Valve Accessories

In this section on valve accessories we will discuss valve actuators, control valve positioners, limit switches, position transmitters, volume boosters, solenoid valves, quick exhaust valves and lock-up valves
Globe Valve Actuators

Nearly all globe control valve actuators are the spring and diaphragm type shown above. These come in two configurations, **Direct acting** and **Reverse acting**. **Direct acting** means that putting air into the actuator causes the actuator stem to extend out of the actuator. **Reverse acting** means that putting air into the actuator causes the stem to retract into the actuator. Since all modern globe valves close when the valve stem is pushed down, that means that the direct acting actuator has an air to close (thus also fail open) action. The reverse acting actuator has an air to open (and thus fail closed) action.
Samson (and some other manufacturers of newer design valves) use actuators like this one, where the springs are inside the diaphragm case, making a much more compact design, and also a design that can be easily changed between “fail open” and “fail closed.”

Something you need to keep in mind when specifying Samson actuators, is that Samson does not use the “direct” and “reverse” acting terminology. Instead, Samson names their actuator action by what the stem does on LOSS of air.

What would have been called “direct acting” (stem extends on application of air), Samson calls “stem retracts” because that is what happens on loss of air. Likewise, what would have been called “reverse acting” (stem retracts on application of air) Samson calls “stem extends” because that is what happens on loss of air.
The simplest and least expensive of the rotary actuators is the double acting piston actuator.

There are four common types of mechanisms for converting linear to rotary motion, rack and pinion, pinned crank, scotch yoke and articulated crank. Starting with the next slide, we will look at the torque output characteristics of each type.
The torque graphs for all of these actuators is torque factor vs. the actuator’s angular position. A torque factor of 100 is the rated, or nominal, torque of the actuator.

The motion conversion mechanism of the rack and pinion is gear teeth attached to the pistons, turning a gear (pinion). The moment arm distance between the rack and the center of the pinion remains constant at all times, so the torque output is constant at the actuator’s rated torque at all degrees of opening as shown in the orange graph.

The actuator pictured here is the Jamesbury “RP” (which stands for rack and pinion).
The pinned crank actuator gets its name from the fact that the rod that connects the piston and the crank arm is pinned at both ends and both connections are free to rotate around the pin.
As air pressure moves the piston downward, the rod connecting the piston to the crank arm rotates around the pins at each end. When the piston is at mid position, as shown with the black lines, the moment of the crank arm is longer than it was at the beginning of the stroke, so the torque curve peaks at mid stroke as shown in the cyan curve.

The pinned crank actuator pictured here is the Jamesbury ST actuator which is no longer made. We are discussing the pinned crank design here, because it will help us understand the Jamesbury QuadraPowr spring and diaphragm actuator which is a pinned crank design.
In the scotch yoke mechanism, the rod that is attached to the piston has a solid fixed connection that cannot rotate. Also there is a bearing at the bottom of the cylinder. As a result the rod can only move up and down in a straight line.
As air pressure moves the piston downward, the rod connecting the piston to the crank arm slides in the slot toward the rotating shaft. At mid position the moment arm is shorter than it was at the beginning of the stroke, so the torque curve starts and ends high and reaches a minimum at mid stroke as shown in the pink curve.
The geometry of the articulated crank is fairly complex and produces a complex torque output curve as shown in the purple curve. The picture and diagram are of the Metso BC double acting piston actuator.
Here we have added a typical torque requirement curve for a butterfly valve. The torque requirement is greatest when the disk is coming out of or going into the seat at zero degrees of rotation. The torque requirement drops significantly when the disk has cleared the seat. Dynamic torque caused by flow interacting with the disk peaks somewhere around 80 degrees.

The maximum torque requirement was arbitrarily drawn at 90% of the rated actuator torque because actuators for on-off service are typically selected to have at least a 10% safety factor. Rated actuator torques and valve torque requirements are usually quite conservative, so only a small safety factor is necessary.

In the throttling range for valves in control service, in order to get very smooth accurate control, it is necessary to have the actuator torque capability be much greater than the valves torque requirement.

To easily compare torque requirements with available actuator torque, we often use the term “Load Factor,” where the load factor is the percentage of the actuator’s torque capability that is required by the valve at any particular degree of rotation. At the point where the valve is going into or out of the seat, Neles recommends that the load factor be less than or equal to 90%, that is the seating torque needs to be less than 90% of the actuator’s capability at that point. In the throttling range, Neles recommends that the load factor in the throttling range be less than 60%, and the lower the better.
The ball valve torque requirement is similar in shape to that of the butterfly valve. (As with the butterfly valve curve this one is typical, however actual values will depend on valve construction, shutoff pressure and the pressure drop across the valve when it is throttling.)

