WGMSC
western gas measurement short course

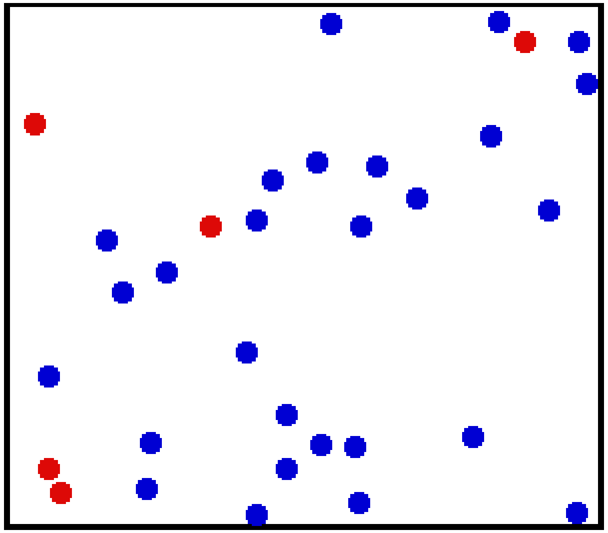
Introduction to Gas Regulation

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.



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

LAWS AND CHEMICAL-PHYSICAL CHARACTERISTICS OF GASES

PRESSURE

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)

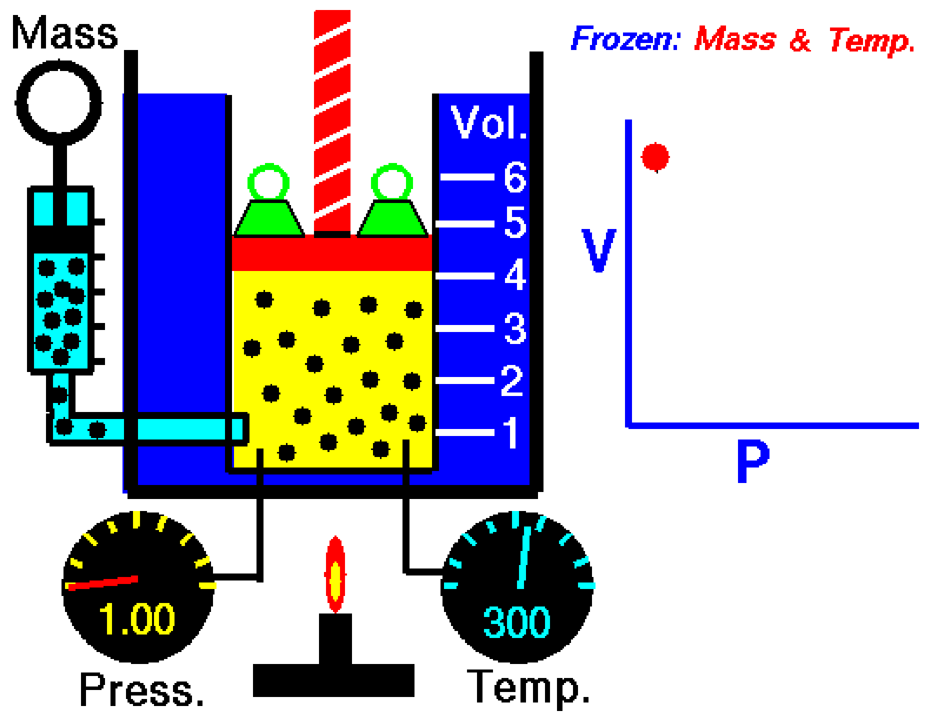
U N I T O F M E A S U R E

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***



UNIT OF MEASURE

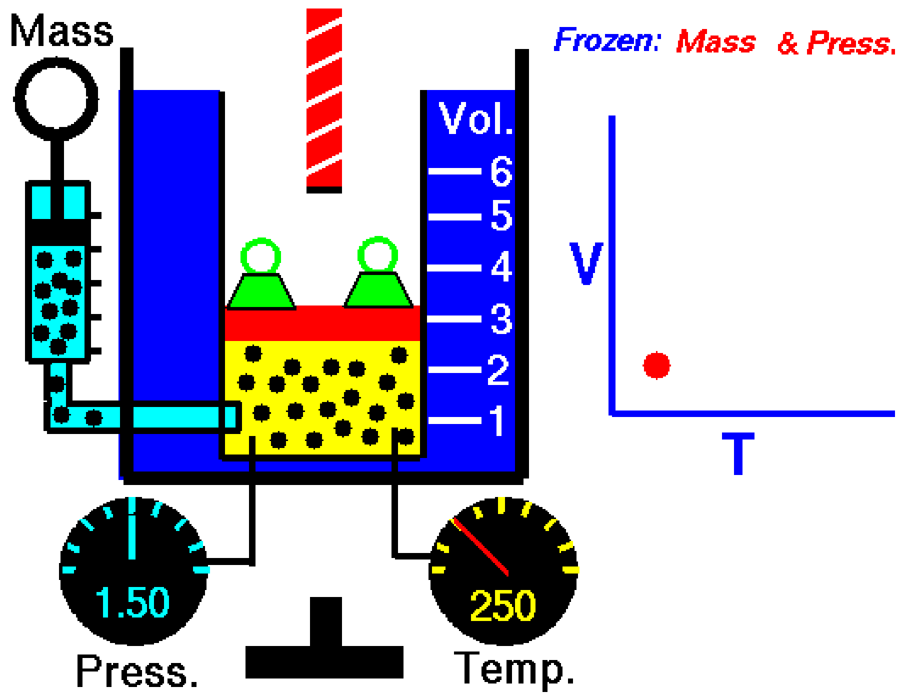
LAWS AND CHEMICAL-PHYSICAL CHARACTERISTICS OF GASES

VOLUME

Charles' law

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

P x V / T = constant.



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

LAWS AND CHEMICAL-PHYSICAL CHARACTERISTICS OF GASES

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 cubic feet per hour (ft^3/hr).

UNIT OF MEASURE

LAWS AND CHEMICAL-PHYSICAL CHARACTERISTICS OF GASES

Flow rate

Standard condition → It refers to measurements taken at a temperature of 60 ˚F (15 ˚C) and at an atmospheric pressure equal to 14.7psi (101.325 kPa). The Standard cubic foot is normally indicated by SCF. While standard cubic meter is normally indicated with SCM

Normal condition → It refers to measurements taken at a temperature of 32 ˚F (0 ˚C) and at atmospheric pressure equal to 14.7 psi (101.325 kPa). The Standard cubic meter is normally indicated by Nm^3.

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

FUNCTIONS OF A PRESSURE REGULATOR

- Functions of a Pressure Regulator:

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

2. To reduce the upstream pressure (P1) to a value established and acceptable for use in the downstream piping system (P2)

3. To keep the operating pressure downstream (P2) as close to its set value as possible despite variations of both the upstream operating pressure and flow rate

The pressure regulator is an essential part of a gas pressure reduction System; i.e. Meter Set, Gate Station, Distribution Station, etc.

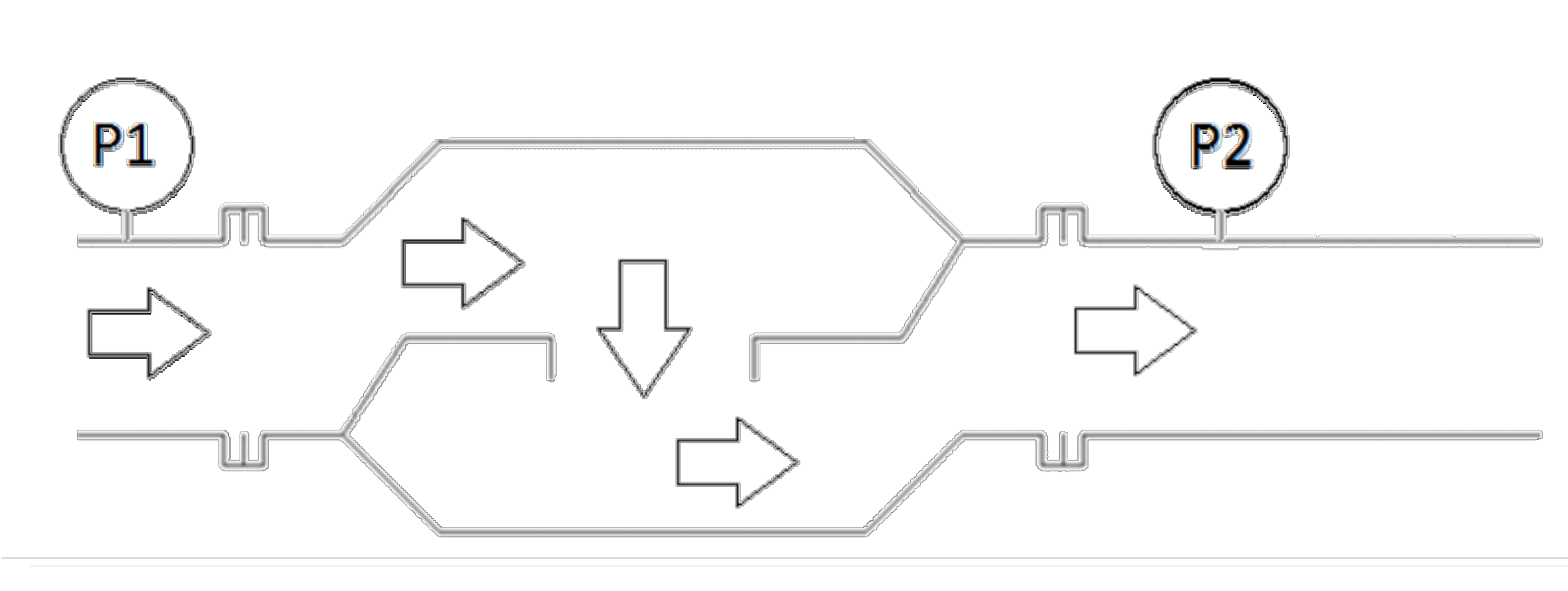
It must ensure the gas supply in quantity and pressure while under volatile operating conditions, namely:

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

B) Compensate for variations no matter the inlet pressure value.

C) Have the ability to stop the gas supply when there is no gas consumption in the distribution system or house fuel-line.

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 delivers pressure to a system downstream **P2** that is lower than that upstream, due to gas flowing through an orifice or valve.

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.

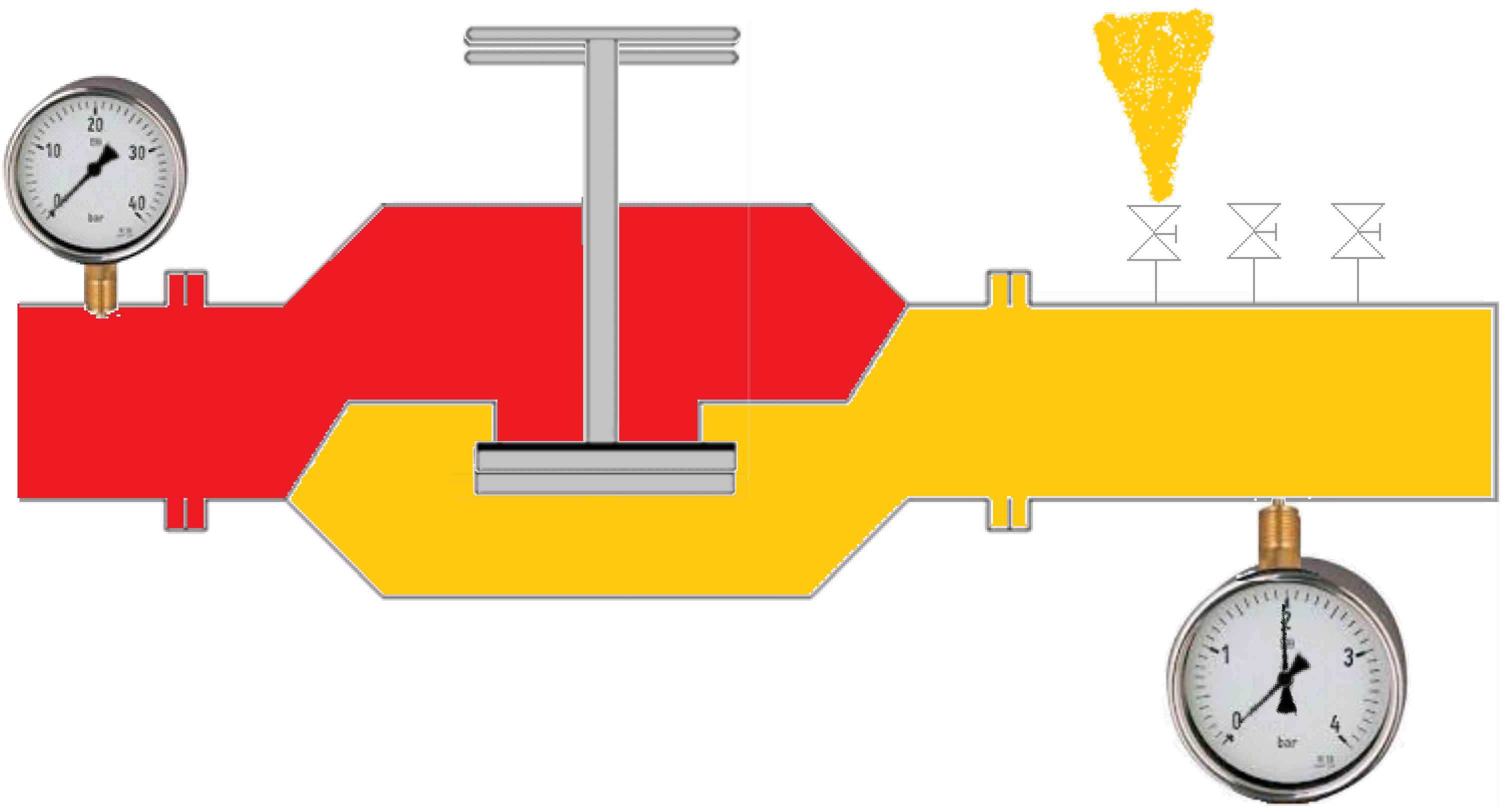
$$Q = K \times S \times \sqrt{Pd \times (Pu - Pd)}$$

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*

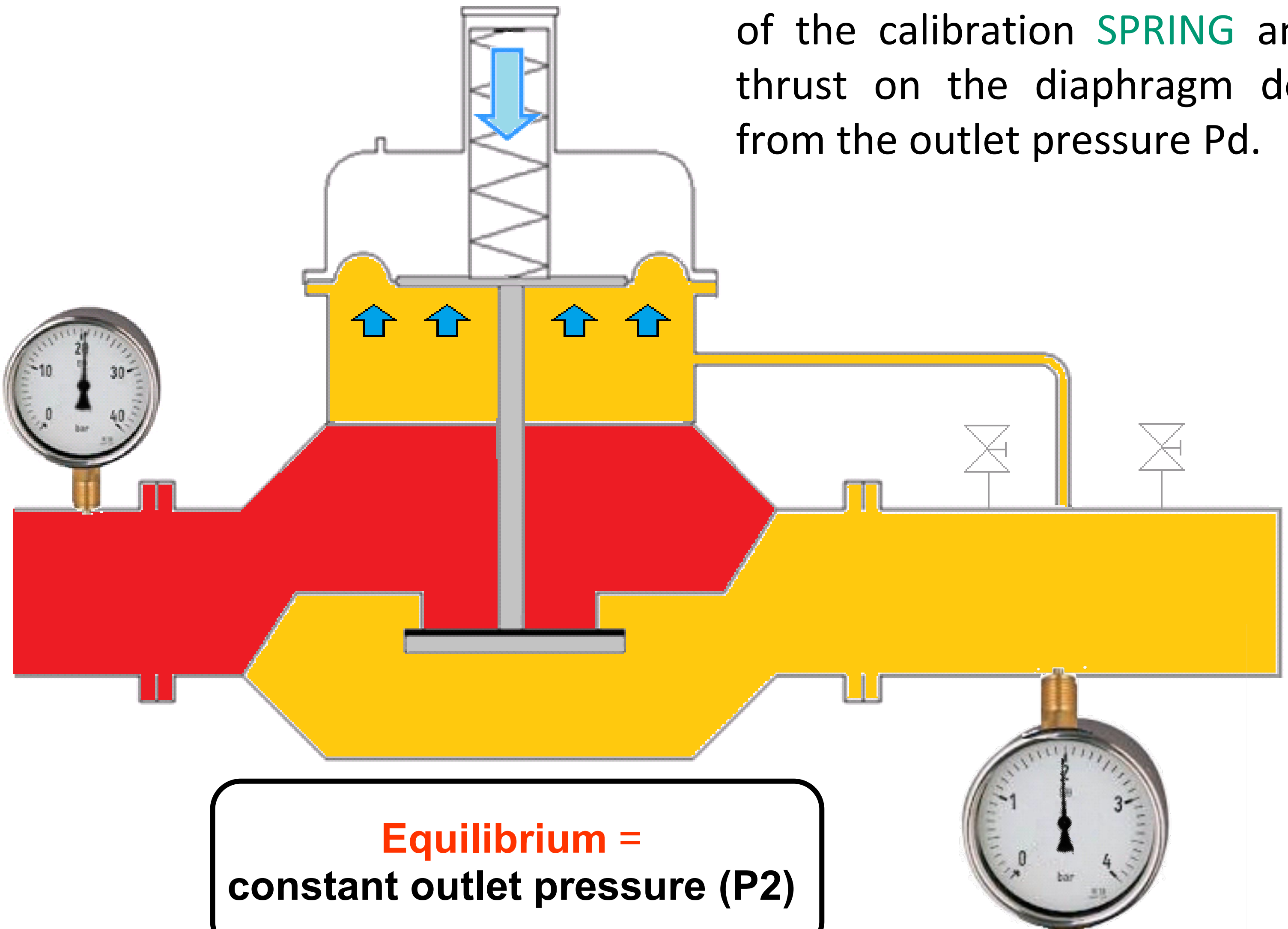
From here it can be inferred that for a given flow rate, for any value of the upstream pressure there is always a value of S which allows setting the downstream pressure to the desired value, and S will be as smaller as higher is the upstream pressure.

