

“Welcome to the K Controls e-training course designed to deliver useful “Pneumatic Valve Actuation” application information in small instalments.”

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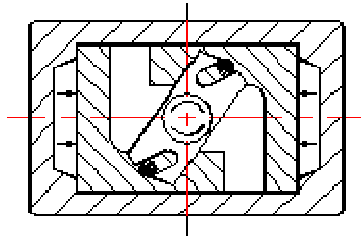
## Operating characteristics and sizing of pneumatic actuators

### The main types of pneumatic actuator

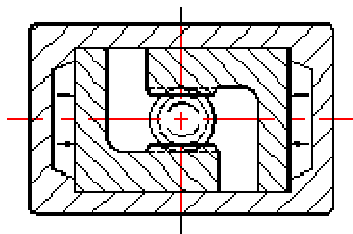
Pneumatic actuators provide (rotary) torque or (linear) thrust to operate a valve via the application of compressed air to a piston, diaphragm or vane.

Pistons or vanes are sealed with elastomeric "O" rings. Linear actuators apply the thrust from a piston or diaphragm directly, whereas rotary or quarter turn actuators convert thrust to torque via mechanisms such as a scotch yoke, rack and pinion or vane.

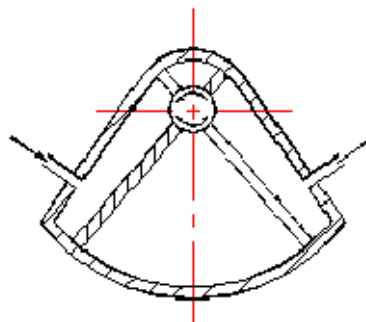
Scotch yoke design:



Rack and pinion design:



Vane design:



If compressed air is available pneumatic actuators can be used in place of electric equivalents because they can operate faster and more frequently, their cost is usually lower (especially when fail safety is required), they are often more compact (on smaller valves) and they can readily be adapted for use in hazardous areas.

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For a given design of actuator, the pressure applied to the piston, diaphragm or vane will determine the output thrust or torque. The volume of air available and the rate at which it enters and exhausts the actuator will determine its speed. The addition of quick exhaust valves or adjustable speed restrictors can increase or decrease cycle times. The internal porting size of the actuator also determines the speed that can be obtained.

It should also be noted that the torque output from rotary actuators is not always constant. As torque equals the force applied multiplied by the distance from the pivot point, actuator design is important. In a rack and pinion or vane type actuator the distance from the pivot point is constant throughout the stroke and so, therefore, is the torque. With a scotch yoke design however, the distance from the pivot point varies throughout the stroke and so, therefore, does the torque. As the torque requirement of most valves also varies throughout the stroke, an attempt should be made to match the operating characteristics of valve and actuator as closely as possible.

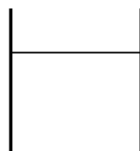
The torque output from a given size of actuator has been increased with special designs. E.g. Two vane units attached together or in the case of quarter turn rack and pinion actuators, using double opposed or even four opposing pistons. Extended rack and pinion designs are available for multi-ported valves that operate through 180 degrees.

Scotch yoke typical torque output (double acting):

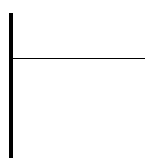


*Solid line: Angled slot. Dotted line: Parallel slot*

Rack and pinion typical torque output (double acting):



Vane typical torque output (double acting):





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Piston and vane based devices can either use air for both strokes (known as "double acting") or air for one stroke and springs for the other (known as "single acting" or "spring return"). Piston devices will usually have one or more coil springs housed within the main actuator housing. Vane actuators have a clock type spring situated in an enclosure above or below the actuator.

Diaphragm actuators will usually have springs to provide the thrust on the return stroke. When compressed air is allowed to vent from the actuator, the springs will automatically start to move the valve in the opposite direction to a pre-determined "failsafe" position. As the effective area of a diaphragm is quite large and the response is linear, it can operate with low pressures and be used to respond to a 3-15 psi control signal without the use of a positioner. Flat diaphragms have a limited stroke length. Moulded or rolling diaphragms permit longer strokes and are better at maintaining the effective area.

When the springs are below the diaphragm the unit is said to be direct acting. When the springs are above the diaphragm the unit is said to be reverse acting. Whether a valve fails open or fails closed with a reverse acting actuator will be a function of valve design.

Where the addition of springs would make the actuator too large or heavy, an accumulator tank may be installed to store air pressure. This adds an "air fail safe" facility to a double acting actuator.

The process of filling and venting actuators is usually controlled by solenoid valves that are either fitted to each actuator or panel mounted remotely.

## Controlling the air supply to pneumatic actuators

The process of filling and venting actuators is usually controlled by solenoid valves. For detailed information on how this is done see the e-training document on solenoid control.

## Failsafe pneumatic actuators

One of the benefits of pneumatic actuators is that springs can be used to return a valve to its pre-determined "failsafe" position in the event of air, signal or solenoid failure. However, it is important to note that the failsafe position might be the last set position. If this is the case double acting actuators should be used with solenoid control that provides a "stay put" function.

