Basic Pressure Regulation Theory R101

Chip Trimble

Energy Nexus | Annual Technical Conference

Fuelling the Future

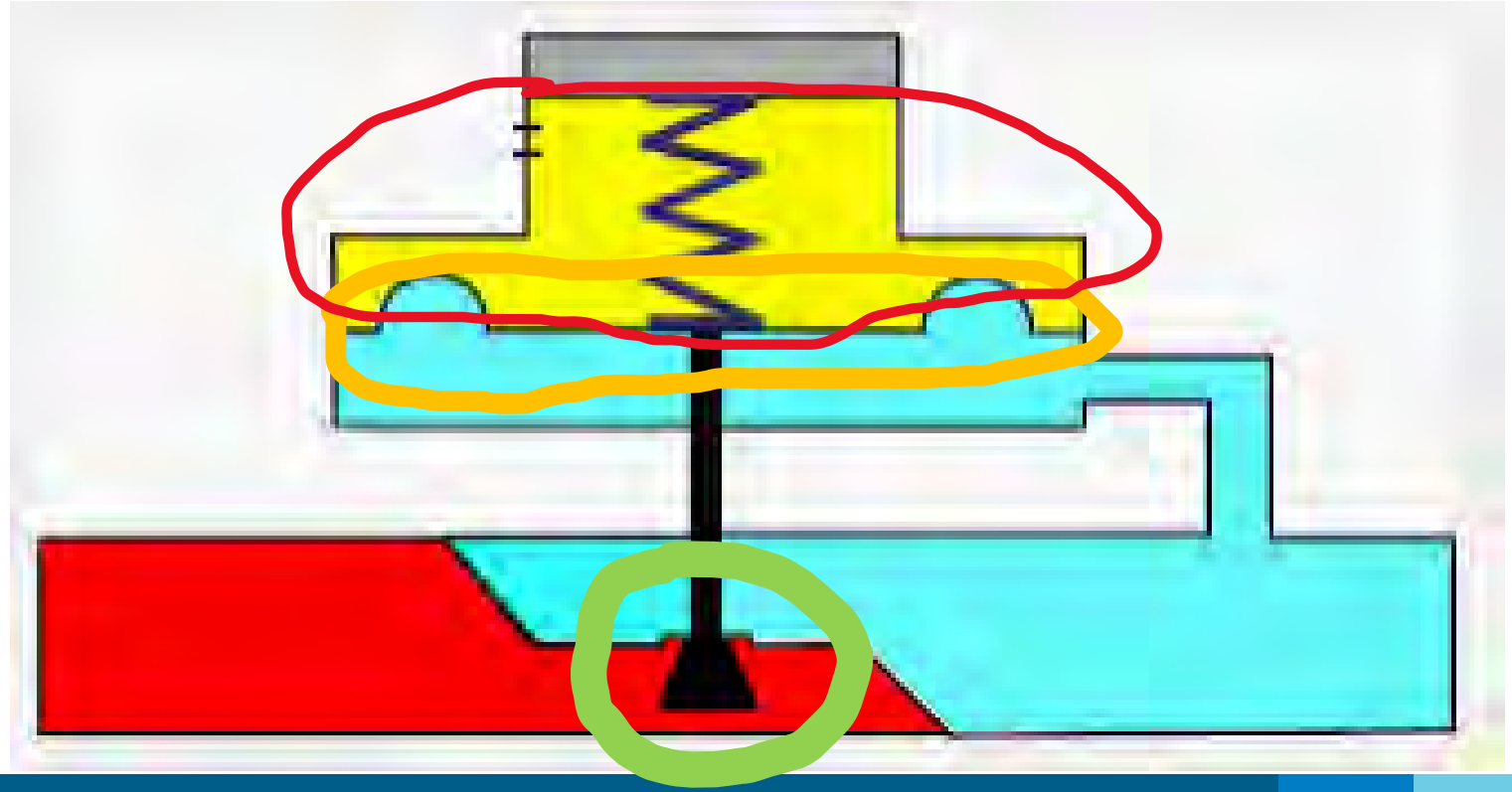
Agenda

- What is a Regulator
- Forces Acting on a Direct Operation Regulator
- What is Droop?
- What is Boost?
- Applications for Direct Op Reg
- CSA 6.18

