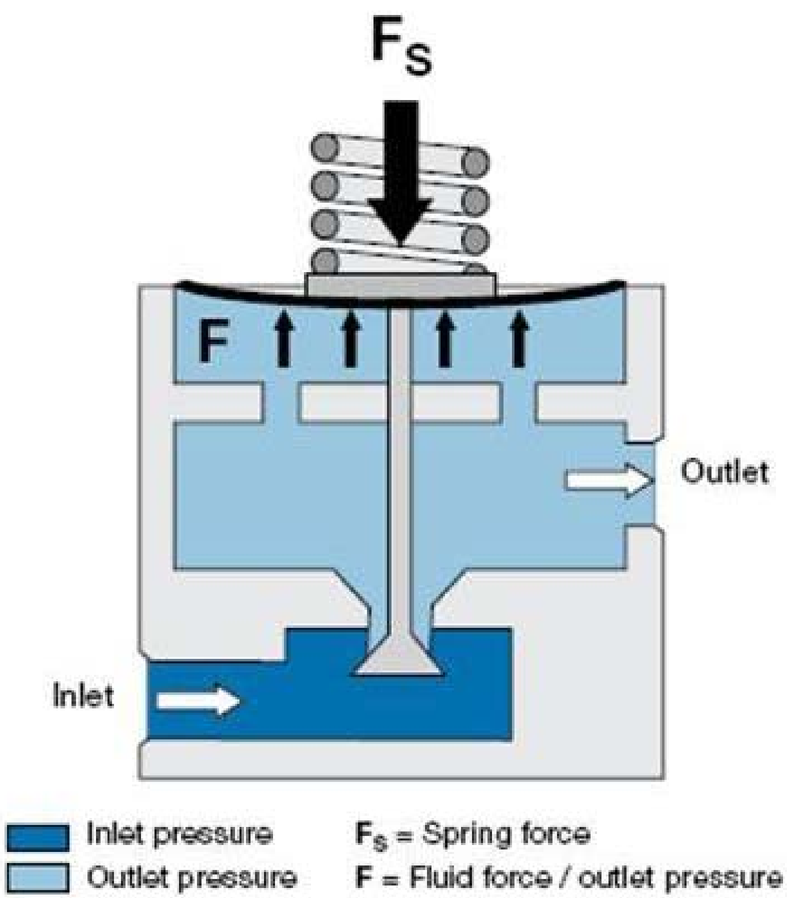
Introduction to Regulator Theory and Operation

Agenda

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

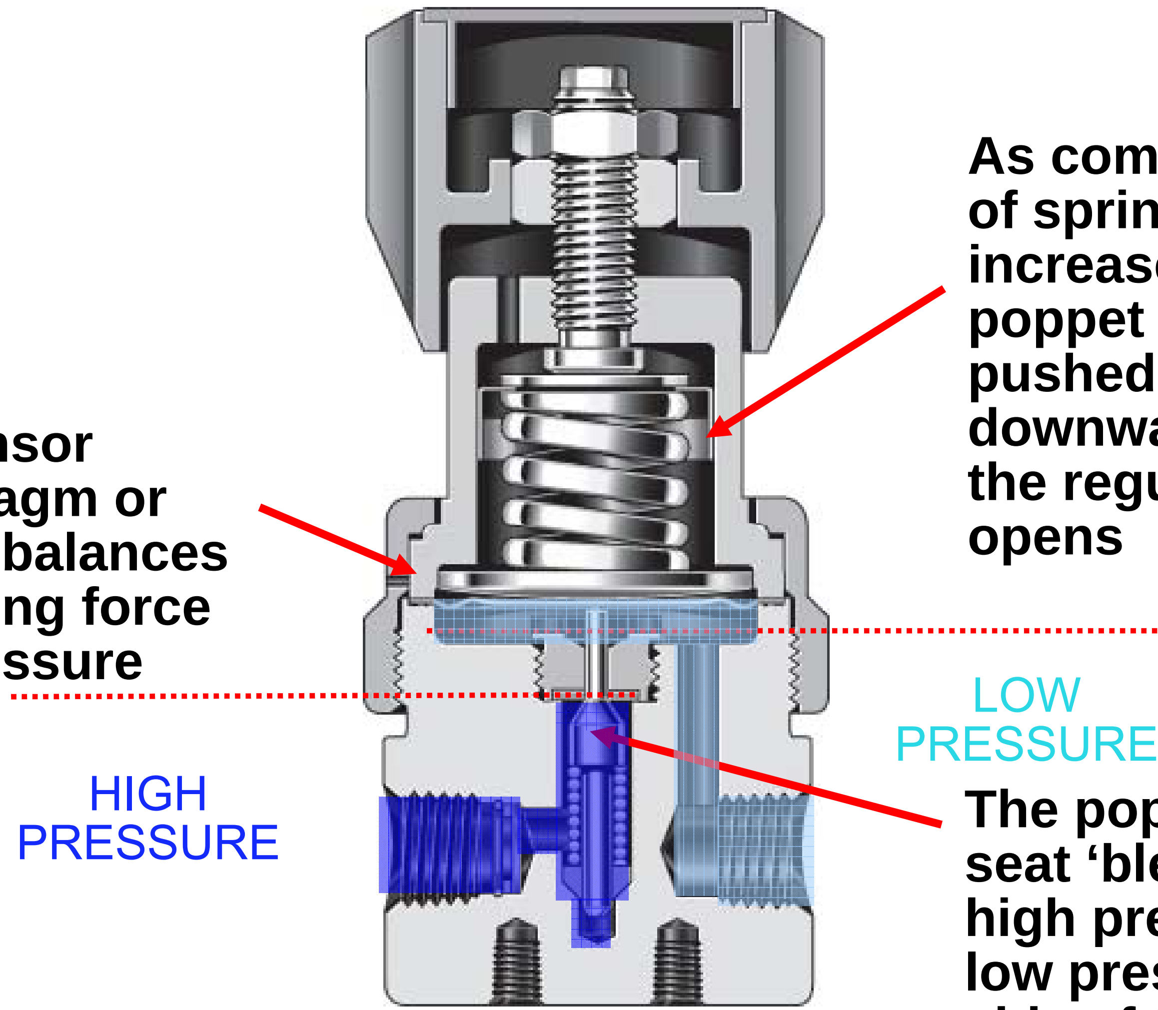
Operating Principle

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.

Operating Principle

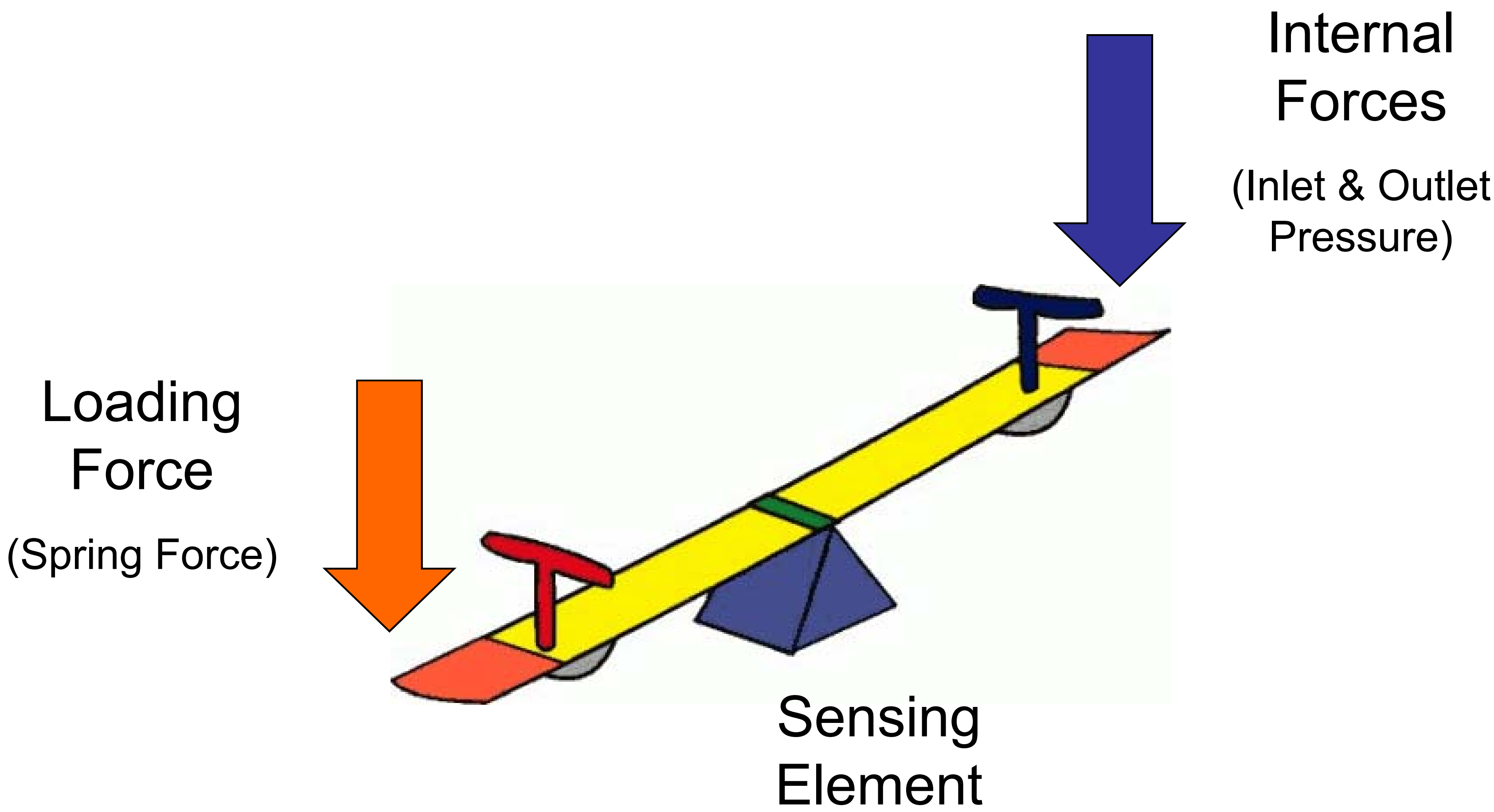


The sensor (diaphragm or piston) balances the spring force and pressure forces

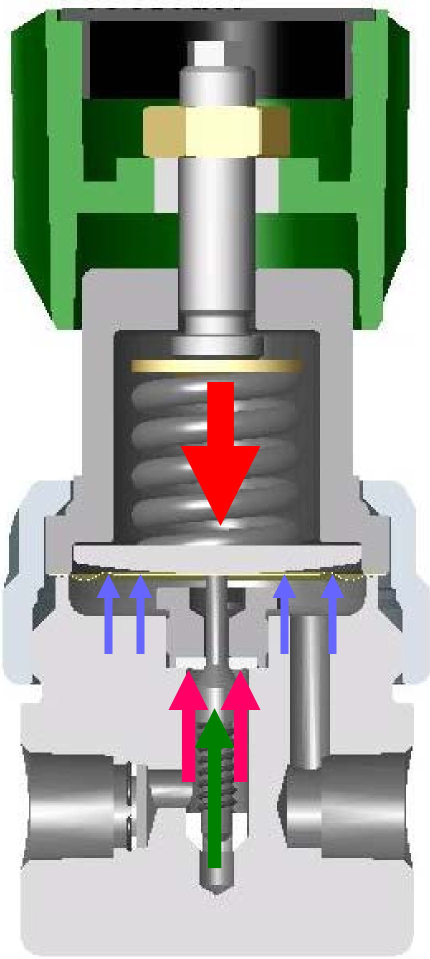
As compression of spring increases, the poppet is pushed downwards and the regulator opens

