WGMSC

western gas measurement short course

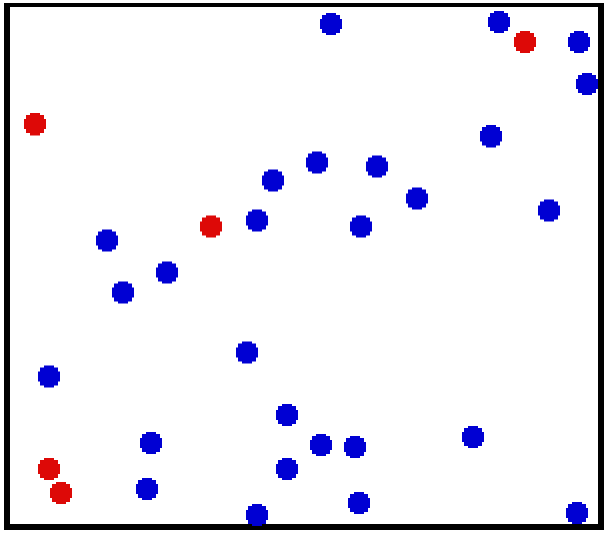
Introduction to Gas Regulation

This presentaton provides an overview of the theory of pressure regulation for natural gas. Participants will learn about the basic operation and components of a self-operated pressure regulator and in what applications they are used. We'll discuss droop, offset, and velocity boosting including how manufacturers document these characteristics of regulators. We will also touch on the basics of ANSI B109.4 Service Regulators for Natural Gas.

Introduction to Gas Regulation

PRESSURE

Gas pressure is defined as the force perpendicularly exerted on the surface of the wall of the vessel that contains it. The kinetic theory has shown that this force is due to gaseous molecules in motion colliding against the wall of the vessel. Pressure is extremely important in fluids (liquids and gases) because it is the quantity that determines the balance conditions in the fluid and, conversely, because motions in fluids is determined by the differences in pressure.



LAWS AND CHEMICAL-PHYSICAL CHARACTERISTICS OF GASES

U N I T O F M E A S U R E

PRESSURE

The unit of measurement of pressure is the newton per square meter renamed Pascal (Pa) in the International System of Units, which, however, is a very small unit of measurement and, therefore, normally multiples are used:

- **megapascal (MPa)= 10^6 pascal**
- **kilopascal (kPa) = 10^3 pascal**
- **hectopascal (hPa) = 10^2 pascal**
- **decapascal (daPa) = 10 pascal**

LAWS AND CHEMICAL-PHYSICAL CHARACTERISTICS OF GASES

UNIT OF MEASURE

PRESSURE

Other units of measurement used in the world of gas.

- Bar (bar) - Millibar (mbar)
- Millimeters of mercury (mmHg)
- Metric atmosphere (atm)
- Inches of water column (in H_2O)
- Pounds square inch (psi)

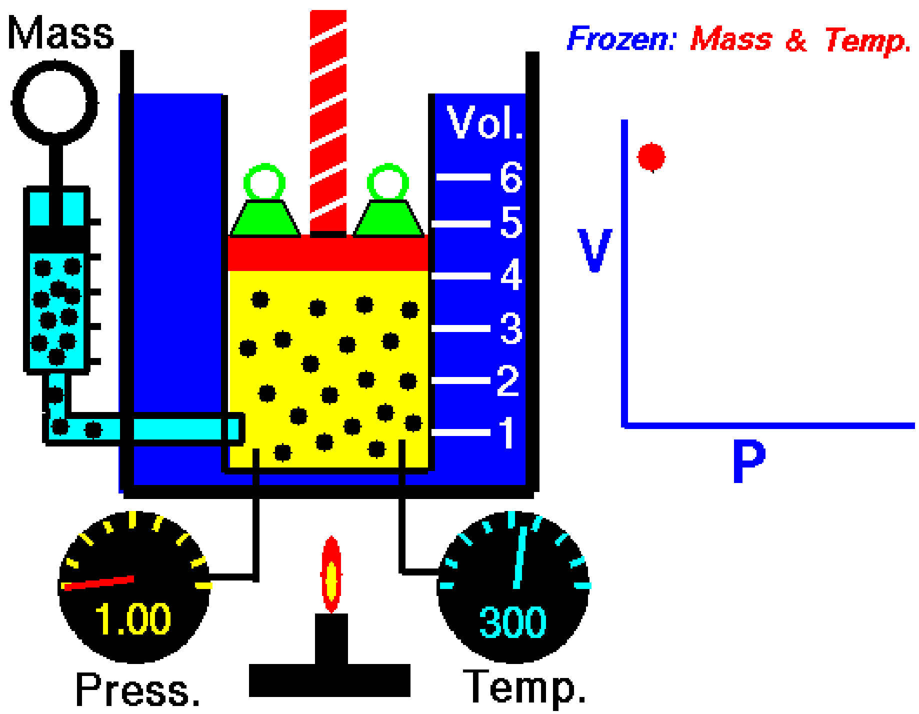
U N I T O F M E A S U R E

LAWS AND CHEMICAL-PHYSICAL CHARACTERISTICS OF GASES

VOLUME

Boyle's law

At constant temperature, pressure and volume of the gas are inversely proportional to each other: ***P x V = constant***



U N I T O F M E A S U R E

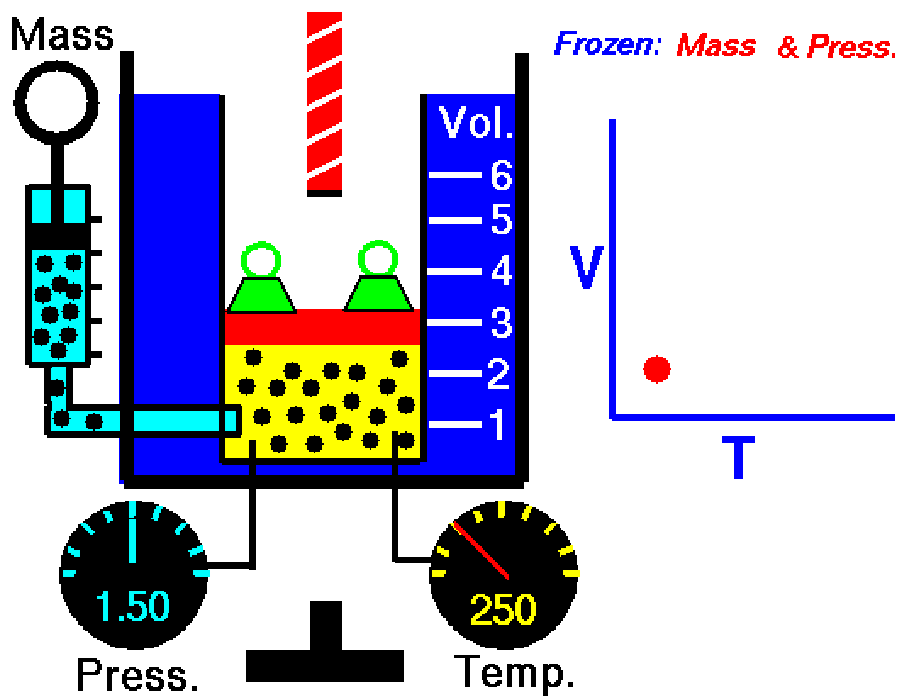
LAWS AND CHEMICAL-PHYSICAL CHARACTERISTICS OF GASES

VOLUME

Charles' law

volume of an ideal gas at constant pressure is directly proportional to the absolute temperature.

P x V / T = constant.



LAWS AND CHEMICAL-PHYSICAL CHARACTERISTICS OF GASES

U N I T O F M E A S U R E

FLOW RATE

Pressure differences between two different zones of a fluid cause a motion of the fluid itself, which tends to move from the area of higher pressure to that of lower pressure.

In the International System the unit of measurement is the cubic meter per second (m^3/sec) or cubic feet per second (ft3/sec).

For gaseous fluids always refer to the volume measurement conditions; therefore, depending on the conditions we will talk about standard or normal cubic meter per hour (Sm^3/sec or Nm^3/sec) or standard or normal cubic feet per hour .

U N I T O F M E A S U R E

LAWS AND CHEMICAL-PHYSICAL CHARACTERISTICS OF GASES

Flow rate

Standard condition → It refers to measurements taken at a temperature of 15 °C (60 °F) and at atmospheric pressure equal to 101.325 kPa (14.7 psi). The Standard cubic meter is normally indicated with Sm^3. The Standard cubic feet is normally indicated with SCF

Normal condition → It refers to measurements taken at a temperature of 0 °C (32 °F) and at atmospheric pressure equal to 101.325 kPa. The Standard cubic meter is normally indicated with Nm^3.

$$1\ Nm^3 = 1{,}0561\ Sm^3$$

FUNCTIONS OF A PRESSURE REGULATOR

- Functions of a Pressure Regulator may be synthesized as a sum of at least three following single functions listed in the order of decreasing priority and/or importance

1. To ensure Downstream pressure is not higher than maximum allowable pressure (MAOP)

2. To reduce the upstream pressure (P1) to the value established for the downstream side (P2)

3. To keep the operating pressure at downstream side close to its set value despite variations of both the upstream operating pressure and flow rate

The pressure regulator is an essential part of a gas pressure reduction system or MSA.

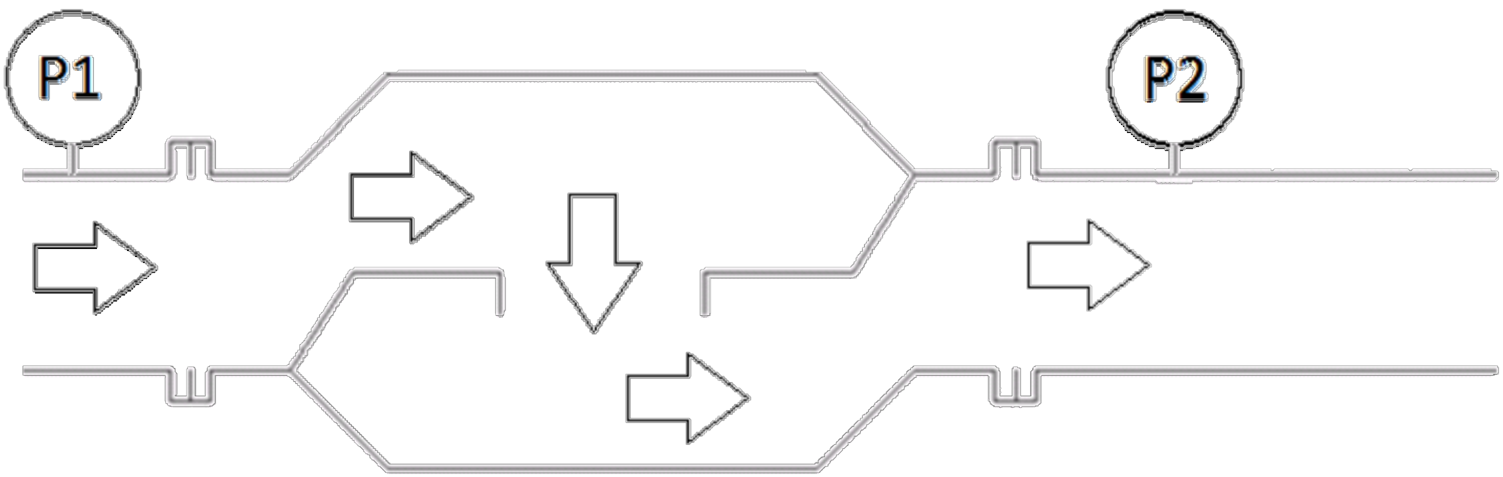
It must ensure the gas supply in quantity and pressure while under volatile operating conditions, namely:

A) Withstand variations in flow gradual or sudden without altering the outlet pressure.

B) Compensate variations in the inlet pressure value.

C) Have the ability to cut off the gas supply when there is no gas consumption in the network or houseline.

The throttling of a fluid flow by means of valves or the like produces a reduction in the pressure. This process, in which the expansion takes place without production of useful work, is called "**thermal expansion**".



A pressure control valve is a device that receives the gas at an upstream pressure **P1** and brings it back, downstream, to a delivery pressure **P2** than is lower than that upstream, due to the loss of load that the gas flow undergoes in its passage through the valve.

It is possible to use this loss of load in such a way as to act on the downstream pressure and keep it at a constant value.

It should be noted that, according to the physical laws that regulate the outflow of gas through an orifice, there is a well definite relationship between the orifice passage section, the upstream pressure Pu, and the flow rate in cubic meters Q at the reference conditions.

