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The Basics of Pressure Regulators

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Installation Guide

Beswick pressure regulators can be viewed at <http://catalog.beswick.com>

Pressure regulators are found in many common home and industrial applications. For example, pressure regulators are used in gas grills to regulate propane, in home heating furnaces to regulate natural gas, in medical and dental equipment to regulate oxygen and anesthesia gases, in pneumatic automation systems to regulate compressed air, in engines to regulate fuel and in fuel cells to regulate hydrogen. As this partial list demonstrates there are numerous applications for regulators yet, in each of them, the pressure regulator provides the same function. Pressure regulators reduce a supply (or inlet) pressure to a lower outlet pressure and work to maintain this outlet pressure despite fluctuations in the inlet pressure. The reduction of the inlet pressure to a lower outlet pressure is the key characteristic of pressure regulators.

When choosing a pressure regulator many factors must be considered. Important considerations include: operating pressure ranges for the inlet and outlet, flow requirements, the fluid (Is it a gas, a liquid, toxic, or flammable?), expected operating temperature range, material selection for the regulator components including seals, as well as size and weight constraints.



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MATERIALS

A wide range of materials are available to handle various fluids and operating environments. Common regulator component materials include brass, plastic, and aluminum. Various grades of stainless steel (such as 303, 304, and 316) are available too. Springs used inside the regulator are typically made of music wire (carbon steel) or stainless steel.

Brass is suited to most common applications and is usually economical. Aluminum is often specified when weight is a consideration. Plastic is considered when low cost is of primary concern or a throw away item is required. Stainless Steels are often chosen for use with corrosive fluids, use in corrosive environments, when cleanliness of the fluid is a consideration or when the operating temperatures will be high.

Equally important is the compatibility of the seal material with the fluid and with the operating temperature range. Buna-n is a typical seal material. Optional seals are offered by some manufacturers and these include: Fluorocarbon, EPDM, Silicone, and Perfluoroelastomer.

FLUID USED - (GAS, LIQUID, TOXIC, or FLAMMABLE)

The chemical properties of the fluid should be considered before determining the best materials for your application. Each fluid will have its own unique characteristics so care must be taken to select the appropriate body and seal materials that will come in contact with the fluid. The parts of the regulator in contact with the fluid are known as the “wetted” components.

It is also important to determine if the fluid is flammable, toxic, explosive, or hazardous in nature. A non-relieving regulator is preferred for use with hazardous, explosive, or expensive gases because the design does not vent excessive downstream pressure into the atmosphere. In contrast to a non-relieving regulator, a relieving (also known as self-relieving) regulator is designed to vent excess downstream pressure to atmosphere. Typically there is a vent hole in the side of the regulator body for this purpose. In some special designs, the vent port can be threaded and any excess pressure can be vented from the regulator body through tubing and exhausted in a safe area. If this type of design is selected the excess fluid should be vented appropriately and in accordance to all safety regulations.



TEMPERATURE

The materials selected for the pressure regulator not only need to be compatible with the fluid but also must be able to function properly at the expected operating temperature. The primary concern is whether or not the elastomer chosen will function properly throughout the expected temperature range. Additionally, the operating temperature may affect flow capacity and/or the spring rate in extreme applications.

OPERATING PRESSURES

The inlet and outlet pressures are important factors to consider before choosing the best regulator. Important questions to answer are: What is the range of fluctuation in the inlet pressure? What is the required outlet pressure? What is the allowable variation in outlet pressure?



FLOW REQUIREMENTS

What is the maximum flow rate that the application requires? How much does the flow rate vary? Porting requirements are also an important consideration.

SIZE & WEIGHT

In many high technology applications space is limited and weight is a factor. Some manufactures specialize in miniature components and should be consulted if overall size and weight are critical. Material selection, particularly the regulator body components, will impact weight. Also carefully consider the port (thread) sizes, adjustment styles, and mounting options as these will influence size and weight.



PRESSURE REGULATORS IN OPERATION

A pressure regulator is comprised of three functional elements:

- 1.) A pressure reducing or restrictive element. Often this is a spring loaded poppet valve.
- 2.) A sensing element. Typically a diaphragm or piston.
- 3.) A reference force element. Most commonly a spring.

