Introduction Swagelok

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Swagelok Pressure Regulators

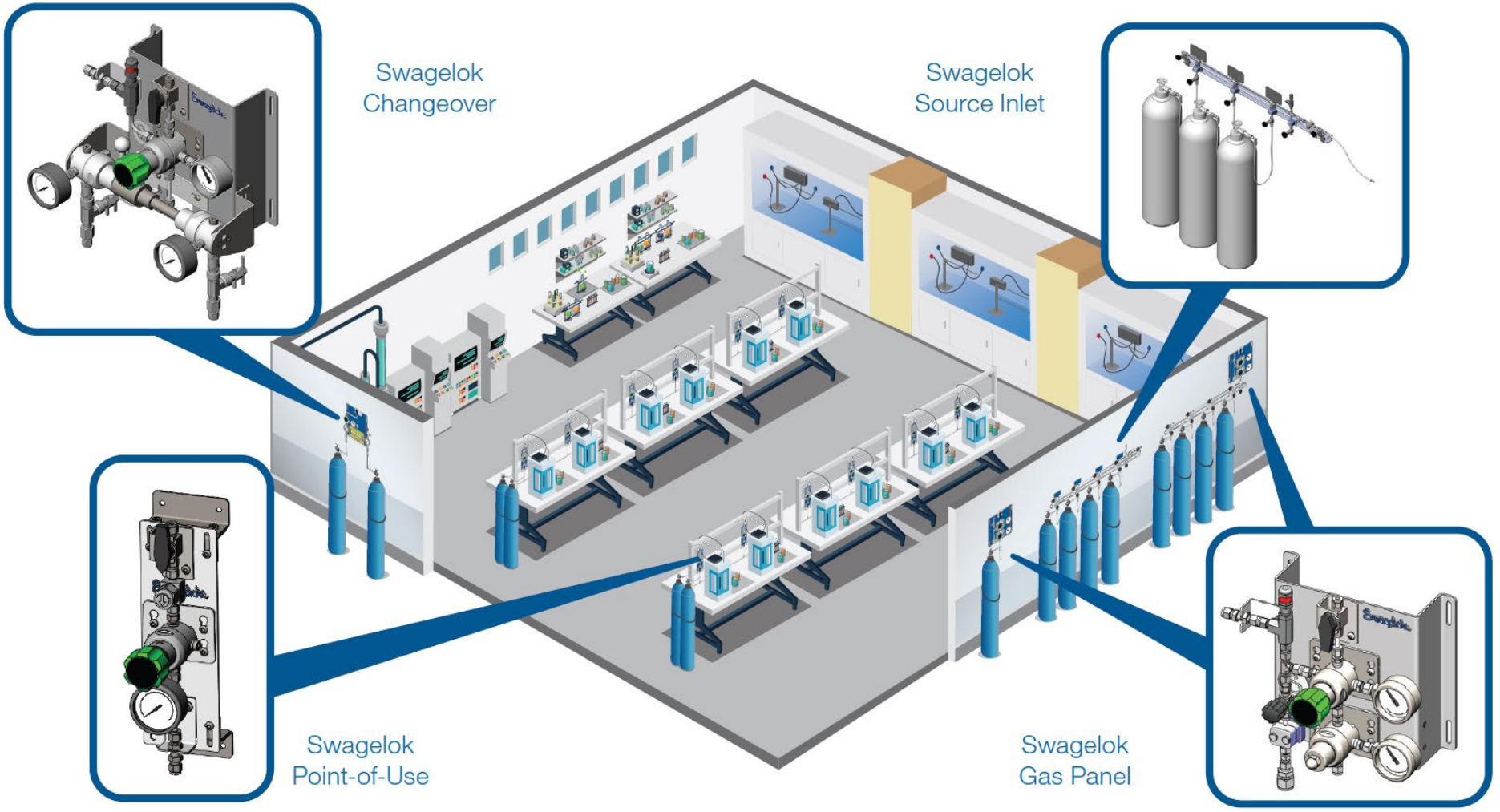
Nico Dissel & Paul Krouwels

June 6, 2023

Swagelok Pressure Regulators Content

- **How Pressure Regulators work**
  - Pressure-Reducing Regulators
  - Back-Pressure Regulators

- **How to choose a Regulator**
  - Assess Your Process Conditions
  - Determine What You Need to Control
  - Get to Know Regulator Behaviors
  - Identify the Appropriate Loading Element
  - Follow Best Practices


Swagelok
Changeover
Swagelok
Source Inlet
Swagelok
Point-of-Use
Swagelok
Gas Panel

Swagelok Pressure Regulators

To determine which regulator is the right one for the application in question, a calculation is often required and is not only based on pressure and flow information but depends on various system data as shown below.

- Type of fluid (Hydrogen gas)
- Pressure source versus SPE
- Inlet Pressure (P1)
- Outlet Pressure (P2)
- Flow (Q)
- Gas velocity (v)
- Type Regulator
- End Connections
- Anti Tamper option
- Expected temperature (t)
- Seal / Seat / O ring Material
- Certain Droop acceptable
- Joule Thomson Effect

Swagelok Pressure Regulators

Swagelok Nederland Regulator checklist

Customer name	
Contact name	
Tel. number	
E-mail address	
What is the application	
Type regulator *(Pressure reducing, Backpressure or Tank Blanketing)*	
Type actuating *(Spring loaded or Dome loaded)*	
Exernal feedback EF of EFP *(only for pilot operated domeloading)*	
Connections *(thread, flange, Swagelok fitting)*	
Thread type *(NPTF / BSPP)*	
Flange type *(ASME B16.5 / DIN)*	
Flange class *(ASME class / DIN class)*	
Pressure gauges requested	

Swagelok Pressure Regulators - By Types

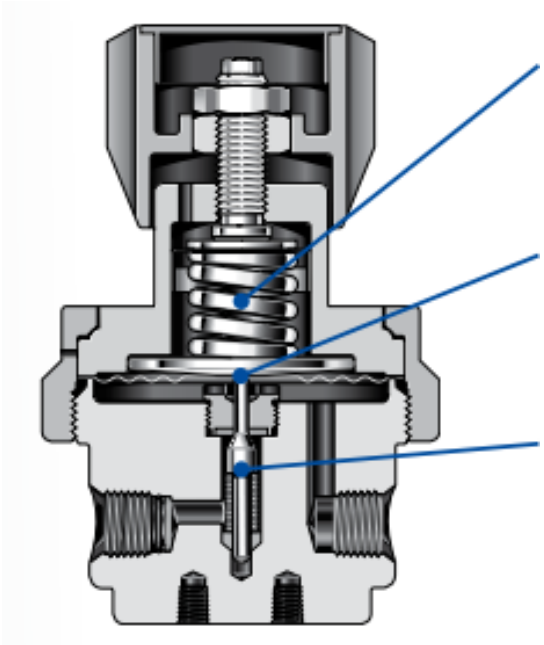
- **Pressure-Reducing**
  - Spring-Loaded
  - Dome-Loaded
- **Back Pressure Regulators**
  - Spring-Loaded
  - Dome-Loaded
- **Specialty**
  - Vaporizing regulators
  - Automatic switching regulators
  - Tank-blanketing regulators

How Pressure Regulators Work

- **How Pressure Regulators Work**
  - Pressure-Reducing Regulators
  - Back-Pressure Regulators

How Pressure Regulators Work

Understanding a regulator's functionality begins with familiarity of its component parts:

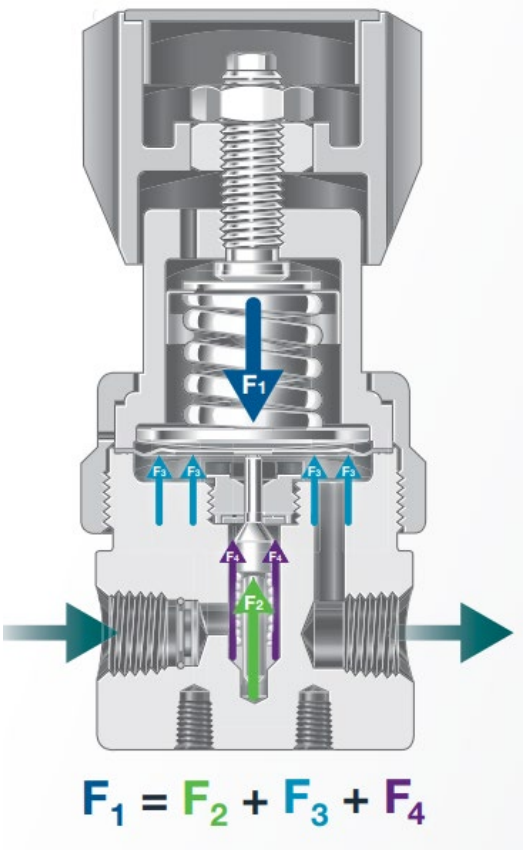


A loading element, Regulators may be spring-loaded or dome-loaded. The loading element applies a downward, balancing force on top of the diaphragm.

A sensing element, typically a diaphragm or piston. The sensing element allows the poppet to rise and fall in the seat, controlling inlet or outlet pressure.

A control element, including a seat and poppet. The seat contains pressure and prevents fluid from leaking to the opposite side of the regulator when flow is closed. Together with the seat, the poppet regulates pressure by maintaining a fine gap between the two while a system is flowing

How Pressure Regulators Work



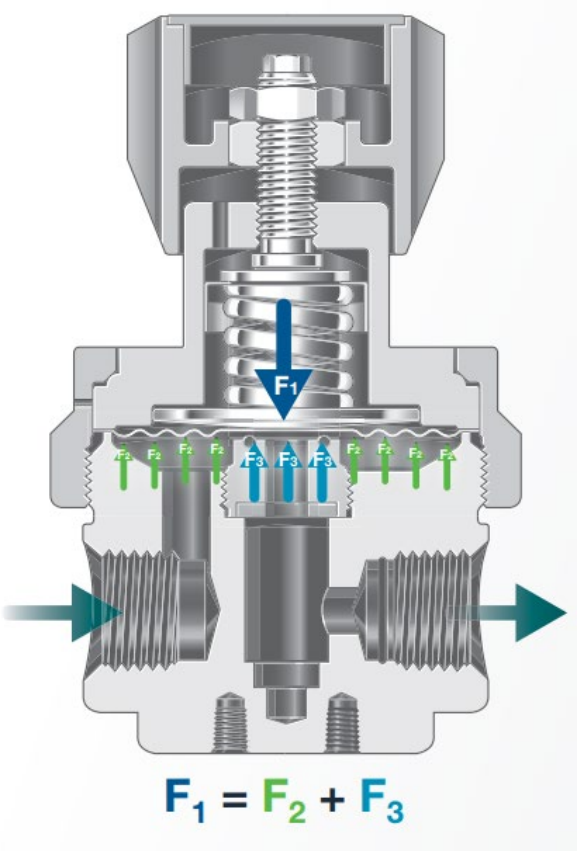
Pressure-Reducing Regulators

A pressure-reducing regulator decreases pressure and keeps it as constant as possible as inlet pressure and flow rate vary. Four different forces must be balanced.

These include loading force (**F1**), inlet spring force (**F2**), outlet pressure force (**F3**), and inlet pressure force (**F4**).

Total loading force must be equal to the combination of inlet spring force, outlet pressure force, and inlet pressure force

How Pressure Regulators Work



Back-Pressure Regulators

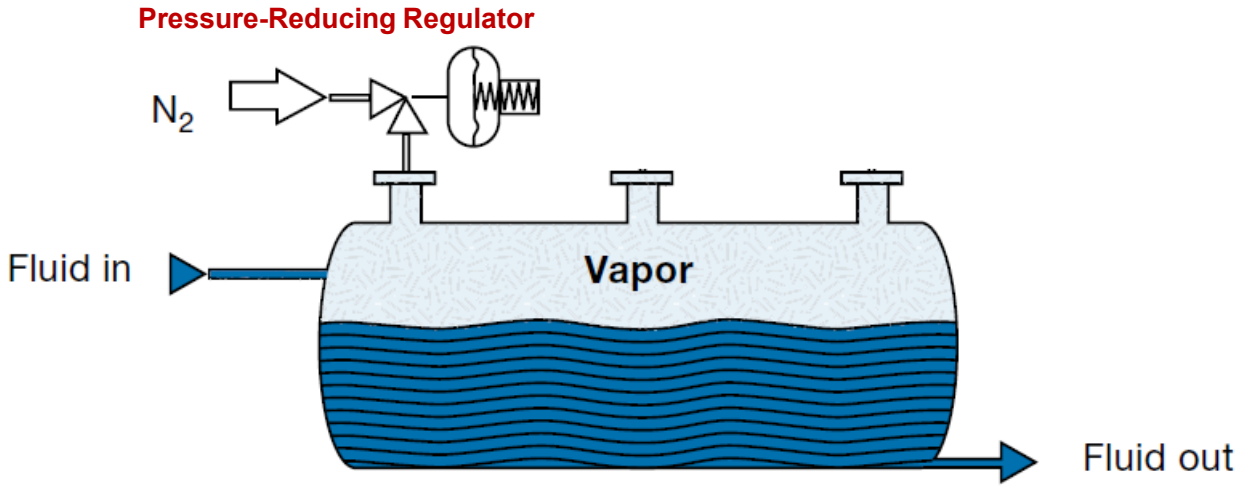
A back-pressure regulator keeps inlet pressure below a set pressure. It can either open when exposed to excess pressure or close when pressure drops below a desired level.

