

DANIEL®  
**LIQUID CONTROL VALVES**  
TECHNICAL GUIDE

**Flow Meter Systems**



**DANIEL®**  
Decades Proven. Field Chosen.™

# THEORY, PRINCIPLE OF OPERATION AND APPLICATIONS

This brochure has been prepared to provide a thorough understanding of the principle of operation and typical applications of the Daniel Control Valves.

The Daniel Valves operate on a basic hydraulic principle and are of the balanced-piston design, spring biased (loaded). The valves are self contained, pilot operated for most applications (some exceptions) and use the line product as their power source. The exceptions are valves with an external power operator that do not require line product to operate. (Ref. Models 531, 532, and 762 Series).

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## Section 1

# AN INTRODUCTION TO BASIC HYDRAULICS

The study of hydraulics deals with the use and characteristics of liquids. Since the beginning of time, man has used fluids to ease his burden. It is not hard to imagine a caveman floating down a river, astride a log with his wife, and towing his children and other belongings aboard a second log with a rope made of twisted vines.

Earliest recorded history shows that devices such as pumps and water wheels were known in very ancient times. It was not, however, until the 17th century that the branch of hydraulics with which we are to be concerned first came into use. Based upon a principle discovered by the French scientist Pascal, it relates to the use of confined fluids in transmitting power, multiplying force and modifying motions.

### **Pascal's Law simply stated, says this:**

Pressure applied on a confined fluid is transmitted undiminished in all directions, and acts with equal force on equal areas, and at right angles to them.

This precept explains why a full glass bottle will break if a stopper is forced into the already full chamber. The liquid is practically non-compressible and transmits the force applied at the stopper throughout the container (Figure 1-1). The result is an exceedingly higher force on a larger area than the stopper. Thus, it is possible to break out the bottom by pushing on the stopper with a moderate force.

Perhaps it was the very simplicity of Pascal's Law that prevented men from realizing its tremendous potential for some two centuries. Then, in the early stages of the industrial revolution, a British mechanic named Joseph Bramah utilized Pascal's discovery in developing a hydraulic press.

## PRESSURE (FORCE PER UNIT AREA) IS TRANSMITTED THROUGHOUT A CONFINED FLUID

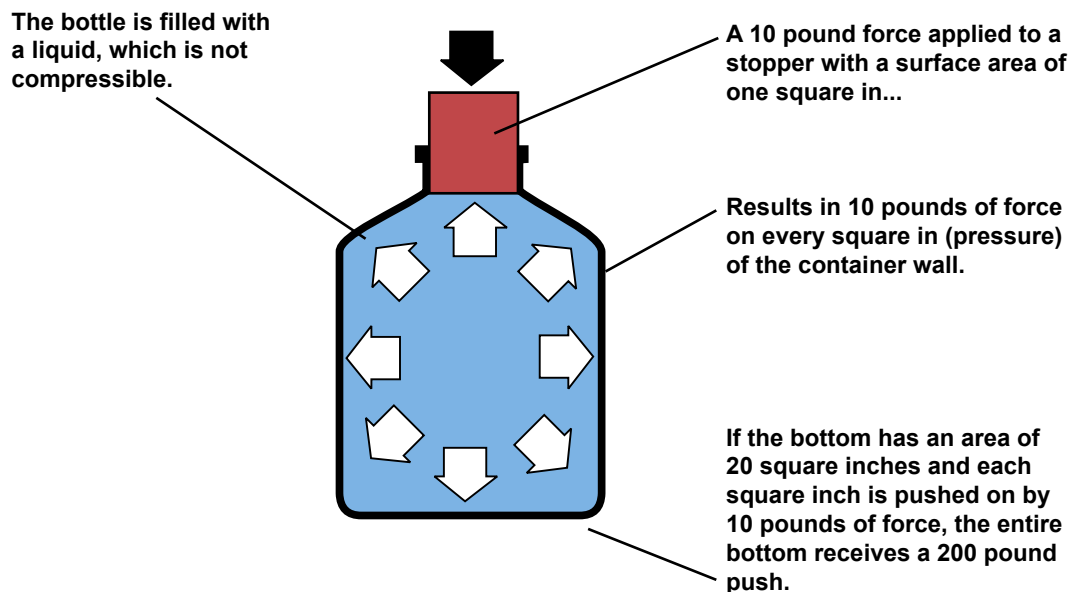


Figure 1-1



**Pressure Defined:**

In order to determine the total force exerted on a surface, it is necessary to know the pressure or force on a unit of area. We usually express this pressure in "Pounds per Square Inch", abbreviated psi. Knowing the pressure and the number of square inches of area on which it is being exerted, one can readily determine the total force.

(Force in Pounds = Pressure in psi x Area in Sq. In.)

**How Pressure is Created:**

Pressure results whenever the flow of a fluid is resisted. The resistance may come from (1) a load on an actuator, (2) a control valve or, (3) a restriction (or orifice) in piping. See [Figure 1-3](#).

**PRESSURE CAUSED BY RESTRICTION AND LIMITED BY PRESSURE CONTROL VALVE.**

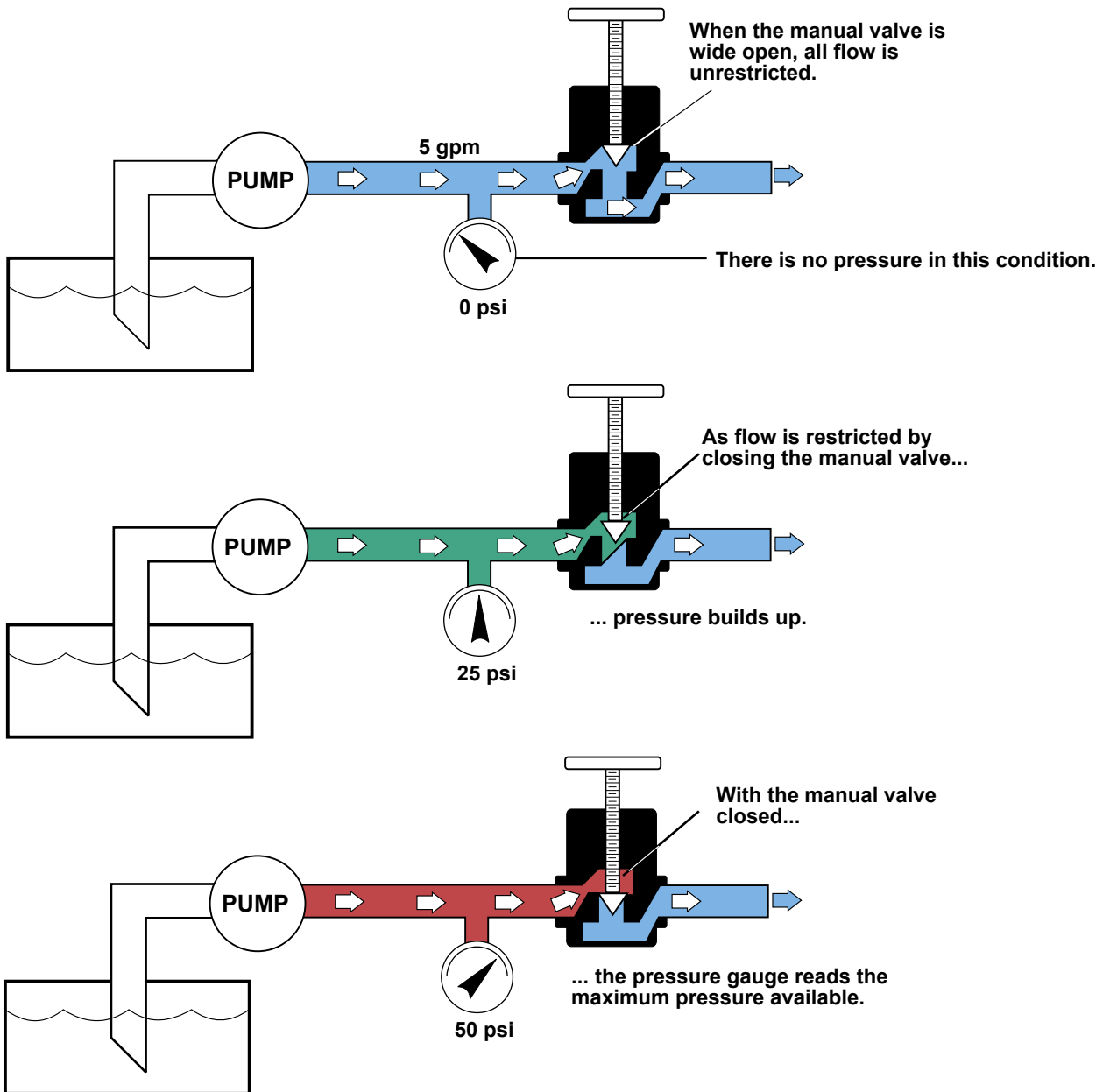


Figure 1-3

**Pressure Indicates Work Load:**

Figure 1-4 illustrates how pressure is generated by resistance of a load. It was noted that the pressure equals the force of the load divided by the piston area.

We can express this relationship by the general formula:

In this relationship:

- P is pressure in psi
- F is force in pounds
- A is area in square inches

From this we can see that an increase or decrease in the load will result in a like increase or decrease in the operating pressure. In other words - pressure is proportional to the load, and pressure gauge reading indicates the workload, in psi, at any given moment.

Pressure gauge readings normally ignore atmospheric pressure. That is, a standard gauge reads zero at atmospheric pressure. An absolute gauge reads 14.7 psi at sea level atmospheric pressure. Absolute pressure is usually designated "psia".

**Force is Proportional to Pressure and Area:**

When a hydraulic cylinder is used to clamp or press, its output force can be computed as follows:  $F = P \times A$

Again:

- P is pressure in psi
- F is force in pounds
- A is area in square inches

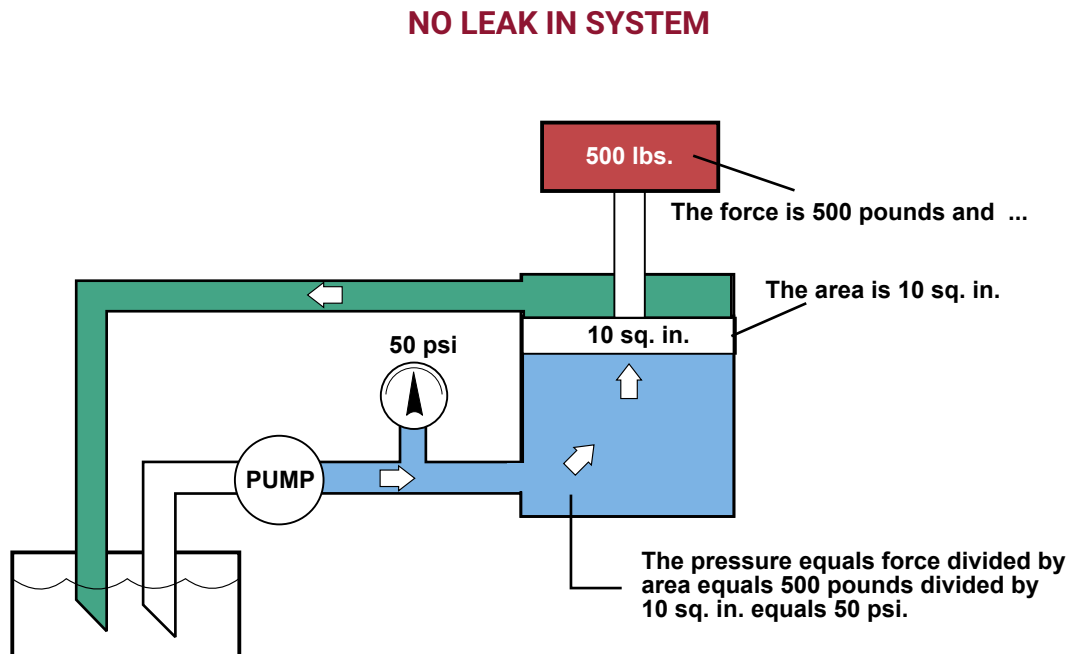


Figure 1-4

### Parallel Flow Paths

An inherent characteristic of liquids is that they will always take the path of least resistance. Thus, when two parallel flow paths offer different resistances, the pressure will increase only to the amount required to take the easier path.

In [Figure 1-5](#) the oil has three possible flow paths. Since valve A opens at 10 psi, the oil will go that way and pressure will build up to only 10 psi. Should flow be blocked beyond A, pressure would build up to 20 psi, then oil would flow through B. There would be no flow through C unless the path through valve B should also become blocked.

### Series Flow Paths

When resistances to flow are connected in a series, the pressures add up. [Figure 1-6](#) shows the same valves as [Figure 1-5](#), but connected in a series. Pressure gauges placed in the lines indicate the pressure normally required to open each valve plus back pressure from the valves down-stream. The pressure at the pump is the sum of the pressures required to open the individual valves.

## PARALLEL FLOW PATHS

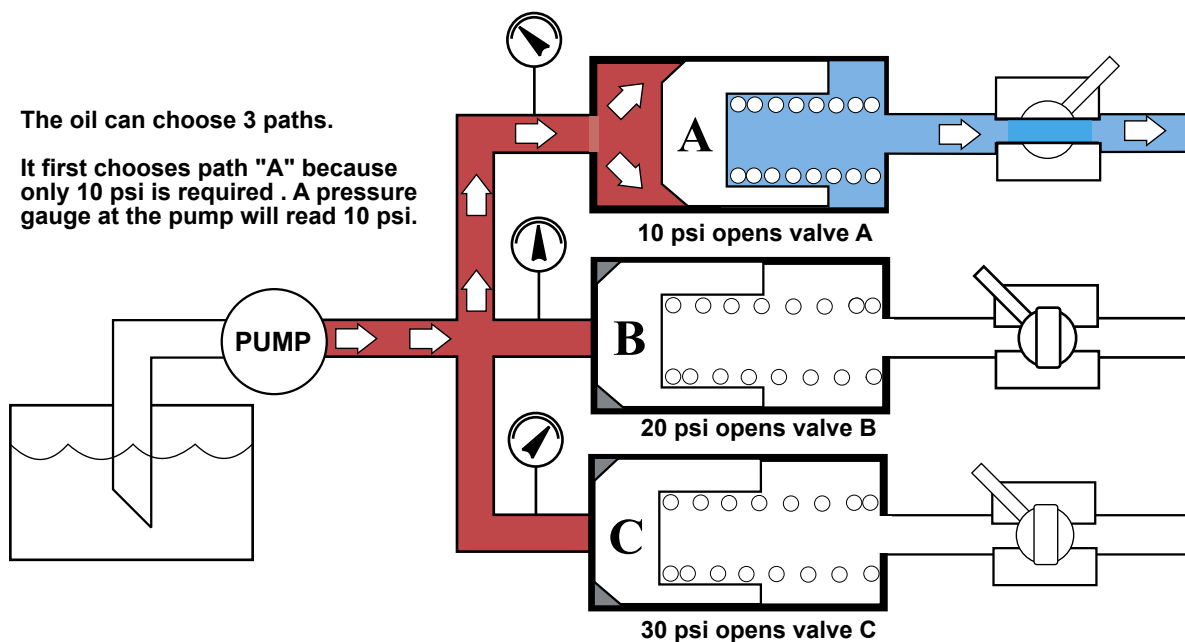


Figure 1-5

**SERIES RESISTANCES ADD PRESSURE**

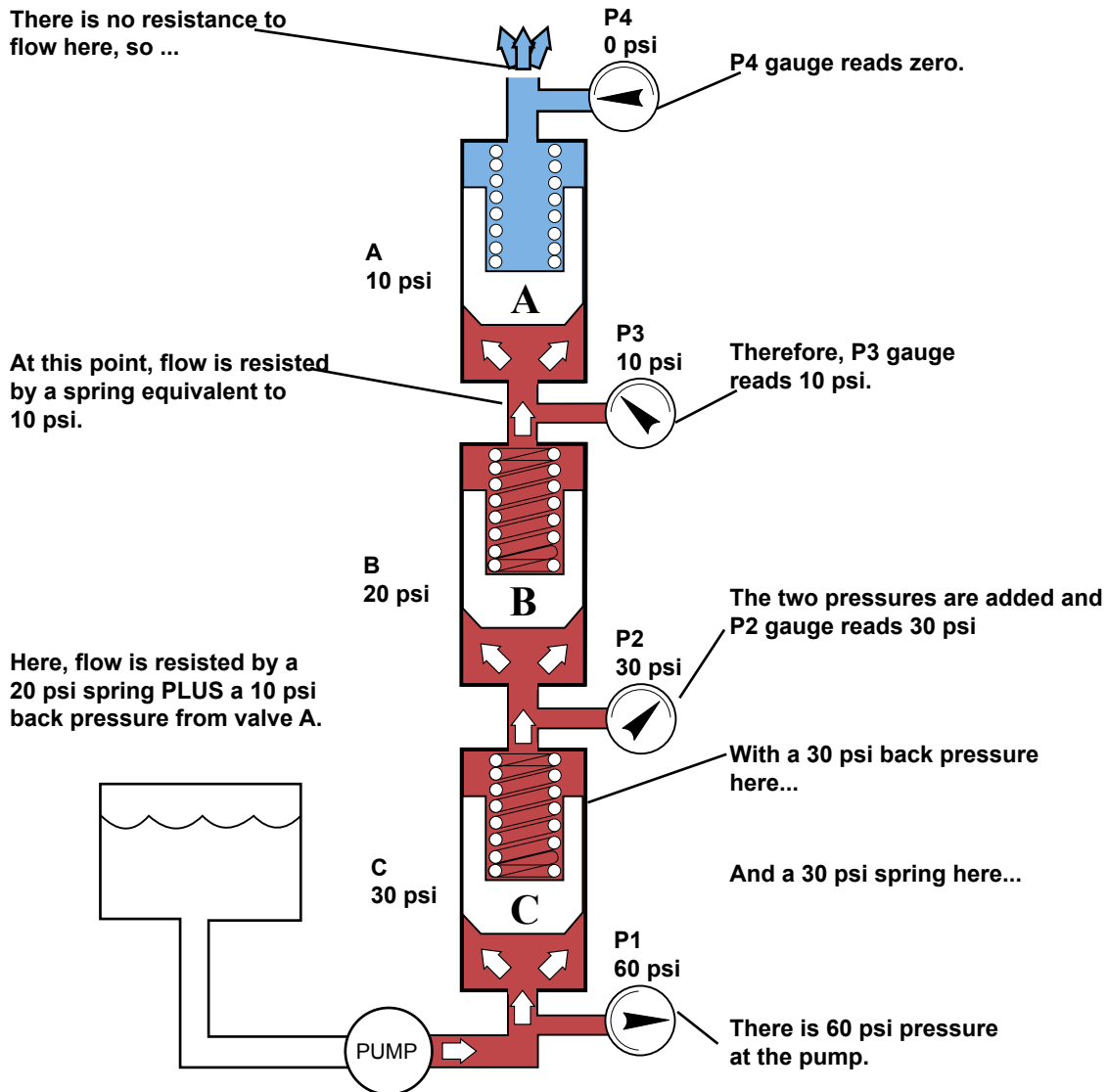


Figure 1-6

**Pressure Drop Through an Orifice**

An orifice is a restricted passage in a hydraulic line or component, used to control flow or create a pressure difference (pressure drop).

In order for oil to flow through an orifice, there must be a pressure difference or pressure drop through the orifice. The term “drop” comes from the fact that the lower pressure is always downstream. Conversely, if there is no flow, there is no difference in pressure across the orifice.