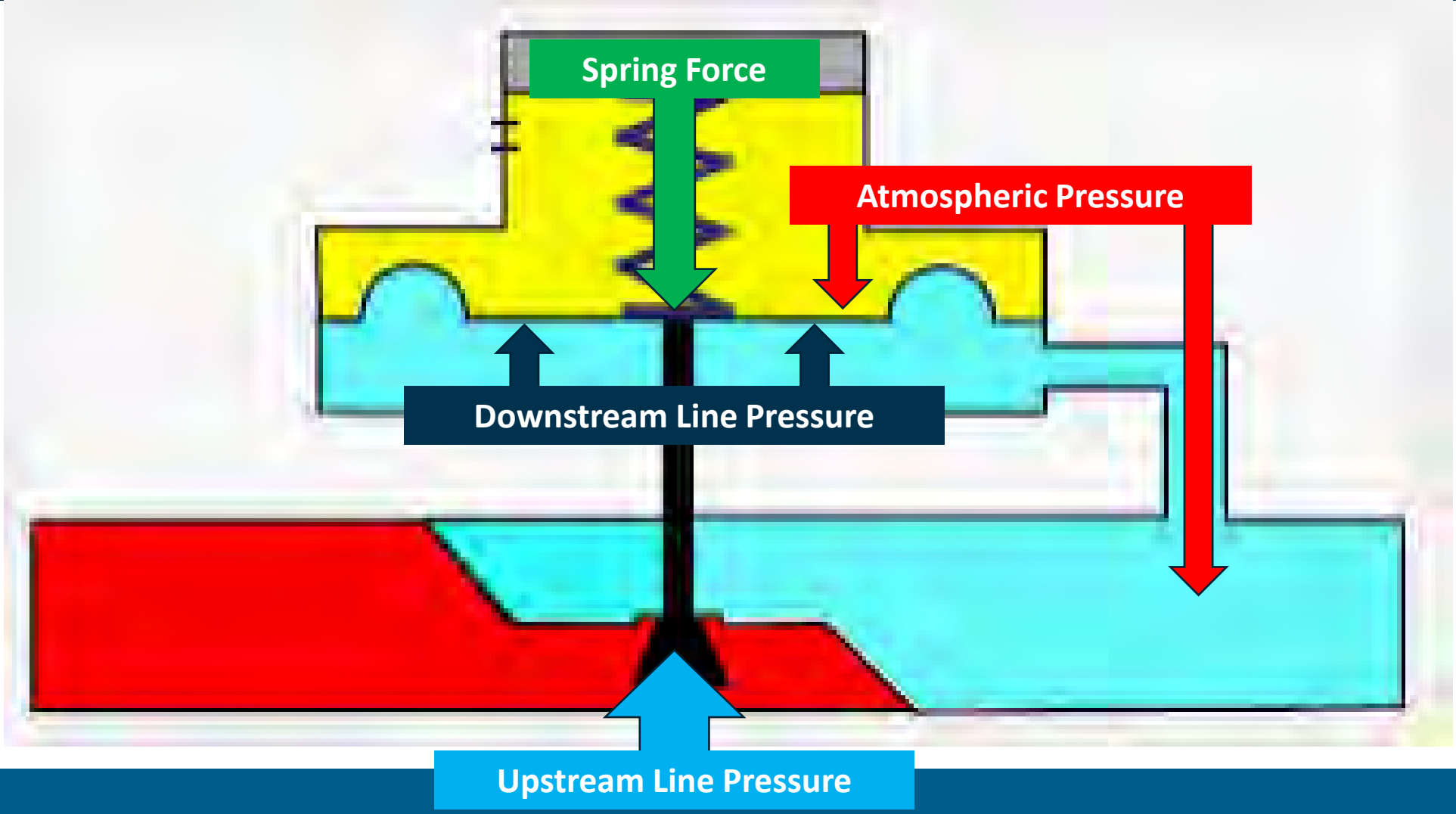
3 Basic Components

Pressure Regulator Definition- is a valve, actuator, and controller combination that provides flow to a downstream load while keeping downstream pressure with in acceptable tolerances