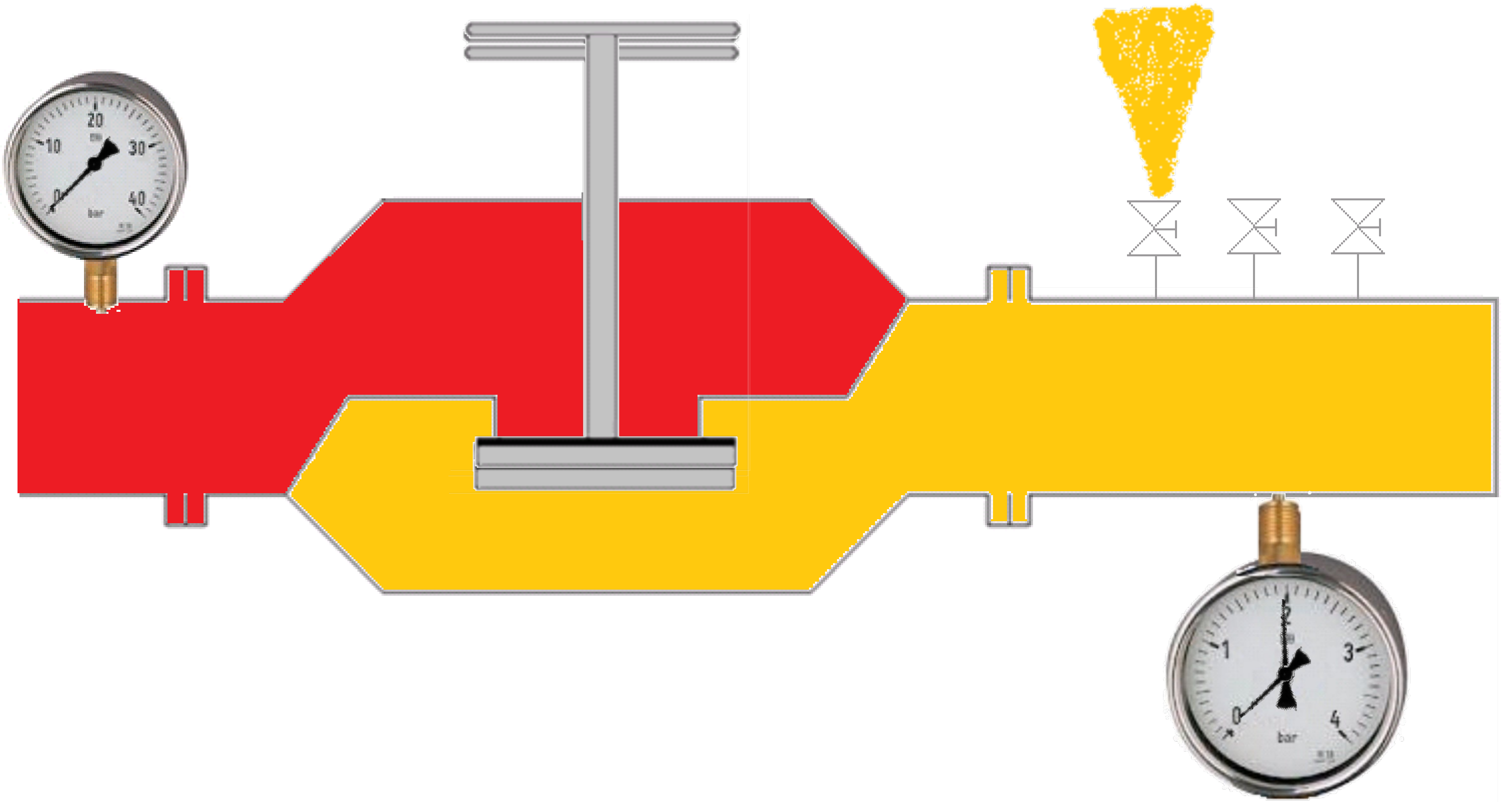
$$Q = K \times S \times \sqrt{Pd \times (Pu - Pd)}$$

Q=	*flow rate in cubic meters at reference conditions*
K=	*constant which sums up a number of factors*
S=	*orifice passage section*
Pu=	*upstream pressure*
Pd=	*downstream pressure*

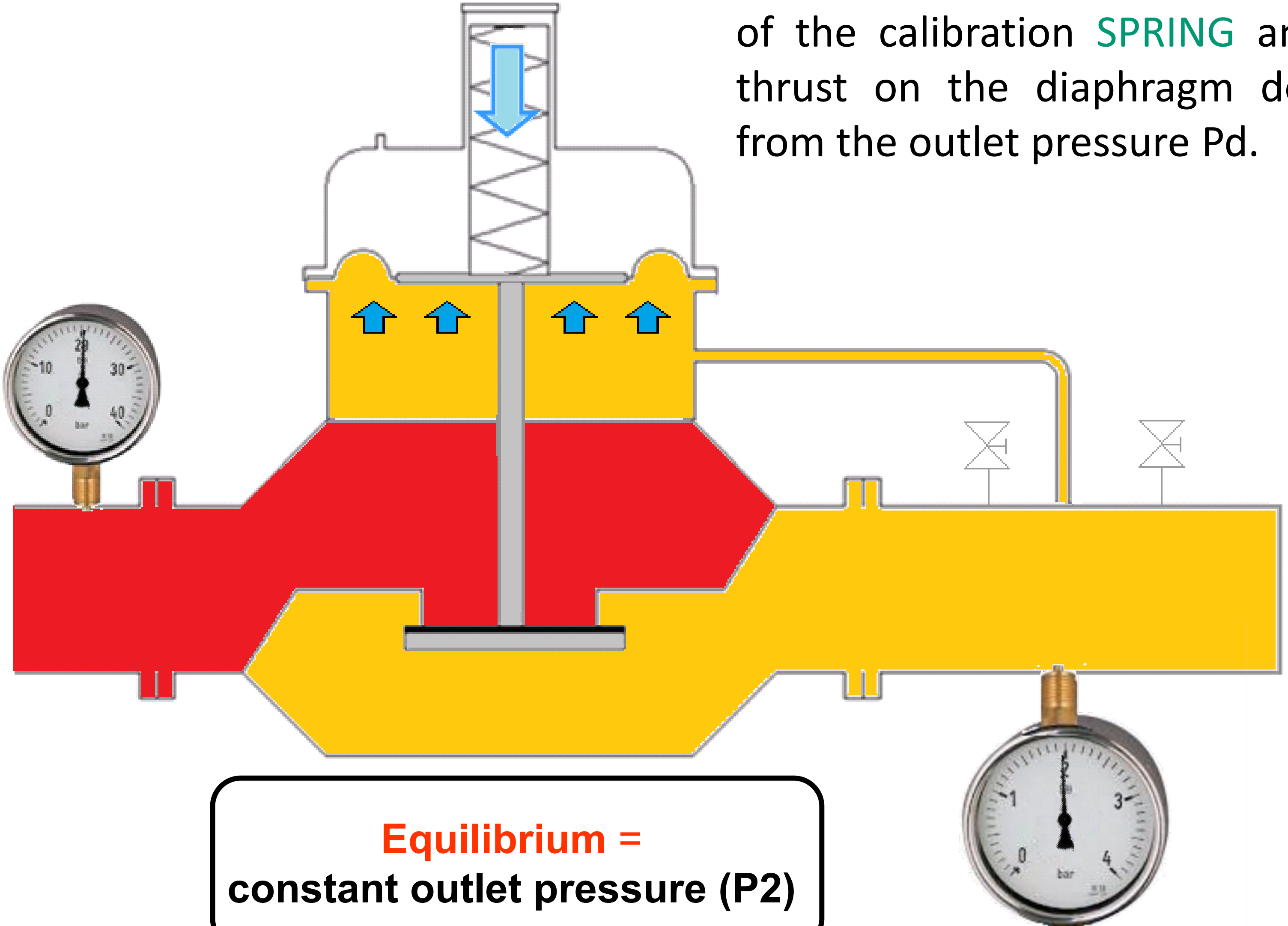
From here it can be inferred that for a given flow rate, for any value of the upstream pressure there is always a value of S which allows setting the downstream pressure to the desired value, and S will be as smaller as higher is the upstream pressure.

It is, however, clear that the concept of pressure reduction cannot be separated from the concept of pressure adjustment.

Indeed, if the function of the device that is going to be installed is that if reducing pressure, this latter shall also be kept within certain limits, which implies a regulation.

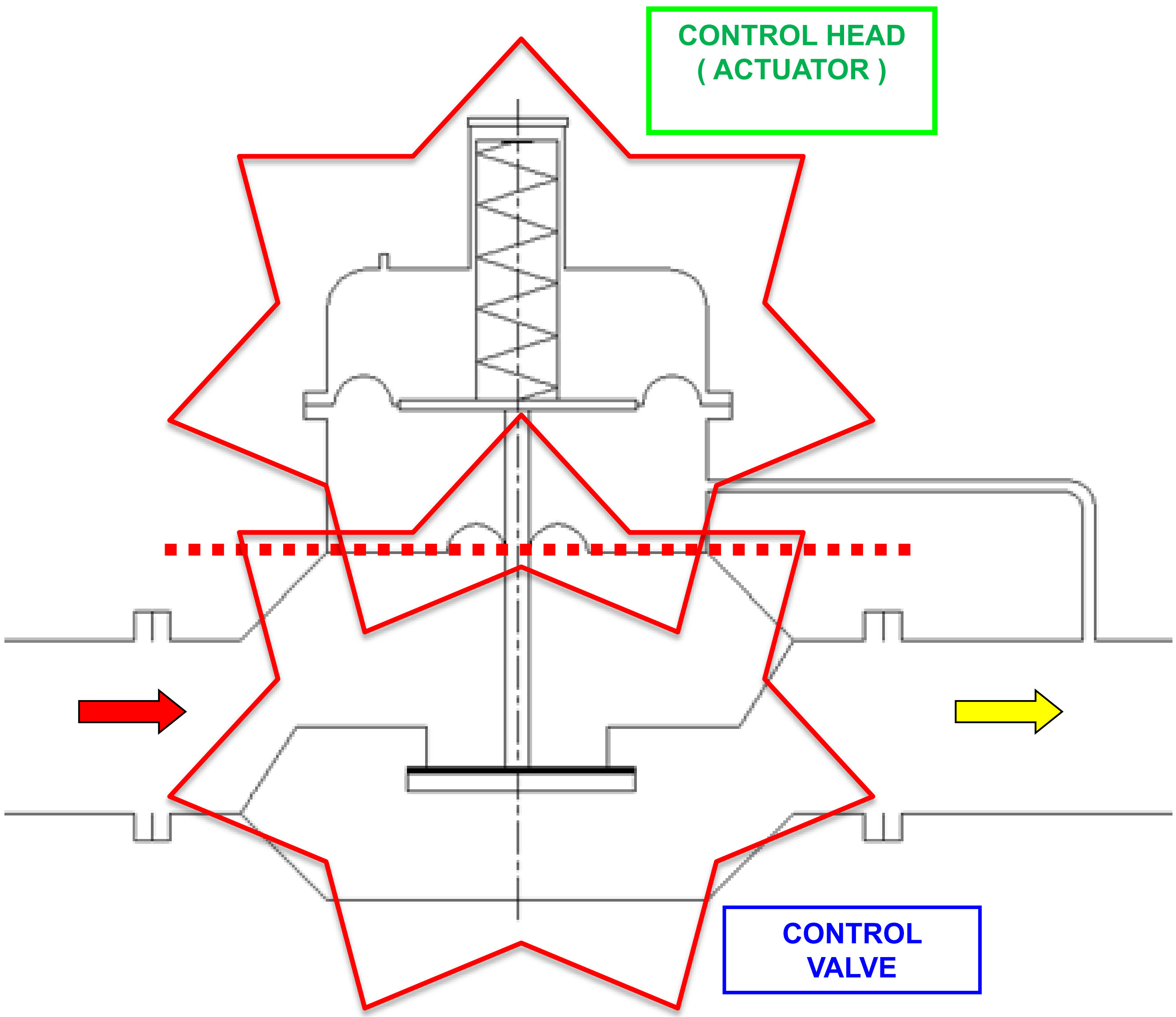


Setting is therefore obtained from the comparison between the load of the calibration SPRING and the thrust on the diaphragm deriving from the outlet pressure Pd.