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

Balance of Forces



Balance of Forces



F_1 = Loading Force

F_2 = Inlet Spring Force

F_3 = Outlet Pressure Force

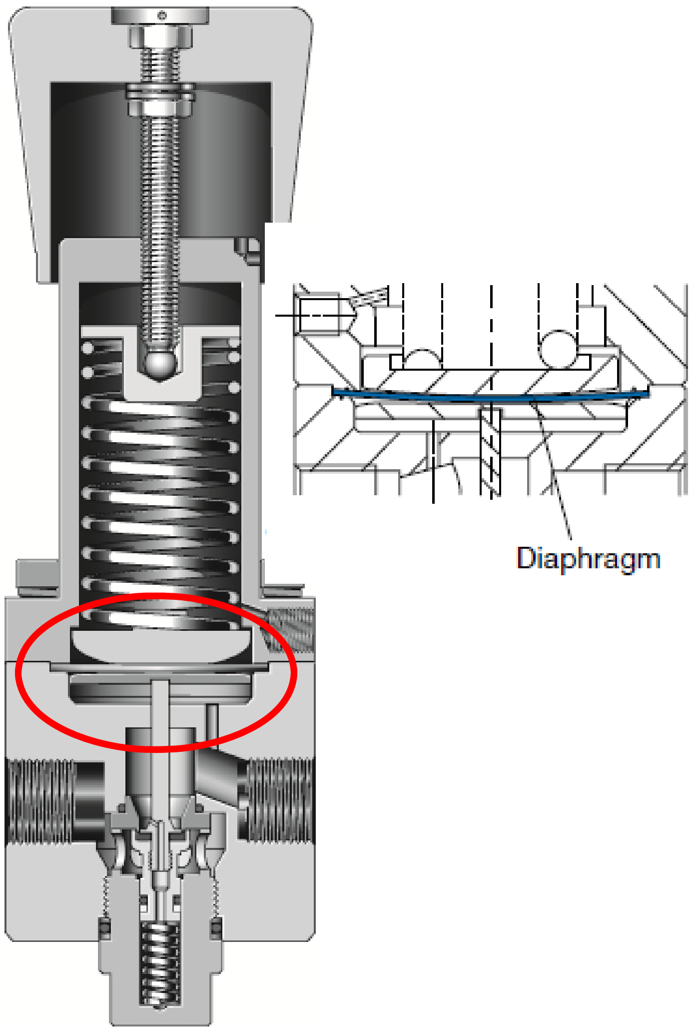
F_4 = Inlet Pressure Force

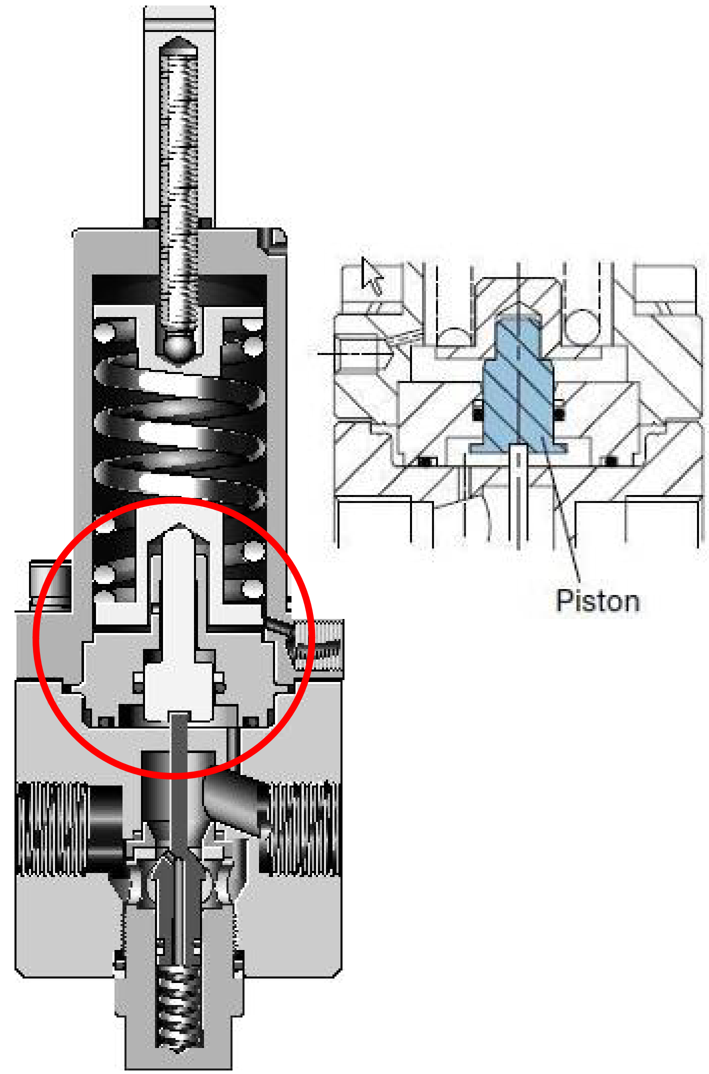
$$F1 = F2 + F3 + F4$$

Loading Force

Internal Forces

Two Types of Sensing Elements

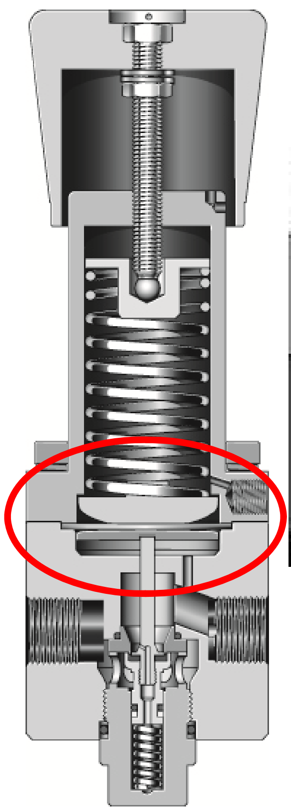


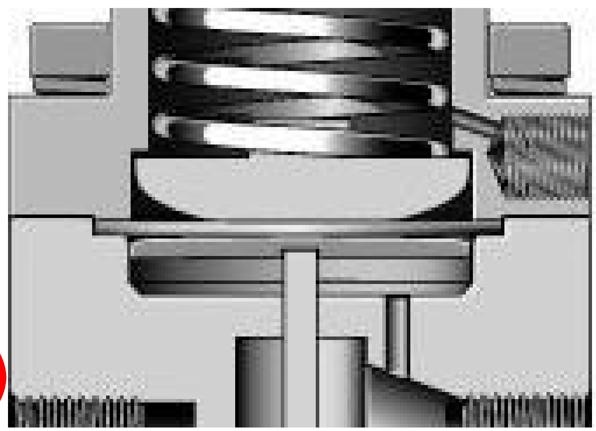


Diaphragm vs. Piston Sensing

Diaphragm

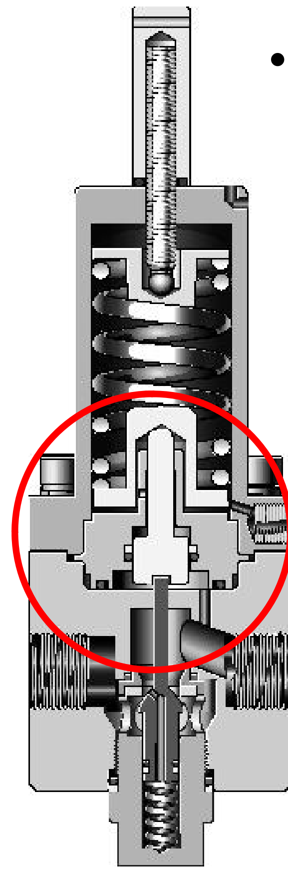
- Greater sensitivity
- Choice of material