- Loading Element
- Measuring Element
- Restricting Element



Acting Forces



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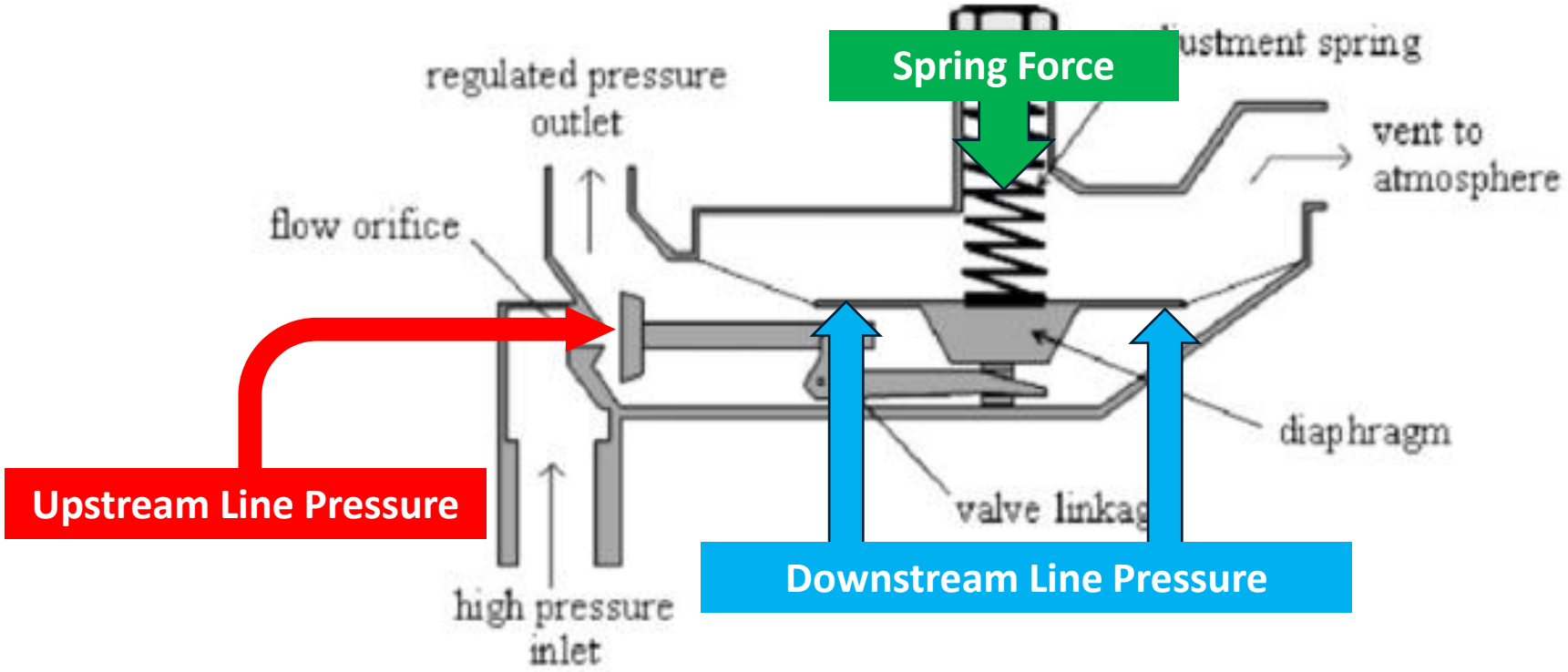