Equilibrium =
constant outlet pressure (P2)

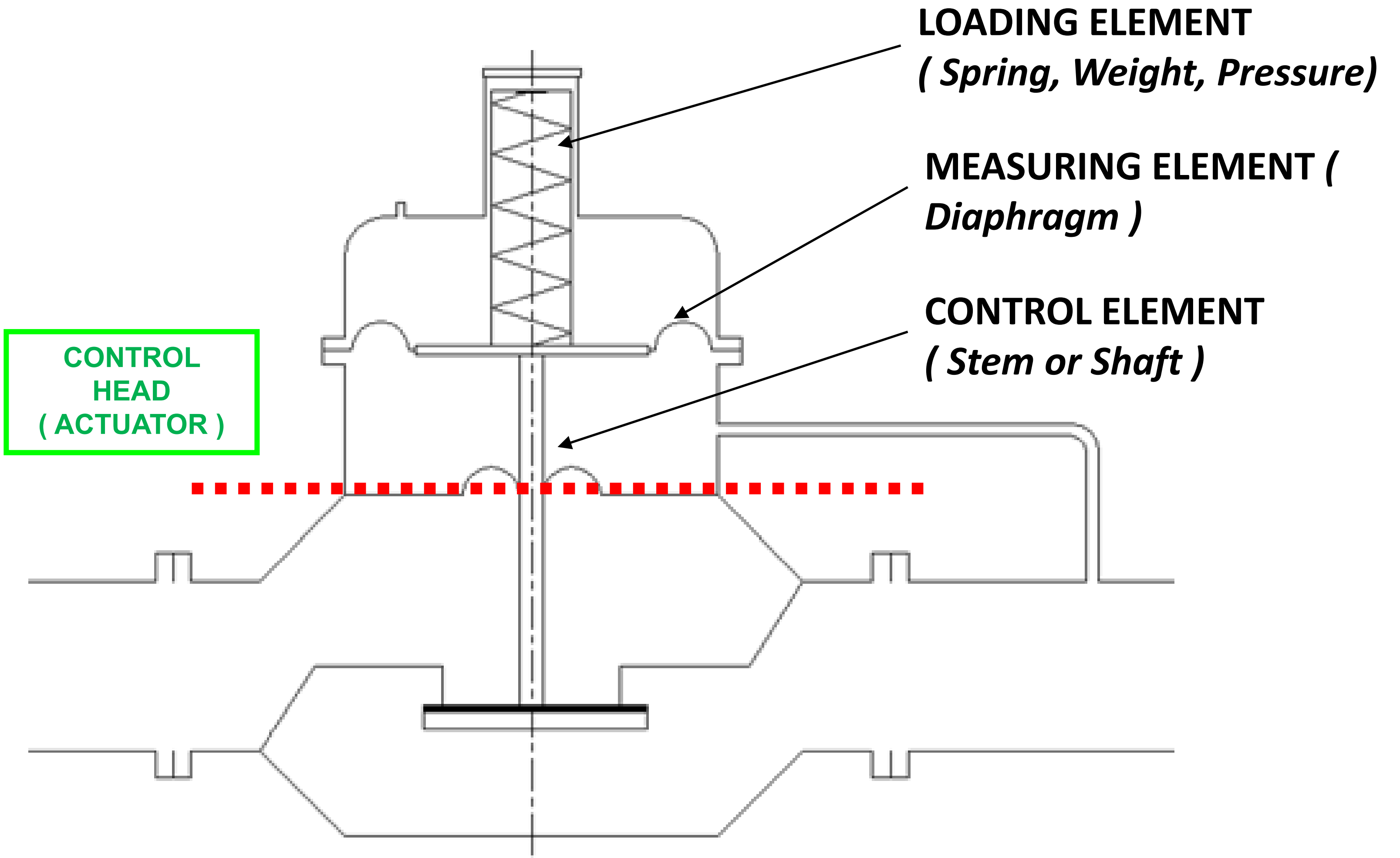
THE COMPONENTS OF A NATURAL GAS PRESSURE REGULATOR



THE COMPONENTS OF A NATURAL GAS PRESSURE REGULATOR

CONTROL HEAD

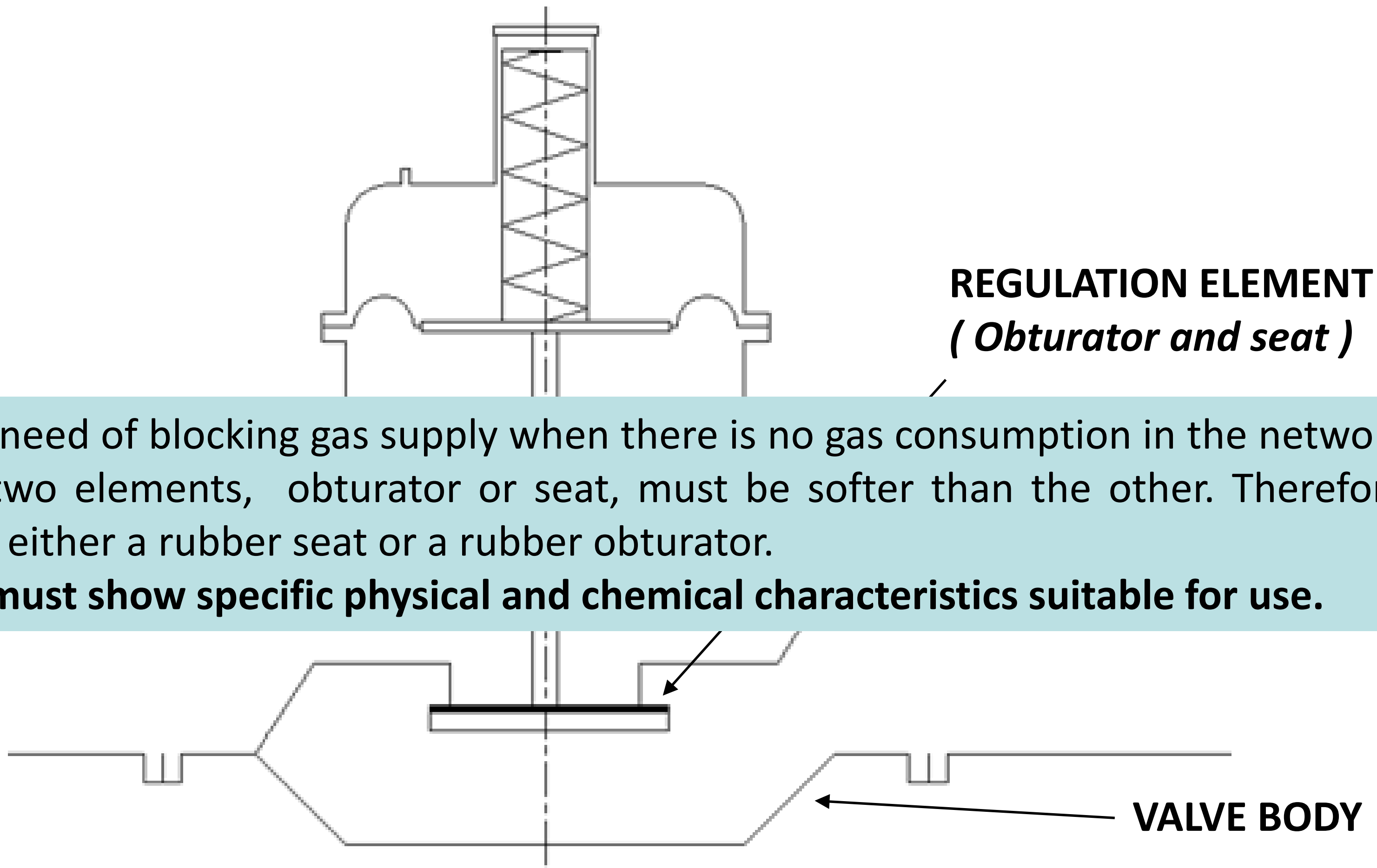
IT TRANSMITS TO THE CONTROL VALVE THE NECESSARY FORCE THAT THE SHUTTER WILL BE CARRIED OUT OF THE SEAT IN THE NECESSARY TRANSITION POSITION TO FEED EQUIVALENTLY THE NETWORK IN ACCORDANCE WITH THE NEED.



THE COMPONENTS OF A NATURAL GAS PRESSURE REGULATOR

CONTROL VALVE

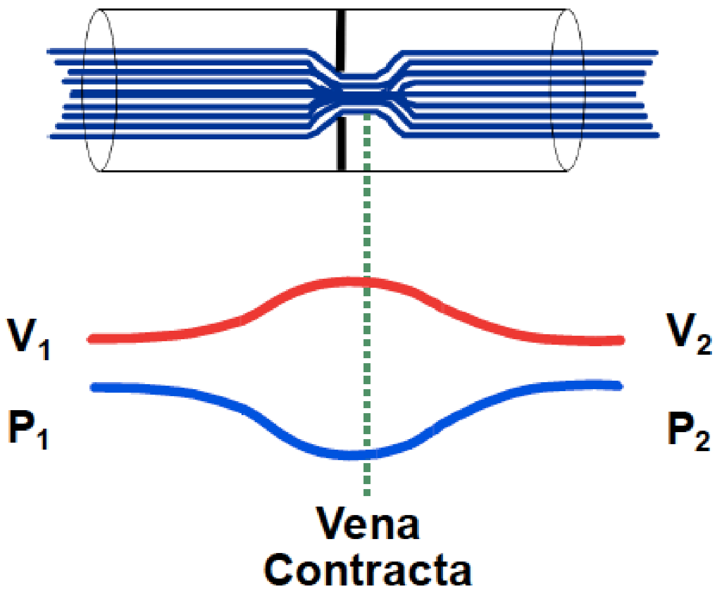
IT IS CALLED ALSO NARROWING OR REDUCTION ELEMENT, IT IS THAT PART OF THE REGULATOR WHERE THE GAS TRANSITS, THE FLOW RATE IS CONTROLLED AND, THEREFORE, THE PRESSURE IS REDUCED.

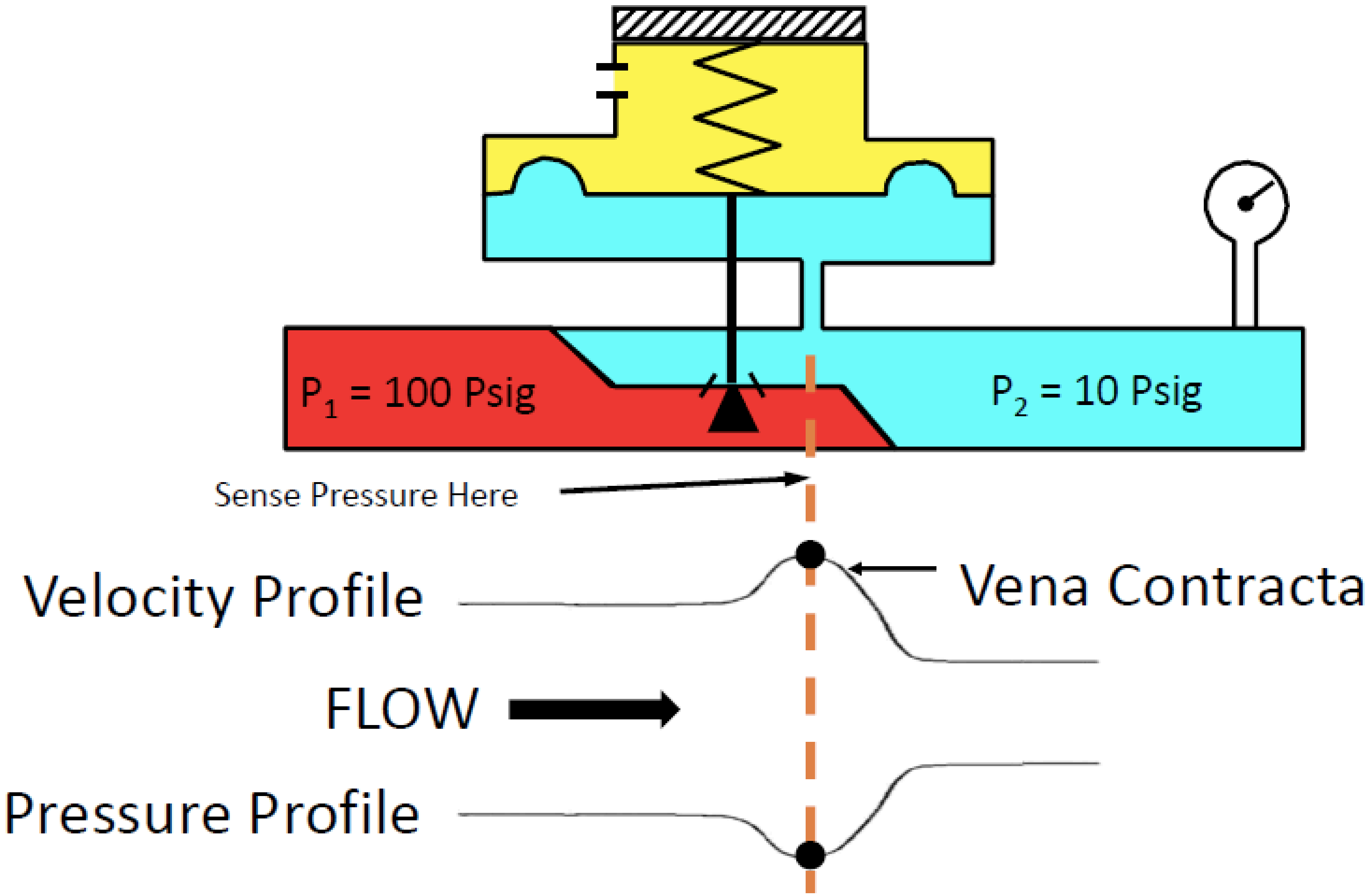


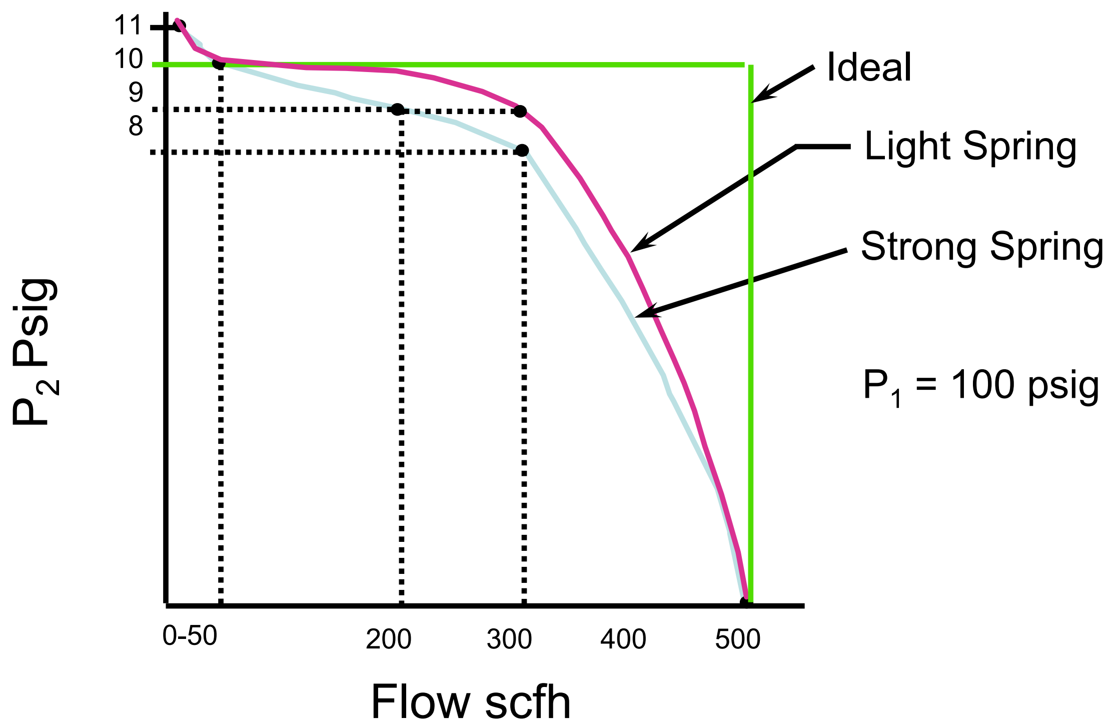
To meet the need of blocking gas supply when there is no gas consumption in the network, one of the two elements, obturator or seat, must be softer than the other. Therefore, there will be either a rubber seat or a rubber obturator.

