 2: Normal face seal with retaining lip**
  - Easier geometry to machine, made of stainless
  - Harder tolerances on retaining lip
  - Middle and upper piece is same as design 1

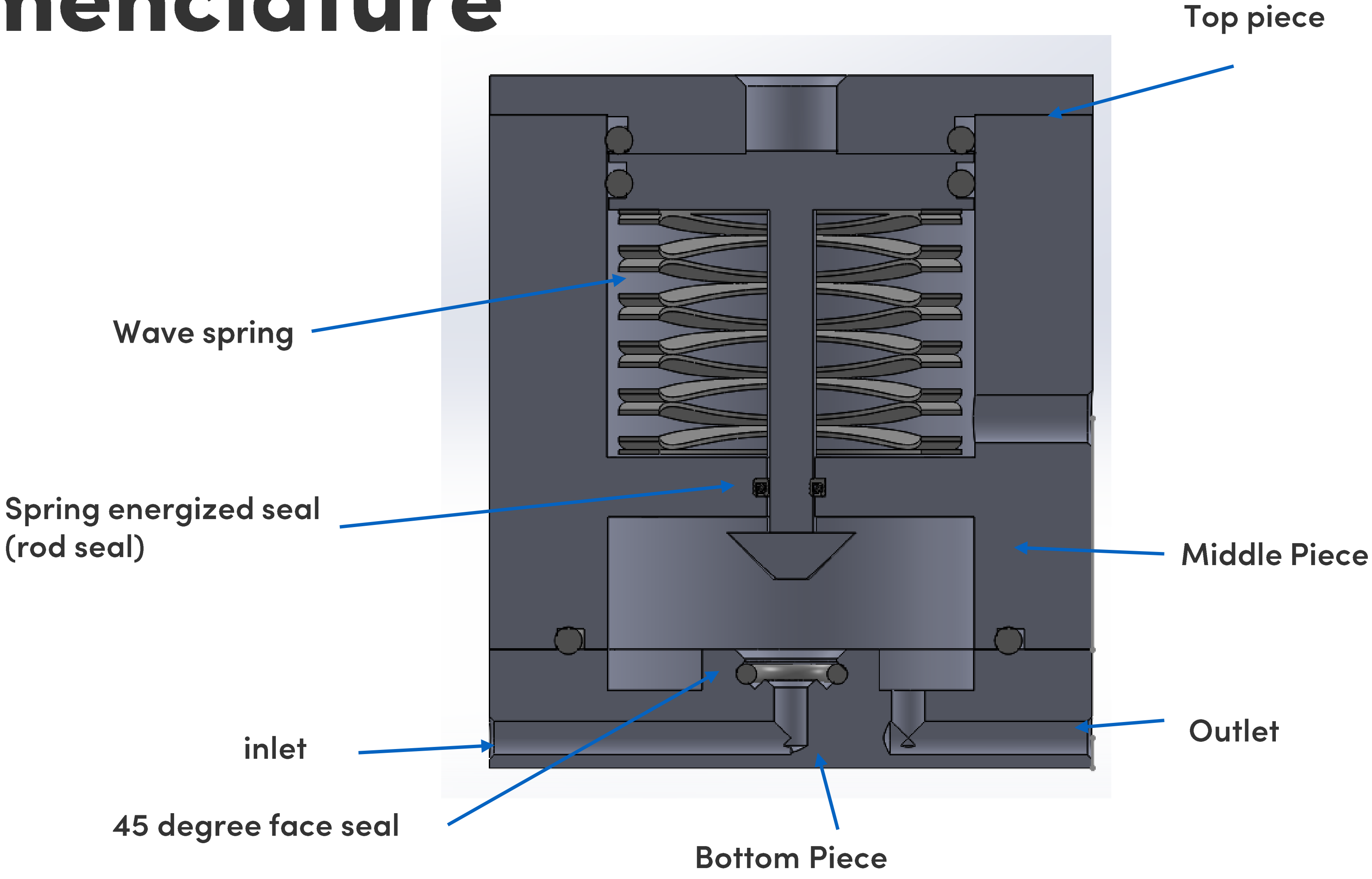


**imagine a normal face seal

Why make both?