An increase in pressure drop across an orifice will always be accompanied by an increase in flow.

If the flow is blocked beyond an orifice, the pressure will immediately equalize on both sides of the orifice in accordance with Pascal’s Law. This principle is essential to the operation of many control valves.

**Note:** A control valve is a variable orifice.



**Flow and Pressure Drop**

Whenever a liquid is flowing, there must be a condition of unbalanced force to cause motion. Therefore, when a fluid flows through a constant-diameter pipe, the pressure will always be slightly lower downstream than to any point upstream. The difference in pressure or pressure drop is required to overcome friction in the line.

Figure 1-7 illustrates pressure drop due to friction. The succeeding pressure drops, from maximum pressure to zero pressure, are shown as differences in head in succeeding vertical pipes.

**Fluid Seeks A Level**

When there is no pressure difference on a liquid (no flow) it is distributed equally in the pipes as shown in Figure 1-7. If the pressure changes the liquid levels rise until the weight is sufficient to make up the difference in pressure. The difference in height (head) in the case of oil is one foot per 0.4 psi. Thus, it can be seen that additional pressure difference will be required to cause a liquid to flow up a pipe or to lift the fluid, since the force due to the weight of the liquid must be overcome. In circuit design, naturally, the pressure required to move the oil mass and to overcome friction must be added to the pressure needed to move the load. In most applications, good design minimizes these pressure “drops” to the point where they become almost negligible.

**FRICION IN PIPES RESULTS IN A PRESSURE DROP**

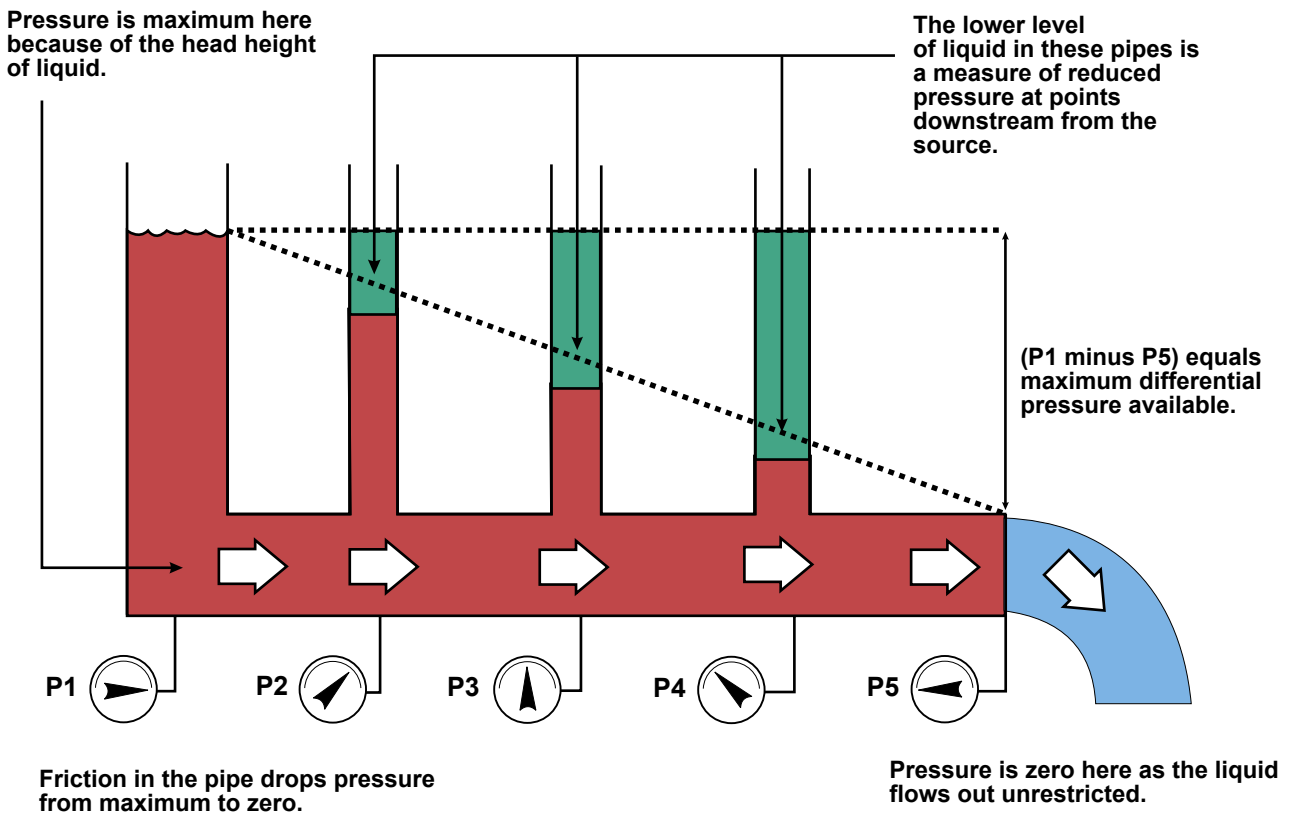


Figure 1-7

**Section 2**

**PRESSURE VERSUS VARIABLE FORCE REQUIRED**

Pressure, force, and area were discussed in the Pressure Defined section. It was stated that pressure indicates work load, and force is proportional to pressure and area.

The principle described for Figures 2-2 and 2-3 is the same for Figure 1-4, with the exception of the work load. It is, in this instance, a variable force (linear spring). The spring exerts 100 pounds of force or resistance in the full position of the power cylinder (Figure 2-2) and 50 pounds in the down position (Figure 2-3). The spring is linear in force; therefore, if the power cylinder were at 50% of stroke, the spring force would be 75 pounds (Figure 2-1).

Also, if the spring force were divided by the area in square inches of power cylinder piston, the answer would be the equivalent force of the spring in psi. Therefore, the force of the spring can be rated as 5 to 10 psi resistance.

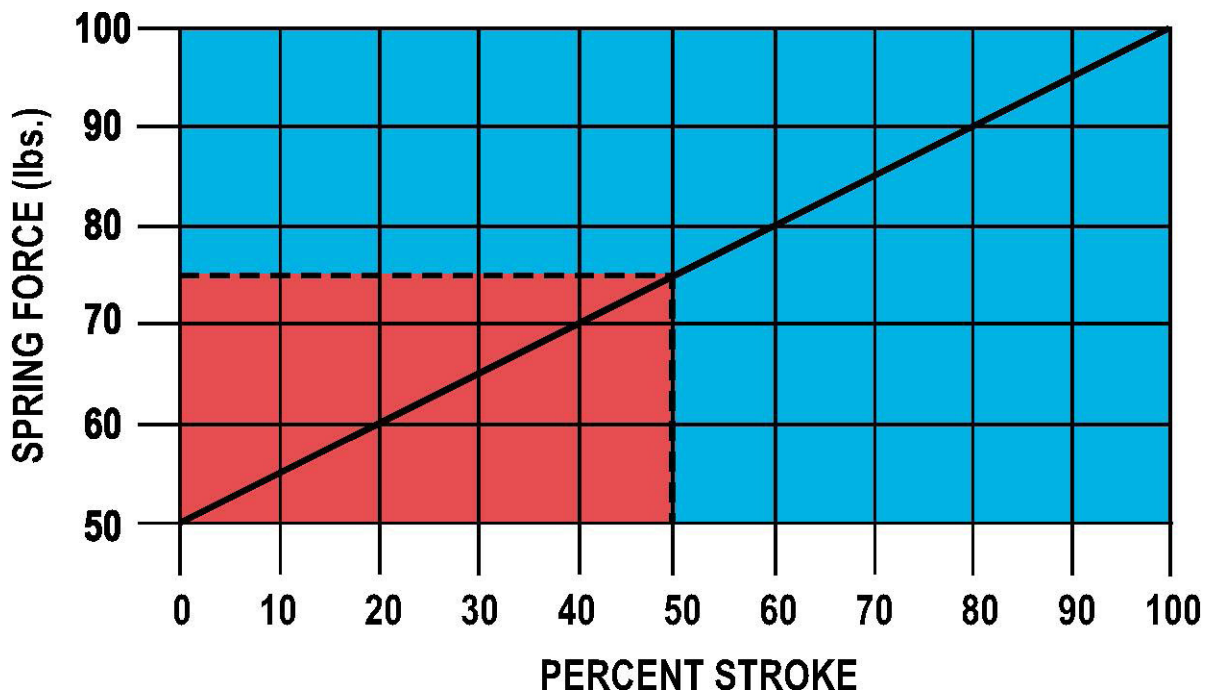


Figure 2-1

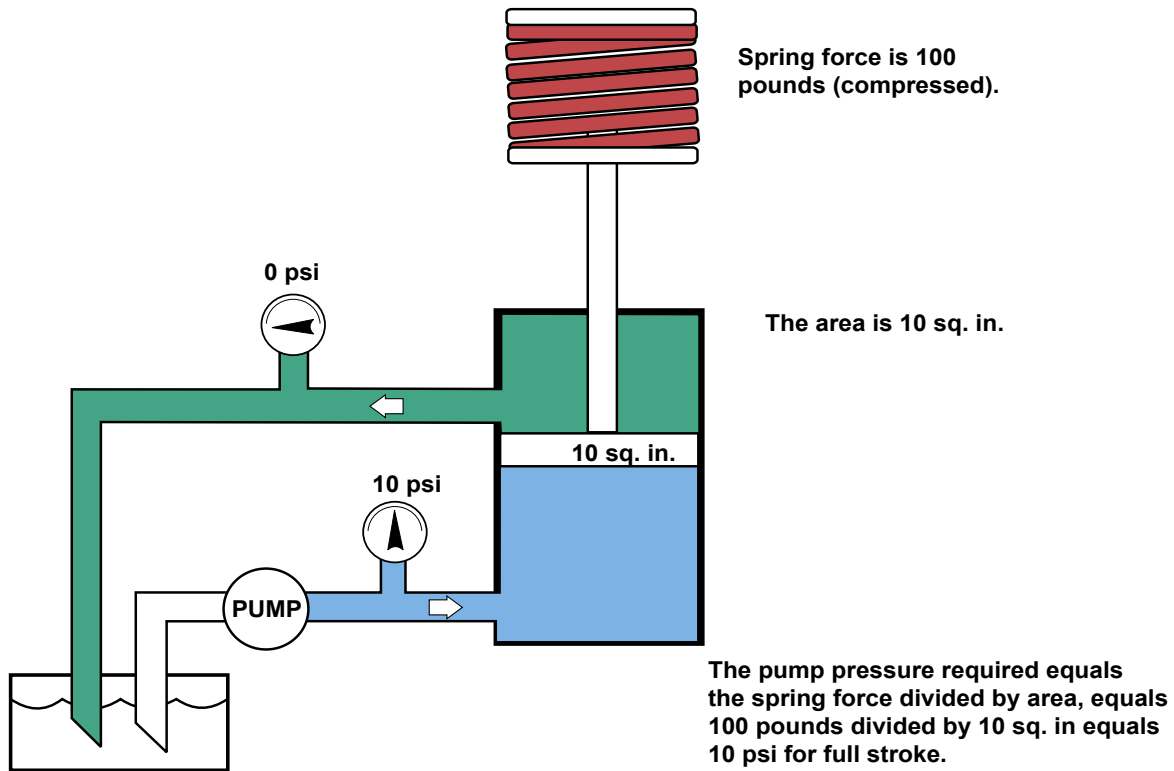


Figure 2-2

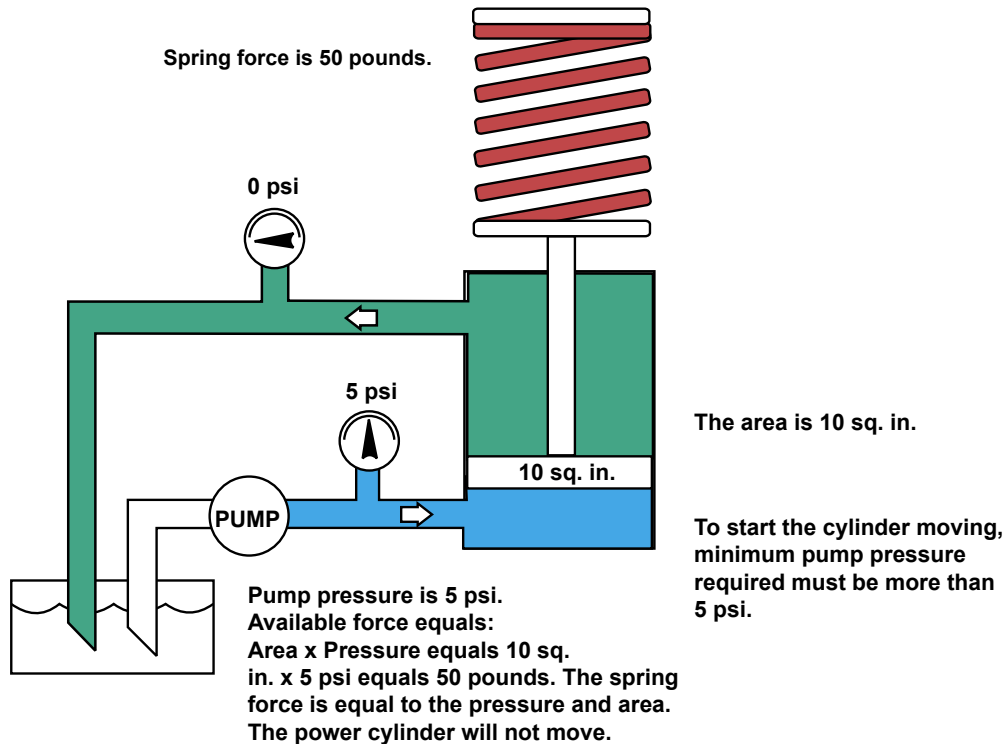


Figure 2-3

## Section 3

# BASIC VALVE - NO CONTROLS

The Introduction to Basic Hydraulics covered the subjects of pressure, force and area and how the three are combined to perform various functions. Note the similarity between the spring loaded hydraulic cylinder in Figures 2-2 and 2-3 on Page 11, and the basic control valve in Figures 3-1, 3-2, and 3-3. P1 is similar to pump pressure, P2 is similar to downstream pressure, and P3 is similar to spring force. The Basic Control Valve uses the principles of hydraulics as described in Section 1, Introduction to Basic Hydraulics, and performs the various control functions illustrated and described in the following pages.

The valve as shown serves no useful purpose because it does not have a pilot control loop to regulate the pressure at (P3).

The purpose of these illustrations is to show the effects and force of the main valve spring, which is the total control force of the basic valve. All main valve springs are linear in force and are rated in psi.

The basic valve operates on a balanced piston principle and is spring biased (loaded). Since the area of the nose (P1 side) of the main valve piston is exactly the same as the spring side (P3 side), it can be seen that the main valve spring now becomes the differential force necessary to control the position of the main valve piston.

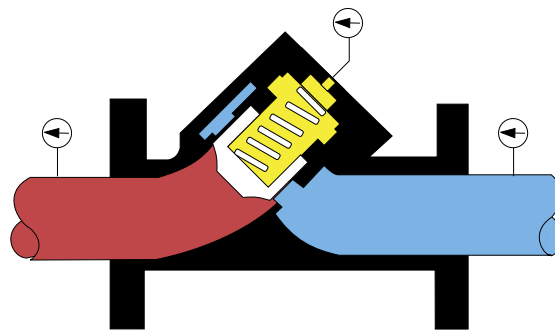
Three (3) different springs are applicable and selection is based on the intended service. These springs are:

- Light - 4 to 6 psi force
- Medium - 5 to 10 psi force
- Heavy - 10 to 30 psi force

The first number given is seated force and the last is full open force.

### CLOSED POSITION –

The valve is closed because (P1) is less than the spring force in the seated position or; (P2) is greater than (P1).

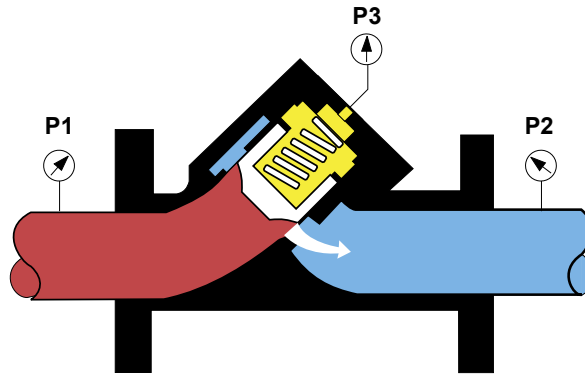


- = Inlet Pressure
- = Outlet Pressure
- = Spring Force

Figure 3-1

**50% OPEN –**

The pressure differential across the valve (P1 minus P2) is equal to the spring force in the 50% open position.






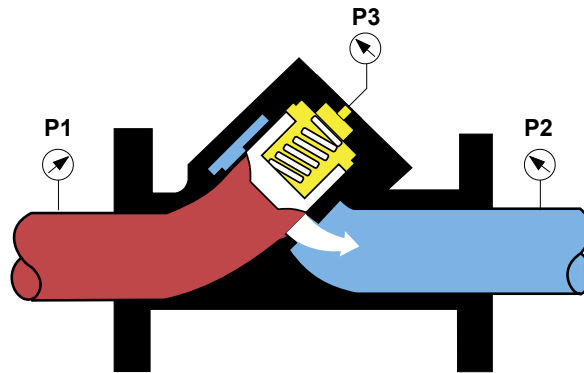
-  = Inlet Pressure
-  = Outlet Pressure
-  = Spring Force

Figure 3-2

**FULLY OPEN –**

The pressure differential across the valve (P1 minus P2) is equal to the spring force in the fully open position.






-  = Inlet Pressure
-  = Outlet Pressure
-  = Spring Force

Figure 3-3

## Section 4

# 700 SERIES VALVES

### Typical 700 Series Valve

This is the starting point for unlimited control applications. The basic valve now incorporates a pilot control loop, which is mandatory for it to function.

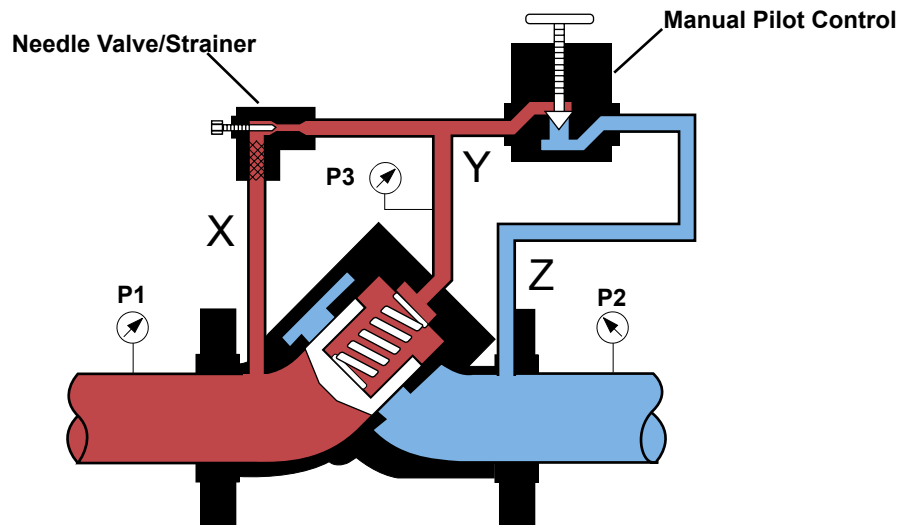
The basic valve operates on a balanced piston principle, spring biased (loaded). The term balanced piston means that the exposed area on the spring side (P3) of the piston and the bottom side (P1) are equal in area. The spring is the differential force that closes the piston when (P1) and (P3) pressures are equal.