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.

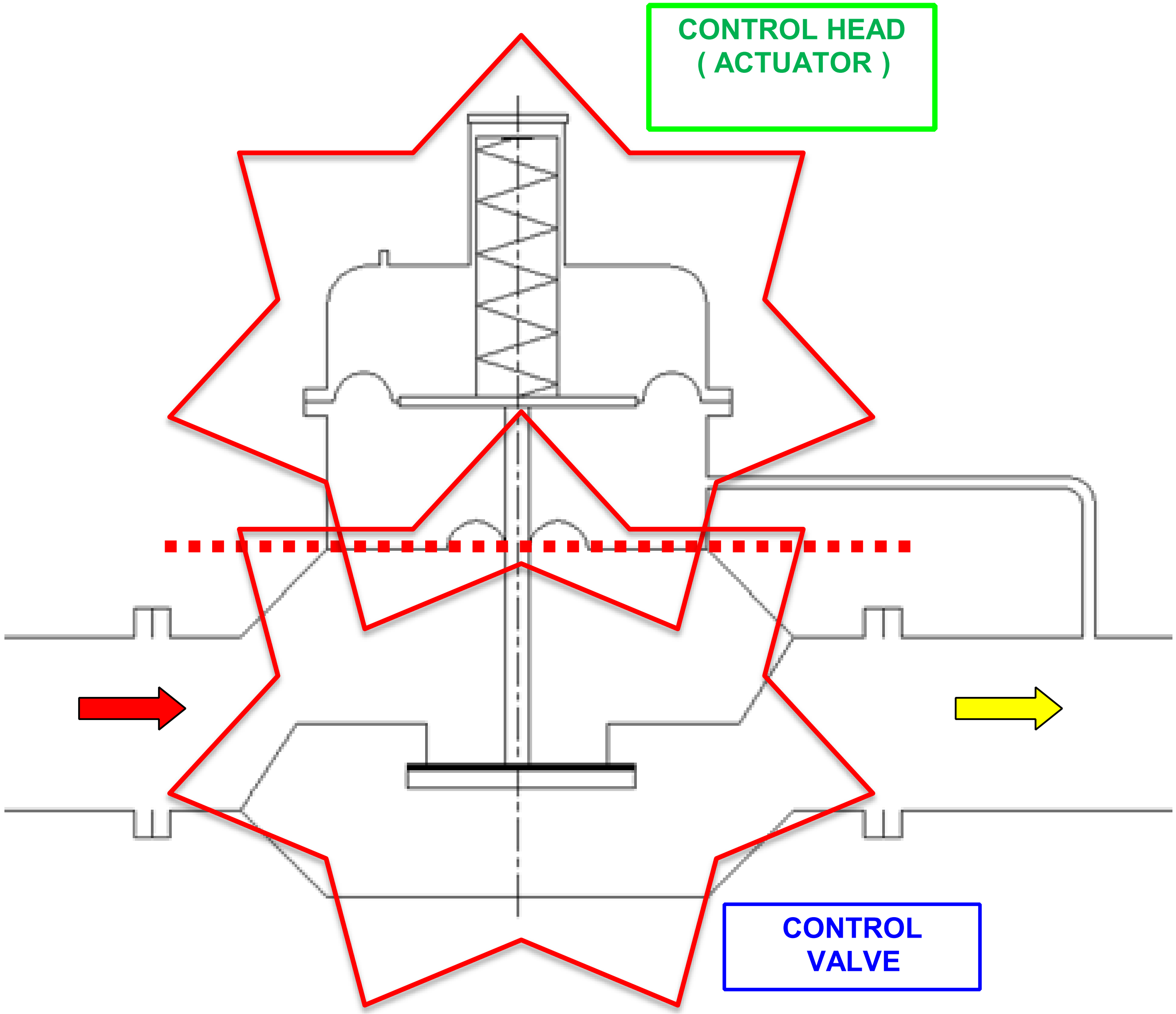


Setting is therefore obtained from the comparison between the load of the calibration SPRING and the thrust on the diaphragm deriving from the outlet pressure Pd.



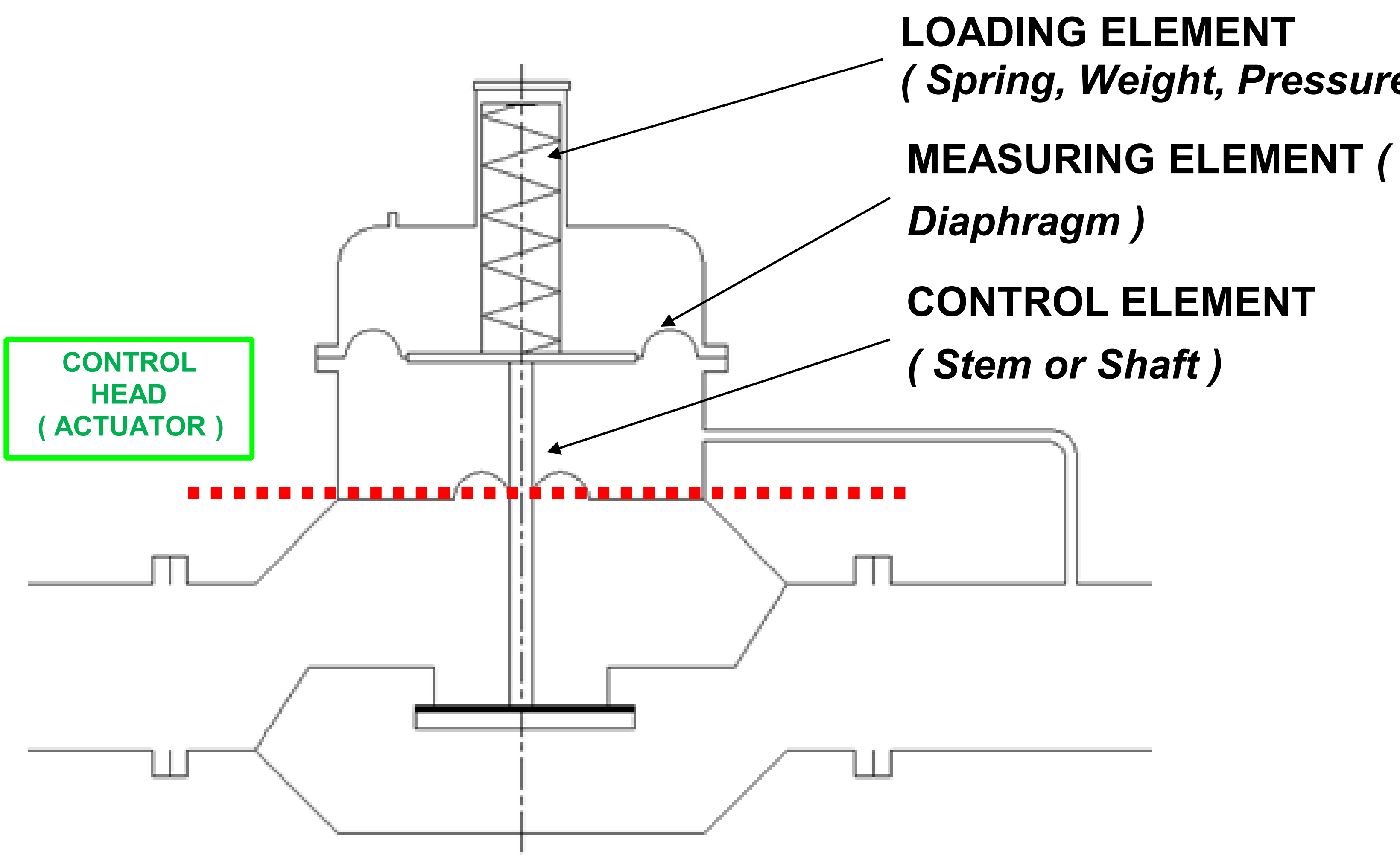
Equilibrium =
constant outlet pressure (P2)

THE COMPONENTS OF A NATURAL GAS PRESSURE REGULATOR



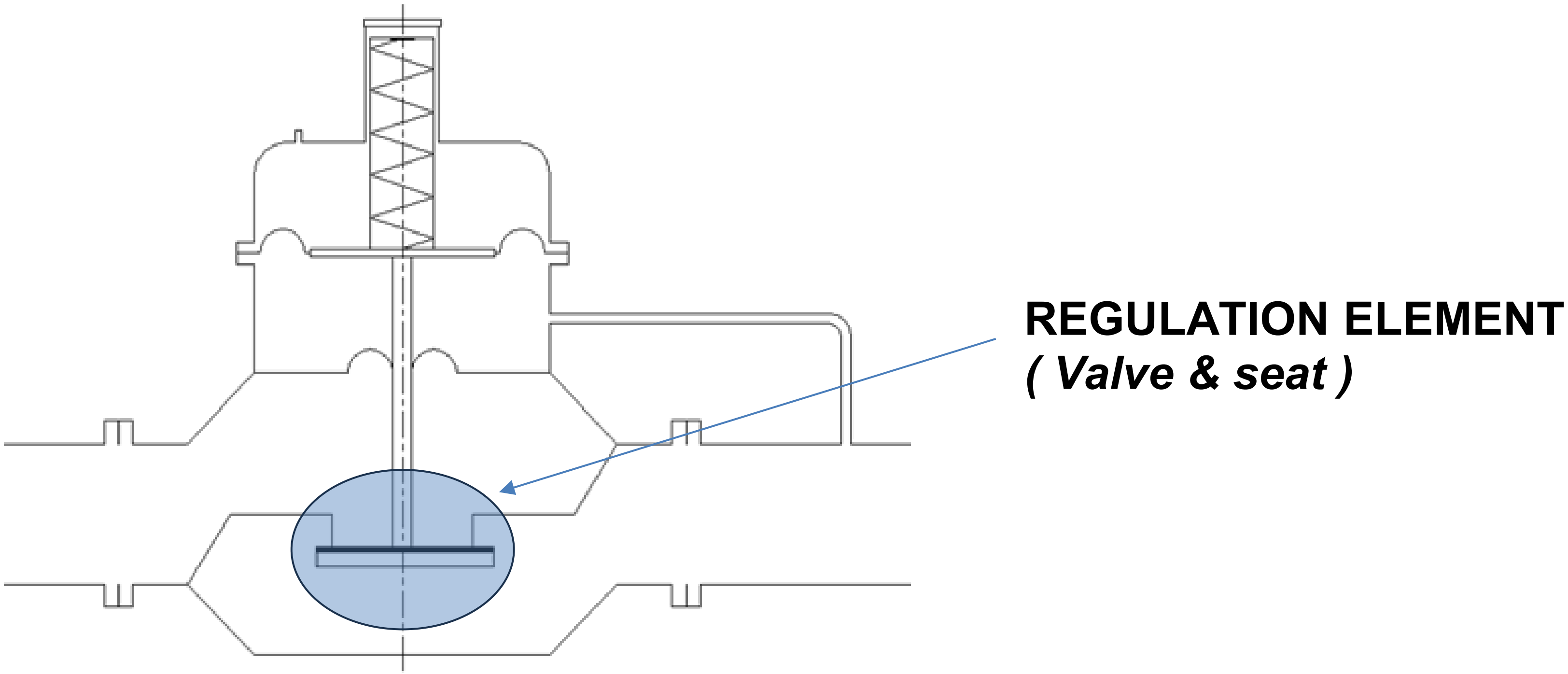
THE COMPONENTS OF A NATURAL GAS PRESSURE REGULATOR
CONTROL HEAD

IT TRANSMITS TO THE CONTROL VALVE THE NECESSARY FORCE THAT THE SI BE CARRIED OUT OF THE SEAT IN THE NECESSARY TRANSITION POSITIO EQUIVALENTLY THE NETWORK IN ACCORDANCE WITH THE NEED.



THE COMPONENTS OF A NATURAL GAS PRESSURE REGULATOR CONTROL VALVE

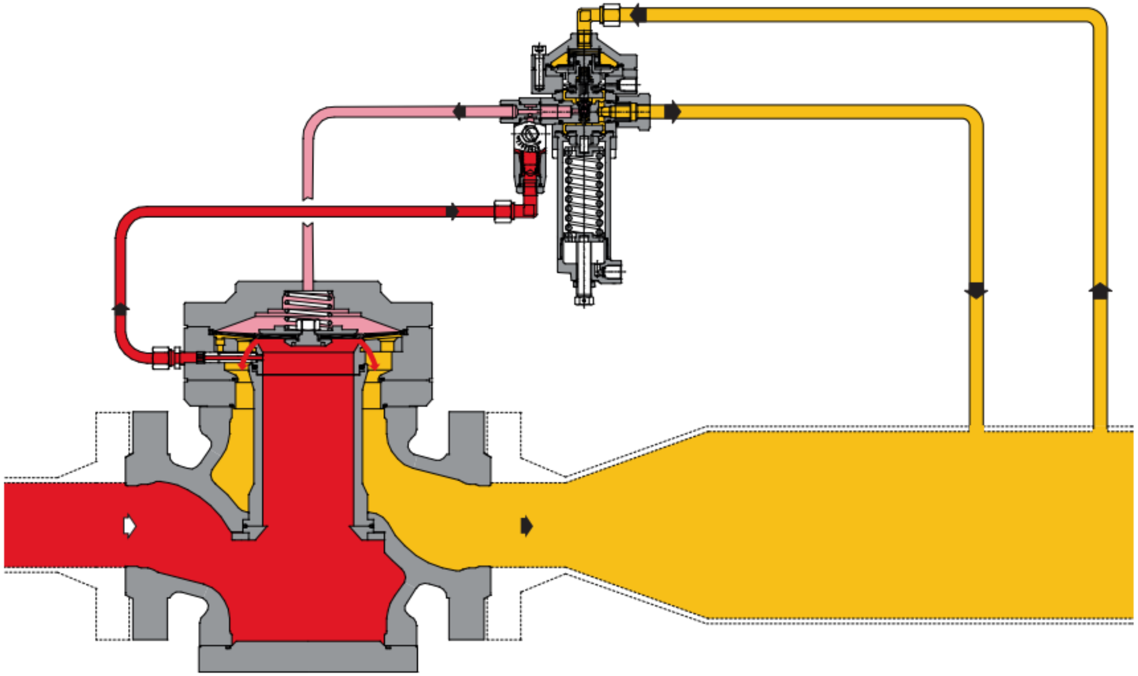
IT IS CALLED ALSO NARROWING OR REDUCTION ELEMENT; THE PART OF THE REGULATOR WHERE THE GAS MOVES THROUGH, THE FLOW RATE IS CONTROLLED & THEREFORE THE PRESSURE IS REDUCED.



