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Value beyond the expected℠

Introduction to Regulator Theory and Operation



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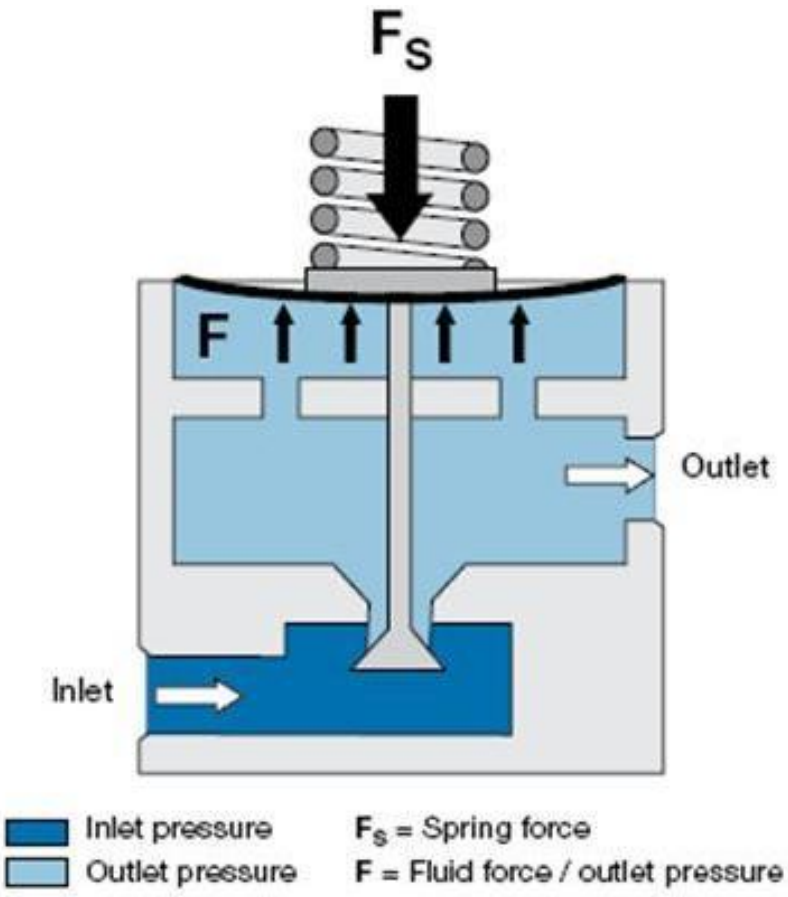
Agenda

- Pressure Reducing Regulator Operating Principle – Balance of Forces
- Sensing Elements
- Hard Seat vs. Soft Seat
- Loading Mechanisms
- Terms

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Operating Principle

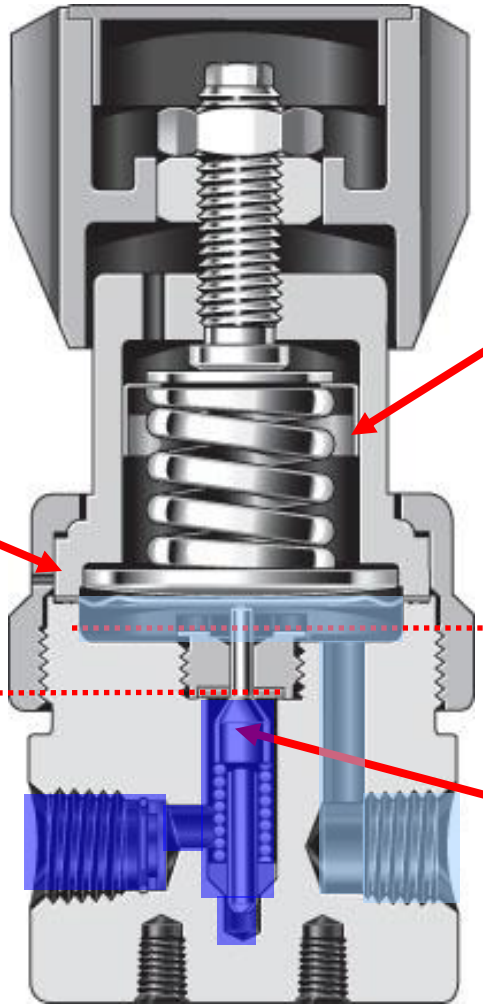
Pressure Reducing Regulator



The function of a pressure reducing regulator is to reduce a pressure and to keep this pressure as constant as possible while the inlet pressure and the flow may vary.

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Operating Principle



As compression of spring increases, the poppet is pushed downwards and the regulator opens

The sensor (diaphragm or piston) balances the spring force and pressure forces

LOW PRESSURE

HIGH PRESSURE

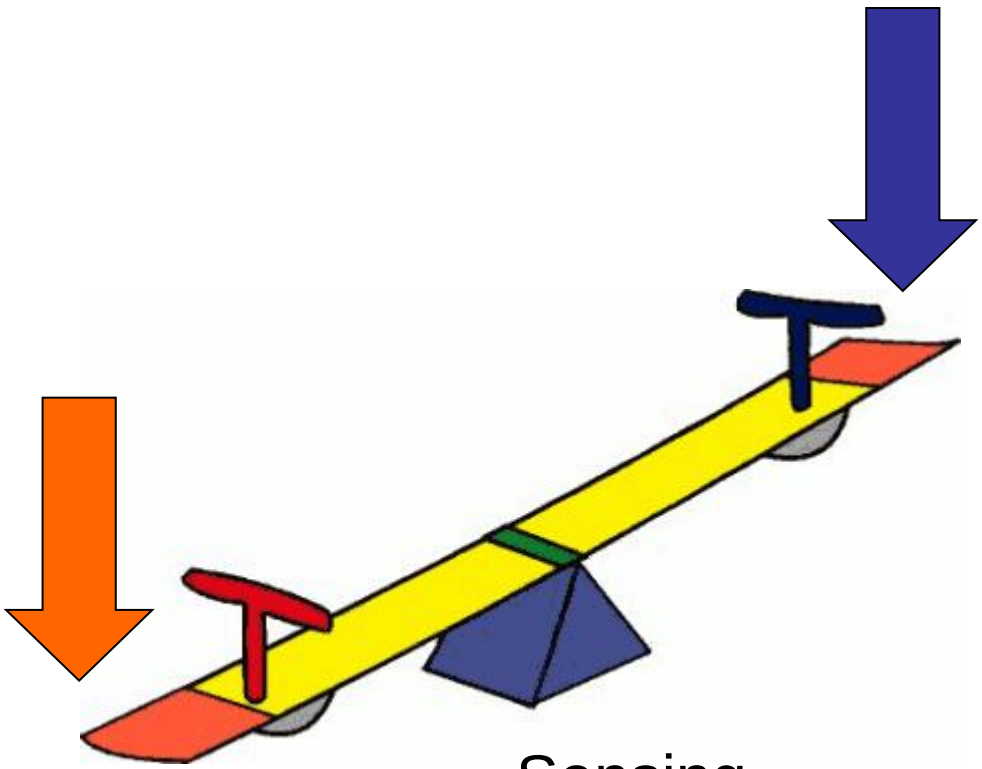
The poppet & seat 'bleed' the high pressure to low pressure side of the regulator

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Balance of Forces

Internal Forces

(Inlet & Outlet Pressure)



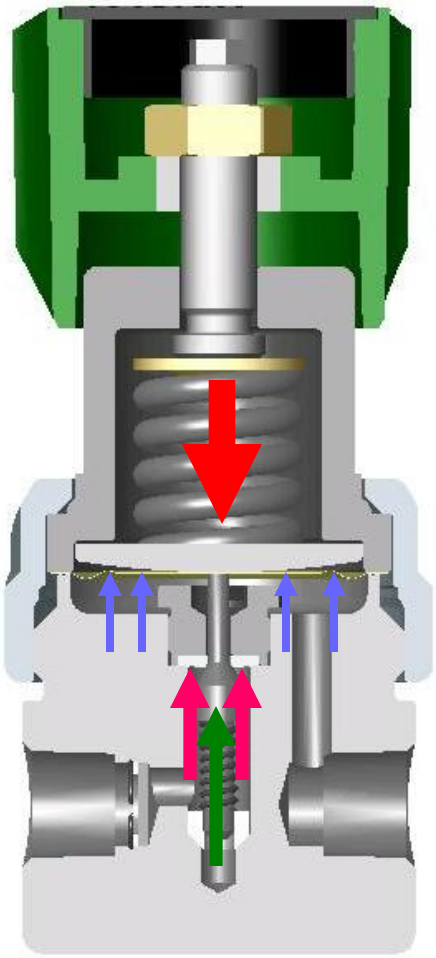
Loading Force

(Spring Force)

Sensing Element

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Balance of Forces



F_1 = Loading Force

F_2 = Inlet Spring Force

F_3 = Outlet Pressure Force

F_4 = Inlet Pressure Force

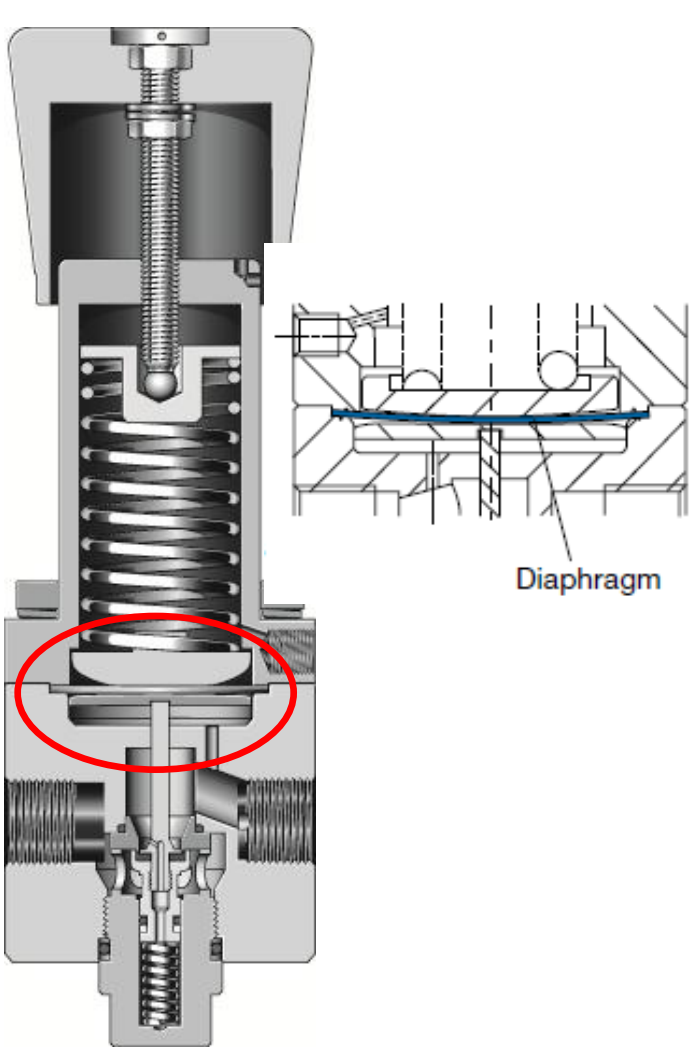
F1 = F2 + F3 + F4

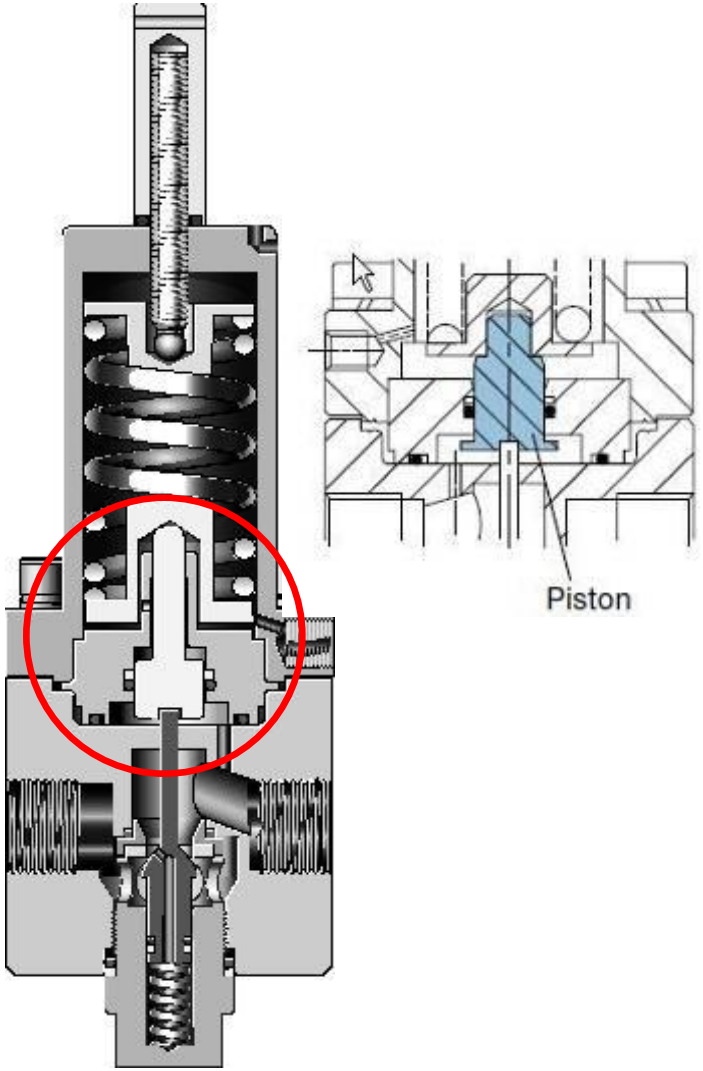
Loading Force

Internal Forces

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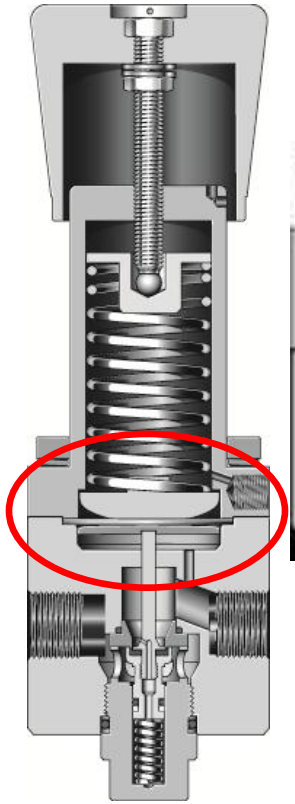
Two Types of Sensing Elements