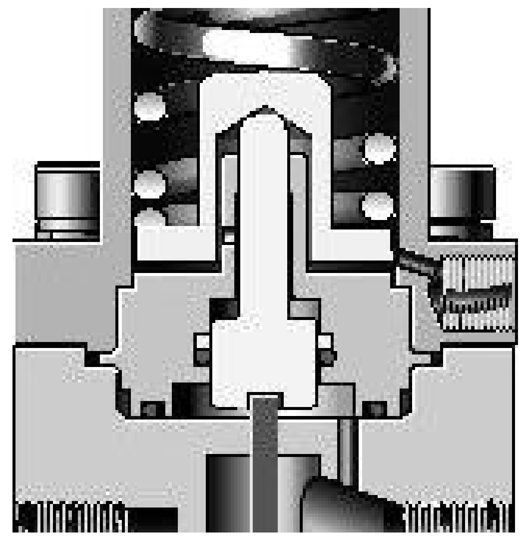




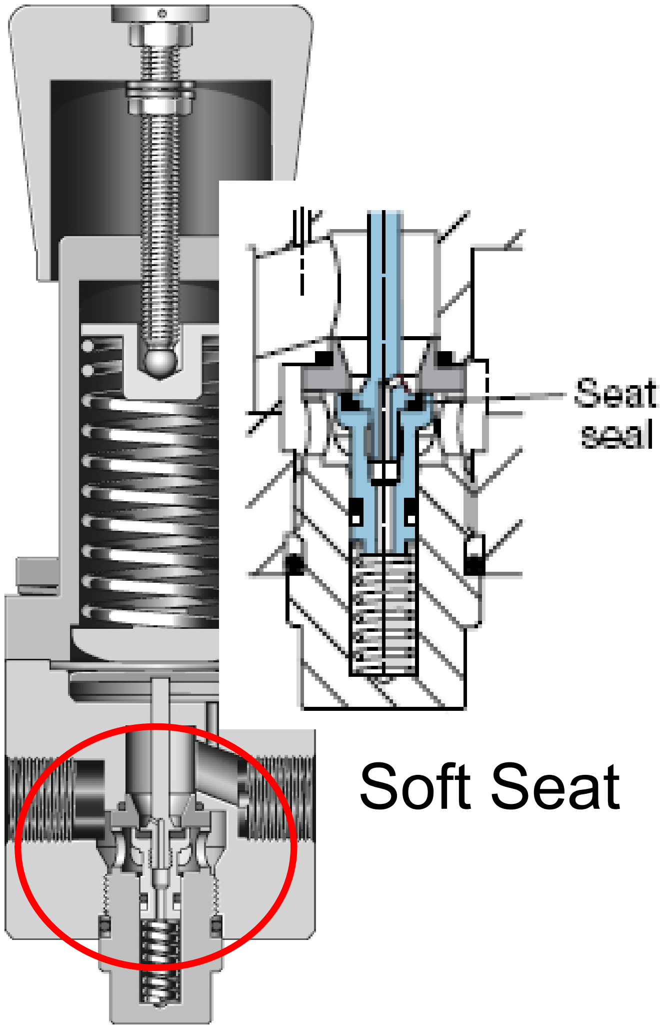
Piston Sensing

- Higher outlet pressure
- Less sensitive

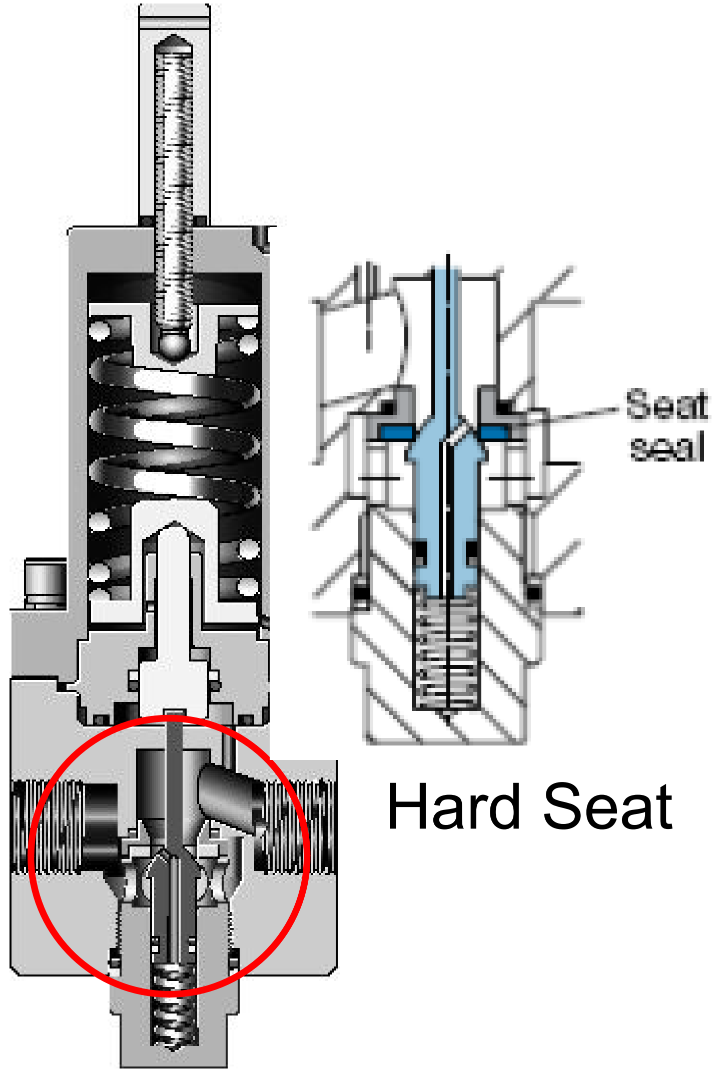




Soft Seat vs. Hard Seat

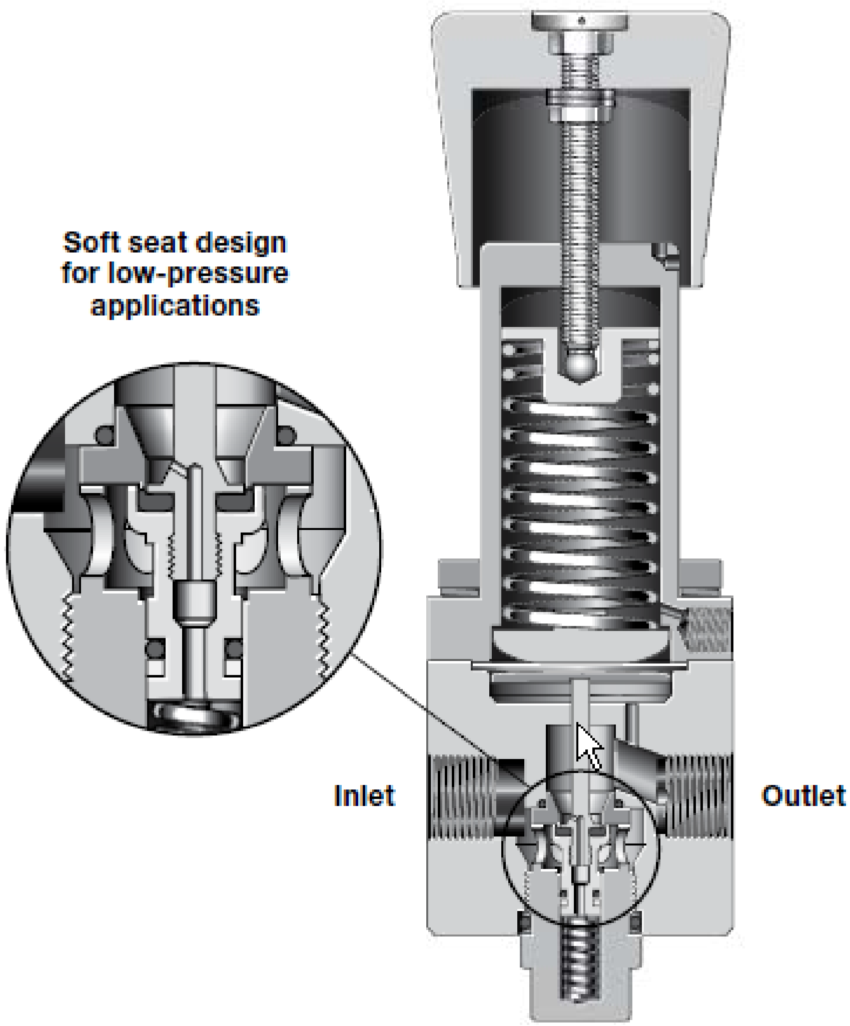


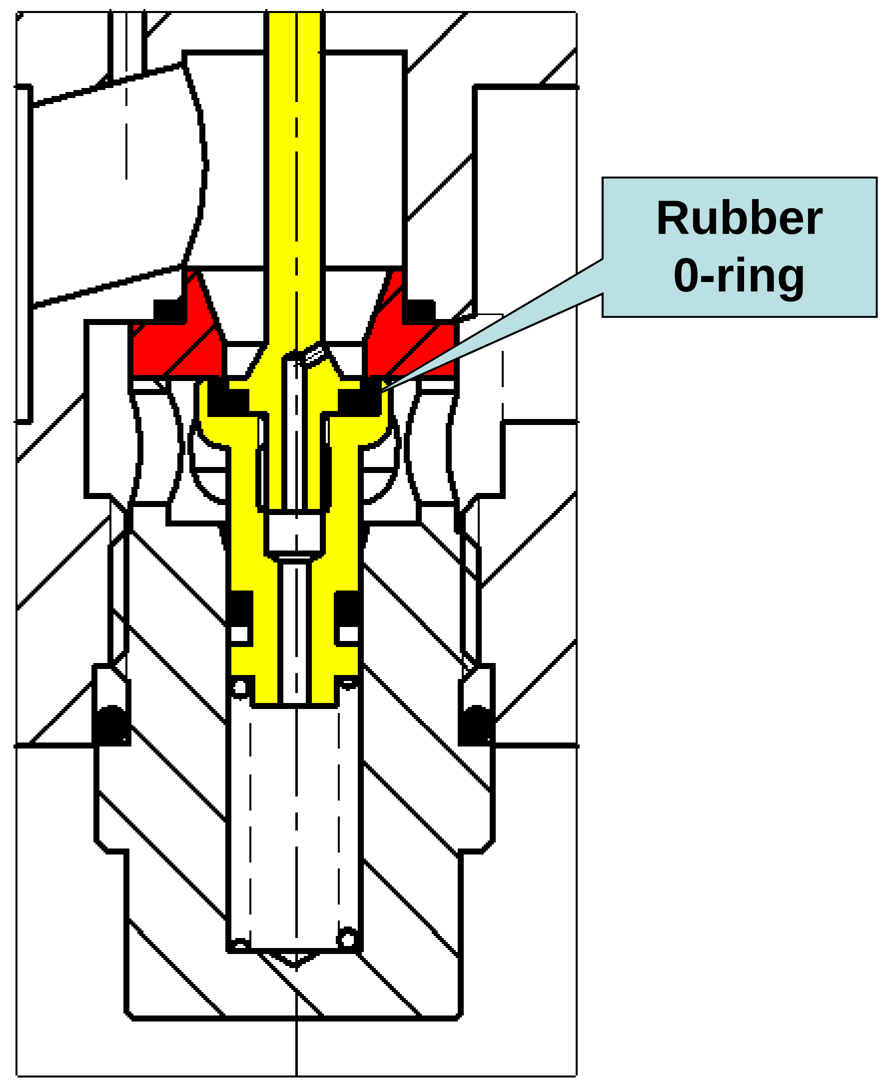
Soft Seat



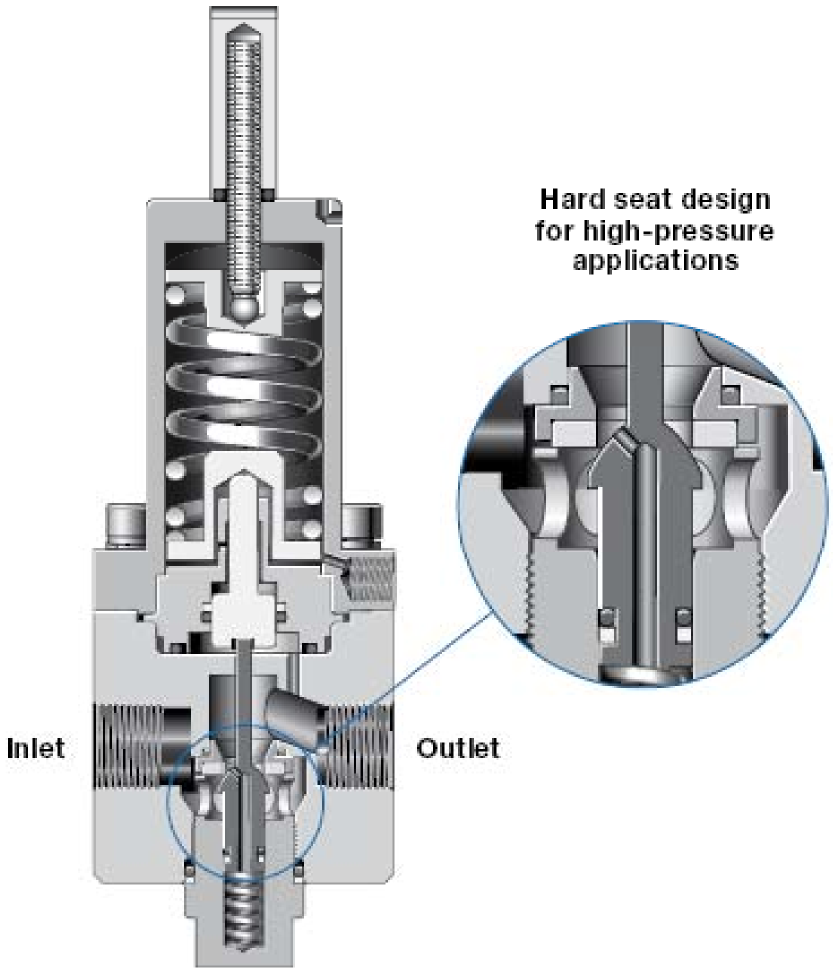
Hard Seat

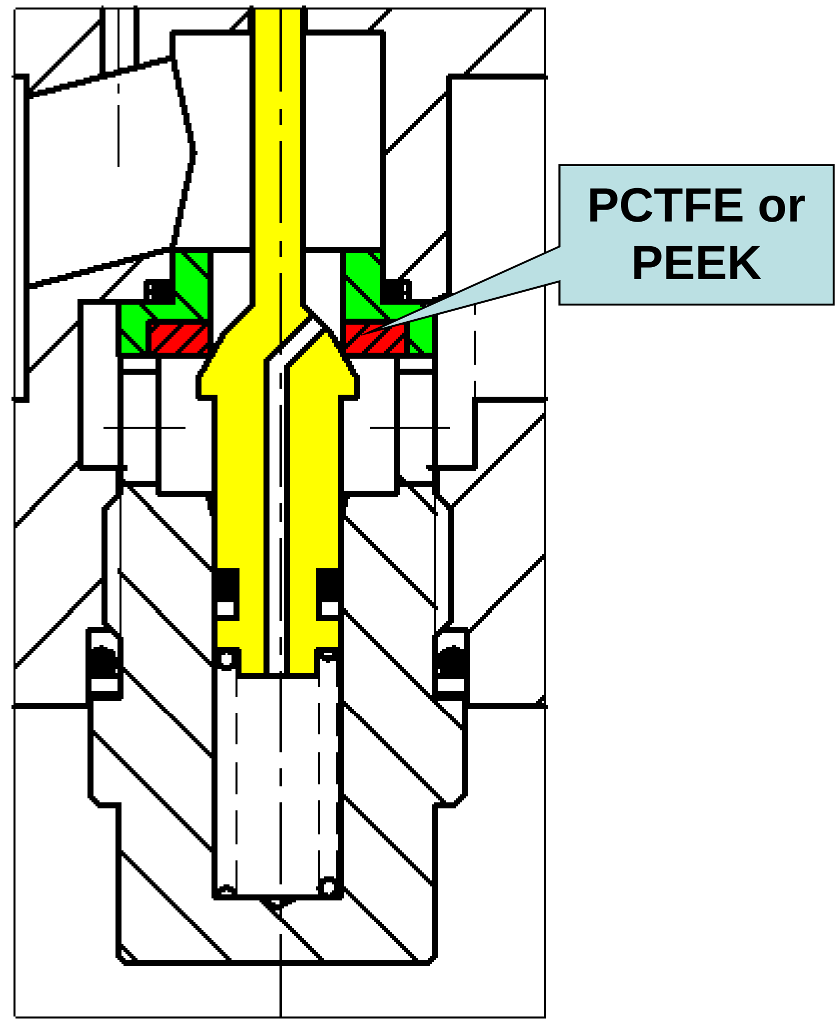
Regulator with Soft Seat





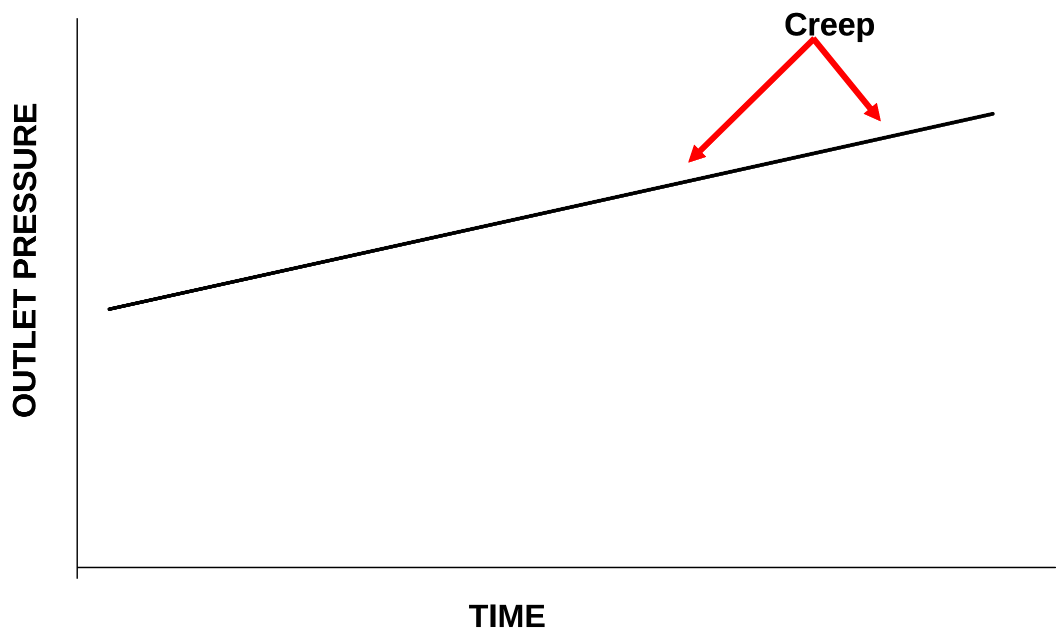
Regulator with Hard Seat





Creep

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



Regulators are not shut off devices…

Loading Mechanisms

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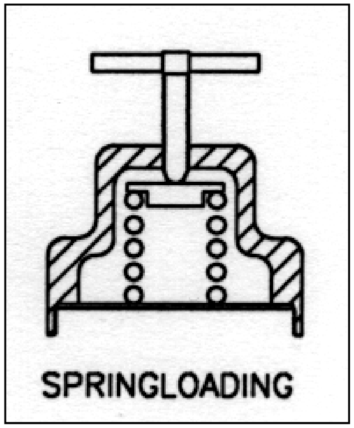
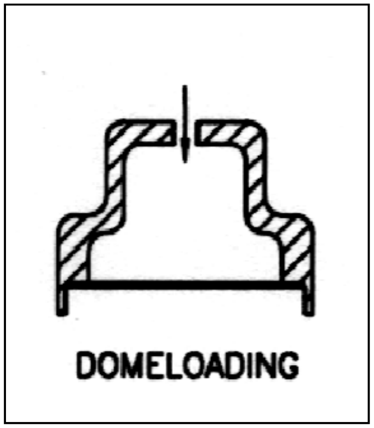
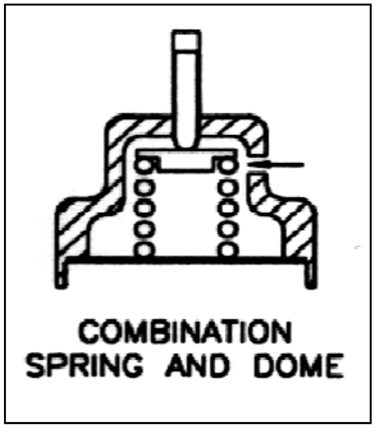
3 TYPES







