

Basics of Pressure Regulation

Technical Information

DEBUL2008X012

What is a regulator?

A pressure reducing regulator is a device which reduces a high source pressure (e.g. an inlet pressure of 3000 psig / 207 bar) to a lower working pressure (e.g. an outlet pressure of 100 psig / 6.9 bar) that is suitable for a user's application. The regulator will attempt to maintain the outlet pressure within acceptable limits as other conditions vary. Source pressure and media (gas or liquid) flow are among these varying conditions. A regulator's accuracy and efficiency in performing its function is determined by the combination of the basic regulator elements designed into a specific regulator unit.

The basic elements of a regulator often will determine the regulator type and series selected for a specific application. In this manual, it will discuss the three basic elements common to all pressure reducing regulators whether manufactured by TESCOM or other manufacturers.

Pressure Reducing Regulator/Valve (PRV)

The function of a pressure reducing regulator is to precisely reduce a high upstream pressure of a gas or liquid (from a cylinder, compressor, pump, etc) to a lower, stable pressure for the user's application. Furthermore, the regulator will attempt to maintain and control the outlet pressure within limits as other conditions vary but the regulator will not control flow, only the delivery pressure. A regulator should not be used as a shut-off device as there is always a small amount of leakage across the seat. A shut-off valve must be used downstream of the regulator if isolation is required.

Backpressure Regulator/Valve (BPR)

The function of a backpressure regulator is to limit and precisely control the upstream pressure of a gas or liquid (from a tank, pump, etc) and is much more accurate than a relief valve. Most direct spring operated safety relief valves have a high reseating pressure which is inconsistent and unreliable. This is the primary difference between a safety relief valve and a backpressure regulator. A safety relief valve is designed to protect downstream personnel and equipment should over-pressurization take place. As such, when it's set pressure is overcome, it will blow wide open immediately and exhaust all of the

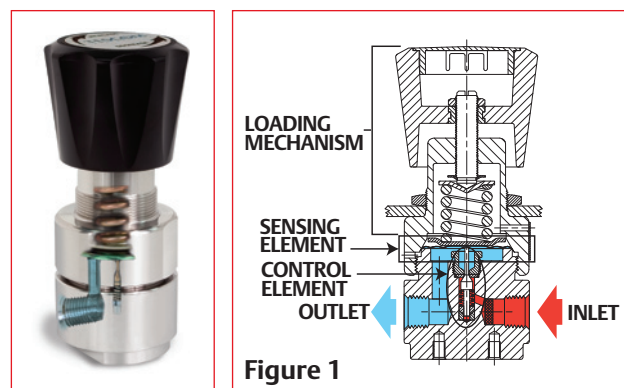


Figure 1

pressure. It needs to be able to handle the full flow of the system in order to rapidly exhaust to protect downstream apparatus. A backpressure regulator is not a safety device, it is designed for precision upstream pressure control. When the regulator set-point is overcome, it will "crack" open (not blow wide open) and try to exhaust just the excess pressure above the set-point. When it cracks open, it uses its sensing element (relief valves do not have sensing elements) to reseat very close to its original set pressure. Most TESCOM backpressure regulators have "crack-to-reseat" pressures less than $\pm 2\%$ of the set-point (relief valves are typically $\pm 10\%$).

Three Basic Elements

The Three Basic Elements are:

1. The **LOADING MECHANISM** provides the means by which the operator can set the force that determines the outlet (control) pressure of the regulator. P_2 is a term commonly used for outlet pressure.
2. The **SENSING ELEMENT** senses the changes in the outlet pressure (P_2) through a cavity located underneath it, allowing the regulator to react accordingly to these changes in P_2 .

The sensing element also provides a physical link between the loading element and the control element.

3. The **CONTROL ELEMENT** acts to reduce the inlet pressure, commonly called P_1 , to a lower working pressure and maintain it by increasing or decreasing the orifice area as the control element moves away or towards the seat.

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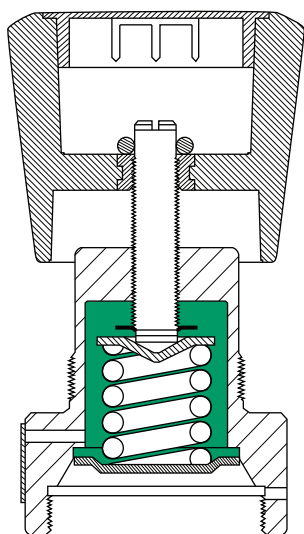
I. Loading Mechanisms

The first basic element is the **LOADING** mechanism of a regulator. This mechanism determines what the regulator outlet pressure (P_2) will be.

The load element provides the force which is in turn transmitted through the **SENSING** element and to the **CONTROL** element, to provide the desired outlet pressure. It provides a preload force which establishes the demand level of the regulated or outlet pressure.

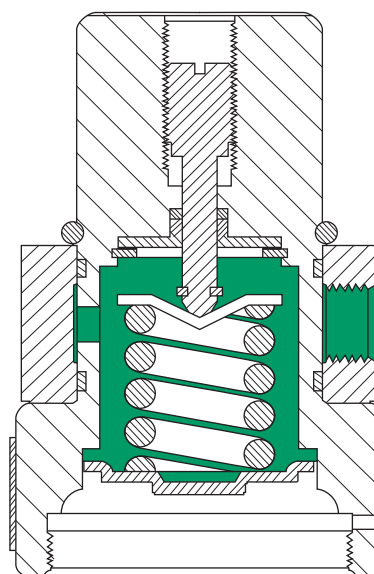
There are four types of loading:

- Spring Load
- Dome Load (also called gas or liquid loading)
- Air Load
- Combination of Spring and Dome Load



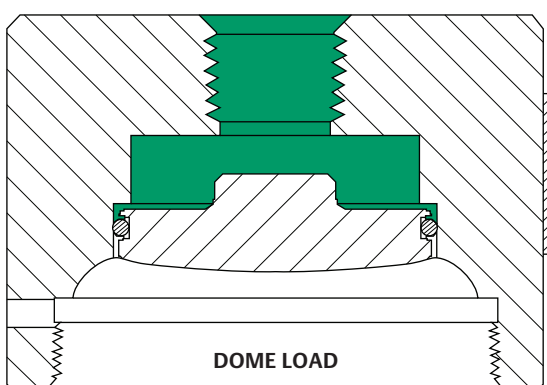
SPRING LOAD

Figure 2



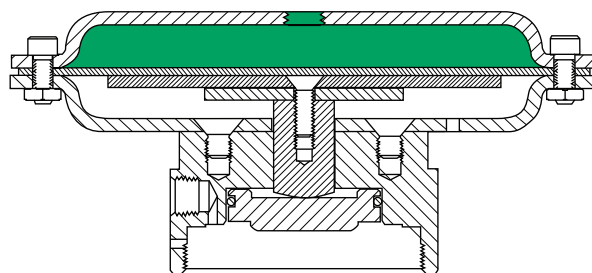
SPRING AND DOME LOAD

Figure 4



DOME LOAD

Figure 3



AIR LOAD

Figure 5

I. Loading Mechanisms

A. Spring Load

The spring (Figure 6) is the most common loading device in regulators because of its dependability and low cost.

The spring load is determined by the amount of compression placed on the spring by the operator. This is accomplished by turning the regulator knob or adjusting screw in a clockwise direction (Figure 7). The knob is turned, compressing the load spring, until the desired outlet or set pressure is reached on the regulator's outlet pressure gauge.

Caution must be used during adjustment to prevent thread stripping. This commonly occurs when an operator attempts to set an outlet pressure which exceeds the regulator's capacity or the available inlet pressure.

The mechanical advantage of a standard adjusting screw or handknob provides easy adjustment for outlet pressures up to 500 psig / 34.5 bar. For high pressures, up to 15,000 psig / 1034 bar, TESCOM uses a non-rising stem handknob with bearings that enables manual adjustment of pressures with only 30-40 in-lbs / 3.4-4.5 N•m of torque.

