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

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Solenoid control of pneumatic actuators

Pneumatic actuators need solenoid valves to control the supply of air. This they do by diverting or stopping the supply of air to one side of the piston or vane while allowing for air to be exhausted from the other. A direct acting solenoid is not often used on its own as the flow rate is usually insufficient, causing the actuator to operate too slowly. To overcome this problem direct acting solenoids are used in combination with pilot valves that contain either spools or poppets. These allow air to enter and leave the actuator more quickly. Solenoids can either be fitted remotely, usually grouped together in cabinets, or directly to the actuator. Remotely sited solenoids can be protected from a harsh or hazardous plant environment but the air has to be exhausted via the interconnecting pneumatic piping. This can cause a time lag between solenoid and actuator operation. In addition identifying a faulty solenoid via an actuator failure can take longer unless they are clearly identified in the cabinet.

What is a solenoid?

Here are some definitions:

1) A current-carrying coil of wire that acts like a magnet when a current passes through it.

2) An assembly used as a switch, consisting of a coil and a metal core free to slide along the coil axis under the influence of the magnetic field.

3) The solenoid valve is a device aiming to stop or to allow the flow of pressurized media. It permits to convert an electrical current into a fluid flow.

Direct acting solenoid valves

The magnetic plunger acts directly on the valve seal to open or close the valve orifice depending upon whether the solenoid is energised or de-energised. The pressure and flow capability of this type of solenoid valve depend directly on the orifice size and the coil power. Direct acting solenoid valves are rarely used on their own to control pneumatic actuators as although they can usually handle the pressure, the orifice size restricts the flow rate to the actuator and limits its speed of operation.

Pilot valves

This type of valve is operated via a direct acting solenoid valve and is designed to direct air pressure, at a higher flow rate than would otherwise be possible, to the air inlet ports of the actuator to drive it to the desired position. The flow rate to the actuator no longer depends on the coil power and the resultant orifice size of the direct acting solenoid valve.

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When energised the direct acting solenoid valve can operate a spool or poppet valve pneumatically. The air from the direct acting valve fills a small chamber in the pilot valve that is separated from the moving poppet or spool by a cup or diaphragm seal.

Springs are usually incorporated into the design to return the spool or poppet to its original position when the solenoid is de-energised.

The capacity of a solenoid or pilot valve to pass a given flow is defined by its flow coefficient "Cv". Pilot valves with a Cv or 0.3 or 0.5 will usually be adequate for most compact actuator applications but large pipeline actuators will need much larger pilot valves.

Actuator mounted solenoid and pilot valve assemblies are either "Namur" mounted directly to the actuator inlet/outlet ports or integrated into top mounted enclosures that also contain position monitoring switches or sensors.

If position monitoring is not required then a "Namur" mounted assembly would usually be selected.

A "Namur" solenoid can be "back wired" into a switchbox in order to allow single multi-core wiring of switches and solenoid.

If position monitoring is required then an integrated device allows switches and solenoid to be wired via a single multi-core, saving cable, junction box, glanding and termination costs as well as helping to organise the field mounted hardware in an aesthetically pleasing form.

The solenoid is also protected within a dust, water and impact protected enclosure. This integrated approach can also be useful where a "Namur" interface is not available e.g. on linear actuators.

Pneumatic connection is normally via 1/4 inch or 1/8 inch screwed BSP or NPT ports. A facility to manually override the solenoid is sometimes required although this is often disliked as operators are then able to operate a valve locally with undesired consequences. Manual overrides can be momentary or maintainable or a combination of the two (e.g. a push button complete with a screw driver slot).

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When the override is on a pilot solenoid within a top mounted integrated device, a deliberate act of cover removal would need to precede manual operation. If speed control is required this is best achieved by fitting a needle valve to each exhaust port (not inlet) of the pilot valve.

The voltage and power consumption of a solenoid coil needs careful selection (e.g. 24vdc 1 watt or extremely low powered piezo devices for connection to fieldbus couplers). The coil must also have adequate protection from the ingress of dust or water (e.g. IP65). Materials of construction need to be compatible with the application and if hazardous gasses or dusts are present the device will need to be certified (e.g. EExi – intrinsically safe, EExd – flameproof or EExm – encapsulation).