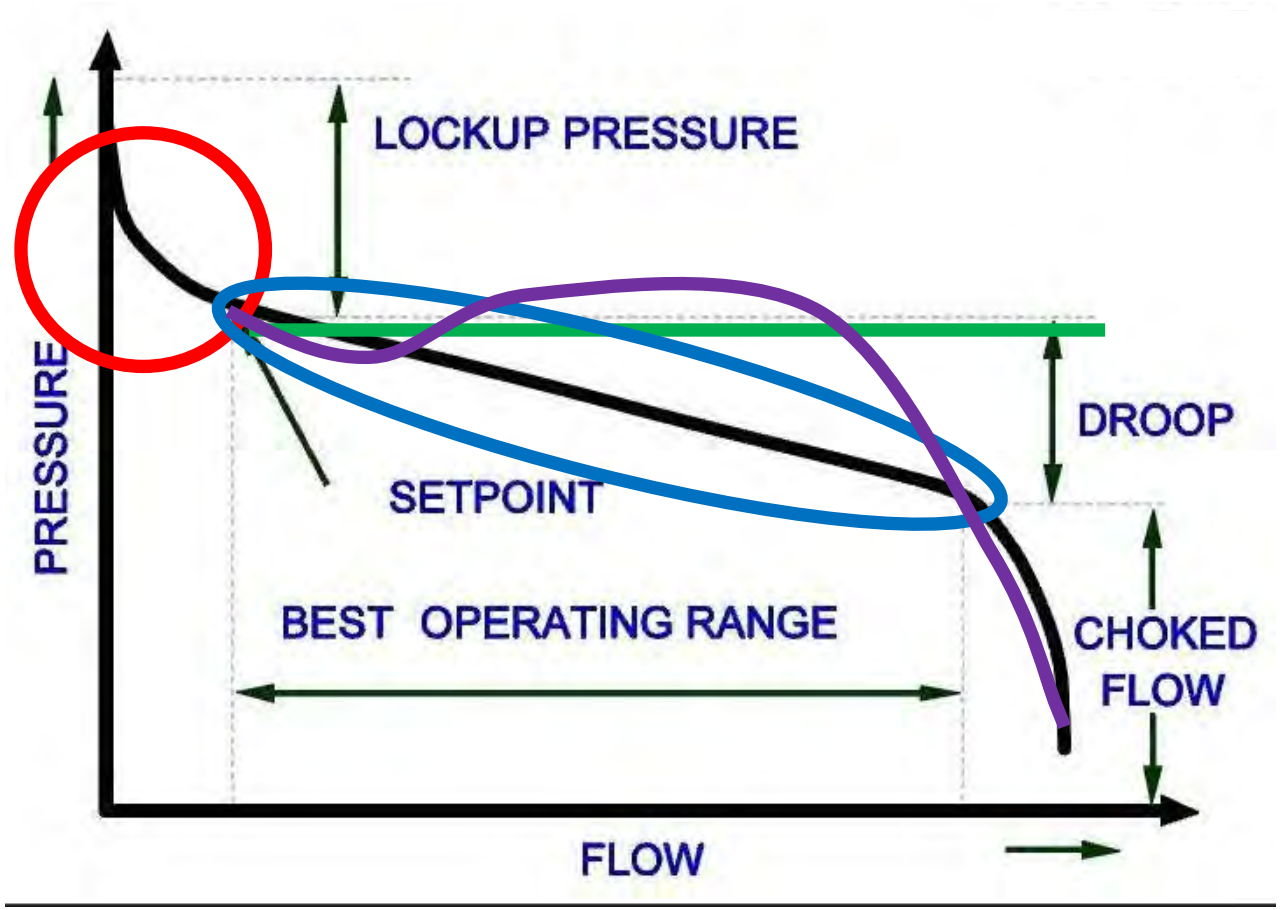
Applied Forces Calculation
Opening Forces = Closing Forces

- Opening Forces
  - $F_i + F_s = F_o$
    - F_i = Inlet Pressure force
    - F_s = Spring force
    - F_o = Outlet pressure force
      - $F_s = K_s * x$
        - K_s = Spring constant (lb/in)
        - X = Spring compression (in)
      - $F_i = P_i * A_o$
        - Pi = inlet pressure (psig)
        - A_o = orifice area (in^2)

- Closing Forces
  - $F_c = P_o * A_d$
    - F_c = Closing force
    - P_o = Outlet Pressure (psig)
    - A_d = Effective diaphragm area