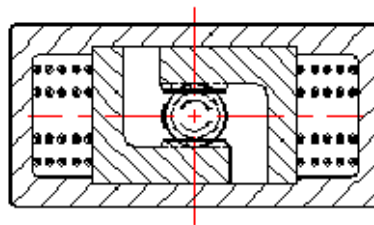
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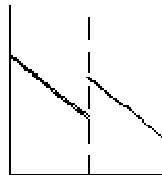
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A single acting or spring return actuator will need to be larger than the double acting equivalent. This is because air pressure is needed to both operate the valve and compress the springs at the same time. The torque or thrust available to operate the valve will also change throughout the stroke because the more a spring is compressed, the greater the force required to maintain it in any given position. This means that that the torque or thrust available at the beginning of the air and spring strokes will be greater than that available at the end of the air and spring strokes. This is very important when sizing a single acting (spring return) actuator to match the requirements of a particular valve operating under a given set of conditions.

Single acting (spring return) rack and pinion design:



Rack and pinion typical torque output (single acting):



*From left to right: Start of air stroke, end of air stroke, start of spring stroke, end of spring stroke*

## Reduced or fluctuating air pressure

The air pressure available at the actuator needs to be established and monitored. For example, the pressure at the compressor could be 5 bar, while at the actuator it could have dropped to 4 bar. If a double acting actuator has been sized based on 5 bar then insufficient torque or thrust may be available to operate the valve at 4 bar. Another consequence of reduced or fluctuating air pressure can be the unwanted movement of spring return actuators. If the pressure is insufficient to keep the springs fully compressed at one end of travel the actuator will start to "creep" and a valve may start to move with unintended consequences. With multi-spring actuators the number of springs can be reduced so they will remain compressed at a lower pressure; however the resultant torque available will then be lower.

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A typical actuator torque chart will show torque outputs at various positions and operating pressures. With rotary single acting actuators the torque varies with the degree of spring compression, therefore torque figures are given for each of four positions: Start of air stroke, end of air stroke, start of spring stroke and end of spring stroke.

## Sizing a pneumatic actuator

The torque or thrust requirement of a valve is determined by a number of factors:

Operating frequency – some valves will have a tendency to stick if left in one position over a period of time. This will increase the torque requirement.

Type of service – a wet media will help reduce valve torque whereas a dry media will increase it.

Temperature – this affects the hardness of the seating materials which in turn alters the valves torque requirement.

Chemical attack on the valve seats – swelling of the seats may result in increased interference and therefore higher torque.

Finish of the sealing surface – different friction coefficients give rise to different torque requirements.

Stem torque or friction - that is mainly a function of the tightness of the stem nut that compresses the packing against the stem.

Pressure – pressure drop across the valve will directly affect the loading on the valve and therefore the torque or thrust required to move it.

Dynamic forces - caused by fluid velocity through a partially closed valve. (Dynamic torque can be positive or negative at different points in the cycle).

The valve manufacturer will usually add an overall factor of safety prior to stating the figure that should be used for actuator sizing.

The resultant torque or thrust requirement of the valve can then be matched against the torque or thrust output of the actuator. It is important that the torque or thrust of the actuator does not exceed the mechanical strength of the valve stem or shaft. Should there be an obstruction in the valve an oversized actuator could cause the stem or shaft to twist or bend.

Maximum valve torque usually occurs at the "break out" point and this is usually when the valve starts to move from the closed position. When flow through a valve has started the torque drops to its lowest point, known as the "running" torque.

The way that the torque requirement of the valve is distributed over the open / close cycle should also be examined because economies can be made by matching the torque characteristic of the valve and actuator as closely as possible.

The diagram below indicates the average torque characteristics for three different valve types, under line pressure and flow conditions, for opening followed by immediate closing.

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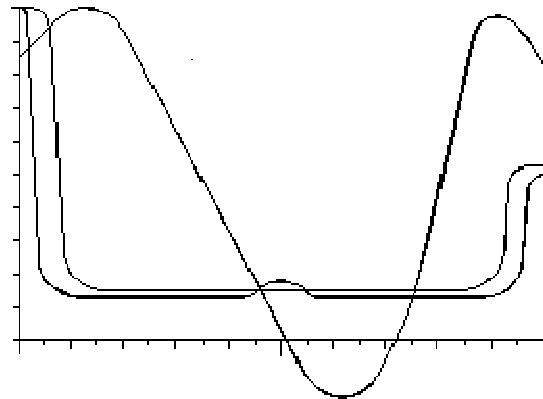
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*Left – Closed      Centre – Open      Right – Closed*



Valve type

*Butterfly valve*

*Plug Valve*  
*Ball valve*

The ball and plug valves have similar characteristics. The main difference is the slight increase exhibited by the ball valve curve about the fully open position caused by the increasing surface area of the ball coming into contact with the seats. The butterfly valve has a very different characteristic and a negative torque requirement is shown for a period on closure of the valve. Any actuator used for this application must have a minimum amount of free movement in order to retain control of the valve and prevent shock loads developing in this phase of operation.

In summary when sizing a pneumatic actuator it is best to have as much information about the torque or thrust characteristics of both the valve and the actuator across all points of the cycle. However if this is not possible, then matching the maximum valve torque or thrust (including a safety factor) to the minimum torque or thrust available from the actuator (while checking stem strength limits are not exceeded) is a practical alternative.

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