By design, the valve serves as a check valve because there can be no reverse flow. It is possible, in some applications, to reverse flow through the pilot control loop, but this can be eliminated by installing a check valve in the X-port. To open the valve, the pressure against the bottom of the piston (P1) must exceed the pressure on the spring side of the piston (P3) plus spring force.

### CLOSED POSITION –

Pilot is closed. Y-port (P3) to Z-port (P2) is closed. X-port (P1) and Y-port (P3) pressures are balanced.  
The differential force created by the main valve spring, closes the piston and keeps it seated.

Therefore, total pressure equals 40 psi @ (P1) and 45 psi @ (P3) or (P3 minus P1) - 5 psid. The needle valve incorporated with the strainer controls the speed of the closure by controlling the flow through the X-port.

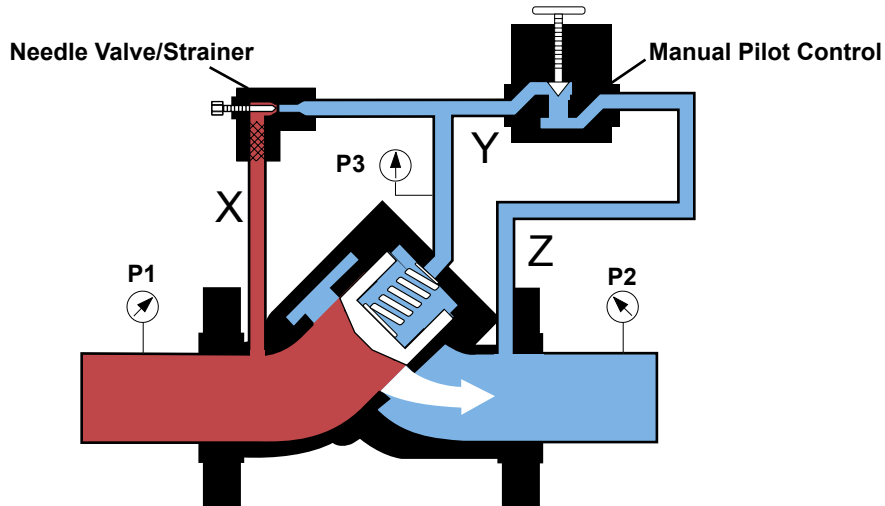


■ = Inlet Pressure  
■ = Outlet Pressure

Figure 4-1

**FULLY OPEN - NO CONTROL -**

Pilot is fully open. Y-port (P3) is open to Z-port (P2). The pressure on the bottom of the piston (P1) is greater than the pressure at (P3) plus spring force. The valve will not open unless the pressure drop across the valve (P1 minus P2) is slightly greater than the force applied by the main valve spring. In a non-control state, the main valve is opened in a percentage directly proportional to (P1 minus P2).

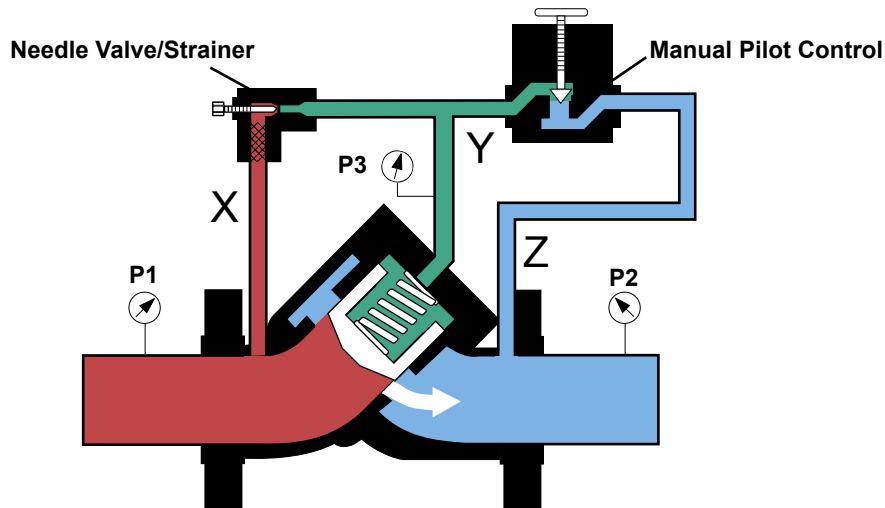


- = Inlet Pressure
- = Outlet Pressure

Figure 4-2

**OPEN CONTROLLED POSITION -**

Pilot is partially open. Y-port (P3) is open to Z-port (P2) but is being restricted by the control pilot. The pilot control is a variable orifice that regulates the pressure at Y-port (P3) by controlling the flow through Z-port. By increasing or decreasing the Y-port pressure (P3) causes the piston to change positions.



- = Inlet Pressure
- = Outlet Pressure
- = Controlled Pressure

Figure 4-3

**Solenoid Operated On-Off Valves - Model 710 (N.C.) and Model 711 (N.O)**

N.C. = Normally closed, energize to open

N.O. = Normally open, energize to close

A solenoid valve is either open or closed. It does not perform any control functions unless the other controls have been incorporated. It is an on-off block valve, and is inherently a check valve.

As a line block valve, it is used for remote on-off control to start or stop a flowing stream such as:

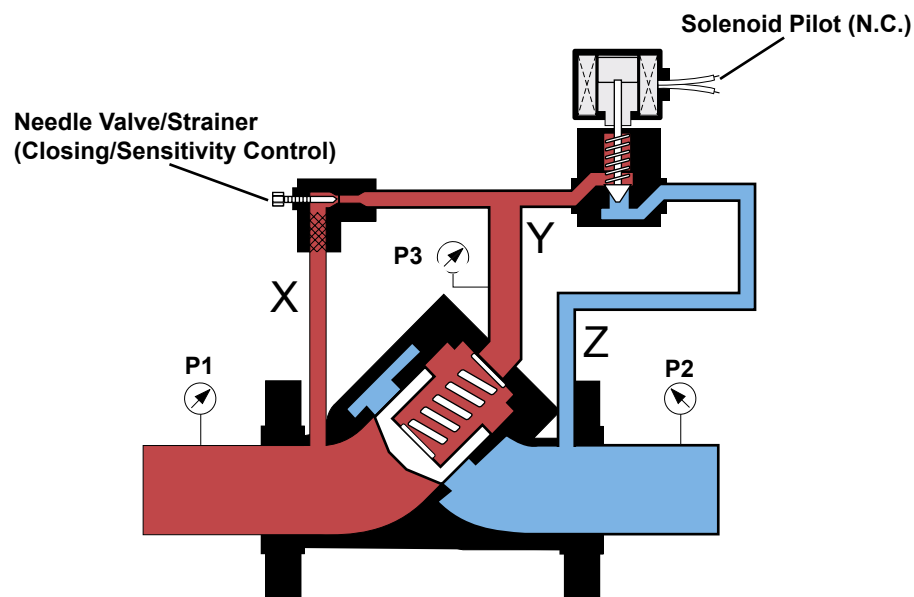
1. Batching operation by preset
2. Tank filling high level control
3. Line block valve

**CLOSED POSITION –**

The solenoid pilot is closed (N.C. illustrated). Y-port (P3) to Z-port (P2) is closed. X-port (P1) and Y-port (P3) pressures are balanced. The main valve spring, being the differential force, closes the piston and keeps it seated. The needle valve controls the speed of closure.

**MODEL 710 - (N.C.) ILLUSTRATED - Opens when energized.**

**MODEL 711 - (N.C.) - Closes when energized.**



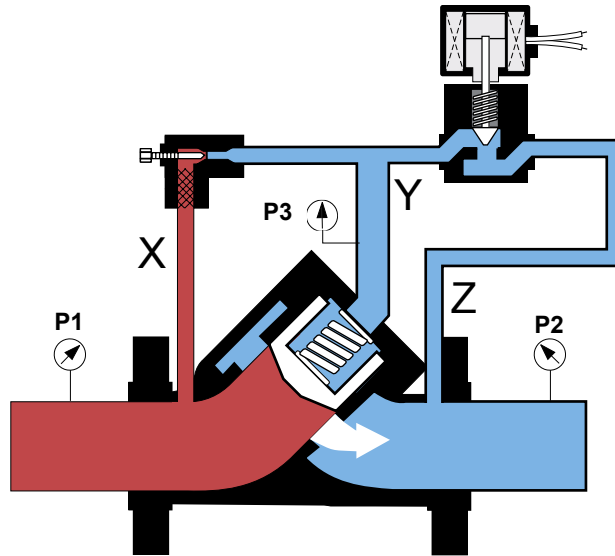
= Inlet Pressure  
 = Outlet Pressure

Figure 4-4



**OPEN POSITION –**

The solenoid pilot is open. Y-port (P3) is open to Z-port (P2). The pressure on the bottom of the piston (P1) is greater than the pressure at (P3) plus the spring force. (P1 minus P2) is equal to or greater than the spring force.



- = Inlet Pressure
- = Outlet Pressure

Figure 4-5

**Model 750 Pressure Reducing Control Valve (N.O.)  
Closes on increasing Outlet Pressure**

A pressure reducing valve is normally open and throttles toward a closed position on increasing outlet pressure. It is a regulating or positioning type valve that does not require any outside power source to operate.

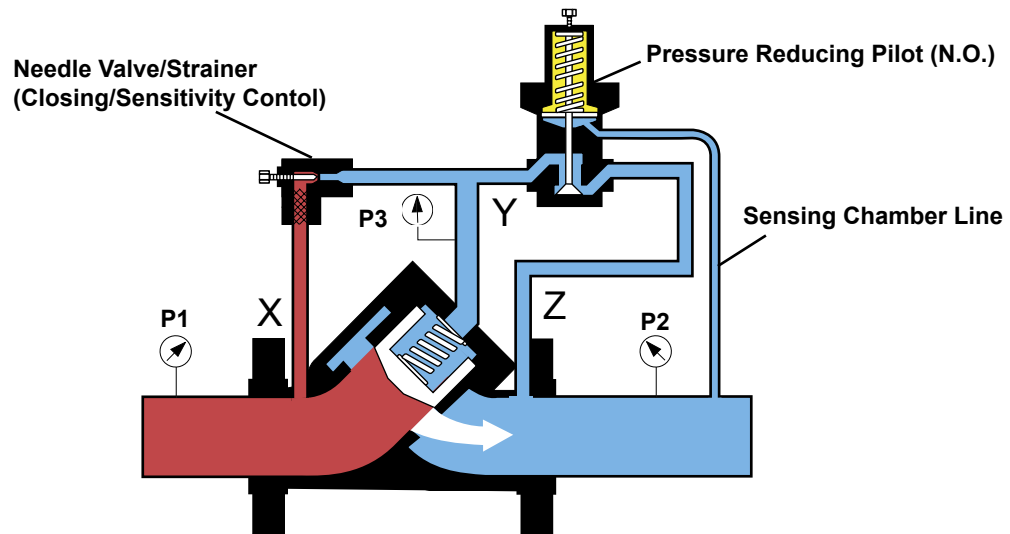
The pilot control is normally open. It is an adjustable spring loaded variable orifice in the Z-port. The pilot is piston operated, spring biased (loaded) with a pressure sensing chamber connected on the downstream (P2) side.

Pressure reducing valves are used for:

1. Precise pressure control in process streams.
2. Over-pressure protection of meters, pipe line manifold systems, etc.

**FULLY OPEN - NO CONTROL -**

The pilot is fully open. Open pressure (P2) is less than the pilot spring setting. Y-port (P3) is open to Z-port (P2). The valve is floating the stream and is not required to control.



- = Inlet Pressure
- = Outlet Pressure
- = Pilot Spring Pressure

Figure 4-6

**OPEN - CONTROLLED POSITION -**

The pilot is partially open. Outlet pressure has slightly exceeded the pilot spring. Z-port (P2) is being squeezed off by the throttling of the pilot, placing higher pressure on Y-port (P3). The increasing pressure at Y-port (P3) plus the main valve spring force, establishes a position of the valve piston so it balances outlet pressure equal to the pilot setting (plus or minus 2 psi).

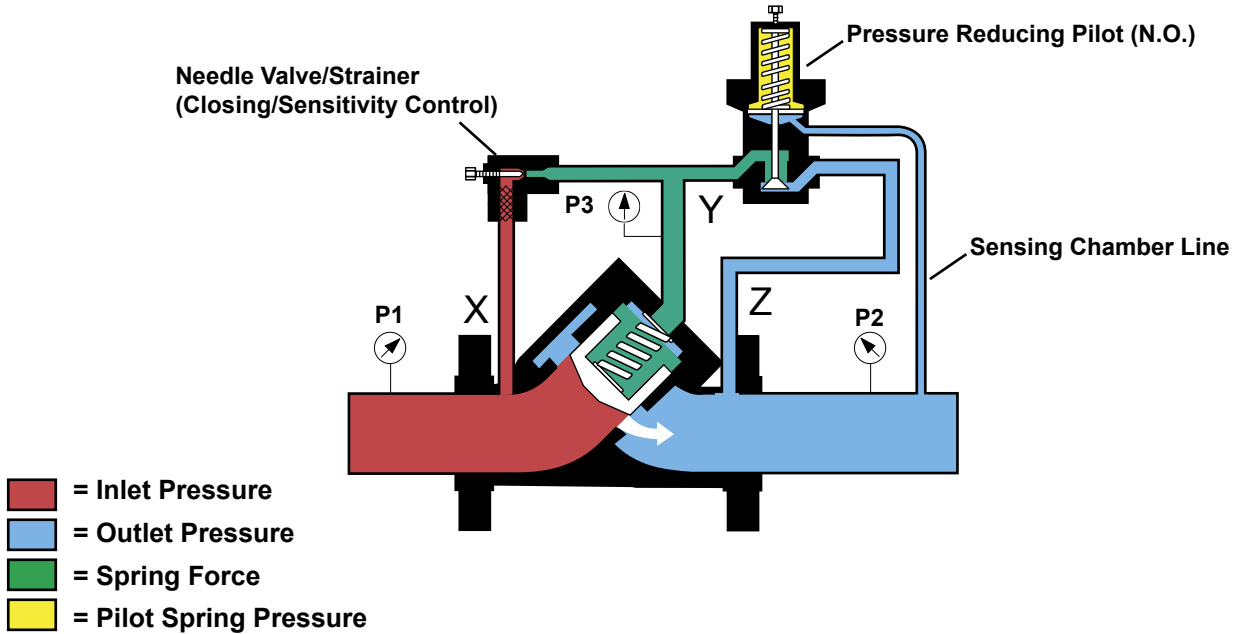


Figure 4-7

**CLOSED POSITION -**

The pilot is closed. Outlet pressure (P2) exceeded the pilot spring setting, indicating the main line downstream (P2) is closed. Y-port (P3) to Z-port (P2) is closed. X-port (P1) and Y-port (P3) pressures become balanced. The main valve spring, being the differential force, closes the piston and keeps it seated.

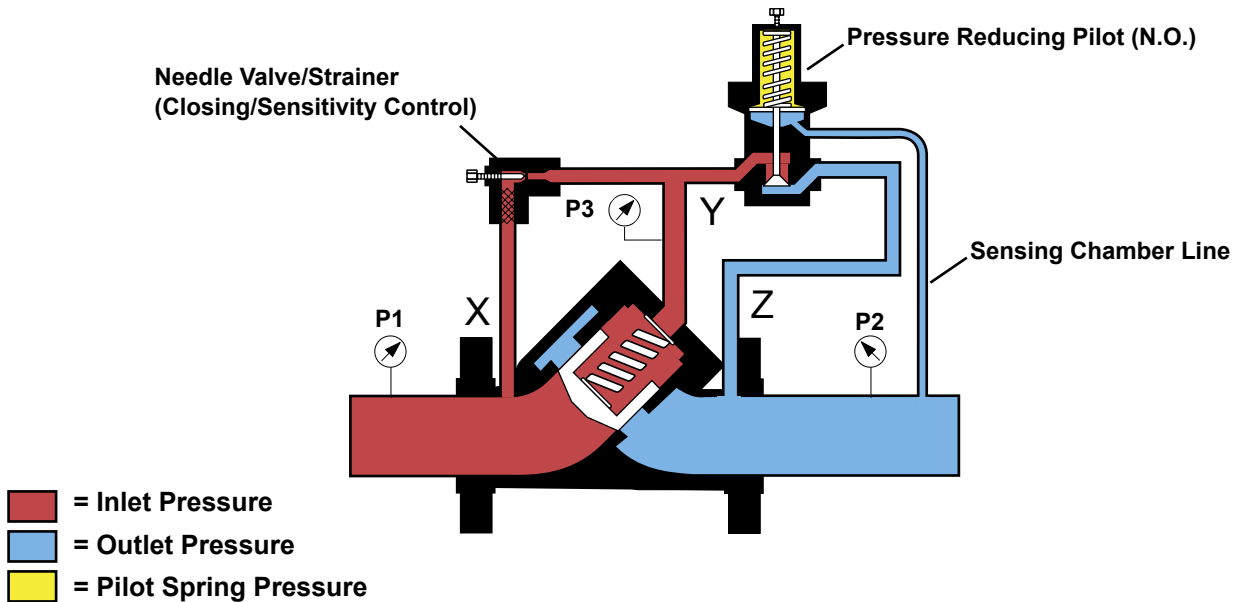


Figure 4-8

**Model 760 Back Pressure/Pressure Relief Control (N.C.)  
Opens on increasing inlet pressure**

A back pressure/pressure relief valve is normally closed and throttles open on increasing inlet pressure. This valve is used to maintain minimum pressure for more efficient operating conditions or to relieve excess pressure. It is a regulating or positioning type valve that does not require any outside power source to operate.

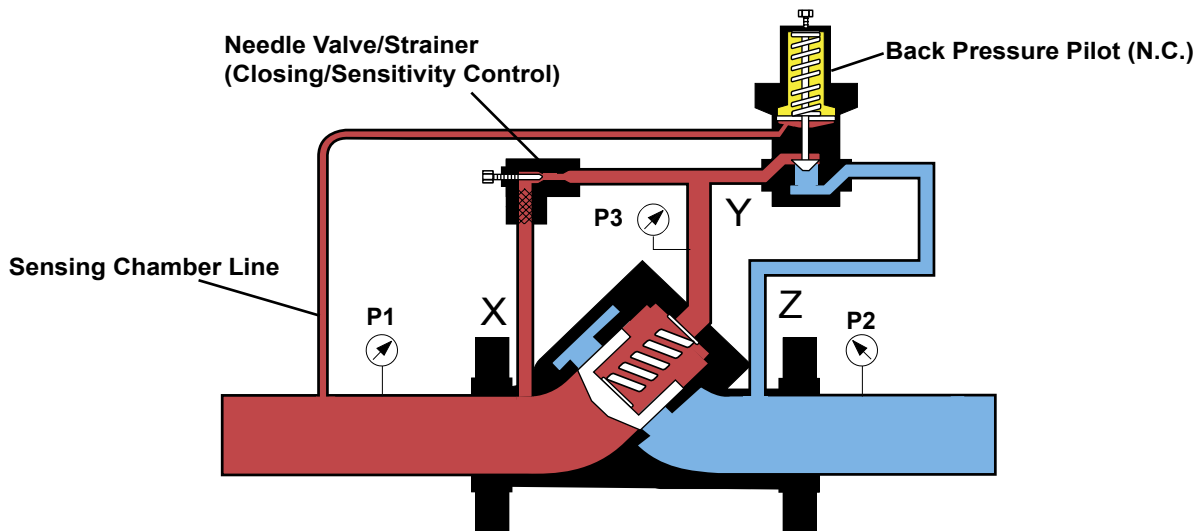
The pilot control is normally closed. It is an adjustable spring loaded variable orifice in the Z-port. The pilot is piston operated, spring biased (loaded) with a pressure sensing chamber connected to upstream (P1).