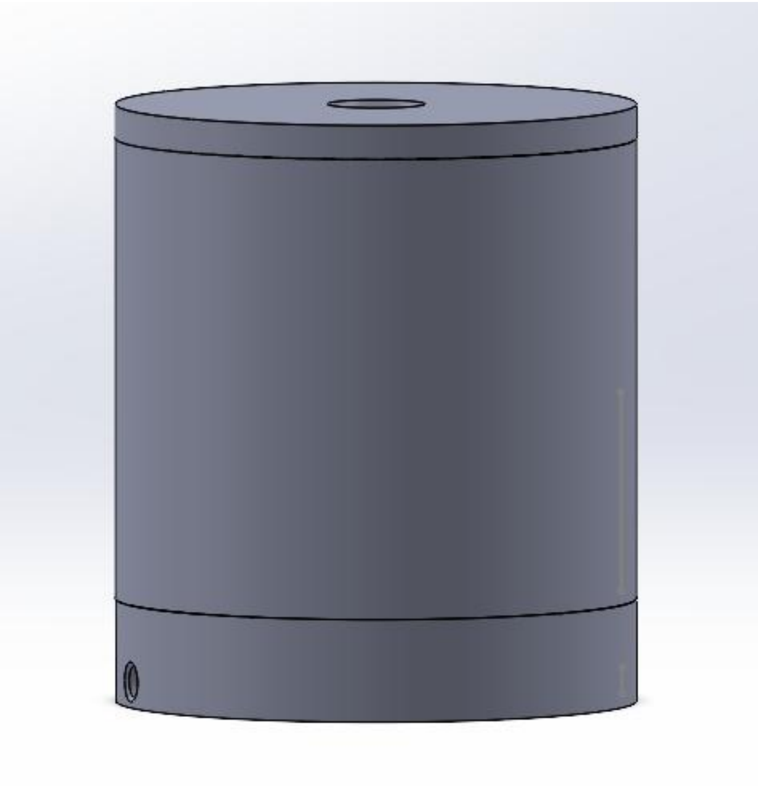
- Main difference is how each design seals
  - Higher confidence in sealing of design 1
  - Poor machining could worsen sealing ability of design 1 so design 2 could be better option
- Low cost high reward to make and test both designs