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.

Flexible element or rubber Urburator/Valve used to throttle flow

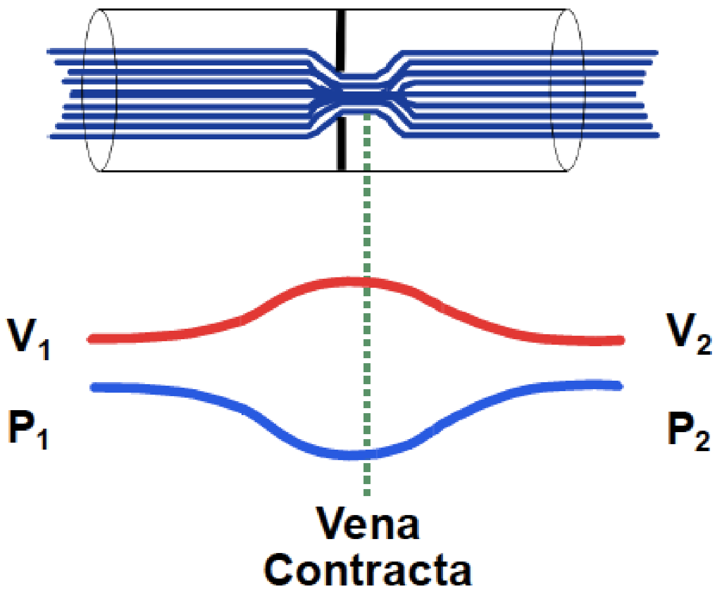


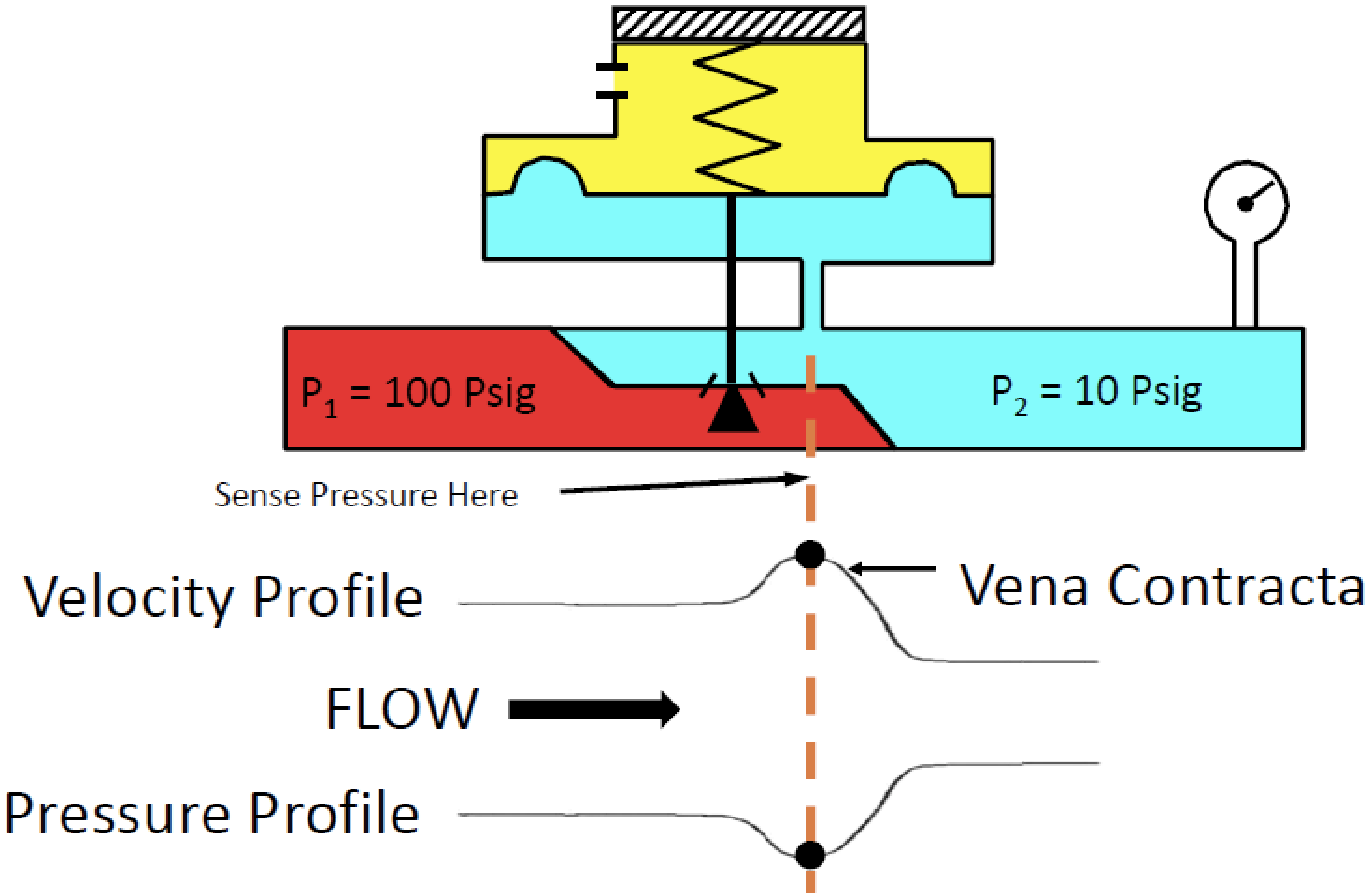
Inlet pressure

Control pressure

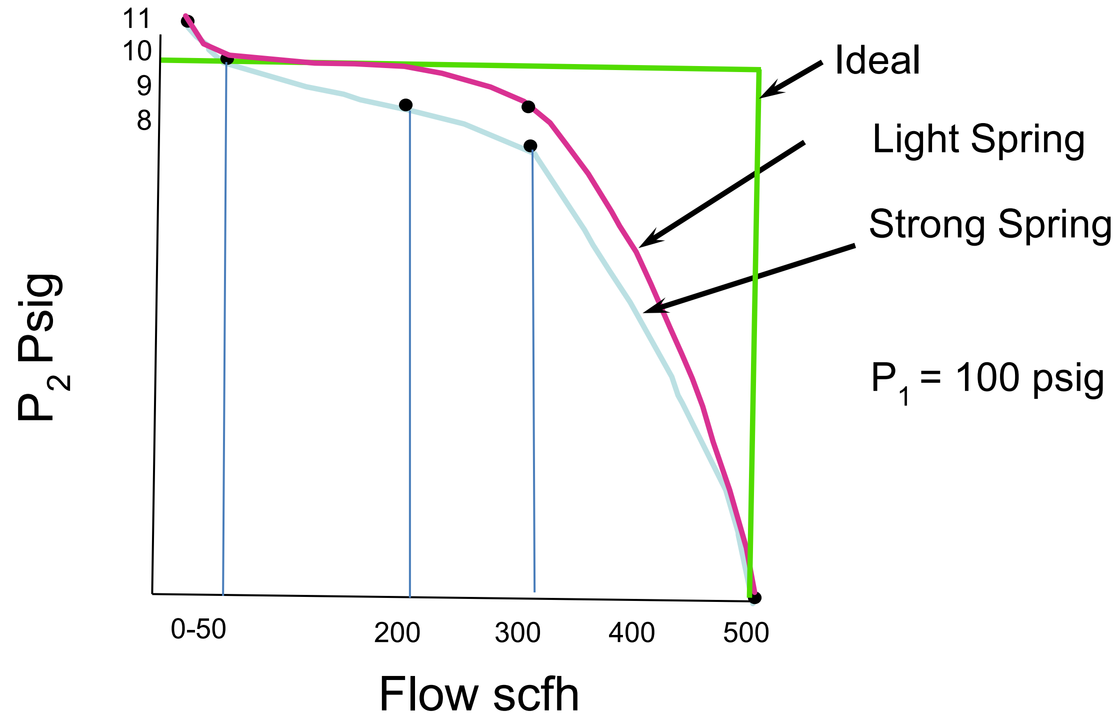
Outlet pressure

Dynamics of Flow

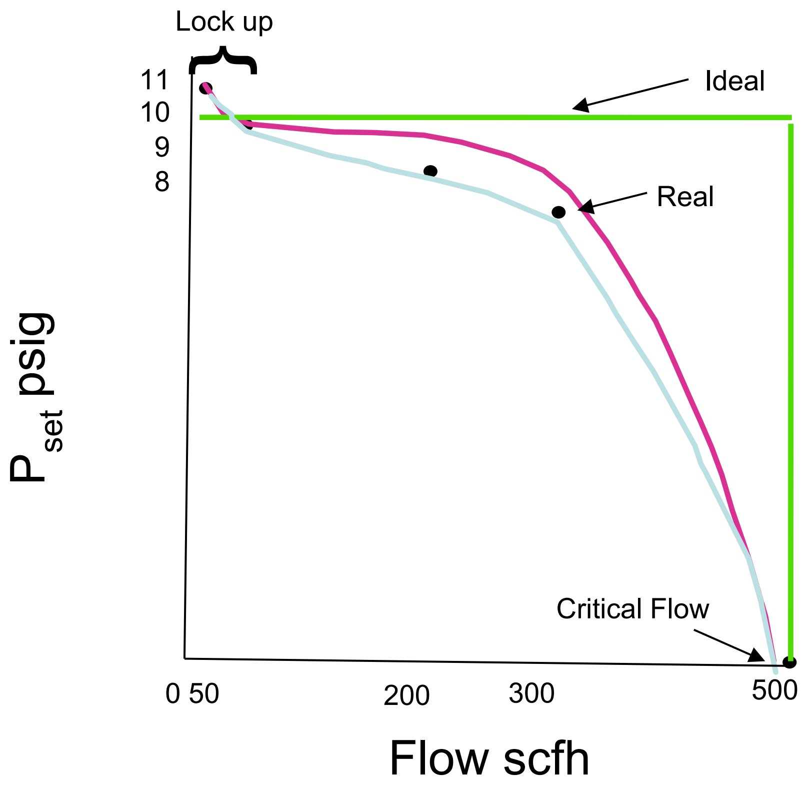




P_1 = 100 Psig
P_2 = 10 Psig
Sense Pressure Here
Velocity Profile
Vena Contracta
FLOW
Pressure Profile



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



Lock-Up Pressure:

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

Critical Flow:

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

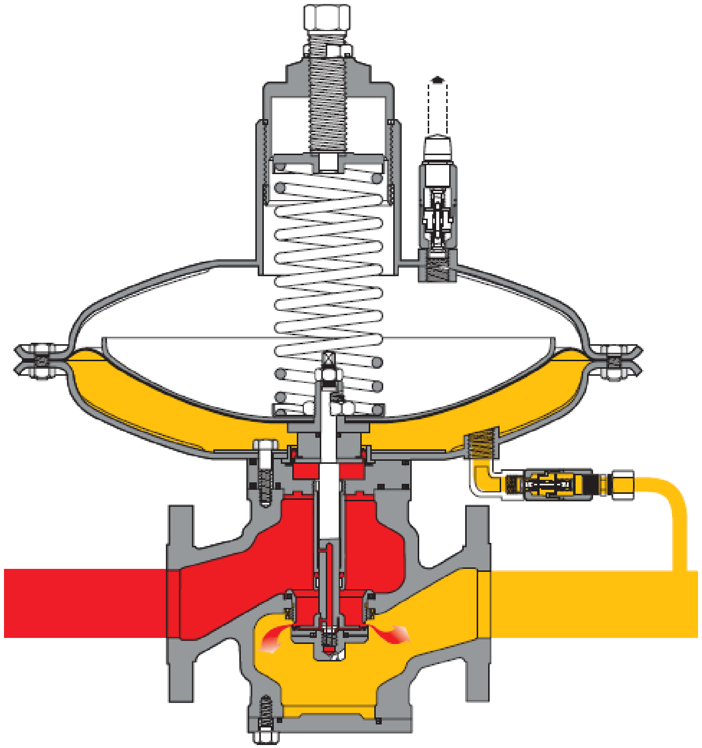
Rule: Use the smallest orifice and lightest spring for the required flow rate capacity

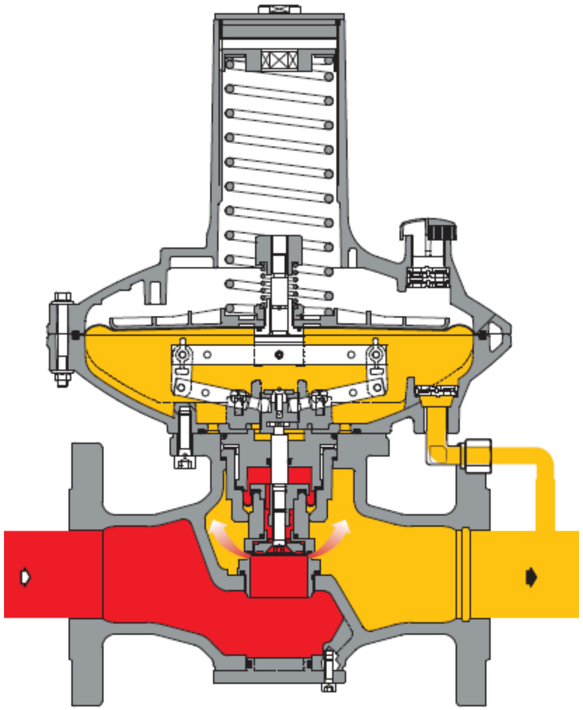
PRESSURE REGULATOR TYPES:

- SELF OPERATED
- PILOTED OPERATED (We will discuss later)
  - CONSTANT LOADED
  - TWO PATH
  - PILOT UNLOADING