Advantages

- Simple design
- Relatively small size
- Springs of various rate can be adjusted to provide different outlet pressures
- There is a variety of spring sources which makes the prices competitive and economical

Disadvantages

- Spring forces vary with compression and thus the load is not uniform
- Susceptible to the effects of shock, vibration and temperature

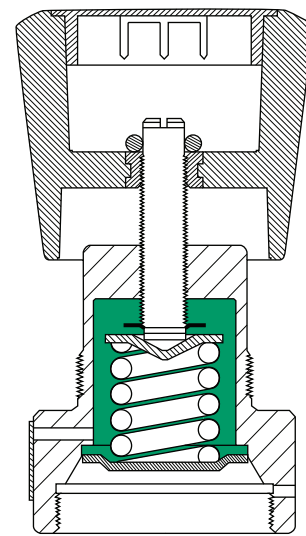


Figure 6

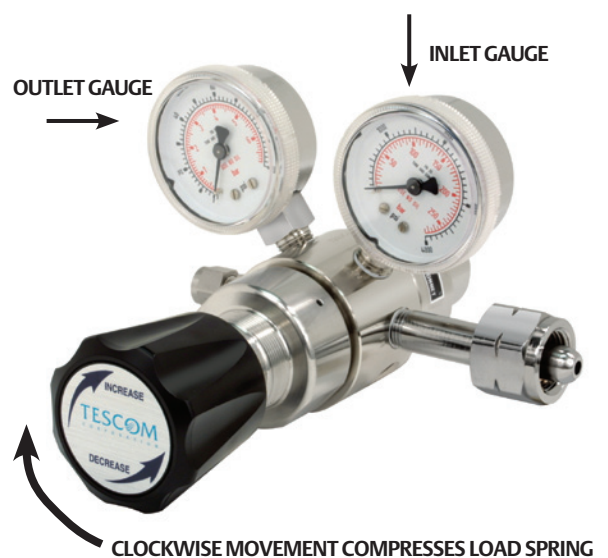


Figure 7

I. Loading Mechanisms

B. Dome Load

The second loading method is called dome load (Figure 8). Instead of a spring, pressure in the dome area is used to provide loading force to the regulator. This is accomplished by sealing the dome area to prevent leaks and then pressurizing it with gas or liquid coming from a pilot regulator.

The pressure in the dome determines the regulator's outlet pressure. The dome pressure is essentially equal to the regulator outlet pressure.

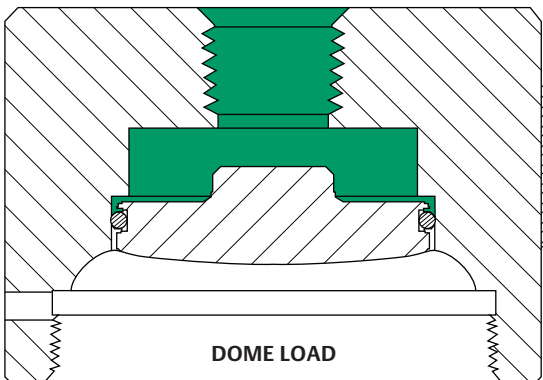


Figure 8

In the example in Figure 9, a 26-1200 Series dome loaded regulator is connected to a 26-1000 Series venting regulator. The 26-1000 regulator acts as a pilot regulator and provides the loading pressure to the dome of the 26-1200 regulator. To set the pressure in the dome, the pressure coming from the pilot regulator is adjusted until the outlet pressure gauge of the dome regulator reads the desired set pressure.

If the dome is loaded to 1000 psig / 69.0 bar, then the outlet pressure will be close to 1000 psig / 69.0 bar. The slight difference is primarily due to the control element (valve) spring force which counteracts the dome load pressure force.

When the regulator strokes downward in response to increased flow, the pilot regulator will add more gas to make up the pressure lost due to the increase in the dome area and keep the dome pressure constant. A pilot regulator with venting capability should be used to load dome loaded regulators. This venting capability is necessary to allow an operator to adjust the dome pressure in both increasing and decreasing directions.

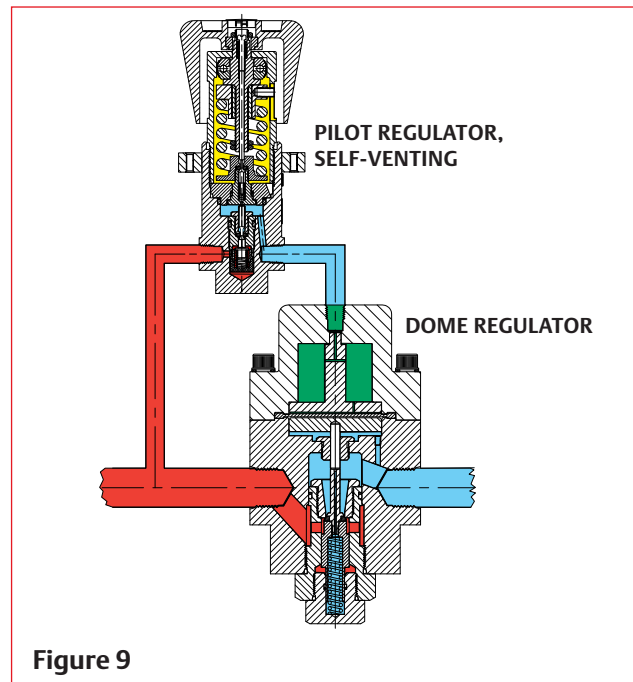


Figure 9

Almost all TESCOM regulator series are available with dome load.

Advantages

- Enables remote pressure control which allows the operator to adjust pressure at a safe distance, away from hazardous gases or conditions
- Offers convenience by providing a means of adjusting pressure when the dome regulator is located in an area difficult to reach
- Maintains outlet pressure more accurately under flowing conditions than a spring loaded regulator, minimizing droop
- Faster response to pressure changes

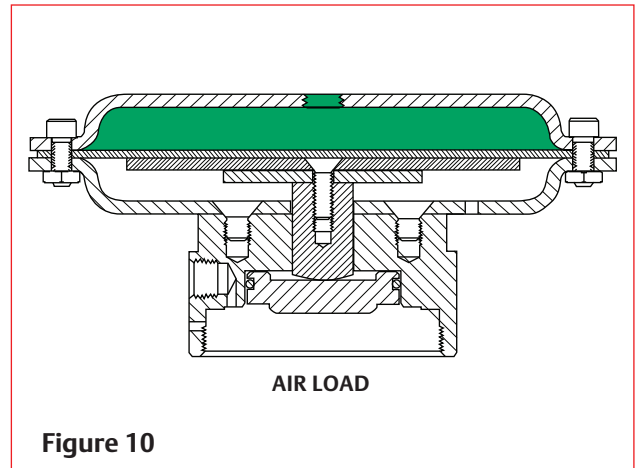
Disadvantage

- Requires two regulators: the dome regulator and the pilot regulator. This means increased cost and greater space requirement for installation

I. Loading Mechanisms

C. Air Load

A third loading method is Air Actuated or Air Loaded. This is similar to dome load, but has a ratio greater than 1:1 between the loading force (pilot pressure) and the control pressure. This is the primary difference between a dome loaded and air loaded regulator. Another difference is inert gas can only be used to pilot an air actuated regulator. Dome loaded regulators can be piloted with either gas or liquid. Air actuated loading is available on many TESCOM regulator series and with our wide range of pressure capability up to 30,000 psig / 2069 bar we offer ratios from 2.5:1 to 375:1. The ratios are approximate, so in order to set the regulator at the desired setpoint you need to monitor a pressure indicator from the control pressure side of the regulator the same way you do with a dome loaded regulator. The maximum control pressure of the air actuated regulator is typically achievable with ~80 psig / ~5.5 bar pilot pressure. The mechanical advantage of air actuated regulators allows use of low pressure inert gas (facility air) and low pressure plumbing/pressure regulation for the pilot pressure source. It also allows use of TESCOM's ER3000 Electropneumatic Pressure Controller to provide the pilot pressure control as well as closed loop electronic control. Like the dome loaded regulator, the pilot pressure regulator/controller should be a venting type to allow pressure adjustment in both increasing and decreasing directions.