Spring-Loaded Regulators

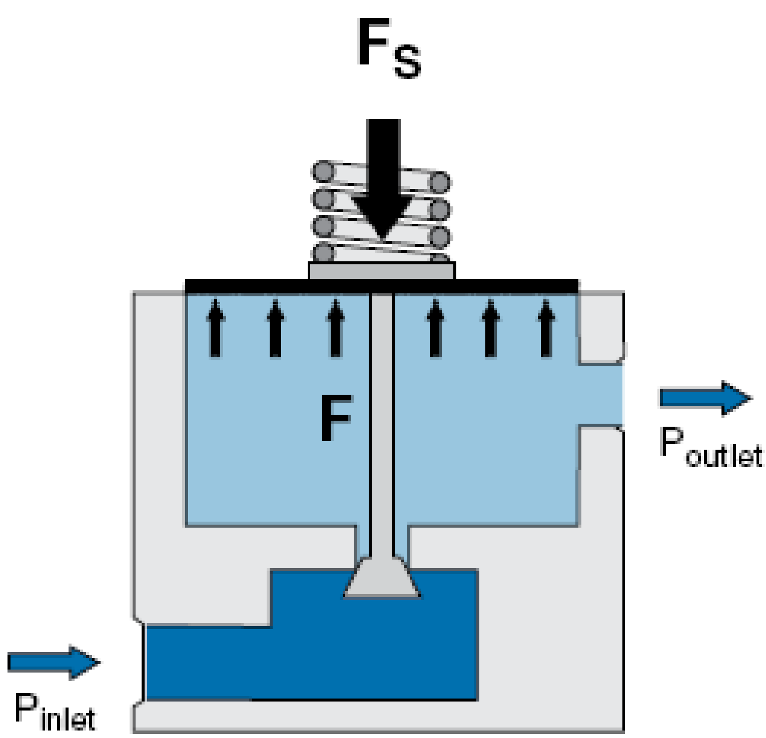
Loading Mechanism

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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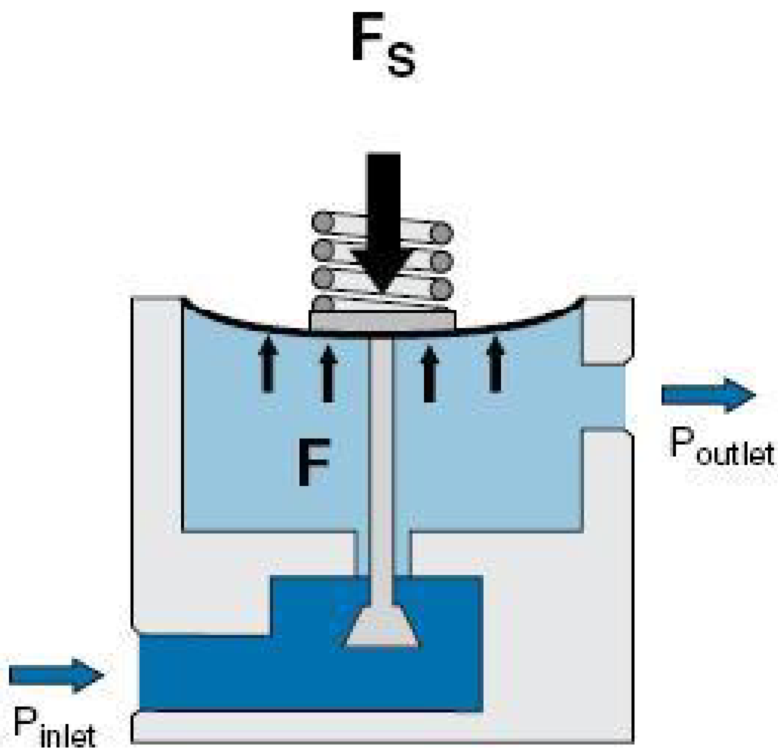
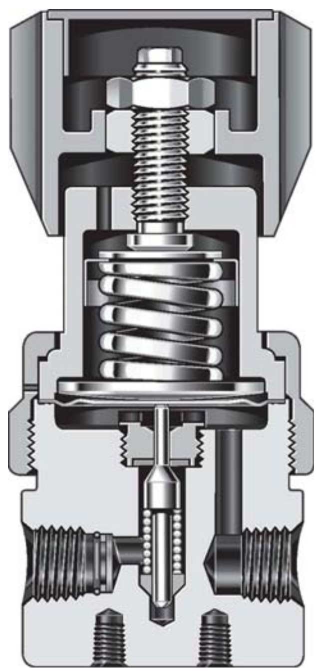
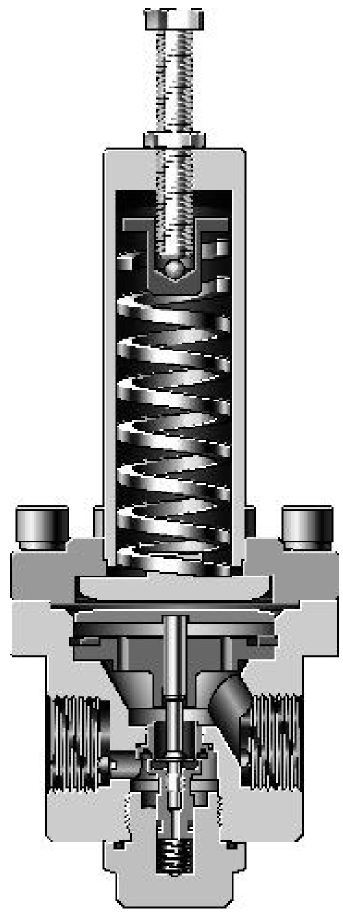
$F_s > F$



Spring-Loaded Pressure Regulator

Swagelok





Instrumentation Type

Process Type

Spring-Loaded Regulator Flowcurves

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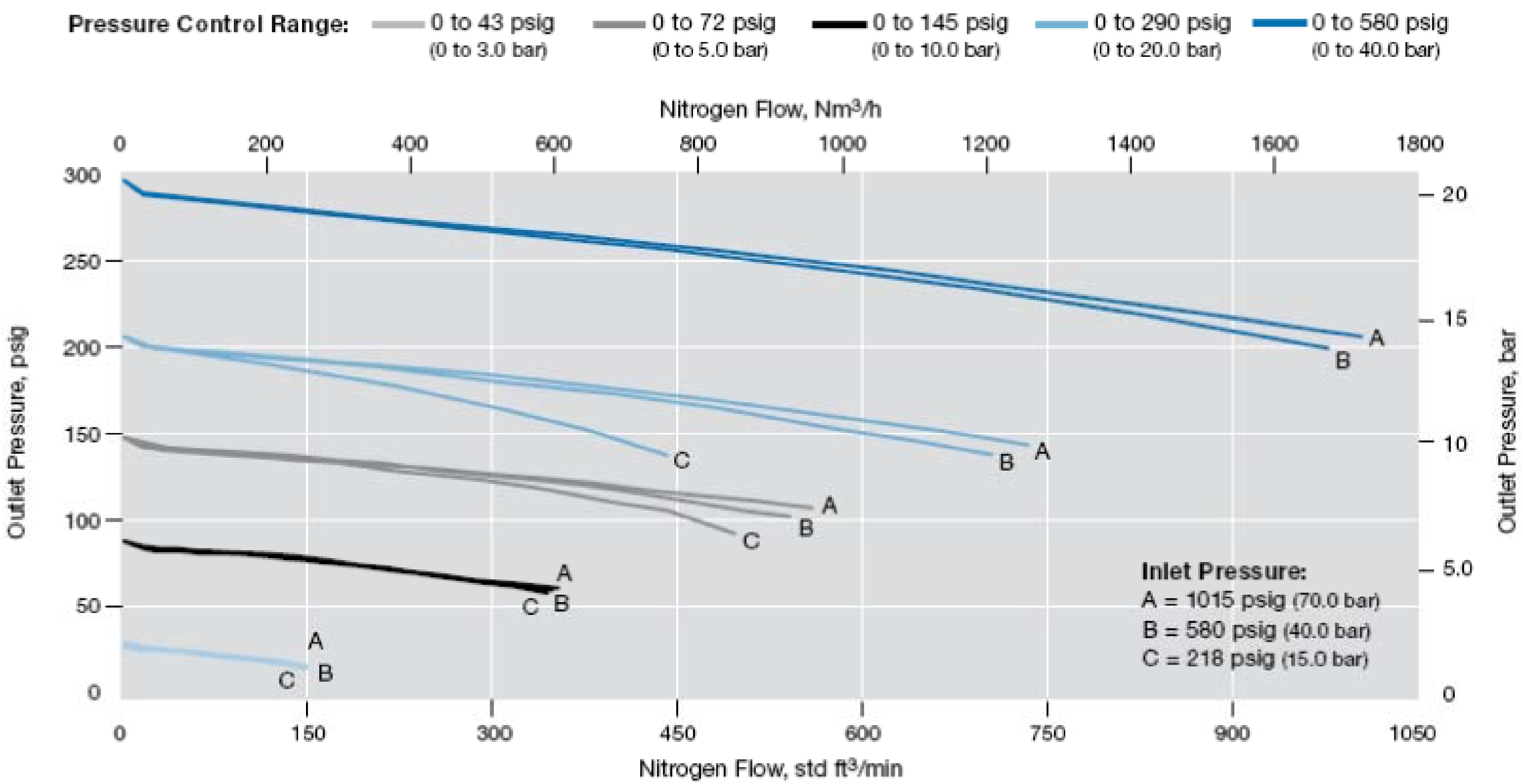
Flow Coefficient: 3.79

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

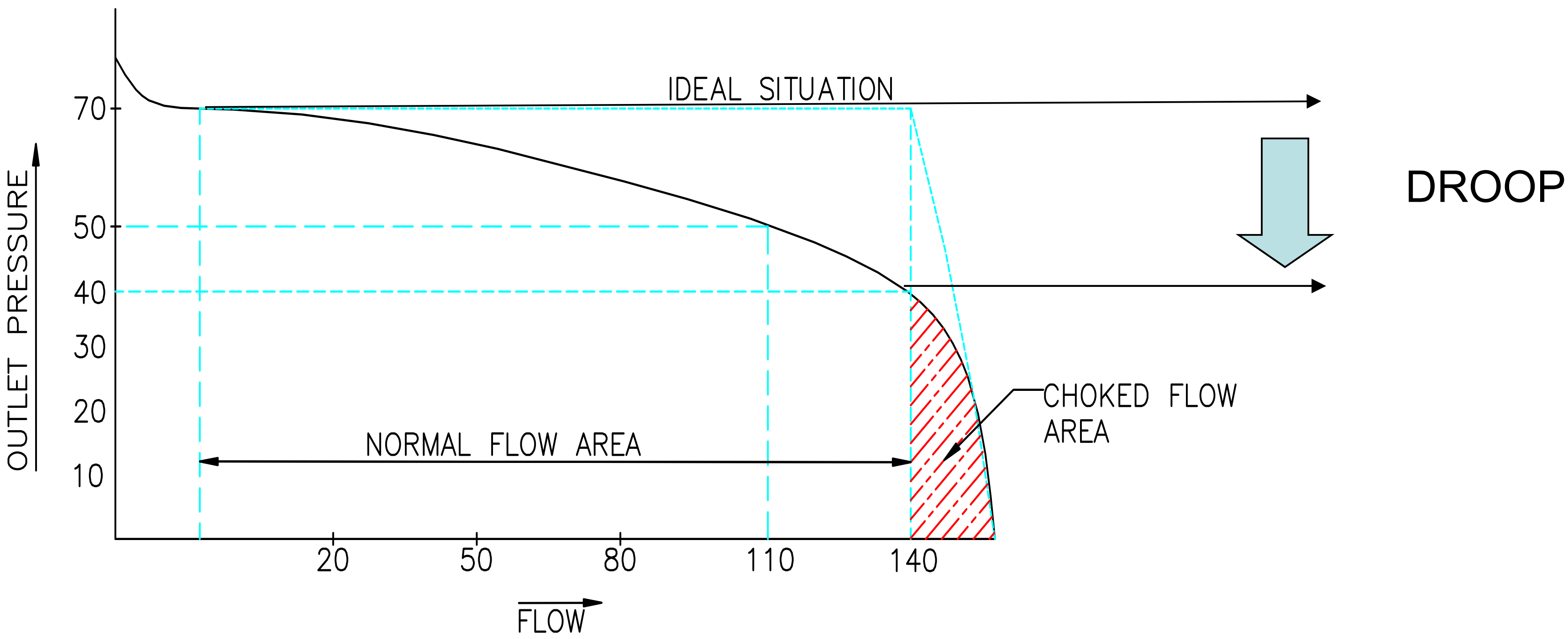
Outlet Pressure Control Range: 0 to 3625 psig (0 to 250 bar)



Pressure-Reducing Regulator

Droop

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



Dome-Loaded Regulators

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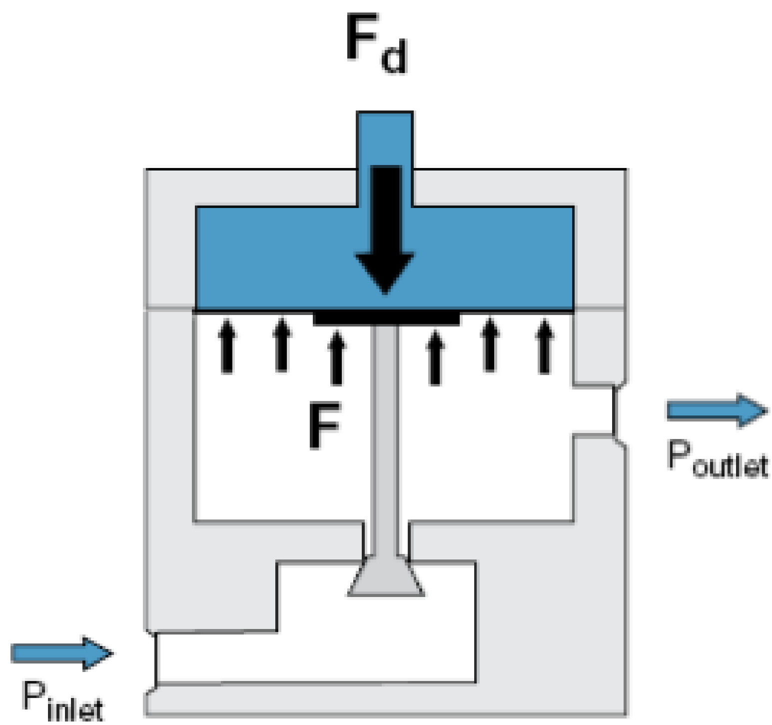
Dome-Loaded