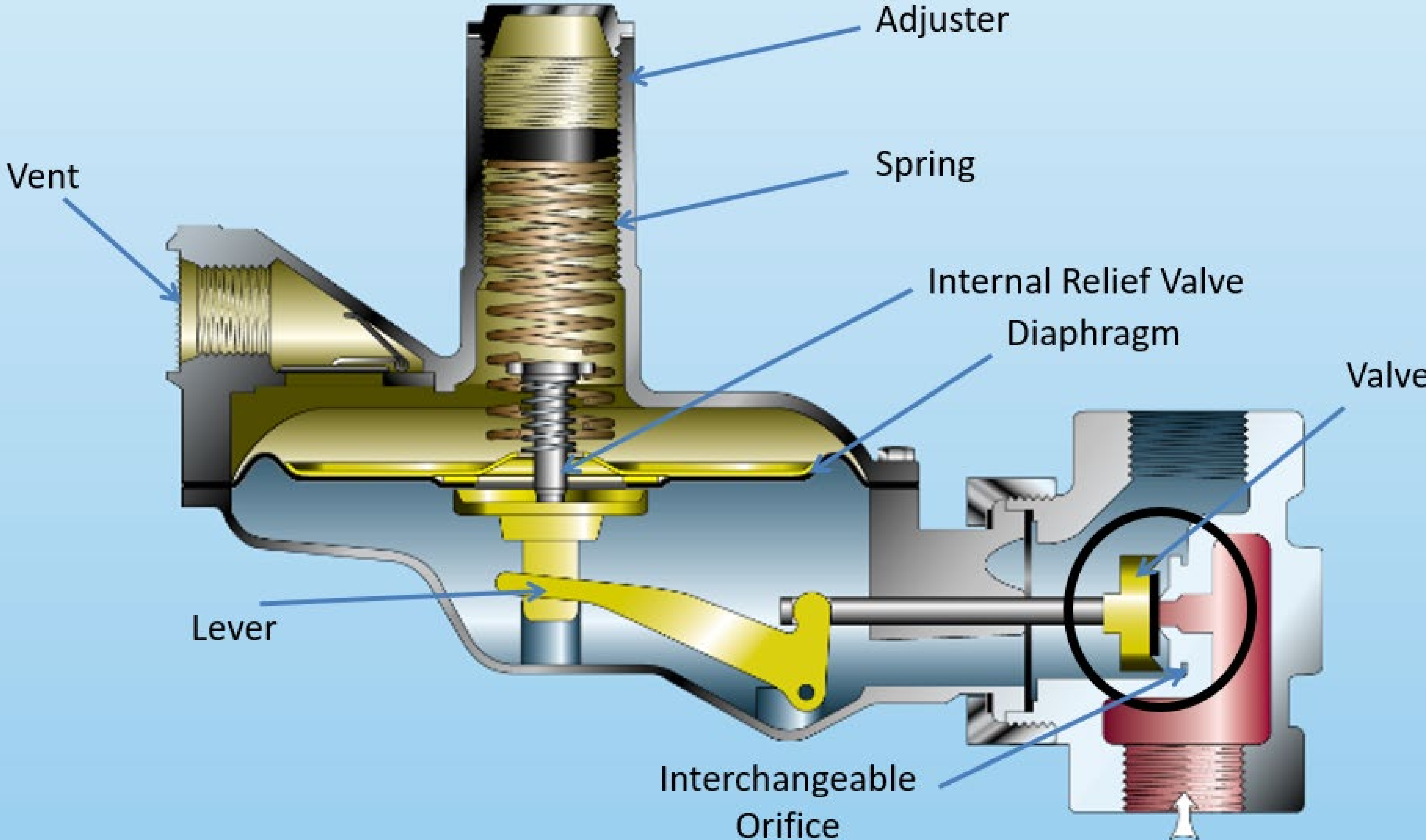
SELF OPERATED PRESSURE REGULATOR

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



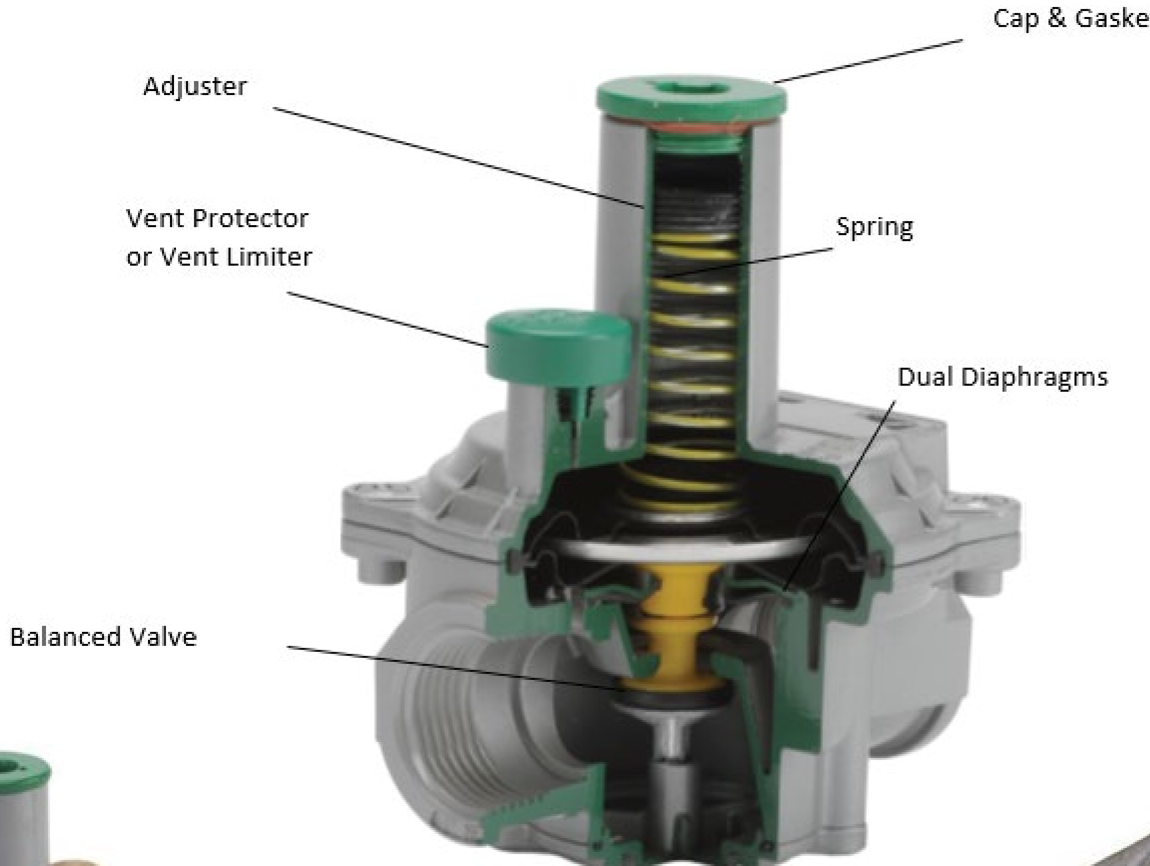


Lever Operated Regulator



Lever Acting – Close Position

Direct Acting Regulator



➢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

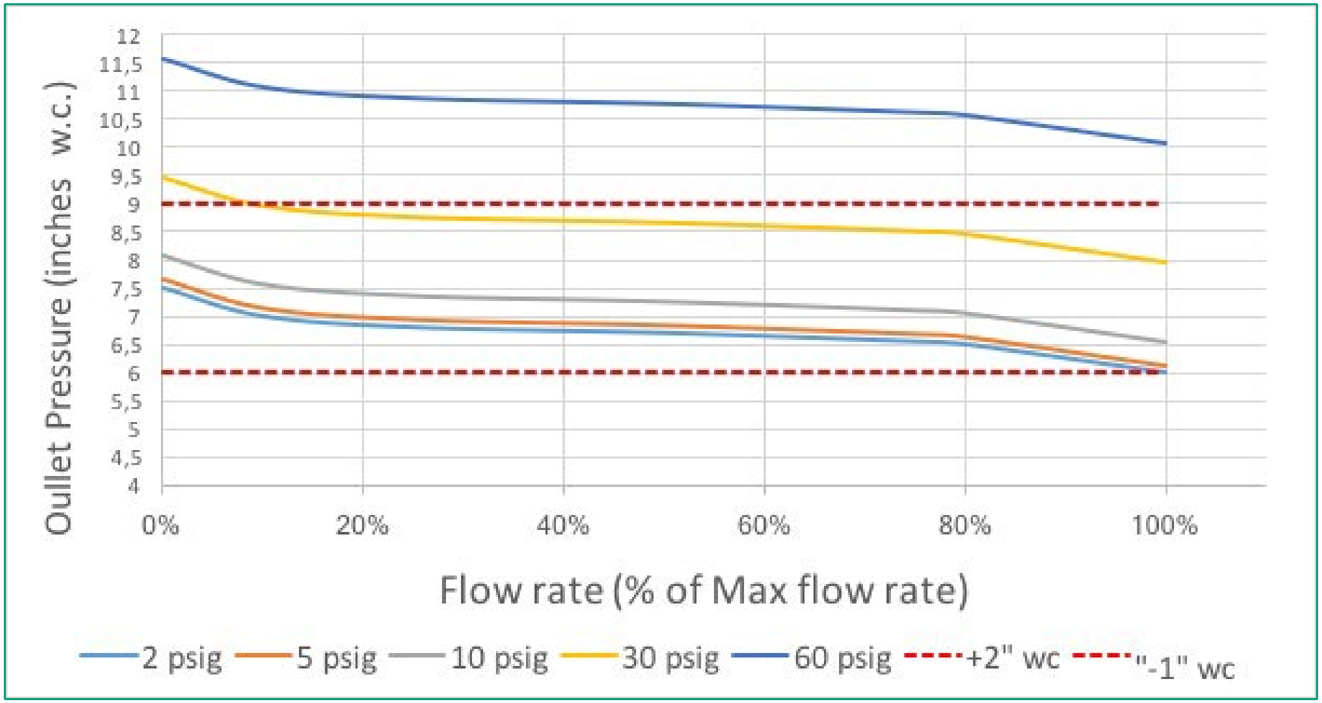
Droop Definition:

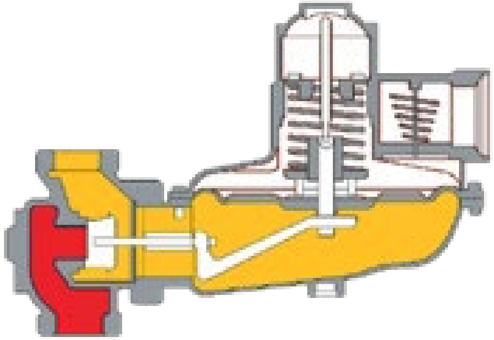
Droop is the reduction of outlet pressure experienced by pressure-reducing regulators as the flow rate increases. It is stated as a percent, in inches of water column or in pounds per square inch and indicates the difference between the outlet pressure set point made at low flow rates and the actual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

1% Absolute Droop vs AC Class:

Set Point	Measurement Unit	1% Abs Accuracy	Reletive Accuracy (%)
6	Inches WC	4.07	67.9
8	Inches WC	4.09	51.2
10	Inches WC	4.11	41.1
20	Inches WC	4.21	21.1
1	PSI	0.16	15.5
2	PSI	0.17	8.3
4	PSI	0.19	4.6
8	PSI	0.23	2.8
10	PSI	0.25	2.5

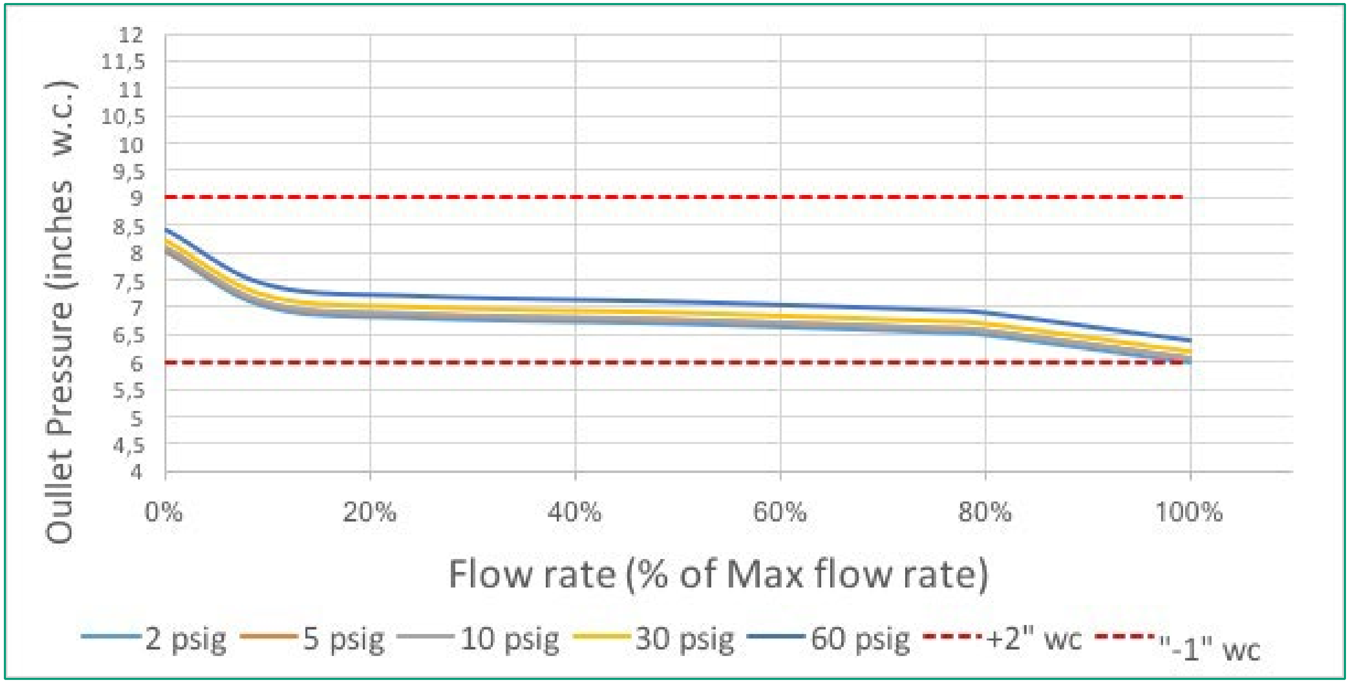
Unbalanced Valve

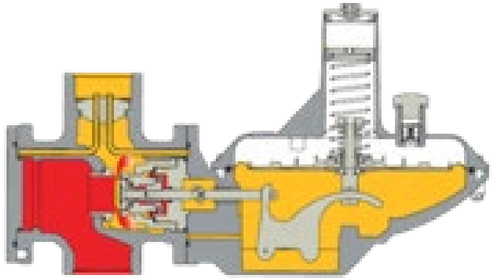




- By increasing the inlet pressure there is a shift of the set point.
- The higher the variation between the minimum and maximum inlet pressure, the greater the deviation from the set point.