These regulators must balance spring force (**F1**), inlet pressure force (**F2**), and outlet pressure force (**F3**), as shown.

Here, the spring force must equal the combined force of the inlet pressure force and the outlet pressure force.

How Pressure Regulators Work

Pressure-Reducing Regulators versus Back-Pressure Regulators



How Pressure Regulators Work

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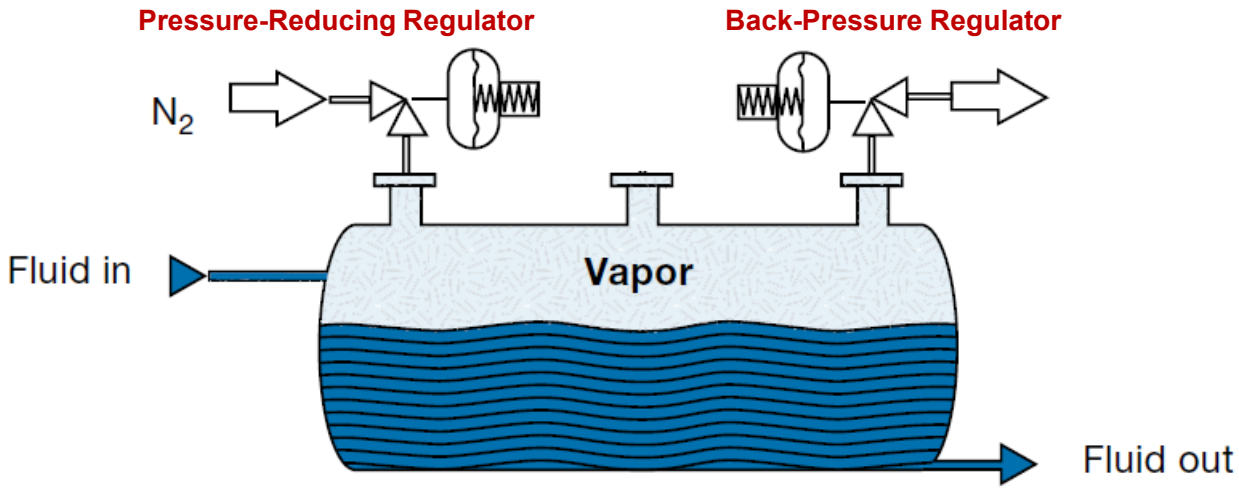

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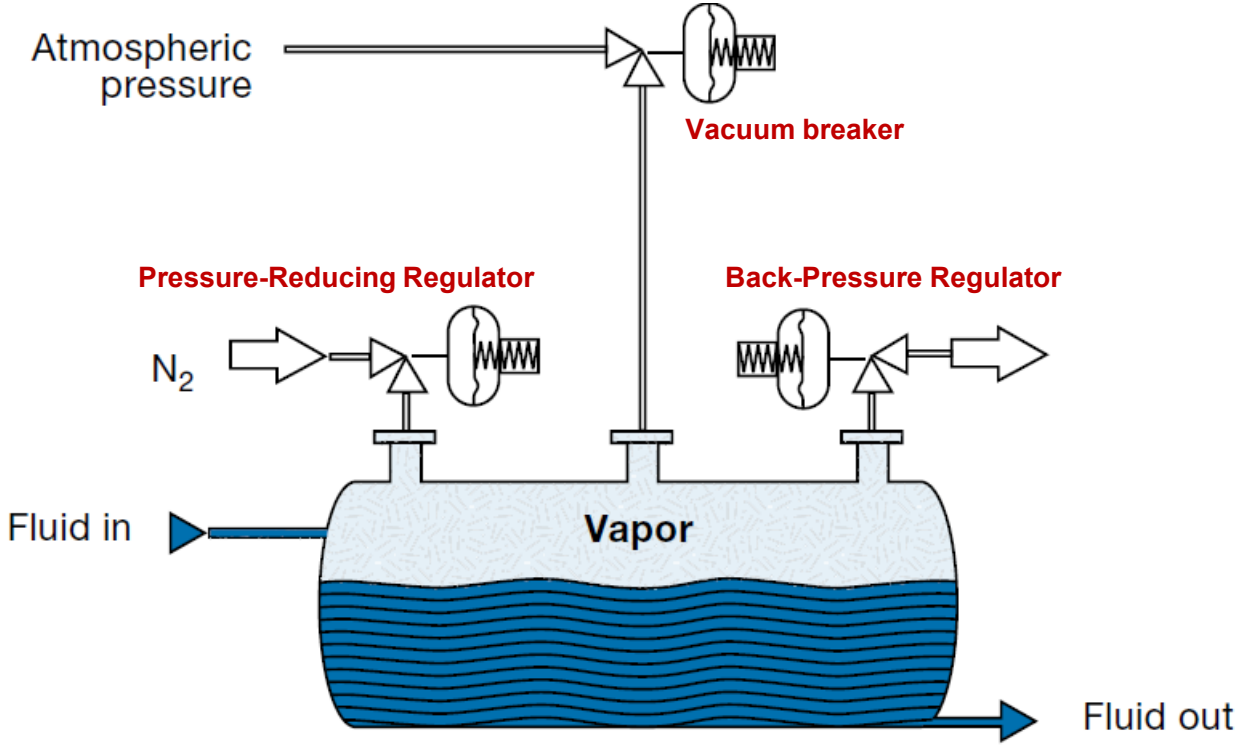

Swagelok Pressure Regulators Content

- **How to Choose a Regulator**
  - Assess Your Process Conditions
  - Determine What You Need to Control
  - Get to Know Regulator Behaviors
  - Identify the Appropriate Loading Element
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How to Choose a Regulator

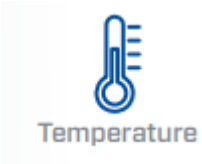
Step 1: Assess Your Process Conditions

The composition of your fluid (whether it is a liquid or a gas) can influence the required size of your regulator. For example, a regulator can handle a low-density gas at higher flows more readily than a high-density gas.

Because your regulator is intended to control pressure, be sure it is appropriately rated for the maximum, minimum, and regularly anticipated pressures within your system. Pressure control ratings are demonstrated by a regulator's flow curve.

How to Choose a Regulator

Step 1: Assess Your Process Conditions

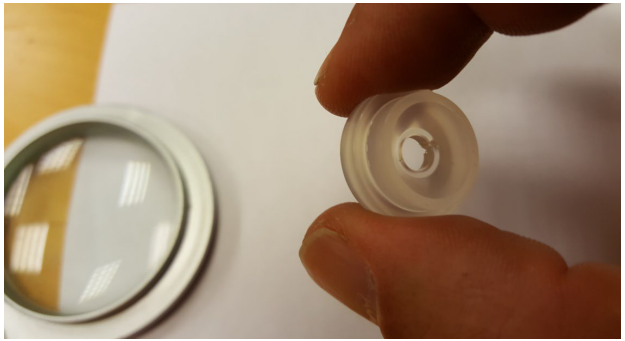


Know your expected operating temperature and how pressure changes across the regulator may influence temperature. The Joule-Thomson effect can cause significant temperature fluctuations during pressure drop, for example.

Determine your regulator’s material compatibility with your system media. Certain gases can cause damage to internal components, interfering with your regulator’s operation like O ring & Seat material, damage of membranes as a results of hydrogen embrittlement.

How to Choose a Regulator

Step 1: Assess Your Process Conditions



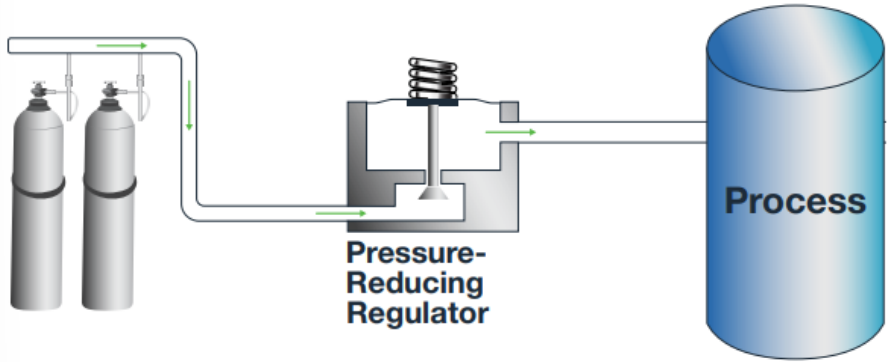
The most common cause of leakage is damage to the Seat or Elastomer seals as a result of the wrong choice of material or as a result of debris coming out of the system somewhere.

A system filter can help enormously to prevent leakage due to damaged parts.

How to Choose a Regulator

Step 2: Determine What You Need to Control

Whether you need a pressure-reducing or back-pressure regulator depends on your process requirements:



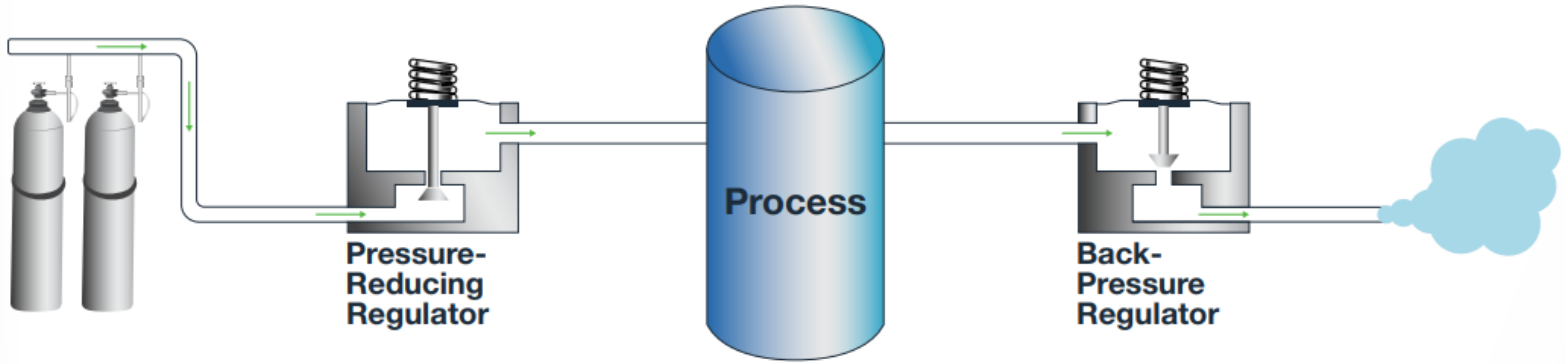
If you need to reduce pressure from a high-pressure source before system media reaches the main process, a **pressure-reducing regulator** will be the correct choice.

Used in the right context, these regulators can help you maintain desired pressures throughout your system.

How to Choose a Regulator

Step 2: Determine What You Need to Control

Whether you need a pressure-reducing or back-pressure regulator depends on your process requirements:



If you need to reduce pressure from a high-pressure source before system media reaches the main process, a **pressure-reducing regulator** will be the correct choice.

If you need to control and maintain upstream pressure and prevent unwanted pressure increases, a **back-pressure regulator** is typically the right choice.

Used in the right context, these regulators can help you maintain desired pressures throughout your system.