Advantages

- Provides a ratio between actuator pressure and media pressure (e.g. 1:75)
- Enables remote pressure control in combination with pilot regulators
- Low pressure drop under dynamic conditions (minimized droop)
- Allows use of low pressure inert gas (facility air) and low pressure plumbing/pressure regulation for the pilot pressure source
- Can be combined with the ER3000 Electropneumatic Controller

Disadvantage

- Requires two regulators: the air loaded regulator and the pilot regulator. This means increased cost and greater space requirement for installation

I. Loading Mechanisms

D. Combination of Spring and Dome Load

This hybrid regulator uses a combination of spring and dome loading (Figure 11) and is identified by several names:

- Bias Regulator
- Tracking Regulator
- Algebraic Regulator
- Differential Pressure Regulator

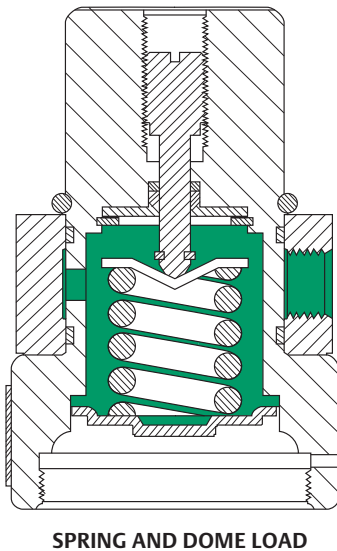


Figure 11

It is called a “bias” regulator because the spring provides a “bias” or added force.

The term “tracking” is used because the regulator can follow the pressure of one system as the pressure goes up or down. The regulator supplies pressure equal to the bias setting plus the reference pressure and sends the total pressure of the two signals to a second system.

It is sometimes called an “algebraic” regulator because it can add or subtract pressure equal to its bias spring setting. The pressure is added when the bias spring is located above the sensing element, diaphragm or piston, and subtracted when the bias spring is located below the sensing element.

This is how the combination dome and spring regulator works:

First, the bias spring is manually adjusted to provide a specific bias pressure, for instance 50 psig / 3.4 bar (Figure 12). The bias pressure will remain constant and maintain that difference above the reference pressure.

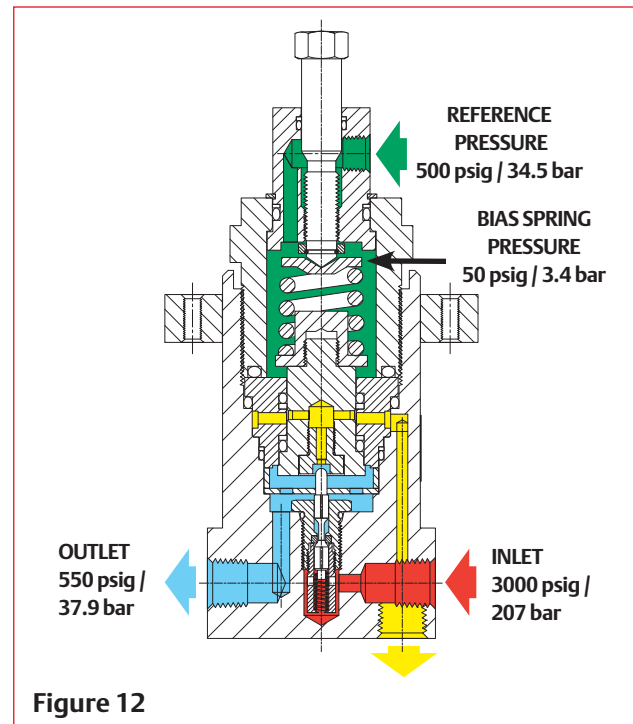


Figure 12

Then the dome is loaded with pressure from a “reference source”, another system, at a pressure of 500 psig / 34.5 bar. The dome is now loaded with a total of 550 psig / 37.9 bar, the sum of the bias pressure (50 psig / 3.4 bar) and pressure from the reference source (500 psig / 34.5 bar). The regulator will now deliver an outlet pressure of 550 psig / 37.9 bar.

If for any reason the reference should change either up or down and provided there is flow or the regulator has a venting feature, the outlet pressure will also change. An example: the reference pressure drops by 100 psig / 6.9 bar, from 500 psig / 34.5 bar down to 400 psig / 27.6 bar, the bias pressure set on the spring remains at 50 psig / 3.4 bar. Consequently the outlet pressure of the combination spring and dome regulator is now 450 psig / 31.0 bar.

Regulators with combination spring and dome load are used in a variety of applications and are especially useful in commercial diving, oil exploration, laboratory and autoclave applications.

Advantage

- Provides gas pressure accurately for tracking applications

Disadvantage

- More expensive than a spring or a dome loaded regulator

II. Sensing Elements

The function of the sensing element is to sense changes in the downstream or outlet pressure side of a regulator. The area sensed is immediately below the sensing element in the P_2 cavity of the regulator.

There are three common types of sensing elements:

- Diaphragm (Figure 13)
- Piston (Figure 14)
- Bellows (Figure 15)

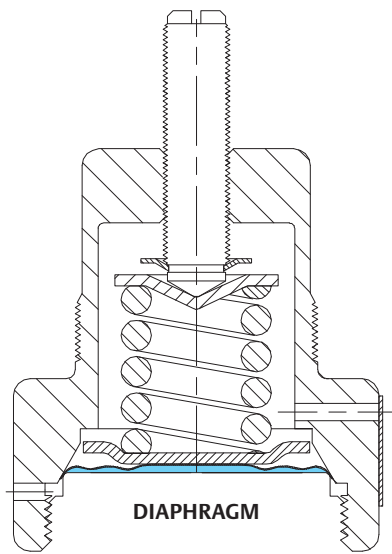


Figure 13

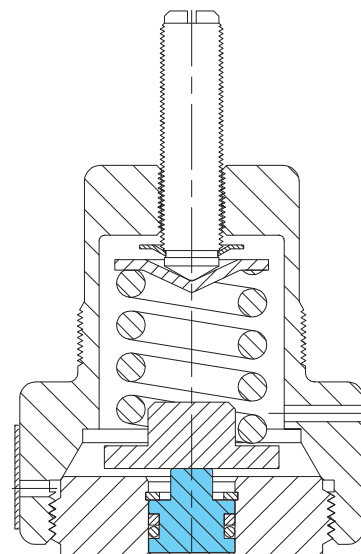


Figure 14

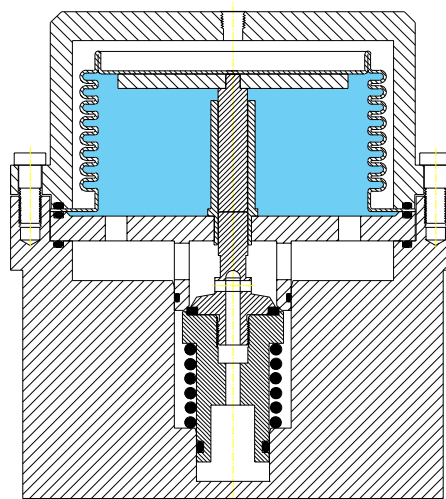


Figure 15

II. Sensing Elements

A. Diaphragm Sensing Element

The diaphragm (Figure 16) is relatively inexpensive and adequate for most applications. The diaphragm provides sensitivity to pressure changes, especially with elastomer materials. Early natural rubber diaphragms have been replaced by elastomers, man-made rubber substitutes, for many applications to provide increased compatibility with the wide variety of gases currently in use. Some of the elastomers in common use are Buna-N, Viton-A®, and Ethylene Propylene.