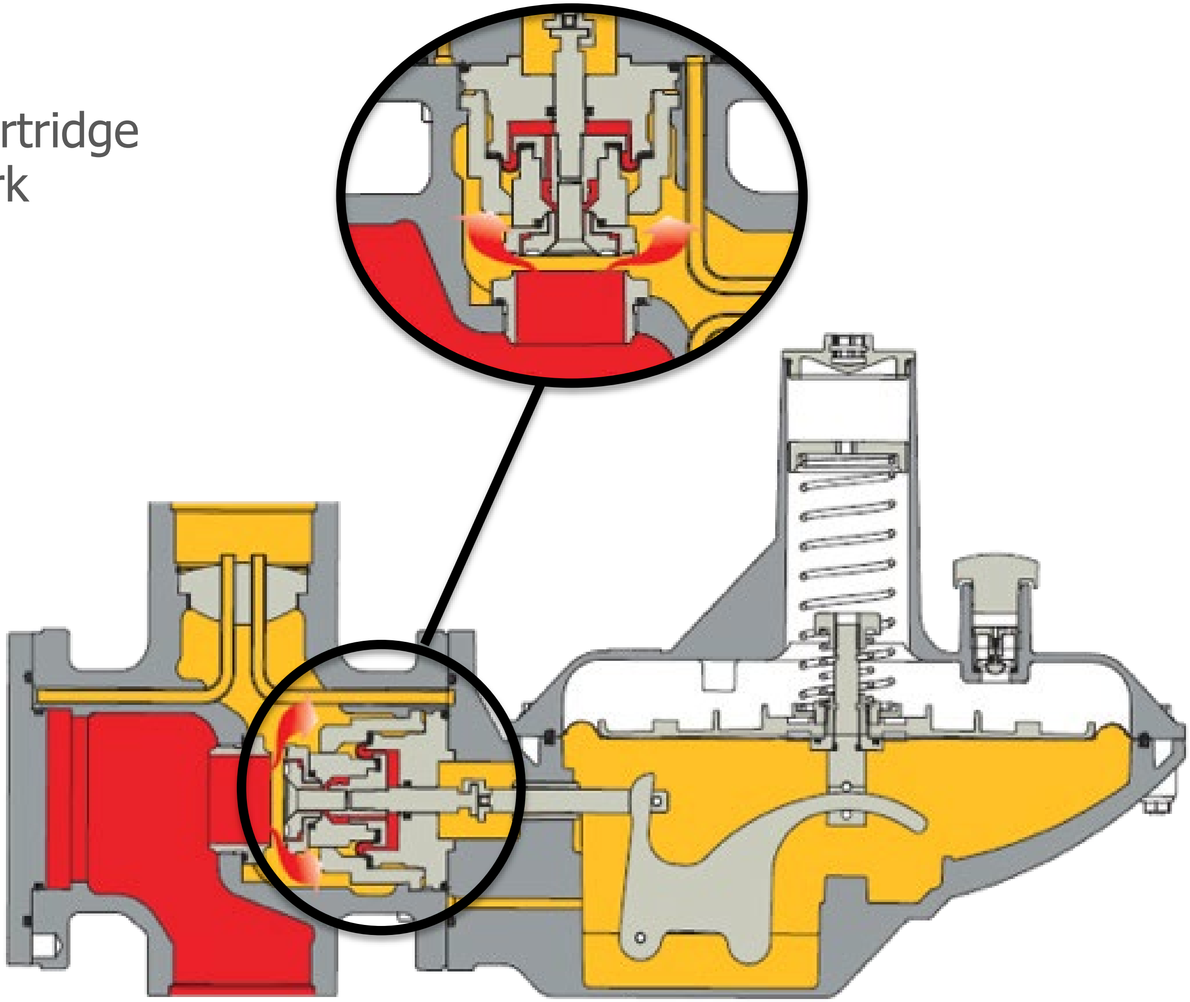
Balanced Valve





- 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

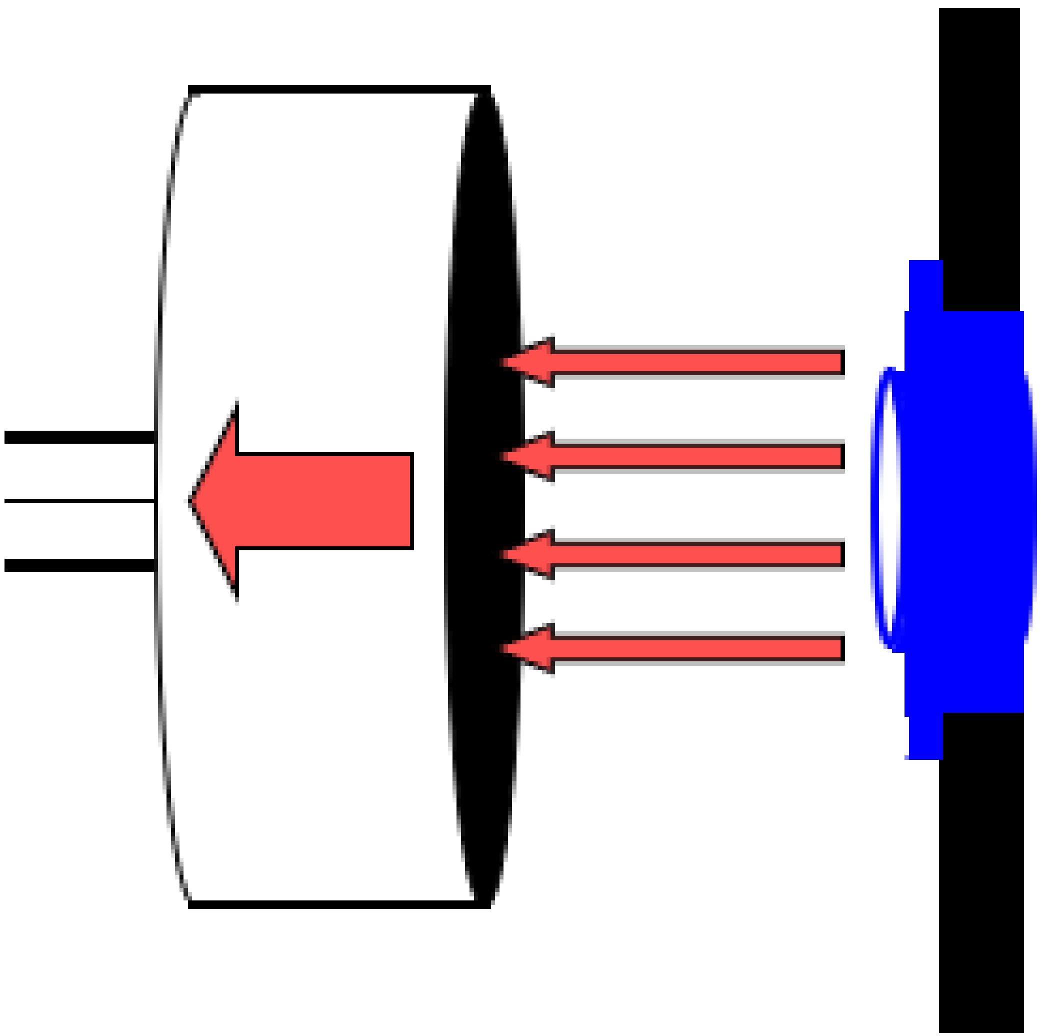
- The balanced valve cartridge makes the system work
- But how does it work?



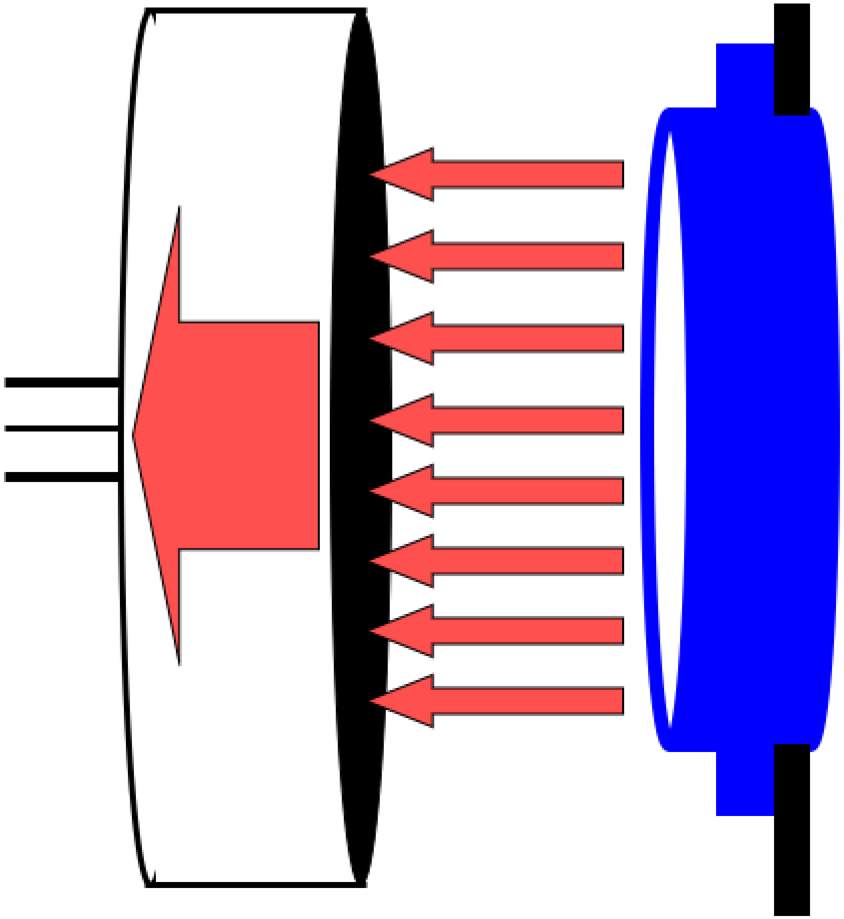
The formula to design a pressure regulator is

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.



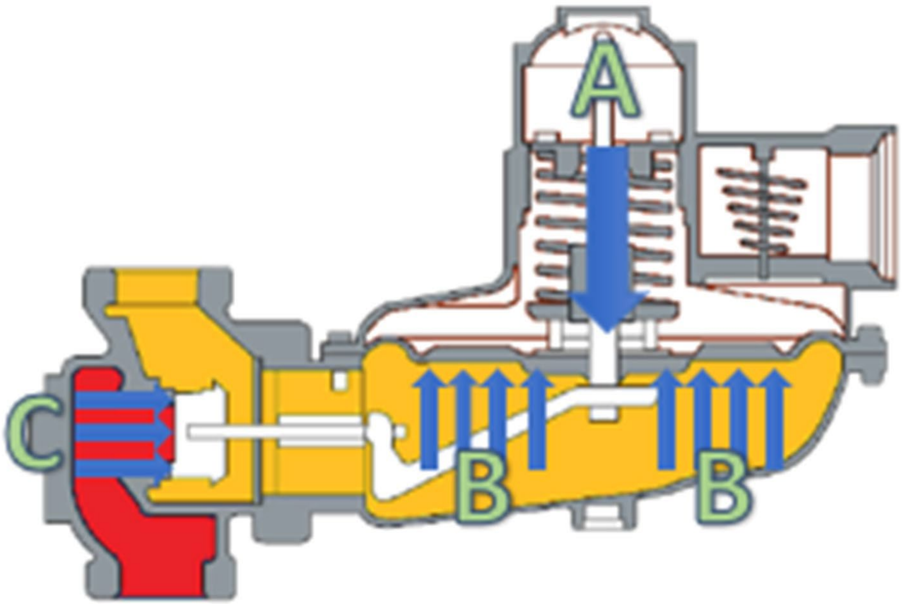
- F= P x Area
- Smaller orifices can be subjected to higher inlet pressures



- 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 dependent on the size of the orifice selected



Unbalanced Regulator

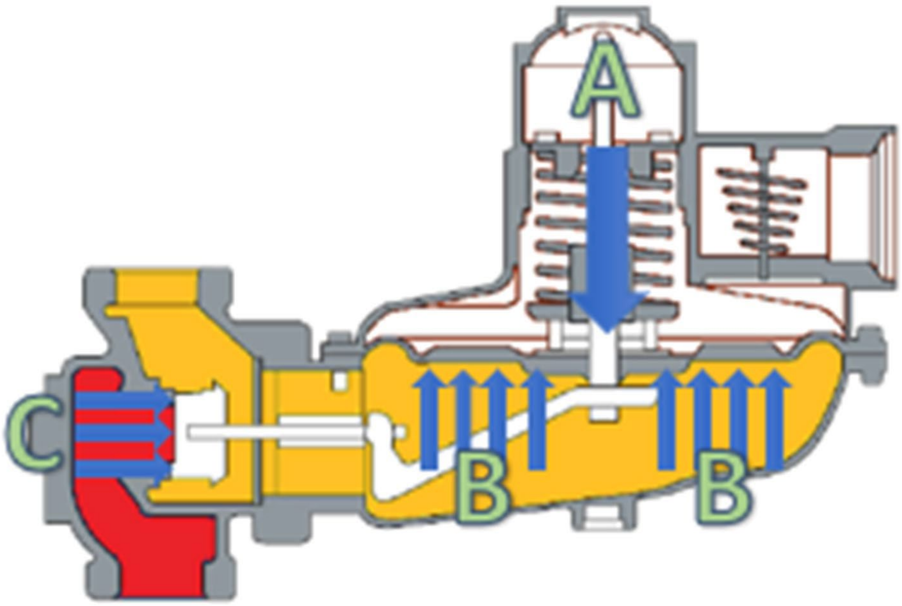
In steady conditions:

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.



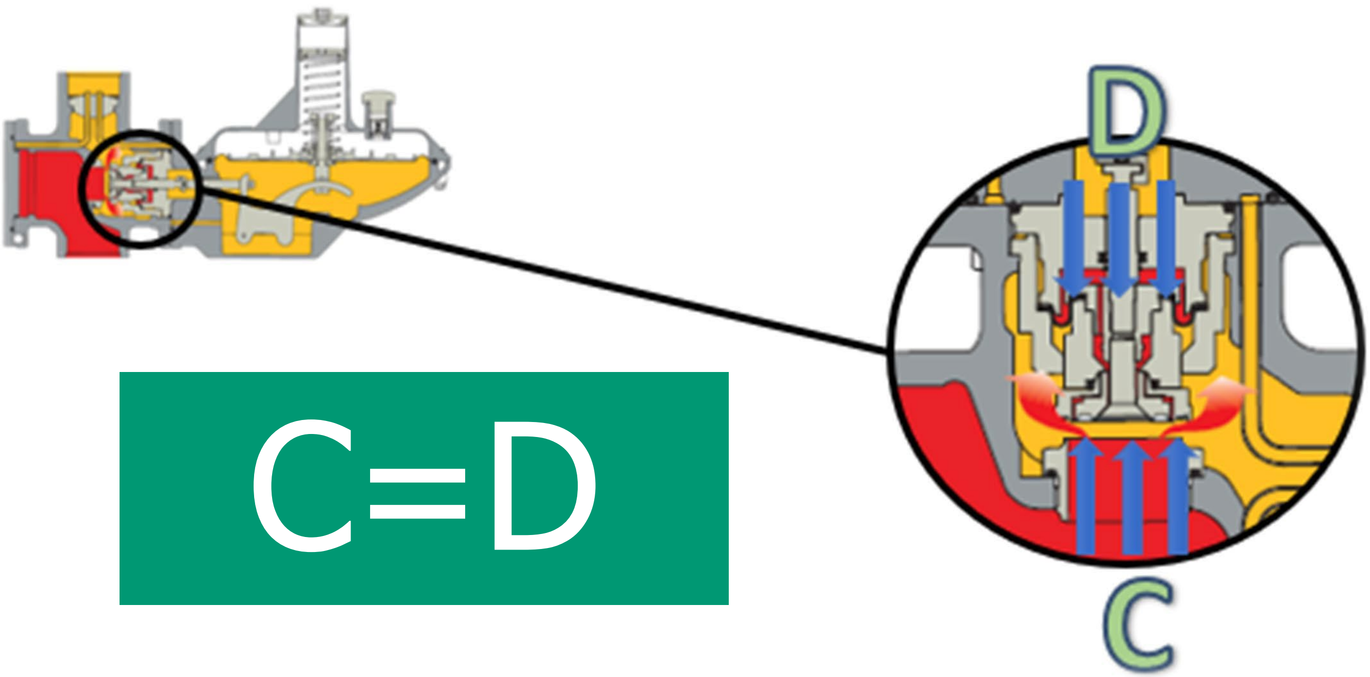
Unbalanced Regulator

In steady conditions:

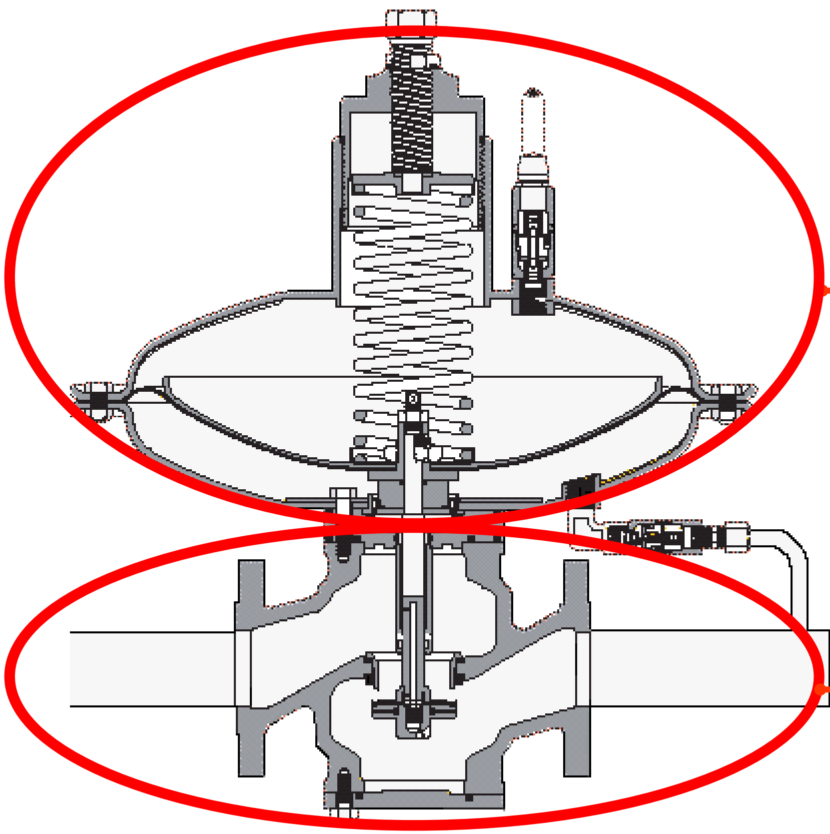
A + C = B

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

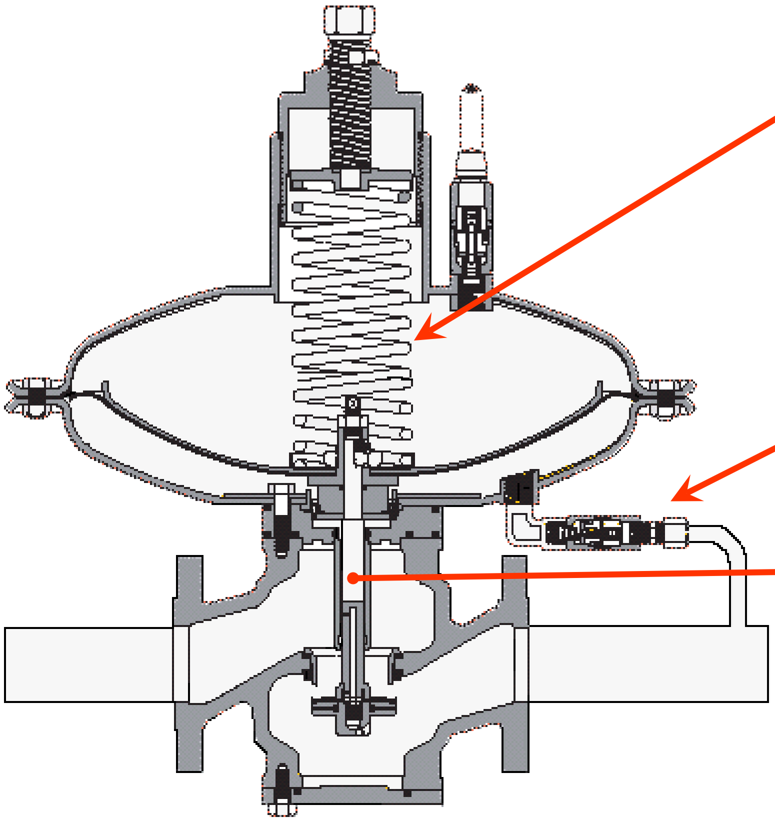


- The balanced valve is designed so the balancing piston creates the same and opposite force created by the inlet pressure.
- Since the surfaces are equal, the two forces neutralize each other under all inlet pressure conditions.