In operation, the reference force generated by the spring opens the valve. The opening of the valve applies pressure to the sensing element which in turn closes the valve until it is open just enough to maintain the set pressure. The simplified schematic "Pressure Regulator Schematic" illustrates this force balance arrangement.

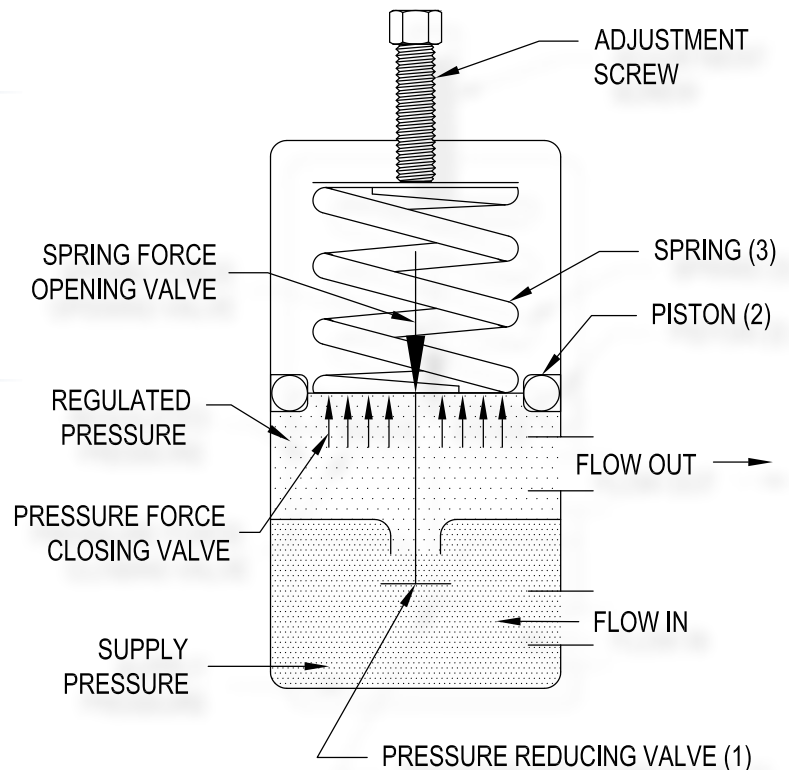
(1) PRESSURE REDUCING ELEMENT (poppet valve)

Most commonly, regulators employ a spring loaded "poppet" valve as a restrictive element. The poppet includes an elastomeric seal or, in some high pressure designs a thermoplastic seal, which is configured to make a seal on a valve seat. When the spring force moves the seal away from the valve seat, fluid is allowed to flow from the inlet of the regulator to the outlet. As the outlet pressure rises, the force generated by the sensing element resists the force of the spring and the valve is closed. These two forces reach a balance point at the set point of the pressure regulator. When the downstream pressure drops below the set-point, the spring pushes the poppet away from the valve seat and additional fluid is allowed to flow from the inlet to the outlet until the force balance is restored.

(2) SENSING ELEMENT (piston or diaphragm)

Piston style designs are often used when higher outlet pressures are required, when ruggedness is a concern or when the outlet pressure does not have to be held to a tight tolerance. Piston designs tend to be sluggish, as compared to diaphragm designs, because of the friction between the piston seal and the regulator body.