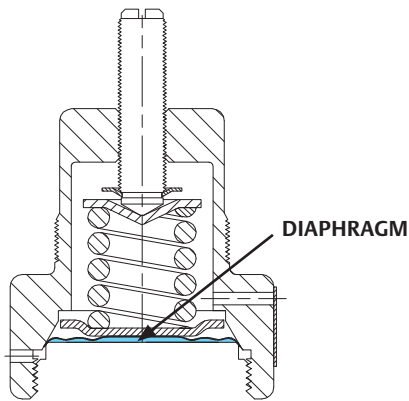


Figure 16

Where elastomers fail to provide media compatibility, metal diaphragms have found their way into use. 316 Stainless Steel diaphragms are in wide use, especially in the semiconductor, specialty gas and petroleum regulator markets. Elgiloy®, a cobalt-chrome-nickel alloy, is also an excellent diaphragm material for applications with wide temperature swings and high cycle life. It is also compatible with a wide range of gases.

However, outlet pressure ratings are limited due to possible diaphragm rupture. This is a consequence of high pressure loading on the underside of the diaphragm and only atmospheric pressure on the top side of the diaphragm (Figure 17). TESCO limits the use of diaphragms to outlet pressures up to a maximum of 500 psig / 34.5 bar.

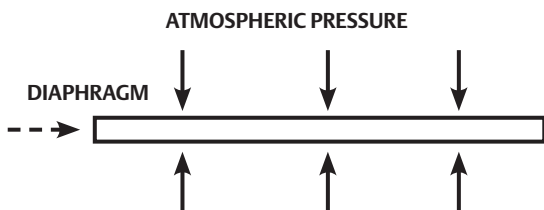


Figure 17

The valve stem motion must be restricted since diaphragm distortion can affect the actuating force characteristics. An additional consideration is the non-constant effective sensing area of the diaphragm as it flexes.

TESCOM's metal diaphragms have two concentric rings (Figure 18) or convolutions to provide natural flexing areas and eliminate the oil-can effect which can lead to early metal fatigue and possible failure.

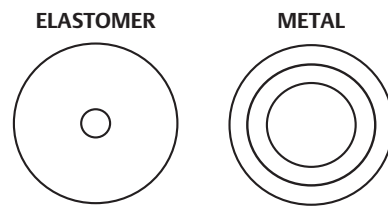


Figure 18

Diaphragms are made of the following materials: Buna-N, Elgiloy®, Ethylene Propylene, Teflon®, Viton-A®, 316 Stainless Steel, Hastelloy®, Gylon®, Chemraz®.

Advantages

- Sensitive
- Inexpensive
- Simple
- 316 Stainless Steel diaphragms are excellent for semiconductor, toxic and corrosive type applications
- Elgiloy® diaphragms are an excellent choice for high cycle metal diaphragm uses and for applications with wide temperature swings

Disadvantages

- Fabric reinforced diaphragms can “wick” water or other liquids leading to diaphragm failure or media contamination
- Diaphragms do not provide a constant effective sensing area
- Diaphragms can be difficult to seal
- Diaphragms can rupture due to a pressure differential
- Metal diaphragms are less sensitive than rubber or elastomer diaphragms
- Pressure limits

II. Sensing Elements

B. Piston Sensing Element

Piston sensing elements (Figure 19) are designed for higher outlet pressures than the diaphragm sensing elements. While the diaphragms are limited to an outlet pressure of 500 psig / 34.5 bar, the piston sensing elements can control outlet pressures up to 20,000 psig / 1379 bar. The piston sensor (Figure 20) is strong, heavy, and well-suited for high outlet pressures.

The piston sensor is made up of a sensor backup, sensor and dynamic seals or o-rings (Figure 21). The sensor backup is held stationary between the body on the bottom and the regulator bonnet on the top. The sensor is allowed to move freely on the o-ring seal in response to changes in the outlet or P_2 pressure cavity.

Piston and diaphragm have the same function, this is to sense changes in the outlet pressure or P_2 cavity and respond to them.

The materials used by TESCOM for sensor assemblies are: Brass, 303 Stainless Steel, 316 Stainless Steel, Hastelloy®, Monel, N60, 17-4 Stainless Steel.

The materials are chosen based on its compatibility with the media flowing through the regulator.

The piston sensor is the least sensitive of the three types of sensing elements, but it is the most durable and is the ideal choice when the outlet pressure exceeds 500 psig / 34.5 bar.

Advantages

- Able to handle high outlet pressures, up to 20,000 psig / 1379 bar
- Piston has constant effective sensing area

Disadvantages

- Less sensitive than diaphragm or bellows sensing elements
- Cannot be used for high purity applications due to o-ring seals
- Lubrication of o-rings is critical for accurate pressure control

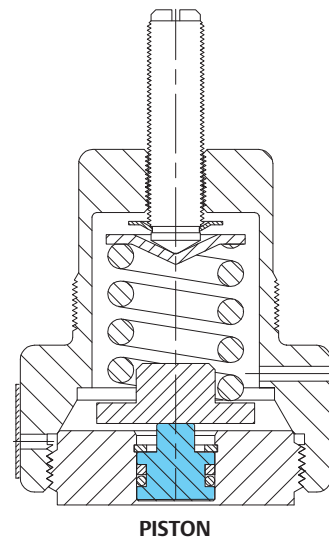


Figure 19

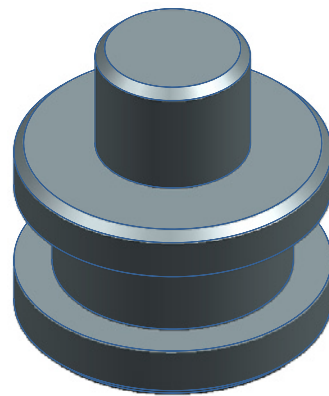


Figure 20

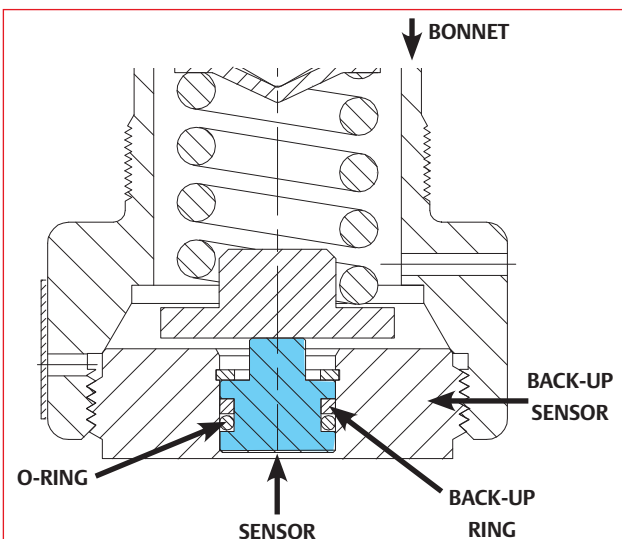
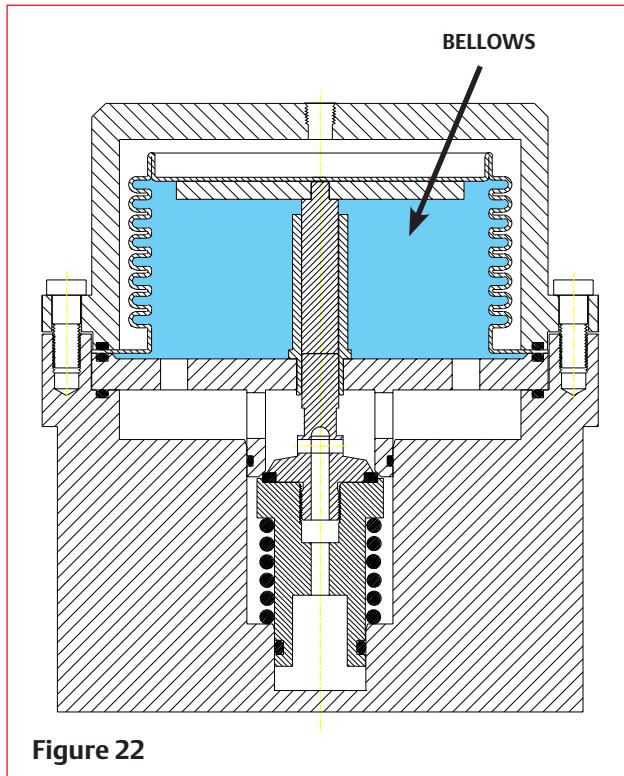


Figure 21

II. Sensing Elements

C. Bellows Sensing Element



The bellows sensing element is the third type of sensing element and it is the most accurate or sensitive of the three sensing elements.