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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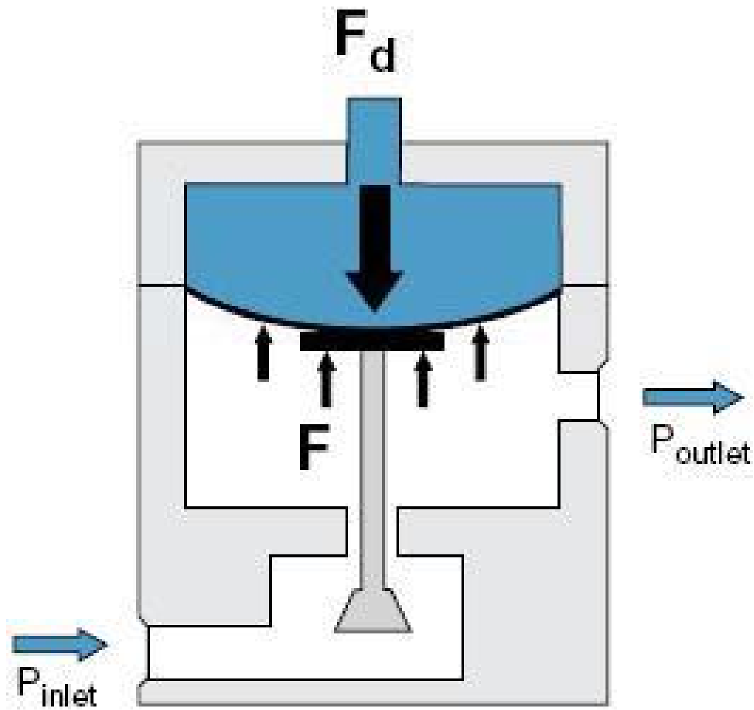
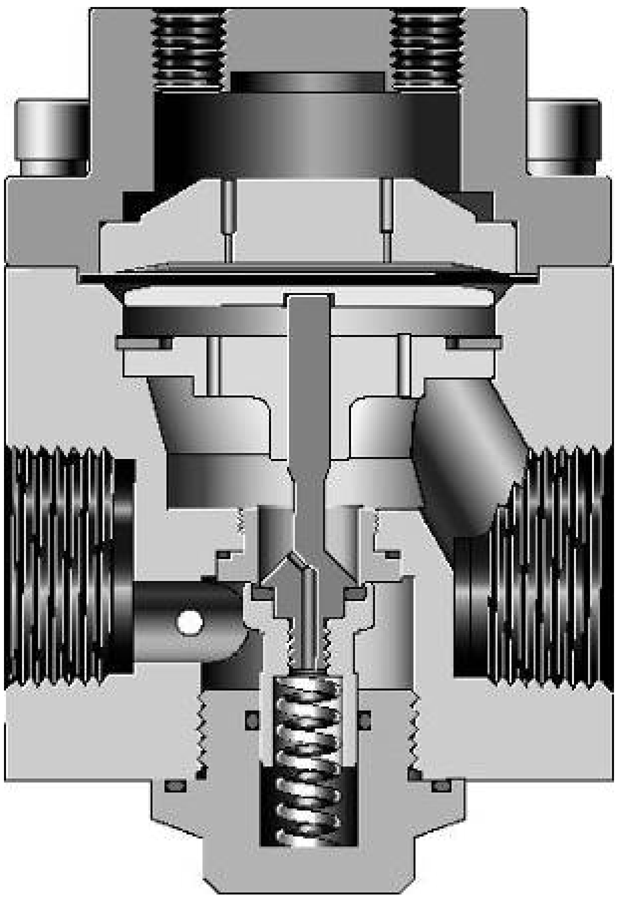
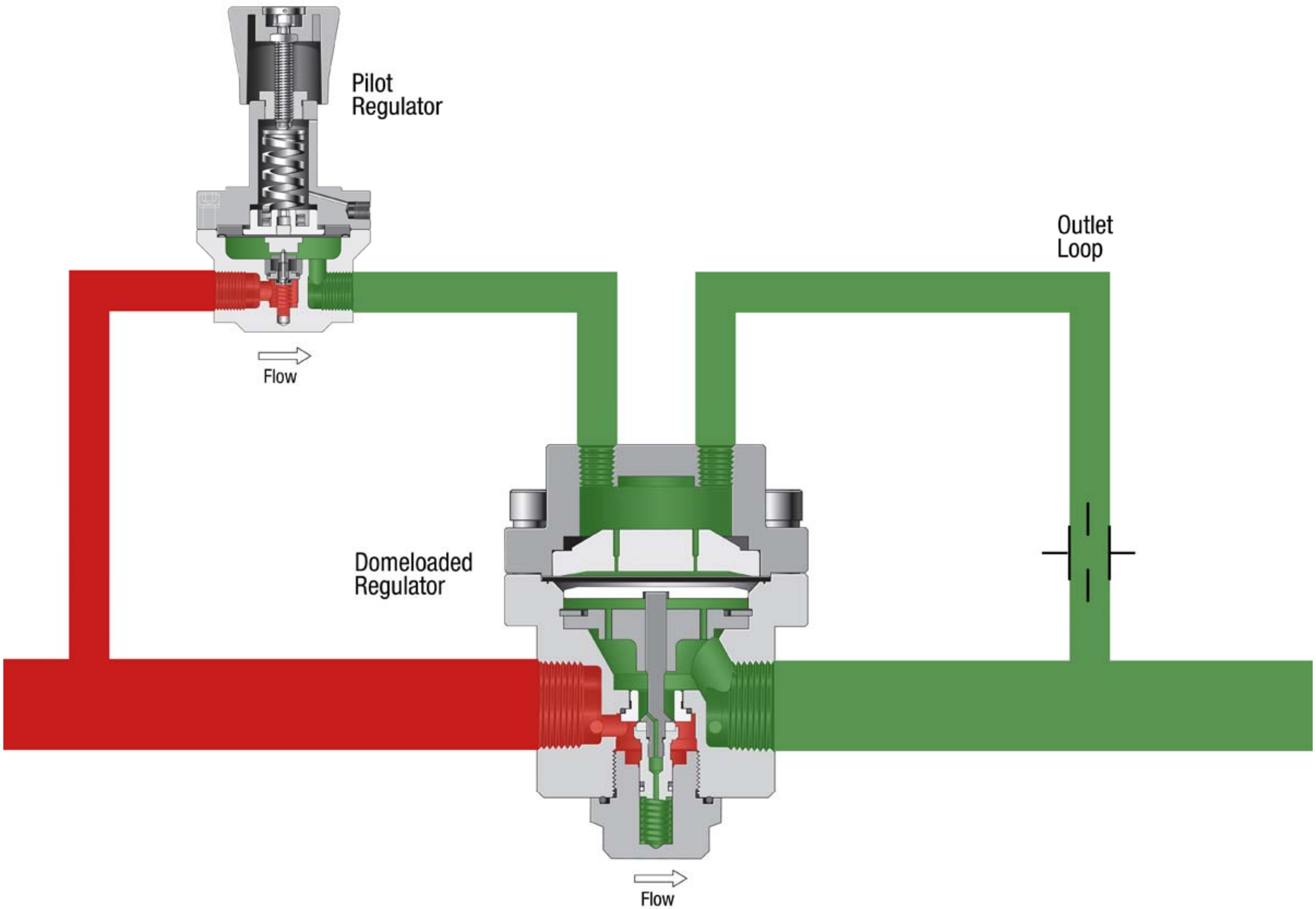
$F_d > F$