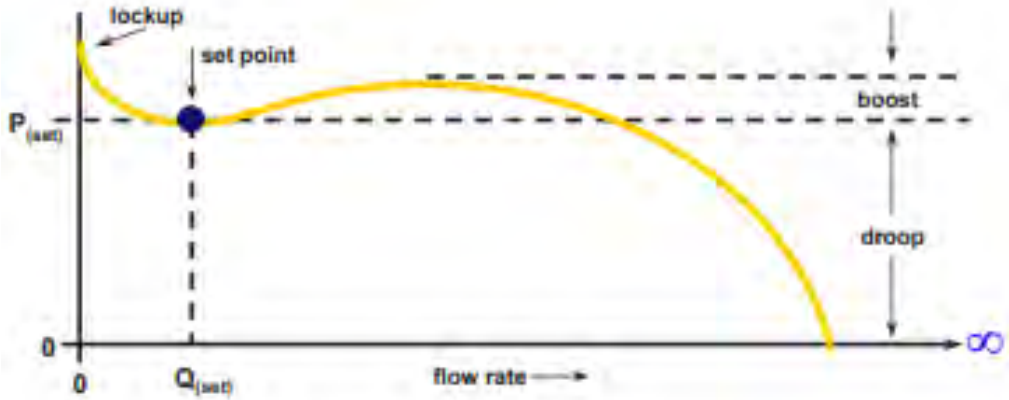
Flow Curve

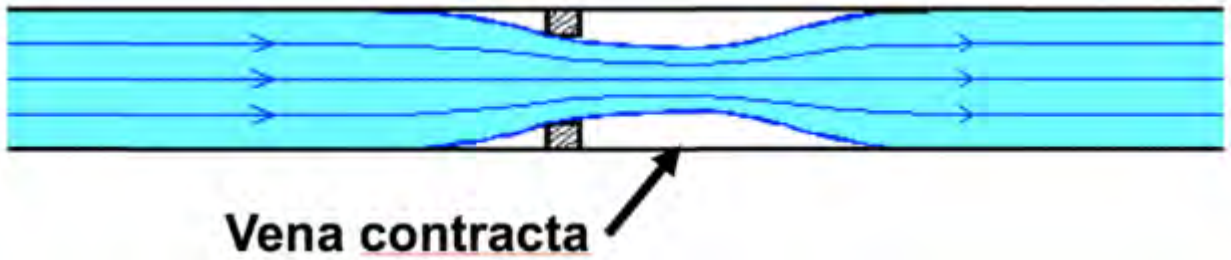
- Lock up Tail
- Ideal flow curve
- Actual flow curve
  - Droop
  - Choked flow (sonic velocity reached)
- Boosted Flow curve

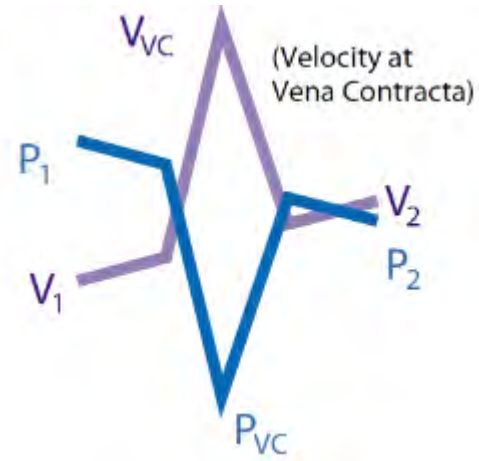


Boost

- What is boost?
  - Boost is a method of controlling droop on a Direct Op Reg.
  - Placing the sense point for the regulator at the vena contracta of the flow.