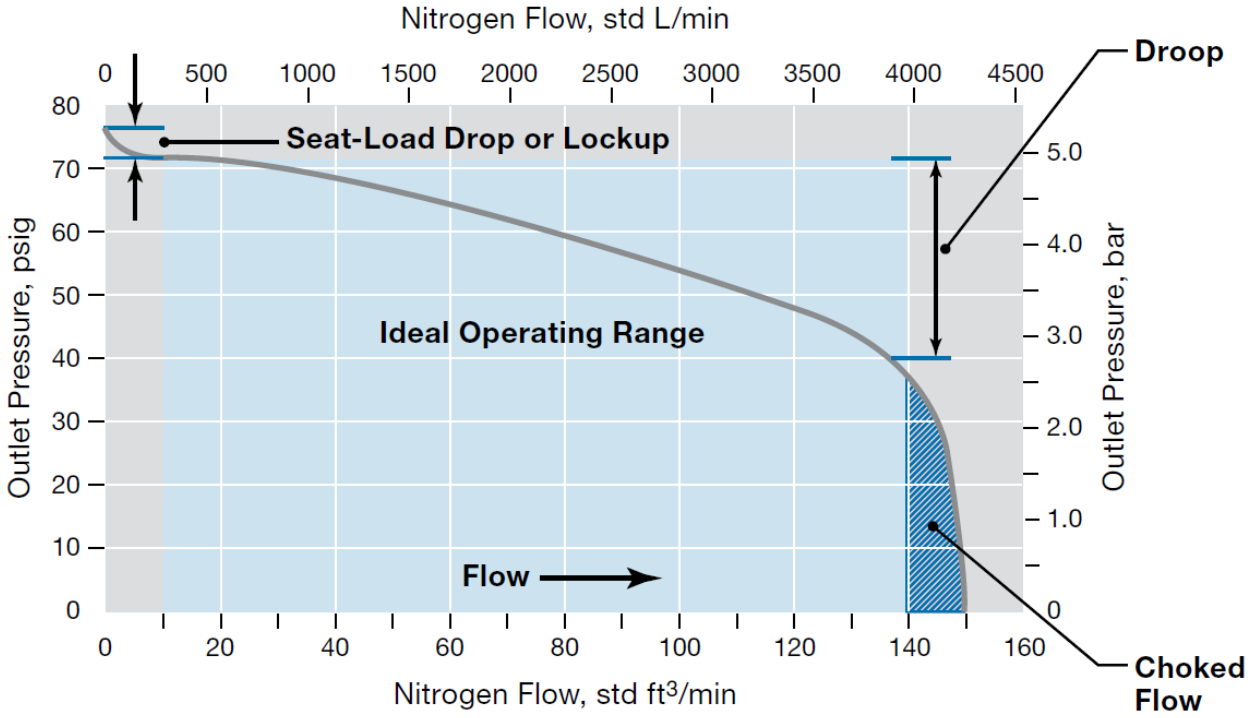
How to Choose a Regulator – Flow Curve

Step 3: Get to Know Regulator Behaviors

Once installed, it is important to account for several commonly occurring operational behaviors.

How to Choose a Regulator - Flow Curve

Step 3: Get to Know Regulator Behaviors



How to Choose a Regulator – Flow Curve

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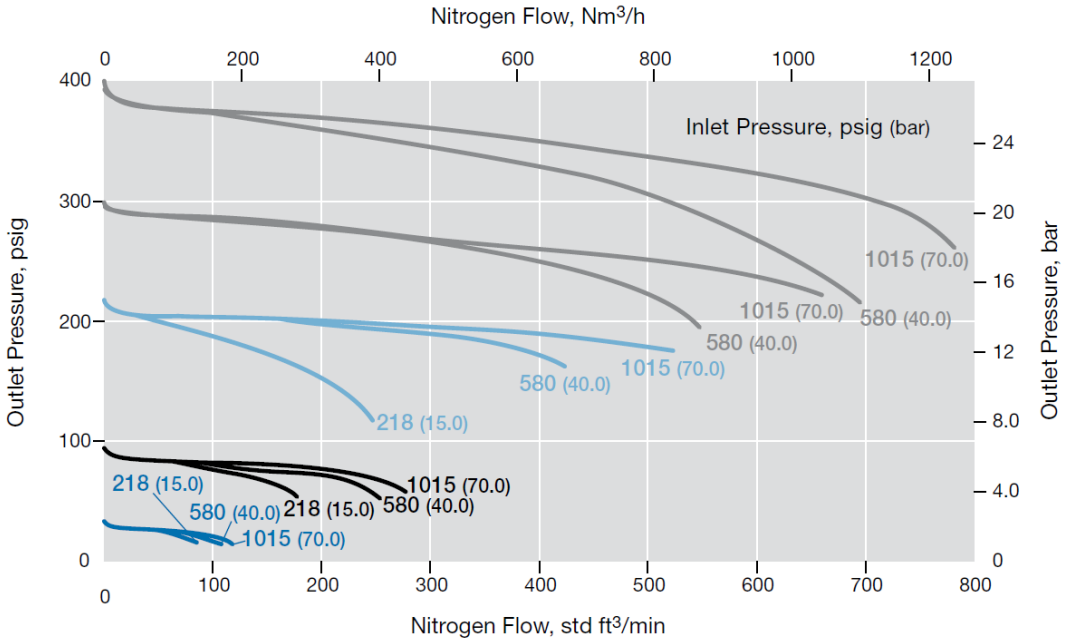

How to Choose a Regulator – Flow Curve

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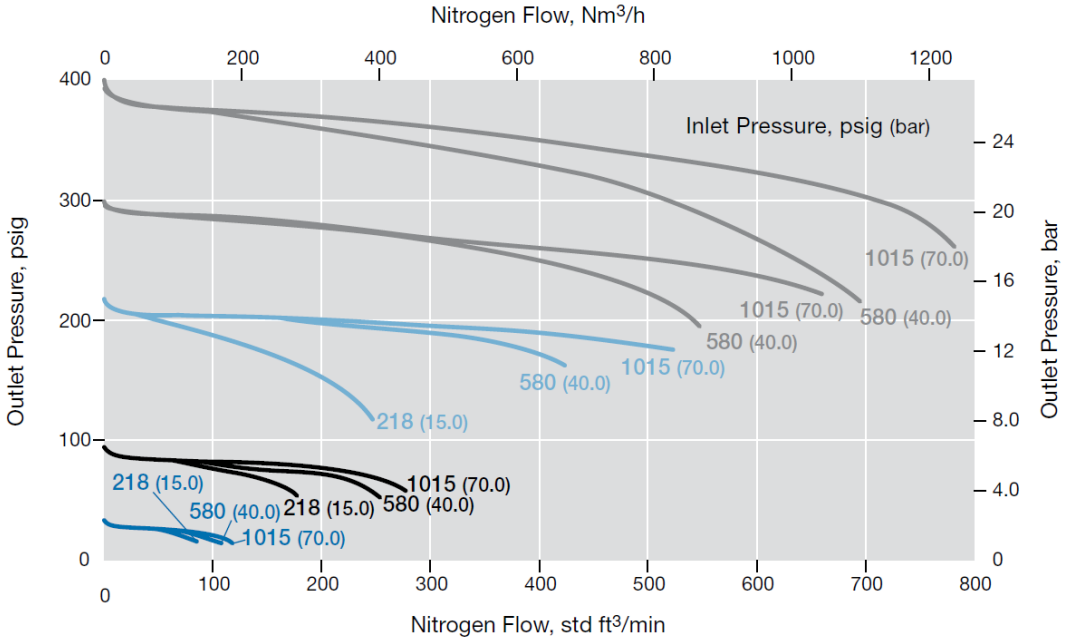

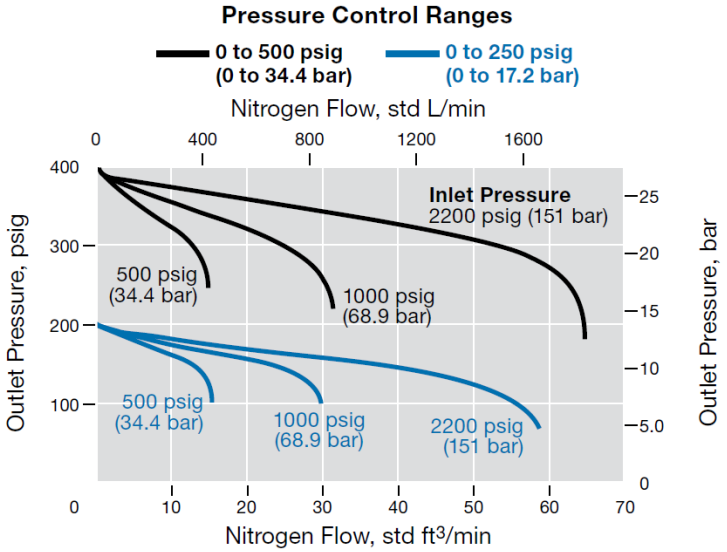

How to Choose a Regulator - Flow Curve

Step 3: Get to Know Regulator Behaviors

Welcome to the Swagelok Regulator Flow Curve Generator

This tool will give you a unique flow curve based on a set of user-specified application parameters for Swagelok® RHPS series regulators.

USE THE FLOW CURVE GENERATOR

What the Tool Does

You can:

- View the performance of one regulator in up to four different applications
- Compare the performance of up to four different regulators in the same application
- View any combination of regulators and applications, adding up to four total, on the same graph

Using the Regulator Flow Curve Generator | Swagelok

How to Choose a Regulator - Flow Curve

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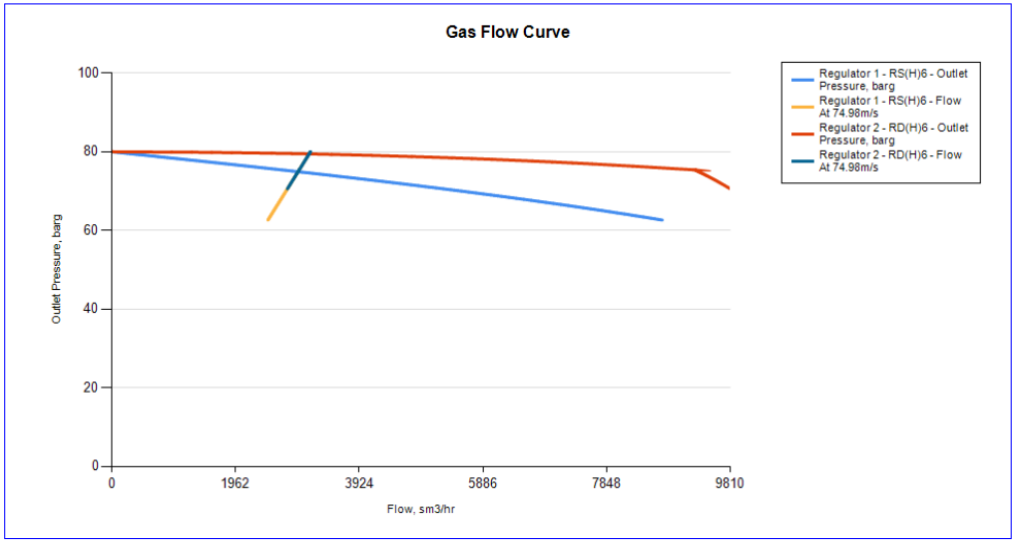
Using the Regulator Flow Curve Generator | Swagelok



Flow Curve Explanation: This line represents the full capacity of the regulator. It shows what droop can be expected for a given flow demand as well as the point of choked flow.

Line Velocity Explanation: This line represents the point at which the downstream gas will exceed the specified velocity. In order to determine the maximum flow for a particular regulator with a specific downstream velocity limit, find the intersection point of this line and the flow curve.

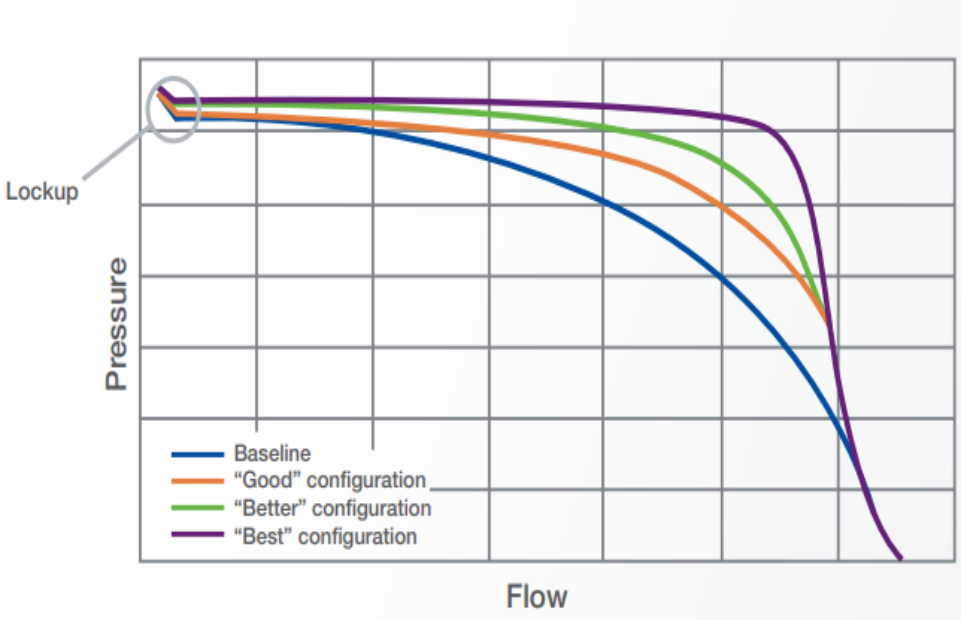
RHPS Series Pressure Regulators Catalog

How to Choose a Regulator - Flow Curve

Step 3: Get to Know Regulator Behaviors

The **flow curve** demonstrates a regulator's ability to maintain desired pressure as flow increases.

The flattest part of the flow curve indicates where a regulator will perform best.