Back pressure/pressure relief valves are used for:

1. Back pressure against a pump, meter, hill pressure, etc.
2. Pressure relief and surge control

**CLOSED POSITION –**

The pilot is closed. Inlet pressure (P1) is less than the pilot spring setting, indicating the main line upstream (P1) is closed, or pressure is not sufficient to overcome the pilot spring setting. Pilot is closed. Y-port (P3) to Z-port (P2) is closed. X-port (P-1) and Y-port (P3) pressures are balanced. The main valve spring, being the differential force, closes the valve and keeps the piston seated.



- = Inlet Pressure
- = Outlet Pressure
- = Pilot Spring Force

Figure 4-9

**OPEN - CONTROLLED POSITION -**

The pilot is partially open. Inlet pressure (P1) has slightly exceeded the pilot spring setting. Z-port (P2) is being opened by the throttling of the pilot, reducing the pressure on Y-port (P3). The decreasing pressure at Y-port (P3) plus the main valve spring force establishes a position of the valve piston such that it balances inlet (P1) pressure equal to the pilot setting (Plus or minus 2 psi).

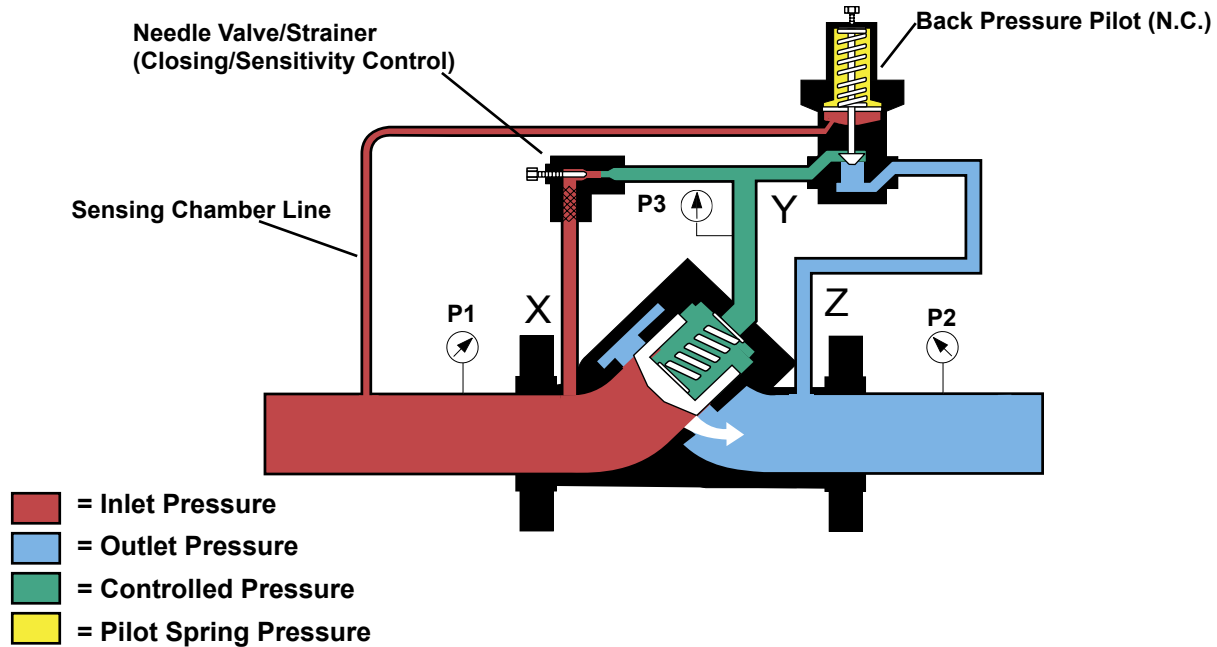


Figure 4-10

**FULL OPEN - NO CONTROL -**

The pilot is full open. Inlet pressure (P1) is greater than the pilot setting. Y-port (P3) is open to Z-port (P2). The valve is floating in the stream and no flow control is required.

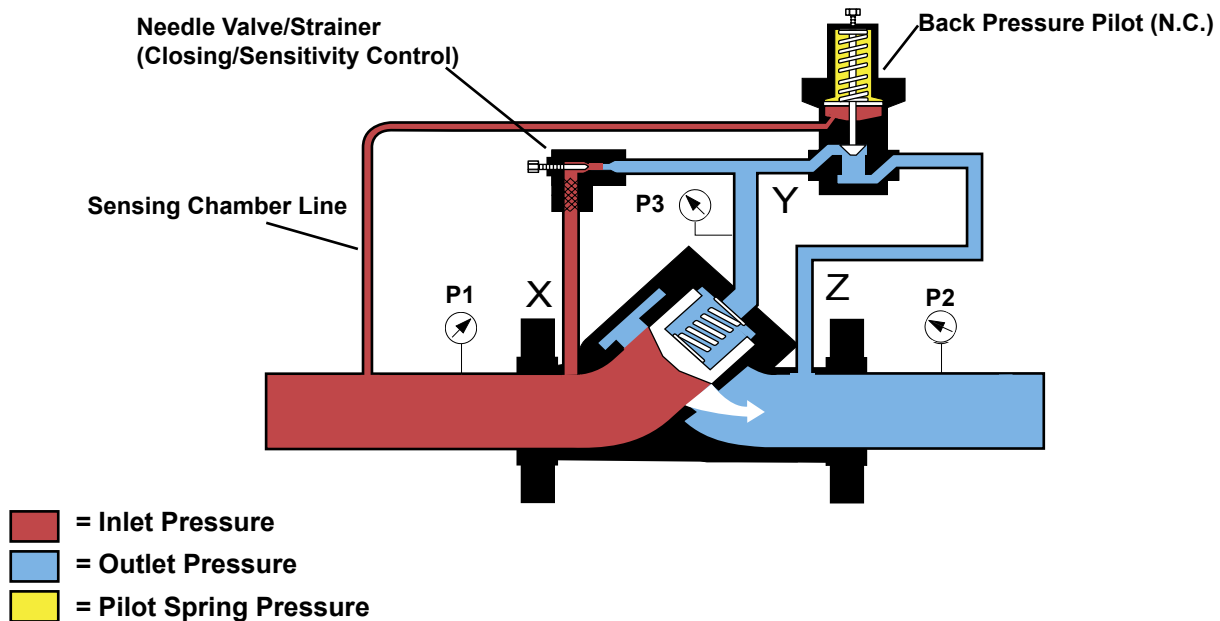


Figure 4-11

**Model 770 Minimum Differential Pressure Control (N.C.)  
Opens on increasing differential pressure**

The Model 770 valve is normally closed and throttles toward an open position on increasing differential pressure. It is a regulating or positioning type valve that does not require any outside power source to operate.

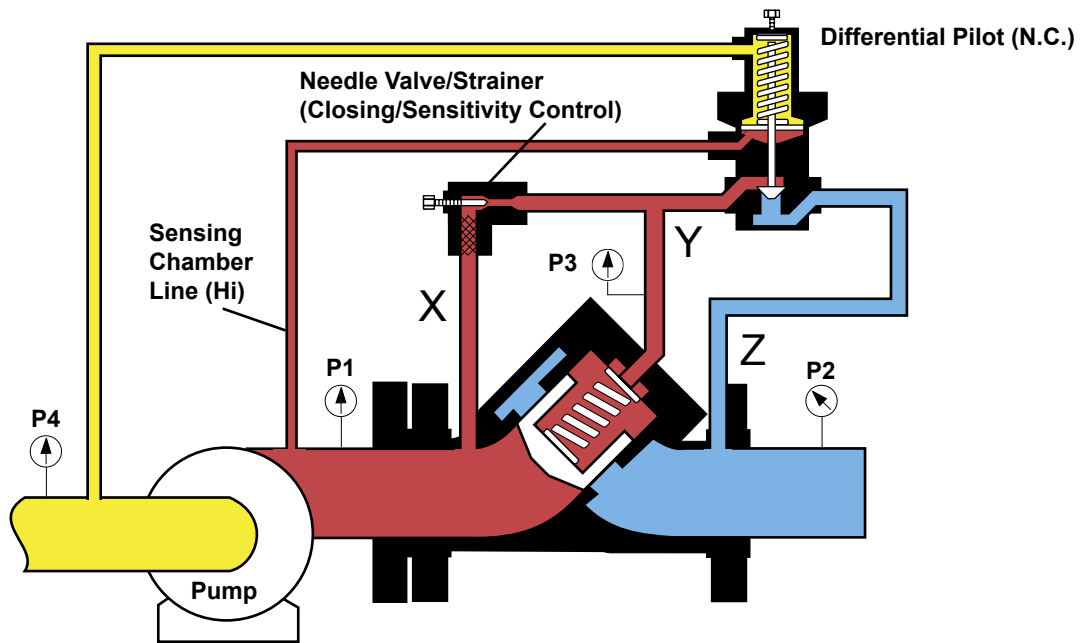
The pilot control is normally closed. It is an adjustable spring loaded variable orifice in the Z-port. The pilot is piston operated, spring biased (loaded) with a differential pressure sensing chamber connected to the high and low pressure sources.

The Model 770 valve is used for:

1. Pump differential pressure control
2. Bypass differential pressure control for pumps, strainers, filters, etc.
3. Vapor pressure control on LPG, NH3 and similar products.

**CLOSED POSITION –**

The pilot is closed. The differential pressure between (P1) and (P4) is less than the pilot spring setting, indicating the pump is not running or sufficient differential pressure (P1 minus P4) is not available to overcome the pilot spring setting. Pilot is closed. Y-port (P3) to Z-port (P2) is closed. X-port (P1) and Y-port (P3) pressures are balanced. The main valve spring, being the differential force, closes the piston and keeps it seated.



- = Inlet Pressure
- = Outlet Pressure
- = Pilot Spring Force plus P4

Figure 4-12

**OPEN - CONTROLLED POSITION -**

The pilot is partially open. Differential pressure (P1 minus P4) has slightly exceeded the pilot spring setting. Z-port (P2) is being opened by the throttling of the pilot, reducing the pressure on Y-port (P3). The decreasing pressure at Y-port (P3) plus the main valve spring force establishes a position of the valve piston such that it balances the pump differential pressure (P1 minus P4) equal to the pilot setting (Plus or minus 2 psid).

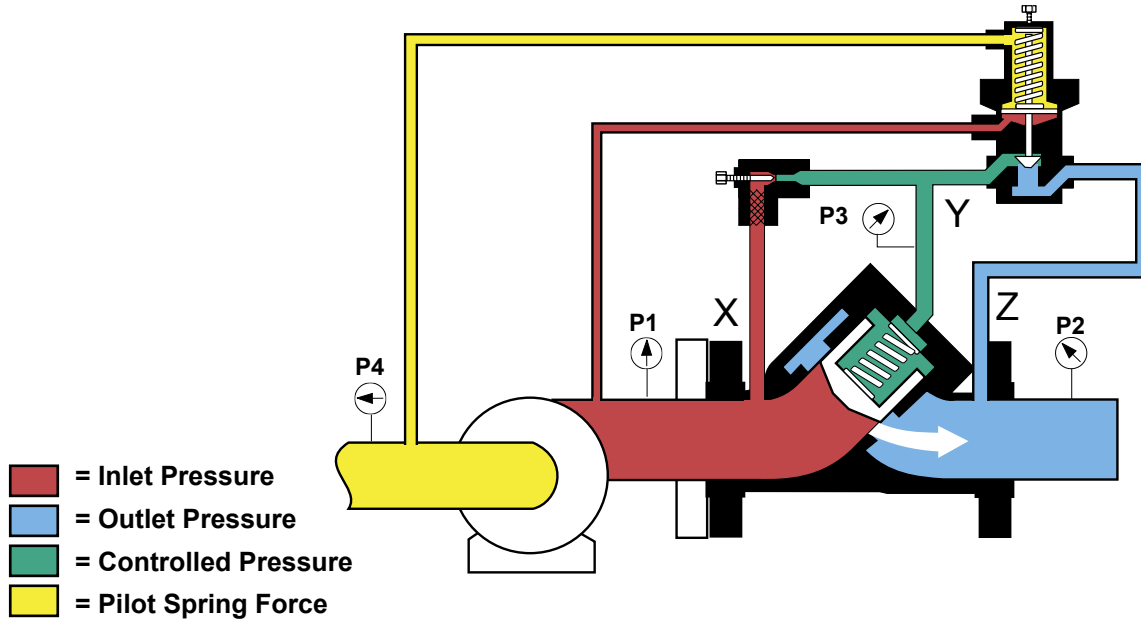


Figure 4-13

**FULL OPEN - NO CONTROL -**

The pilot is full open. Differential pressure (P1 minus P4) has exceeded the pilot spring setting. Y-port (P3) is open to Z-port (P2). The valve is floating the stream and is not required to control.

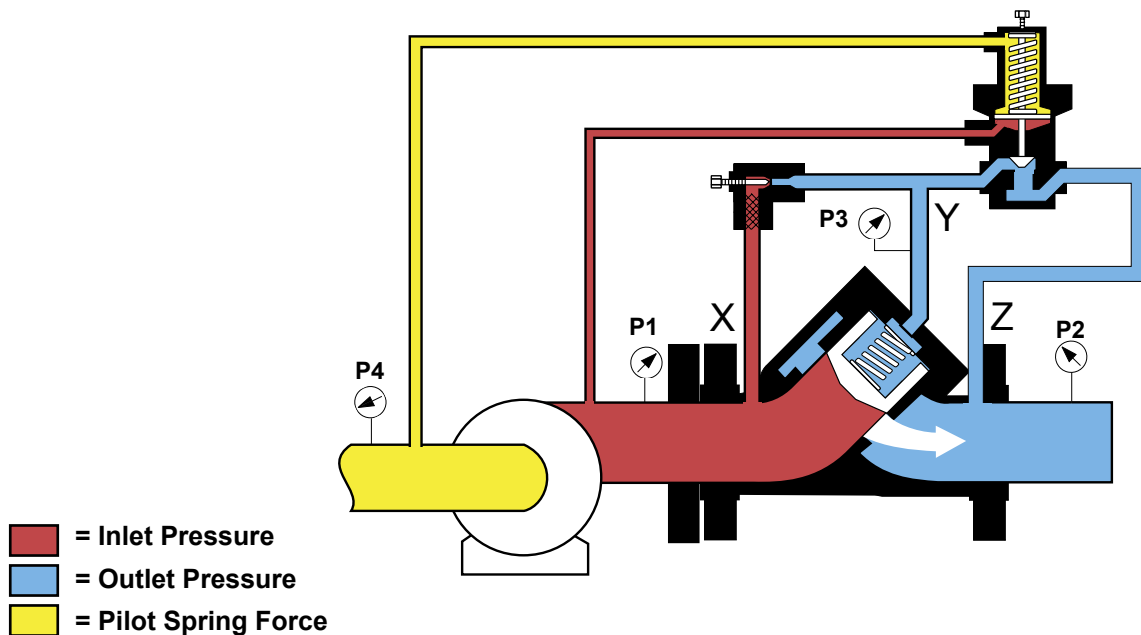


Figure 4-14

**CLOSED POSITION –**

Nitrogen gas pressure is higher than the valve inlet pressure, therefore the force of the nitrogen gas plus the spring keep the valve in the closed position.

**CLOSED POSITION**

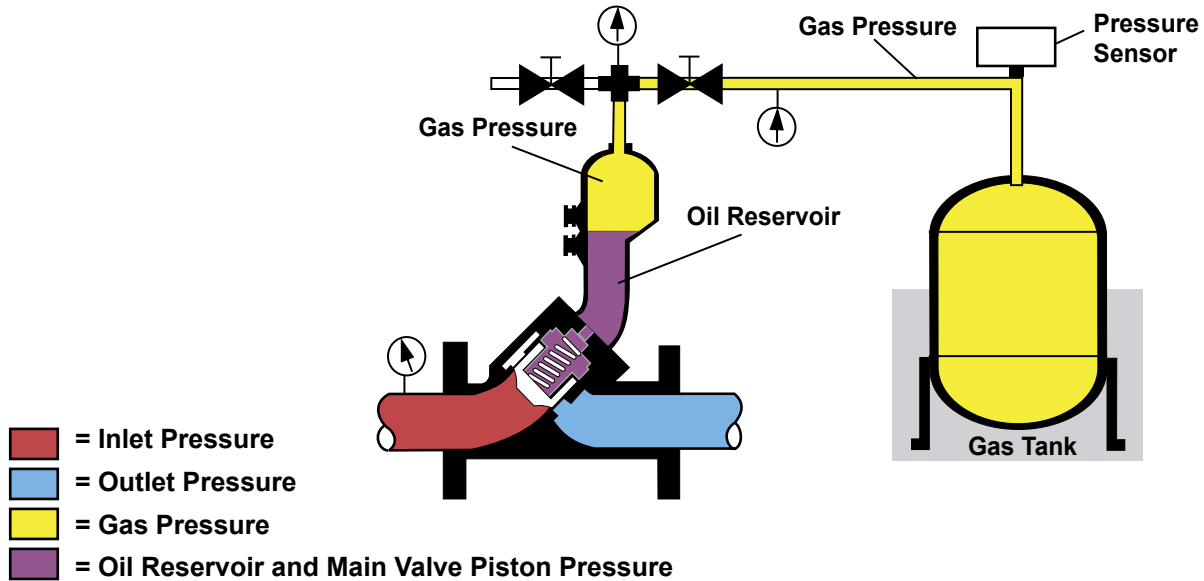


Figure 4-15

**OPEN POSITION –**

The pressure at the inlet of the valve has exceeded the combined force of the nitrogen gas plus the spring, thereby causing the piston to become unbalanced, opening the valve and removing the surge from the pipeline.