Nomenclature



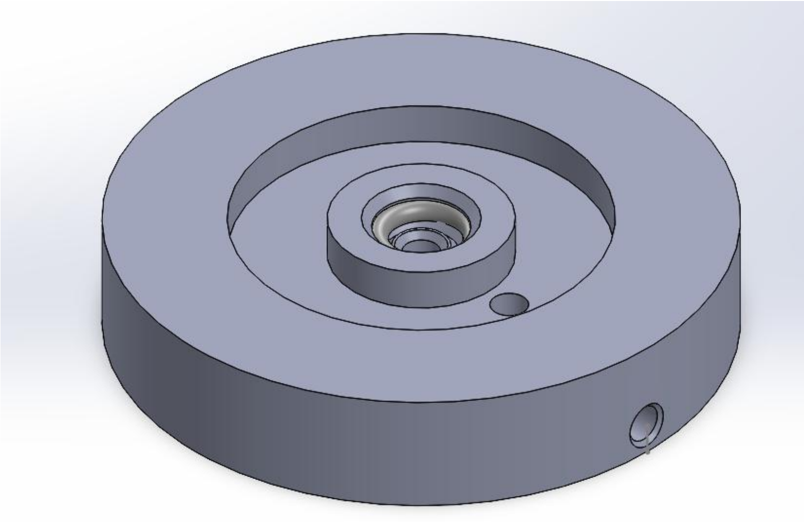
Design
Valve Specifications

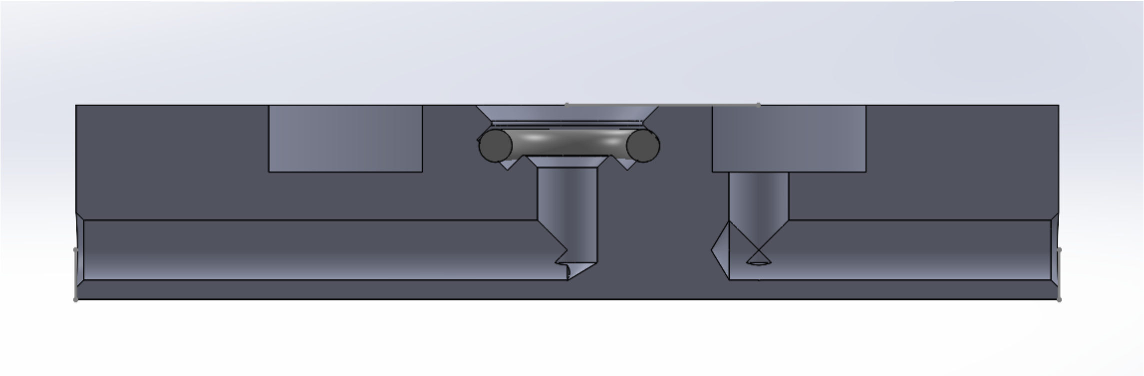
- Bounding Dimensions:
  - 3.08” diameter, 3.7” tall
- Mass: 1.465 lbm
- Smallest CdA value of 0.00015 m^3, can be increased by changing inlet/outlet line sizing
- Hoop stress used throughout as minimum wall thickness



Bottom Piece of Valve “Option 1”