As illustrated from the bellows used in the 15 Series regulator (Figure 22), the sensor is larger than the first two sensing elements. Bellows of smaller sizes than the one used in the 15 Series regulator are also available.

Bellows have accordion style pleats or flexing points (Figure 23) which provide the capability for longer valve travel with minimum resistance, making its performance superior than the other two sensing devices.

While the sensitivity is high, the cost of a 316 Stainless Steel metal bellows is also very high. Because of its high cost, Stainless Steel bellows are rarely used as a sensing element in regulators unless the application requires high sensitivity to changes in P_2 .

The bellows sensing element is used in the 15 Series regulator. This is the facilities regulator designed to provide high flow capacity at relatively low pressures. Pressures on the order of 300 psig / 20.7 bar inlet and 130 psig / 9.0 bar outlet. This regulator is designed for the semiconductor industry and features 316L Stainless Steel welded construction with internally threadless design. It offers a C_v of 20.

Advantages

- Highly sensitive
- Increased valve travel capability

Disadvantages

- Expensive
- Limited sources



III. The Control Elements

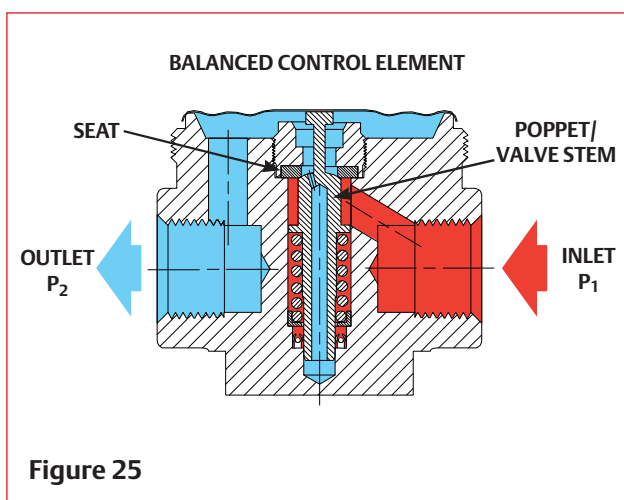
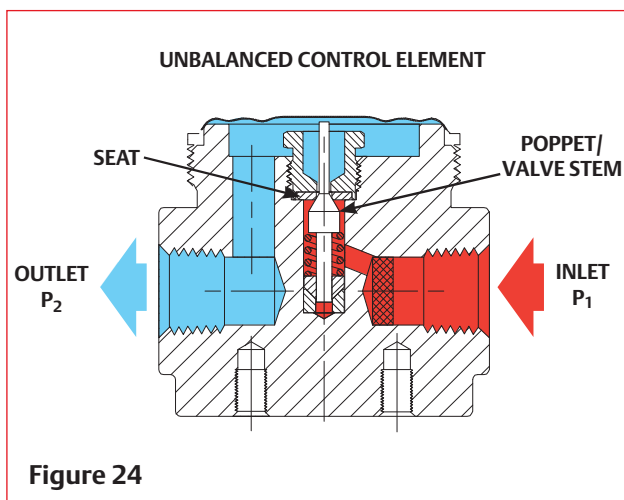
The third and last element is the CONTROL element of which there are two types:

- The UNBALANCED control element (Figure 24)
- The BALANCED control element (Figure 25)

The function of the control element is to do the actual reduction of the high inlet pressure (P_1) down to the lower outlet pressure (P_2). The control element is frequently called a valve stem or poppet.

Media pressure (gas or liquid) is reduced by taking the high pressure gas from a cylinder, compressor, or pump and passing it through a variable size orifice.

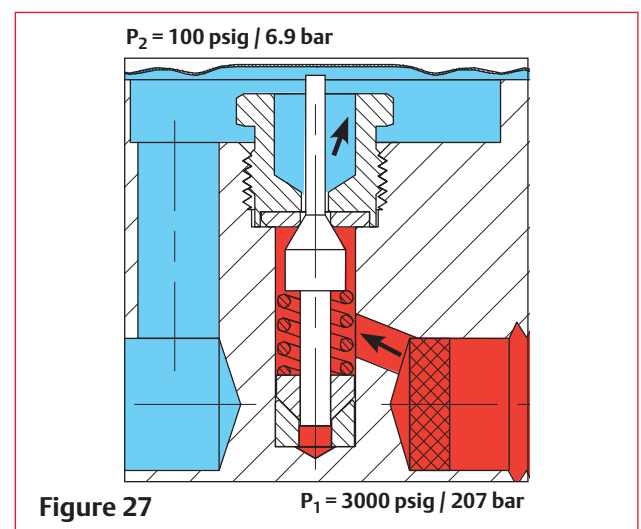
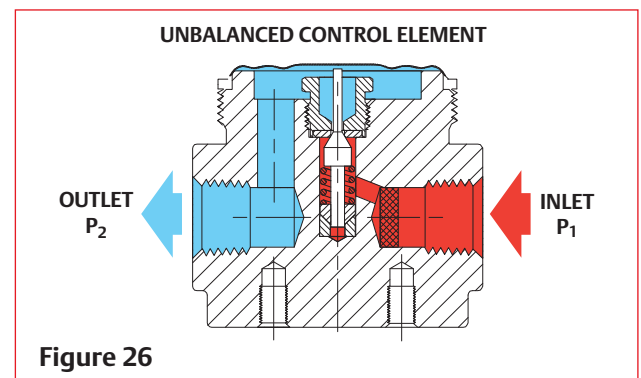
The valve moves towards or away from the regulator seat causing the orifice to become larger or smaller in order to provide the flow demanded and maintain the desired set pressure.



A. Unbalanced Control Element

The UNBALANCED control element has only one sealing point which is the coned shape area of the valve. With this design, the valve is assisted to the closed position by the valve spring and the supply pressure. While the force of the spring is relatively constant at all times, the force on the valve will increase as the supply pressure increases. Likewise, the force on the valve will decrease as the supply pressure decreases. By knowing the orifice size and the supply pressure, one can determine the closing force that is being applied to the valve. As shown in Figures 26 and 27, the P_1 zone, which is 3000 psig / 207 bar starts from the inlet connection and ends at the point of contact of the valve and seat. The P_2 zone which is 100 psig / 6.9 bar starts at that same valve point and continues to the outlet connection.

The UNBALANCED control element has a negative effect called the decaying inlet characteristic (supply pressure effect) which causes changes in outlet pressure as the inlet pressure changes. This occurs when gas cylinders are used as the pressure source for a customer's system.