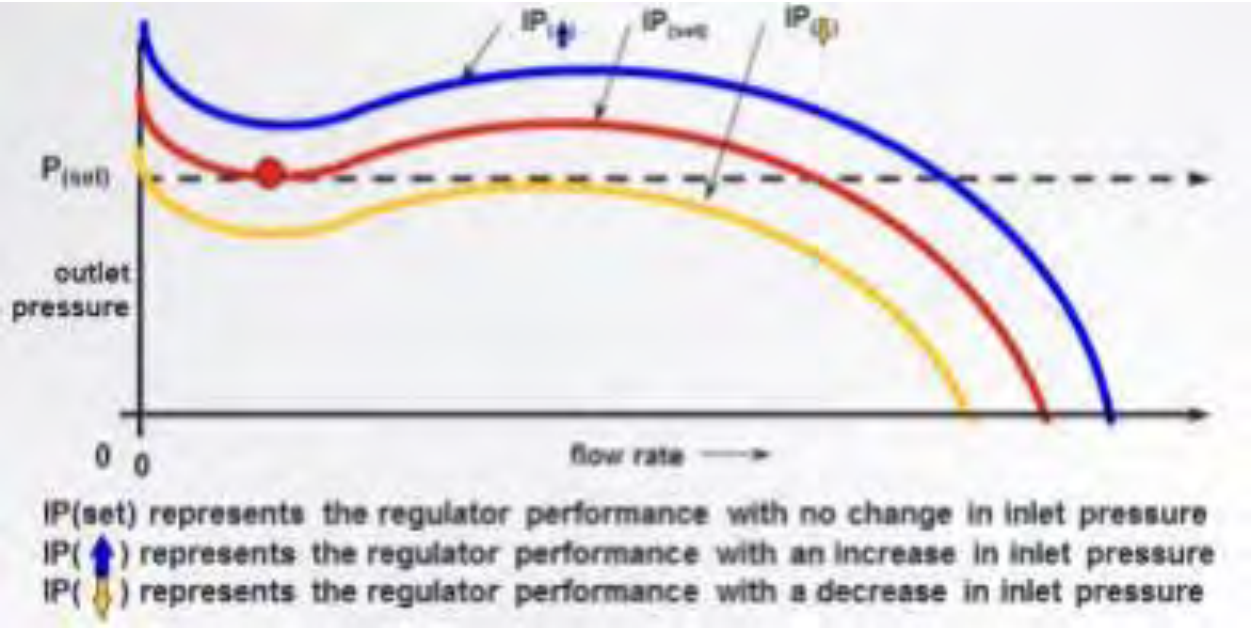






Inlet Pressure Effects

- What happens when inlet pressure fluctuates?
  - Inlet pressure has direct proportional effect on outlet pressure of a Direct Op reg.



Manufacturer Characterisation

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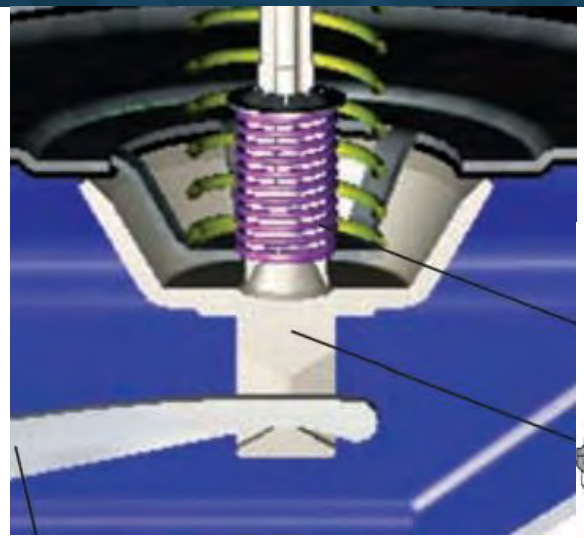
- Typical sizing charts
  - 7” wc delivery, 1” Droop
  - 1 psig delivery, 1” droop