The rubber must show specific physical and chemical characteristics suitable for use.

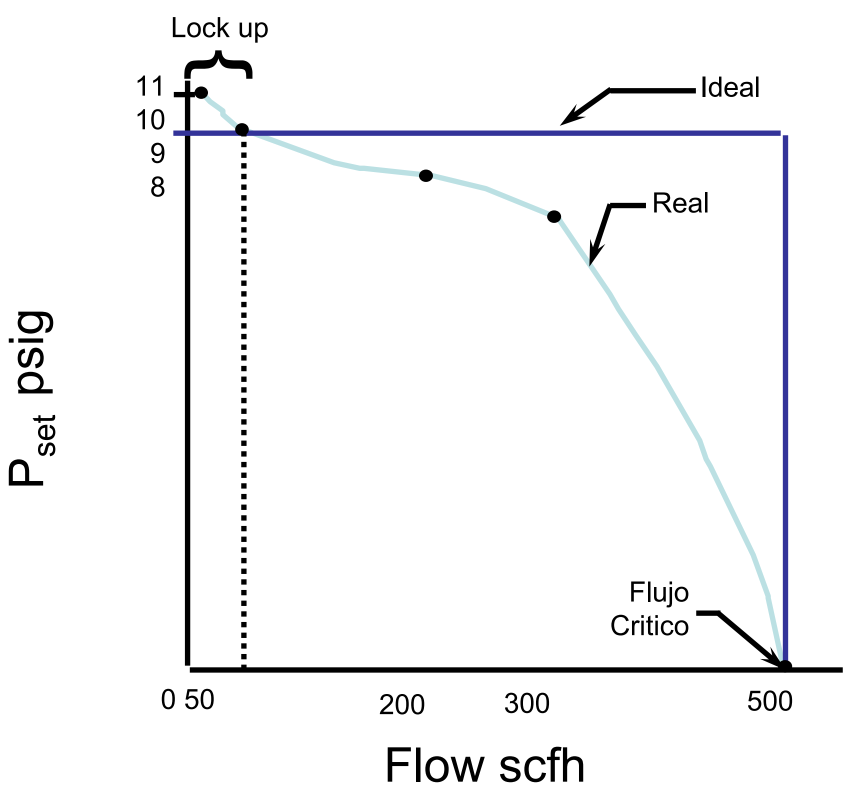
Dynamics of Flow




P1 = 100 Psig
P2 = 10 Psig
Sense Pressure Here
Velocity Profile
Vena Contracta
FLOW
Pressure Profile



Rule: Use a lighter spring with the range for the desired set point



<u>Lock-Up Pressure</u>:

- Offset pressure to obtain tight seal
- Increase in outlet pressure at zero flow
- Affected by range of spring and orifice size

<u>Critical Flow</u>:

- Maximum flow rate for a given restriction
- Dependent on P_1 and orifice size

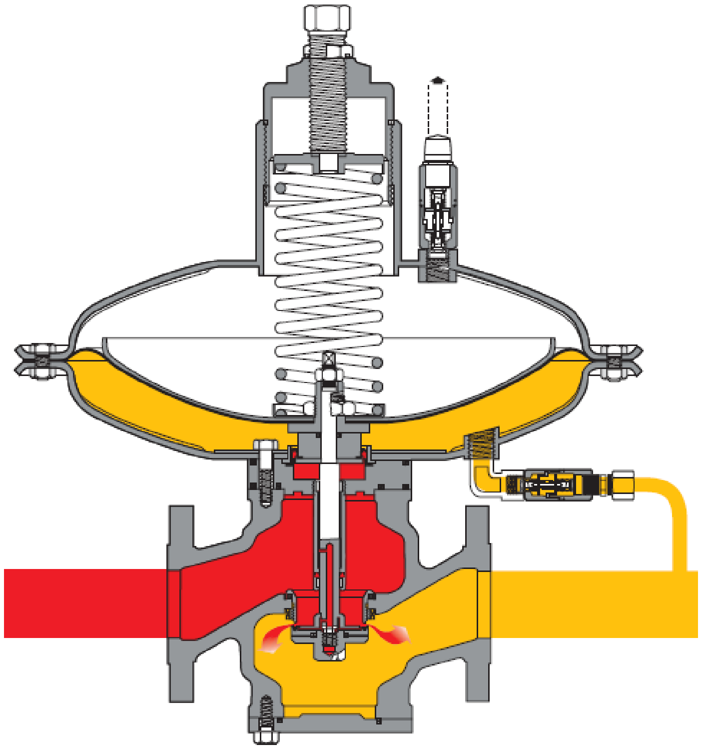
Rule: Use the smallest orifice for the required flow rate capacity

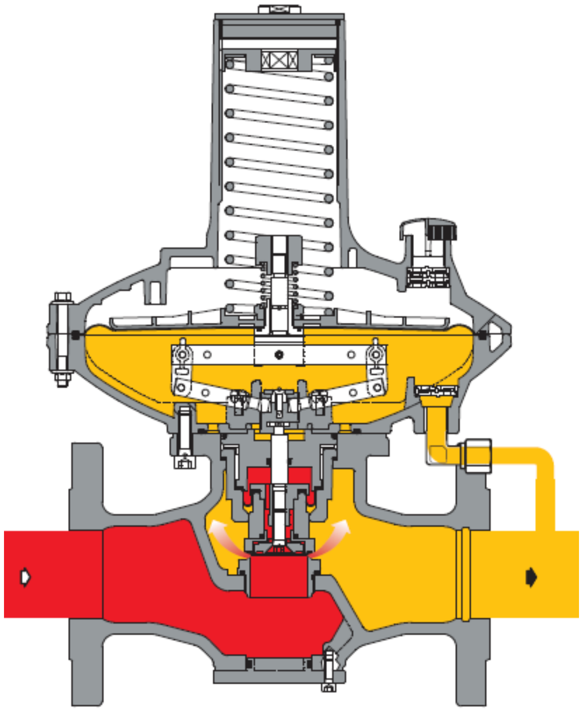
PRESSURE REGULATOR TYPES:

- SELF OPERATED
- PILOTED OPERATED
  - CONSTANT LOADED
  - TWO PATH
  - PILOT UNLOADING

SELF OPERATED PRESSURE REGULATOR

Regulator in which the energy required to operate the control element (obturator) is provided by the controlled variable (outlet pressure).





➢ SELF OPERATED GAS PRESSURE REGULATOR

Advantages:

- Lower capital and operating expense
- Ease of maintenance, less complex
- Fast response time

AC (accuracy class) as per EN334:

Average, expressed as a percentage of the set point, of the absolute maximum values of the positive and negative control deviation within the operating range. Where operating range is range of the inlet pressure for which the regulator ensures a given accuracy class

Droop Definition:

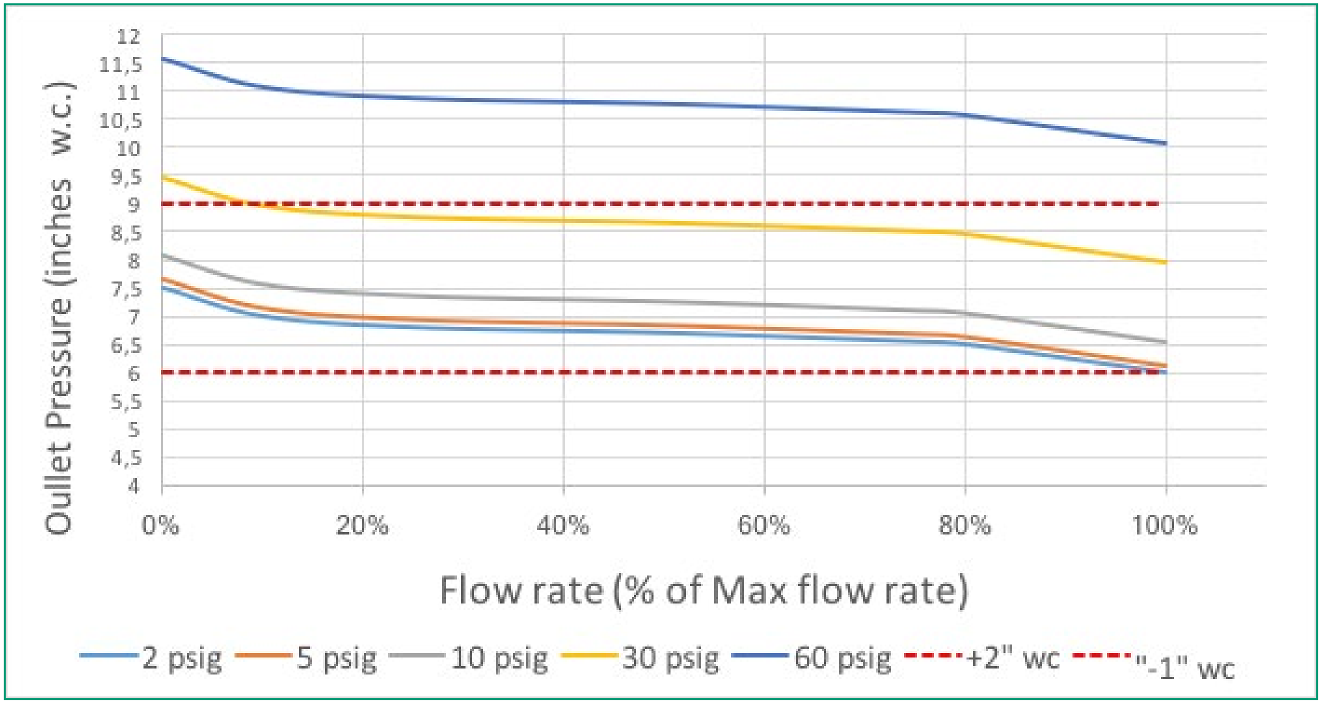
Droop is the reduction of outlet pressure experienced by pressure-reducing regulators as the flow rate increases. It is stated as a percent, in inches of water column or in pounds per square inch and indicates the difference between the outlet pressure setting made at low flow rates and the actual outlet pressure at the published maximum flow rate.