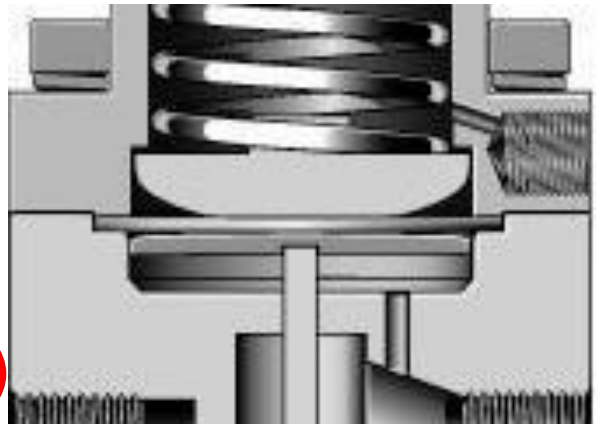
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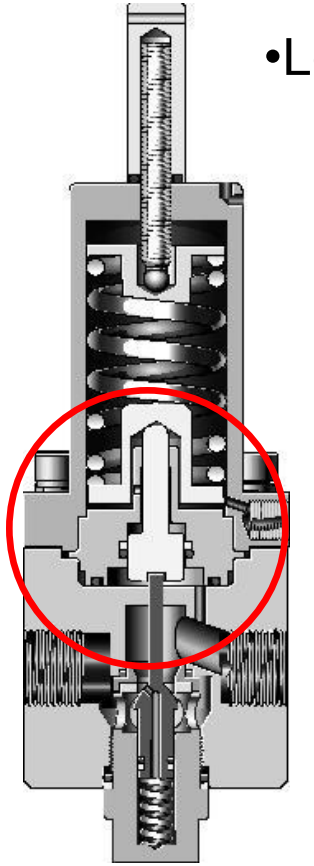
Diaphragm vs. Piston Sensing



Diaphragm

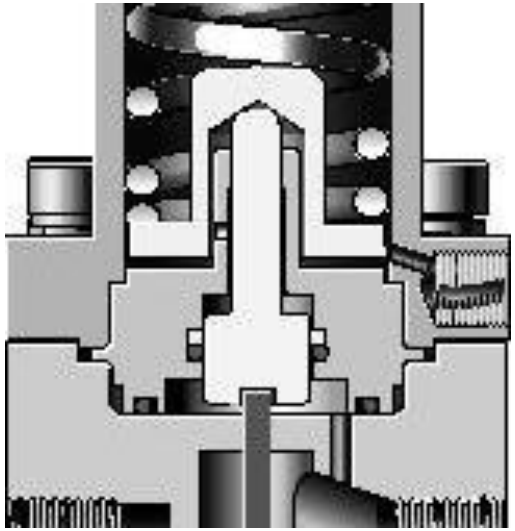
- Greater sensitivity
- Choice of material