When seating and unseating, the ball valve has several degrees of “dead angle” where the ball is turning but the waterway in the ball is fully covered by the seat and there is no flow so the full shutoff pressure is pushing the ball into the seat. Also the ball valve torque does not drop as low as the butterfly does because the ball is always in contact with the seat.

The pinned crank and articulated crank are the preferred construction for control valves because of the extra spare torque in the throttling range.
The Jamesbury spring and diaphragm QuadraPowr rotary actuator uses the pinned crank mechanism, and therefore has a torque curve that peaks mid stroke.

The torque curves of spring return actuators are made more complex by the addition of the spring forces, and the curves are different for the air stroke and the spring stroke. During the air stroke (the red curve on the graph), air is causing the actuator to move away from the 0 degree position and generating torque, but is fighting against the spring whose opposing force increases as the actuator rotates toward the 90 degree position. The air stroke torque starts out high when the spring is lightly compressed, and ends up low when the spring is fully compressed.

During the spring stroke (the blue curve on the graph), the spring force is causing the actuator to move away from the 90 degree position and is generating torque, but the spring force decreases as the actuator rotates toward the 0 degree position at the end of the spring stroke and the spring unwinds. The spring stroke starts out high and ends up low.

To be sure that an actuator has sufficient torque to get the valve into and out of the seat, size the actuator so that the torque at the end of the stroke that closes the valve is greater than the torque required to get the valve into and out of the seat.

For example, for a fail closed valve, that is, a valve that the spring stroke closes the valve, looking at the green graph you can see that the actuator torque at the end of the spring stroke that closes the valve into the seat is lower than the actuator torque at the beginning of the air stroke that opens the valve out of the seat, so it is the actuator torque at the end of the spring stroke that is critical.

For a fail open valve, that is, a valve that the air stroke closes the valve, looking at the orange graph you can see that the actuator torque at the end of the air stroke that closes the valve into the seat is lower than the actuator torque at the beginning of the spring stroke that opens the valve out of the seat, so it is the actuator torque at the end of the air stroke that is critical.
Manual overrides are sometimes specified for both on/off and modulating actuators.

The jackscrews are the least expensive but require more force and are recommended for infrequent use. They can also be used to limit valve position in the spring direction.

Though not shown, there is a top mounted jackscrew, similar to the one shown for globe valves, available for the spring and diaphragm rotary actuator.

The side mounted globe valve hand wheel, geared de-clutchable and hydraulic types are more expensive and easier to operate and are recommended when frequent manual operation will be required. Note that the de-clutchable hand wheel mounts in the same place where a positioner goes, so it is not applicable to control valves.
Next, we will talk about valve positioners, followed by a brief discussion of limit switches and position transmitters.

A control valve positioner is a device that receives a control signal from a process control system, measures the valve’s current position, then sends air to the actuator until the valve positions itself at the required position.
When pneumatic controllers and pneumatic control valves first came into use the controller output was connected directly to the valve’s spring diaphragm actuator. (The circle with “FC” inside it is the symbol for a Flow Controller) The line connecting the flow controller to the valve’s actuator with little hash marks drawn across it is the symbol for pneumatic tubing carrying a pneumatic control signal of 0 to 20 psi. Since a maximum of only 20 psi air pressure was available, the actuator had to be larger than it would have needed to be if more pressure was available. Because there was only a single output from the controller, the actuator had to be a spring return type.

The addition of a pneumatic positioner made it possible to use higher supply pressures making it possible to significantly reduce the size of the actuator and increase valve response time because the positioner could provide greater air volume. If process dynamic forces try to move the valve, the positioner immediately resists any undesired valve movement, having the effect of making the actuator much stiffer than it would be without the positioner. Without a positioner there is only one source of air pressure, so only spring return actuators can be used. Positioners can be designed so that there are two air outputs, one that tends to open the valve and one that tends to close the valve, making it possible us use double acting actuators which are lighter in weight, smaller and less expensive than spring return actuators. When a pneumatic control signal is used, it is almost always a signal ranging between 3 psi and 15 psi, where 3 psi represents 0% and 15 psi represents 100%.

With the introduction of electronic control systems, the addition of a current-to-pneumatic converter mounted on or near the valve took care of the signal conversion from an electrical control signal to a pneumatic control signal. Even with the introduction of electro-pneumatic positioners the use of pneumatic positioners and I to P converters has persisted in many places. One reason for this is that some electro-pneumatic positioners, especially older ones, are sensitive to vibration. The I/P converter is often mounted on a wall away from the vibration.