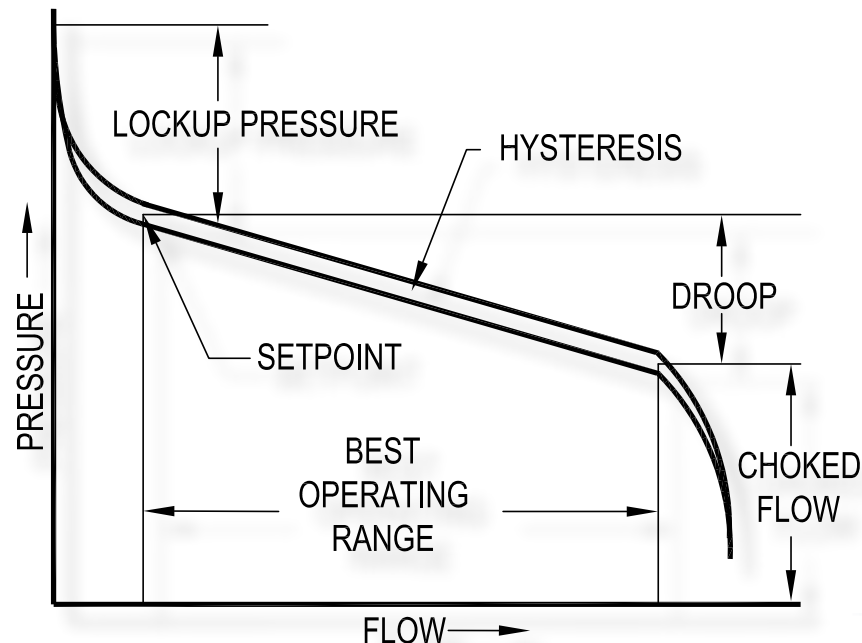
PRESSURE REGULATOR SCHEMATIC SHOWING FORCES ACTING ON THE INDIVIDUAL ELEMENTS



In low pressure applications, or when high accuracy is required, the diaphragm style is preferred. Diaphragm regulators employ a thin disc shaped element which is used to sense pressure changes. They are usually made of an elastomer, however, thin convoluted metal is used in special applications. Diaphragms essentially eliminate the friction inherent with piston style designs. Additionally, for a particular regulator size, it is often possible to provide a greater sensing area with a diaphragm design than would be feasible with a piston style design.

(3) THE REFERENCE FORCE ELEMENT (spring)

The reference force element is usually a mechanical spring. This spring exerts a force on the sensing element and acts to open the valve. Most regulators are designed with an adjustment which allows the user to adjust the outlet pressure set-point by changing the force exerted by the reference spring.



DIRECT ACTING
PRESSURE REGULATOR
OPERATING MAP

HYSTERESIS

Hysteresis can occur in mechanical systems, such as pressure regulators, due to friction forces caused by springs and seals. Take a look at the graph and you will notice, for a given flow rate, that the outlet pressure will be higher with decreasing flow than it will be with increasing flow.

LOCK UP PRESSURE

“Lockup pressure” is the pressure above the set-point that is required to completely shut the regulator valve off and insure that there is no flow.

REGULATOR ACCURACY AND CAPACITY

The accuracy of a pressure regulator is determined by charting outlet pressure versus flow rate. The resulting graph shows the drop in outlet pressure as the flow rate increases. This phenomenon is known as droop. Pressure regulator accuracy is defined as how much droop the device exhibits over a range of flows; less droop equals greater accuracy. The pressure versus flow curves provided in the graph “Direct Acting Pressure Regulator Operating Map”, indicates the useful regulating capacity of the regulator. When selecting a regulator, engineers should examine pressure versus flow curves to ensure the regulator can meet the performance requirements necessary for the proposed application.

DROOP DEFINITION

The term “droop” is used to describe the drop in the outlet pressure, below the original set-point, as flow increases. Droop can also be caused by significant changes in the inlet pressure (from the value when the regulator output was set). As the inlet pressure rises from the initial setting, the outlet pressure falls. Conversely, as the inlet pressure falls, the outlet pressure rises. As seen in the graph “Direct Acting Pressure Regulator Operating Map”, this effect is important to a user because it shows the useful regulating capacity of a regulator.

ORIFICE SIZE

Increasing the valve orifice can increase the flow capacity of the regulator. This may be beneficial if your design can accommodate a bigger regulator however be careful not to over specify. A regulator with an oversized valve, for the conditions of the intended application, will result in a greater sensitivity to fluctuating inlet pressures, and may cause excessive droop.

SINGLE, TWO, & THREE STAGE REGULATORS



PRD-2N2



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SINGLE-STAGE REGULATOR

Single-stage regulators are an excellent choice for relatively small reductions in pressure. For example, the air compressors used in most factories generate maximum pressures in the 100 to 150 psi range. This pressure is piped through the factory but is often reduced with a single-stage regulator to lower pressures (10 psi, 50 psi, 80 psi etc.) to operate automated machinery, test stands, machine tools, leak test equipment, linear actuators, and other devices. Single stage pressure regulators typically do not perform well with large swings in inlet pressure and/or flow rates.