The regulator can be divided in two groups :

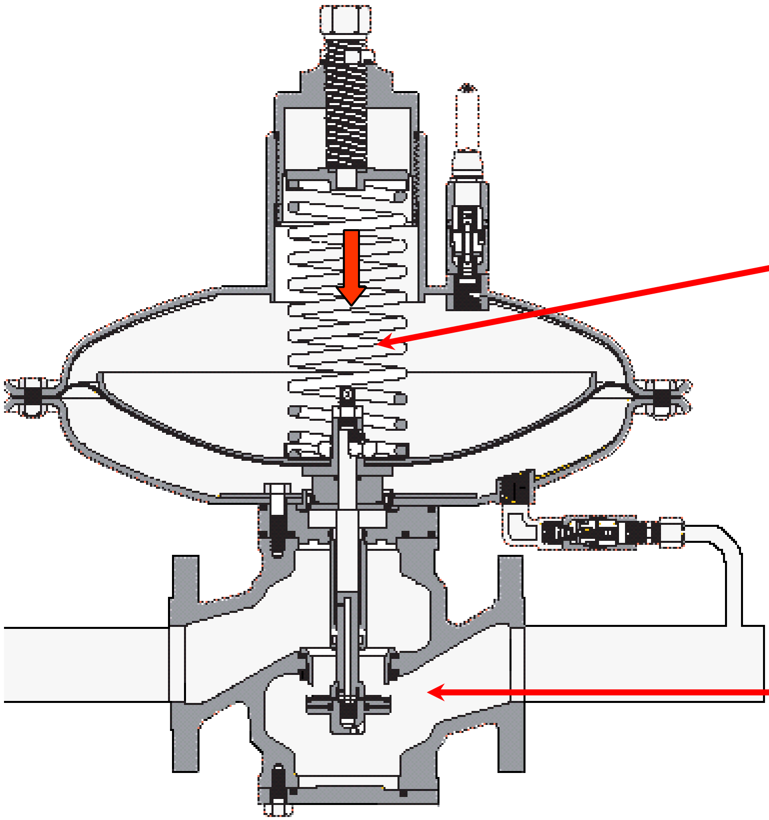
- ACTUATOR
- FLOW REGULATION SYSTEM



It's a **spring** actuated regulator.

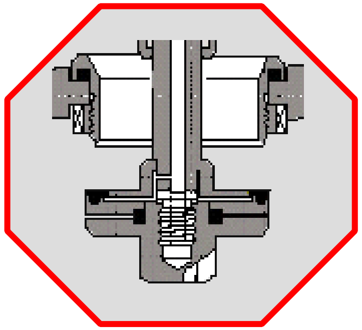
The control of the downstream pressure is maintained by means of **external sensing line.**

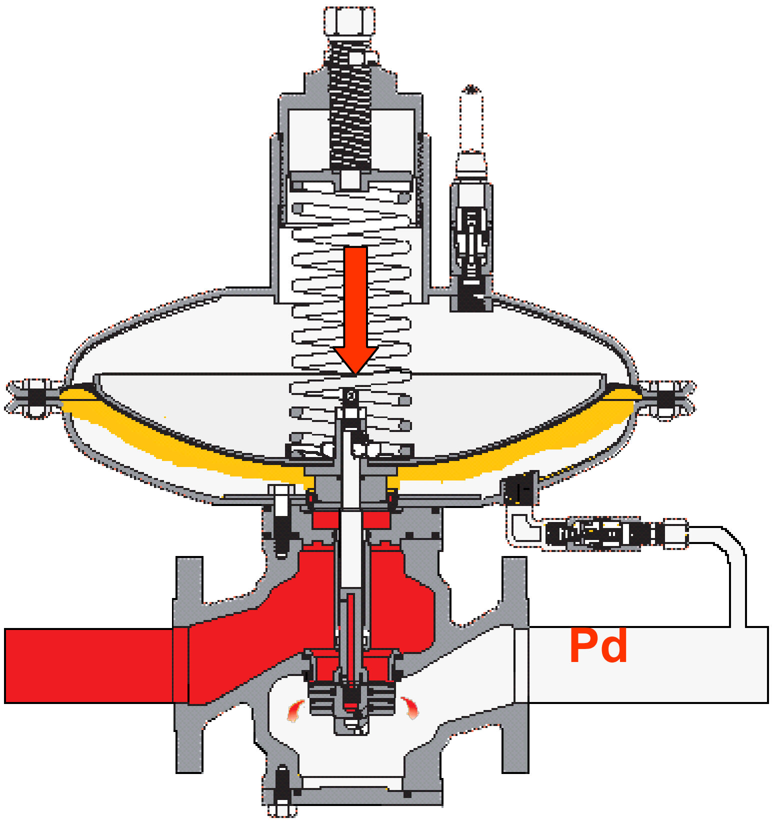
The movement is trasmitted by **the shaft** to the obturator which moves perpendiculary to the gas flow direction.



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

(Therefore the seat is open)





Downstream pressure **Pd/P2** is controlled by means of the equilibrium between the action of the **spring** and the action exerted by the **downstream pressure** on the diaphragm

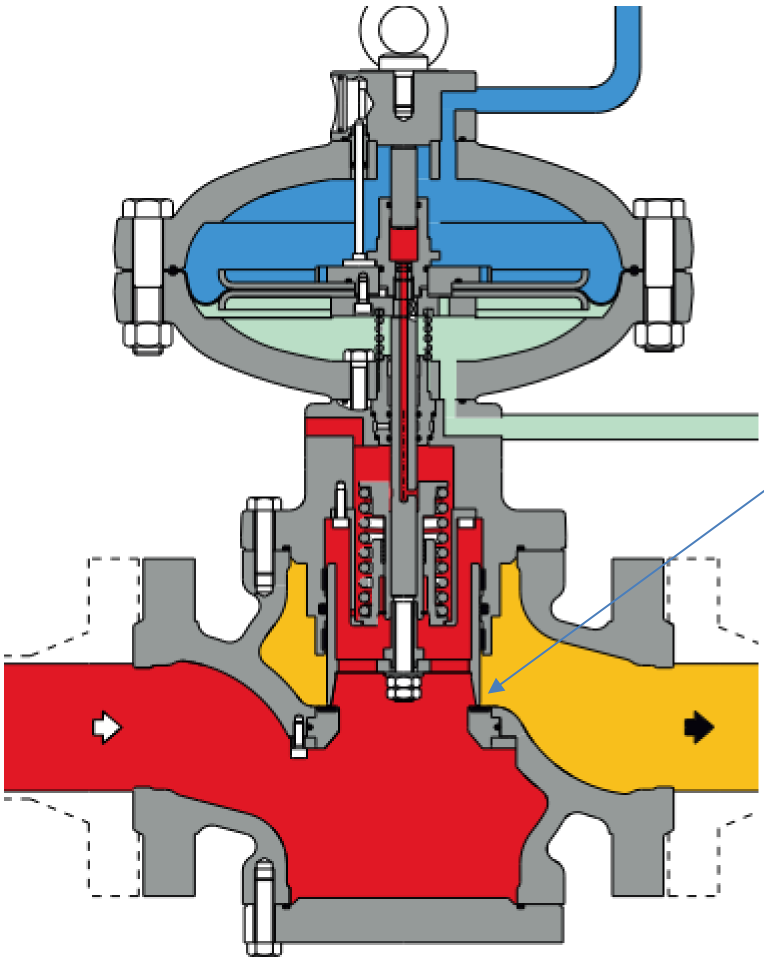
When **Pd Force > Spring Force**

The obturator moves towards the CLOSED position

If Spring Force > Pd Force

The obturator moves towards the OPEN position

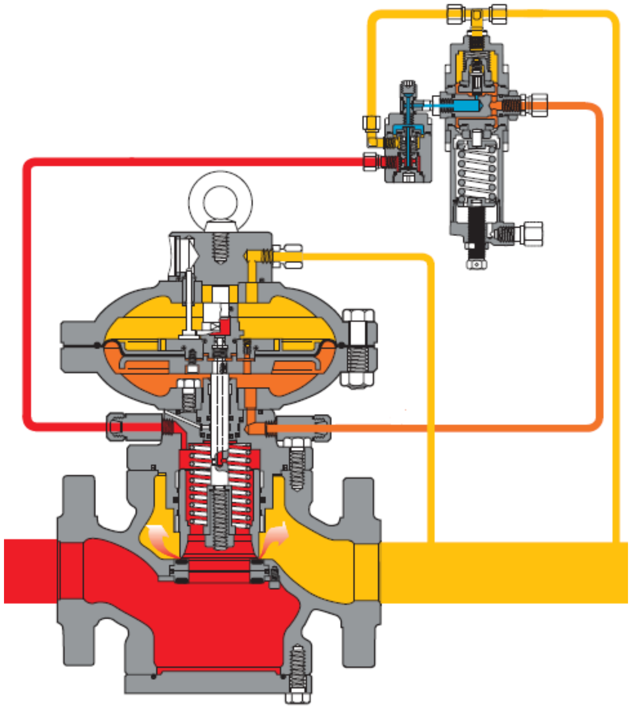
Equilibrium = constant downstream pressure



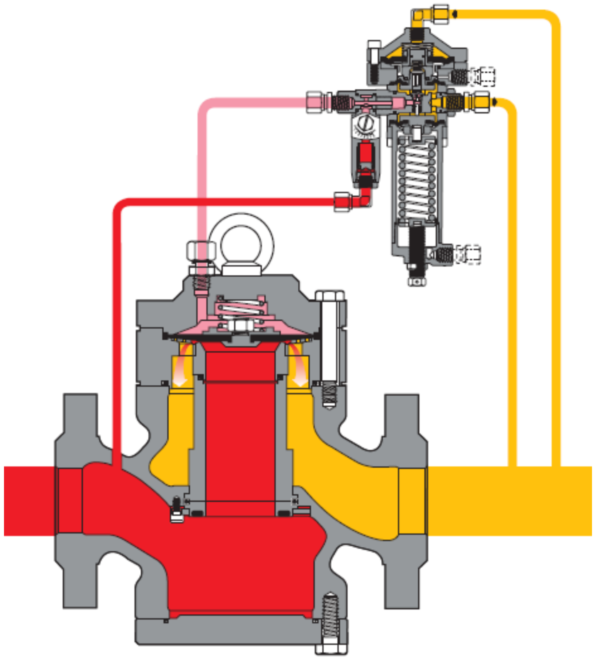
With No flow rate requested hermetic tightness is ensured by a **soft rubber gasket** fixed to the obturator .

➢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)

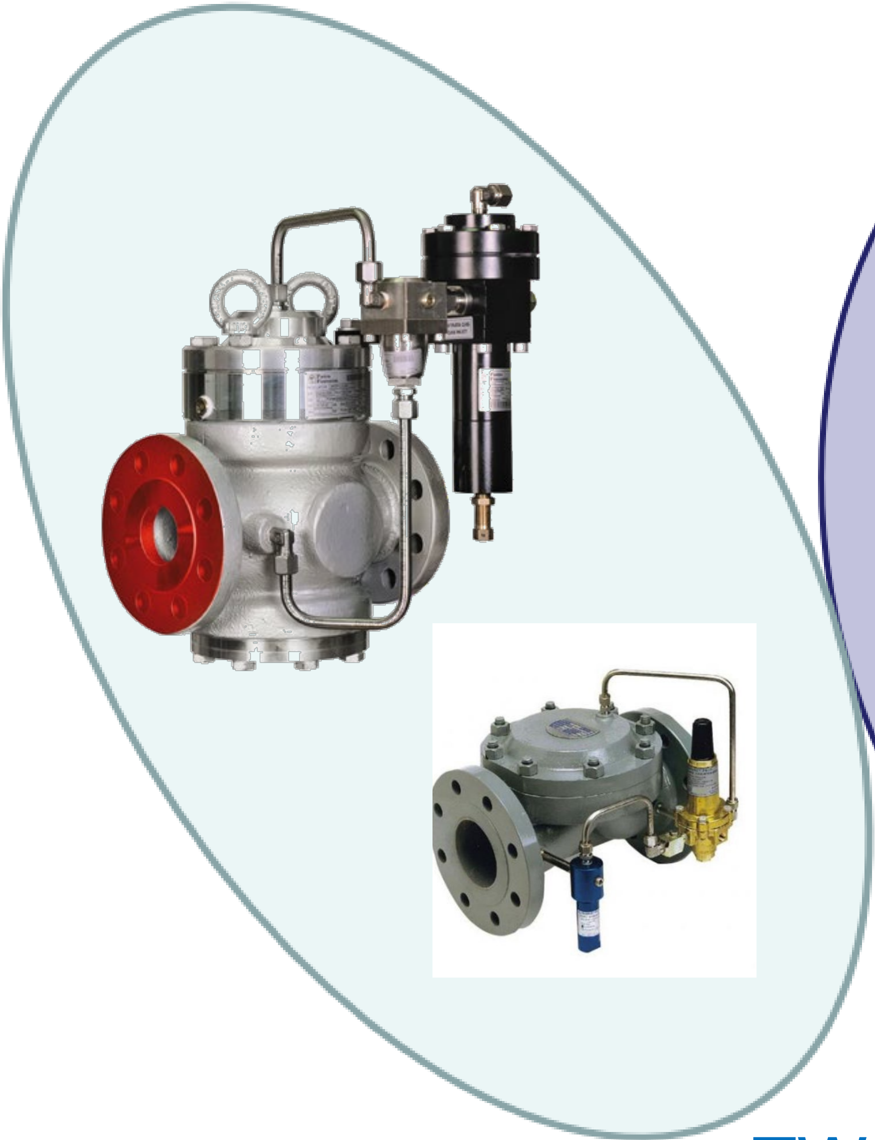
Advantages:

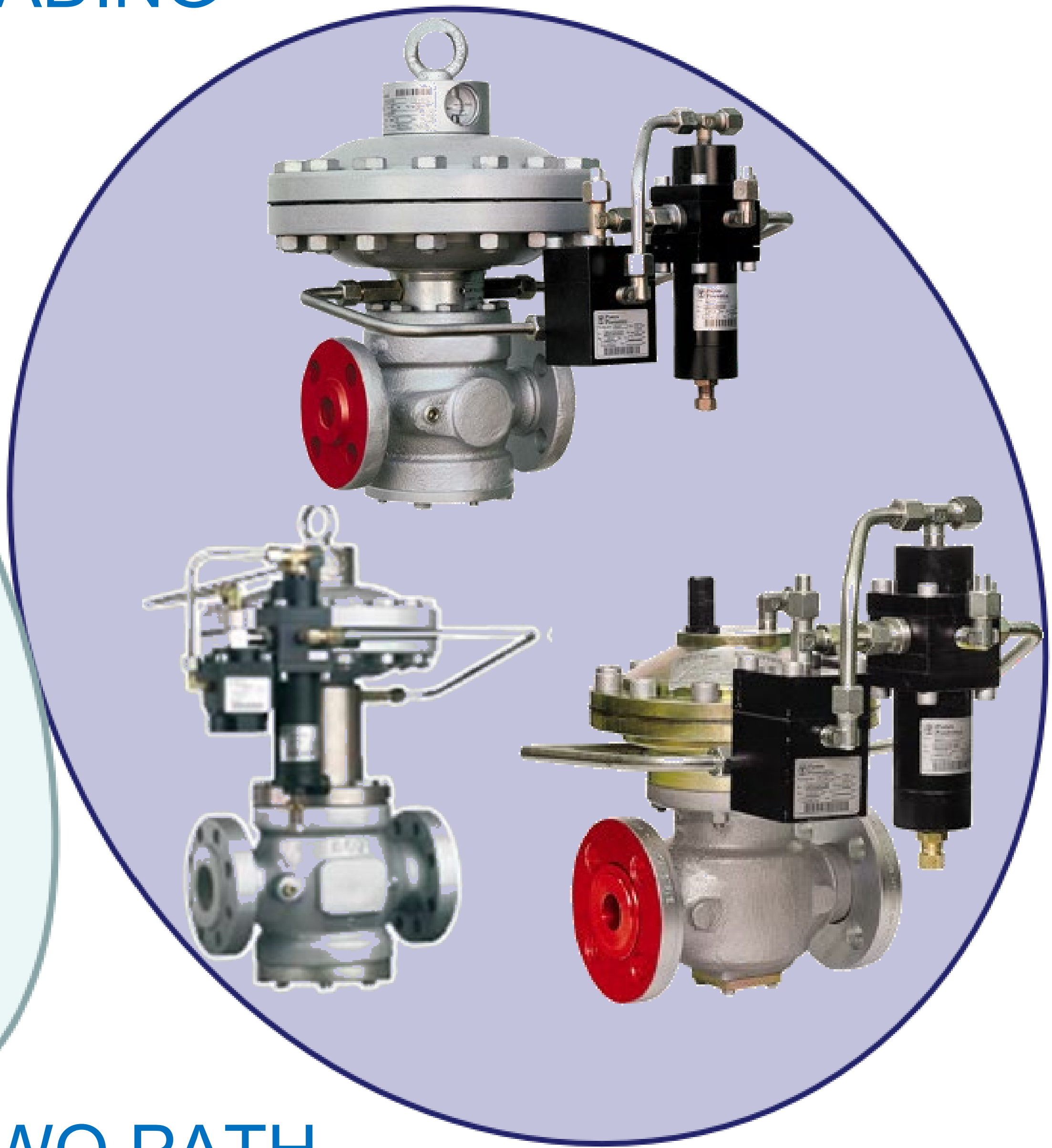
- Wide set range
- Best accuracy class
- High flow rate
- Remote set control

FAIL OPEN

FAIL CLOSE

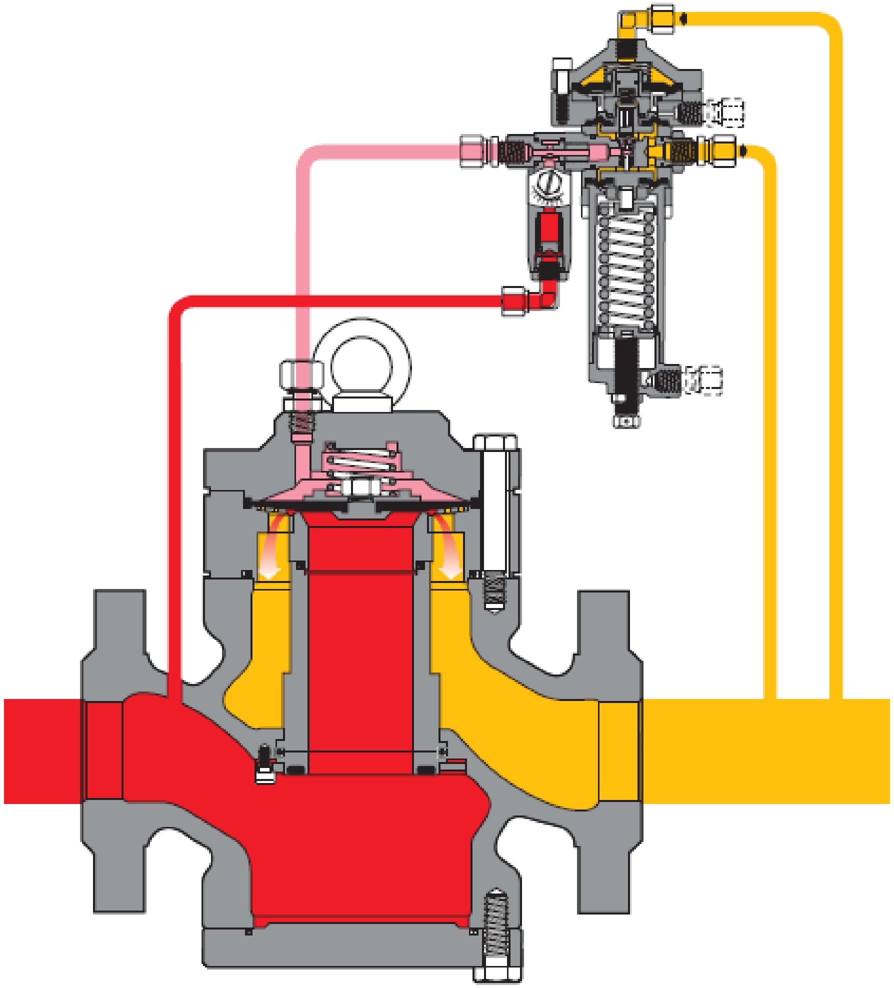
PRESSURE UNLOADING



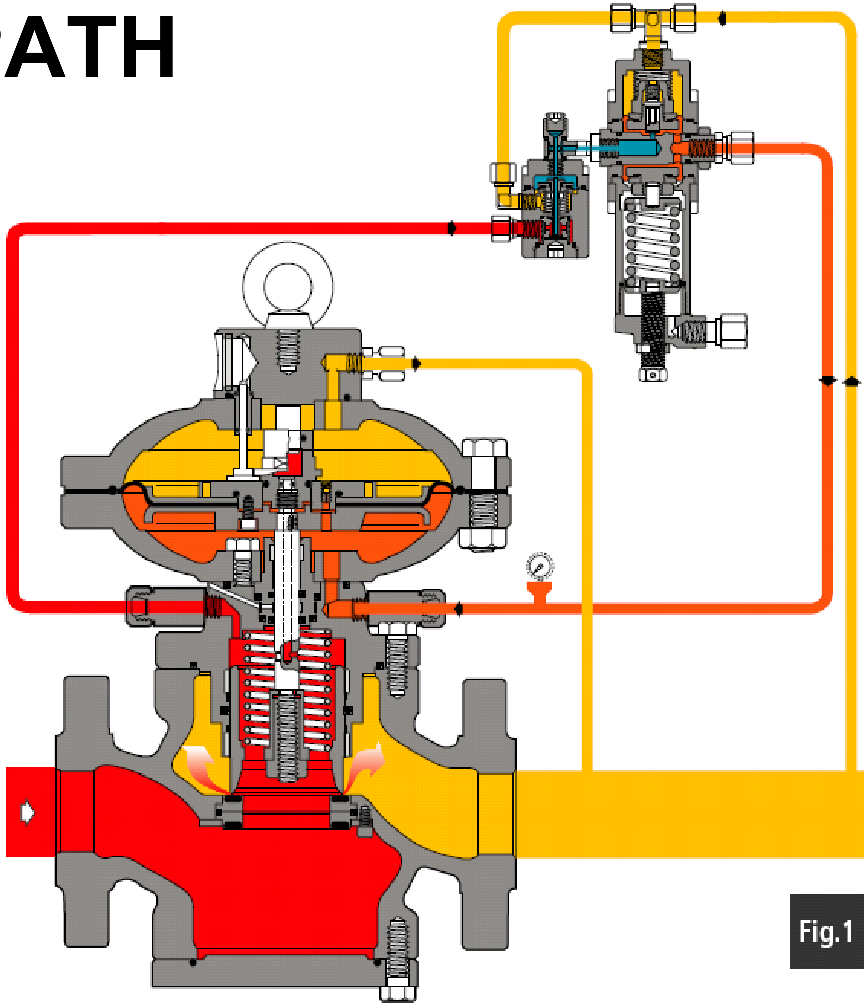


TWO PATH

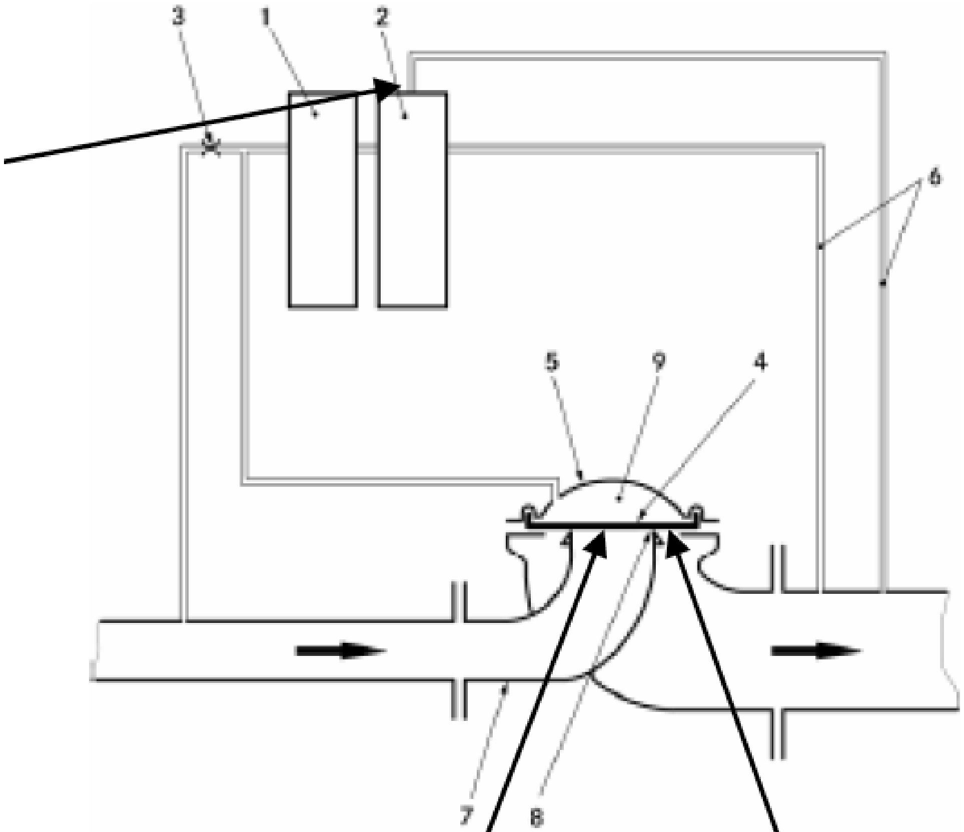
PRESSURE UNLOADING



TWO PATH

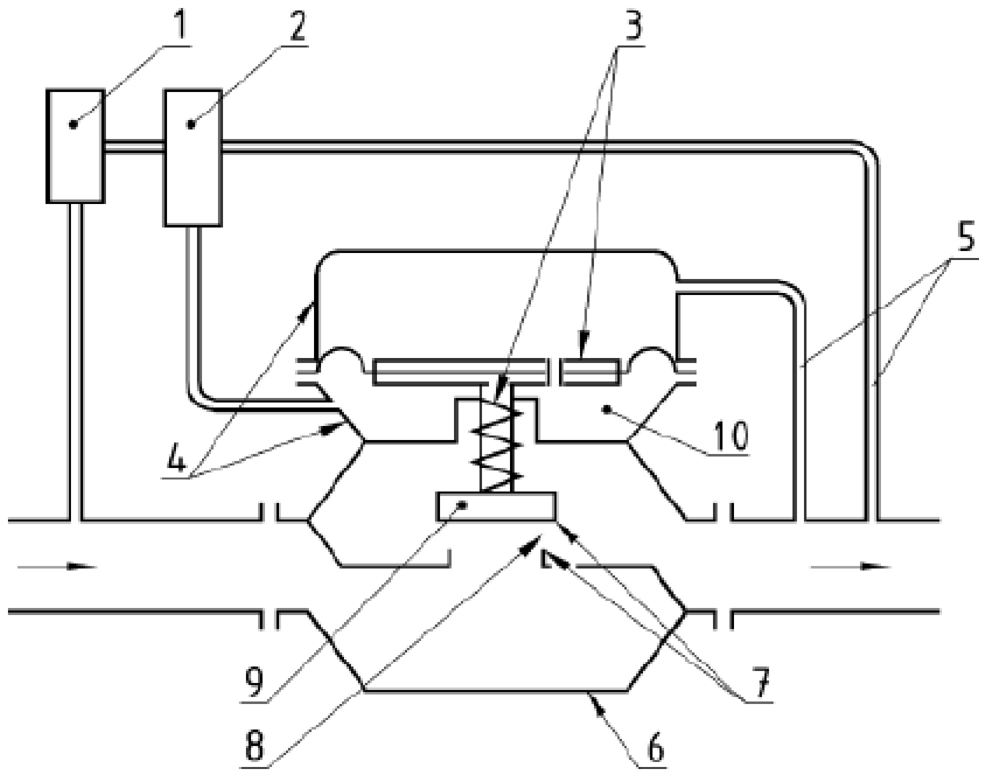


Reflux 819



Key

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



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	C&I Regulator	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 using Universal Gas Sizing Equation: Know Cg?