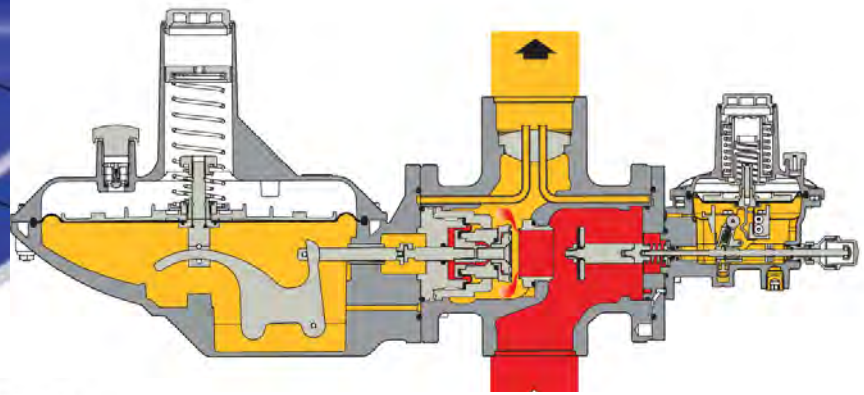
Capacities in SCFH (m3/hr) of 0.6 S.G. gas; base conditions of 14.7 PSIA and 60° F.

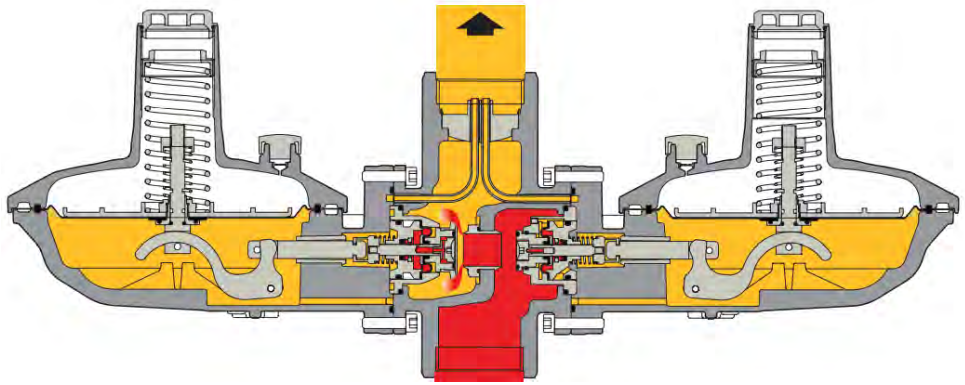
Inlet Pressure		Orifice Size							
PSIG	BAR	1/8"	1/8 x 3/16"	3/16"	1/4"	5/16"	3/8"	1/2"	1/2 x 9/16"
2	0.1	89 (2.5)	115 (3.3)	230 (6.5)	300 (8.5)	330 (9.3)	420 (11.9)	455 (12.9)	475 (13.5)
3	0.2	115 (3.3)	160 (4.5)	280 (7.9)	350 (9.9)	410 (11.6)	540 (15.3)	615 (17.4)	670 (19.0)
5	0.4	230 (6.5)	275 (7.8)	340 (9.6)	490 (13.9)	580 (16.4)	700 (19.8)	790 (22.4)	975 (27.6)
10	0.7	365 (9.5)	410 (11.6)	520 (14.7)	770 (21.8)	870 (24.6)	1130 (32.0)	1145 (32.4)	1330 (37.7)
15	1.0	440 (12.5)	510 (14.4)	730 (20.7)	1050 (29.7)	1190 (33.7)	1390 (39.4)		
20	1.4	535 (15.1)	590 (16.7)	890 (25.2)	1290 (36.5)	1400 (39.6)	1620 (45.9)		
30	2.1	715 (20.2)	760 (21.5)	1150 (32.6)	1630 (46.2)	1740 (49.3)			
40	2.8	910 (25.8)	930 (26.3)	1525 (43.2)	1900 (53.8)				
50	3.5	1080 (30.6)	1100 (31.1)	1740 (49.3)	2140 (60.6)				
60	4.1	1235 (35.0)	1260 (35.7)	1910 (54.1)	2250 (63.7)				
80	5.5	1550 (43.9)	1580 (44.7)	2100 (59.5)					
100	6.9	1660 (47)	1850 (52.4)	2150 (60.9)					
125	8.6	1760 (49.8)	1950 (55.2)	2160 (61.2)					