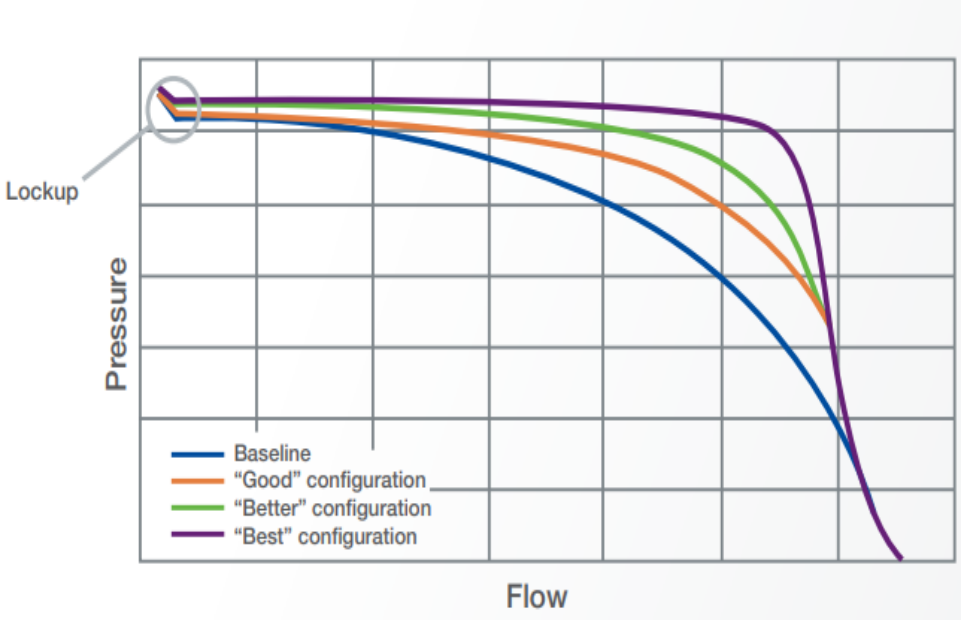


How to Choose a Regulator - Lock Up

Step 3: Get to Know Regulator Behaviors

Lockup refers to a pressure drop just above the set point that is required to shut the regulator off and stop flow.

When flow is turned on, the flow curve will show a drop in pressure to the set point.

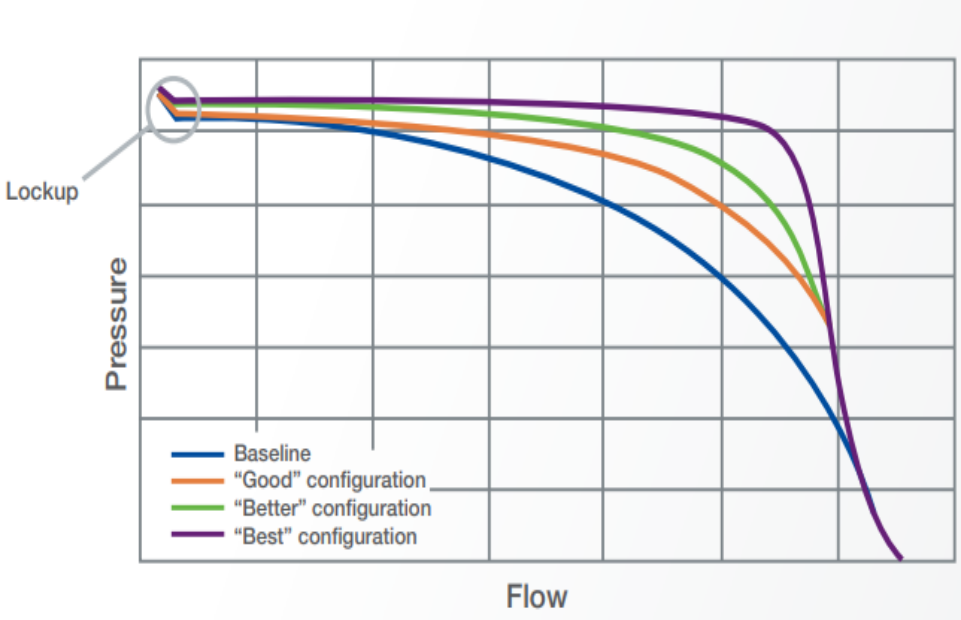


How to Choose a Regulator - Droop

Step 3: Get to Know Regulator Behaviors

Droop occurs when flow requirements cause the regulator's poppet to open wider, eventually and necessarily leading to pressure loss.

Droop is to be expected at certain flows with every regulator, but maintaining a flow curve that is as flat as possible before pressure drops off is ideal

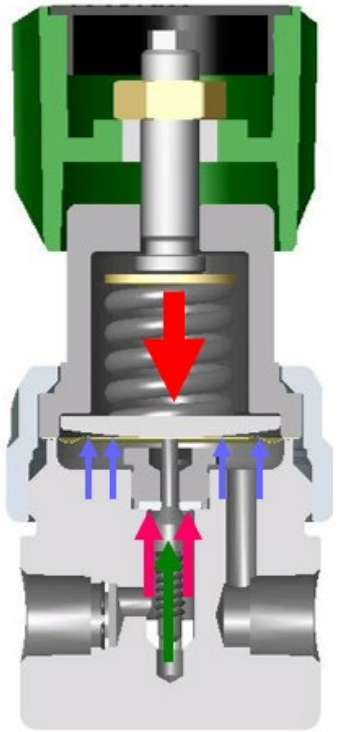


How to Choose a Regulator - Supply pressure effect

Step 3: Get to Know Regulator Behaviors

Supply pressure effect (SPE) is a change in outlet pressure due to a change in inlet pressure. If inlet pressure decreases, there will be a smaller corresponding outlet pressure increase. Conversely, inlet pressure increases will lead to outlet pressure decreases.

Though counterintuitive, system designers must account for this phenomenon when selecting their regulators. One effective way to mitigate SPE is to incorporate a two-stage pressure regulator into your system.



How to Choose a Regulator - Supply pressure effect

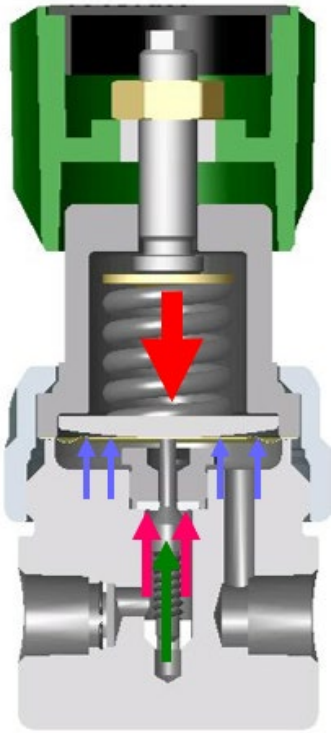
Step 3: Get to Know Regulator Behaviors

F_1 = Spring Force

F_2 = Inlet Spring Force

F_3 = Outlet Pressure Force

F_4 = Inlet Pressure Force



F_1 and **F_2** are constant.

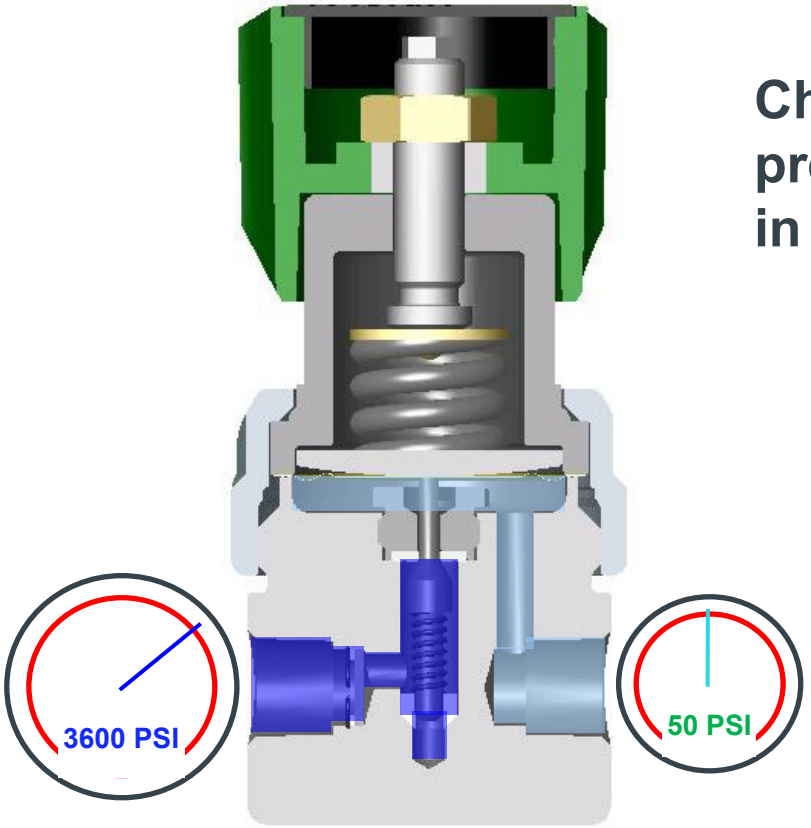
As **F_4** decreases due to reducing inlet pressure (i.e. depletion of a gas cylinder), the poppet is forced down due to constant spring force, **F_1**.

The poppet is forced downwards, the seat opens:

causing the outlet pressure to

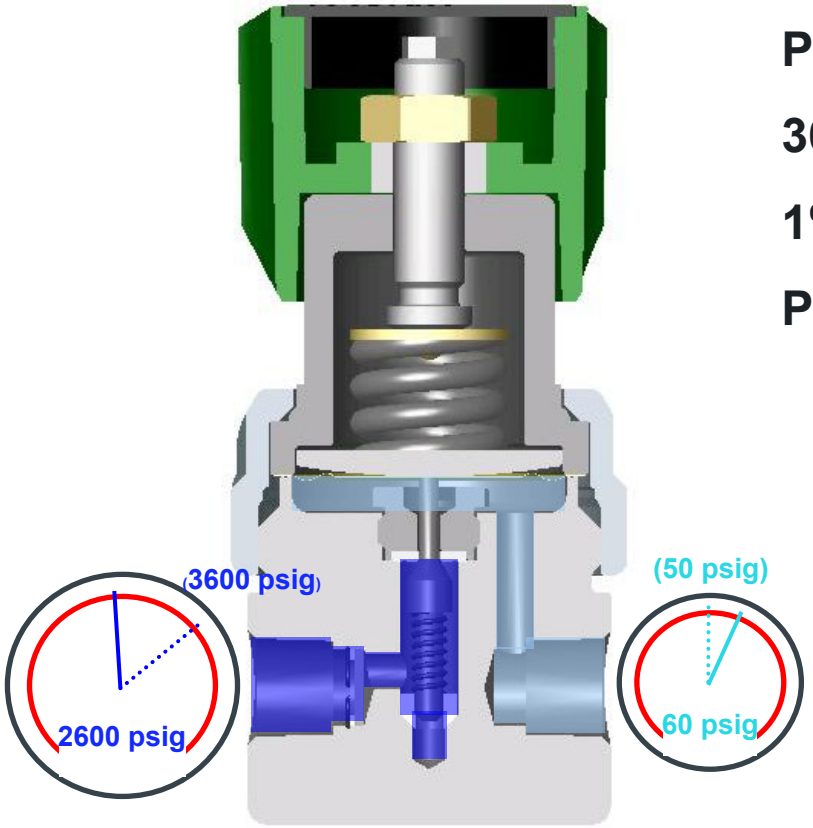
RISE

How to Choose a Regulator - Supply pressure effect



Change in outlet pressure due to change in inlet pressure

How to Choose a Regulator - Supply pressure effect



P_{inlet} decreases from

3600 to 2600 = 1000 psig

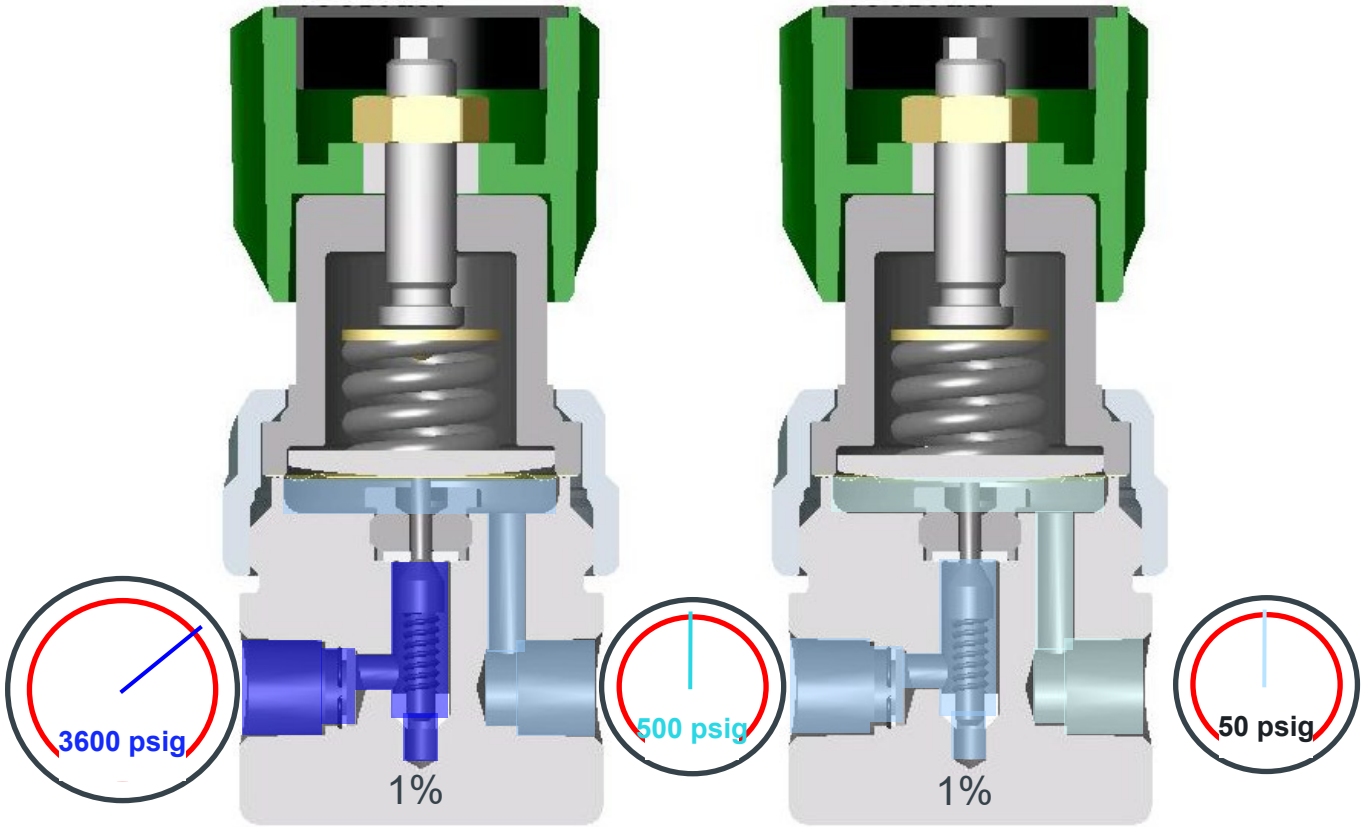
1% of 1000 psig = 10 psig

P_{outlet} increases 10 psig

1. Upstream pressure decreases as cylinder is depleted

2. Downstream pressure increases 1% of the inlet decrease

How to Choose a Regulator - Supply pressure effect



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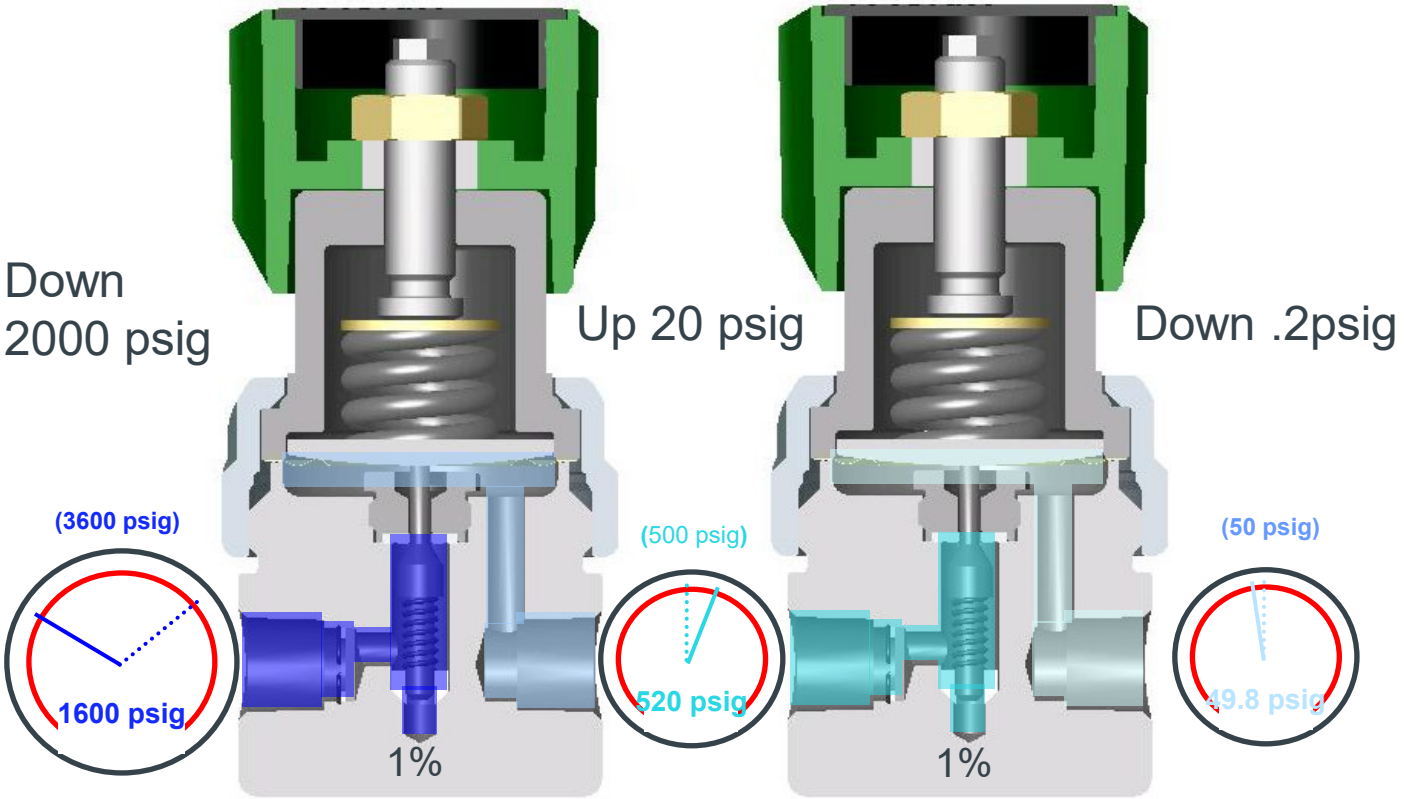
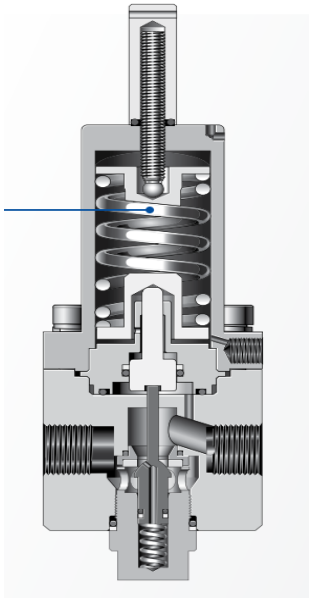


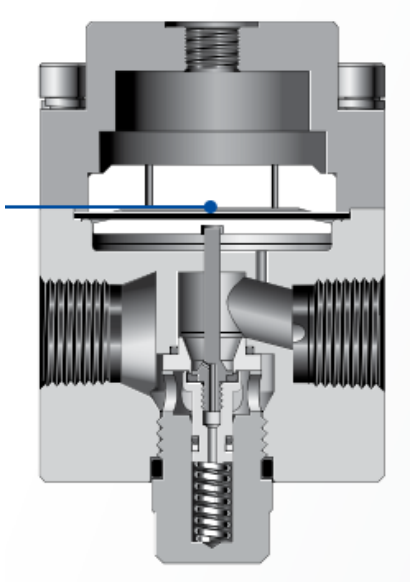
How to Choose a Regulator - Loading Element

Step 4: Identify the Appropriate Loading Element

A regulator's loading element provides a balancing force on top of the diaphragm or piston to control pressure. Two types are common:



Spring-loaded regulators



Dome-loaded regulators

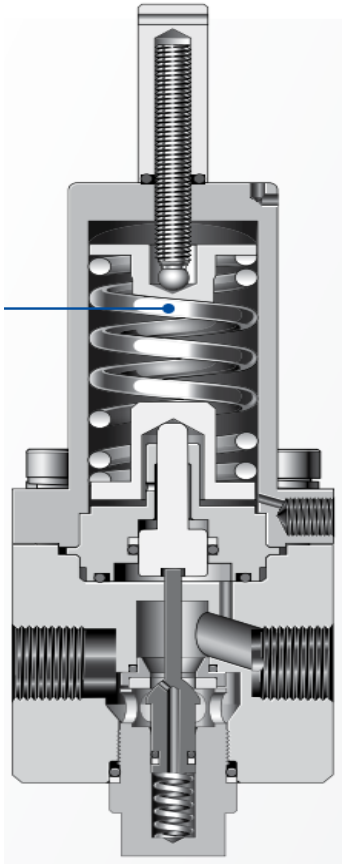
How to Choose a Regulator - Loading Element

Step 4: Identify the Appropriate Loading Element

Spring-loaded regulators are the most common.

A spring applies force on the sensing element, controlling the downstream pressure.

They are a reliable option for many general-purpose applications.



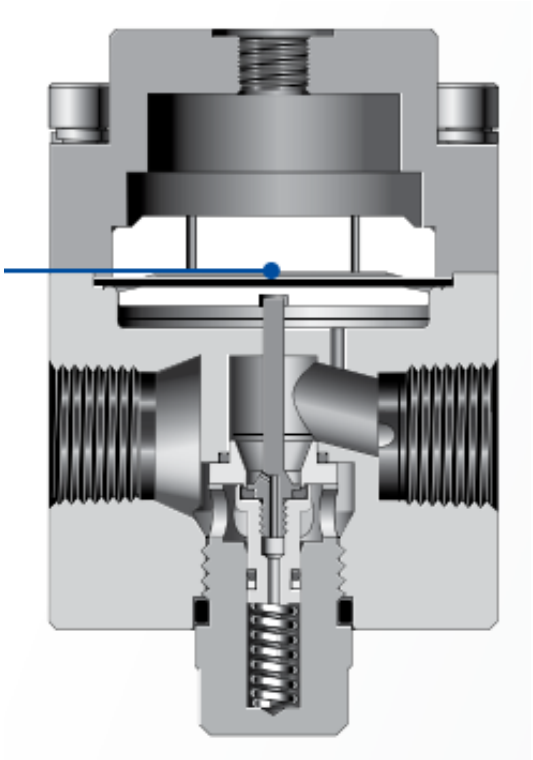
How to Choose a Regulator - Loading Element

Step 4: Identify the Appropriate Loading Element

Dome-loaded regulators enable more dynamic pressure control.

The loading force is controlled by a pressurized gas housed in a dome chamber. Gas flexes a diaphragm, which moves the poppet away from the orifice and controls the downstream pressure.

They are well-suited for applications where flow demands vary and precise pressure control is critical.



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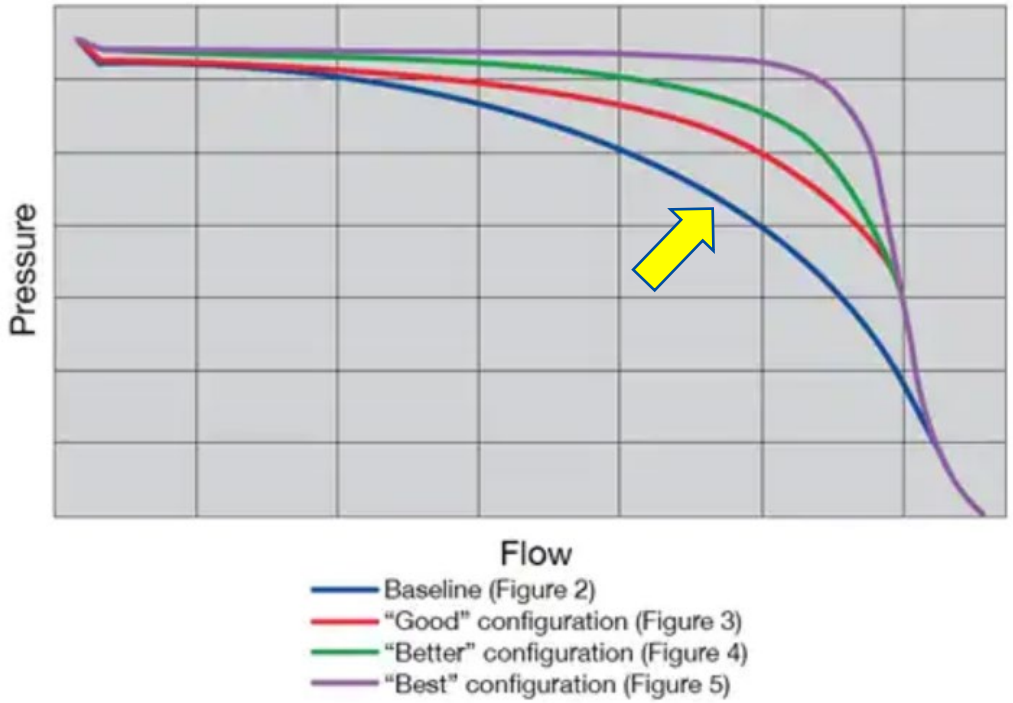