III. The Control Elements

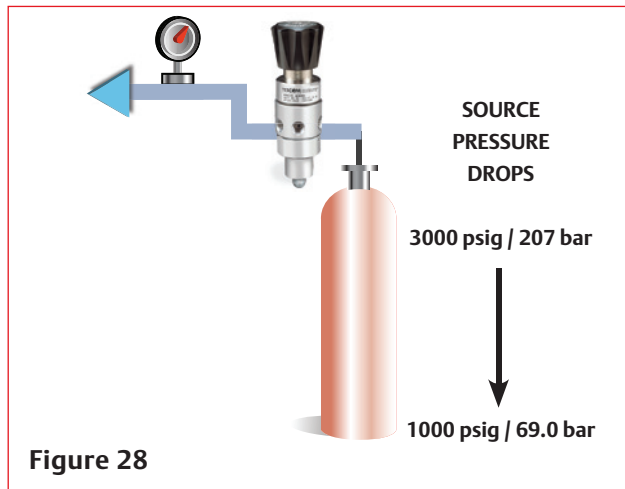


Figure 28

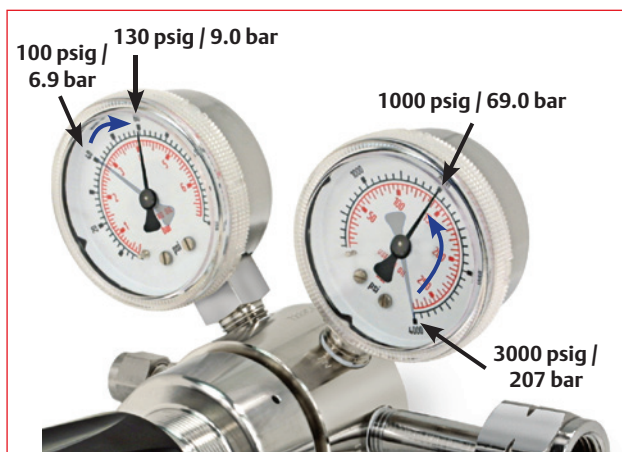


Figure 29

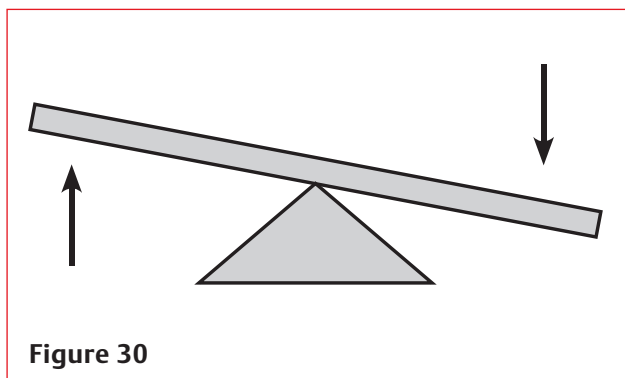


Figure 30

The gas cylinders come with a finite amount of gas and pressure. As the contents of the cylinder (Figure 28) drop, look at the outlet pressure gauge (Figure 29) on the cylinder regulator. Notice that the pressure on the outlet gauge goes up, while the pressure on the inlet gauge goes down. This is a result of the decaying inlet characteristic.

Like the teeter-totter in the kids' playground, when one side goes up, the other side goes down. Each side goes in the opposite (Figure 30) direction of the other.

For most applications, this is acceptable. However, for applications that require the outlet pressure does not alter when the inlet pressure changes, they have three options.

These options are:

- Two-stage regulator
- Balanced type valve stem
- Two regulators in a series

Only the balanced type valve stem will be discussed here.

Advantages

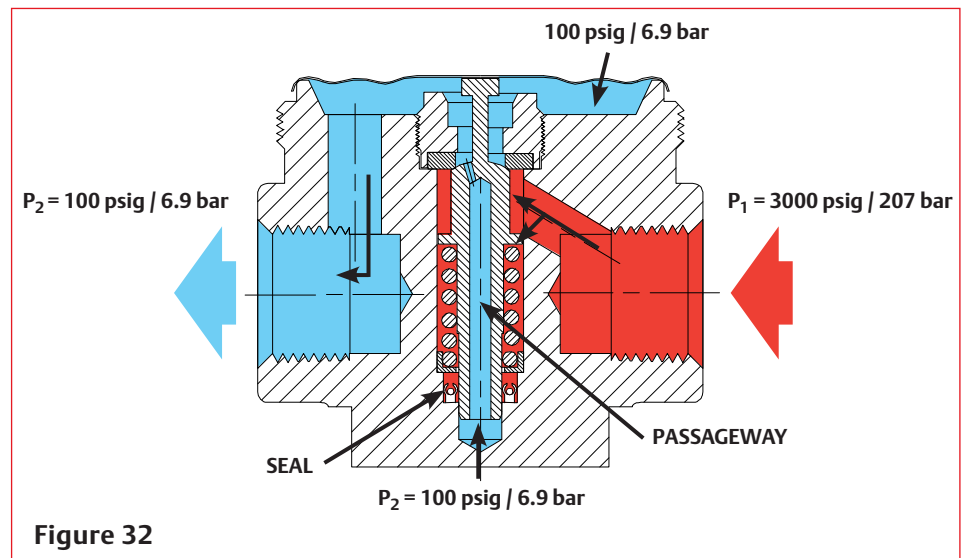
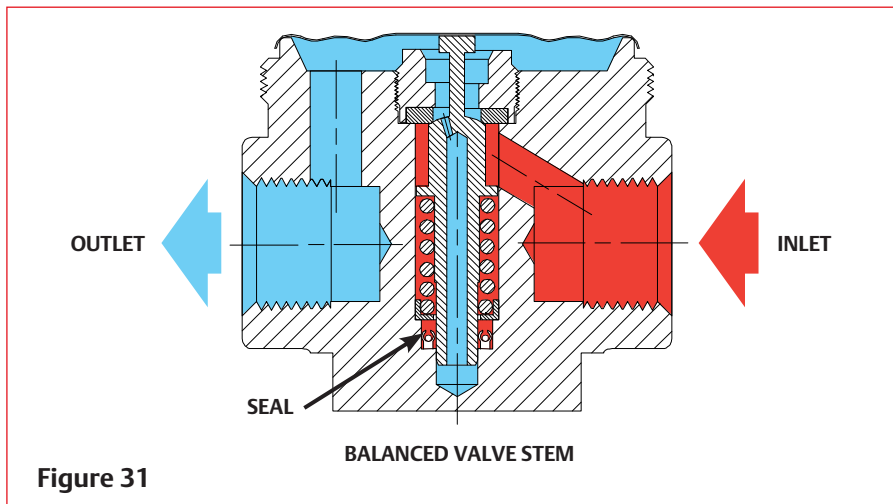
- Inexpensive
- Simple
- Easy to manufacture
- Inlet pressure is used as the main shut-off force

Disadvantages

- Limited to small orifice sizes
- Decaying inlet characteristic
- High seat forces with high inlet pressures
- Requires harder seat material at high pressures

III. The Control Elements

B. Balanced Control Element



The BALANCED control element or valve stem has two sealing points. One is identical to the UNBALANCED valve stem. The other seal is located near the end of the valve stem in the P_1 zone (Figure 31). In effect, by sealing both ends of the valve stem the supply pressure cannot force the valve closed or open. Hence the name BALANCED valve stem (Figure 32). With this design, the supply pressure has little effect on the amount of force on the valve.

One other difference between the UNBALANCED and BALANCED valve stem is that a balanced valve stem will also have a passageway from the P_2 zone to the other side of the valve seal (Figure 32). This is required so that the P_2 pressure is equalized on both sides of the valve and the valve stem remain balanced.

In actual practice, the balanced valve is designed to have a slightly higher inlet pressure. If there should be a regulator failure, it is desirable to have the inlet pressure help close the valve tightly.

Advantages

- Reduced seat load
- Reduced decaying inlet characteristic
- Larger seat orifice at high pressures
- High flow capability

Disadvantages

- More expensive to manufacture
- Large seats make low flows difficult

Putting All the Elements Together

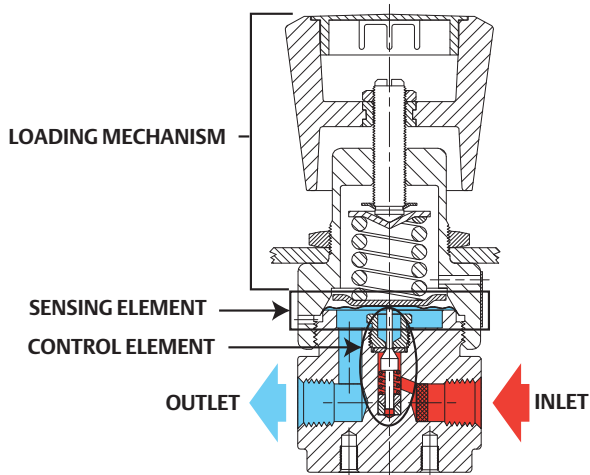


Figure 33

In this section, the three basic elements will be put together to demonstrate how they work. Figure 33 illustrates a regulator with all three basic elements: the loading mechanism, the sensing element, and the control element.