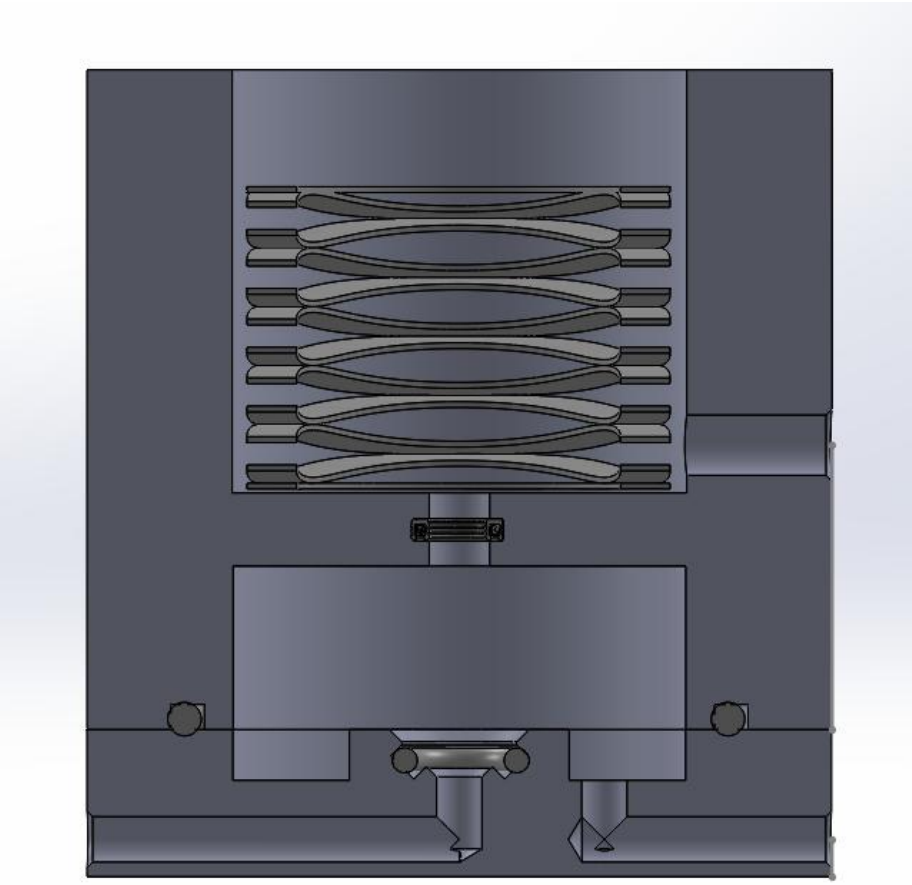
- 45 degree face seal, hard to machine





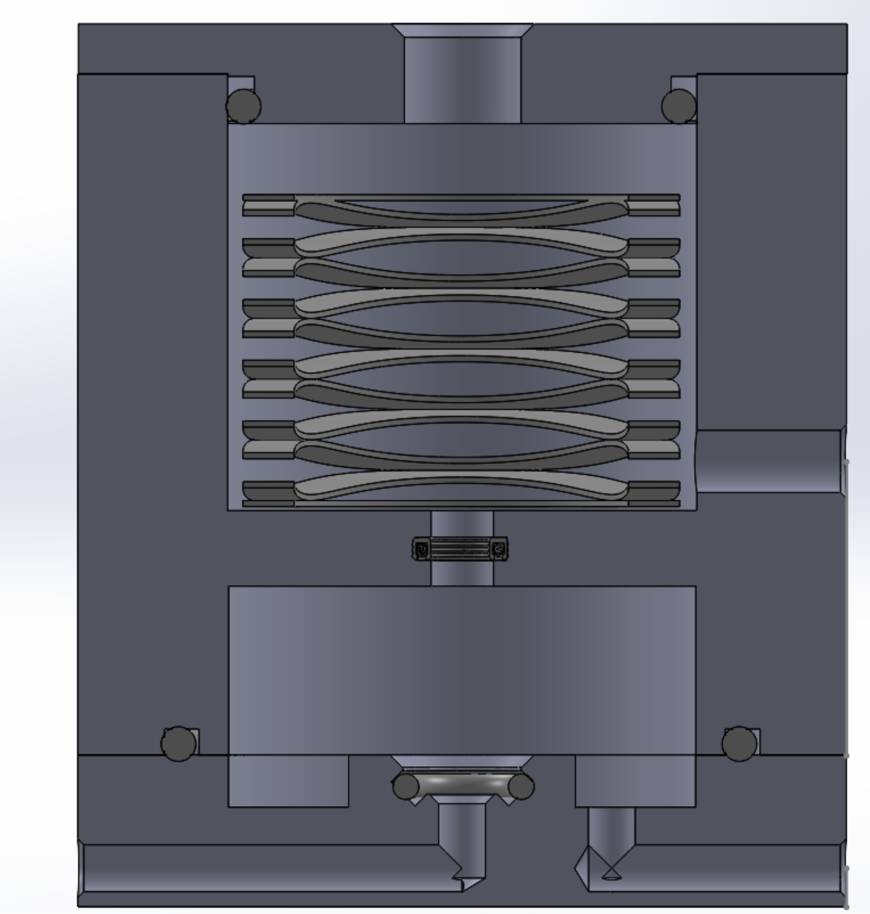
Middle Piece, works for both options

- PTFE spacers prevent galvanic corrosion
- Valve components made of AL
  - Chosen because lightweight and ease of machinability
  - Middle piece has a PTFE spring energized rod seal
- Weep hole in spring chamber
- Face seal to seal between two
- Bolts will exist
- Wave spring is extra tall to provide “stroke length” of 0.437 in, greatly increasing valve CdA
- CdA = 0.00015m^2



Top piece of valve

- Top piece seals with face seal
- Top fitting is orb into pneumatics cavity

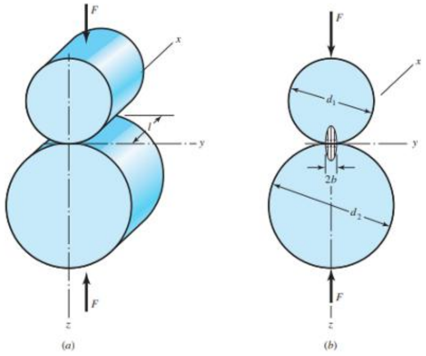


Contact Sealing

- Valve is NO due to spring force
- Hertzian contact between oring and poppet
- Back calculate force needed to seal based on expected oring squeeze aka strain
- For example for W = 0.103, need F = 18.23 to seal