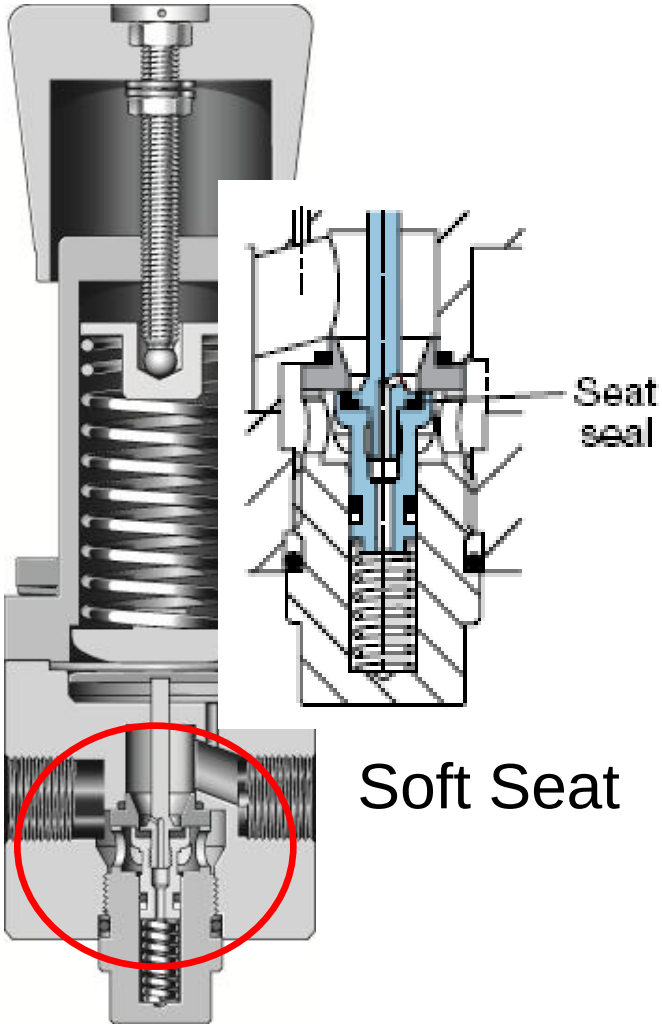
Piston Sensing

- Higher outlet pressure
- Less sensitive

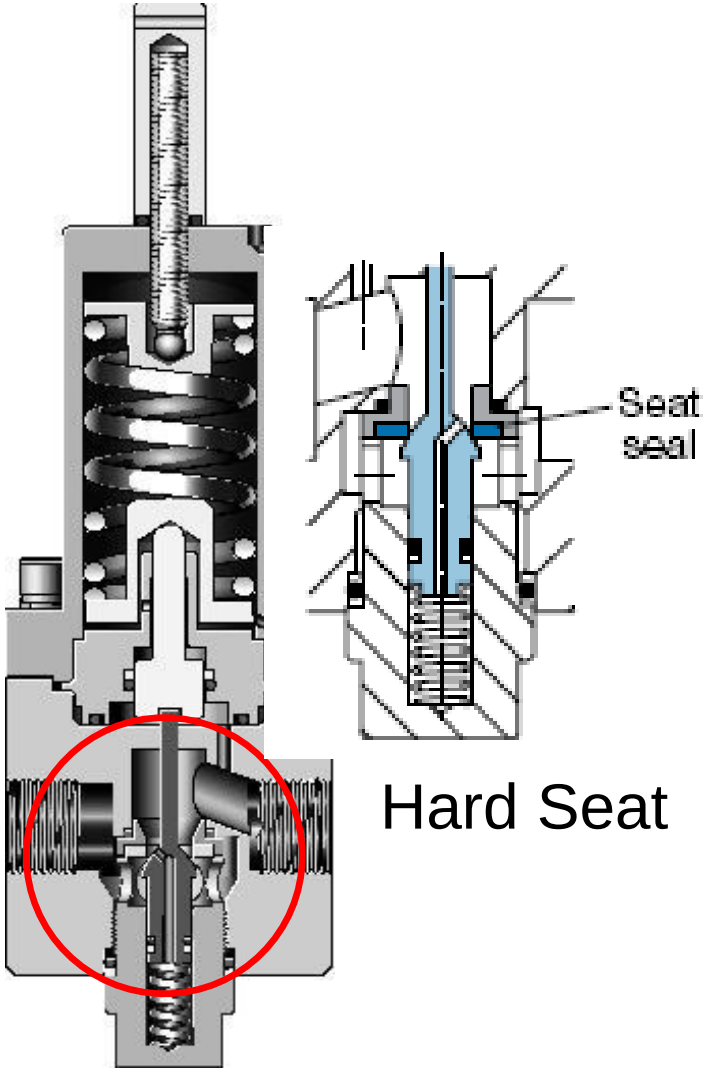


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Soft Seat vs. Hard Seat



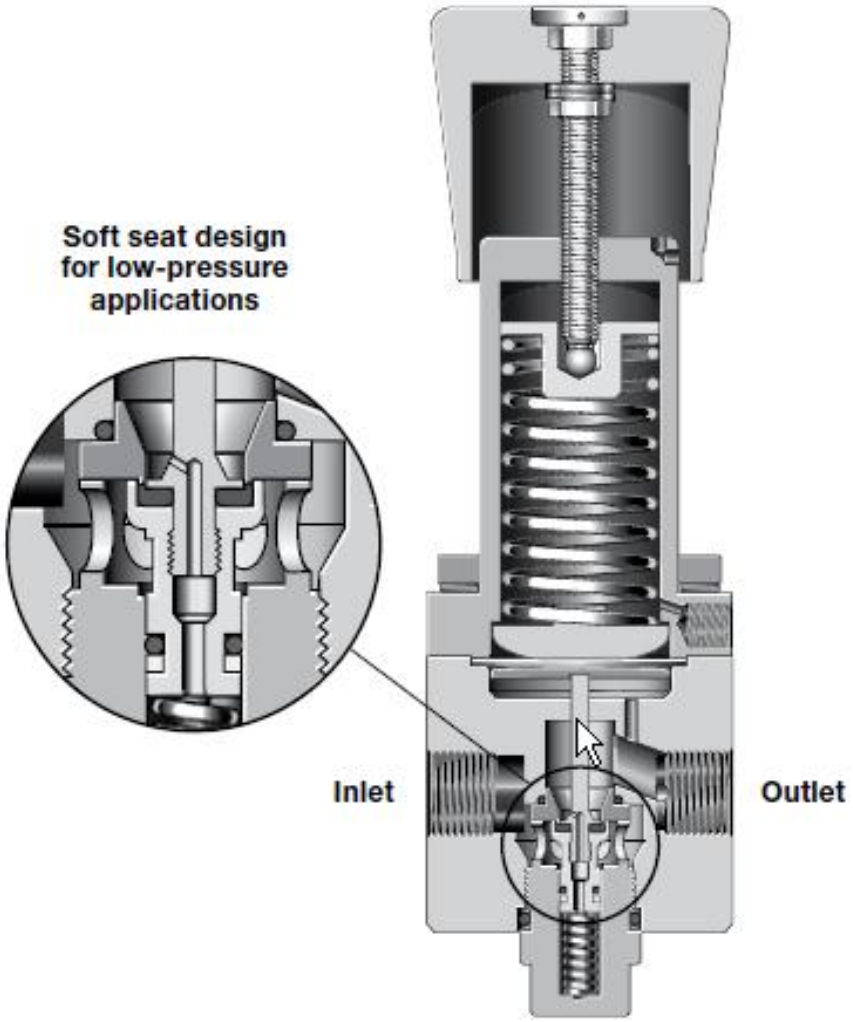
Soft Seat

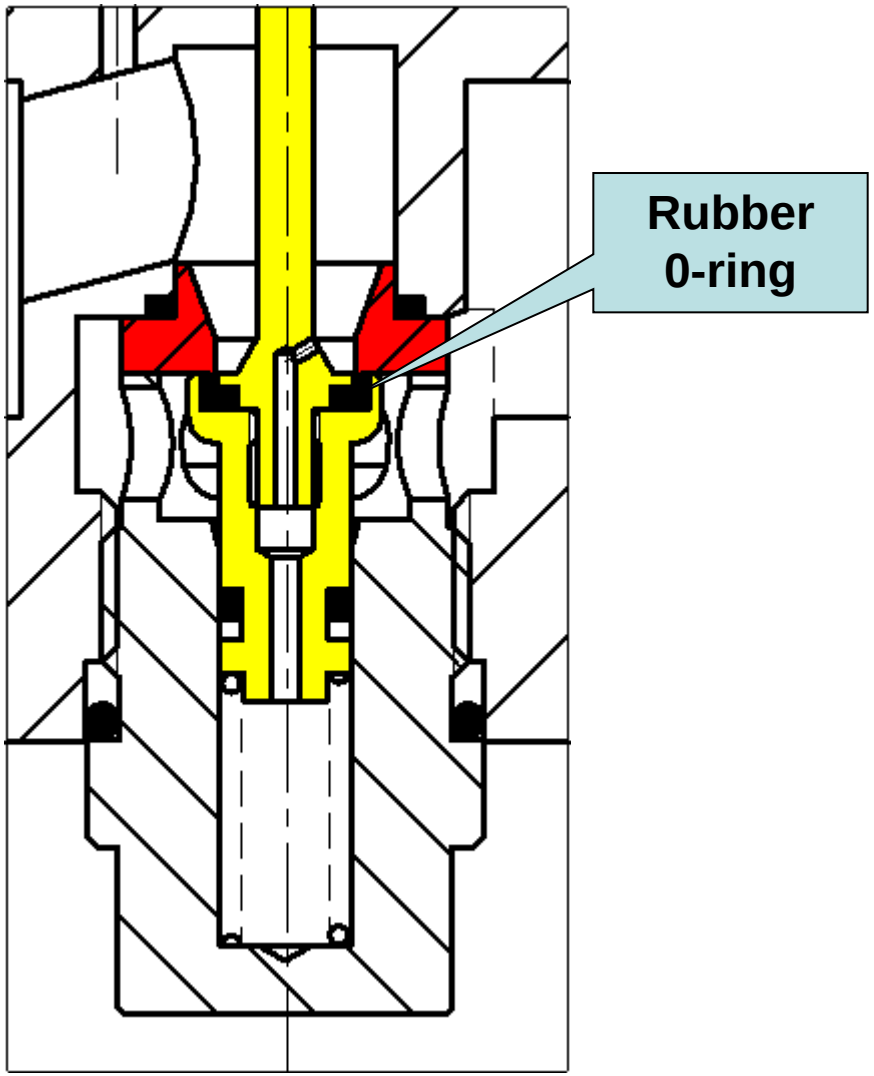


Hard Seat

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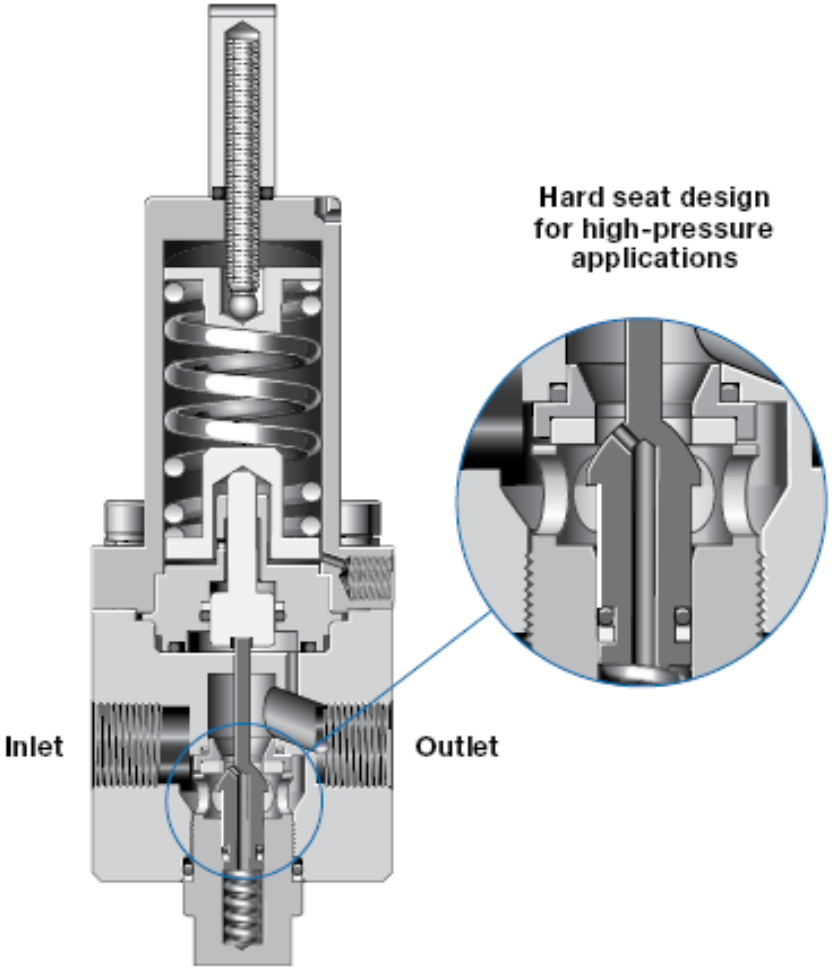
Regulator with Soft Seat

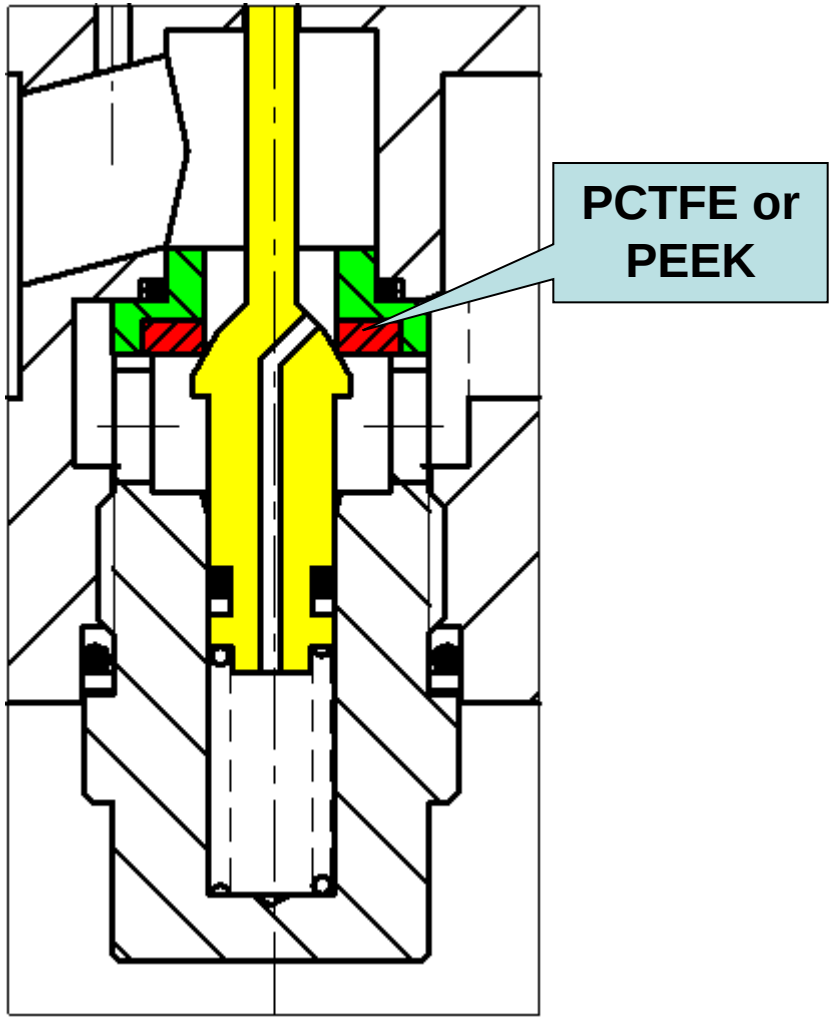




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Regulator with Hard Seat

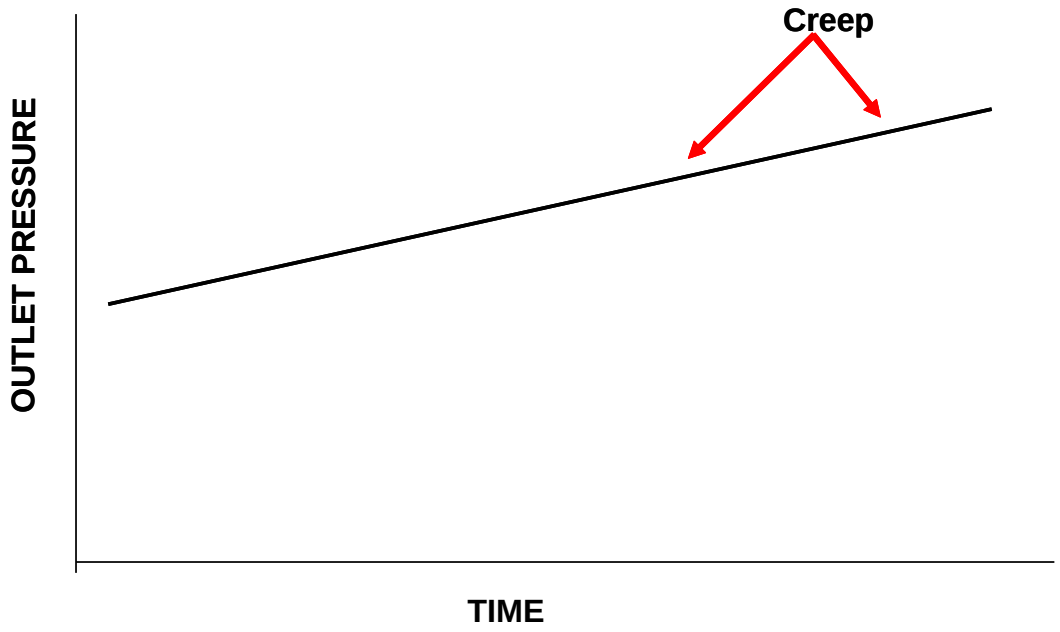




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Creep

An increase in outlet pressure typically caused by regulator seat leakage.

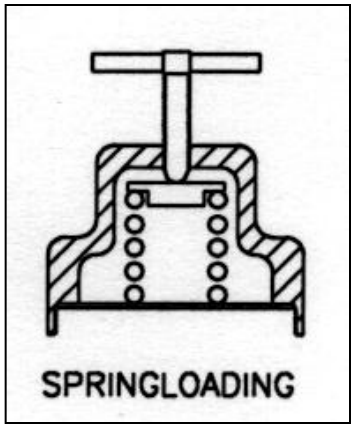


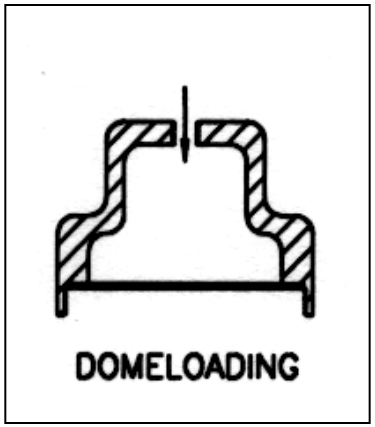
Regulators are not shut off devices…

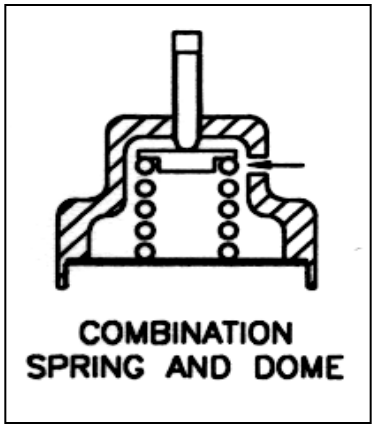
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Loading Mechanisms

3 TYPES













Spring-Loaded Regulators

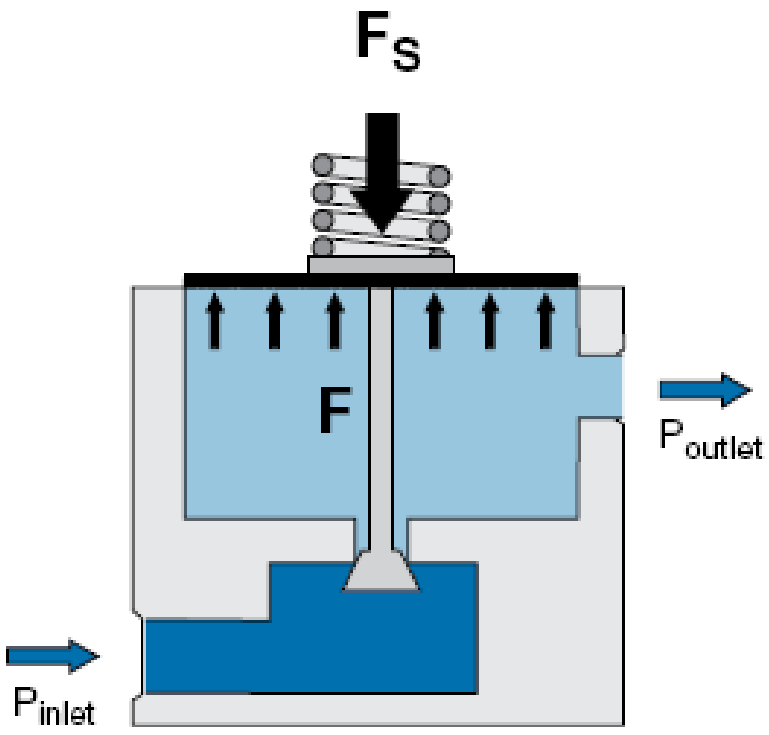
Loading Mechanism

The loading mechanism is the component of the regulator that balances the force or pressure.