The regulator is connected to the gas cylinder and is linked to a system downstream of the pressure regulator (Figure 34). The handknob or adjusting screw of the regulator is turned counterclockwise and the regulator shuts off.

The cylinder valve is then opened, releasing the contents of the cylinder to the inlet side of the regulator. The pressure reading on the inlet gauge climbs and stops at the pressure reading indicating the pressure in the gas cylinder. The outlet pressure gauge indicates zero pressure (Figure 35).

To open the regulator's valve, turn the handknob in the clockwise direction. The pressure reading on the outlet pressure gauge climbs until it reaches the desired outlet pressure or set pressure (Figure 36). Set pressure is the outlet pressure at no flow.

By turning the handknob clockwise the load spring is compressed to provide the outlet pressure required by the downstream system. This is the pressure that is necessary for the operation of the system. The system downstream is not in operation, therefore the regulator shuts off. In other words, the valve stem or control element is closed tight against the seat causing no gas to pass.



Figure 34

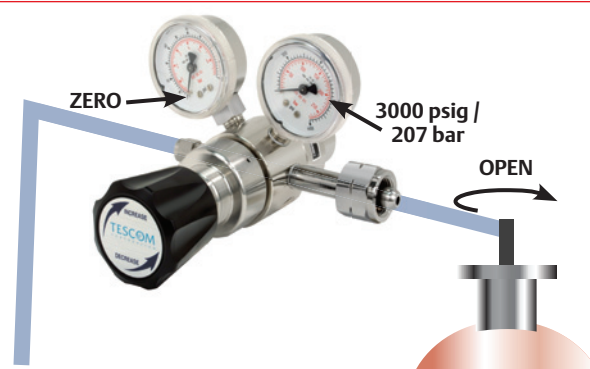


Figure 35

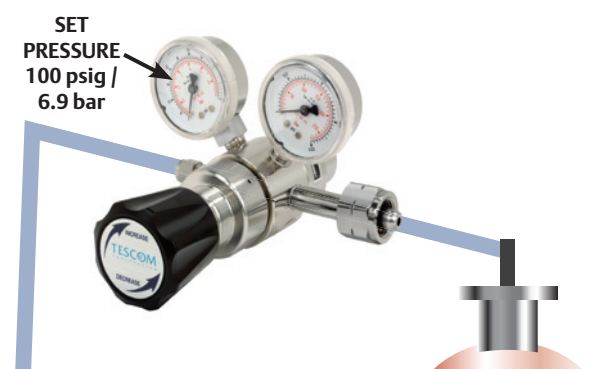


Figure 36

Putting All the Elements Together

When the downstream system opens or starts, it demands a flow, a quantity of gas, from the regulator. When this flow starts, there is an initial drop in P_2 in the outlet cavity of the regulator (Figure 37) as indicated by the outlet pressure gauge. The sensing element, the diaphragm in Figure 37, senses this pressure drop and it moves down because of the pressure imbalance between the force of the outlet pressure and the force of the load spring.

At this point, the force of the load spring is greater than the force of the outlet pressure. Since the load spring force is greater, it helps move the diaphragm down,

causing the valve to move away from its seat (Figure 38) and allowing gas to flow through the seat opening and into the outlet or P_2 cavity of the regulator.

The valve stays open trying to build up the outlet pressure to its initial set pressure. As long as the system downstream is demanding flow, the spring loaded regulator will not be able to reach the initial set pressure. However, it will keep on trying to reach the initial set pressure as long as the system downstream is in operation and demanding flow. The difference between the initial set pressure and the flowing pressure is called DROOP.

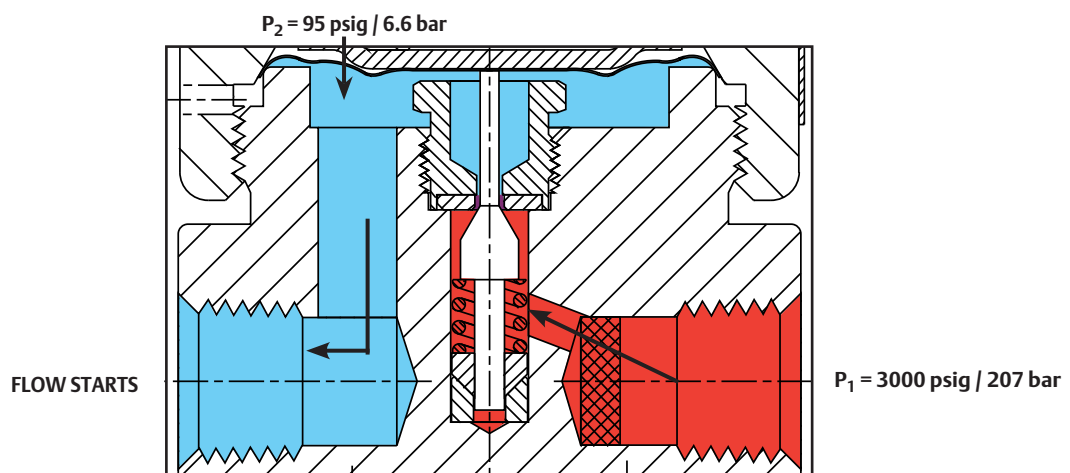


Figure 37

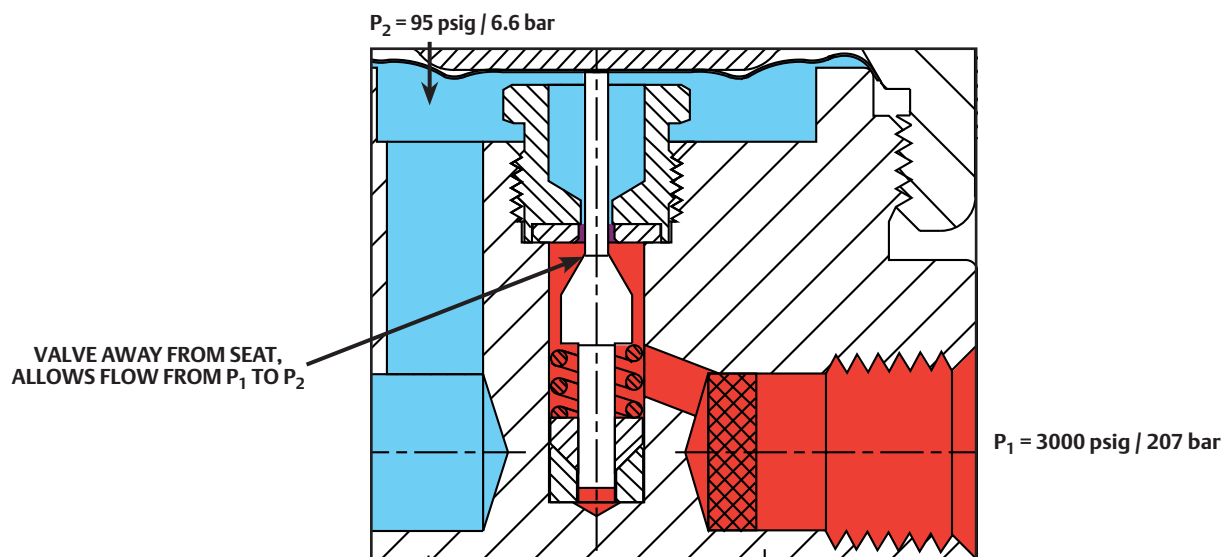
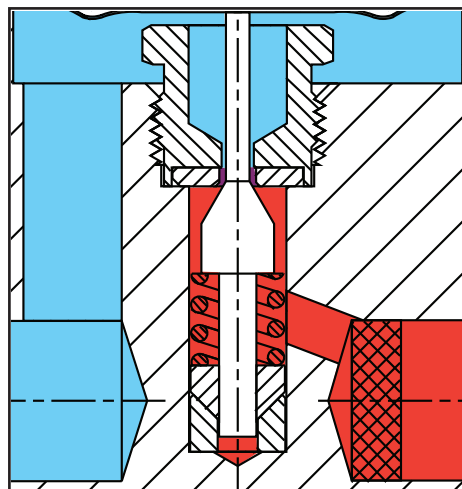