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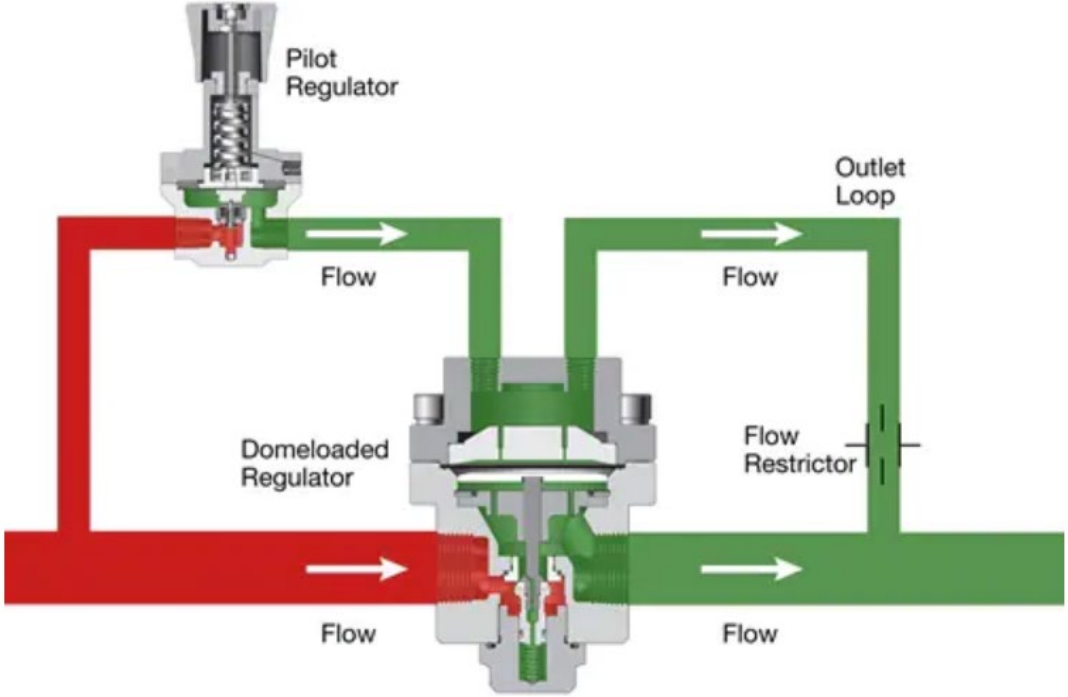
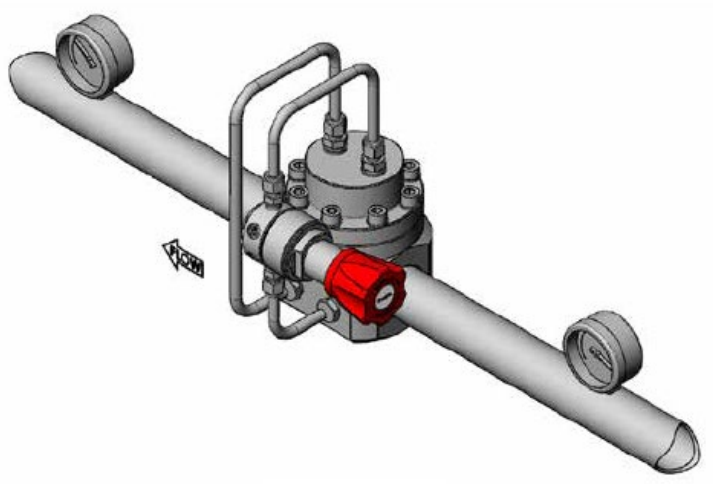
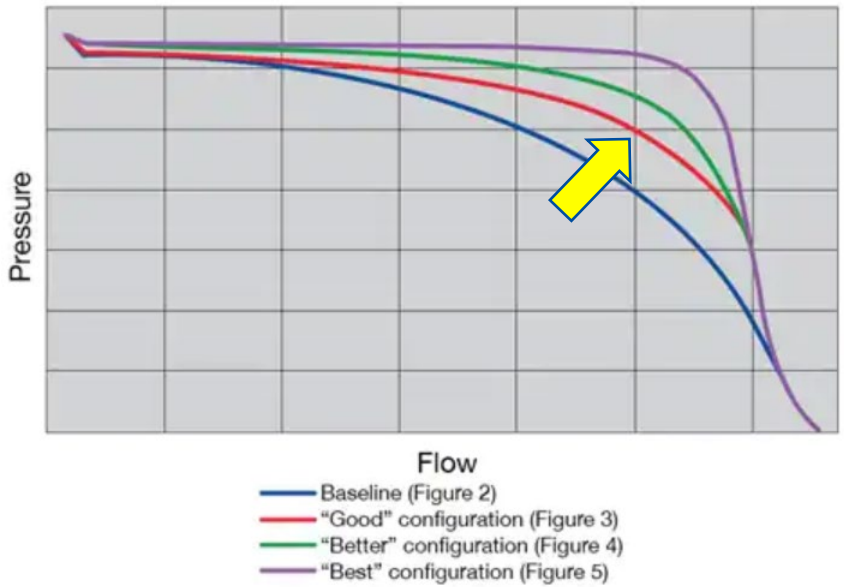
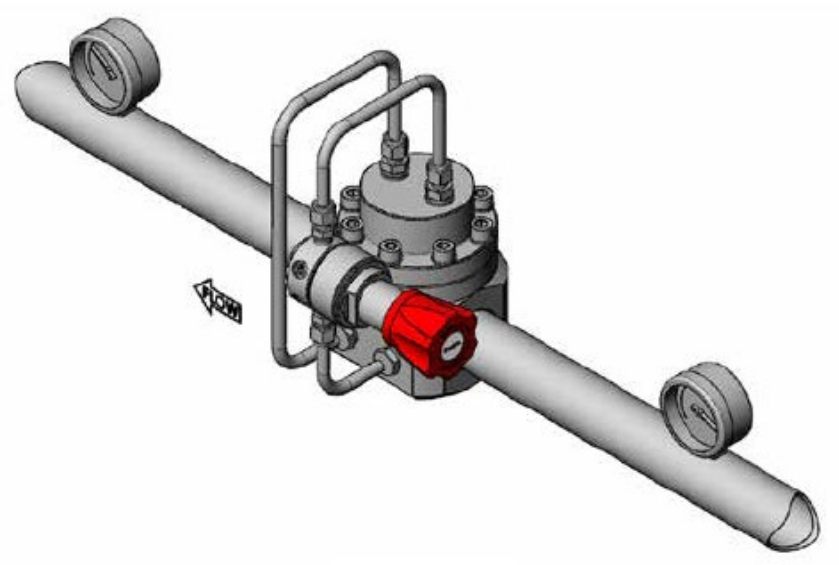




How to Choose a Regulator - Loading Element

How to Flatten a Regulator Flow Curve to Reduce Droop





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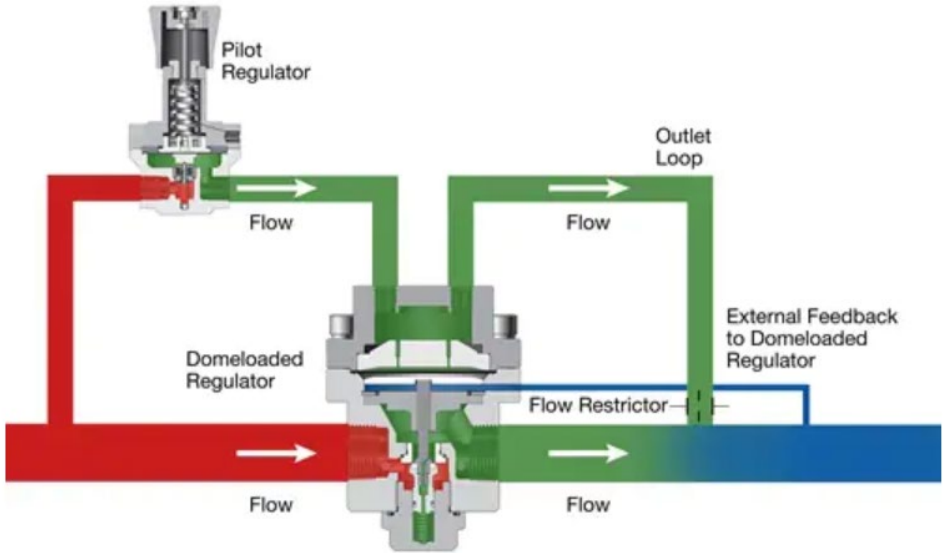
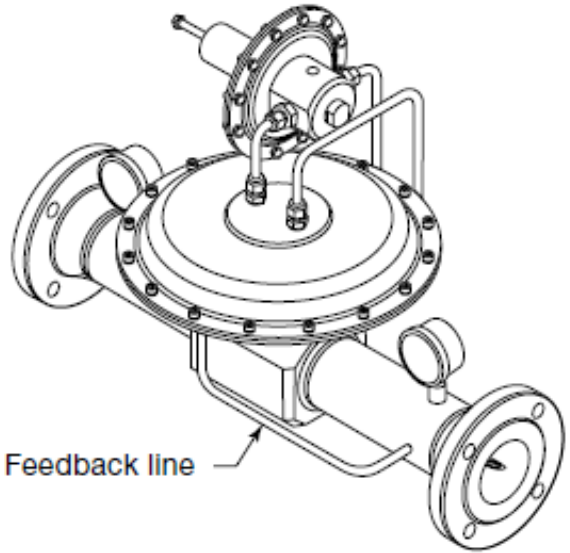
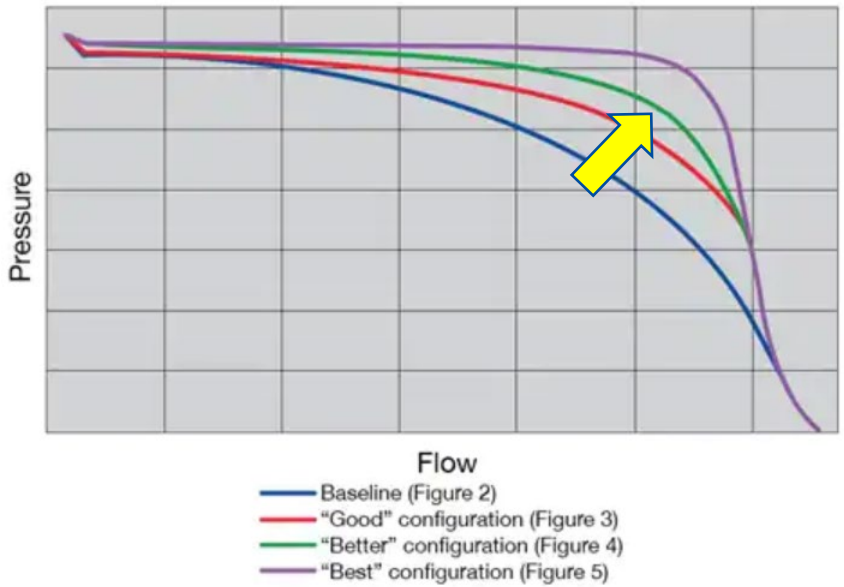