Spring-Loaded

In a spring-loaded regulator, a coil spring is used to generate a load (F_S) against the sensing mechanism. The amount of spring force or load can be adjusted by turning the handle or adjusting screw of the regulator.

$$F_s \leq F$$



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Spring-Loaded Regulators

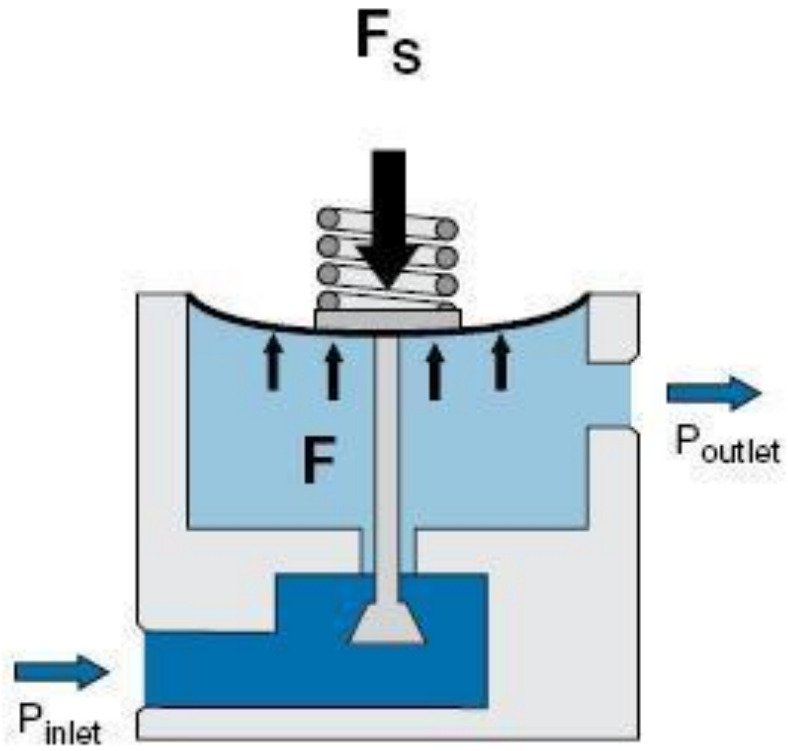
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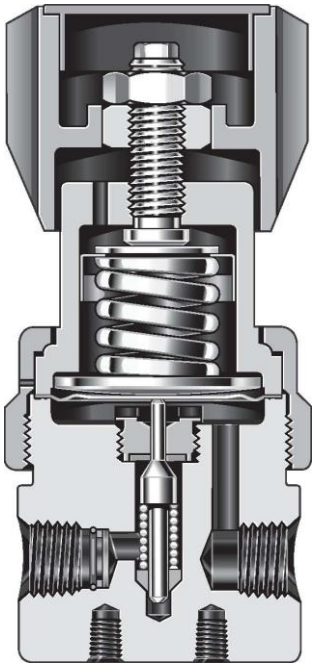
$F_s > F$

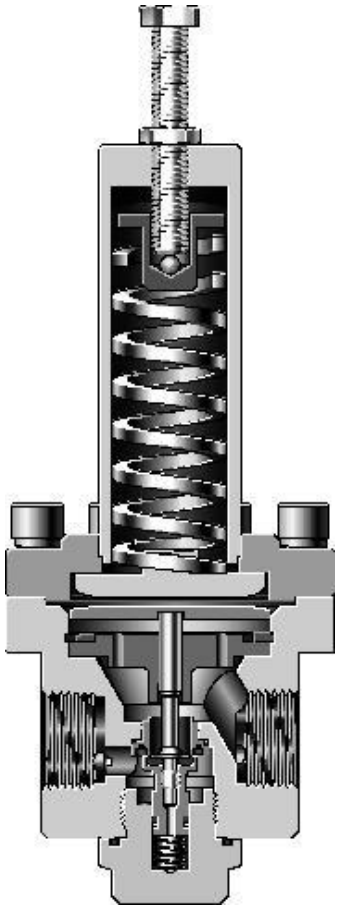


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Spring-Loaded Pressure Regulator









Instrumentation Type

Process Type

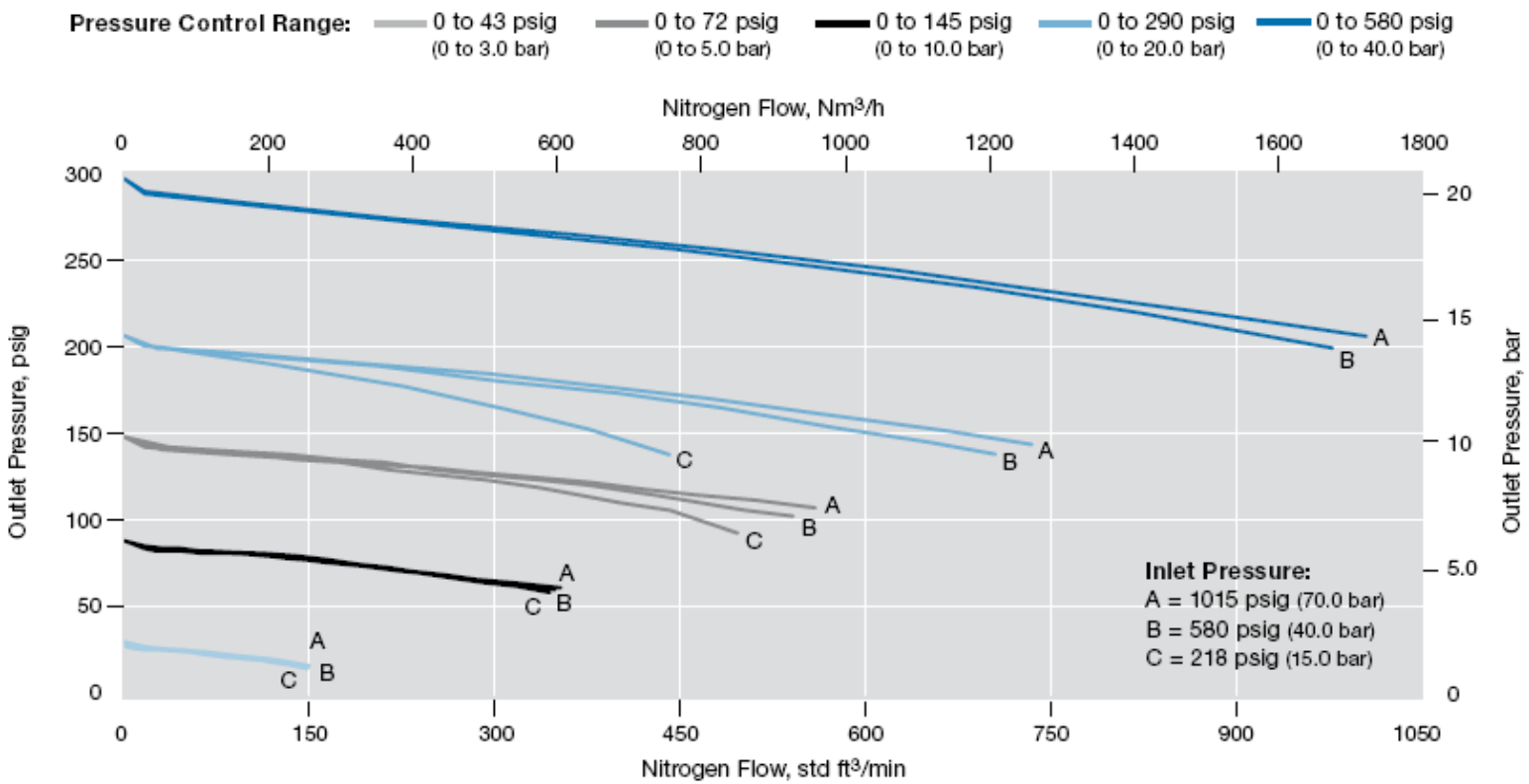
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Spring-Loaded Regulator Flowcurves

Flow Coefficient: 3.79

Maximum Inlet Pressure: RS—1015 psig (70.0 bar)

Outlet Pressure Control Range: 0 to 3625 psig (0 to 250 bar)

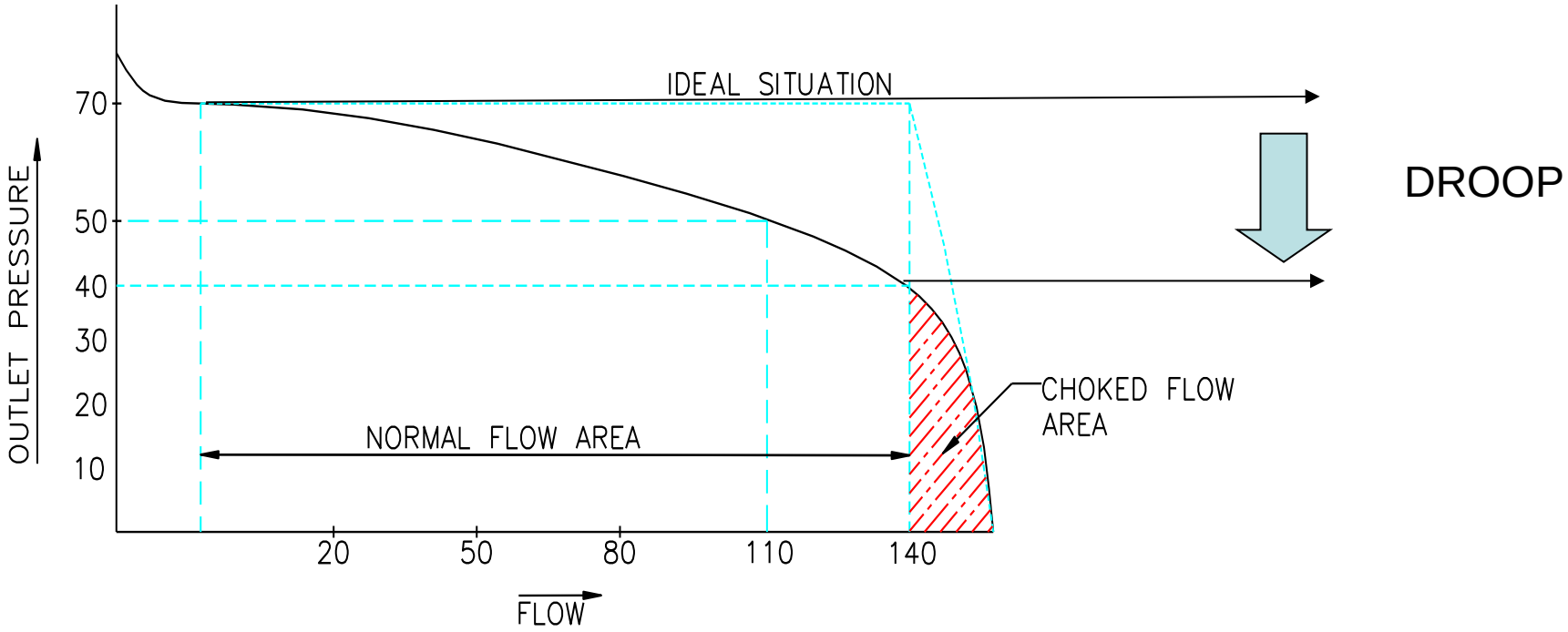


Pressure-Reducing Regulator

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Droop

A decrease in outlet pressure caused by an increase in flow rate to a pressure reducing regulator.



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Dome-Loaded Regulators

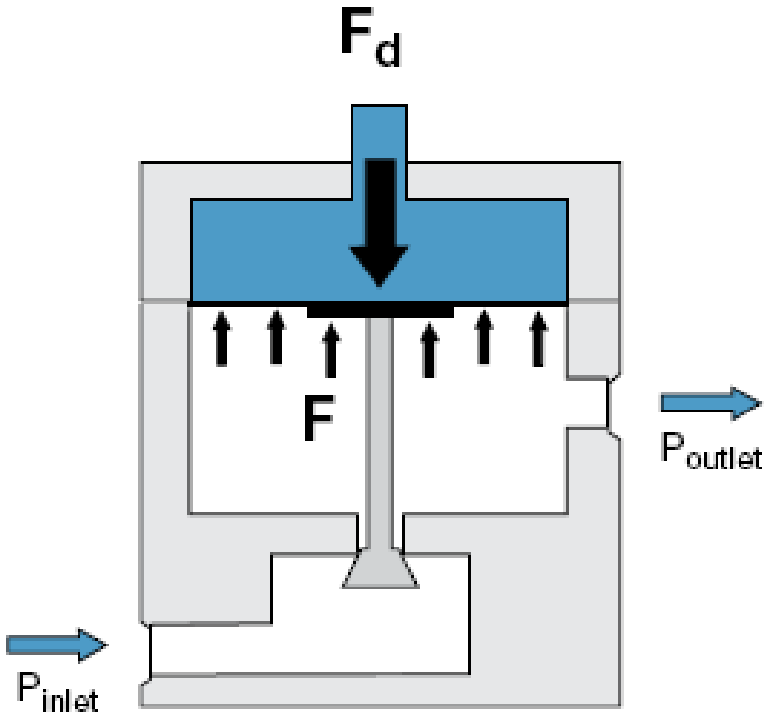
Loading Mechanism

The loading mechanism is the component of the regulator that balances the force or pressure.

Dome-Loaded

In a dome-loaded regulator, a gas is fed into the dome chamber above the sensing mechanism at a pressure equal to or slightly above the required outlet pressure. This volume of gas is used like a spring. The dome pressure (F_d) is typically supplied by a second regulator called a pilot regulator.

$$F_d \leq F$$



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Dome-Loaded Regulators

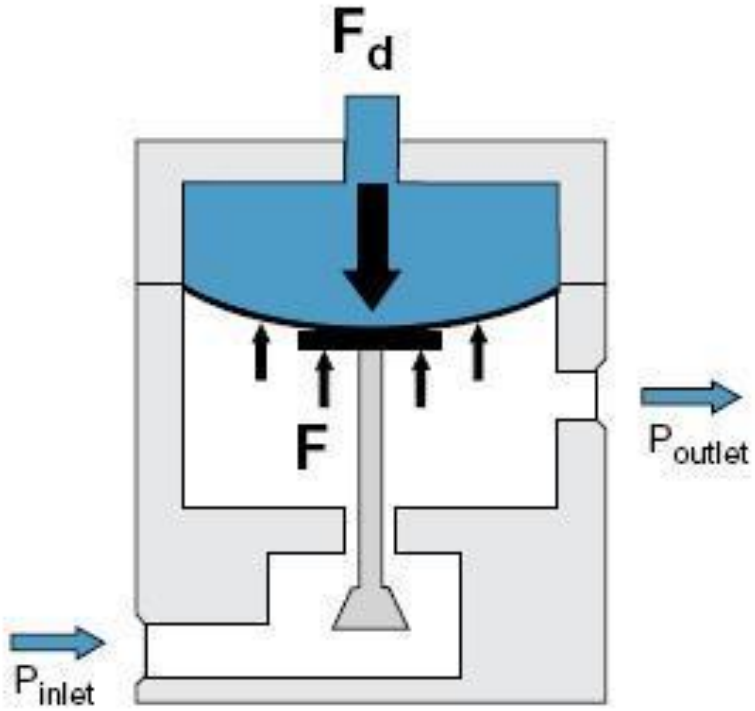
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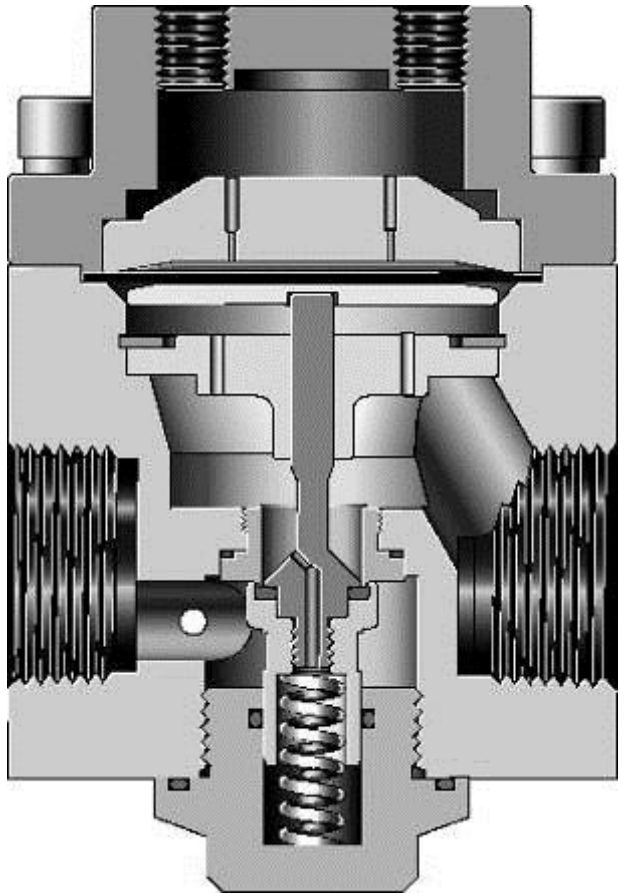
$F_d > F$