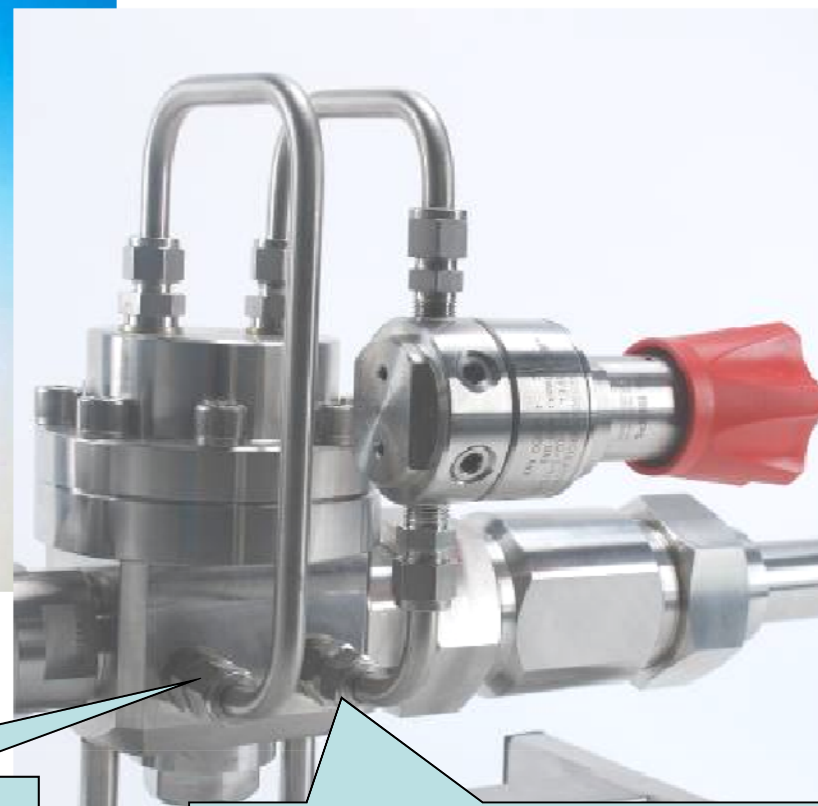
Dome-Loaded Pressure Regulator



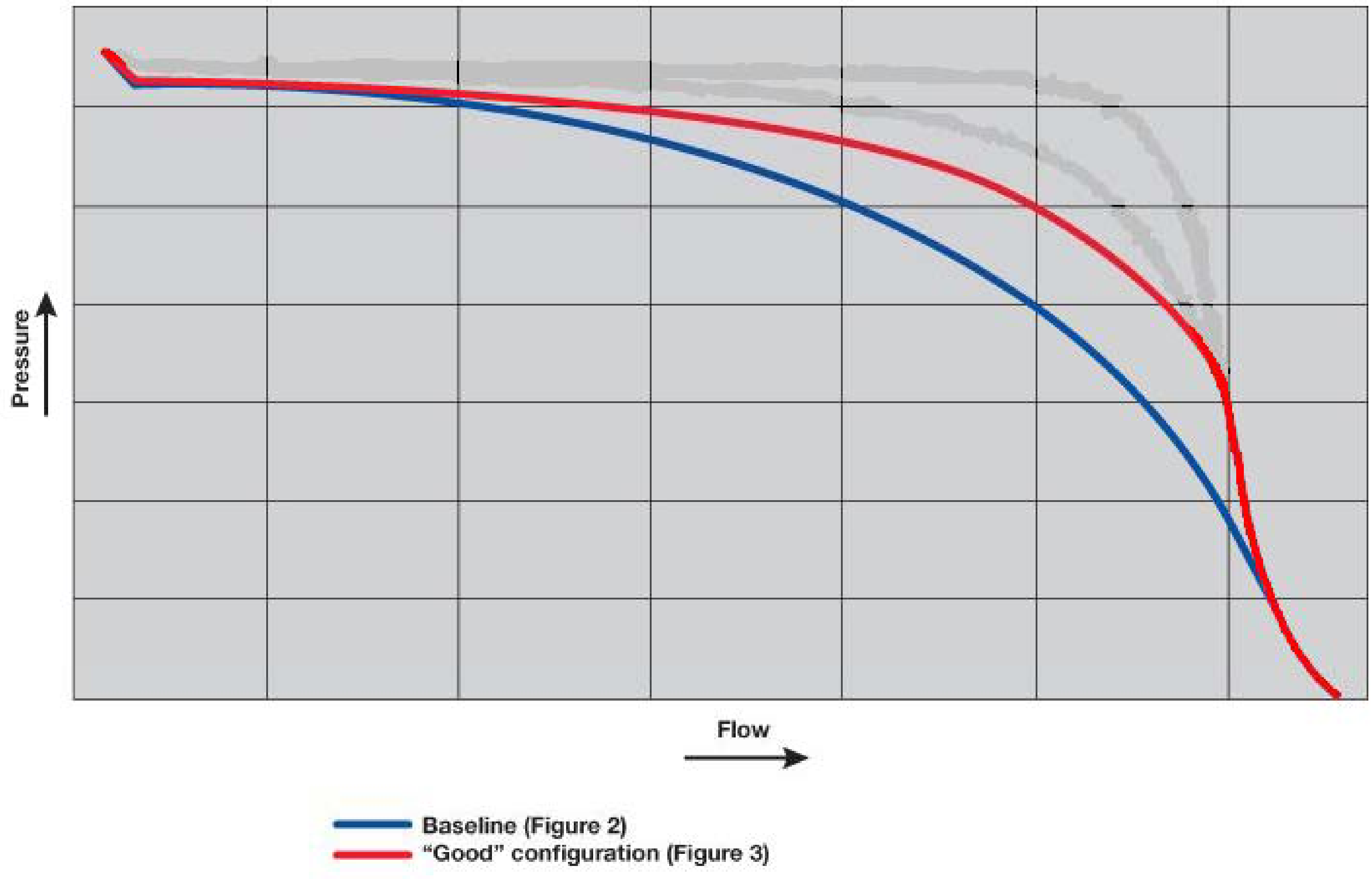
Dynamic Control



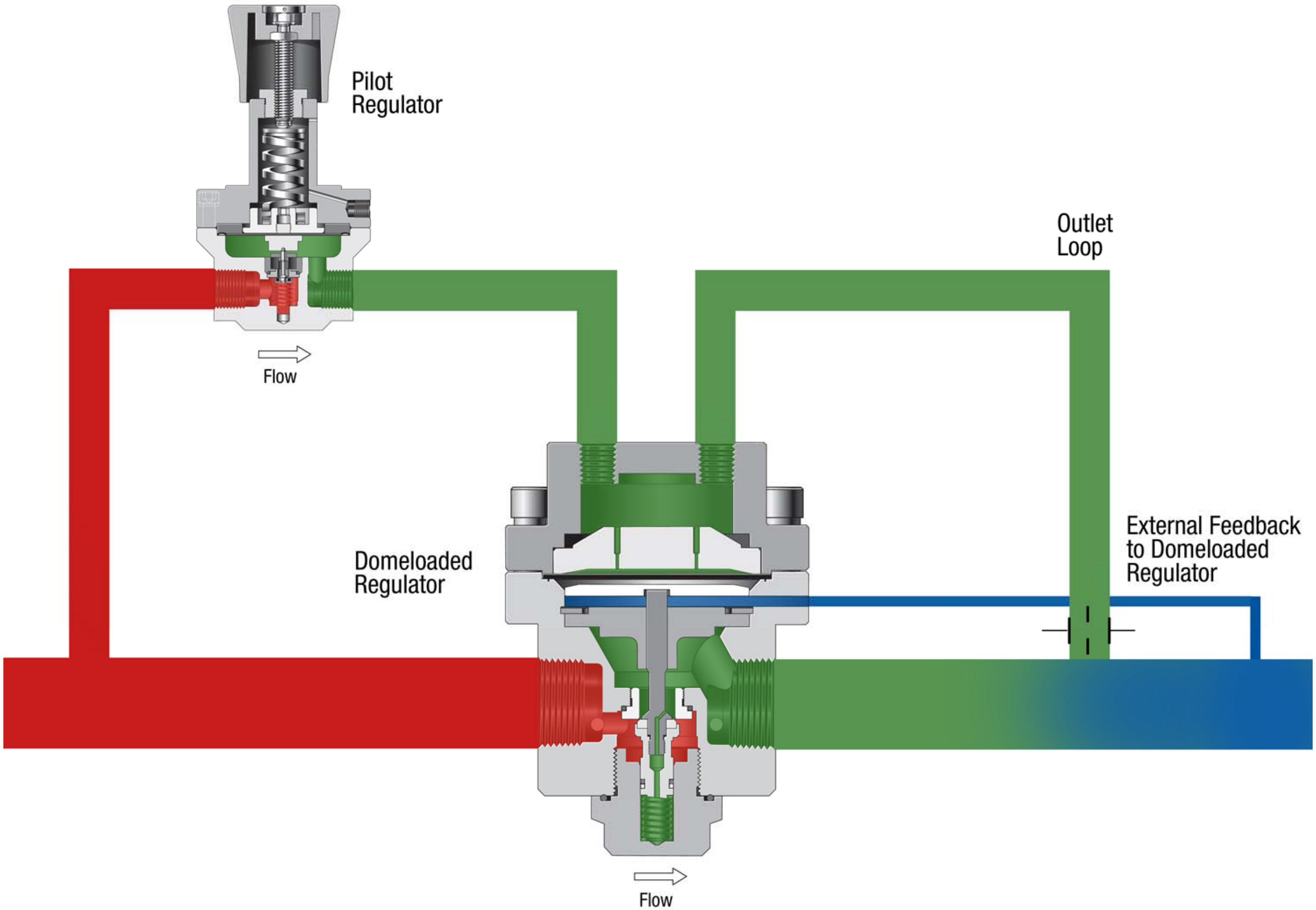
Dynamic Control



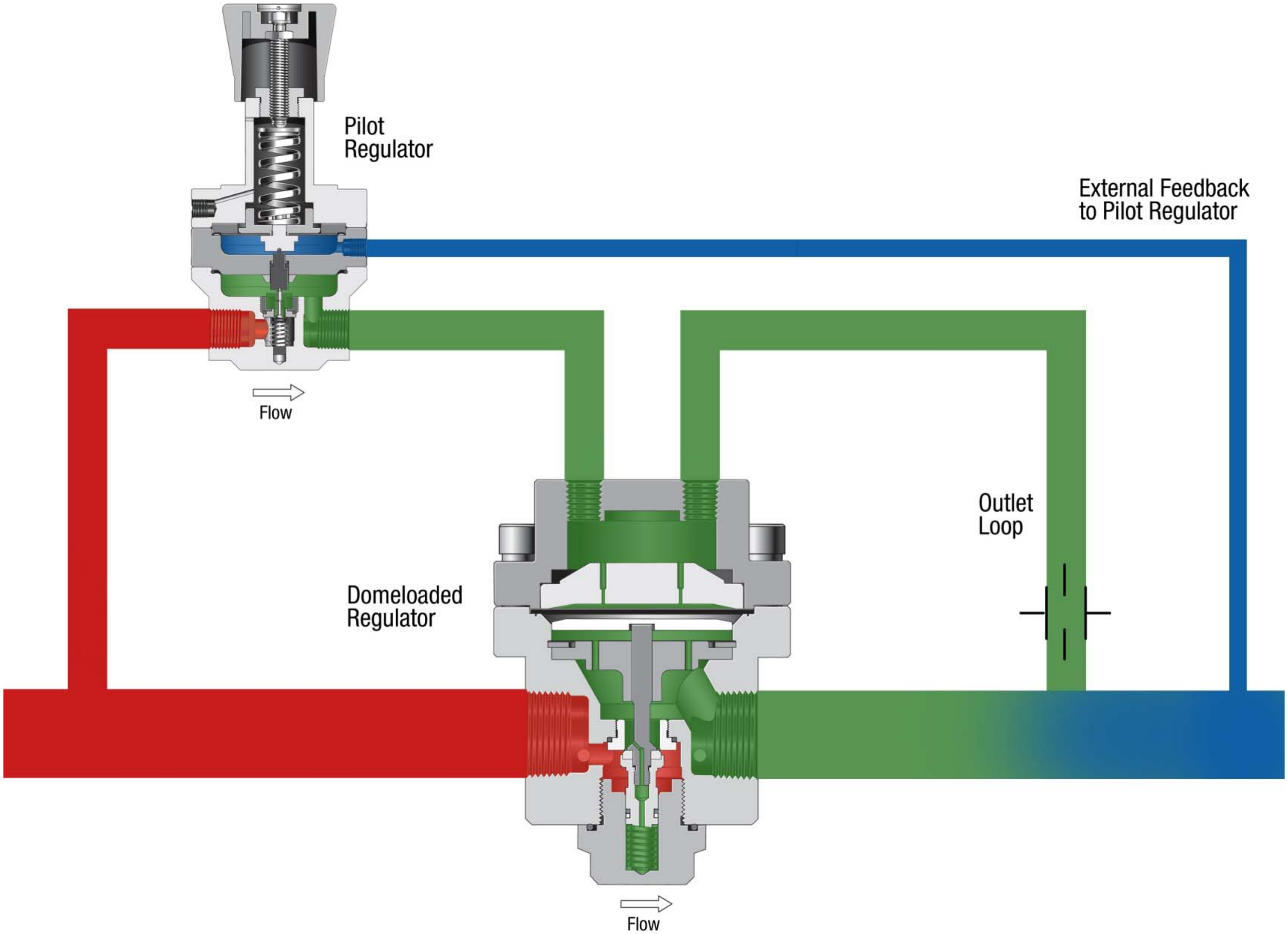
Dome-Loaded Regulator Flowcurves



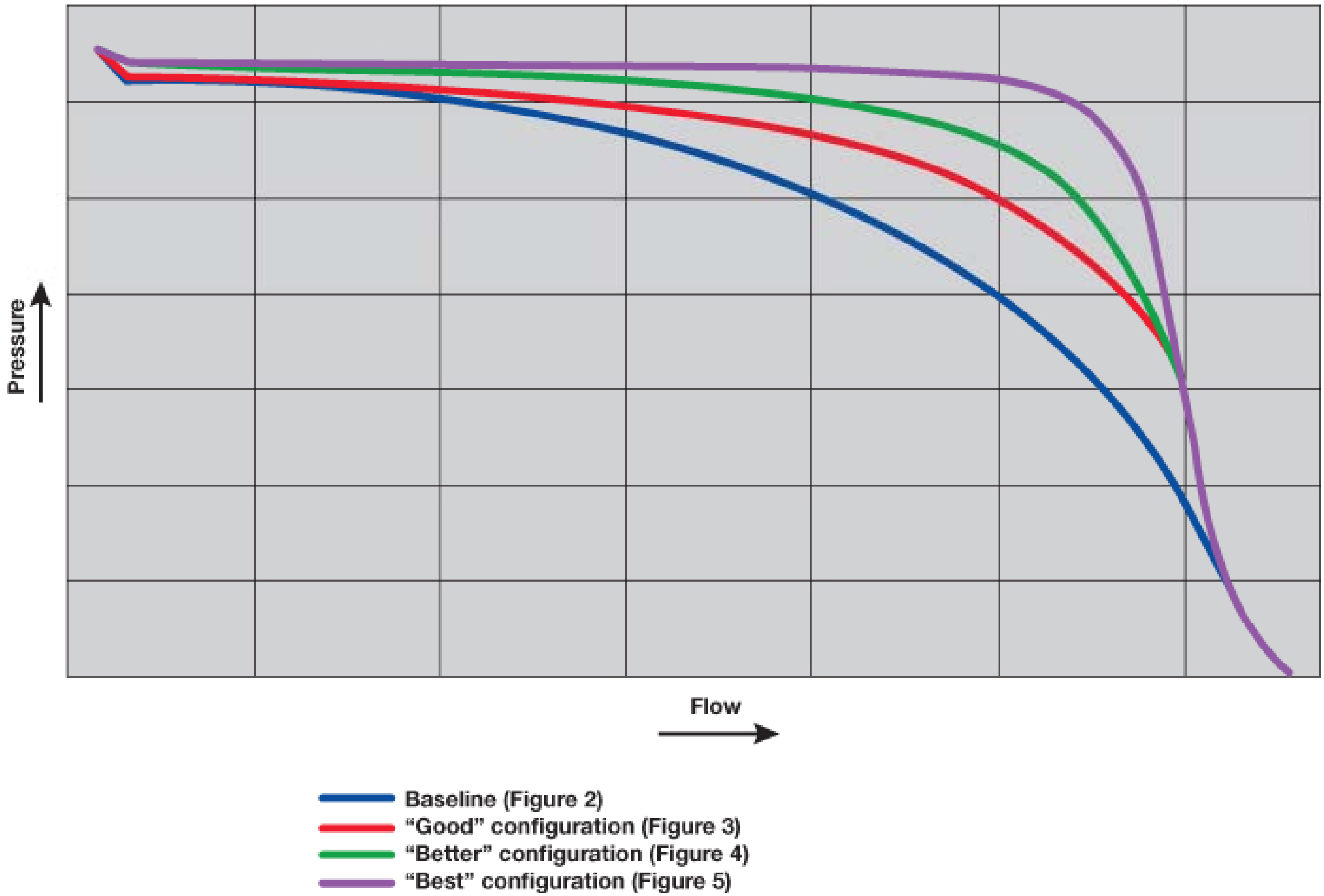
Dome-Loading
with External Feedback to Main