**OPEN POSITION**

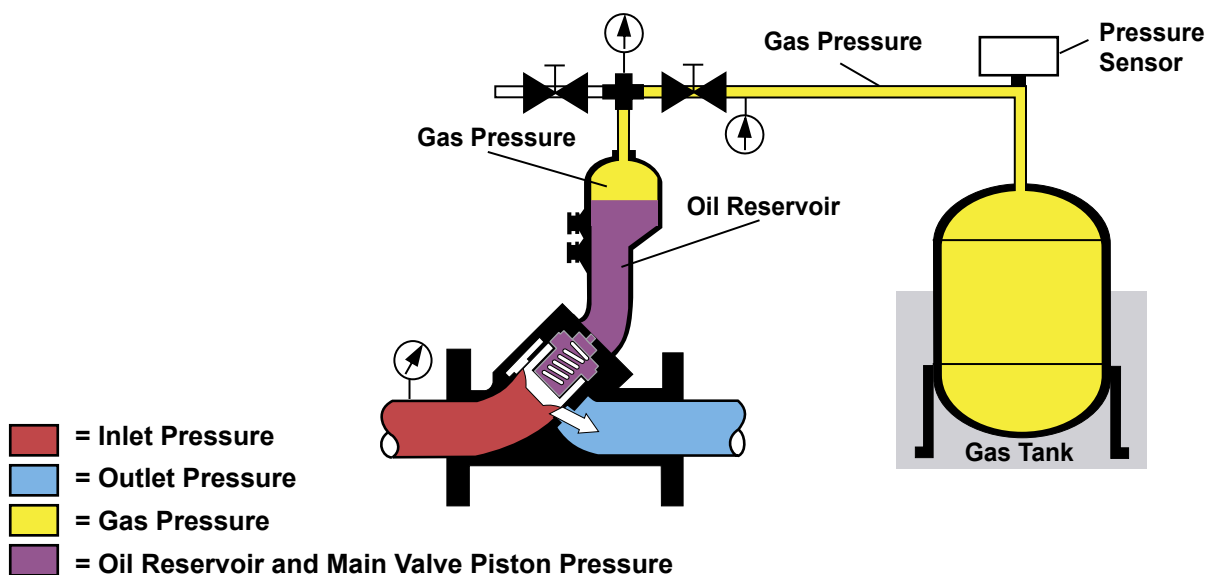


Figure 4-16



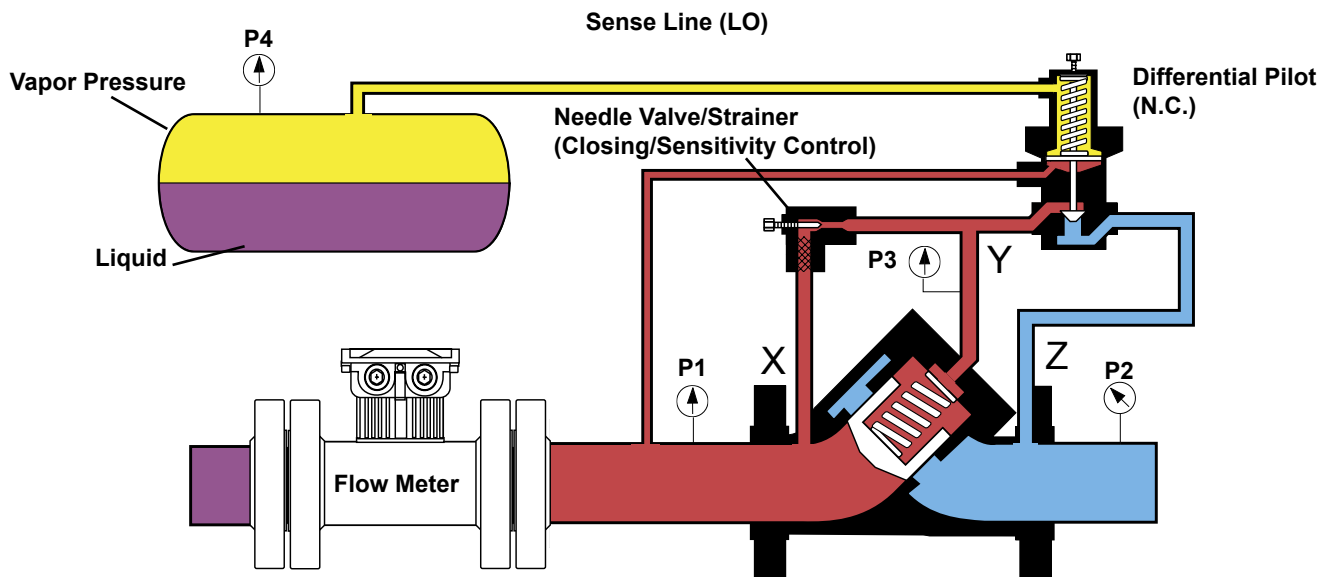
**Model 770 Differential Vapor Pressure Control (N.C.)**  
**Opens on increasing differential pressure**  
**Typical for LPG, NH3 or similar products**

The Model 770 as illustrated is identical to the previously described 770 valve except it is shown as a vapor pressure control valve for products having high flash points such as: butane, propane, anhydrous ammonia or other products with similar characteristics.

When metering these products, the pressure at the meter must be higher than the vapor pressure of the product, otherwise it turns into a gaseous state resulting in meter damage due to overspeed plus inaccurate measurement and possible pump damage. The differential pressure between the meter inlet pressure and the vapor pressure (P4) is generally 10 to 30 psid, to assure the product is in a liquid state when it passes through the meter.

**CLOSED POSITION –**

The pilot is closed. Vapor pressure (P4) plus pilot spring setting is greater than the line pressure (P1), indicating the pump is not running or sufficient differential pressure (P1 minus P4) is not available to overcome the pilot spring setting. Pilot is closed. Y-port (P3) to Z-port (P2) is closed. X-port (P1) and Y-port (P3) pressures become balanced. The main valve spring being the differential force, closes the piston and keeps it sealed.



- = Inlet Pressure
- = Outlet Pressure
- = Pilot Spring Force plus P4
- = Product Pressure

Figure 4-17

## **Model 762, 763, 764, 765, 766 and 767 Gas Loaded Pressure Relief / Back Pressure Control Valves (N.C.) Open on increasing inlet pressure**

These valves are normally closed and open upon increasing inlet pressure. They are used to relieve excess surge pressures that may occur during a pipeline upset and can also be used to maintain a minimum back pressure for more efficient operating conditions. These valves are direct acting and do not utilize pilots to operate. They incorporate an integral oil reservoir mounted on the external surface of the valve cylinder head, which upon installation is partially filled with a light oil. Gas under pressure is applied to the reservoir. The oil is a moveable barrier between the gas and the valve piston.

### **Principle of Operation**

The valve is normally closed and opens upon increasing inlet pressure. Pressure applied to the nose of the piston is equally transmitted to the spring side of the piston. When the line pressure on the nose of the piston exceeds the gas pressure, the moveable barrier of oil compresses the gas and the valve opens.

As line pressure falls below the set point, the gas pressure, added to the spring pressure closes the valve and it remains closed as long as gas pressure is higher than line pressure. Opening and closing speeds are controlled by a check valve mounted to the internal surface of the cylinder head. Opening speed is relatively unrestricted which results in very fast opening response. Closing speed is controlled by a fixed orifice in the check valve.

### **Typical Applications**

#### **A) Pipeline Pressure and Surge Relief (models 765, 766, 767)**

Product movement by pipeline requires over-pressure protection. Response time to pressure rise is critical. These valves will respond very quickly and only relieve the necessary volume of liquid to decrease pipeline pressure back to or below set-point.

#### **B) Back Pressure Control (models 762, 763)**

These valves are ideally suited for back pressure control and minimum pressure drop. When line pressure exceeds the gas pressure, the valve will open and follow the CV curve for pressure loss.

**OPEN - CONTROLLED POSITION -**

The pilot is partially open. Differential pressure (P1 minus P4) has slightly exceeded the pilot spring setting. Z-port (P2) is being opened by the throttling of the pilot, reducing the pressure on Y-port (P3). The decreasing pressure at Y-port (P3) plus the main valve spring force establishes a position of the valve piston such that it balances inlet pressure (P1) equal to the pilot setting plus vapor pressure (P4) (Plus or minus 2 psid).

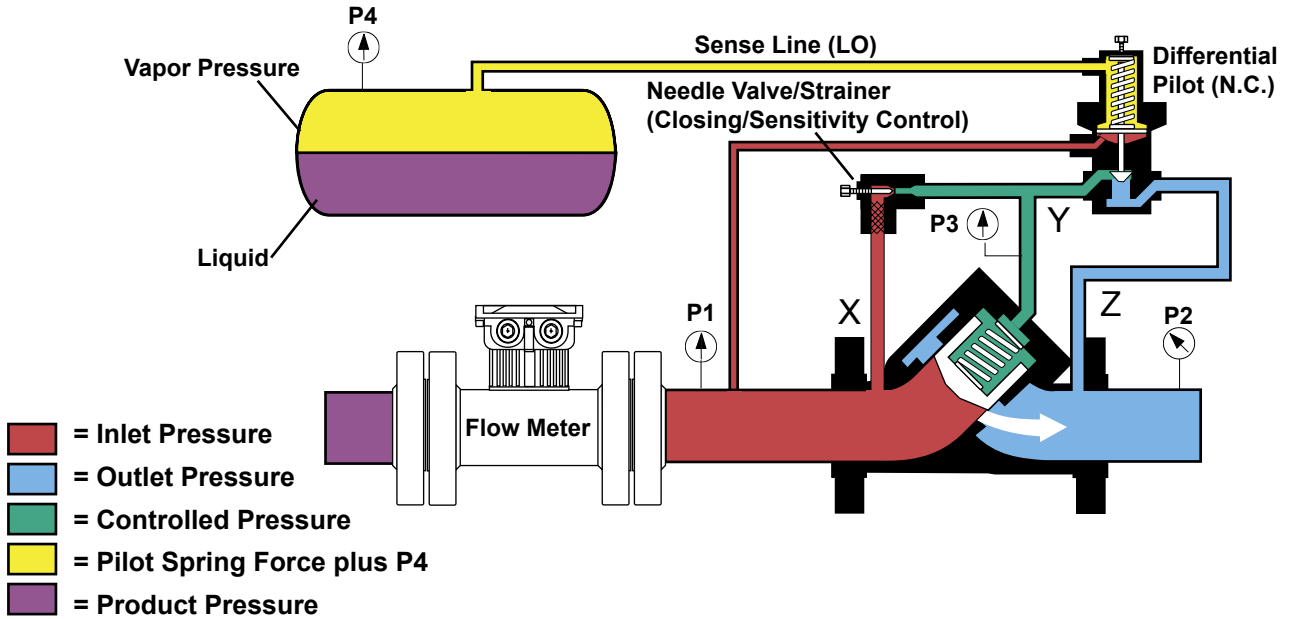


Figure 4-18

**FULL OPEN - NO CONTROL -**

The pilot is full open. Differential pressure (P1 minus P4) has exceeded the pilot spring setting. Y-port (P3) is open to Z-port (P2). The valve is floating the stream and is not required to control.

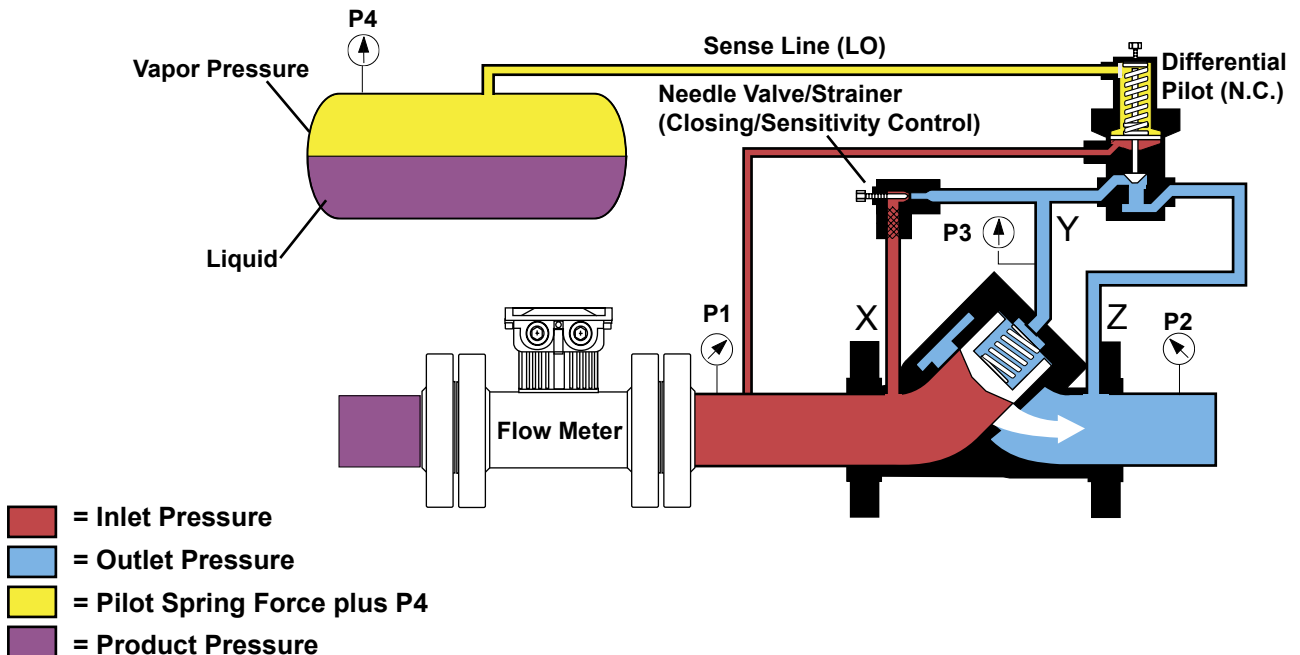


Figure 4-19

**Model 754 Rate of Flow Control (N.O.)  
Closes on increasing differential pressure**

A rate of flow or flow limiting valve is normally open and throttles toward a closed position on increasing differential pressure (P4 minus P1). It is a regulating or positioning type valve that does not require any outside power source to operate.

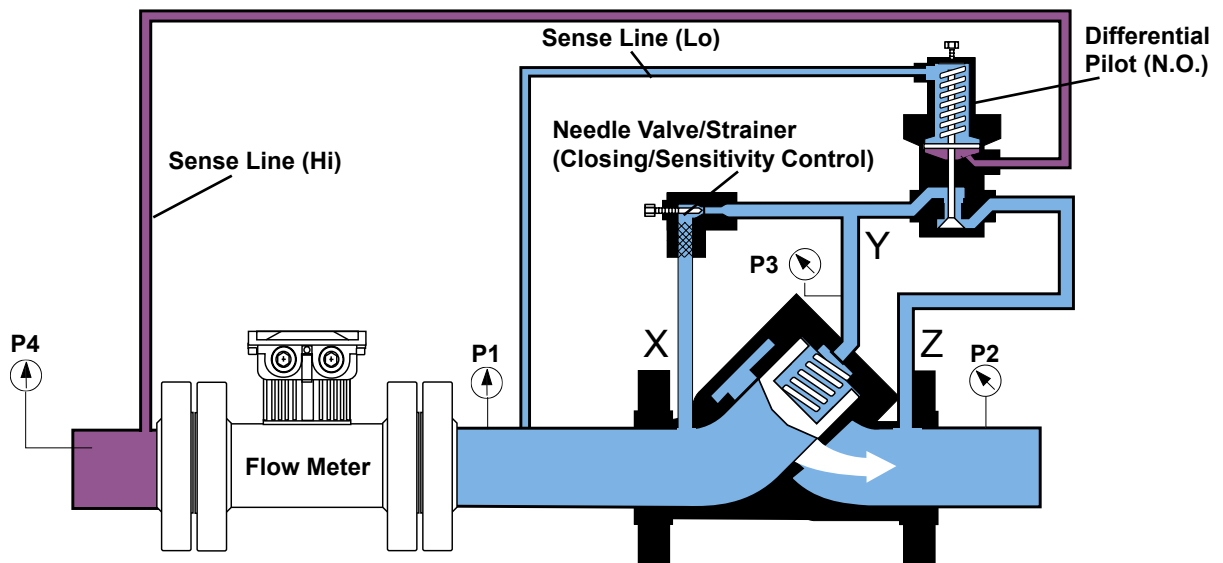
The pilot control is normally open. It is an adjustable spring loaded variable orifice in the Z-port. The pilot is piston operated, spring biased (loaded) with a differential pressure sensing chamber connected to two separate pressure sources.

Rate of flow valves are used for:

1. Limiting the maximum flow through meters.
2. Limiting the maximum flow through pumps, process streams, etc.

**FULL OPEN - NO CONTROL -**

The pilot is full open. Differential pressure (P4 minus P1) is less than the pilot spring setting. Y-port (P3) is open to Z-port (P2). The valve is floating the stream and is not required to control.



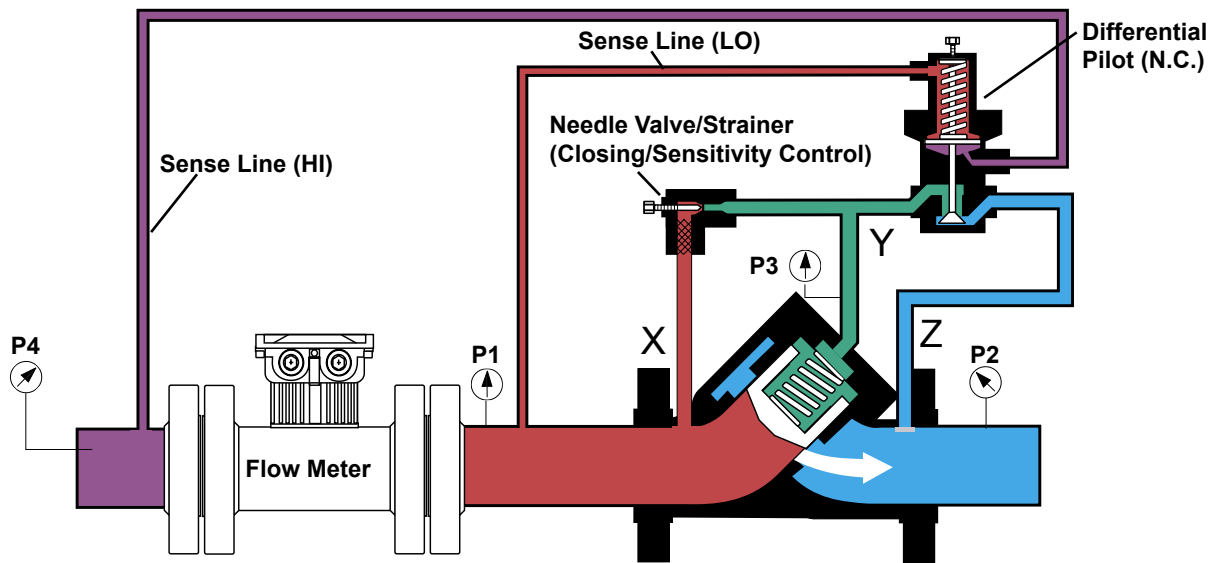
**Note: Minimum of 5 psid required for Control**

- = Inlet Pressure
- = Outlet Pressure
- = Product Pressure

Figure 4-20

**OPEN - CONTROLLED POSITION -**

The pilot is partially open. Differential pressure (P4 minus P1) has slightly exceeded the pilot spring setting. Z-port (P2) is being squeezed off by the throttling of the pilot, placing higher pressure on Y-port (P3). The increasing pressure at Y-port (P3) plus the main valve spring force establishes a position of the valve piston such that it balances differential pressure (P4 minus P1) equal to the pilot setting (plus or minus 2 psid), which is proportional to the flow rate.