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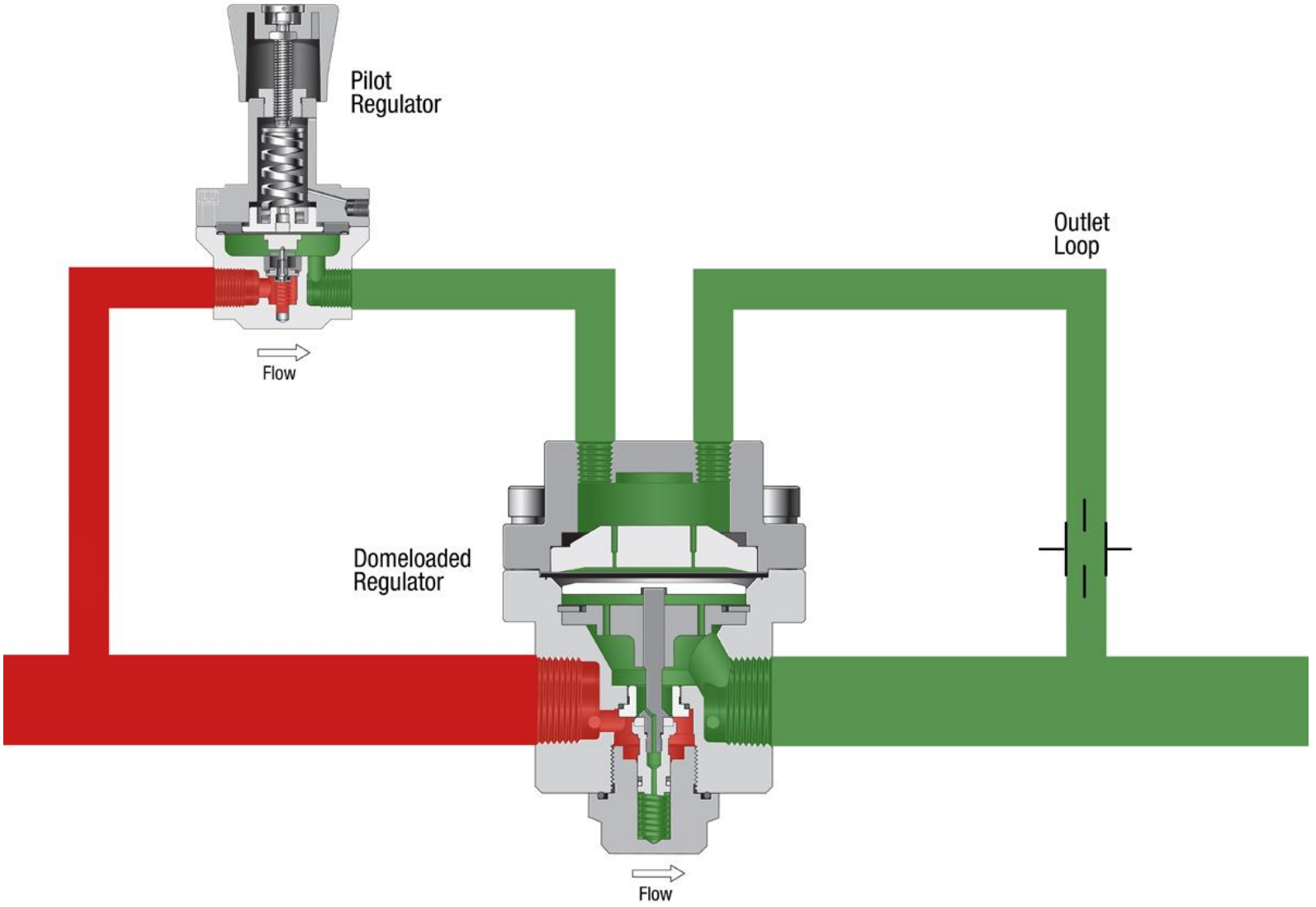
Dome-Loaded Pressure Regulator





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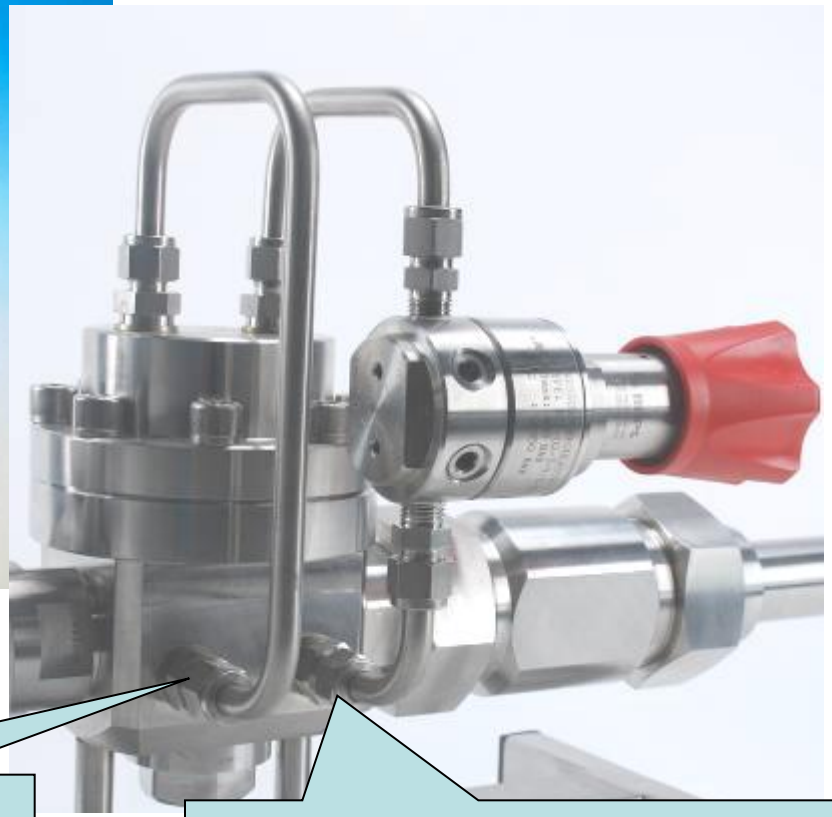
Dynamic Control



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Dynamic Control



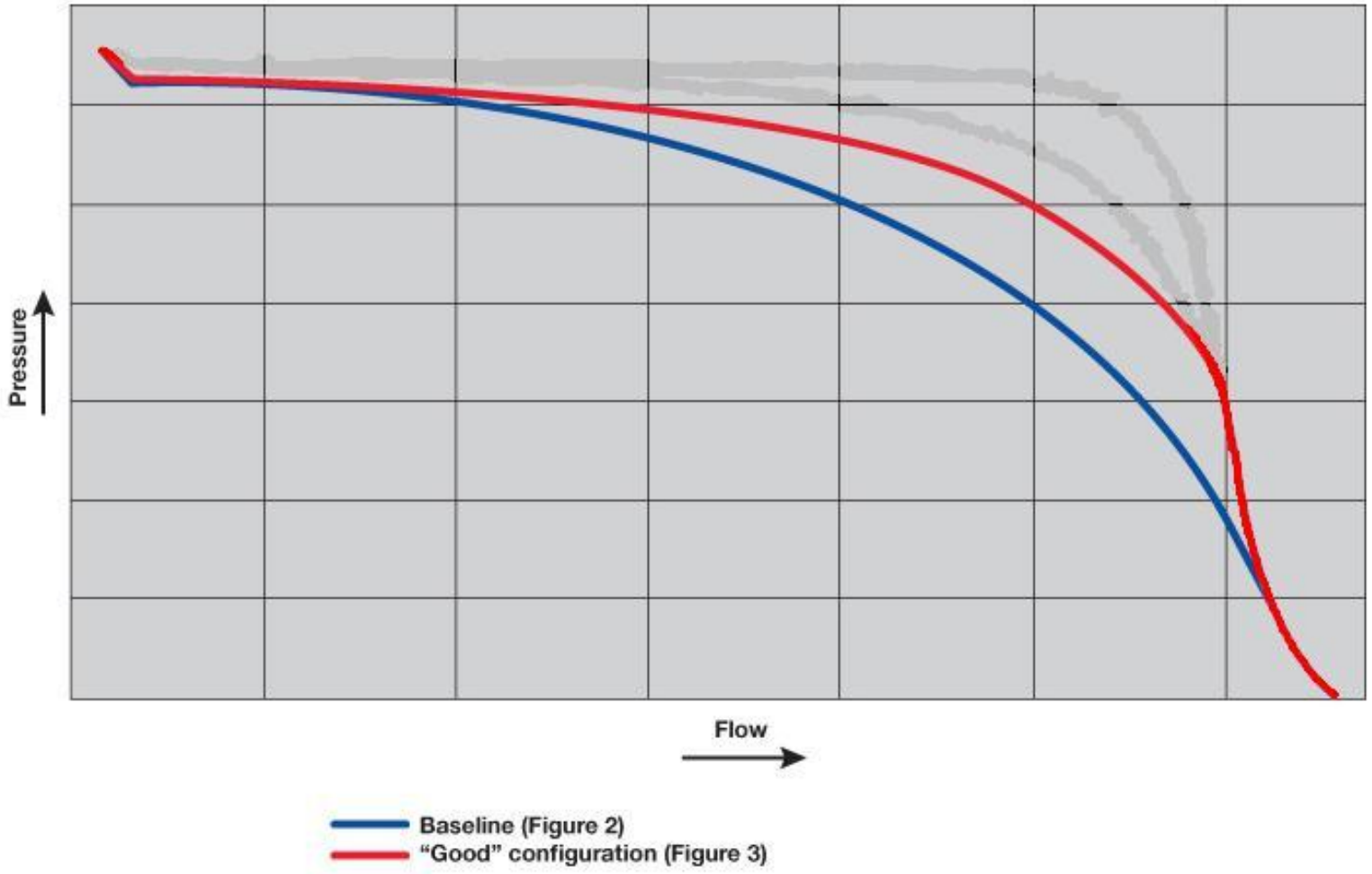


Bleed to outlet (restricted orifice)

Pressure to pilot from inlet

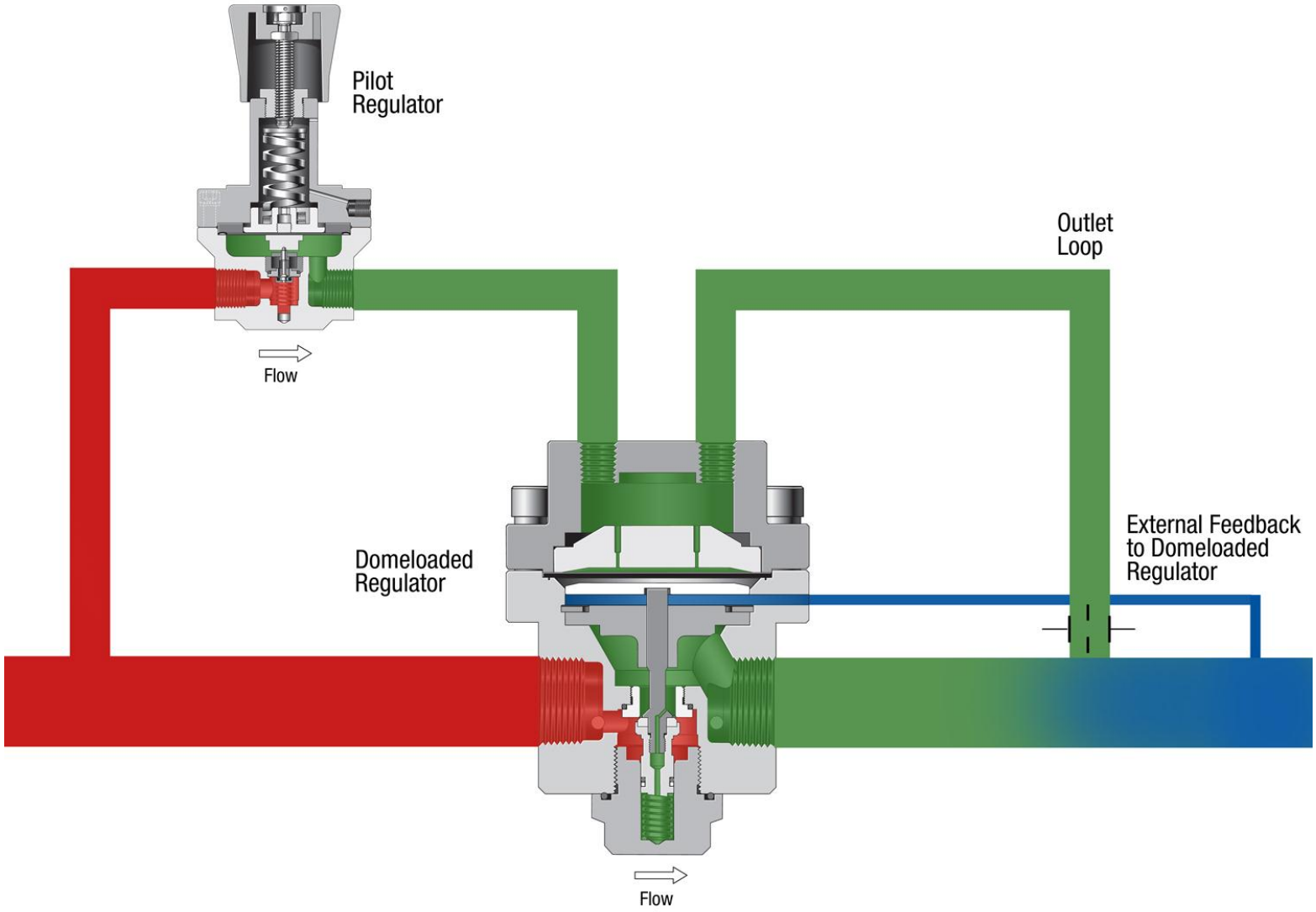
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Dome-Loaded Regulator Flowcurves