Dome-Loading with External Feedback to Pilot



Improving the Flow Curve



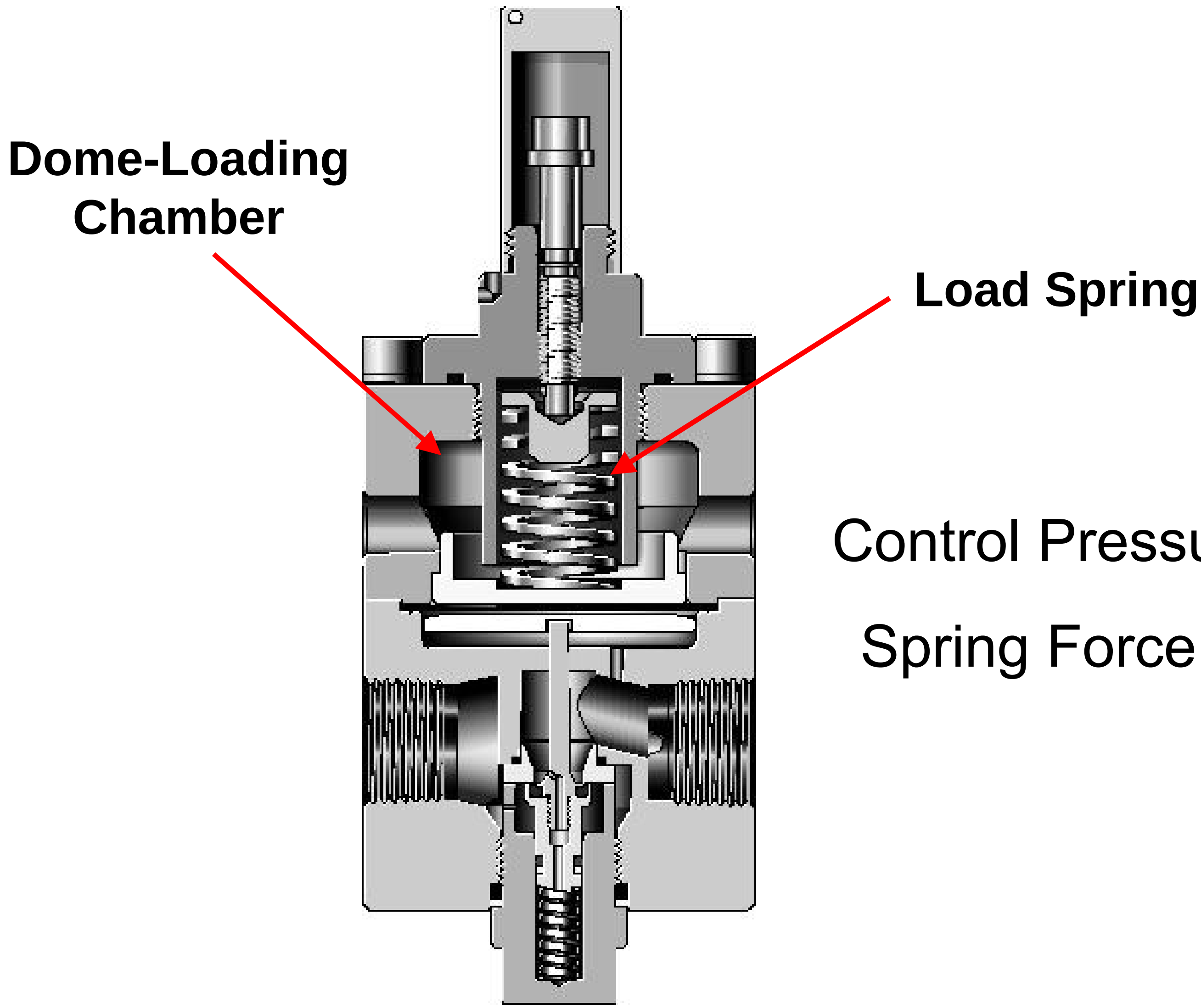
Dome-Loaded with Feedback to Pilot

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).

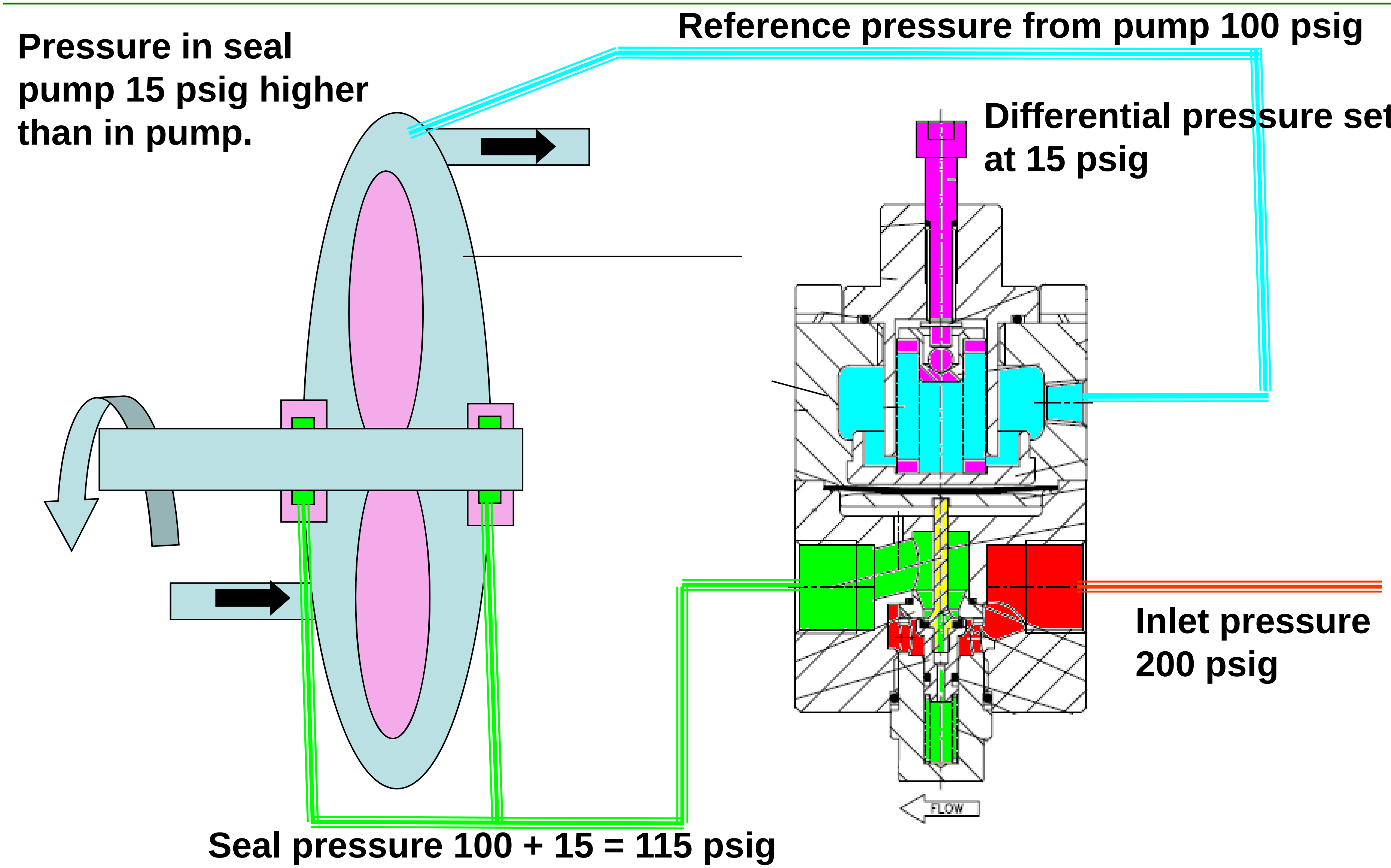
Differential Pressure Regulator



Control Pressure =

Spring Force + Dome Pressure

Differential Pressure Regulator Application



Regulator Terminology

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

Lockup

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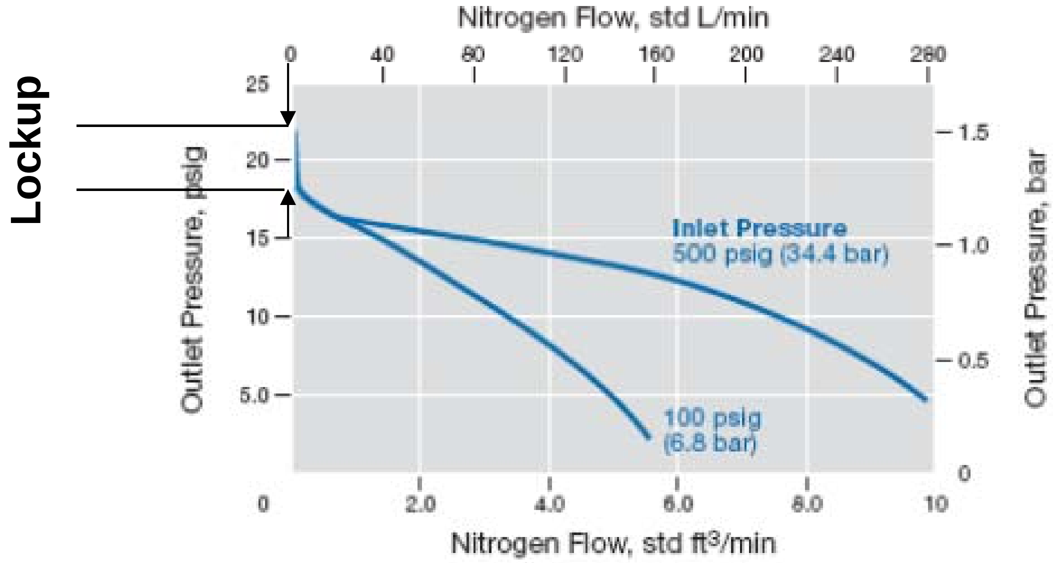
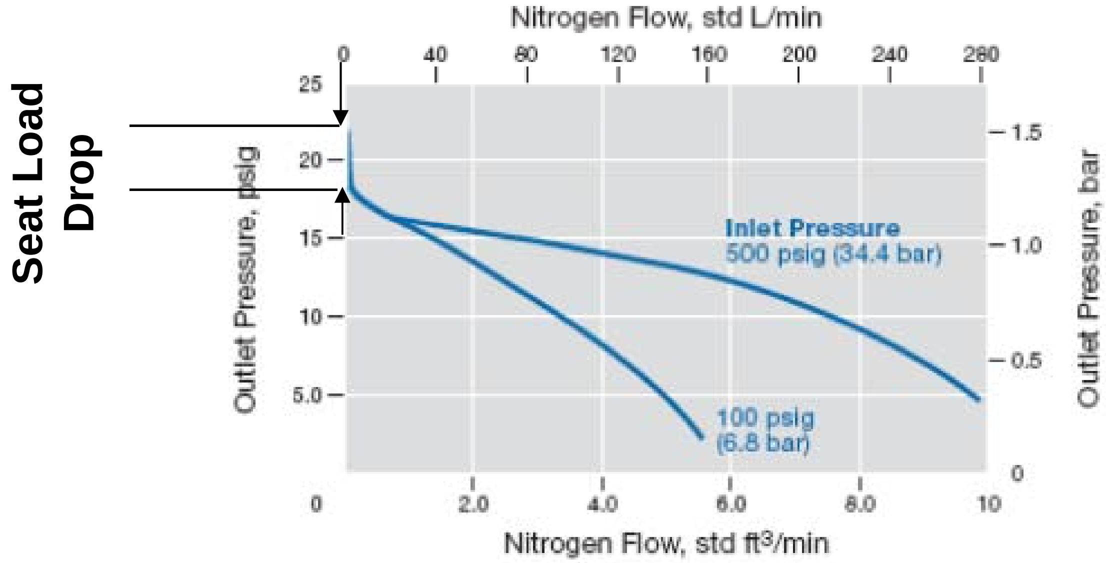
An increase in outlet pressure that occurs as the flow rate is decreased to zero.



Seat Load Drop

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

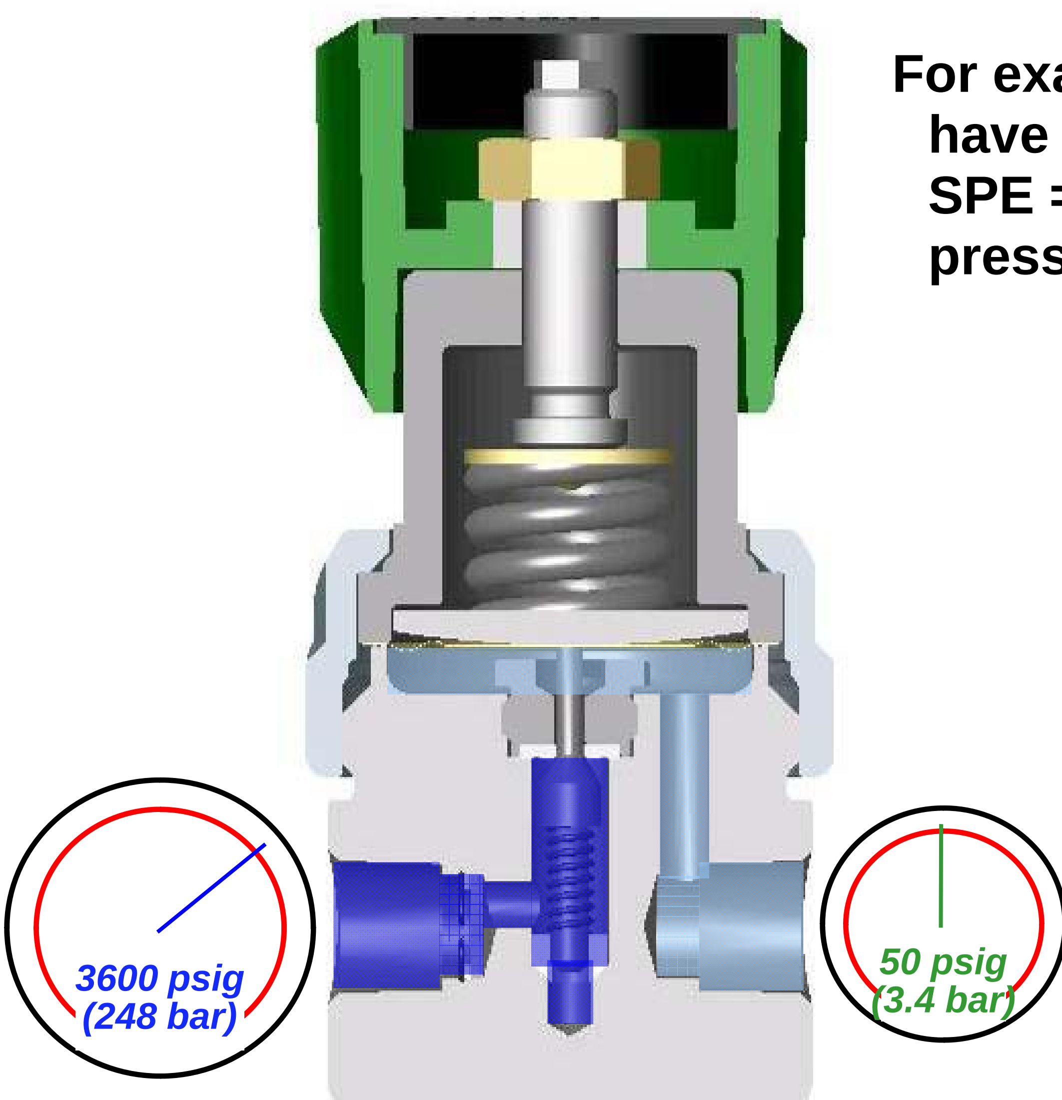


Supply Pressure Effect

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.