External Feedback To Dome

How to Choose a Regulator - Loading Element

How to Flatten a Regulator Flow Curve to Reduce Droop



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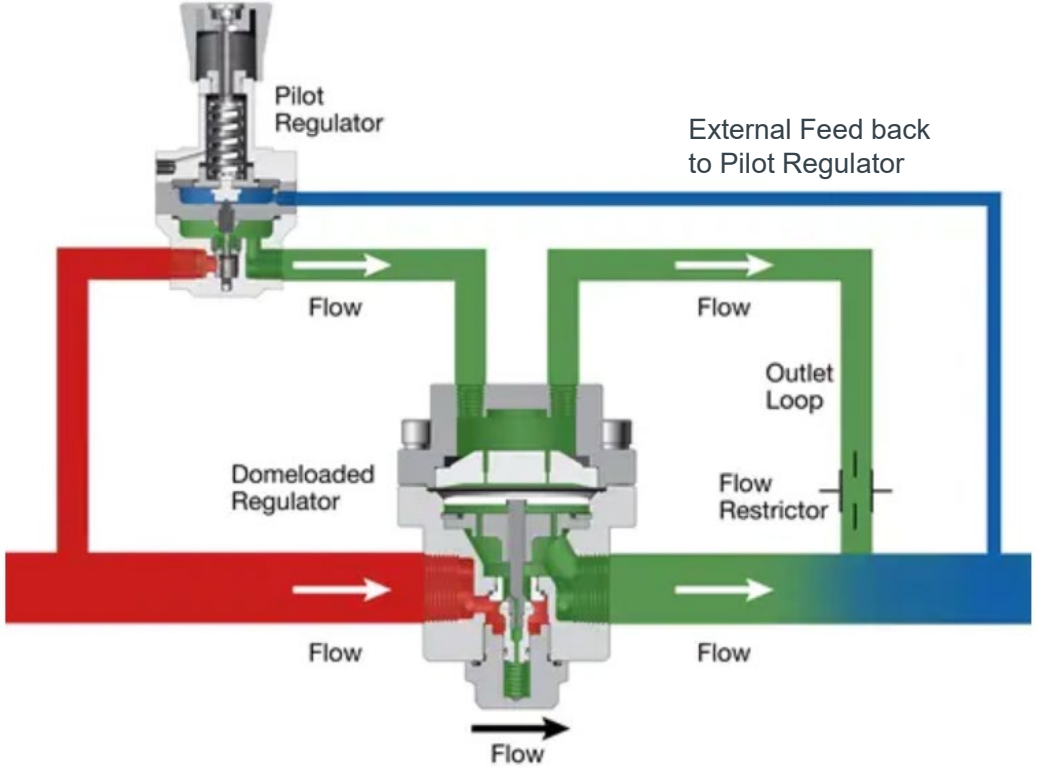
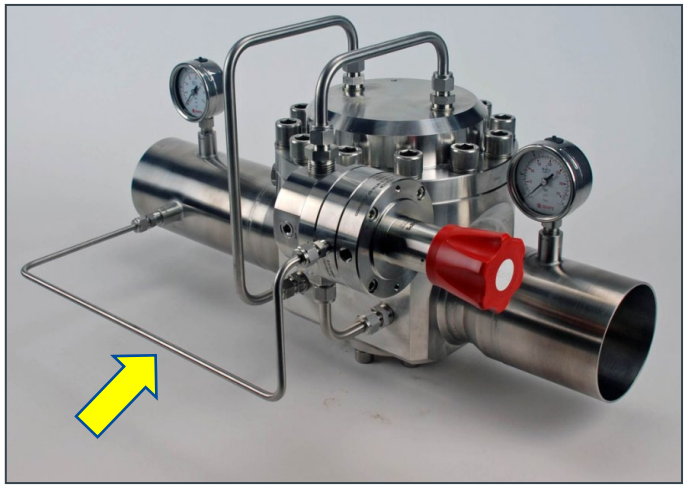
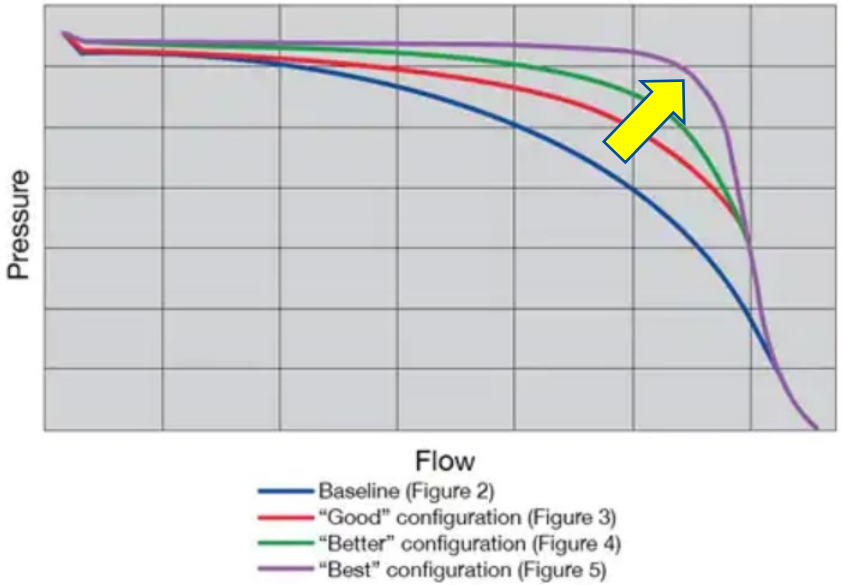
How to Choose a Regulator - Loading Element

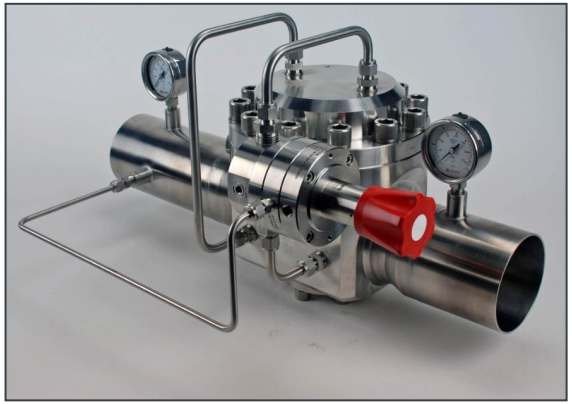




How to Choose a Regulator - Loading Element

How to Flatten a Regulator Flow Curve to Reduce Droop





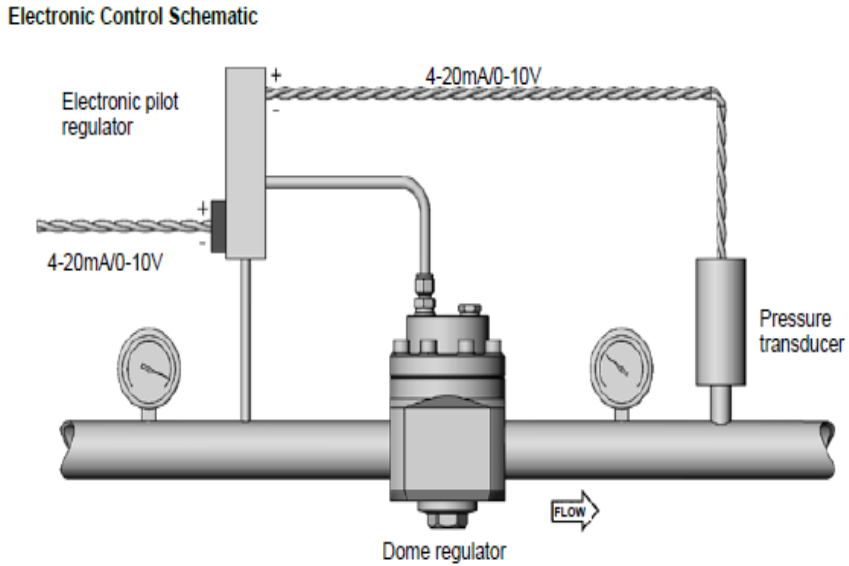
External Feedback To Pilot

How to Choose a Regulator - Loading Element

No loading element can eliminate droop depending on your system, some droop may be acceptable.

When maintaining pressure where flow change is critical, more sophisticated setups incorporating feedback loops, pilot regulators, and other methods can help.

When in doubt, consult your Swagelok regulator specialist.



How to Choose a Regulator - Creep

Step 5: Follow Best Practices

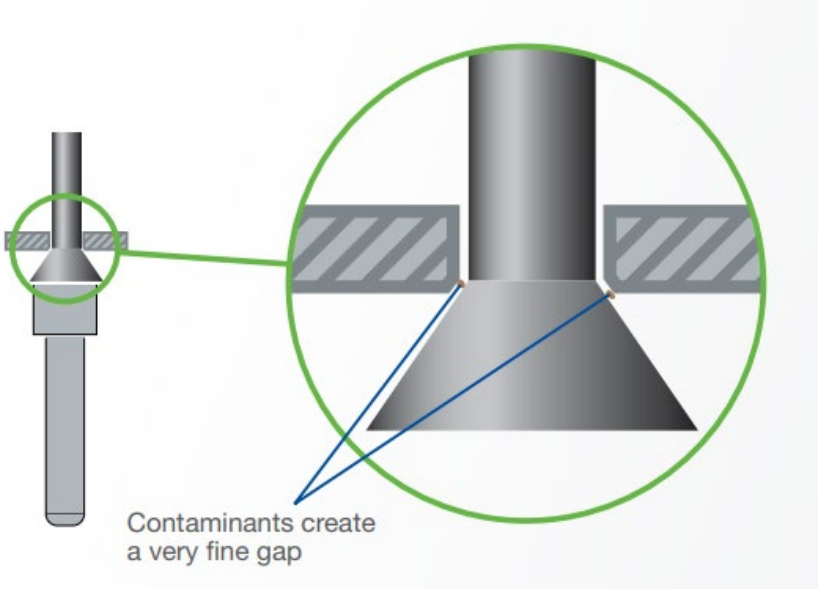
Once you have selected and installed your regulator, properly maintaining it will help you maximize its performance.

One issue that can arise is Creep.
Creep occurs when a contaminant creates a fine gap between the regulator's seat and poppet. This gap can prevent the poppet from creating a reliable seal, allowing media to flow to the low pressure side of the seat.

System media will unintentionally flow across the seat, resulting in unwanted pressure increases downstream.

How to Choose a Regulator - Creep

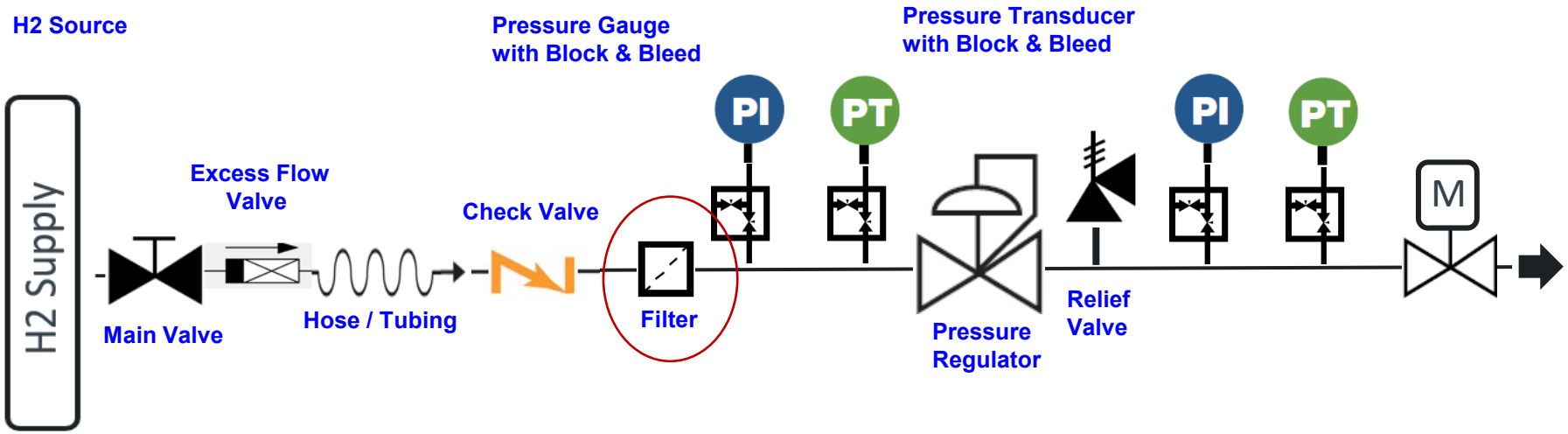
Step 5: Follow Best Practices



Most common leakage is Poppet Seat Leakage caused by system contamination like debris from welding spatters, burs, teflon tape from thread connection etc.

How to Choose a Regulator - Creep

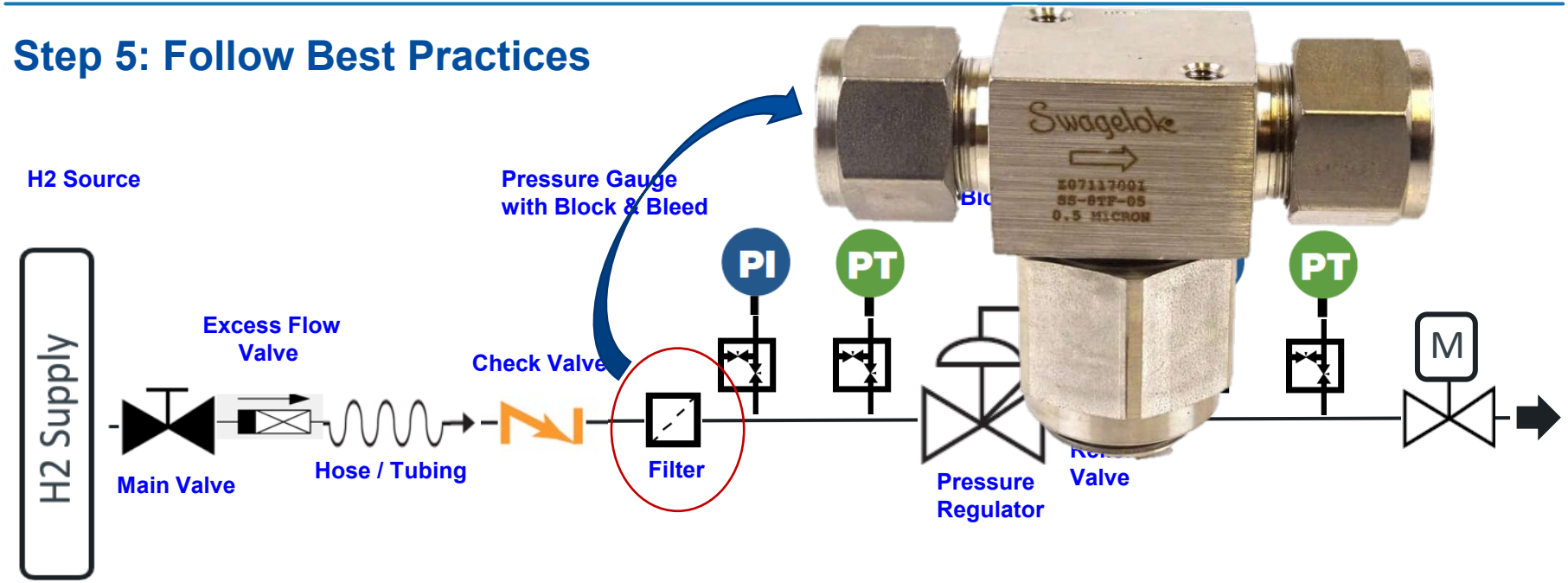
Step 5: Follow Best Practices



The above P&ID is intended as an example. When selecting a product, the total system design must be considered to ensure safe, trouble-free performance. Function, material compatibility, adequate ratings, proper installation, operation, and maintenance are the responsibilities of the system designer and user.