46	F (min overall force needed to cause seal to seal) (lbf)**from matlab	18.23
47	Big piston seal friction force (ESTIMATE)	10
48	Little piston seal friction force (ESTIMATE)	10
49	Spring force(when all the way compressed)	90
50	Pneumatics Force (lbf)	115.522
51	FoS	1.4
52	~~Force exerted by pneumatics (double F) NA~~	~~161.7308~~
53	Area of plunger(in^2)	2.68655814
54	Plunger AKA Piston diameter (in)	1.849495083
55		
56	E1 of viton oring (psi)	1640
57	E2 of stainless steel poppet in psi = 200 Gpa	29010000
58	v1 poissons ratio of	0.48
59	v2 poissons ratio of stainless steel	0.27
60		
61	Find stress due to compressed O-ring:	
62	E viton	1640
63	strain of o-ring	0.3
64	stress of oring (psi)	492
65	spring FoS I would need for it not to fail due to over compression	1.283577778

Figure 3–39
(*a*) Two right circular cylinders held in contact by forces *F* uniformly distributed along cylinder length *l*. (*b*) Contact stress has an elliptical distribution across the contact zone of width 2*b*.



contact is a narrow rectangle of width $2b$ and length l, and the pressure distribution is elliptical. The half-width b is given by the equation

$$b = \sqrt{\frac{2F}{\pi l} \frac{(1-\nu_1^2)/E_1 + (1-\nu_2^2)/E_2}{1/d_1 + 1/d_2}} \qquad (3\text{–}73)$$

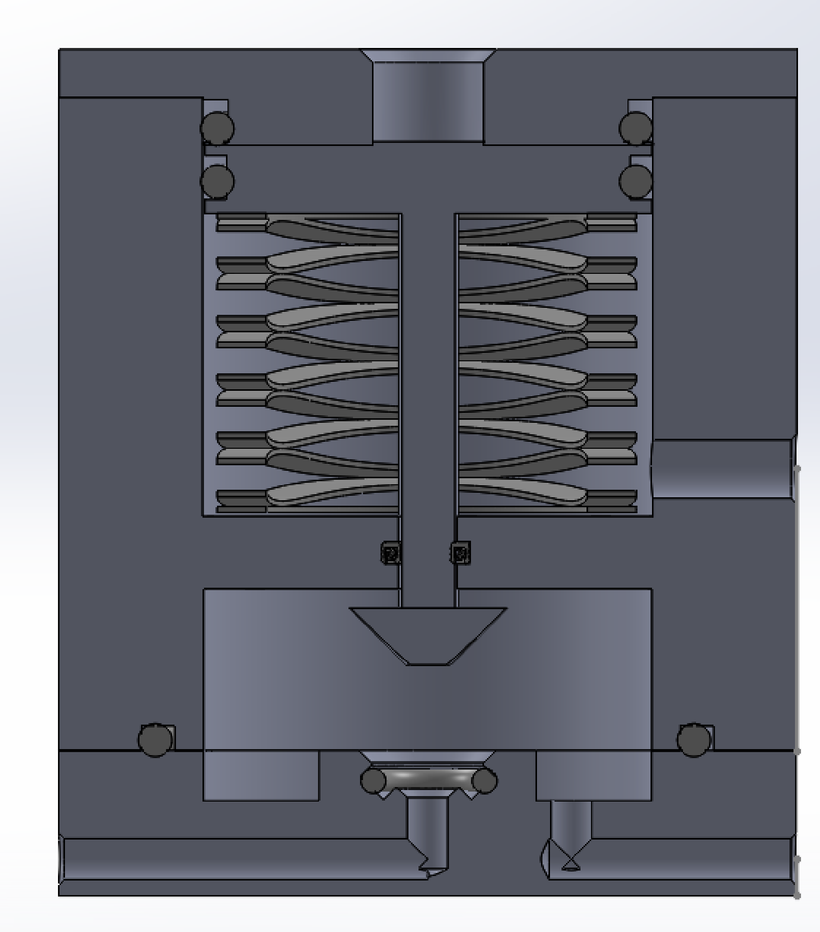
The maximum pressure is

$$p_{\max} = \frac{2F}{\pi b l} \qquad (3\text{–}74)$$

Opening Actuation

- Elimination of pressure to pneumatics cavity results in spring force returning valve to NO state
- Spring force = 90 lbs
- Opening FoS of about 4.5, depending on piston and rod seal friction