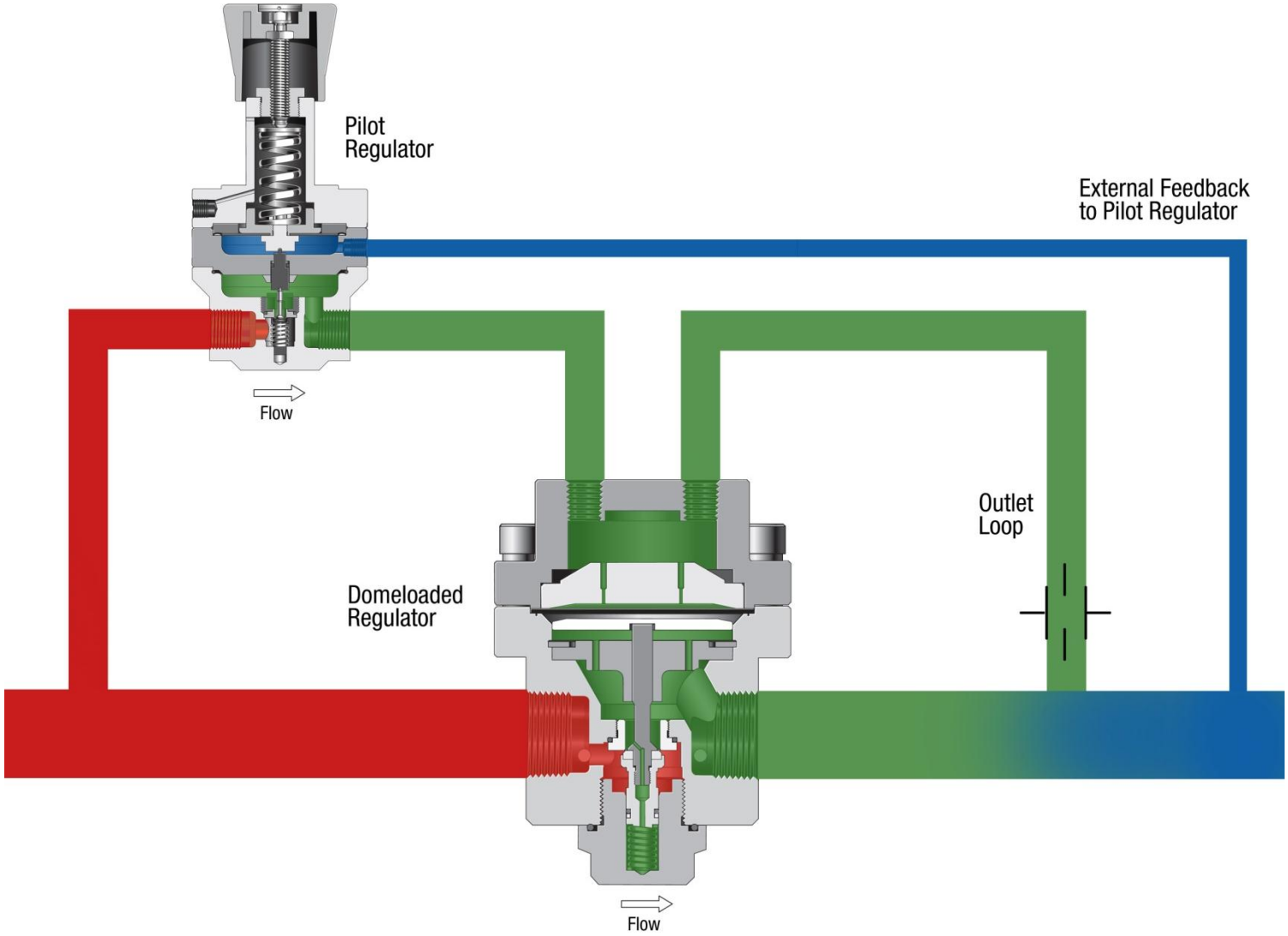
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Dome-Loading with External Feedback to Main



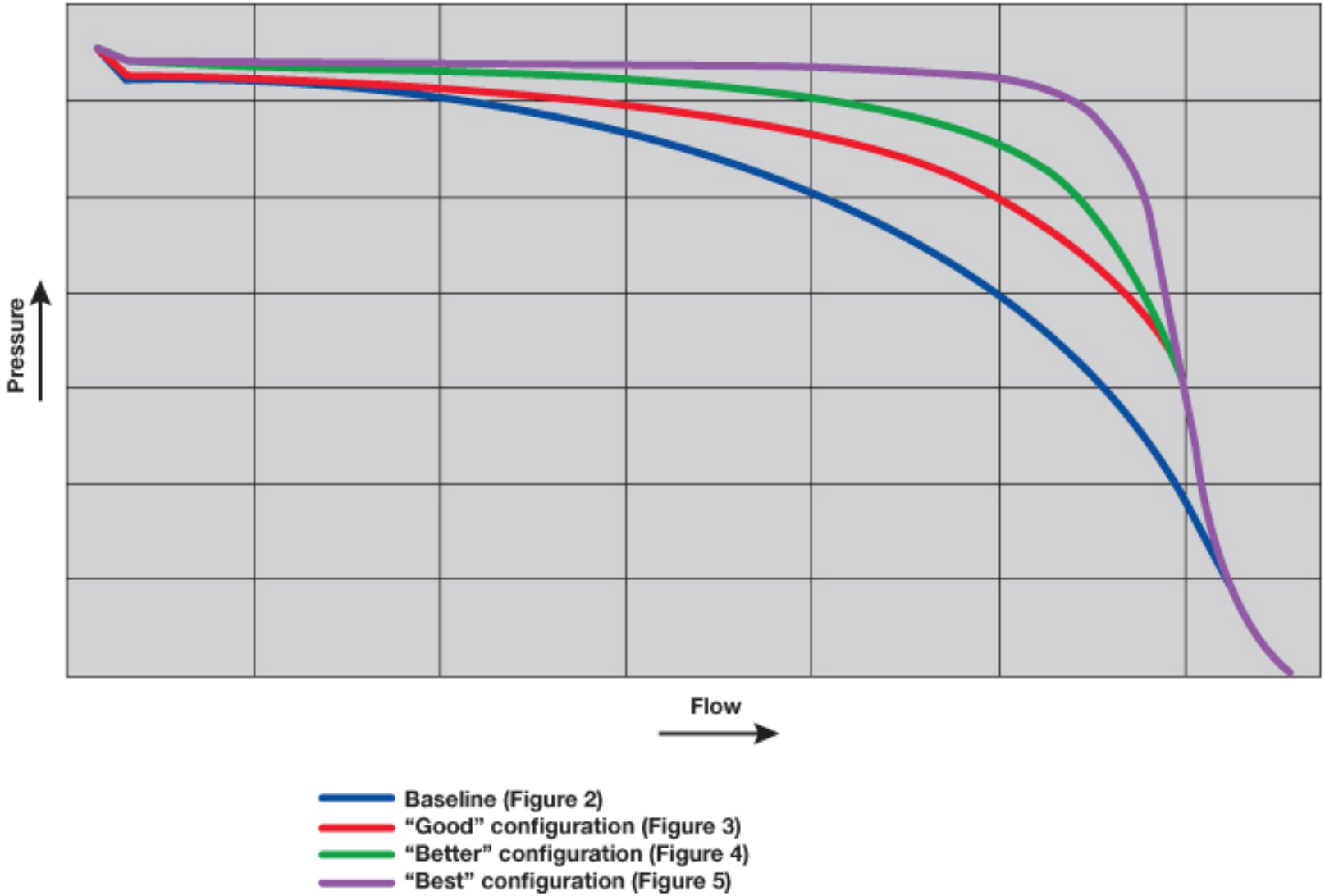
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Dome-Loading
with External Feedback to Pilot



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Improving the Flow Curve



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Dome-Loaded with Feedback to Pilot



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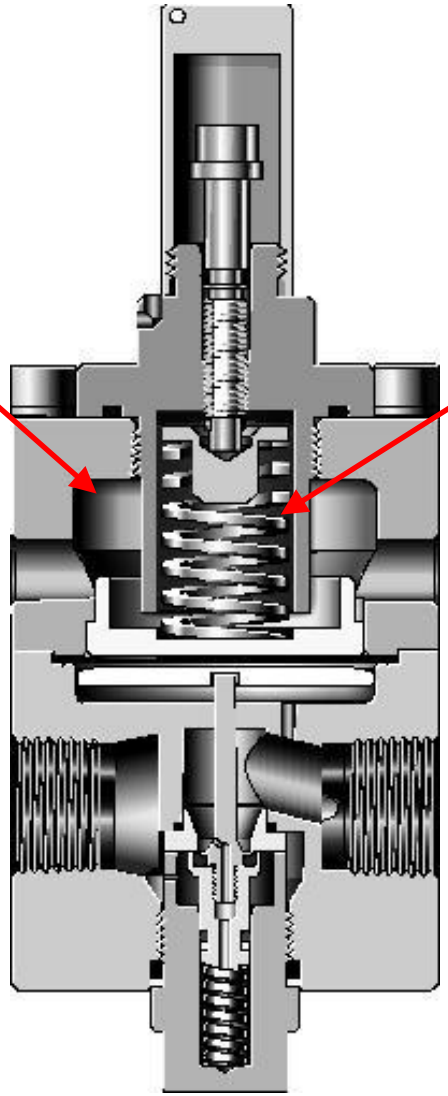
Combination Spring- and Dome-Loaded

- The Spring-and Dome-Loaded mechanisms can be used in combination with one another to provide the function of a differential pressure regulator.
- The regulator is designed to control pressure which is the sum of a reference pressure (provided by the dome) and a bias pressure (provided by the spring).



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Differential Pressure Regulator



Control Pressure =

Spring Force + Dome Pressure

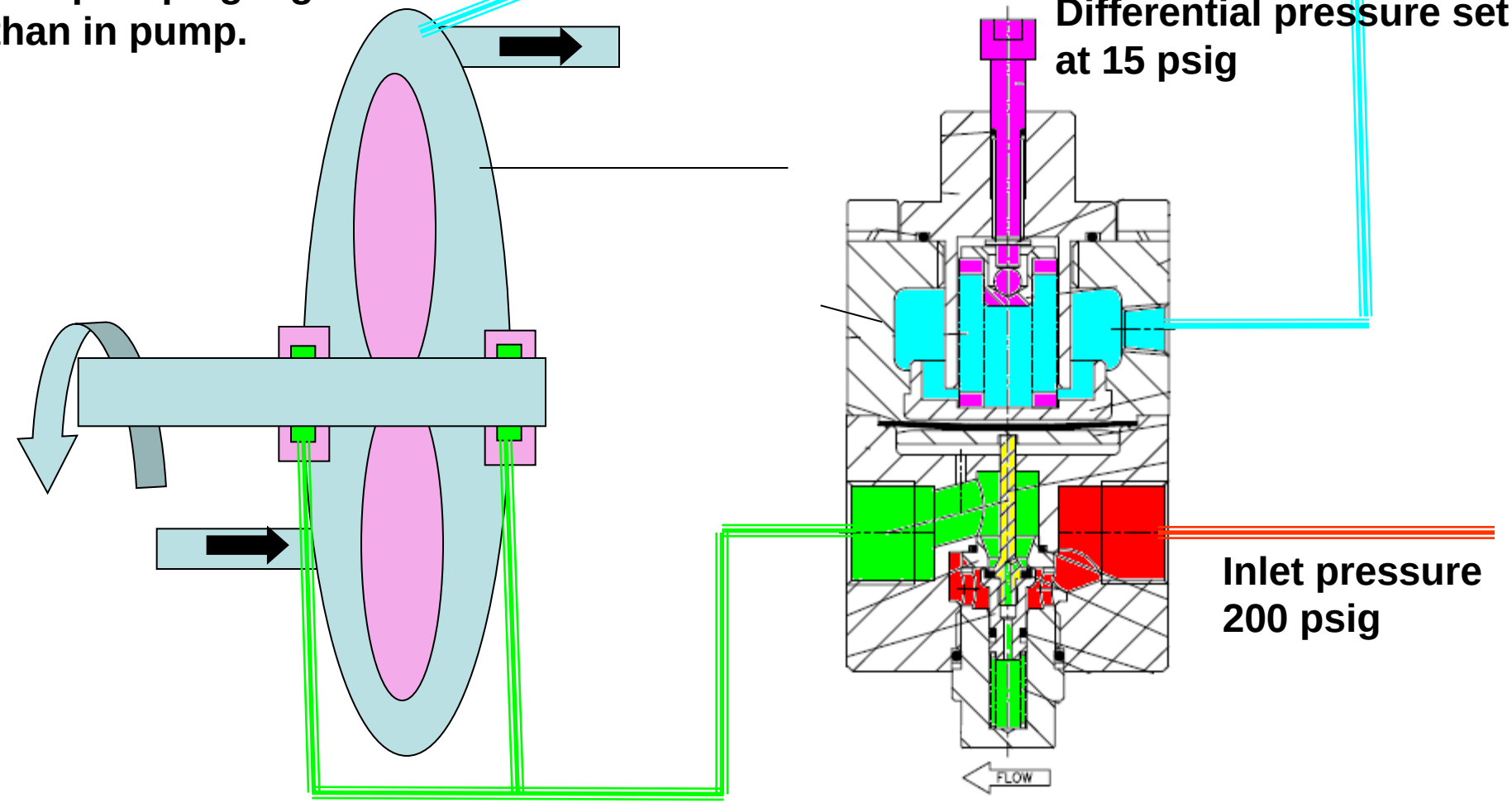
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Differential Pressure Regulator Application

Reference pressure from pump 100 psig

Pressure in seal pump 15 psig higher than in pump.