Finally it is very important to ensure that the solenoid and pilot valve are matched to actuator type and the function required.

Cetop symbols

In the following diagrams Cetop symbols have been used. In system 1 a spring return double rack and pinion pneumatic is shown on the left. The origin of the pneumatic supply is shown as a black dot on the far right. Pneumatic pathways to and from the actuator are shown as solid lines and arrows. The pneumatic supply to the pilot valve is shown as a dotted line. The two squares with arrows in them show the pathways through the pilot valve when it is in each position.

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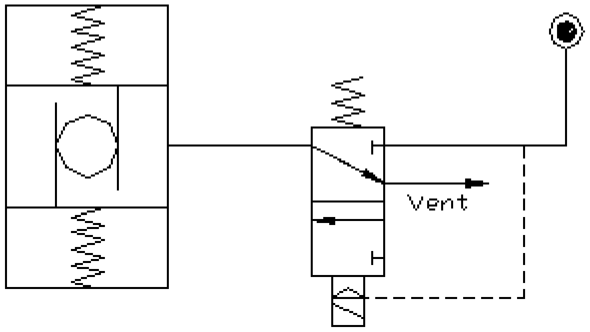
System 1



Single acting
3/2 Pilot operated fail safe

In system 1 air is passing from the actuator to vent when the solenoid is de-energised. Air is exhausted from the centre chamber of the actuator and the springs move the actuator (spring stroke) to the fail position (open or closed depending on how the valve is connected to the actuator). Now, in your minds eye, reverse the position of the two squares. With the solenoid energised the top square now shows air passing from the supply to the centre chamber of the actuator and the vent line is now blocked. This will move the actuator pistons apart (air stroke) and compress the springs.

System 1 is by far the most common way of controlling a spring return (failsafe) actuator. If the electric supply to the solenoid should fail the actuator will move the valve to the pre-determined fail safe position.

Should the air fail and the solenoid remain energised then, providing the air from the actuator centre chamber can exhaust back via the supply line, the valve will again move to the pre-determined fail safe position. Should the air pressure decay but not fail completely, a point may be reached where the spring force behind the actuator pistons overcomes the air pressure and the actuator will gradually move. To overcome partial or slow movement a dump valve can be fitted that will exhaust the supply line if the pressure drops below a certain level; the actuator will then move to the pre-determined fail safe position.

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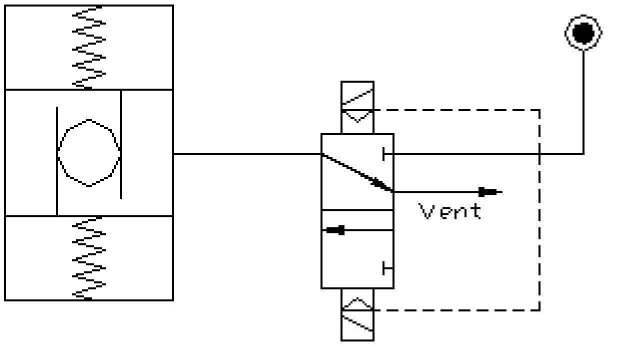
System 2

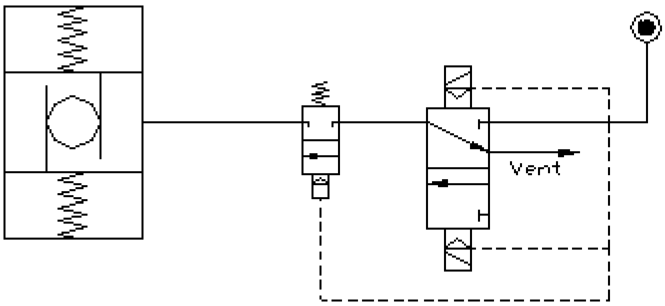


Single acting
3/2 Pilot operated
Stay put on electrical failure

In system 2 two solenoids are used. One has to be energised to fill the actuator but nothing will happen when it is de-energised because the second solenoid has to be energised before the air will vent from the actuator. The actuator will therefore "stay-put" on electrical failure.

The actuator will behave in the same way as system 1 when the air fails.

System 3



Single acting
3/2 Pilot operated
Stay put on air and
electrical failure

System 3 adds a further pilot operated valve to system 2. If the air fails the air in the centre chamber will not be allowed back up the supply line until the third valve is operated.