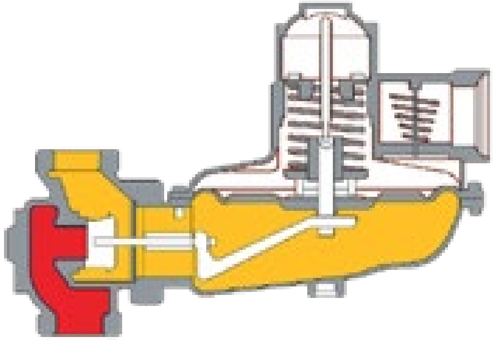
1% Absolute Droop vs AC Class:

Setting	measurement unit	1% abs accuracy	Relative Accuracy	Equivalent AC
6	inch w.c.	4,0746	67,9%	worse than 30
8	inch w.c.	4,0946	51,2%	worse than 30
10	inch w.c.	4,1146	41,1%	worse than 30
20	inch w.c.	4,2146	21,1%	30
1	Psi	0,155	15,5%	20
2	psi	0,165	8,3%	10
4	psi	0,185	4,6%	5
8	psi	0,225	2,8%	5
10	psi	0,245	2,45%	2,5

Setting	measurement unit	1% abs accuracy	Relative Accuracy	Equivalent AC
15	mbar	10,28	68,5%	worse than 30
20	mbar	10,33	51,7%	worse than 30
25	mbar	10,38	41,5%	worse than 30
50	mbar	10,63	21,3%	30
0,07	bar	0,01083	15,5%	20
0,14	bar	0,01153	8,2%	10
0,28	bar	0,01293	4,6%	5
0,56	bar	0,01573	2,8%	5
0,7	bar	0,01713	2,45%	2,5

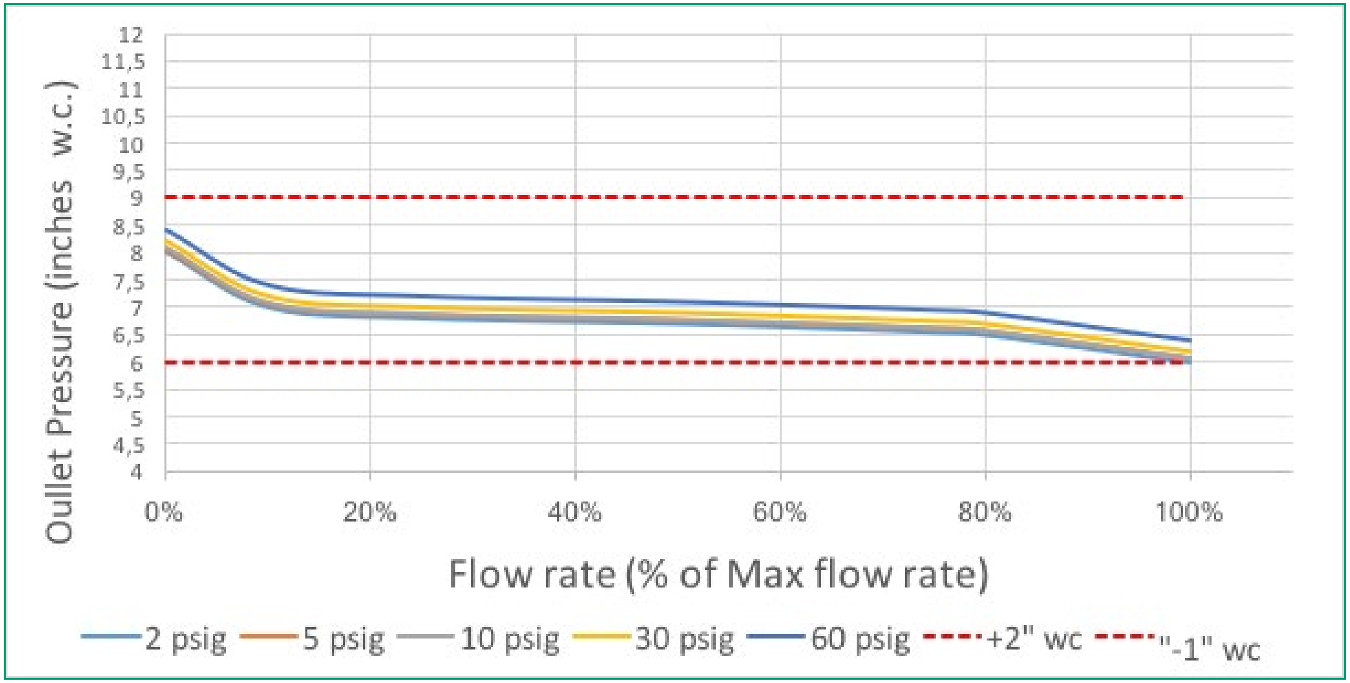
Unbalanced Valve

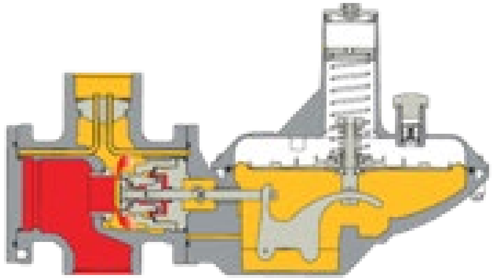




- By increasing the inlet pressure there is a shift of the set point.
- The higher the variation between the minimum and maximum inlet pressure, the greater the deviation from the set point.

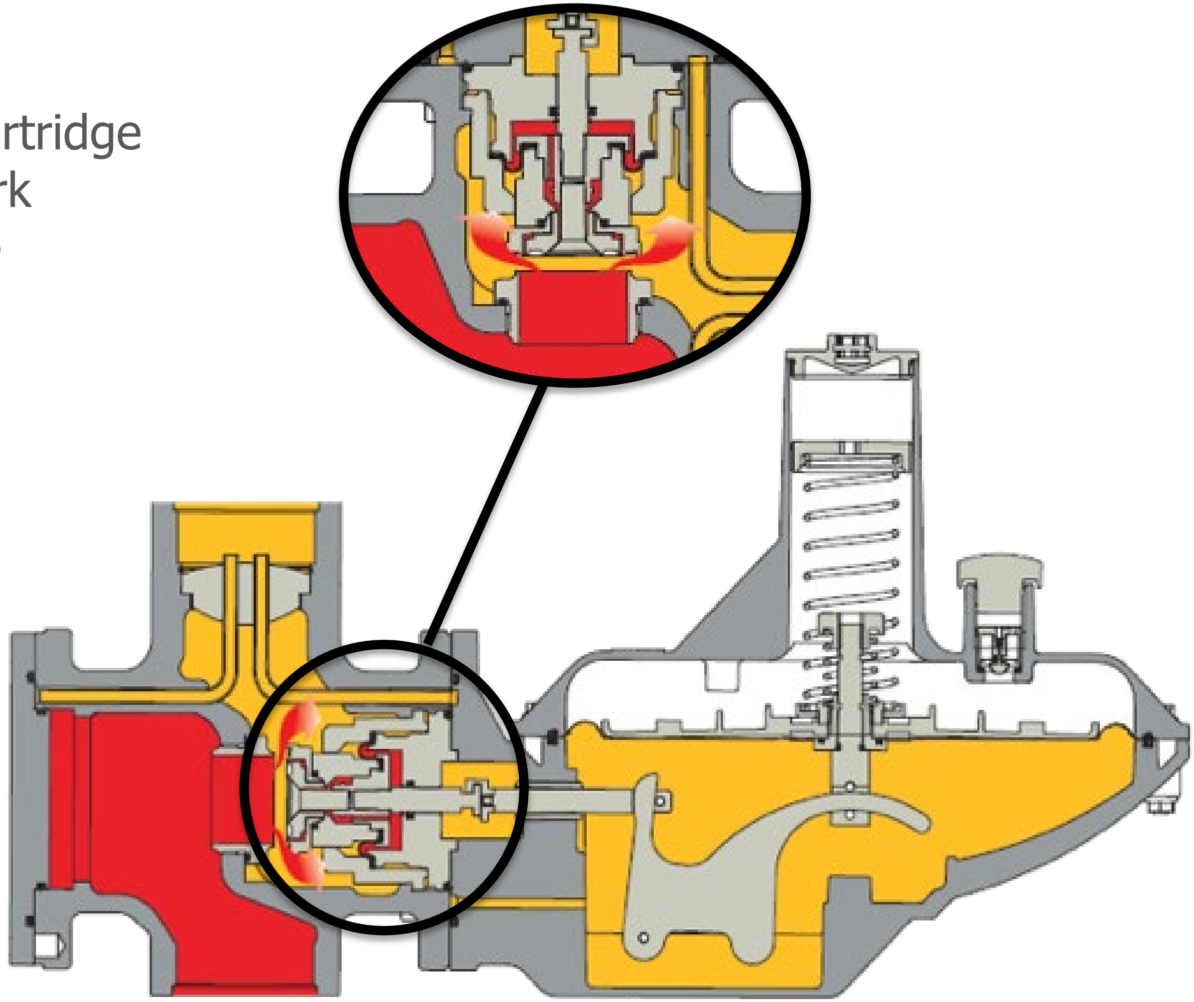
Balanced Valve





- When increasing the inlet pressure there is a minimal/negligible shift of the set point
- The balancing system makes the regulator insensitive to inlet pressure variation

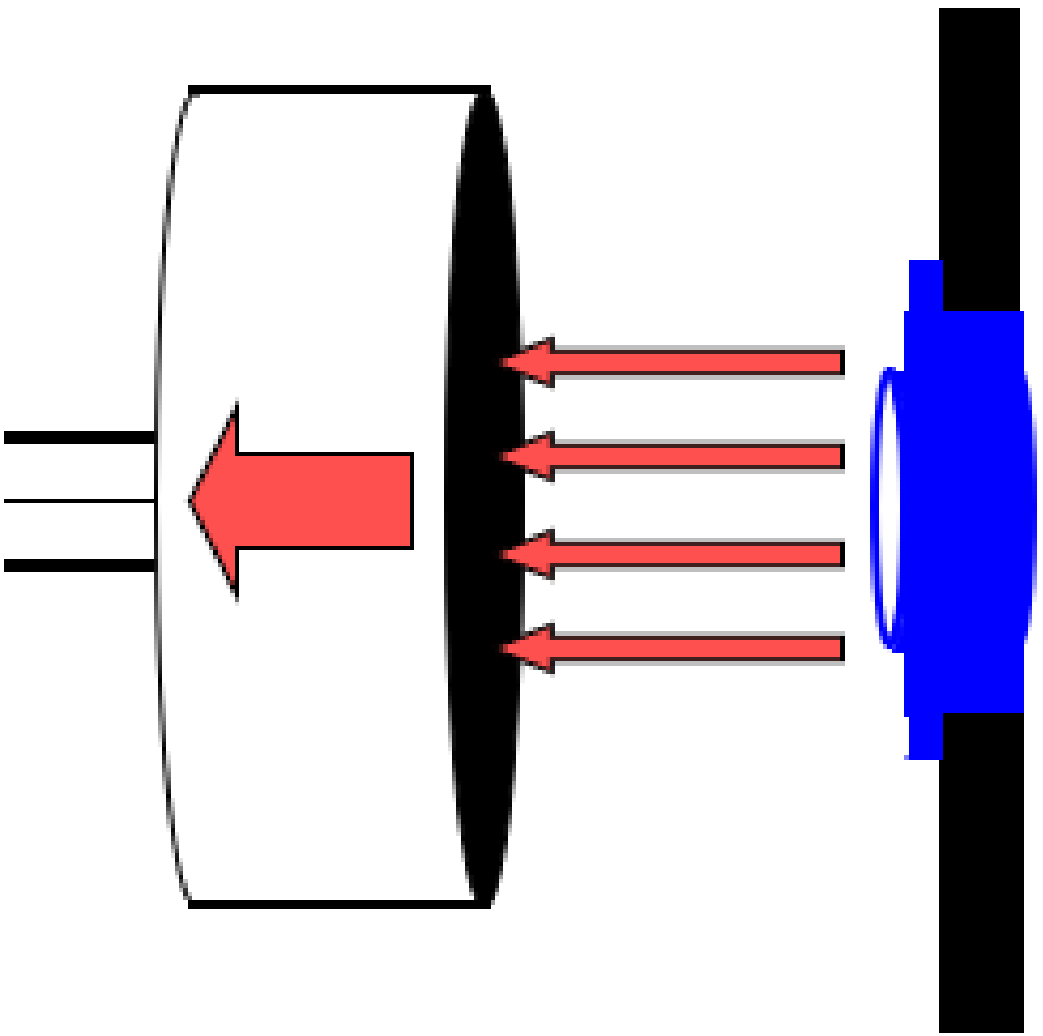
- The balanced valve cartridge makes the system work
- But how does it work?



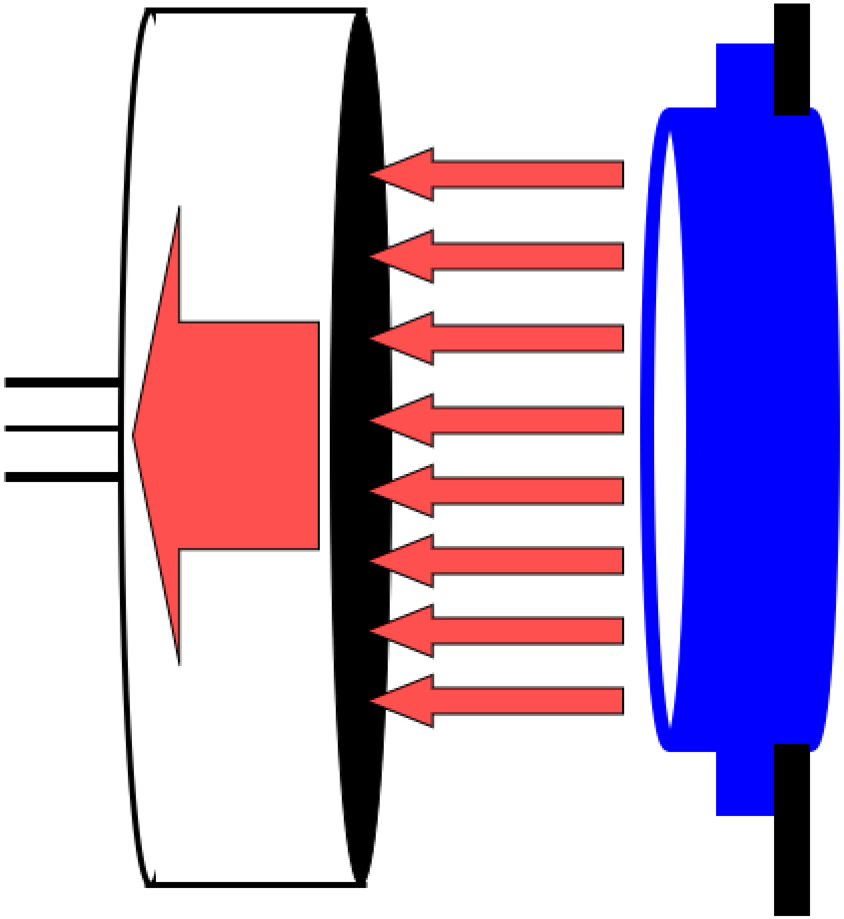
The formula to design a pressure regulator is

FORCE = PRESSURE * AREA

Because of the inlet pressure force on the regulator’s orifice seat, one needs to change the orifice depending on the maximum inlet pressure.