Differential pressure set at 15 psig



Inlet pressure 200 psig

Seal pressure 100 + 15 = 115 psig

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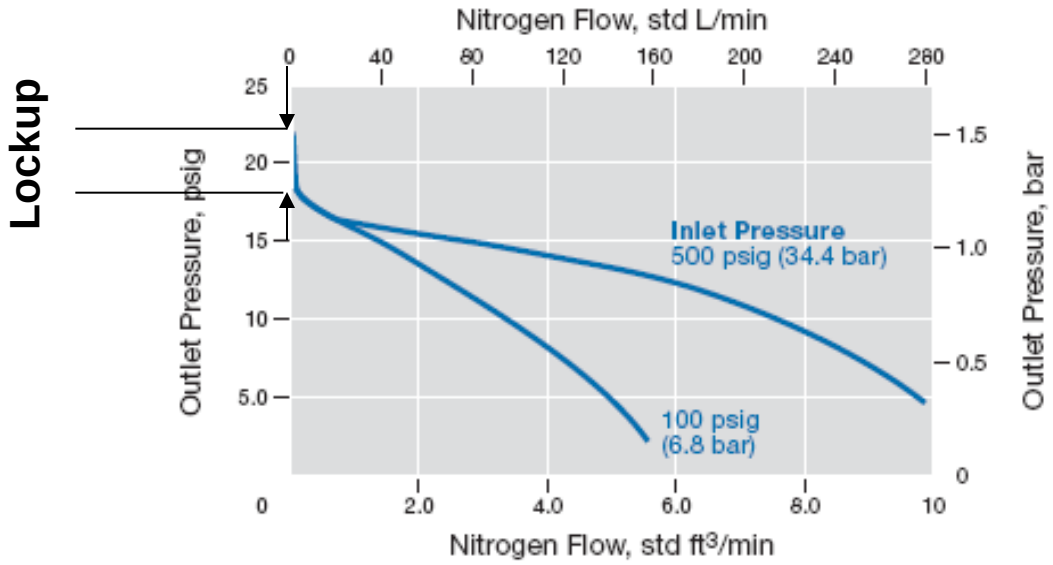
Regulator Terminology

- Lock-up
- Seat Load Drop
- Supply Pressure Effect

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Lockup

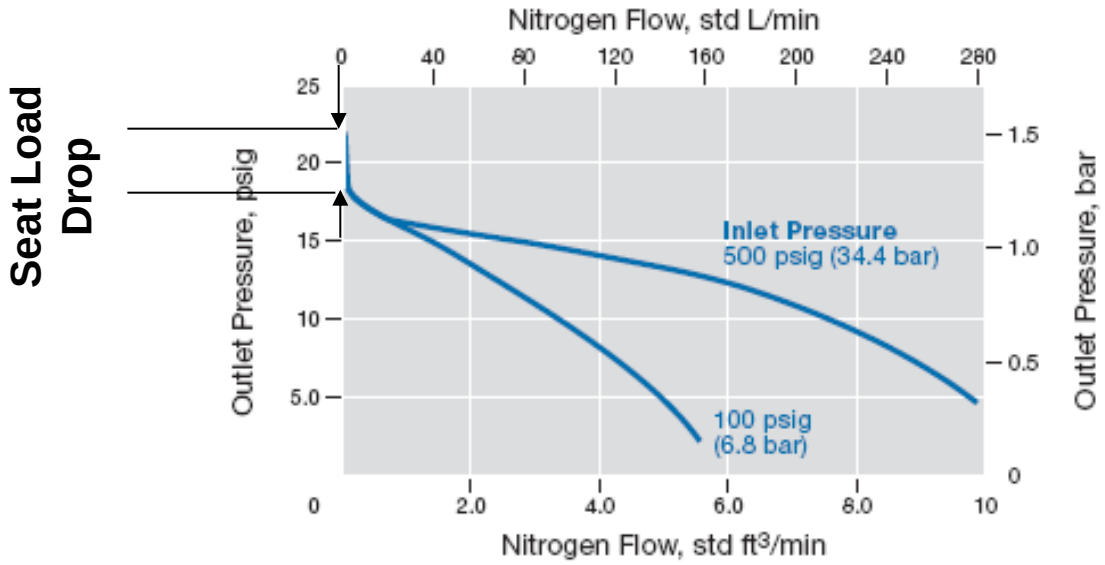
An increase in outlet pressure that occurs as the flow rate is decreased to zero.



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Seat Load Drop

A decrease in outlet pressure that occurs as the flow rate is increased from zero. The opposite of Lockup.



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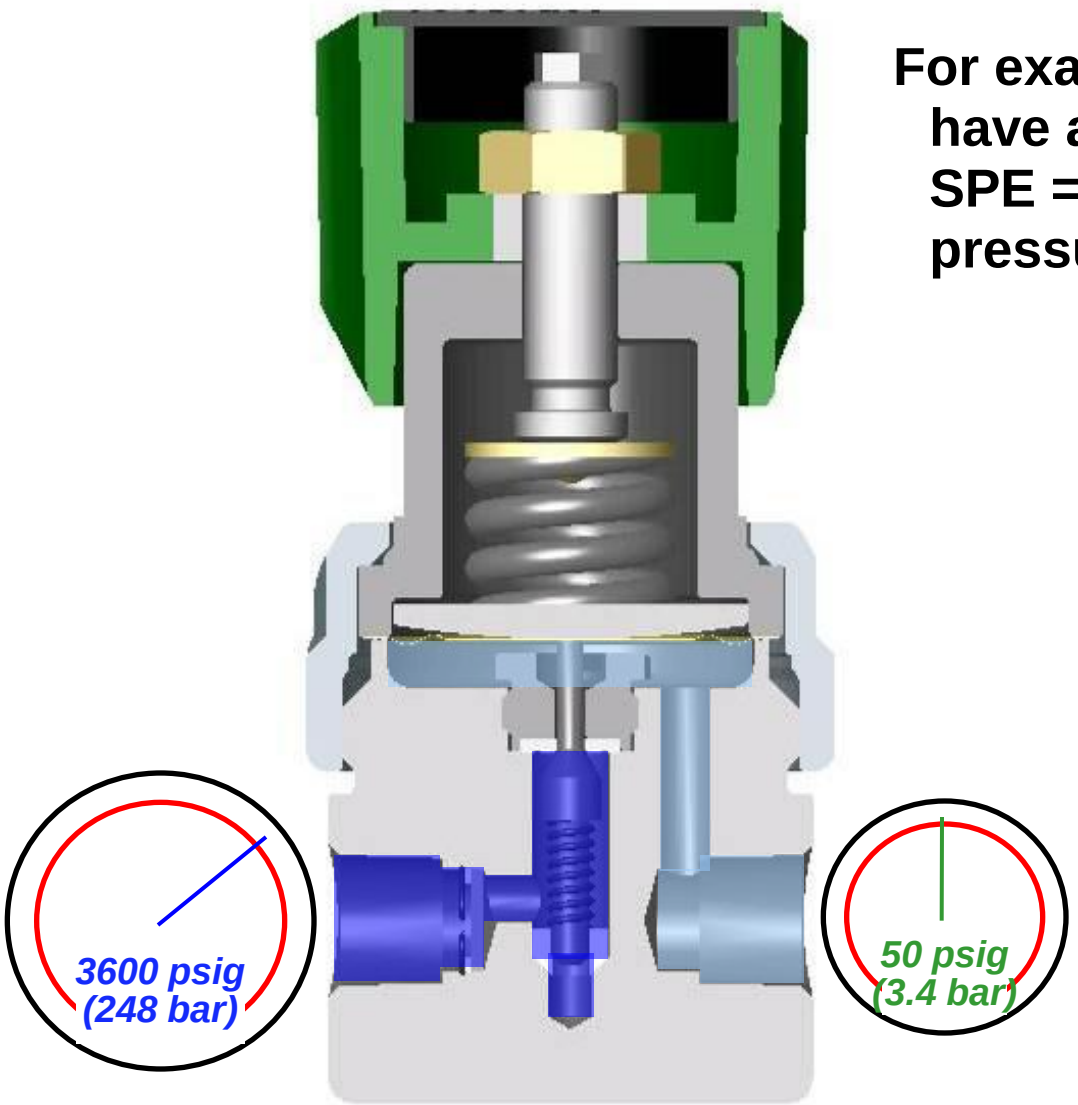
Supply Pressure Effect

Supply Pressure Effect (SPE):

The effect on the set pressure of a pressure reducing regulator as a result of a change in inlet pressure, normally experienced as an increase in outlet pressure due to a decrease in inlet pressure. Also known as Dependency.

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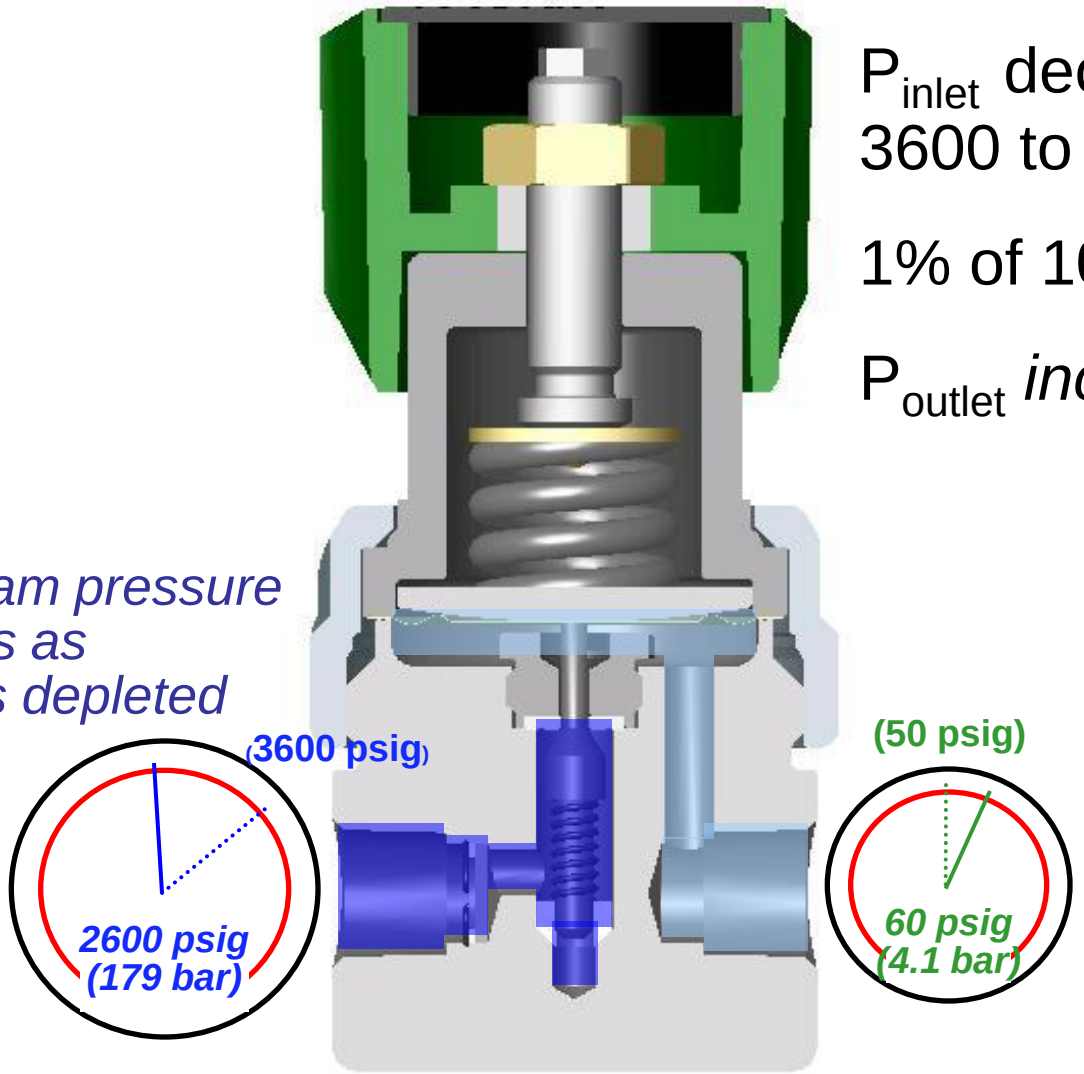
SPE in Action



For example, suppose we have a regulator with SPE = 1% of the inlet pressure change.