Note: Minimum of 5 psid required for Control

- = Inlet Pressure and Pilot Spring Force plus P1
- = Outlet Pressure
- = Controlled Pressure
- = Product Pressure

Figure 4-21

Section 5

# MULTIPLE PILOTS (SERIES AND PARALLEL)

## Model 710S750 Combination Solenoid On-Off and Pressure Reducing Control in Series

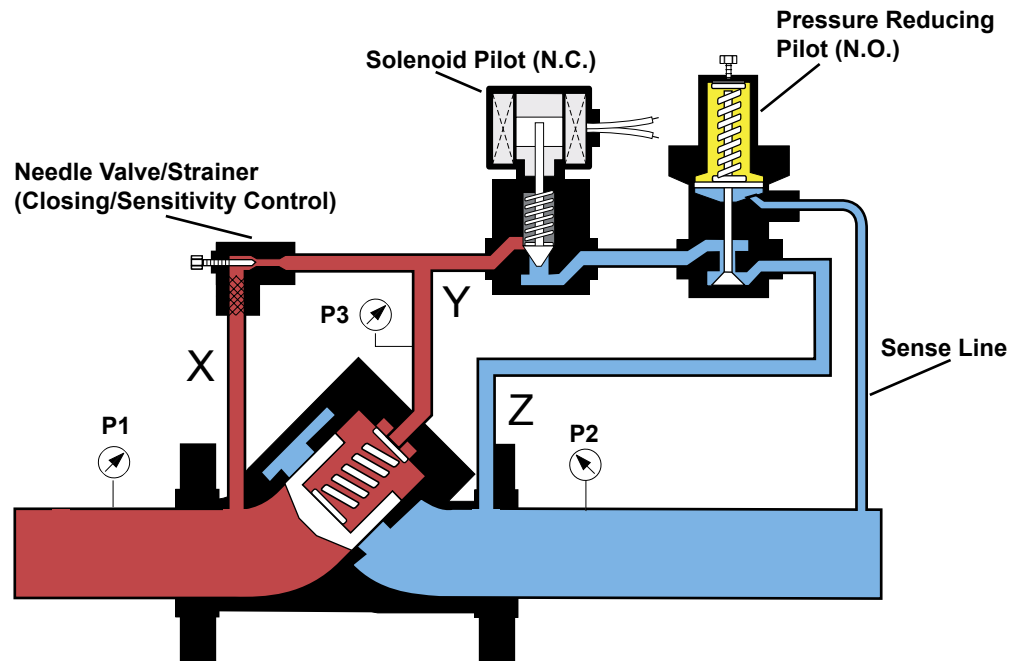
Both pilots have been illustrated as separate functions on a basic valve (Models 710 and 750). Now the pilots are combined on a single valve. This is the starting point for multiple control functions on one basic valve.

**When pilots are in a series, all pilots must be open for the main valve to open, but should one pilot close, the main valve will also close.**

The advantage of multiple controls is to incorporate various functions on a single valve.

### CLOSED POSITION –

The solenoid pilot is closed (de-energized). Y-port (3) to Z-port (P2) is closed. X-port (P1) and Y-port (P3) pressures are balanced. The main valve spring being the differential force, closes the piston and keeps it seated.



- = Inlet Pressure
- = Outlet Pressure
- = Spring Force

Figure 5-1

**OPEN CONTROLLED POSITION -**

The solenoid pilot is energized. The pressure reducing pilot is partially open. Outlet pressure has slightly exceeded the pressure reducing pilots spring setting. A-port (P2) is being squeezed off by the throttling of the pressure reducing pilot, placing higher pressure on Y-port (P3). The increasing pressure at Y-port (P3) plus the main valve spring forces establishes a position of the valve piston such that it balances outlet pressure (P2) equal to the pilot setting (Plus or minus 2 psi).

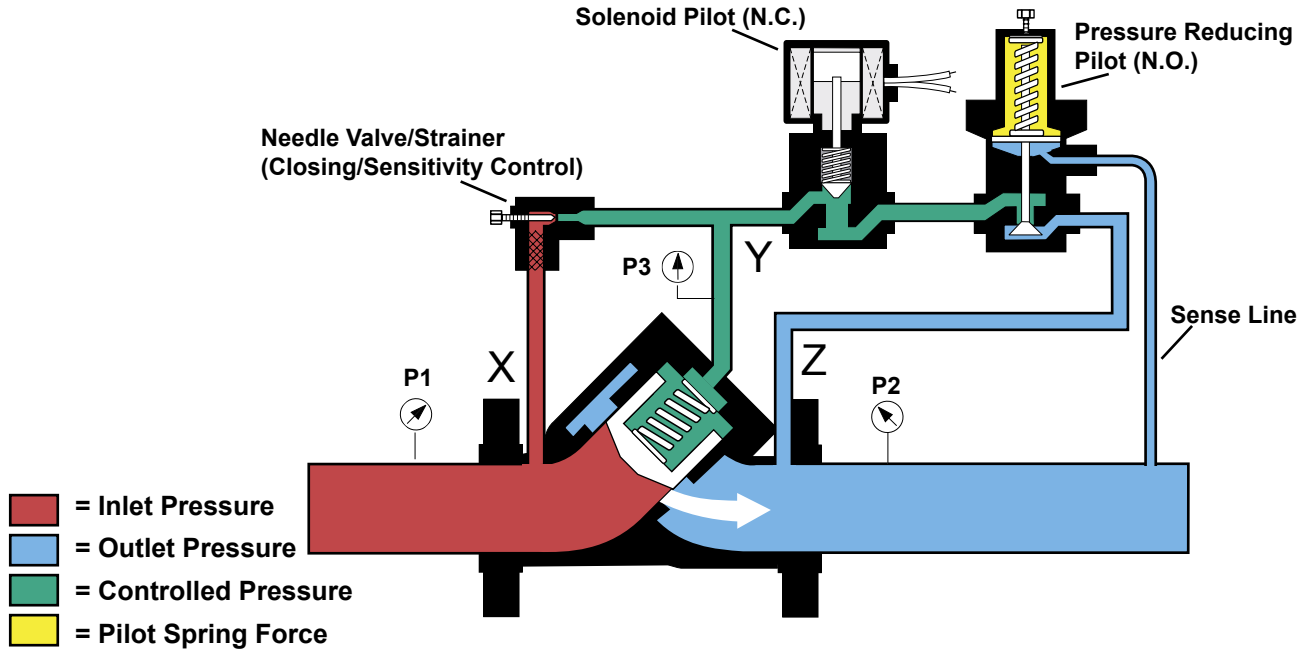


Figure 4-2

**OPEN CONTROLLED POSITION -**

Pilot is partially open. Y-port (P3) is open to Z-port (P2) but is being restricted by the control pilot. The pilot control is a variable orifice that regulates the pressure at Y-port (P3) by controlling the flow through Z-port. By increasing or decreasing the Y-port pressure (P3) causes the piston to change positions.

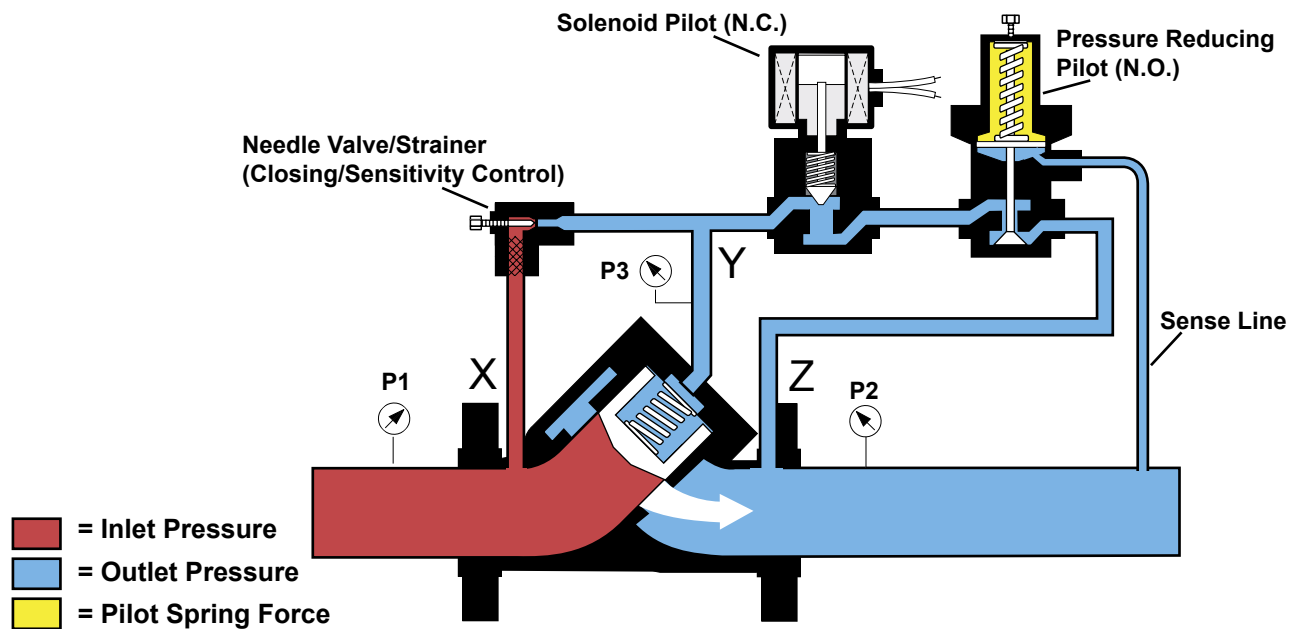


Figure 4-3

**Model 710P760 Combination Solenoid On-Off and Back Pressure Control in Parallel**

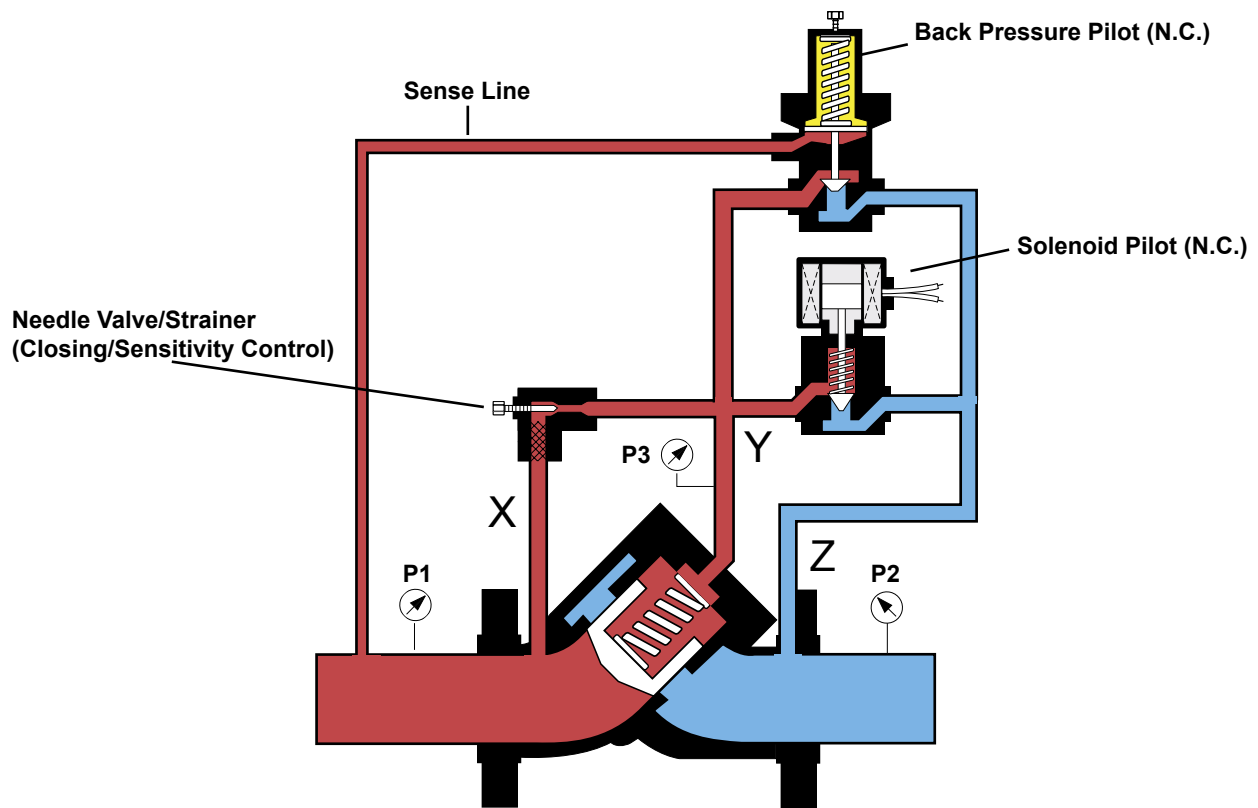
Both pilots have been illustrated as separate functions on a basic valve (Models 710 and 760). Now the pilots are combined on a single valve.

When two (2) pilots are in parallel, only one pilot must be open for the main valve to open, but both pilots must close to assure the main valve closes.

The advantage of multiple controls is to incorporate various functions on a single valve.

**CLOSED POSITION –**

Both pilots are closed. The solenoid de-energized. Inlet pressure (P1) is less than the back pressure pilot setting. Y-port (P3) to Z-port (P2) is closed. X-port (P1) and Y-port (P3) pressures are balanced. The main valve spring being the differential force, closes the piston and keeps it seated.



- = Inlet Pressure
- = Outlet Pressure
- = Pilot Spring Force

Figure 5-4



**OPEN - CONTROLLED POSITION -**

The solenoid pilot is closed (de-energized). The back pressure pilot is partially open, bypassing the solenoid pilot. Inlet pressure has slightly exceeded the back pressure pilot spring setting. Z-port (P2) is being opened by the throttling of the pilot, reducing the pressure on Y-port (P3). The decreasing pressure at Y-port (P3) plus the main valve spring force establishes a position of the valve piston such that it balances inlet pressure (P1) equal to the pilot setting (Plus or minus 2 psi).

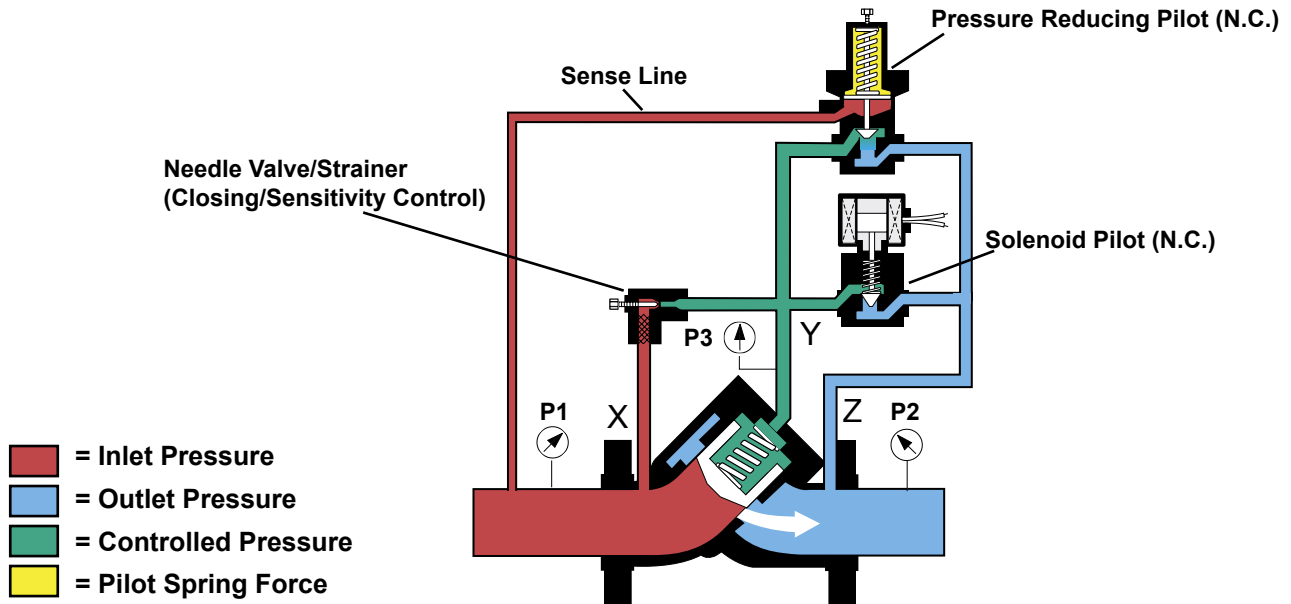


Figure 5-5

**FULL OPEN - NO CONTROL -**

The solenoid pilot is open (energized), bypassing the back pressure pilot which is closed. As long as the solenoid pilot is open, the back pressure control function is bypassed and cannot perform, even though inlet pressure (P1) is less than the pilot spring setting. Y-port (P3) is open to Z-port (P2). The valve is floating the stream and is not required to control.

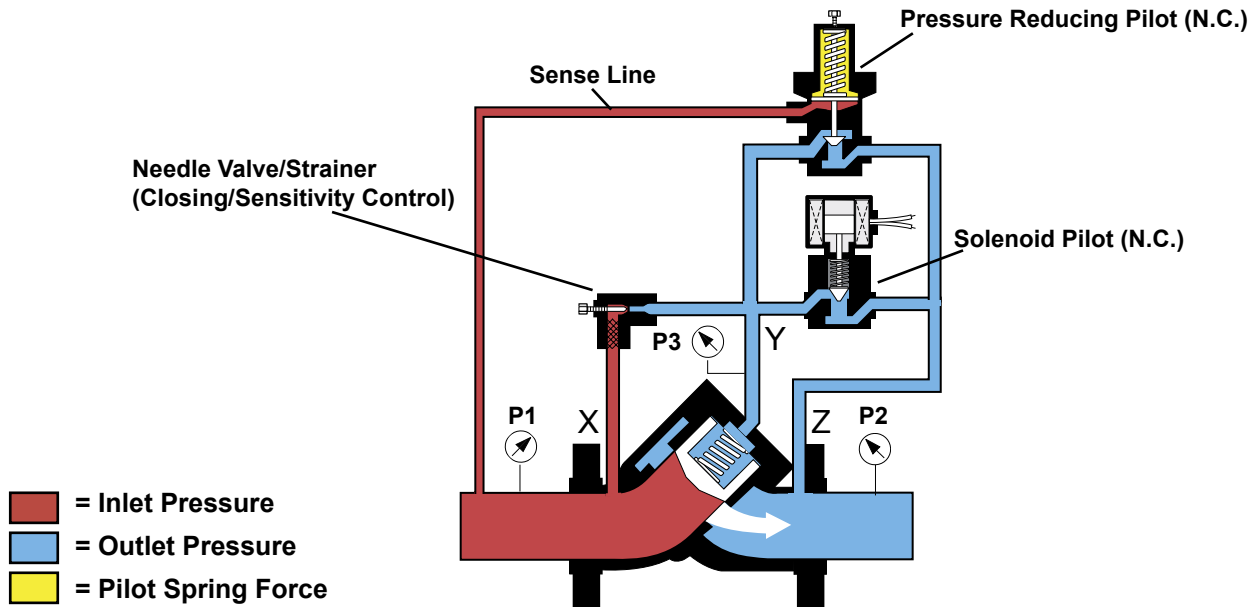


Figure 5-6

**Section 6**

**DIGITAL AND TWO-STAGE ELECTRIC SHUT-OFF VALVES**

**Model 788 DVC Digital Control Electric Shut-off Valves**

These valves are normally closed (N.C.) and they will open only when both solenoids are energized. The valves are fail-safe as they close upon loss of power. They use the line product as the source of hydraulic power to open and close the main valve piston. An electrical supply controlled by an electronic preset is the source of power for energizing the two solenoids.

These valves are used mainly for batching and they provide a means of reducing the rate of flow on startup and before final shutoff of a predetermined delivery. This minimizes surges of pressure and line shock and assures ±1/4 gallon shut-off (sizes 2 inch - 6 inch) of the preset volume.

The total system generally consists of three pieces of equipment: (1) a flowmeter, (2) electronic preset with digital control, and (3) a digital electric control valve. The electronic preset is the device used to set the predetermined volume of liquid that is to be delivered by the valve.