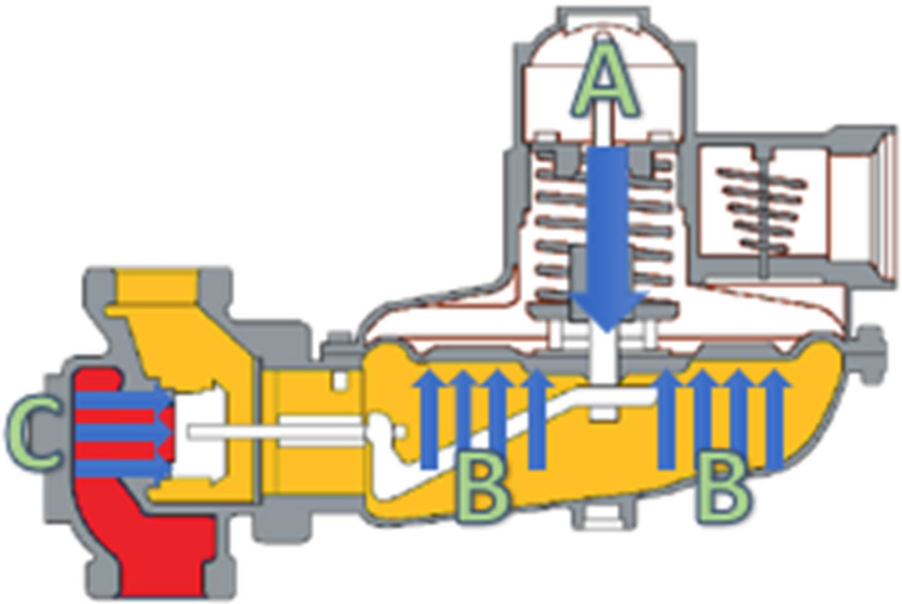
- F= P x Area
- Smaller orifices can be subjected to higher inlet pressures



- F= P x Area
- Larger orifices are limited to lower maximum inlet pressures.

In an unbalanced regulator, you need to change the orifice due to the force on the orifice seat resulting from the pressure and flow changes which limit the performance of the regulator and causes;

1. The outlet pressure changes as the inlet pressure changes.
2. Multiple orifices are required to achieve wide performance.
3. Turndown performance is limited.
4. MAOP is reduced (Maximum Allowable Operating Pressure).

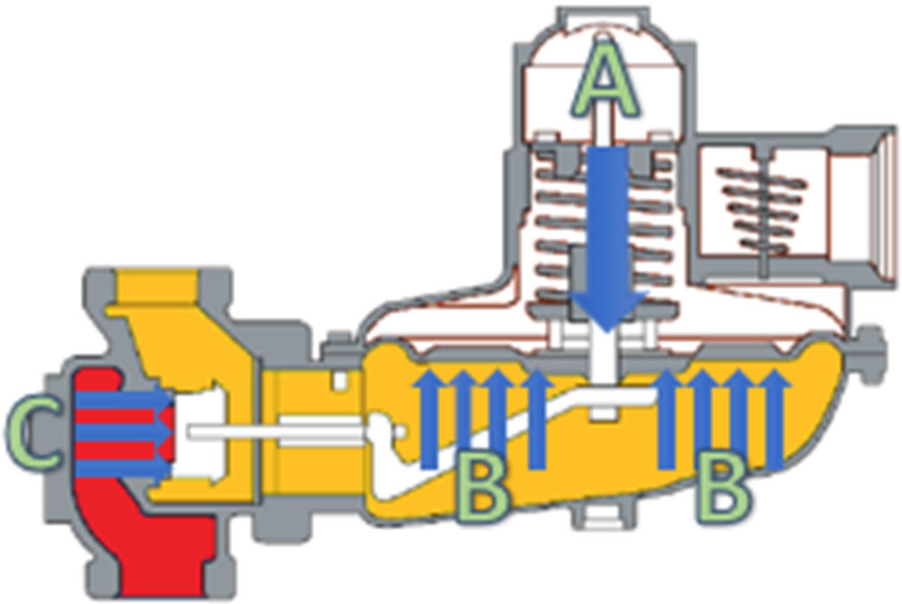


Unbalanced Regulator

In steady conditions:

A + C = B

A. The spring force pushes down to make the regulator open
B. The outlet pressure on the diaphragm area forces the regulator to close
C. The inlet pressure's force on the valve seat surface (equal to the area of the orifice) forces the regulator to open.



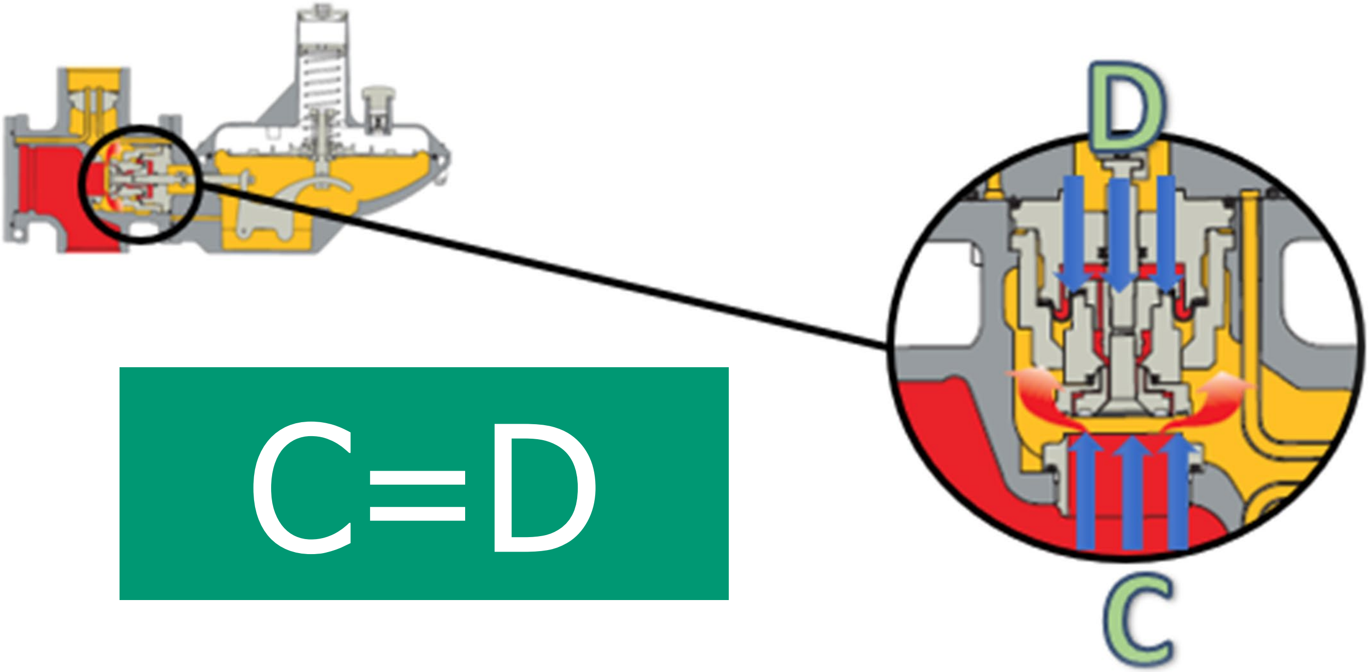
Unbalanced Regulator

In steady conditions:

A + C = B

When the inlet pressure increases, force "C" increases and causes "B" to be greater to keep the equation valid. This causes downstream pressure to be higher than the initial set point.

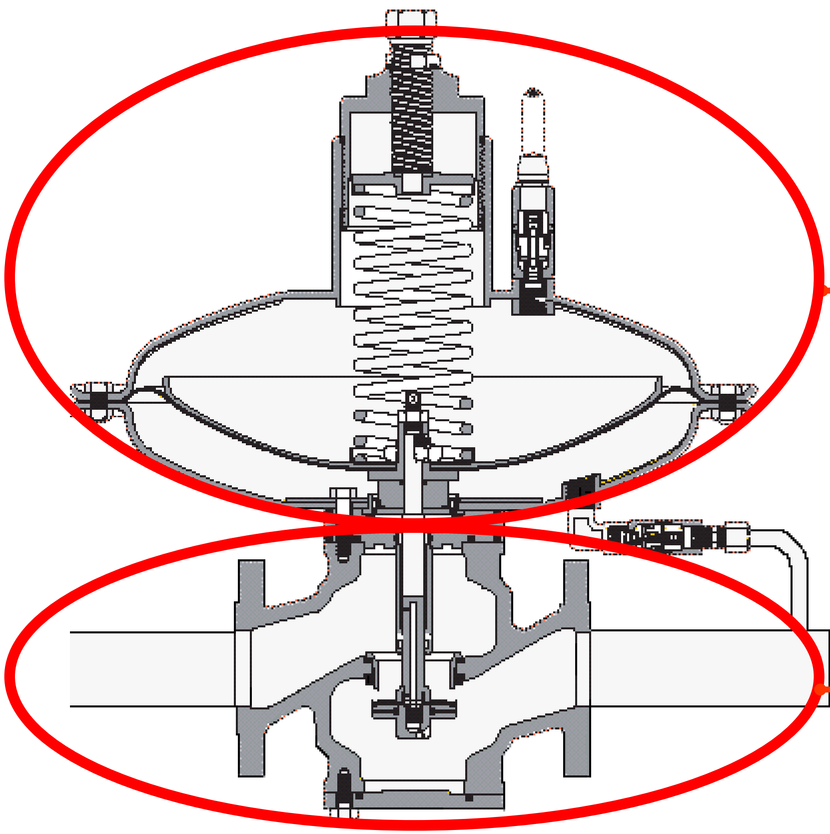
Balanced Regulator



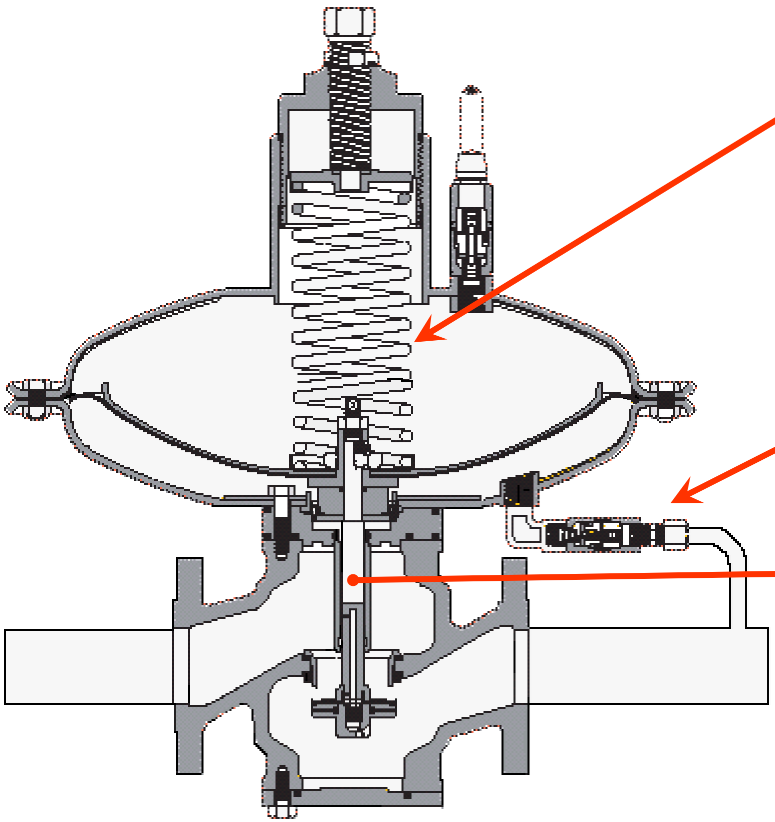
C=D

- The balanced valve is designed so the balancing piston creates the same and opposite force created by the inlet pressure.
- Since the surfaces are equal, the two forces neutralize each other under all inlet pressure conditions.