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SPE in Action



P_{inlet} decreases from 3600 to 2600 = 1000 psig

1% of 1000 psig = 10 psig

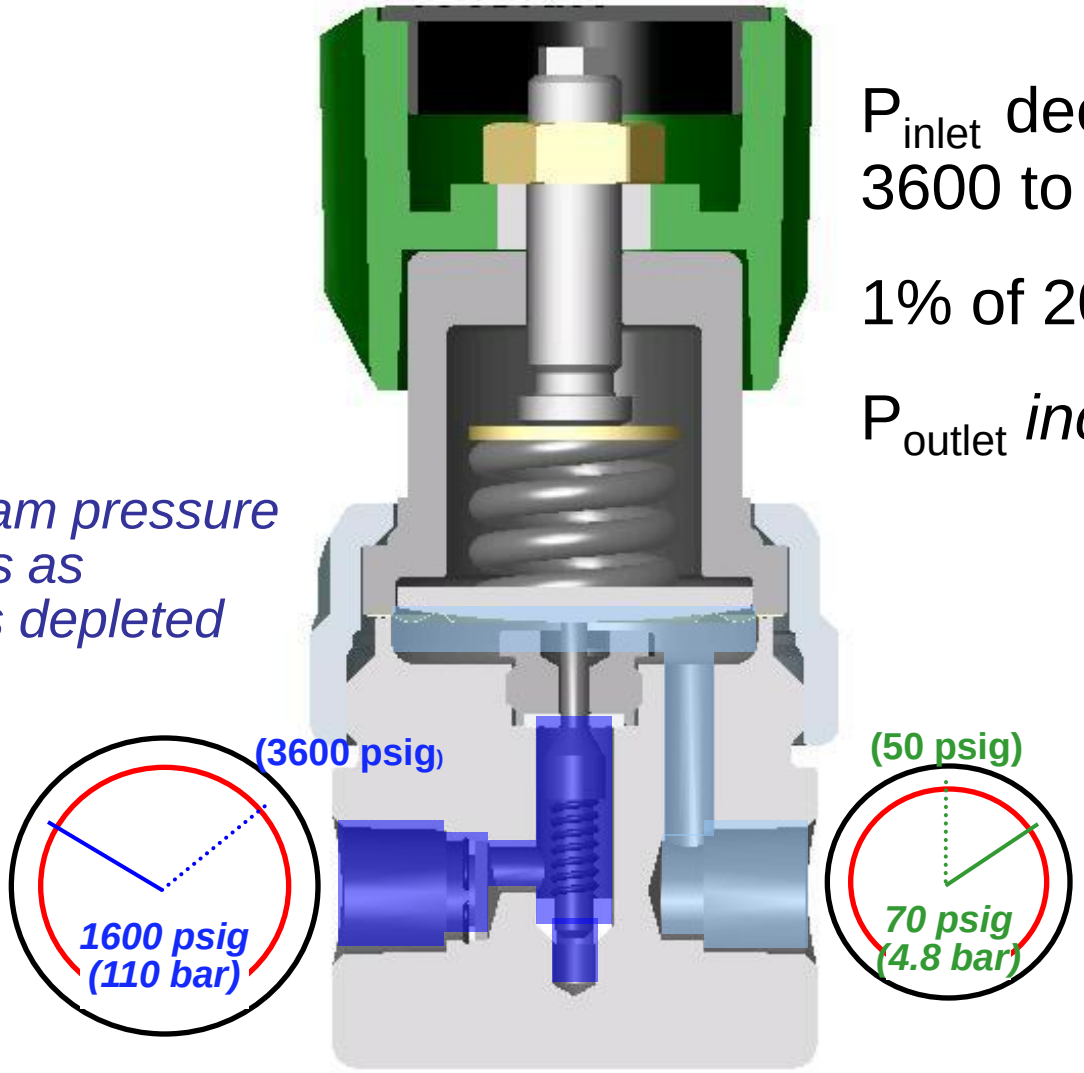
P_{outlet} *increases* 10 psig

1. *Upstream pressure decreases as cylinder is depleted*

2. *Downstream pressure increases 1% of the inlet decrease*

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SPE in Action



P_{inlet} decreases from 3600 to 1600 = 2000 psig

1% of 2000 psig = 20 psig

P_{outlet} *increases* 20 psig

1. *Upstream pressure decreases as cylinder is depleted*

2. *Downstream pressure increases 1% of the inlet decrease*

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So how do we help manage SPE?

Two-stage Pressure Reduction

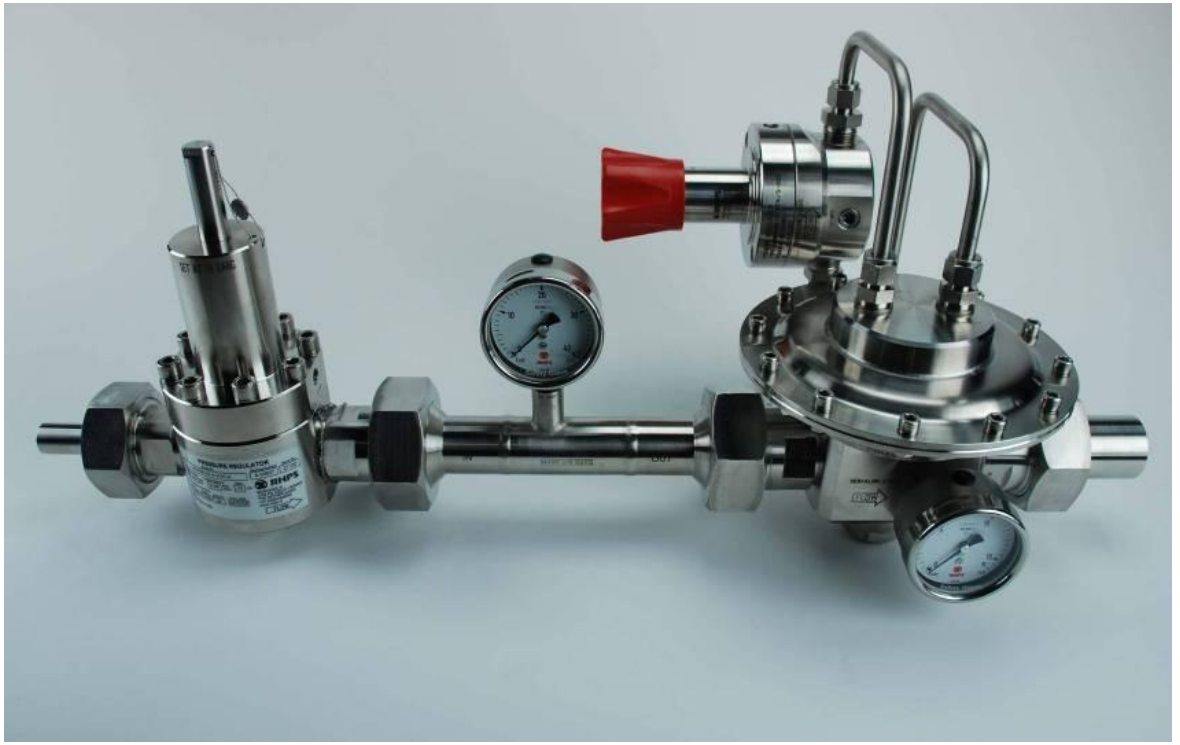
or

Modify the controlling mechanism…

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Two-Stage Pressure Reduction





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So how do we help manage SPE?

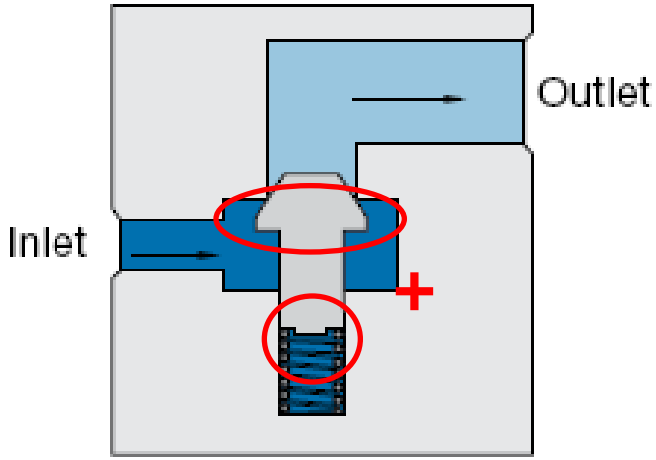
Two-stage Pressure Reduction

or

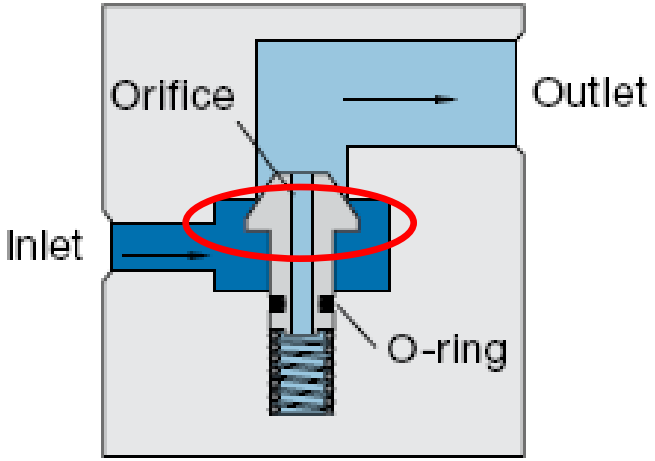
Modify the controlling mechanism…

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Balanced vs. Unbalanced Poppet Design



Unbalanced Poppet



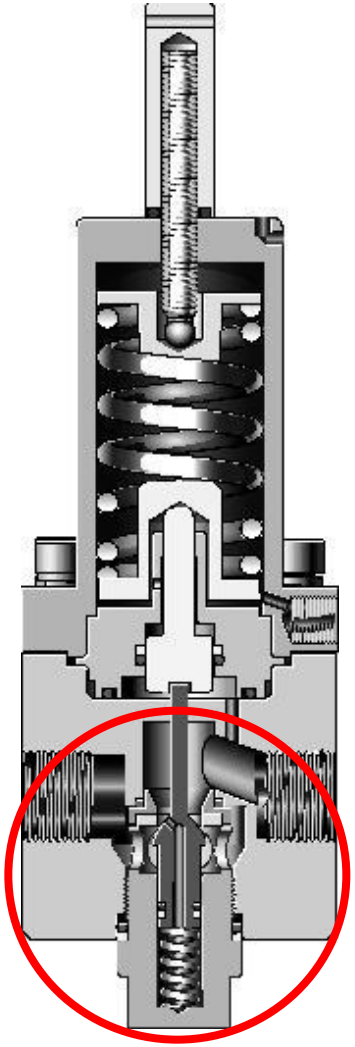
Balanced Poppet

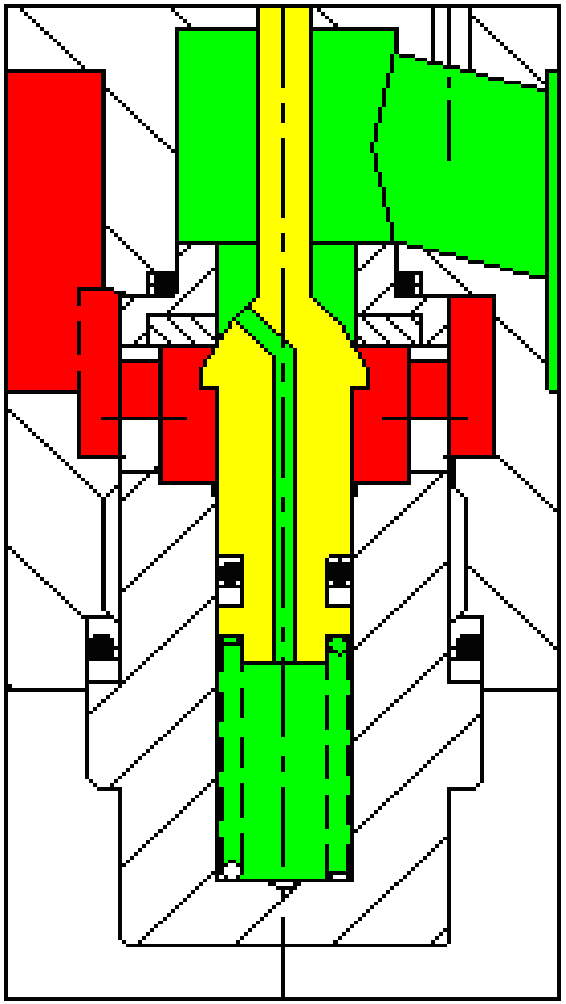
Balancing reduces the area on which P_{inlet} acts.

Advantages: **-Less sensitivity to Supply Pressure Effect**

-Reduced Seat Load Larger seat can be used for more flow

Balanced Poppet





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Swagelok Regulator Resources

Regulator Support Website

http://www.swagelok.com/CAregulatorsolutions/

Regulator Reference Guide



Local Swagelok Distributors

- Edmonton Valve & Fitting Inc. 780.437.0640
- Swagelok Grande Prairie 780.538.4280
- Calgary Valve & Fitting 403.243.5646
- Swagelok Central Canada (Winnipeg) 204.633.4446
- Columbia Valve & Fitting Ltd. (Vancouver) 604.629.9355

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