SPE in Action



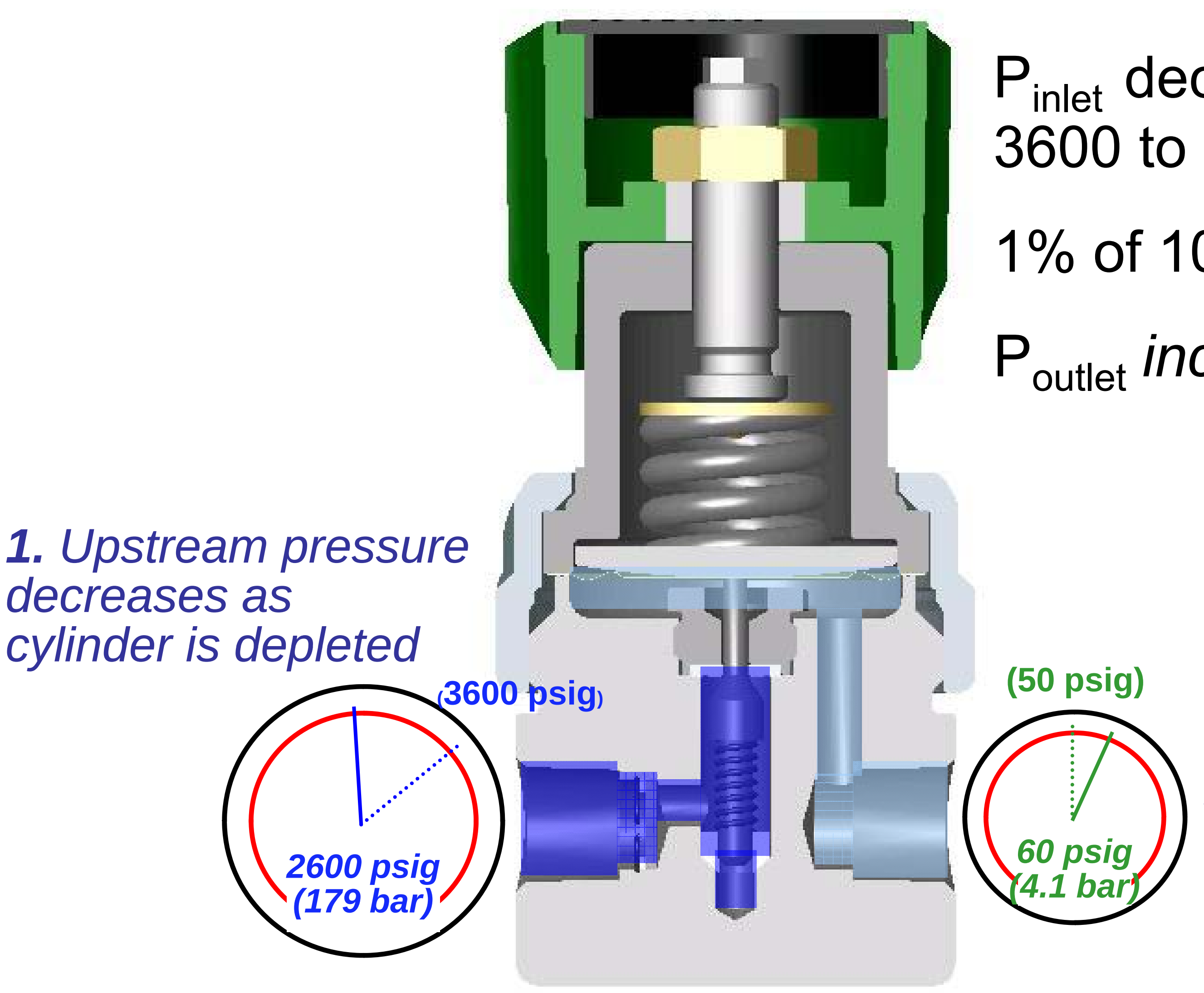
For example, suppose we have a regulator with SPE = 1% of the inlet pressure change.

SPE in Action

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

1% of 1000 psig = 10 psig

P_{outlet} *increases* 10 psig



SPE in Action

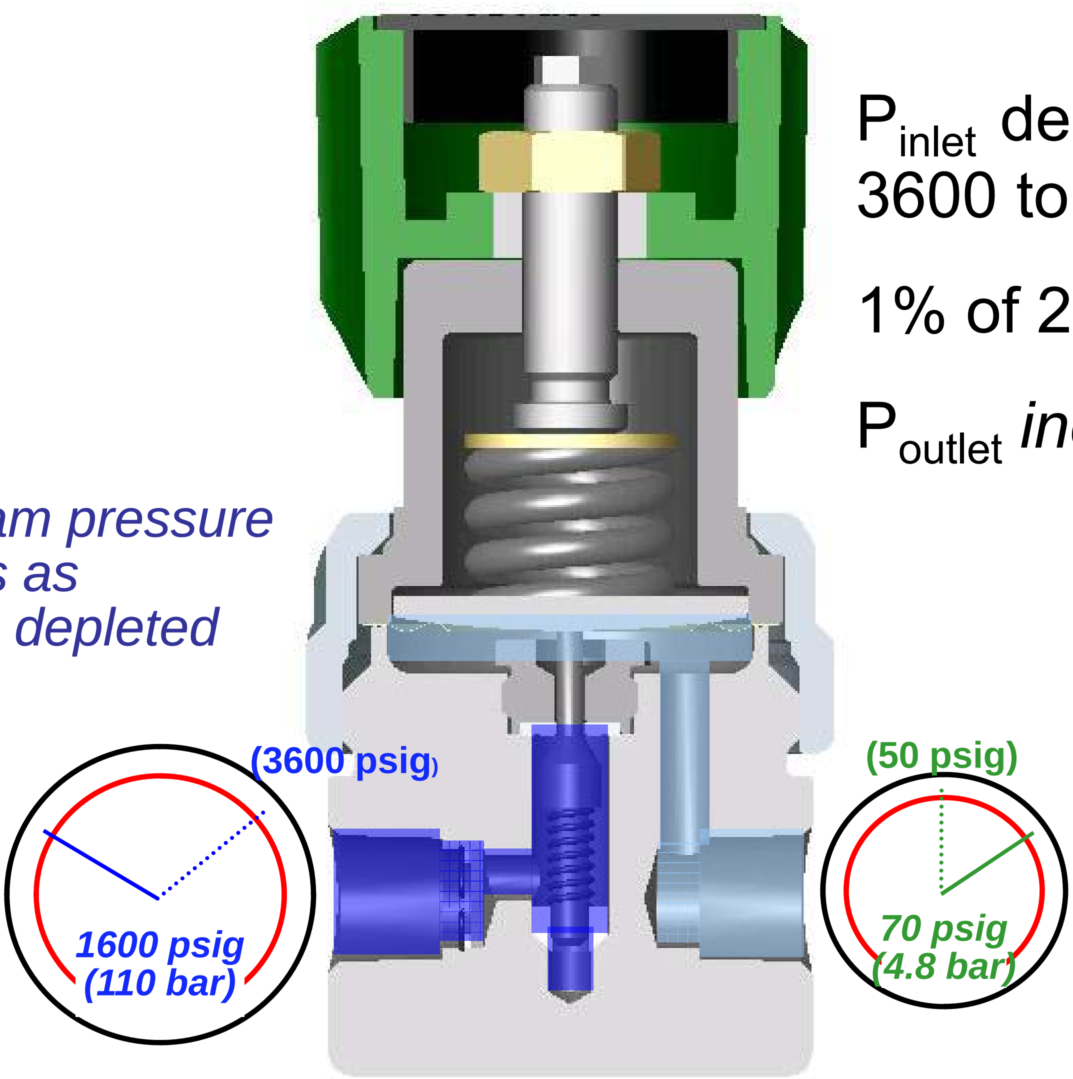
Swagelok

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*

So how do we help manage SPE?

Two-stage Pressure Reduction

or

Modify the controlling mechanism…

Two-Stage Pressure Reduction

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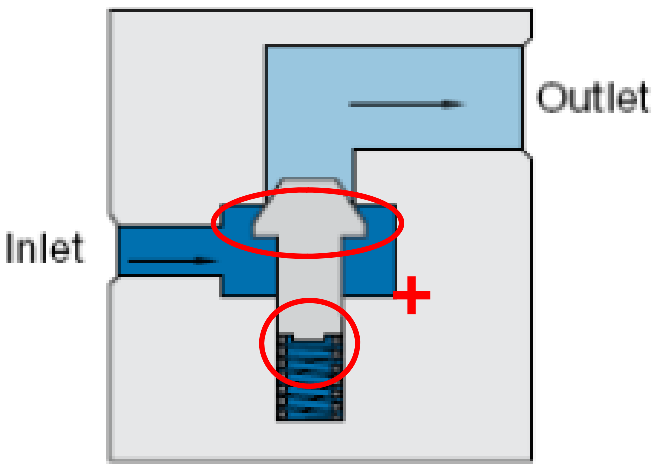
Two-stage Pressure Reduction

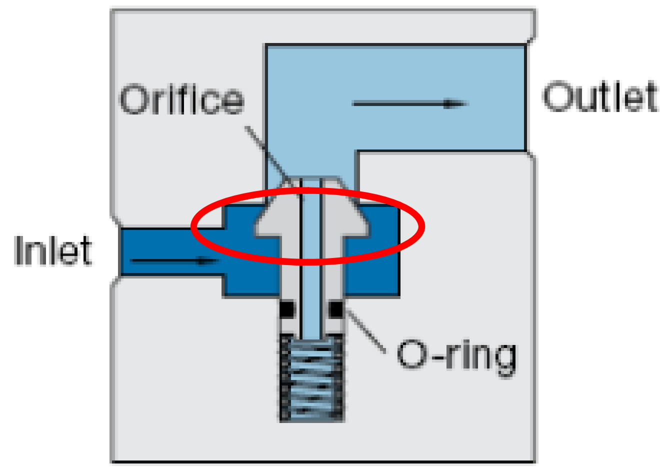
or

Modify the controlling mechanism…

Balanced vs. Unbalanced Poppet Design



Unbalanced Poppet



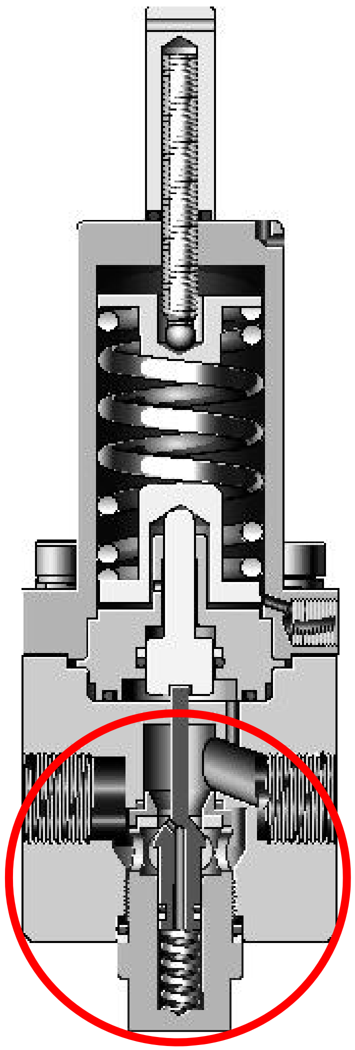
Balanced Poppet

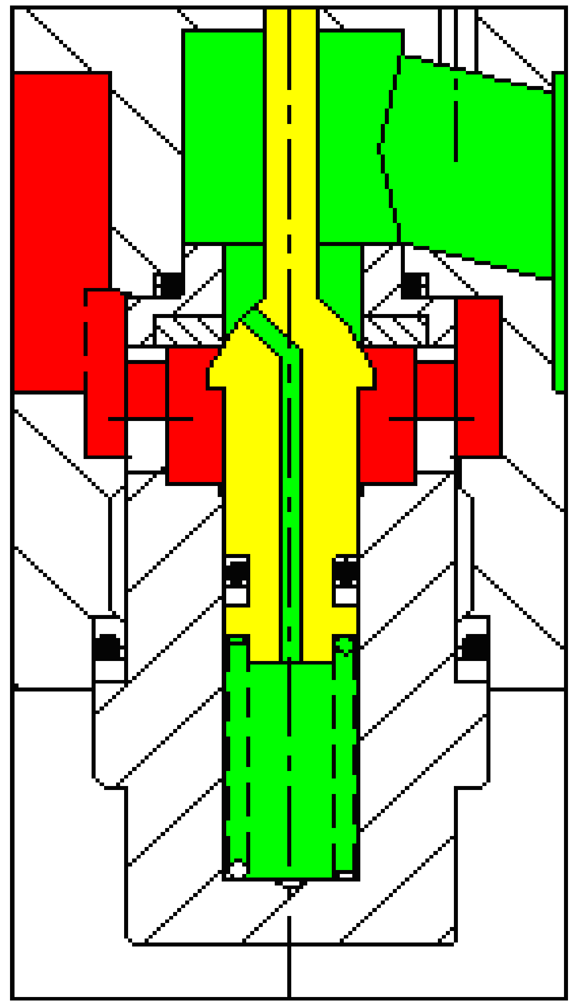
Balancing reduces the area on which P_{inlet} acts.

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

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

Balanced Poppet





Swagelok Regulator Resources

Regulator Specific 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