TWO-STAGE (DUAL-STAGE) REGULATOR

A two-stage pressure regulator is ideal for applications with large variations in the flow rate, significant fluctuations in the inlet pressure, or decreasing inlet pressure such as occurs with gas supplied from a small storage tank or gas cylinder.

With most single-stage regulator regulators, except those that use a pressure compensated design, a large drop in inlet pressure will cause a slight increase in outlet pressure. This happens because the forces acting on the valve change, due to the large drop in pressure, from when the outlet pressure was initially set. In a two-stage design the second stage will not be subjected to these large changes in inlet pressure, only the slight change from the outlet of the first stage. This arrangement results in a stable outlet pressure from the second stage despite the significant changes in pressure supplied to the first stage.

BESWICK ADVANTAGE: 100% TESTED

We take the time to functionally test 100% of our regulators before shipping to ensure that you receive the highest quality product.



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PRD4HP

THREE-STAGE REGULATOR

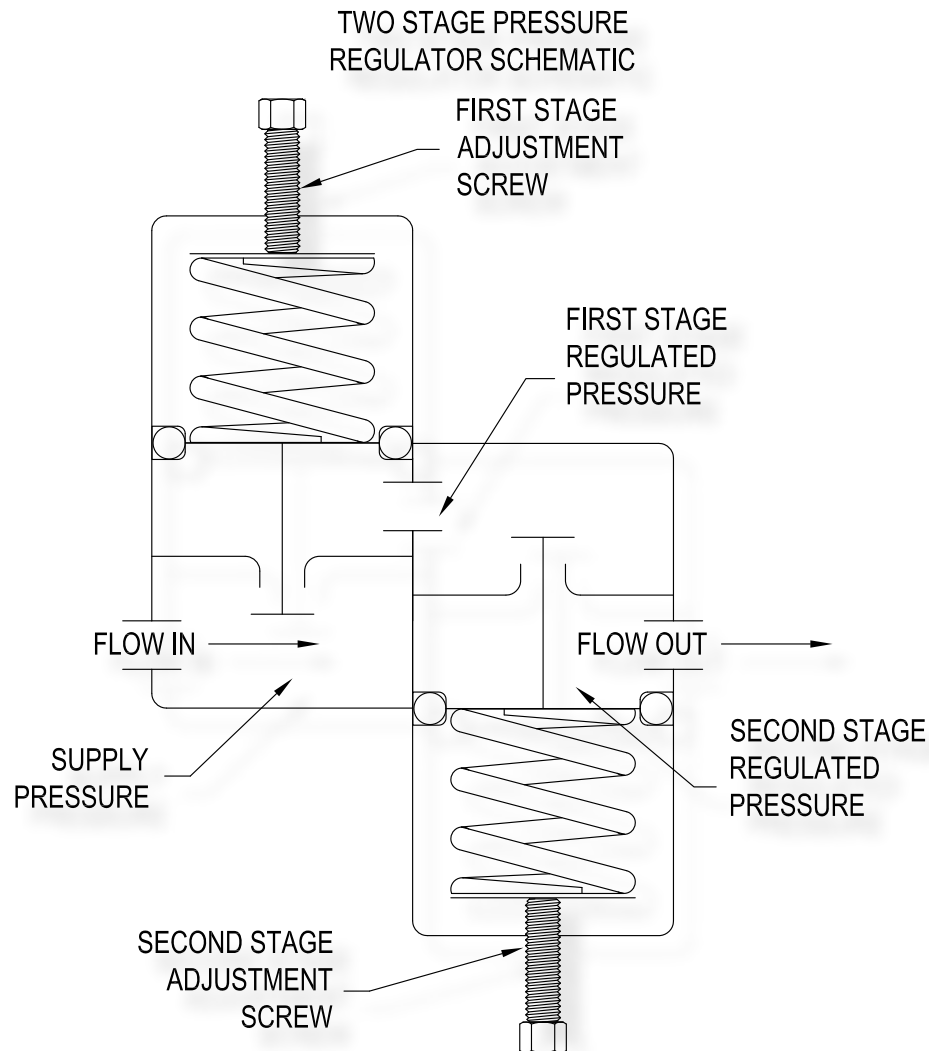
A three-stage regulator provides a stable outlet pressure similar to a two-stage regulator but with the added ability to handle a significantly higher maximum inlet pressure. For example, the Beswick PRD4HP series three-stage regulator is rated to handle an inlet pressure as high as 3,000 psi and it will provide a stable outlet pressure (in the 0 to 30 psi range) despite changes to the supply pressure. A small and lightweight pressure regulator that can maintain a stable low output pressure, despite an inlet pressure that will decrease over time from a high pressure, is a critical component in many designs. Examples include portable analytical instruments, hydrogen fuel cells, UAVs, and medical devices powered by high pressure gas supplied from a gas cartridge or storage cylinder.