ROD GROOVE FRICTION CALCS	
fc: friction due to oring compression obtained from fig 5-9	4
Lr: length of seal rubbing surface in inches for rod groove applications	0.78
fh: friction due to fluid pressure obtained from figure 5-10 **off the chart	80
Ar: projected area of seal for rod groove applications	0.05
Fc: total friction due to seal compression, =fc*Lr	3.12
Fh: total friction due to hydraulic pressure on the seal, = fh*Ar	4
F= Fc + Fh	7.12
ROD GROOVE SEAL CALCS (needs one parbak ring)	2-010
B: rod OD GUESS	0.249 +0, -0.002
D: rod bore diameter (space between wall and rod)	0.251 +0.001, -0.00
A1: rod gland groove diameter	0.359, +0.002, -0.00
W	0.07 +/- 0.003
G without parbak ring	0.093 +0.005, -0
G with parbak ring	0.138 to 0.143
L from 5-2-a	0.055 to 0.057
squeeze (W-L)/W*100 should be 15-25	?
R	0.005 to 0.015



Closing Actuation

- Pressurant vents to ambient.
- Valve closes due to pneumatics force.
  - Assumed pressurant vacates valve instantaneously
  - Pneumatics force must overcome opposing seal friction
  - Valve remains closed as long as pressurized
- Closing FoS of 1.4, will be higher if pressure exceeds 50 psi

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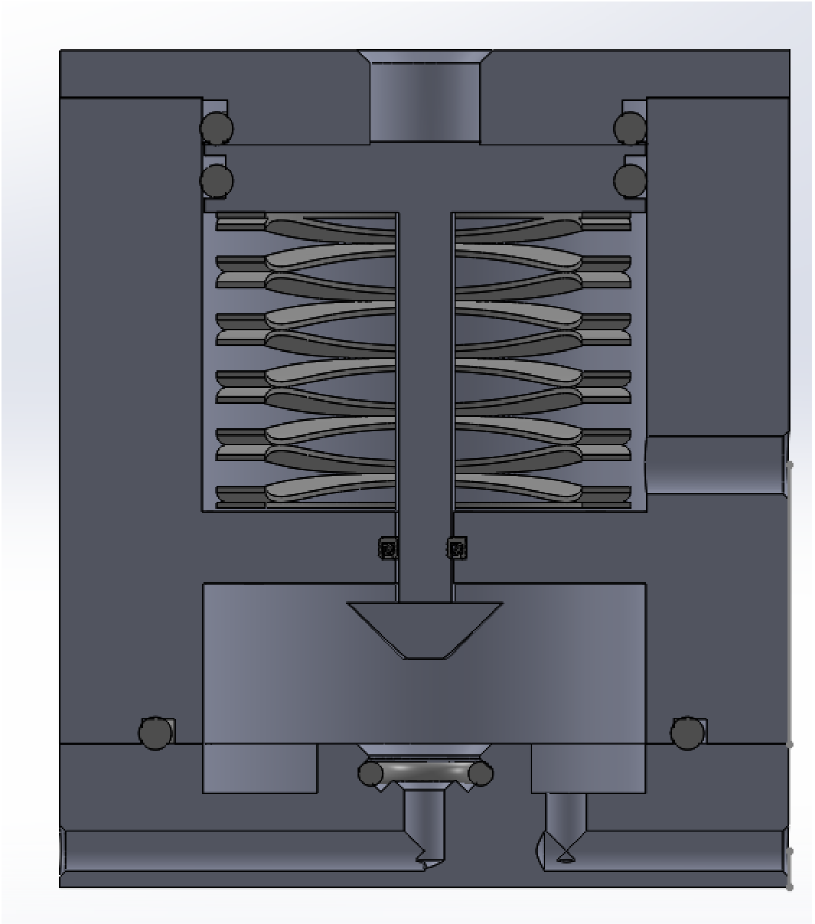
GN2 pressurant ~100 psi



Risks

- Seal extrusion
  - Unsure if will be a problem. Higher pressures make me worried
- Face seal not sealing
  - Must be tested
  - 45 degree face seal geometry is different

Manufacturing

- If can't machine bottom piece option 1 in machine shop, will try protolabs and then try option 2

Bill of Materials

- Aluminum
- Seal list still pending-looking for better spring energized seals than from mcmaster

Questions?