Options: Direct Op Regulators

- OPPD
  - Internal Relief Valves
  - Slam-Shut or “OPCO”
  - Onboard monitor

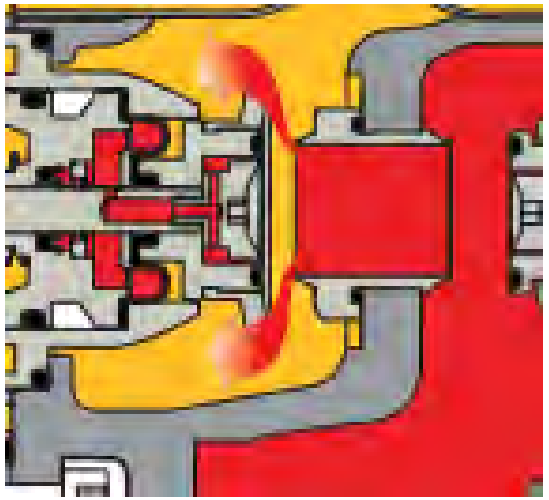


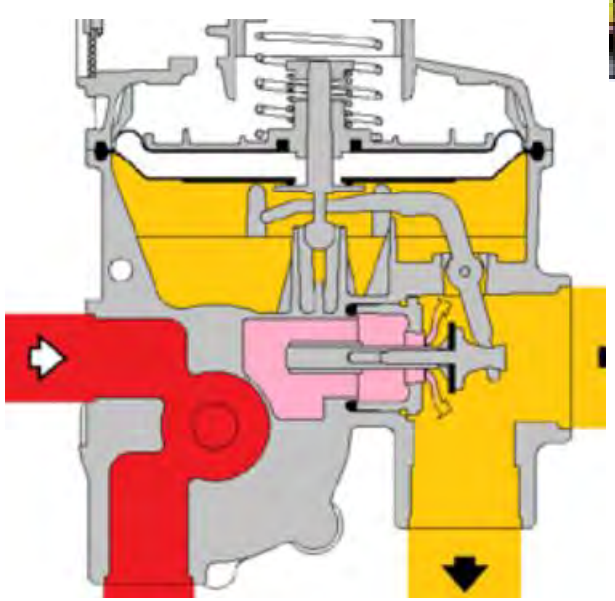




Options: Direct Op Regulators

- Operational design improvements
  - Balanced Plug design
  - 2 stage-cut





Manufacturer Characterisation

- Size Chart – Balance Design
- Sizing Chart – Dual cut

FEX	75 STM3/H	PD + 0.5
FEXS	100 STM3/H	PD + 0.5

Outlet pressure (psig) 7"WC (+2"WC/-1"WC)				
Inlet pressure (psig)	[redacted]			[redacted]
	1 ¼"	**1 ½"**	**2"**	**2"**
2	2,100	2,400	2,500	7,000
5	2,500	2,800	3,000	8,500
7	2,800	3,500	3,700	9,500
10	3,500	4,200	4,600	12,500
15	5,500	6,500	6,500	15,000
25	7,000	8,500	9,000	17,000
40	8,500	8,500	9,000	19,000
60	7,000	7,000	8,000	25,000
72,5	7,000	7,000	8,000	25,000
100	7,000	7,000	8,000	25,000
125	7,000	7,000	8,000	25,000
* Flow Rate (SCFH)				Tab.6

Common Applications

- Appliance Regulator
- Residential Gas delivery service
- Commercial Gas delivery service
- Pneumatic pressure system (air)

CSA 618-02 (R2017)

Scope:

- These provisions apply to the construction, materials, performance, and testing of NPS 1-1/4 in and smaller self-acting service-type regulators with internal relief valves or overpressure cut-off (OPCO) devices, or both, utilized to control the pressure of gas delivered to a customer's piping at a delivery pressure of 5 to 9 in water column (1.24 to 2.24 kPa), for installations designed for capacities up to 250 SCFH (7.1 m3/h). Overpressure cut-off (OPCO) devices are also referred to as overpressure shut-off (OPSO) devices

Summary

- Direct Operated Regulators
  - Fast Acting regulators
  - Narrow range of control
  - Not as tight of tolerances as other options (pilot operated)
  - Very practical in the right applications (cost effective)

Thank you