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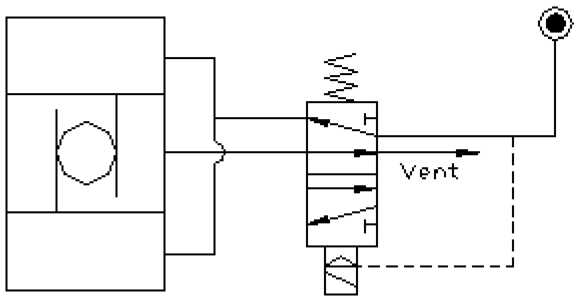
One solenoid has to be energised to fill the actuator but nothing will happen when it is de-energised because the second solenoid has to be energised before the air will vent from the actuator. The actuator will therefore "stay-put" on electrical failure.

The third valve provides a lock condition trapping air in the actuator if the supply pressure falls below a specified limit. This will cause the actuator to also stayput on pneumatic failure. This is the same as "double acting stayput" (see system 6 below but using a spring return actuator. On linear valves double acting actuators are not always readily available.

The third valve could also be piloted by a separate air supply (e.g. from a stand by reservoir). This would enable the actuator to be moved to the fail position some time after mains air failure. This may be required if valves need to be shut down in sequence in order to preserve product or make the plant safe.

System 4



Double acting
5/2 Pilot operated 'fail safe'

System 4 shows the most common way of controlling a double acting actuator. Only a single solenoid is used. When it is energised air fills the outer chambers of the actuator and air from the centre chamber is allowed to vent (actuator moves to position A). When the solenoid is de-energised the process is reversed and the actuator moves in the other direction (position B). If the air fails and there are no significant out of balance forces originating from the valve then the actuator should stay in the last signalled position. However if the air is available and the power to the solenoid fails the actuator will either stay in, or move to, position B. It is important to realise that when a single solenoid control system such as this is used a double acting actuator will not necessarily stay where it is on electrical failure. This can either be a useful feature or something to be avoided depending on the nature of the application.

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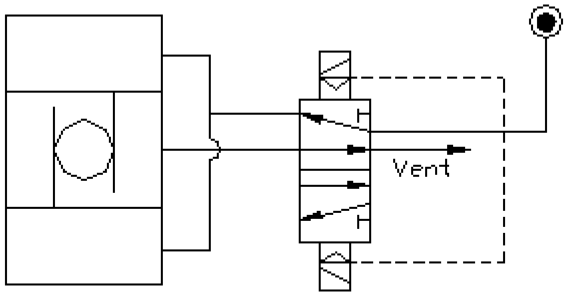
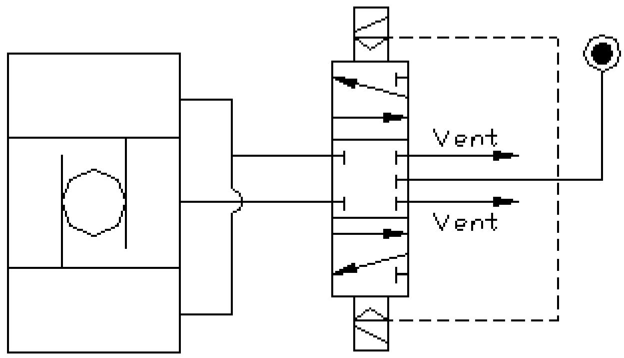
System 5



Double acting
5/2 Pilot operated
Stay put on electrical failure

System 5 is known as double acting "stay-put". Two solenoids are used. One is energised and the other de-energised to move the actuator in one direction and the process is reversed to move it in the other direction. If the air fails and there are no significant out of balance forces originating from the valve then the actuator should stay in the last signalled position. If air is available and the power to both solenoids fails the actuator will "stay-put" in the last signalled position assuming there are no forces acting on the valve to drive the actuator from its rest position.

System 6



Double acting
5/3 Pilot operated
Stay put on air and
electrical failure

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System 6 is similar to system 5 but the pilot block returns to a third “centre lock” position when both solenoids are de-energised or the power fails. In this third position air is locked in the chambers of the actuator. If the supply air fails the actuator will stay in the last signalled position even if there are out of balance forces originating from the valve.