The regulator can be divided in two groups :



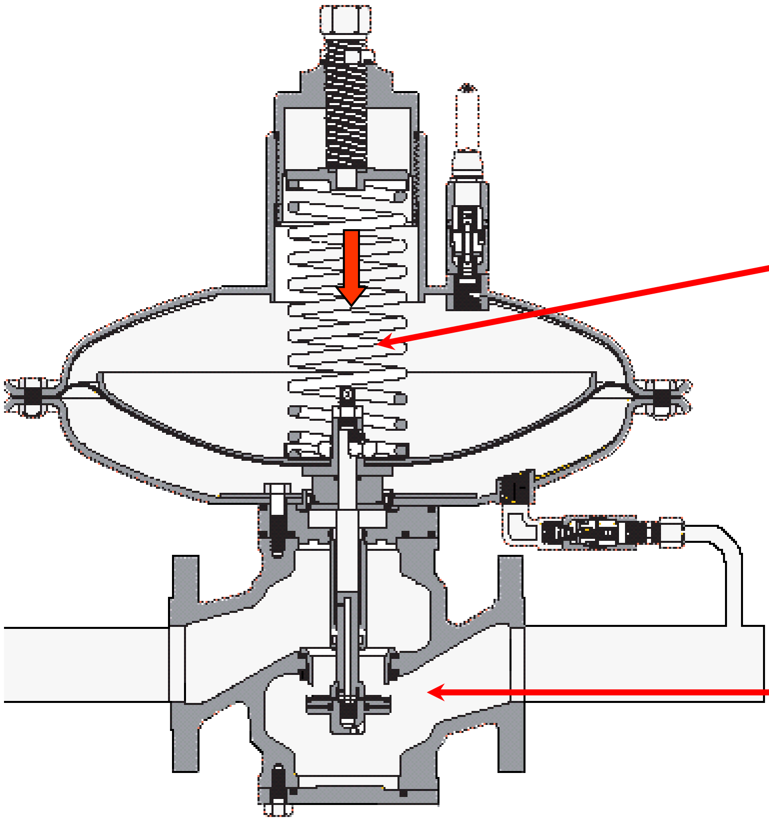
- ACTUATOR
- FLOW REGULATION SYSTEM



It’s a **spring** actuated regulator.

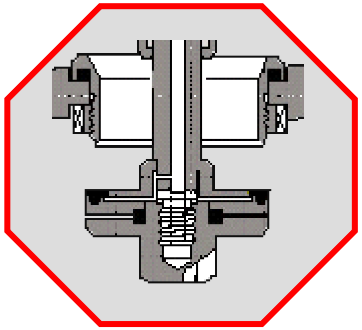
The control of the downstream pressure is done by means of an **external sensing line.**

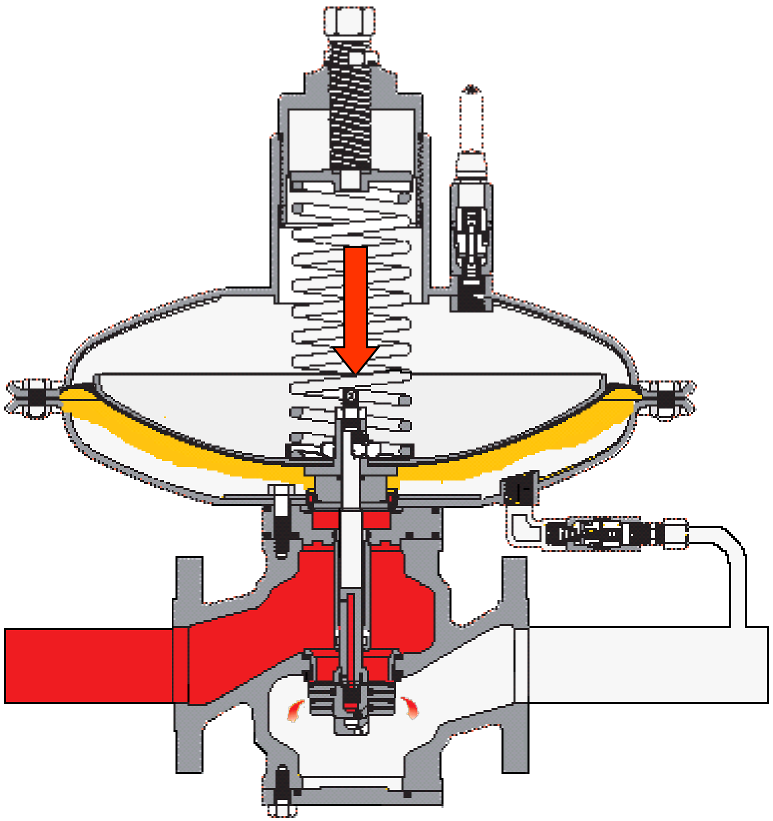
The movement is trasmitted by **the shaft** to the obturator which moves perpendiculary to the gas flow direction.



Without pressure , the obturator is keeps in open position by the setting spring.

(Therefore the seat is open)





Downstream pressure **Pd** is controlled by means of the equilibrium between the action of the **spring** and the action exerted by the **downstream pressure** on the diaphragm

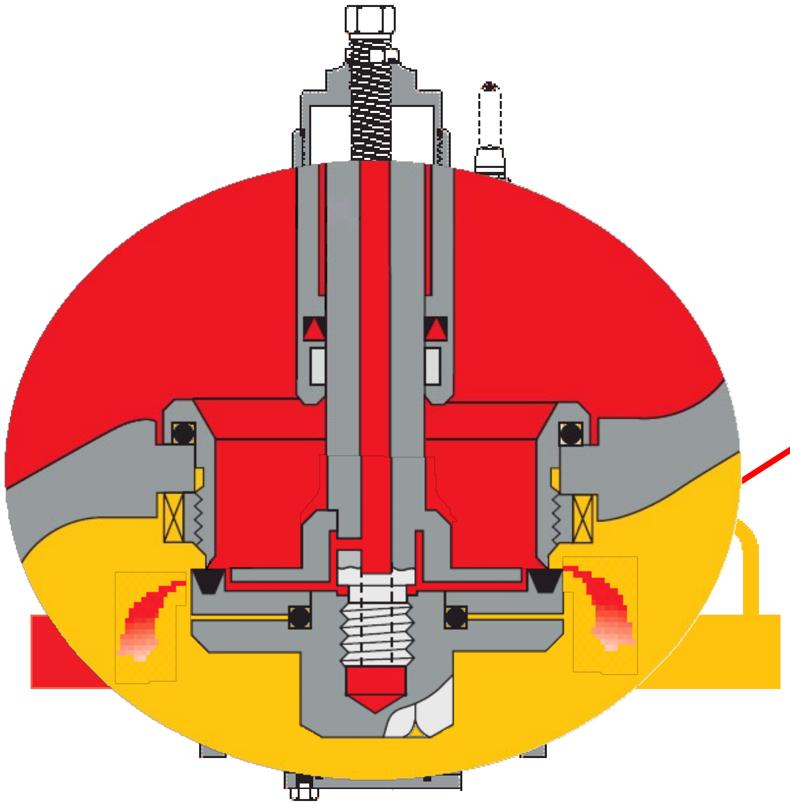
When **Pd Force > Spring Force**

The obturator moves towards CLOSE position

If Spring Force > Pd Force

The obturator moves towards OPEN position

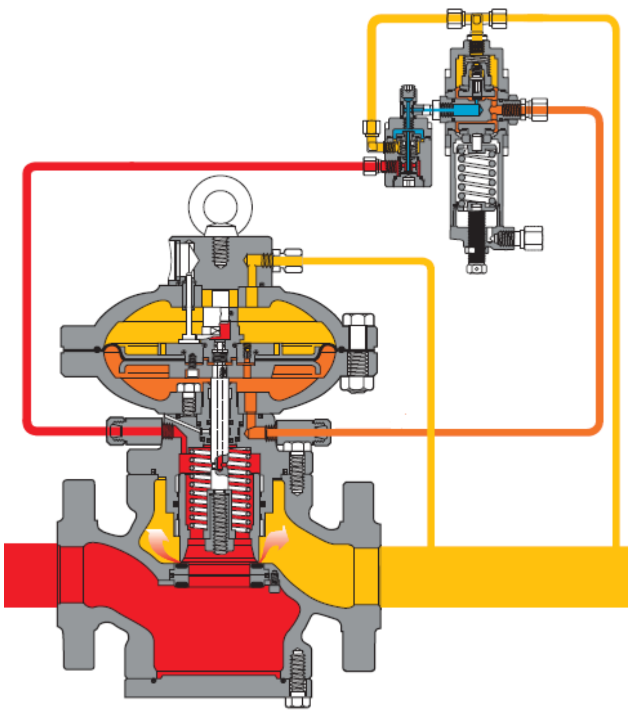
Equilibrium = constant downstream pressure



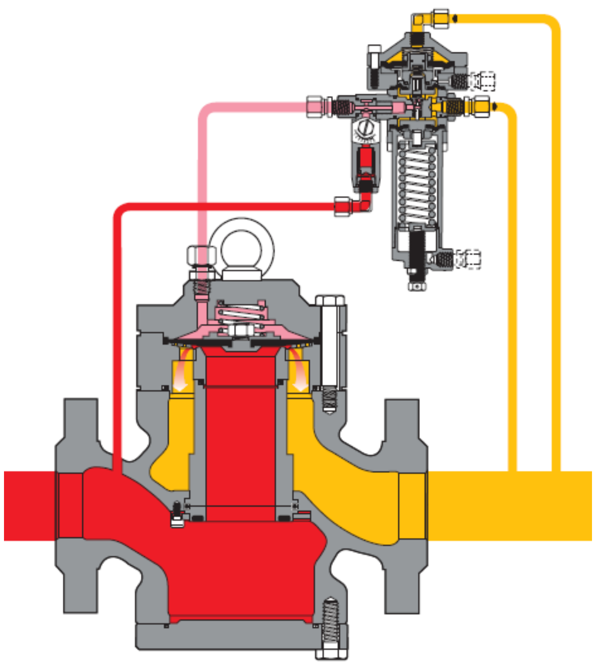
With No flow rate requested hermetic tightness is ensured by a **soft rubber gasket** fixed to the obturator .

➢PILOT CONTROLLED GAS PRESSURE REGULATOR (INDIRECT ACTING)

Regulator in which the net force required to move the control member is supplied by a pilot.



TWO PATH



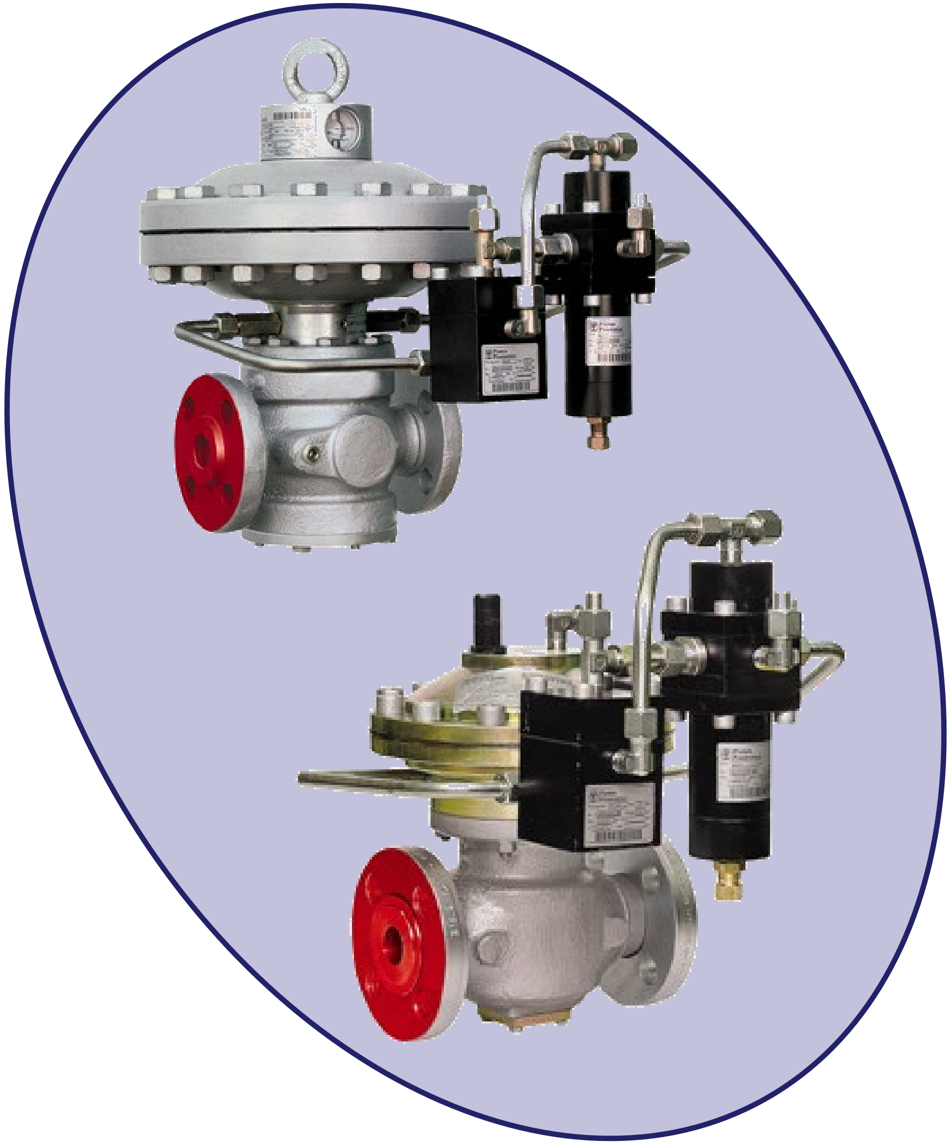
UNLOADING

➢PILOT CONTROLLED GAS PRESSURE REGULATOR (INDIRECT ACTING)