Universal Gas Sizing Equation

$$Q = \sqrt{\frac{520}{G \cdot T}}\; Cg \cdot P_1 \cdot \text{SIN}\left[\frac{3417}{C_1}\sqrt{\frac{\Delta P}{P_1}}\right]\text{deg.}$$

$$Cg = \frac{Q}{\cdot P_1 \sqrt{\frac{520}{G \cdot T}} \cdot \text{SIN}\left[\frac{3417}{C_1}\sqrt{\frac{P_1 - P_2}{P_1}}\right]\text{deg.}}$$

Simplifies 1.29

Natural Gas at 60° F & 0.6 Sg

Simplifies 1.00

Critical Flow

Q	Flow Rate (SCFH)
Cg	Gas Sizing Coefficient
P_1	Inlet Pressure (psia)
ΔP	Pressure Drop Across Valve ($\Delta P = P_1 - P_2$) (psid)
P_2	Outlet Pressure (psia)
C1	Valve Recovery Coefficient ($C_1 = Cg/C_v$)
Cv	Liquid Sizing Coefficient
G	Specific Gravity (0.6 for Natural Gas) (1.0 for Air)
T	Gas Temperature (°Rankine) (T - 460 + °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)

Sizing using K Factors

Full Open Capacity

1. $Q = K\sqrt{P_o(P_i - P_o)}$ .... (for $\frac{P_i}{P_o}$ less than 1.894)

2. $Q = \frac{KP_i}{2}$ .... (for $\frac{P_i}{P_o}$ greater than 1.894)

Orifice size:	.207"	¼"	⅜"	½"	¾"	1"	1¼"
K	90	132	292	520	1100	1800	2480

Gas Velocity in Downstream Pipe

Rule of thumb <80 fps and no more than 100

$$V = \frac{748\,Q}{d^2 P_2}$$

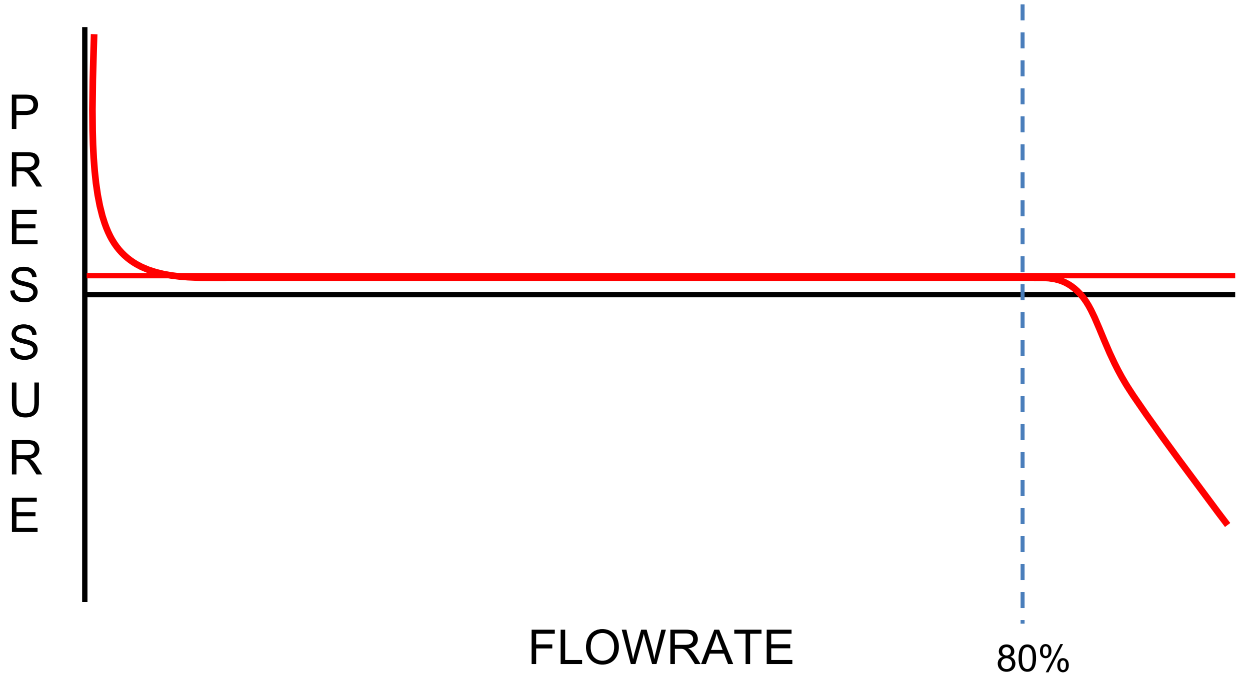
V	Velocity in ft/sec
d	Internal pipe diameter in inches
Q	Flow in MSCFH
P_2	Outlet Pressure (psia)

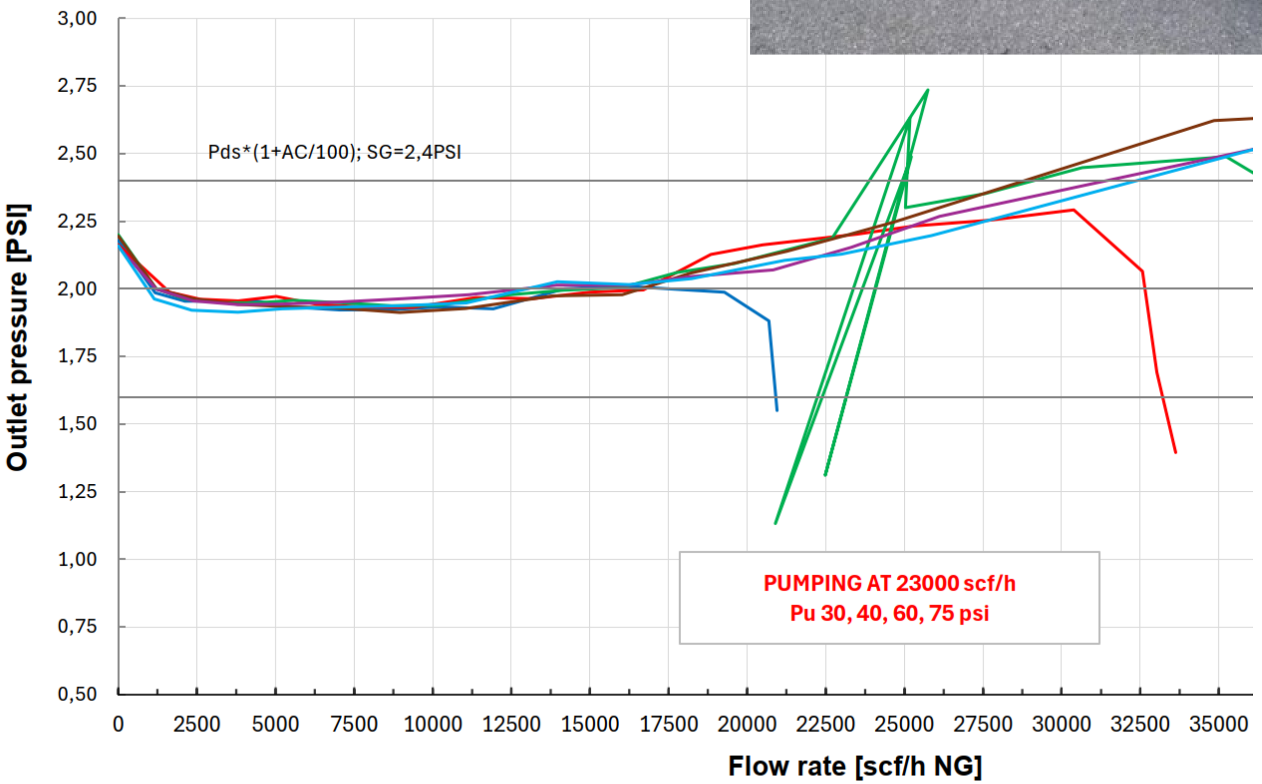
Selecting Regulators

Pipeline Safety

Regardless of Manufacture, size the regulator so that the application is not more than 80% of the regulators capacity

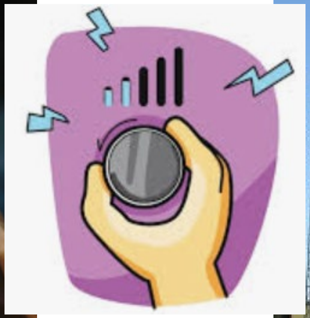
Ideal Regulator Performance Curve




Outlet pressure [PSI]
Flow rate [scf/h NG]
3,00
2,75
2,50
2,25
2,00
1,75
1,50
1,25
1,00
0,75
0,50
0
2500
5000
7500
10000
12500
15000
17500
20000
22500
25000
27500
30000
32500
35000
Pds*(1+AC/100); SG=2,4PSI
PUMPING AT 23000 scf/h
Pu 30, 40, 60, 75 psi

Ratio between the High end of the performance range of a regulator vs. the Low end

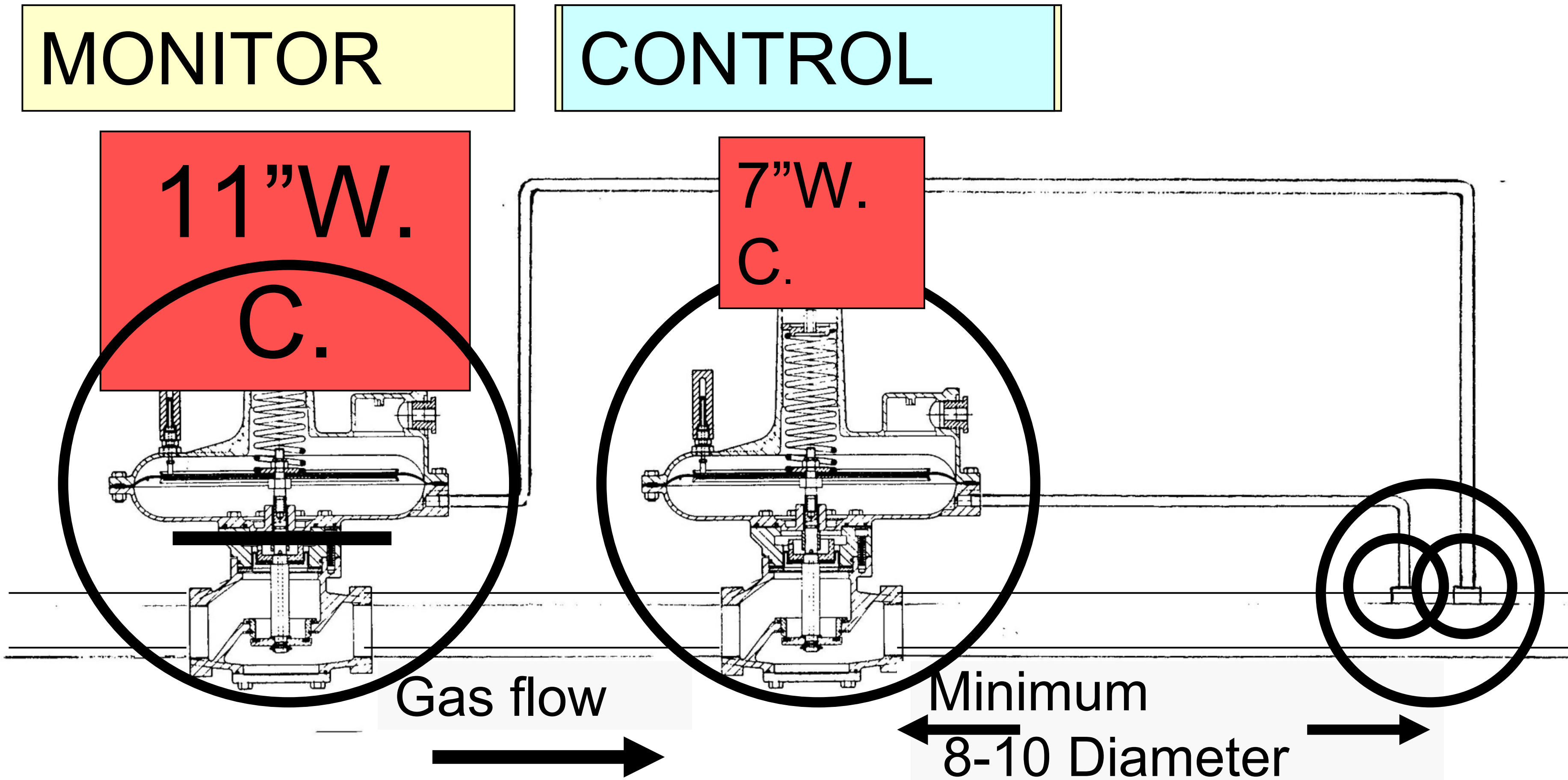
What is the Turndown of the Application?


Monitor-Control

A method of providing overpressure protection by installing two regulators in series, both sensing pressure after the outlet of the downstream regulator. In the event of a regulator failure of the operator regulator, the monitor regulator begins to operate at a slightly higher pressure.

MONITOR REGULATION



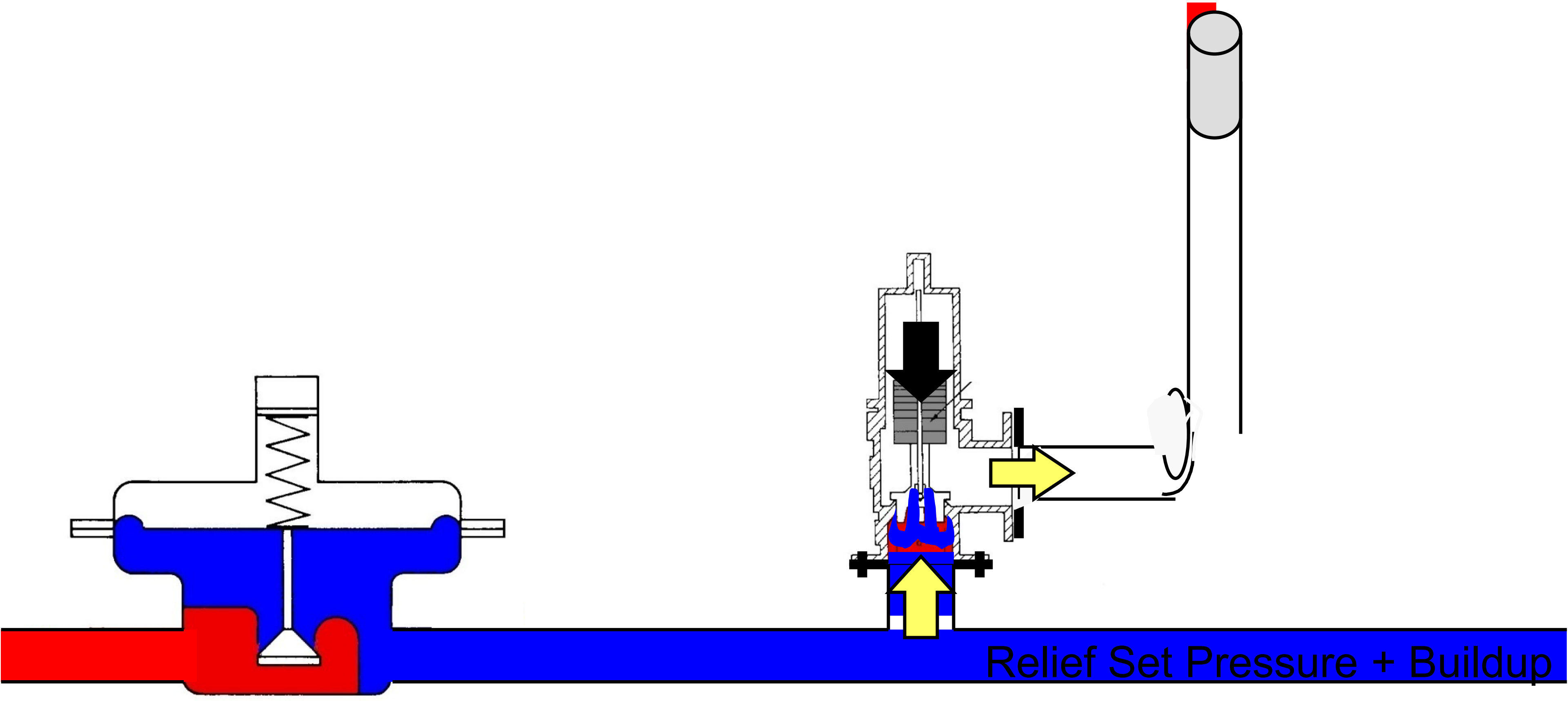
External Relief Valves

An external relief valve is a stand-alone valve installed in a piping system to limit the amount of pressure build-up in the event of an unplanned pressure increase. The valve is typically installed downstream of a regulator. If the regulator fails to control the flow of gas, the external relief valve will vent the gas to a location outside the gas system. The relief valve is set to open and relieve the excess pressure at a set amount above the regulator's delivery pressure, depending upon the maximum amount of pressure the downstream system can experience.






OUTLET



Regulator

Relief Valve

P_{set}

Maximum Pressure of Application


PMC

SLAMSHUTS

- Slam-Shut Valve
- Top Entry, Globe Body
- Sizes: 1”, 1¼”, 1½”, 2”, 2 ½”, 3”, 4”, 6”, 8”

Body Materials: Ductile Iron
Cast Steel
Connections: NPT, FF, RF, RTJ
Ratings: ANSI 125, 150, 300, 600
Shutoff Pressure Range: 32” w.c. to 72 psig
Accuracy Range:
ICN: +/-1% Over - under
+/- 5%
ICN: +/-5% Over - under
+/-15%
Flow Coefficient (Nat.Gas): Kg Range 510 to 23080
Over, Under, Over & Under and Remote Shutoff
Manually Reset

Slam Shut Valves

Questions