**Operational Sequence**

With both solenoids de-energized, the main valve is closed as shown in [Figure 6-1](#). The main valve can be infinitely positioned anywhere between 0 - 100% open by digital control of the solenoids. With both solenoids energized, as shown in [Figure 6-3](#), the valve begins to open. It will only open to the programmed flow rate set in the electronic preset. Normally, the electronic preset is programmed to digitally control low flow start-up, maximum flow rate, low flow rate before shut-off and no flow. The electronic preset will automatically energize and de-energize the solenoids to position the main valve to limit the required flow rate. When the required flow rate is reached, the solenoids will be as shown in [Figure 6-2](#). This hydraulically locks the main valve piston in position. Should flow increase, the valve will close slightly to adjust to the required flow rate. All of the positioning is done by digitally controlling the two solenoids as shown in [Figure 6-1](#), [6-2](#) and [6-3](#).

**CLOSED POSITION –**

The normally closed solenoid is closed. The normally open solenoid is open. Y-port (P3) to Z-port (P2) is closed. X-port (P1 and Y-port (P3) pressures are balanced. The main valve spring being the differential force, closes the piston and keeps it seated.

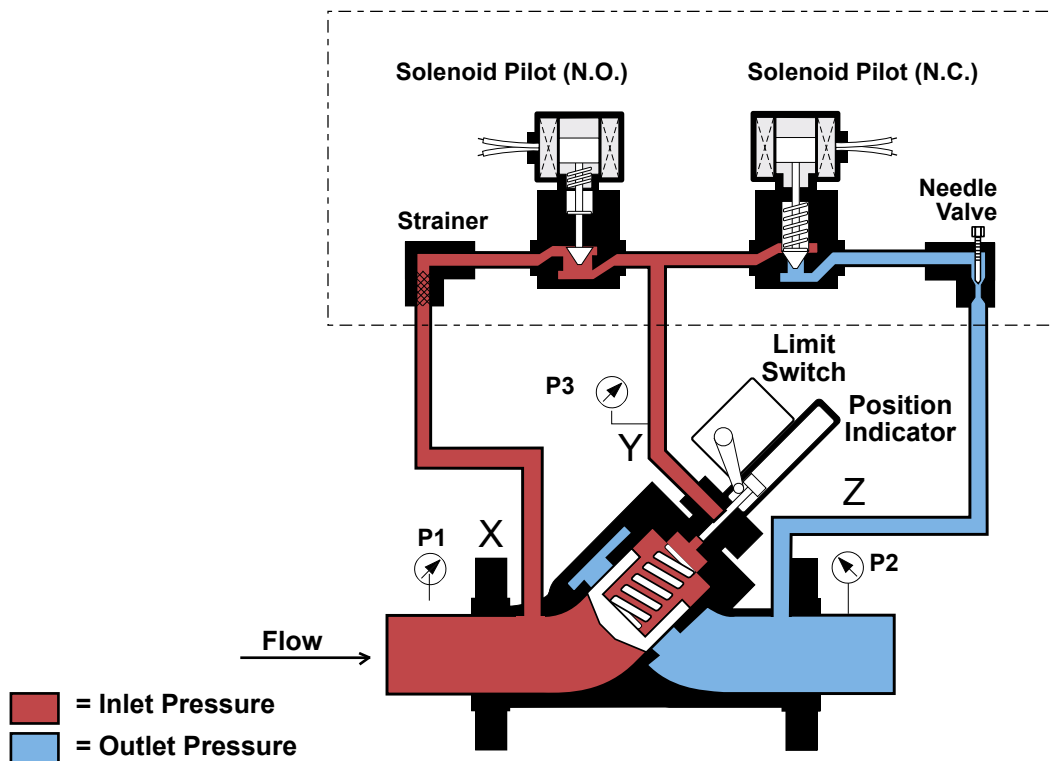


Figure 6-1

**OPEN - CONTROL POSITION -**

The normally closed solenoid is closed. The normally open solenoid is closed. Y-Port (P3) to Z-port (P2) is closed. X-port (P1) to Y-port (P3) is closed. The product cannot flow to or from the top of the piston. The piston is hydraulically locked in position until the electronic preset commands the

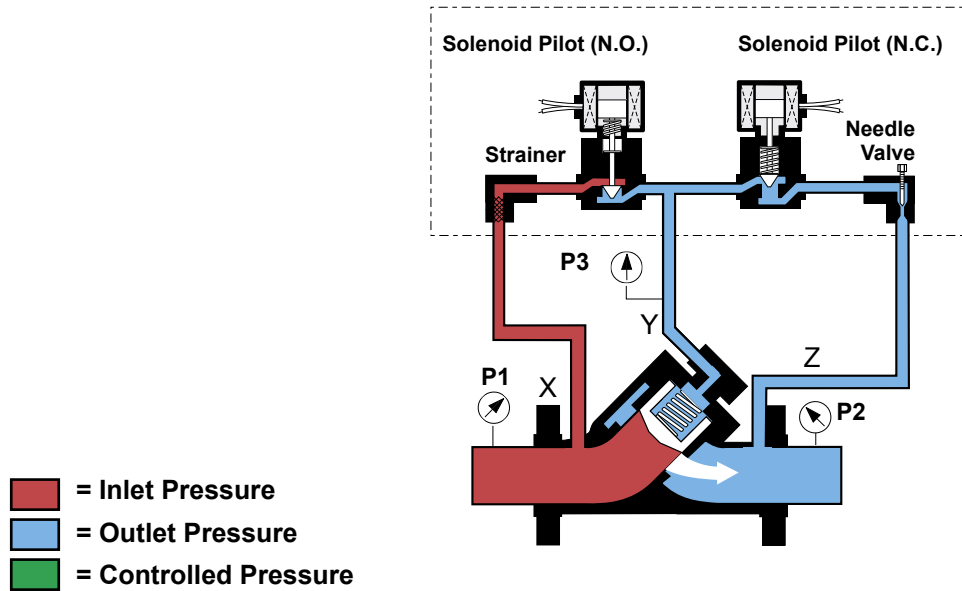


Figure 6-2

**OPEN POSITION -**

(no control) - The normally closed solenoid is open. The normally open solenoid is closed. Y-port (P3) is open to Z-port (P2). X-port (P1) is closed off by the normally open solenoid. The pressure on the bottom of the piston (P1) is greater than the pressure at (P3) plus the spring force; (P1 minus P2) is equal to or greater than the spring force. Therefore, (P1) pressure pushes the piston open. No flow control is required.

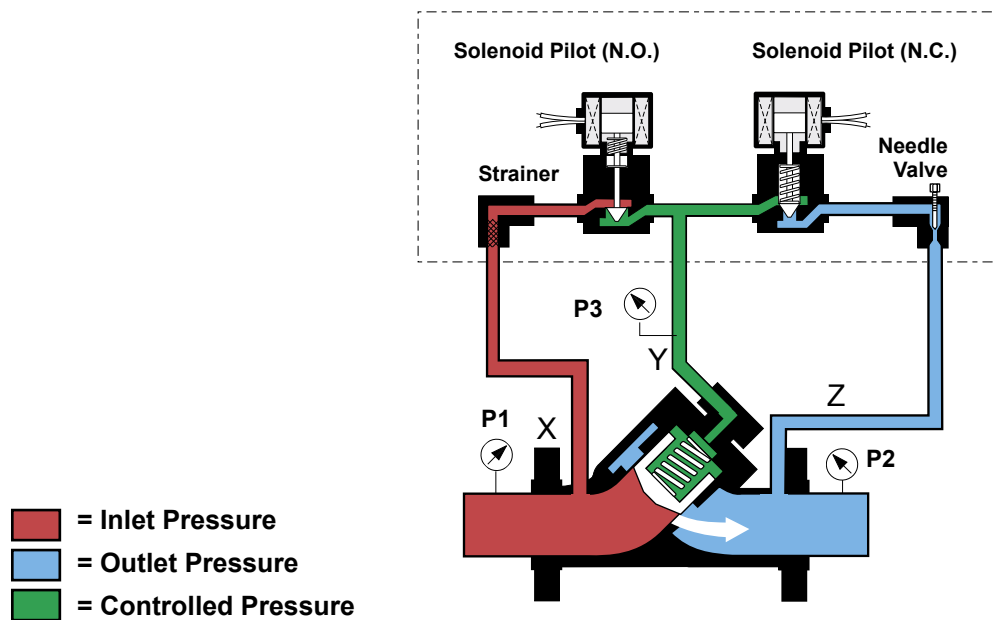


Figure 6-3

**Section 7**

**POWER CYLINDER OPERATED VALVES**

**Model 531, 535, 578 and 588 (N.C.) Pressure to Open and Model 532 and 536 (N.O.) Pressure to Close**

Power cylinder operated valves can perform various functions. The power cylinder can be full open or closed or the pressure can be regulated for two-stage batch control or digital batch control.

All valves employ a bias spring in the power cylinder. There is no spring behind the main valve piston. The power cylinder spring requires 30 psi to make a full stroke. An optional spring to make a full stroke at 15 psi is available for selected applications.

These valves use the line product or an auxiliary supply pressure (pneumatic or hydraulic) to operate the power cylinder. The main valve piston and the power cylinder piston are of balanced design.

The valves are used in a variety of applications such as:

1. Automatic tank safety shut-off
2. Line block valve
3. Emergency shut-off or opening
4. Batching, single or two-stage operation, or digital batch control

The pressure drop across the valve is very low as it follows a Cv curve. Anytime the valve is closed, it is inherently a check valve without adding any additional controls. The main valve piston is balanced at all positions.

**CLOSED POSITION –**

The differential pressure between (P1) and (P2) is less than the spring force of the power cylinder spring. This indicates the pump is not running or insufficient differential pressure (P1 minus P2) to overcome the spring force of the power cylinder spring. The power cylinder spring provides the differential force to close the main valve piston and/or keep it seated.

**TANK SAFETY CONTROL**

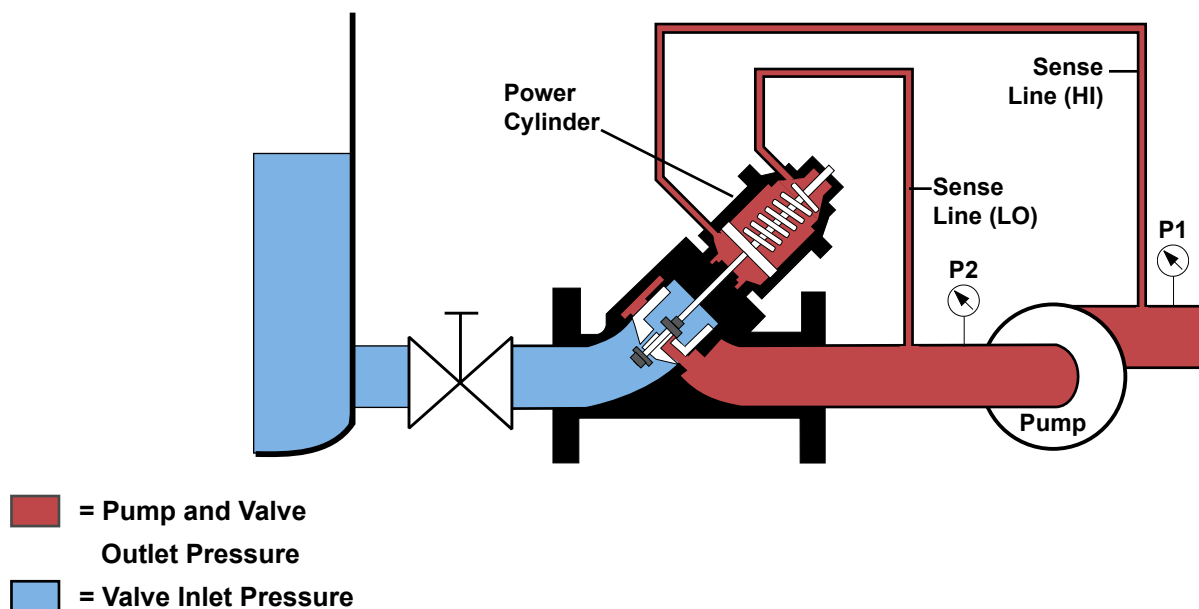


Figure 7-1

**OPEN POSITION -**

The differential pressure between (P1) and (P2) has exceeded the total spring force of the power cylinder spring (P1 minus P2). This keeps the valve in a full-open position.

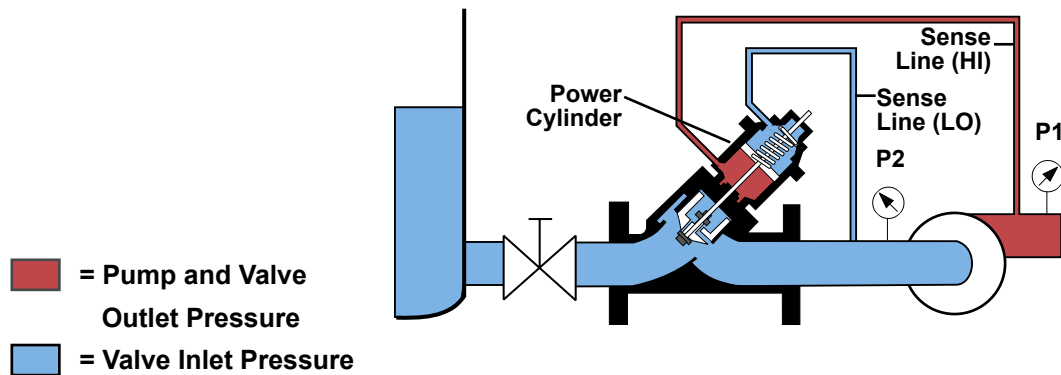


Figure 7-2

**7-3 CLOSED POSITION -**

The solenoid pilot is de-energized. This blocks the supply of pressure and vents the power cylinder pressure (P3) to atmosphere. The power cylinder spring provides the differential force to close the main valve piston and keep it seated. The valve will not allow flow from the forward or reverse direction. 7-4 OPEN POSITION - The solenoid pilot is energized, thus opening the supply pressure to the power cylinder (P3). The supply pressure is equal to or greater than the total spring force. This keeps the valve in a full-open position. Product can flow through the main valve in either direction.

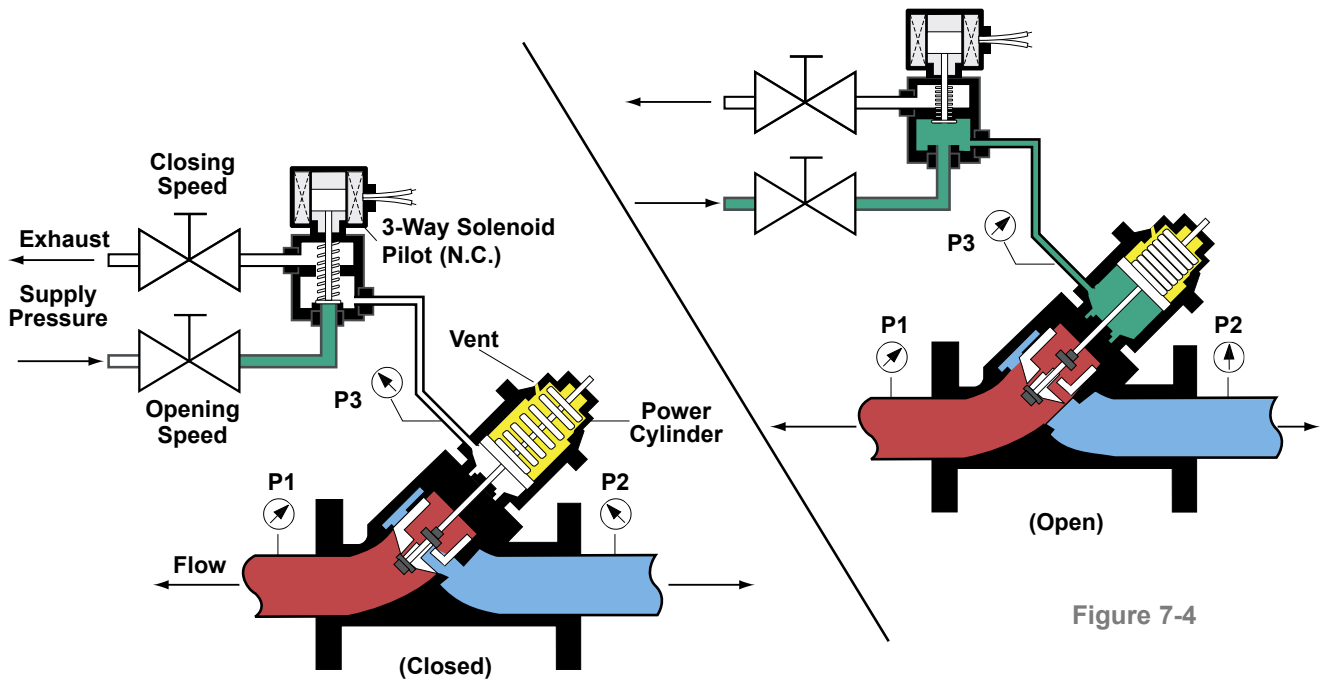


Figure 7-3

Figure 7-4

- = Inlet Pressure
- = Outlet Pressure
- = Power Cylinder Supply Pressure
- = Power Cylinder Spring Force

# DIGITAL CONTROL VALVES

## Model 588 DVC (N.C.) Digital Control Electric Shut-off Valve

Digital Control electric shut-off valves are normally closed (N.C.) and they will open only when both solenoids are energized. The valves are fail-safe as they close upon loss of auxiliary power medium. They use an auxiliary power source (typically regulated instrument air) to open and position the valve. An electrical supply controlled by an electronic preset is the source of power for energizing the two solenoids.

These valves are used mainly for batching and they provide a means of reducing the rate of flow on startup and before final shutoff of a predetermined delivery. This minimizes surges of pressure and line shock and assures ±1/4 gallon shut-off (sizes 2" - 6") of the preset volume.

The total system generally consists of three pieces of equipment: (1) a flowmeter, (2) electronic preset with digital control, and (3) a digital electric control valve. The electronic preset is the device used to set the predetermined volume of liquid that is to be delivered by the valve.

### Operational Sequence

With both Solenoids de-energized, the main valve is closed as shown in [Figure 7-5](#). The main valve can be infinitely positioned anywhere between 0-100% open by digital control of the solenoids. With both solenoids energized, as shown in [Figure 7-7](#), the valve begins to open. It will only open to the programmed flow rate set in the electronic preset. Normally, the electronic preset is programmed to digitally control low flow start-up, maximum flow rate, low flow rate before shut-off and no flow. The electronic preset will automatically energize and de-energize the solenoids to position the main valve to limit the required flow rate. When the required flow rate is reached, the solenoids will be as shown in [Figure 7-6](#). This pneumatically locks the power cylinder piston in position. Should flow increase, the valve will close slightly to adjust to the required flow rate. All of the positioning is done by digitally controlling the two solenoids as show in [Figure 7-5](#), [7-6](#) and [7-7](#).

### CLOSED POSITION –

The normally closed solenoid is closed. The normally open solenoid is open, venting the power cylinder pressure (P3) to atmosphere. The power cylinder spring provides the differential force to close the main valve piston and keep it seated. The closing speed needle valve controls how fast the valve closes or responds to a flow rate change.