(Generally there is about a 5 psi pressure loss in the positioner. This is why the figures show a 65 psi air supply and 0-60 psi going to the actuator.)
The next step in positioner evolution was to eliminate the I/P converter …..(continued on next page)
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…and replace the pneumatic positioner with an electropneumatic positioner. The 4-20 mA signal from an electronic controller is connected directly to the electro-pneumatic positioner eliminating the need for an I to P converter. It also eliminates the dynamics introduced by the I to P converter and eliminates the need for calibrating the I to P converter.
The next, and most recent step in the evolution of control valve positioners is the smart digital positioner. The levers and springs in the electro-pneumatic positioner are replaced by a micro processor. The microprocessor can improve performance and provide additional features.

It improves control performance because the microprocessor can run an advanced control algorithm.

The microprocessor can also generate diagnostic information that tells us if the valve’s control performance is starting to degrade, so that we can plan maintenance at a convenient time before it impacts on product quality.

The connection diagram is the same as the one we saw previously for the electro-pneumatic positioner. The point is that there is nothing special that needs to be done to install a digital positioner. You simply connect the control signal and the air supply.
Positioners can change the flow characteristic of the valve. The mechanical analog positioners do this by installing specially shaped feedback cams. The digital positioners accomplish the same thing by modifying the positioners output through software.
Positioners, What They Do

- Reduce required actuator size
- Increase valve response time
- Increase actuator stiffness
- Allow use of double acting actuators
- Change flow characteristic.

This is a summary of the things that positioners do.
<table>
<thead>
<tr>
<th>Year</th>
<th>Pneumatic Positioners</th>
<th>Electro-pneumatic Positioners</th>
<th>Digital Positioners</th>
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<tr>
<td>1976</td>
<td>6 pages</td>
<td>1 Paragraph</td>
<td></td>
</tr>
<tr>
<td>1998</td>
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<td>0 pages</td>
<td>9 pages</td>
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</tbody>
</table>

Between the ISA control valve book published in 1976 and the one published in 1998 there has been a significant change in what type of positioners are emphasized.
**Limit Switches**

**Electro-mechanical**
- Most common
- Inexpensive
- High power applications
- 400,000 cycles.

**Proximity**
- Low power
  - Computer inputs
- Medium power (3 A max)
- 5,000,000 cycles…

Sometimes, both for on-off automated valves and control valves, there is the need for knowing when the valve is fully open or fully closed. The actual switches are usually mechanical snap acting switches. These tend to be less expensive and have higher voltage and current ratings. The inductive proximity switches usually have a much longer life and can be certified for use in hazardous atmospheres.
Position Transmitter

For control valves there is sometimes the requirement for a position transmitter that will send a 4-20 mA signal that is proportional to actual valve position back to the control system.
Limit switches can be mounted directly onto actuators of on/off actuated valves. For control valves, many analog positioners can have the same types of limit switches and position transmitters mounted on the positioner so that the valve can have both a positioner and a limit switch and/or a position transmitter.
Limit Switch and Position Transmitter Options

For Smart Digital Positioner

Limit switch pack fits between positioner body and cover

Optional position transmitter is included on positioner circuit board

On the Metso digital positioner, the limit switch option consists of metal frame that installs between the positioner body and the positioner cover.
The position transmitter option has to be ordered with the positioner and consists of additional components on the circuit board and an extra terminal block inside the cover.
Solenoid Valves

Mainly used with in-off valves

3 – Way
For spring return actuators

4 – Way
For double acting actuators

Solenoid valves are mainly used on actuated on-off valves, but sometimes with control valves to provide emergency shutdown action to control valves. Three-way solenoid valves are used with spring return actuators, and four-way solenoid valves are used with double acting actuators.
The most common configuration for solenoid valves on spring return actuators is the NORMALLY CLOSED configuration. The normally closed valve is one that when it is de-energized vents the actuator to atmosphere and when energized connects the air supply to the actuator.

Normally closed is the most common, because the valve actuator has the same failure action on loss of air as it does on loss of electricity.

Normally open solenoid valves are also available where the de-energized and energized actions are the opposite of what is shown here.
Solenoid Valves

3 – Way for Spring Return Actuators

This figure shows schematically the flow through a 3-way normally closed solenoid when it is energized. In the energized state the air supply is directed into the actuator, opening the valve and compressing the spring.
When the solenoid valve is de-energized, the air in the actuator is vented to atmosphere and the spring drives the valve to the closed position.

Although not shown here, valves with spring return actuators can also be configured for air to close and spring to open.
Here we see a valve that is normally a control valve, but that can also be closed in an emergency by a signal from another source such as an emergency shutdown system.