Now that you have chosen the regulator that best suits your application it is important that the regulator is installed and adjusted properly to insure that it functions as intended.

Most manufacturers recommend the installation of a filter upstream of the regulator (some regulators have a built-in filter) to prevent dirt and particulates from contaminating the valve seat. Operation of a regulator without a filter could result in fluid leaking to the outlet port if the valve seat is contaminated with dirt or foreign material. Regulated gases should be free from oils, greases, and other contaminants which could foul or damage the valve components or attack the regulator seals. Many users are unaware that gases supplied in cylinders and small gas cartridges can contain traces of oils from the manufacturing process. The presence of oil in the gas is often not apparent to the user and therefore this topic should be discussed with your gas supplier before you select the seal materials for your regulator. Additionally, gasses should be free of excessive moisture. In high flow rate applications, icing of the regulator can occur if moisture is present.

If the pressure regulator will be used with oxygen, be aware that that oxygen requires specialized knowledge for safe system design. Oxygen compatible lubricants must be specified and extra cleaning, to remove traces of petroleum based cutting oils, is typically specified. Make certain that you inform your regulator supplier that you plan to use the regulator in an oxygen application.

Do not connect regulators to a supply source with a maximum pressure greater than the rated inlet pressure of the regulator. Pressure regulators are not intended to be used as shutoff devices. When the regulator is not in use, the supply pressure should be turned off.



STEP 1

Begin by connecting the pressure source to the inlet port and the regulated pressure line to the outlet port. If the ports are not marked, check with the manufacturer to avoid incorrect connections. In some designs, damage can occur to the internal components if the supply pressure is mistakenly supplied to the outlet port.

STEP 2

Before turning on the supply pressure to the regulator, back off the adjustment control knob to restrict flow through the regulator. Gradually turn on the supply pressure so as not to “shock” the regulator with a sudden rush of pressurized fluid. NOTE: Avoid turning the adjustment screw all the way into the regulator because, in some regulator designs, the full supply pressure will be delivered to the outlet port.

STEP 3

Set the pressure regulator to the desired outlet pressure. If the regulator is non-relieving, it will be easier to adjust the outlet pressure if fluid is flowing rather than “dead ended” (no flow). If the measured outlet pressure exceeds the desired outlet pressure, vent the fluid from the downstream side of the regulator and lower the outlet pressure by turning the adjustment knob. Never vent fluid by loosening fittings, as injury may result.

With a relieving style regulator, excess pressure will be automatically vented to atmosphere from the downstream side of the regulator when the knob is rotated to lower the output setting. For this reason, do not use relieving style regulators with flammable or hazardous fluids. Be sure the excess fluid is vented safely and in accordance with all local, state and federal regulations.

STEP 4

To obtain the desired outlet pressure, make the final adjustments by slowly increasing the pressure from below the desired set point. Setting the pressure from below the desired setting is preferred to setting it from above the desired setting. If you overshoot the set point while setting the pressure regulator, back off the set pressure to a point below the set point. Then, again, gradually increase the pressure to the desired set point.

STEP 5

Cycle the supply pressure on and off several times while monitoring the outlet pressure to confirm the regulator is consistently returning to the set point. Additionally, the outlet pressure should also be cycled on and off to ensure the pressure regulator returns to the desired set point. Repeat the pressure setting sequence if the outlet pressure does not return to the desired setting.