How to Choose a Regulator - Creep

Step 5: Follow Best Practices



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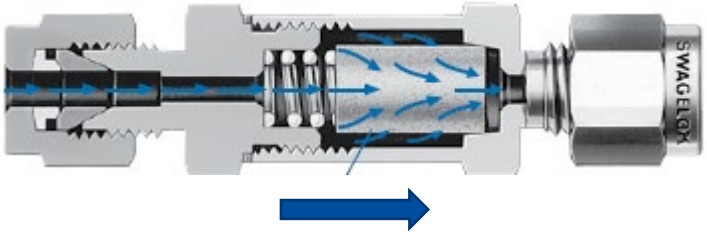
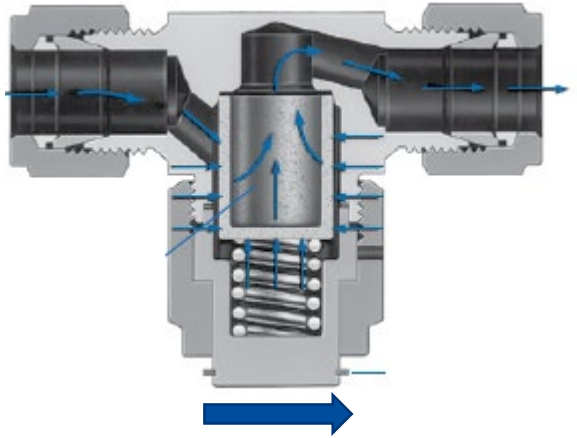
How to Choose a Regulator - Creep

- Filters are crucial parts that can prevent a lot of damage and failure of complete systems
- Every (very) small damage (scratch) can lead to a failure of a component
- Location of a filter in a system is very important
- Pore Size based on the expected particle size
- Required flow through the (clean) filter
- System Working pressure
- Maximum Differential Pressure (Delta P)
- Filtration Area (mm2)
- UHP filter options for lab applications

How to Choose a Regulator - Creep



Inline Filter



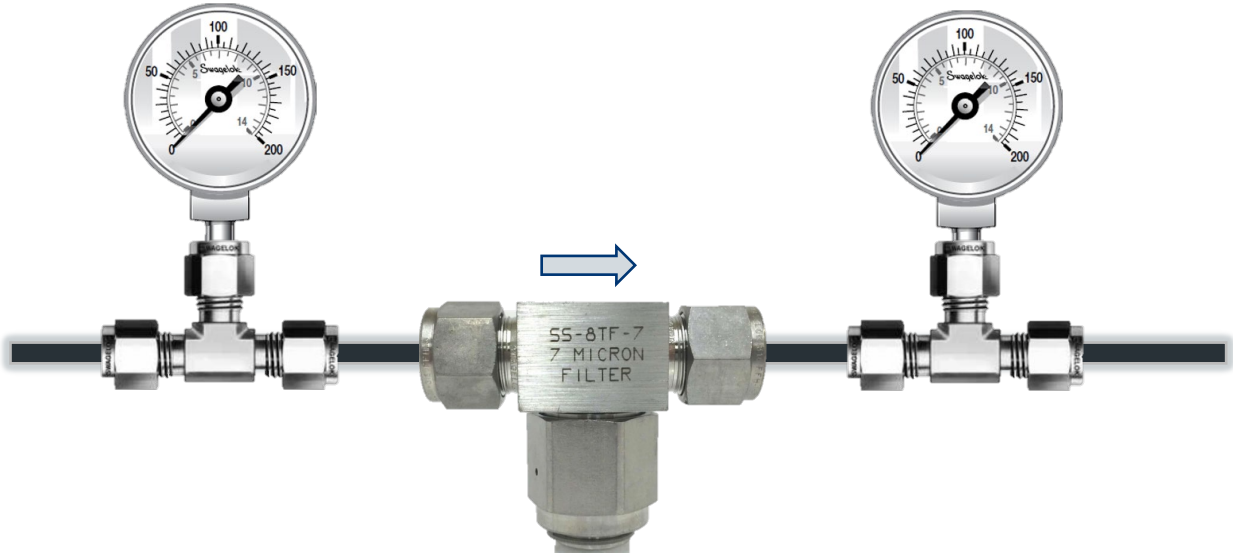
Tee-Type Filter

- Note the arrow for the correct flow direction
- Tee Type Filter simplifies element change.
  - ➢ Filter element can be replaced without removing body from system

Filters - Differential Pressure

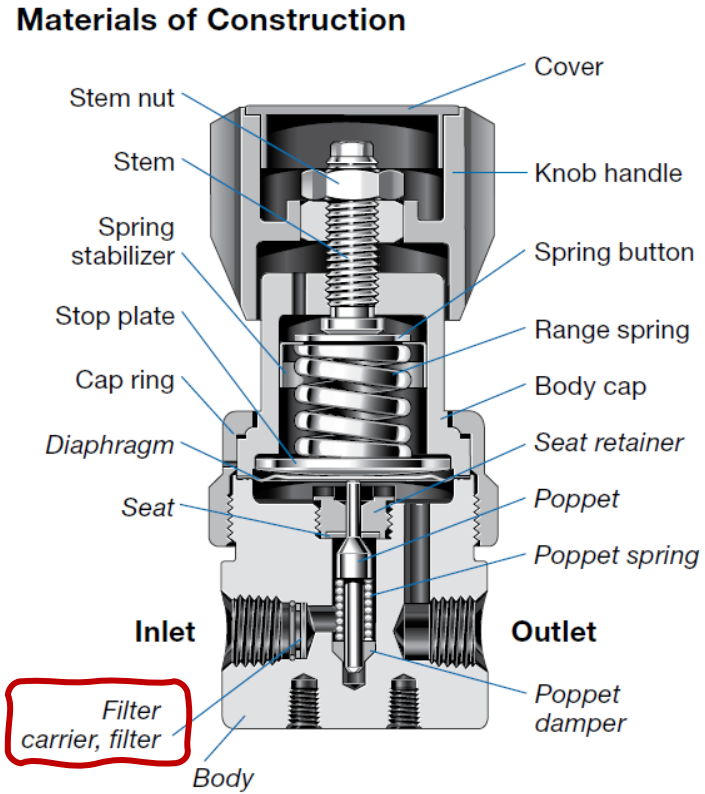
Differential Pressure Ratings

Filter Series	Maximum Differential Pressure psig (bar)		
	Sintered Element	Strainer Element	Pleated Element
FW	600 (41.3)	—	100 (6.8)
F, TF	1000 (68.9)		—



- Trapped particles affect the pressure difference across the element
- The more trapped particles the higher the differential pressure across the element
- System and Filter element can be damaged by clogged filters
- Check regularly the status of the filter element

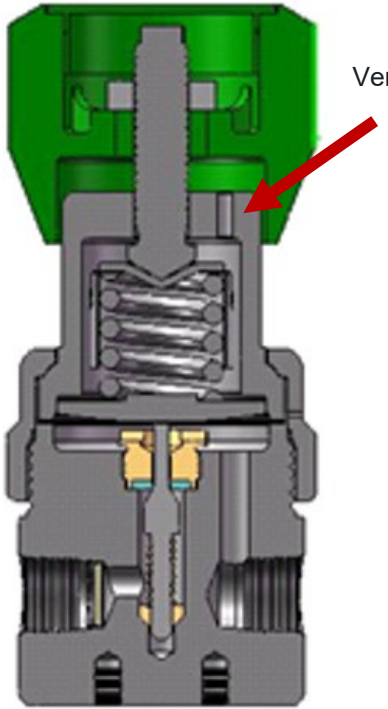
Regulators with integral Filters



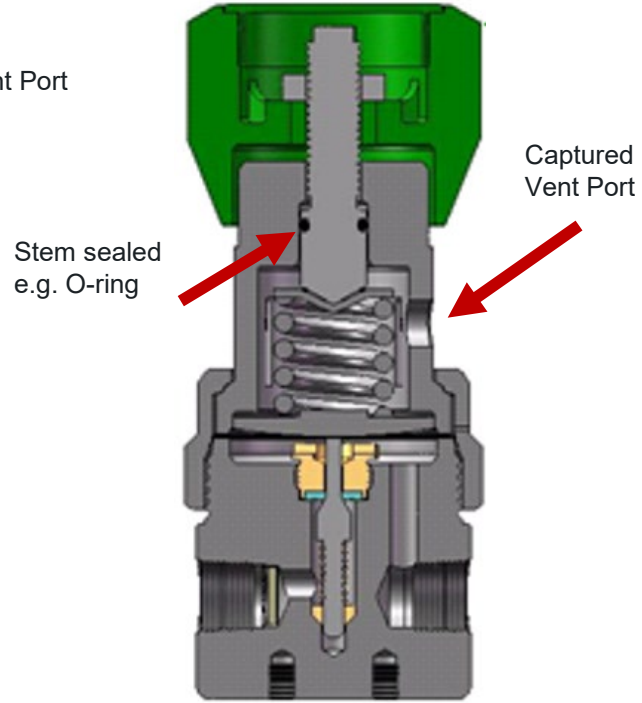
Gauze Inlet Filter

Regulators are susceptible to damage from system particles. Swagelok pressure-reducing regulators can include a **25 µm** press fit filter. *It can be removed to use the regulator in liquid service.*

Pressure Regulators - Venting Option



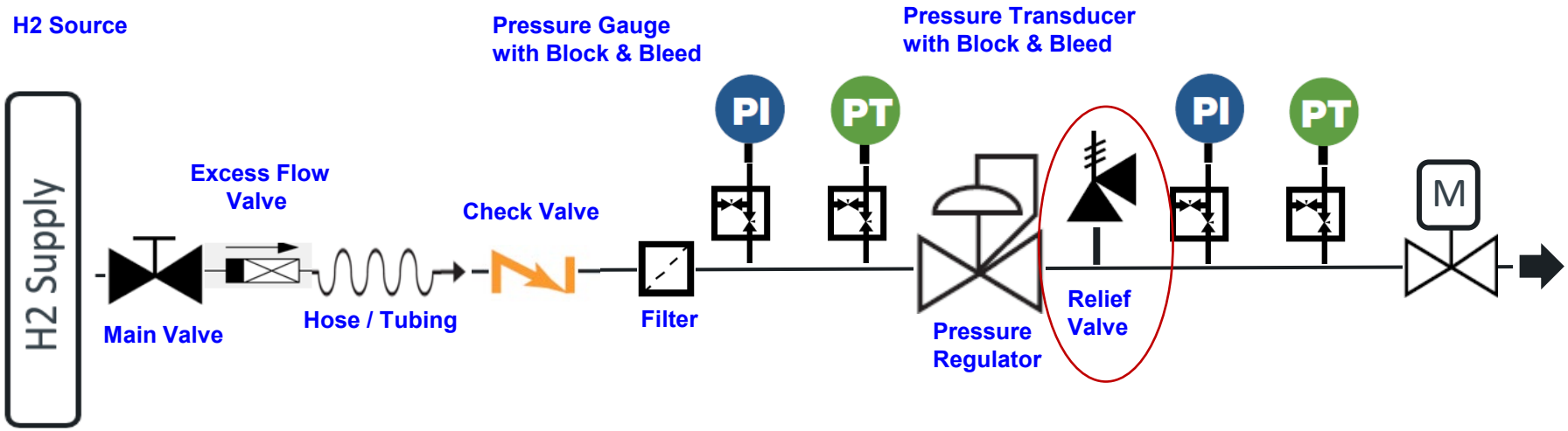
No Captured Vent



Captured Vent

How to Choose a Regulator - Creep

Step 5: Follow Best Practices



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How to Choose a Regulator - Creep

- Relief valves OPEN when system pressure reaches the set pressure and CLOSE when system pressure falls below the set pressure
- Set pressure X% above the MAWP
- Determine capacity of the relief valve based on possible creep caused by the regulator or based on full system flow?
- The effect of system back pressure is depending of the valve design

Ready to Choose Your Regulator?

Swagelok regulator specialists are at the ready to help you properly identify the right regulator solution for your pressure control needs. These certified advisors have the technical expertise to help you with component sizing, material selection, on-site troubleshooting, and system design support.

Get in touch to find the assistance you need to keep your pressurized fluid systems operating dependably.

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