The 3-way solenoid valve normally directs the air from the positioner into the actuator, but when the solenoid is tripped by the emergency shutdown system, the air in the actuator is vented to atmosphere, and the control valve closes.

Some experts discourage relying on control valves to also serve as emergency shut down valves.
Solenoid Valves

3 – Way for Spring Return Actuators

Manual Reset

Operation alternatives:
- No voltage release
- Electrically tripped
- Free handle.

- Prevents inadvertent start-up
- Once tripped must be manually reset to automatic operation

Some critical processes must not be accidentally started up after being shut down.

The manual reset solenoid valves require that the control signal be first applied to the valve and then someone must go to the valve and physically reset the handle.

The most common configuration is the no voltage release option, where electric power energizes the solenoid, and the solenoid is tripped by turning off the power.

The electrically tripped option means that sending a momentary or continuous signal trips the valve.

Both of these options can be manually actuated by turning the handle, but they cannot be reset to automatic operation unless in the case of the electrically tripped valve, the solenoid is de-energized or in the case of the no voltage release valve the solenoid is energized.

Free handle means that the valve trips when the solenoid is de-energized and the handle will only cycle the valve if the solenoid is energized.
Solenoid Valves

4 – Way for Double Acting Actuators

Single coil

Four-way solenoids are required to actuate double acting actuators. The most common configuration is the single coil version which vents and pressurizes a double acting actuator as shown in the figure.

When the coil is de-energized, air is directed into one port of the actuator and the other actuator port is vented. When the solenoid is energized, the pressureized and vented ports of the actuator switch places.
Less often, dual coil solenoid valves are used. Energizing one of the coils sets the valve for one flow path, and energizing the other coil switches the valve to the other flow path.

Only a momentary energization is required, however the coil can also be left energized continuously. However it is not allowed to energize both coils at the same time.

Dual coil solenoid valves are useful where electrical power is limited, such as systems than operate from solar cells, or in cases where the valve that is being controlled by the solenoid valve must remain in place on loss of electrical power.
Solenoid Valves

4 – Way for Double Acting Actuators

This figure shows schematically the flow path through a 4-way solenoid valve when the actuated valve is being opened. Air is directed into one side of the cylinder and vented from the other.
This figure shows schematically the flow path through a 4-way solenoid valve when the actuated valve is being closed.
Volume Booster

- 1 to 1 high capacity pneumatic relay.
- Used when the positioner cannot supply enough air for large valves that must respond quickly
- Rarely needed...

A volume booster is a one to one high capacity pneumatic relay, meaning that it duplicates the input pressure at its output, but can supply a greater volume of air than a positioner.

They are used when a large valve needs to move very fast and the positioner can't supply a high enough volume of air.

We don't see volume boosters used very often.
In some cases, such as emergency shut down valves, a valve is required to close very quickly. Some 3-way solenoid valves are designed to have a higher flow capacity in the venting direction than they have in the pressurizing direction.

If this does not result in fast enough operation, a quick exhaust valve can be added to the circuit as shown in the diagram.

The three ports, IN, OUT and EXHAUST are labeled in both the schematic diagram at the upper right and the cutaway drawing at the lower left.

When the process valve is being opened, the solenoid is energized and the air supply goes through the solenoid valve.
Pressure in the “IN” port of the quick exhaust valve is higher than in the “OUT” port and the “shuttle” flexes downward and flow through the quick exhaust valve is as shown in the cutaway view at the lower left hand side of the slide. This opens the process valve.
When the process valve is called upon to close, the solenoid valve is de-energized and the solenoid starts to vent. This causes the pressure in the “IN” port of the quick exhaust valve to drop below the pressure in the process valve’s actuator and the “OUT” port of the quick exhaust valve causing the “shuttle” to flex upward opening a flow path from the “OUT” port to the exhaust port, abbreviated “EXH” in the diagram. Because the ports in the quick exhaust valve are large compared to the ports in a solenoid valve, the process valve’s actuator vents very rapidly, moving the valve to the spring position very quickly.
Double acting actuators are often referred to as having a “fail in place” action, since if the air pressure on the pressurized side of the piston decays there is no restoring force on the other side to cause it to move.

In the real world the process usually exerts dynamic forces on the valve and in the absence of air pressure in the actuator these dynamic forces may be able to move the valve.

A lock-up valve, piped between the ports of the “control device”, which could be either a 4-way solenoid or a double acting positioner, senses the air supply pressure. When the air supply pressure drops below a preset value, the lock-up valve blocks off the actuator ports, blocking in whatever pressure was in the actuator at the time of the trip, effectively holding the actuator (and process valve) in place.