Figure 38

Three Basic Elements

$P_2 = 103 \text{ psig} / 7.1 \text{ bar}$



$P_1 = 3000 \text{ psig} / 207 \text{ bar}$

LOCKUP
103 psig /
7.1 bar

ORIGINAL
SET PRESSURE
100 psig /
6.9 bar

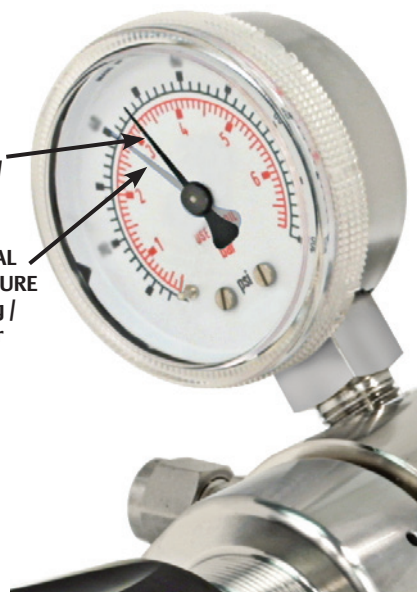


Figure 39

When the system downstream of the regulator is shut off, the demand for flow ends. The P_2 pressure now builds up in the P_2 cavity to the point of the original set pressure, plus an additional 1 to 3 psig / 0.07 to 0.21 bar needed to firmly force the valve against the seat for a positive gas tight shut-off (Figure 39). The additional 1 to 3 psig / 0.07 to 0.21 bar closing pressure is called LOCK UP, and is normal for pressure reducing regulators.

To completely shut down a regulator, the cylinder valve must be closed, the pressure is then drained from the regulator and the handknob or adjusting screw is turned counterclockwise until no pressure is felt from the load spring. The regulator should not be used or relied on as a shut-off device.

This completes the normal working cycle of a spring loaded, pressure reducing, single-stage regulator.

Venting Options

- Venting (Figure 40) feature enables complete relieving of the downstream pressure in dead-ended systems when the handknob is turned in the decrease direction (counterclockwise). The regulator incorporates a second valve to vent the downstream pressure through the bonnet in the standard venting model
- Captured-venting feature offers a separate vent port to pipe away the expelled downstream gas or fluid to a safe discharge point and is suitable for toxic or corrosive media
- Non-venting feature is available when venting is not desirable

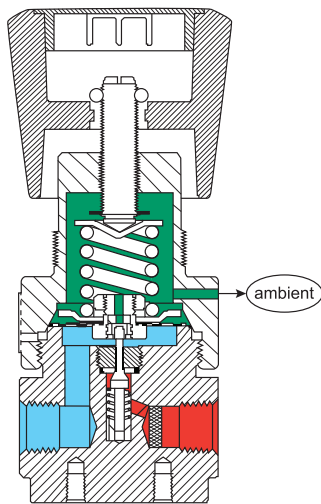


Figure 40

Corrosive Media Options

- Positionable Captured Bonnet (e.g. 44-2800 and 64-2800 Series)
 - Should the media reach the bonnet chamber, it will be piped away to a safe area via the bonnet port, which may be positioned 360 degrees around the regulator body
- Tied Diaphragm or Positive Seal Regulator (e.g. 44-2800 and 64-2800 Series)
 - This design ensures positive shut-off as the valve stem is mechanically connected to the diaphragm, controlling the valve position in both directions. The benefit of the tied diaphragm design is that if the regulator begins to creep, the increasing outlet pressure causes the diaphragm to flex upward away from the orifice pulling the valve stem tighter and tighter into the seat. The more outlet pressure drift or creep, the more sealing force is created. The sealing force will try to compress the contamination into the seat.
- NACE compliant designs are available

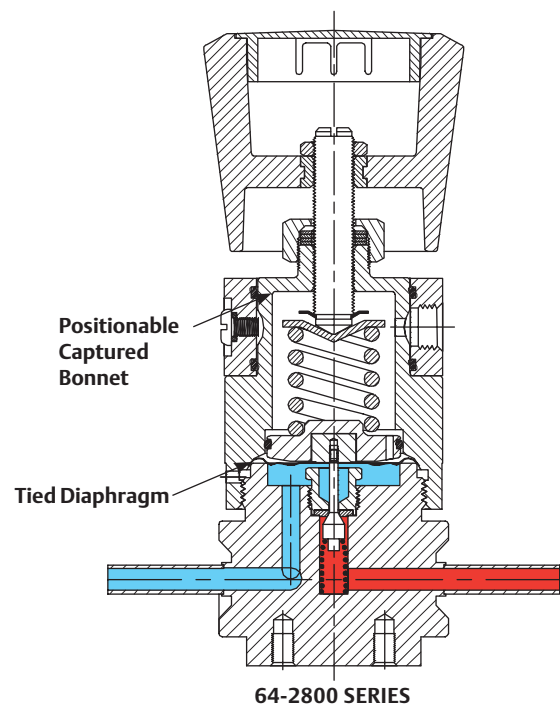


Figure 41

Heated Regulators

Certain speciality gases used in the semiconductor industry such as Hydrogen Chloride (HCl), Nitrous Oxide (N₂O) or Carbon Dioxide (CO₂) have a high Joule-Thomson coefficient. This results in a significant cooling effect when these gases expand in the gas distribution system on their way to the respective process. The use of HCl raises the risk that remaining residual moisture is condensing forming hydrochloric acid, causing corrosion to the whole gas supply system but especially to the pressure regulator where the cooling effect is the highest. Commonly used heat tracing cables have low heat transfer and only heat fraction reaches the inside of the regulator body.

To fight the Joule-Thomson effect, TESCOM has developed the 44-3200 and 64-3200 Series of ultra high purity gas regulators which come with an integrated heater element. This element transfers almost 100% of the heat into the regulator body, eliminating not only condensation and internal corrosion, it also prevents relieving of gas after pressure reduction (mainly observed with liquefied gases). Another approach is to use a vaporizing regulator such as the 44-5800 Series (Figure 42), which employs heat exchanger tubes to warm the gas with integral electrical heaters or steam, for low flow applications.

The electronically controlled 100W heating element guarantees a constant regulator temperature, even in high flow applications or with frequent flow variations. The water-tight connection to the electrical installation allows outdoor use. Other features of the positive seal pressure reducing regulators are a flow capacity of up to $C_v=1.2$, a tied diaphragm design and the Hastelloy® C-22 trim option including the seat retainer, valve stem and diaphragm.



Figure 42

Two-Stage Regulators

Advantages

- Combination of two pressure regulators in-line
- P₁ (red) is reduced to the preset inter-stage pressure (dark blue)
- Inter-stage pressure is reduced to the adjustable outlet pressure P₂ (light blue)
- Reduces decaying inlet characteristic
- Decaying inlet effect on the inter-stage is equal to an unbalanced single-stage regulator
- Final outlet pressure P₂ is stable

Disadvantages

- More expensive to manufacture
- Two-stage regulators require more space

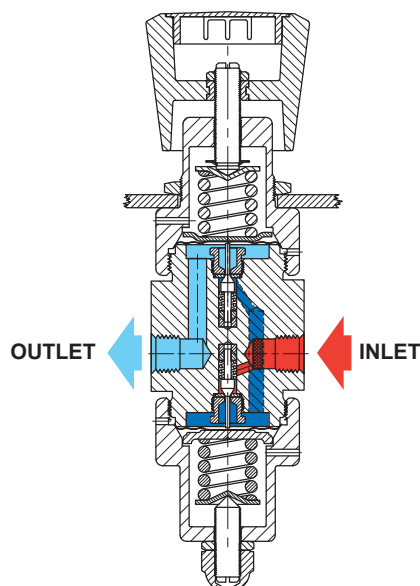


Figure 43