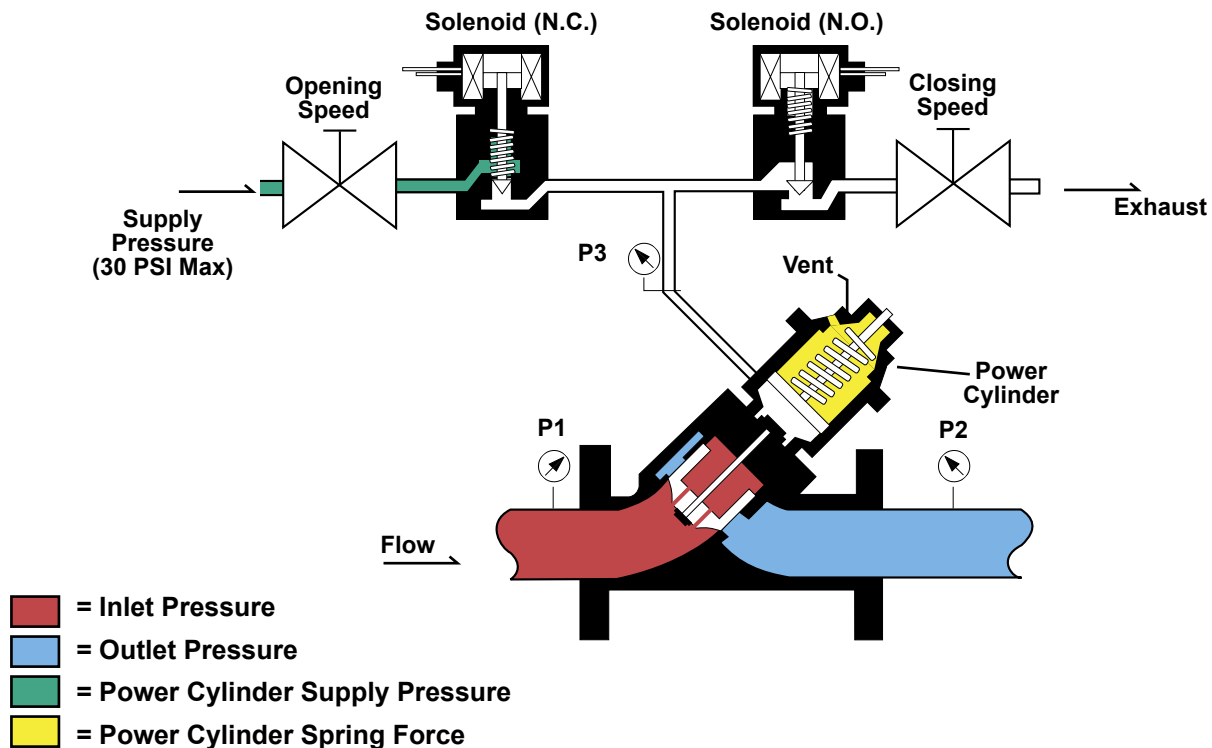


Figure 7-5

**OPEN - CONTROL POSITION -**

The normally closed solenoid is closed. The normally open solenoid is closed. The power cylinder medium (P3) cannot flow to or from the power cylinder. The piston is pneumatically locked in position until the electronic presets command the valve to open or close as required to maintain the desired flow rate.

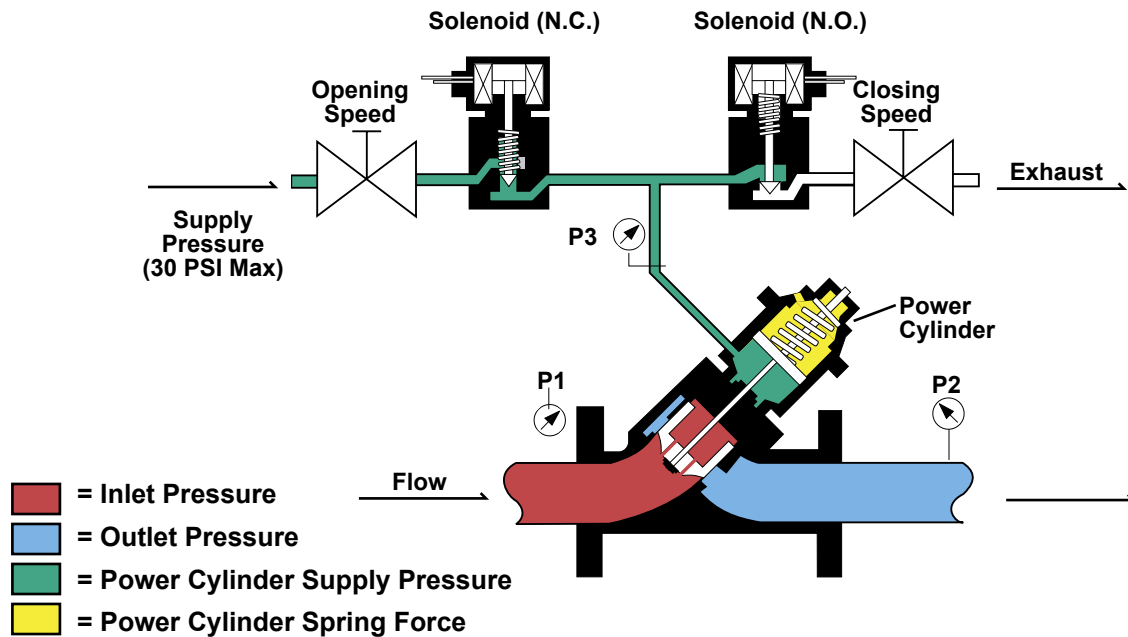


Figure 7-6

**OPEN POSITION - NO CONTROL -**

The normally closed solenoid is open. The normally open solenoid is closed, blocking the exhaust port, and pressure (P3) is applied to the power cylinder. The pressure on the bottom of the power cylinder piston (P3) is greater than the pressure applied by the spring force. Therefore, causing the valve to go full open (No Control). The opening speed needle valve controls how fast the valve opens or responds to a flow rate change.

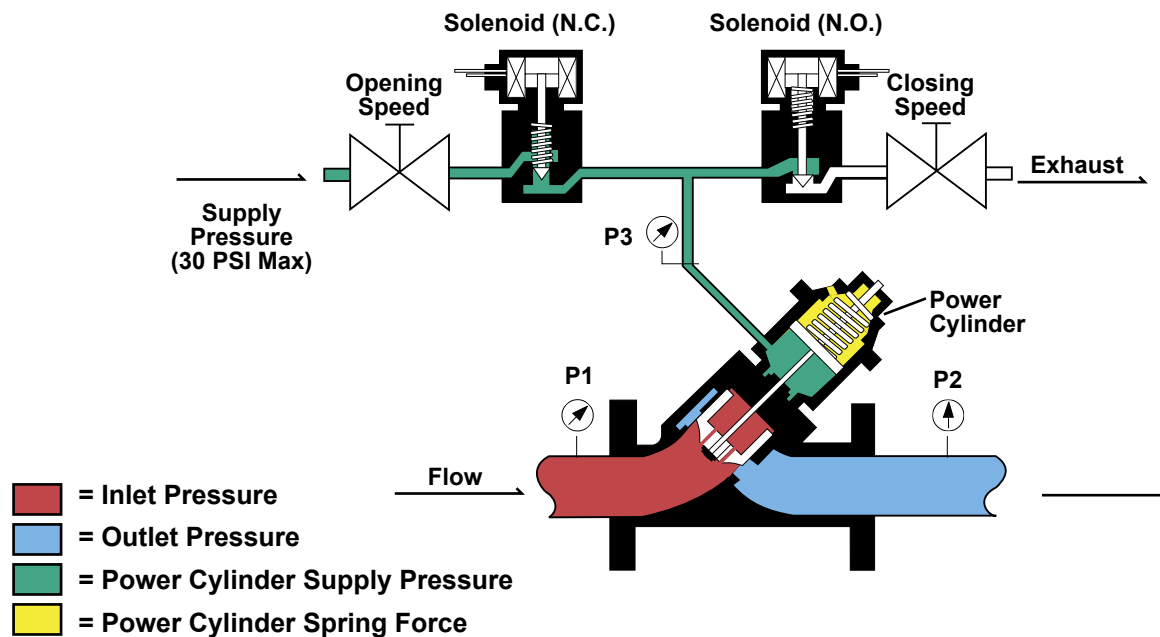


Figure 7-7

# TWO STAGE VALVES

## Model 578 (N.C.) Two-stage Electric Shut-off Valve

Two-Stage Control electric shut-off valves are normally closed (N.C.) and they will open only when both solenoids are energized. The valves are fail-safe as they close upon loss of auxiliary power medium. They use an auxiliary power source (typically regulated instrument air) to open and position the valve for high and low flow. Flow limiting control is not available. An electrical supply controlled by a preset is the source of power for energizing the two solenoids.

These valves are used mainly for batching and they provide a means of reducing the rate of flow on startup and before final shut-off of a predetermined delivery. This minimizes surges of pressure and line shock and assures  $\pm 1/4$  gallon shut-off (sizes 2" - 6") of the preset volume.

The total system consists of four pieces of equipment: (1) a flow meter, (2) a preset counter, (3) dual sequencing switches, and (4) a two-stage electric shut-off valve. The preset counter is the device used to set the predetermined volume of liquid that is to be controlled by the valve. The valve closes in two stages. The first stage closure reduces the flow rate through the valve to approximately 10% to 20% of the rated capacity of the meter. The second stage closes the valve when the predetermined volume of liquid has passed through the meter. See Figures 7-8, 7-9 and 7-10.

### CLOSED POSITION –

The normally closed solenoid is closed. The normally open solenoid is open, venting the power cylinder pressure (P3) to atmosphere. The power cylinder spring provides the differential force to close the main valve piston and keep it seated. The closing speed needle valve controls the closing speed.

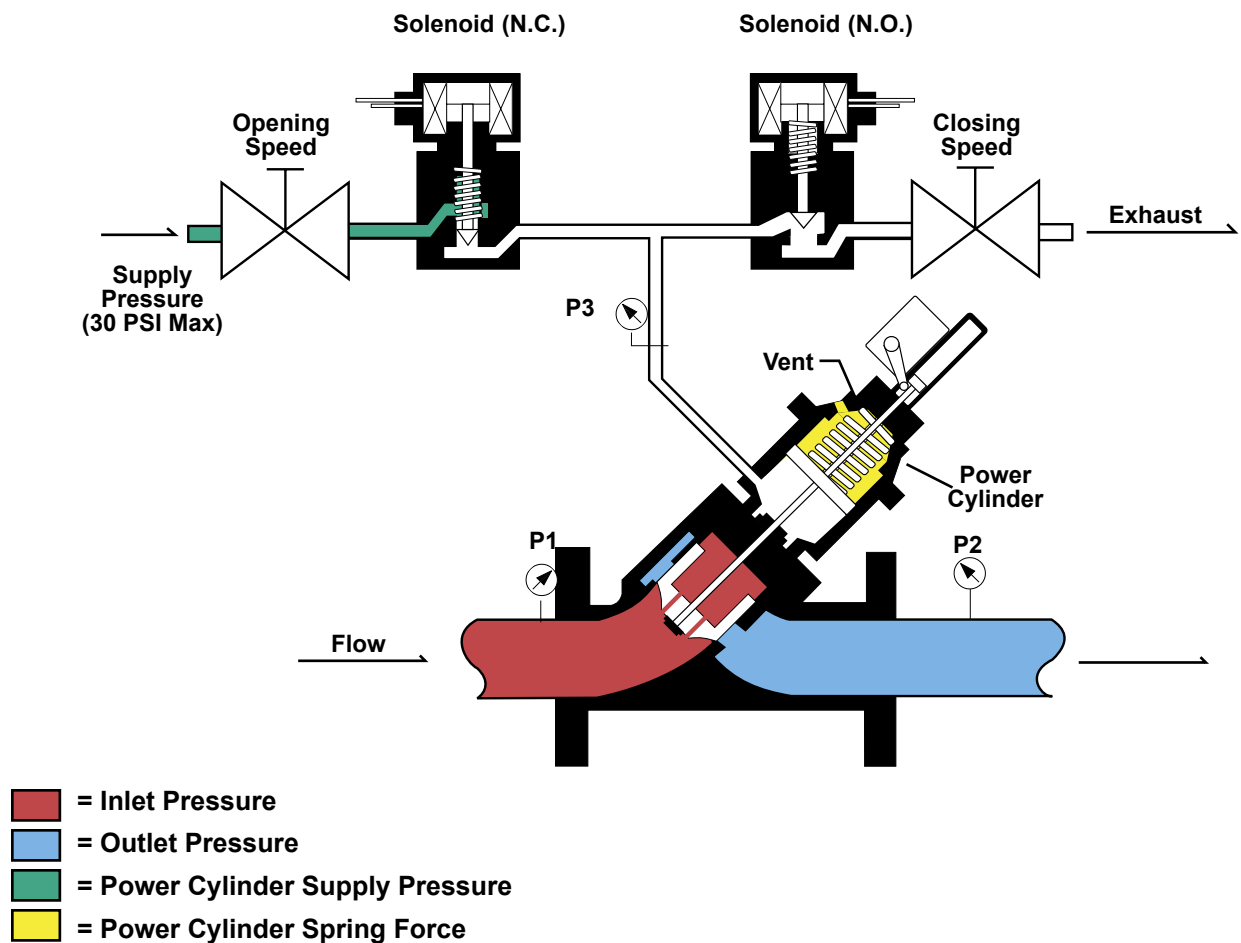


Figure 7-8



**OPEN - HIGH FLOW POSITION -**

The normally closed solenoid is open. The normally open solenoid is closed blocking the exhaust vent and pressure (P3) is applied to the power cylinder. The pressure on the bottom of the power cylinder piston (P3) is greater than the pressure applied by the spring force, therefore, causing the valve to go full open. (Maximum flow limiting control is not available).

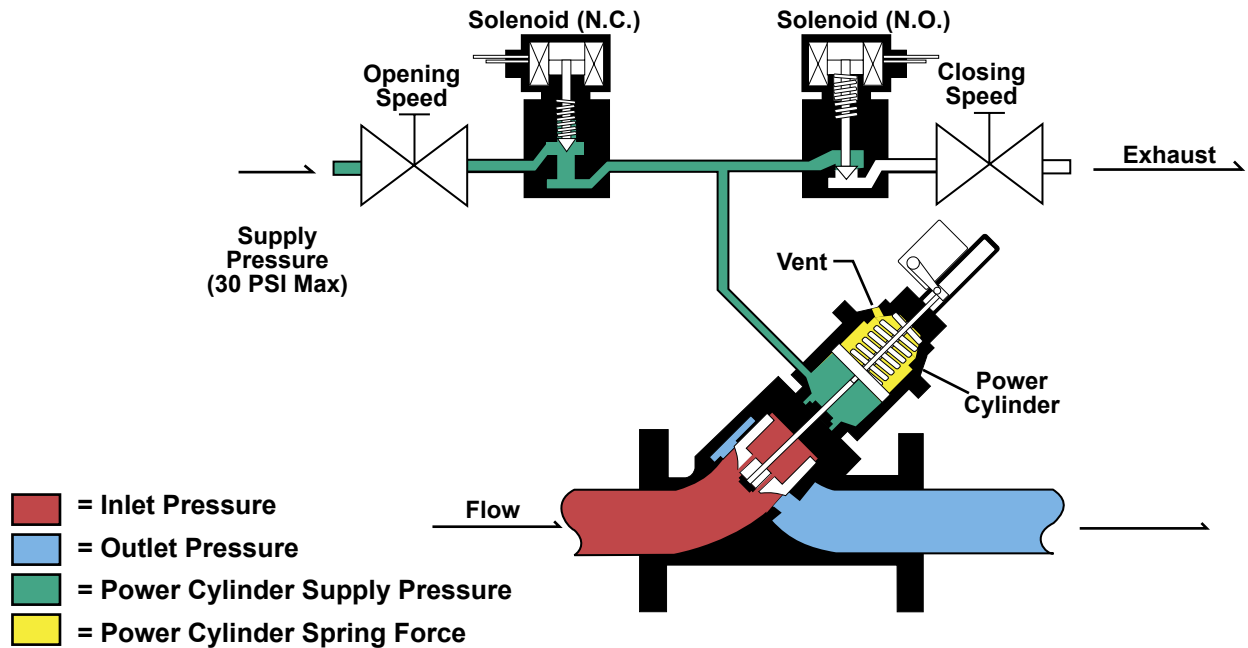


Figure 7-9

**OPEN LOW FLOW POSITION -**

The normally closed solenoid is closed. The normally open solenoid is closed. The power cylinder supply pressure (P3) cannot flow to or from the power cylinder. During the transition stage from high flow to low flow, the normally closed solenoid was closed and the normally open solenoid was open, venting the power cylinder medium through the exhaust port closing speed needle valve. When the valve reaches a predetermined low flow rate equal to 10% to 20% of the maximum flow rate, the limit switch is activated resulting in the normally open solenoid closing. This pneumatically locks the valve in a fixed position until the preset commands the valve to close. (Low flow start-up is available as an option).

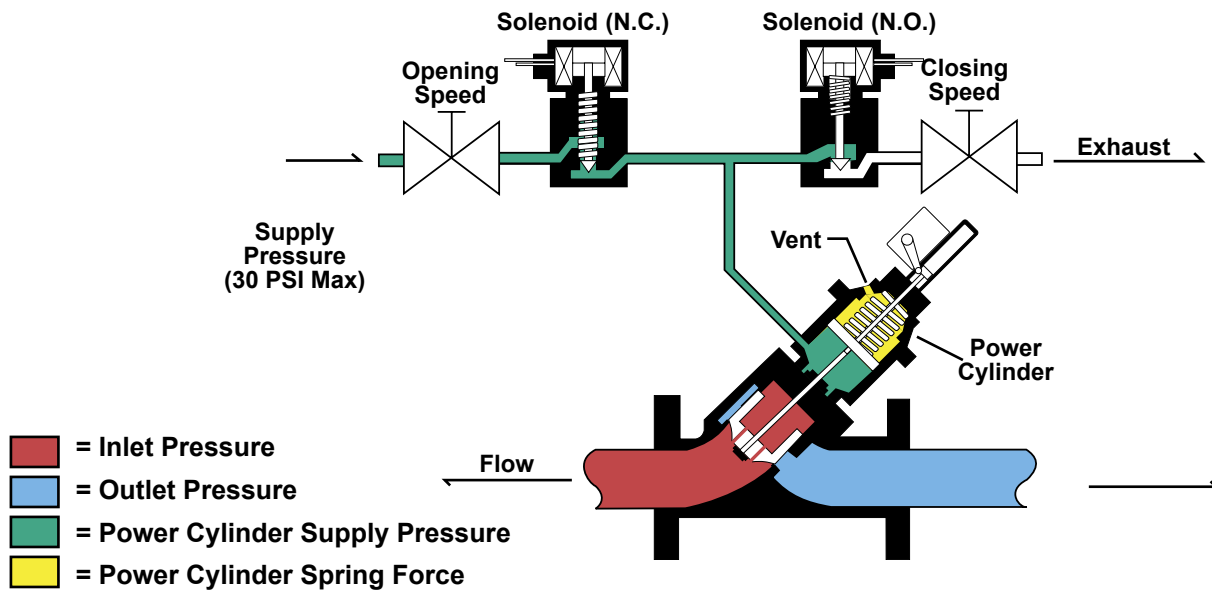


Figure 7-10

January 2022

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