Advantages:

- Wide set range
- Best accuracy class
- High flow rate
- Remote set control

FAIL OPEN

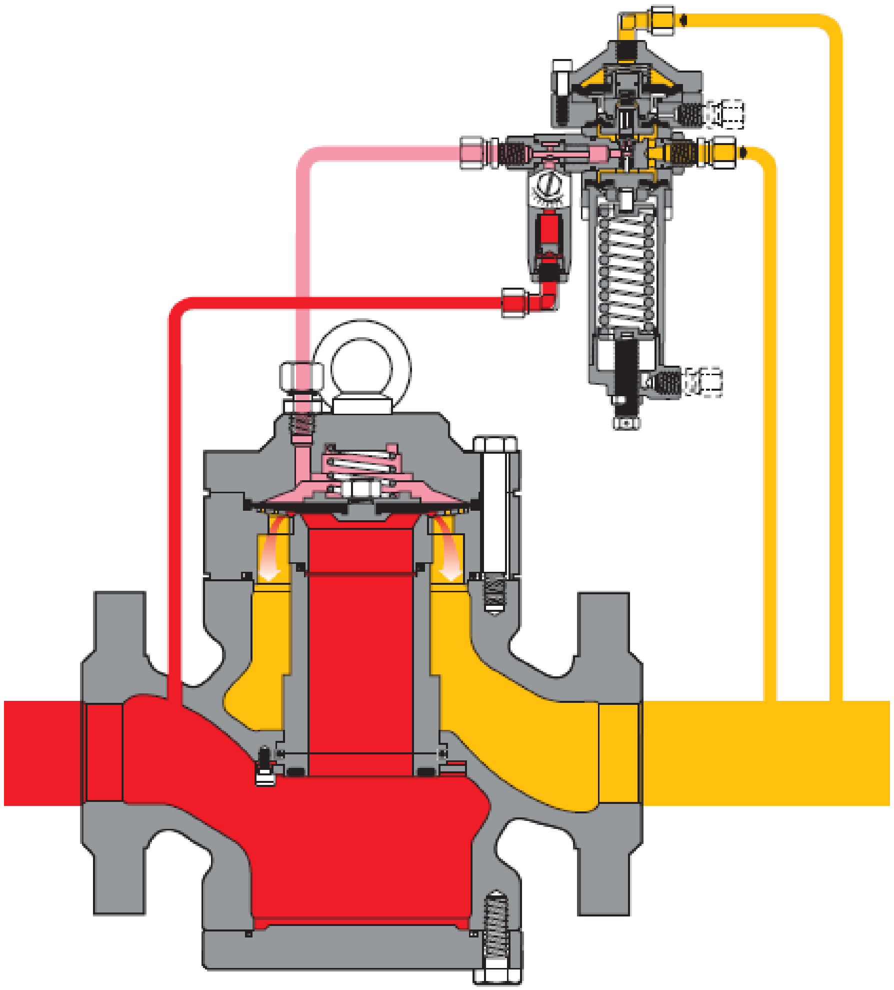


FAIL CLOSE

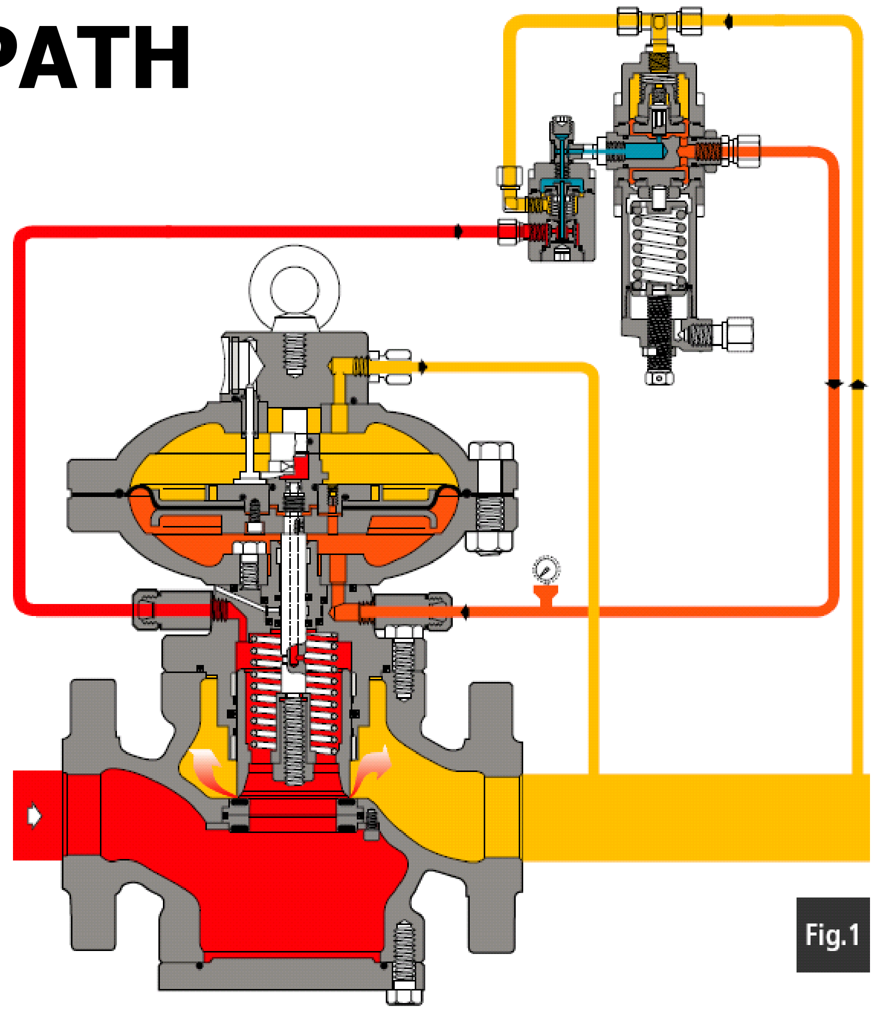
PRESSURE UNLOADING

TWO PATH

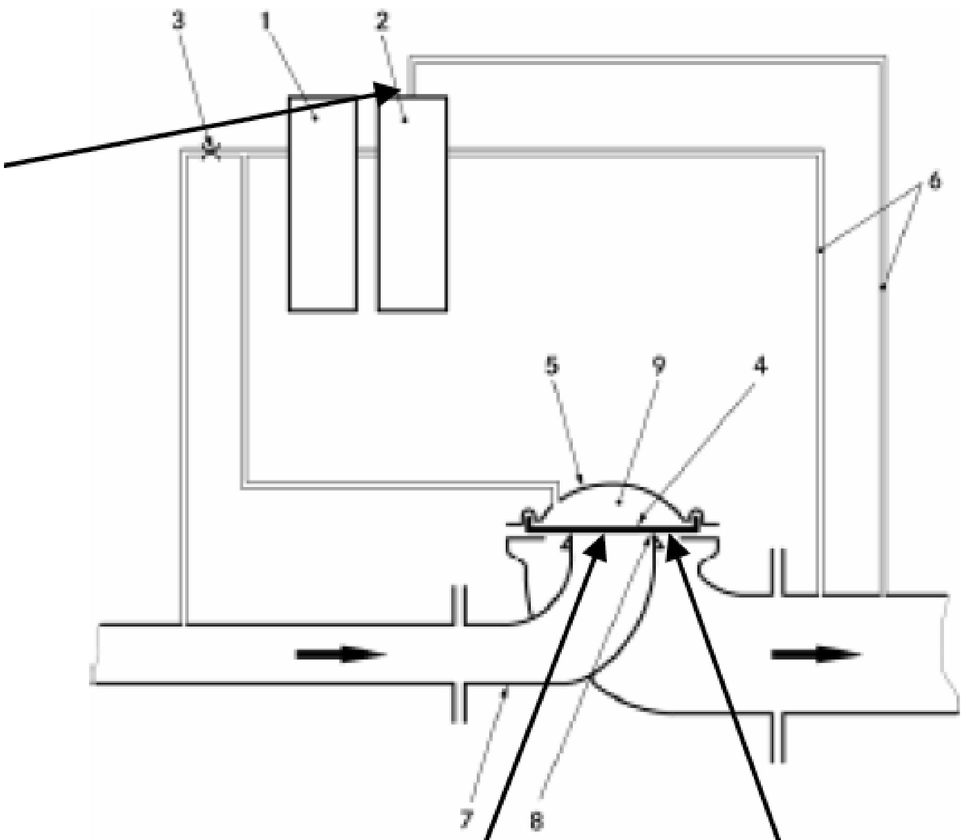
PRESSURE UNLOADING



TWO PATH

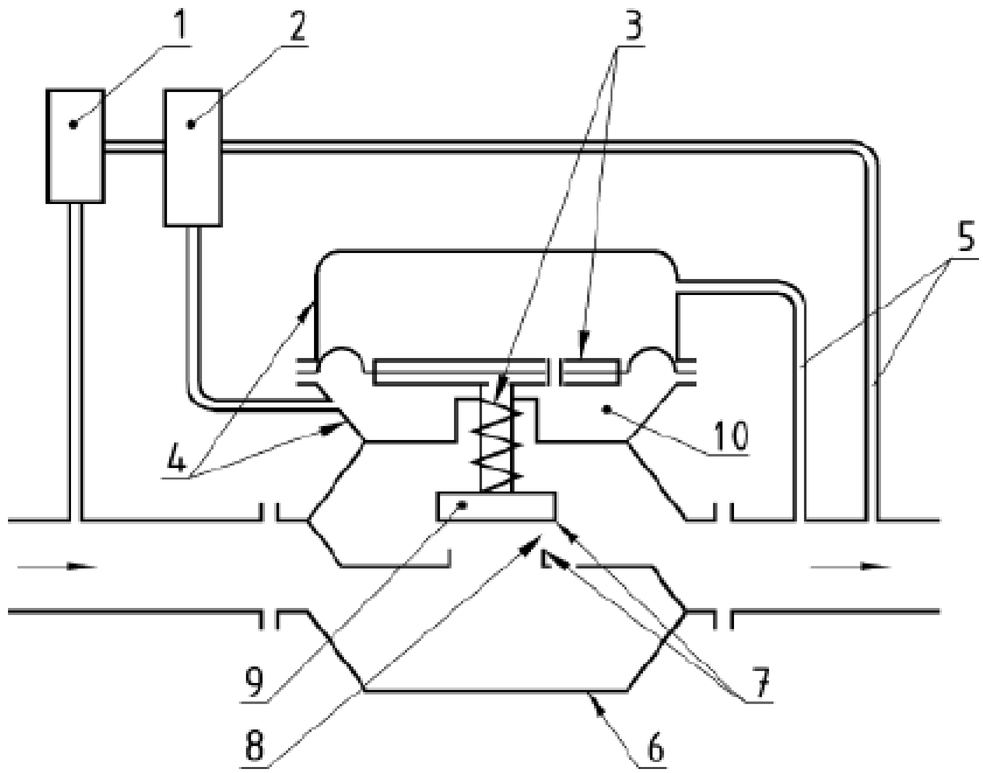


Reflux 819



Key

1	Fixture	6	Sensing / process lines
2	Pilot	7	Regulator body
3	throttle	8	valve seat
4	Control member (diaphragm)	9	Motorization chamber
5	casing of control member		



Key

1	Fixture	6	Regulator body
2	Pilot	7	Valve seats
3	Actuator	8	Seat ring
4	Casing of actuator	9	Control member
5	Sensing/process line	10	Motorization chamber

Parameter	Spring Loaded	Constant Loaded	Pilot Operated	Pressure Unloading
Typical application	Service Regulator	Service Regulator	Service Regulator / District	Gate Station / District / LVC
Minimum DP required	No	Low	Low	Yes
Sensing Line	No	No	Some	Yes
Sensitivity to Contaminants	No	No	No	Yes
Variable Gain	No	No	Some	Yes
Speed of Response	Fast	Relatively fast	Relatively fast	Slow
Cost	Low	Moderate	Relatively Expensive	Relatively Expensive

SIZING EQUATIONS

a) Pressure regulator sizing

$$Q = 1{,}28074 \text{ x } Cg \text{ x } Pu \text{ x } \sin\left(K1 \text{ x } \sqrt{\frac{Pu\text{-}Pd}{Pu}}\right)_{deg} \qquad (1)$$

$$Q = 1{,}28074 \text{ x } Cg \text{ x } Pu \qquad (2)$$

Where:

Q	Flow rate	(Sft3/h)
Cg	Flow coefficient	
K1	Body shape	
Pu	factor Inlet	
Pd	pressure Outlet	(psi abs)
	pressure	(psi abs)

Equation (1) is valid in sub critical condition

Equation (2) is valid in critical condition

Equations (1) and (2) are applicable for gas having a relative density of 0,61 (air = 1) and an inlet temperature of 59 °F.

b) Gas velocity at outlet flange

$$V = 0{,}04981 \text{ x } \frac{Q}{DN^2} \text{ x } \frac{14{,}5037738 - 0{,}002 \text{ x } Pd}{14{,}5037738 + Pd}$$

V	Gas velocity	(ft/sec)
Q	Flow rate	(Scft/h)
DN	Nominal pipe size	(inch)
Pd	Outlet gas pressure	(psig)

Questions

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