Today's process controls range from complete computer systems to the staff-monitored electromechanical type (push buttons, heavy-duty relays, etc.). In the process area, there may also be pressure switches temperature controllers, or other process-monitoring devices that must tie into the control valve and therefore the actuator.

The pneumatic actuator is the workhorse for the automation of quarter-turn valves. When selecting a pneumatic rotary actuator for valve control in process applications, it is important that it be compatible with other components of the control system (power medium, control signals, etc.), the environment (corrosion, temperature), the system (speed, cycle frequency, fail mode), and, of course, the valve.

To work well with an existing control network, the actuator must be available with a few basic control accessories.

- **Solenoid valve** - As a pilot device, available in various voltages and construction for the area classification

- **Limit switches** - For indicating valve position, sequence cycling, alarms, etc.

- **Positioner** - To throttle the valve in response to a varying control signal

For environmental compatibility, the actuator should be available with corrosion-resistant (anodized, stainless-steel) trim, various coatings (polyurethane, epoxy, etc.), and weatherproof, hazardous-area, or intrinsically safe electrical accessories.

**Pilot Valve**

A pilot valve for a pneumatic actuator is a control device that receives a manual or power signal and then directs air pressure to the air inlet ports of the actuator to drive it to the desired position. The most common type of pilot device is the solenoid-operated valve. As an electric device, it readily interfaces with widely used electromechanical control systems and may also be supplied with low-wattage coils for compatibility with computer control signals.

Pilot valves for pneumatic actuators are categorized by the number of port openings or ways air may flow them. For instance a three-port (three-way) valve has a pressure port, output port, and exhaust port. The three-way valve is a logical choice for spring-return pneumatic actuators because only one air chamber is alternately pressurized or exhausted in normal operation.

A four-way valve has a pressure port, two output ports, and an exhaust function. The two output ports will pressurize one or the other chambers of a double-acting cylinder and so it is used with these types of pneumatic actuators.
Pilot valves may also be described by the number of positions provided. Typically their description gives the number of ports and number of positions as figures separated by a stroke—e.g., a 4/2 valve is a four-port, two-position valve. A five-way, two-position valve (5/2) is similar to a four-way valve except that an additional exhaust port is provided. Thus when either of the output ports is switched to exhaust, it does so through a separate exhaust port. This is of particular advantage when the stroke speed of a double-acting actuator must be controlled in both directions. Independent flow control valves may be connected to each exhaust port.

Another useful valve option is the four-way, three-position valve. The function is similar in porting to a four-way, two-position valve except that an additional position is available with all ports blocked. No flow is possible through the valve in either direction in the normal position. A typical application is the control of a double-acting pneumatic actuator that must be held in a given position upon loss of electric or air power. Another version of the 4/3 valve is to have the normal position provide air pressure to both sides of the actuator and the exhaust closed. This holds the actuator in position by pressurizing both sides of the cylinder.

**Standard valve symbols**

Symbols used for designating pilot valves are conventionally in the form of adjacent squares with each square representing one position of the valve. This means that a two-position valve would have two squares and a three-position valve would have three. Flow paths within the valve are indicated by lines and arrows.

The action of a pilot valve in an electric control circuit is initiated by a solenoid operator. The solenoid operator is composed of a coil, plunger, and spring. The coil is a doughnut-shaped electromagnet. When voltage is applied to the coil power leads, the resulting current generates a flux field. This flux field acts like a magnet. A spring and plunger assembly is fitted through the core of the coil. The magnetic field of the coil pulls the plunger inward when the coil is energized, and the spring forces the plunger back to its normal, or original, position when the coil is de-energized. Other means of actuating a pilot valve are manually, by a push button or lever; electrically, by single or dual coils; and pneumatically, by a piston or diaphragm assembly.

Many pneumatic actuators are manufactured with an integral air manifold and internal porting that allow the pilot valve to be mounted in modular fashion directly onto the actuator. This eliminates the cumbersome adaptation of traditional solenoid valves with nipples and tubing, making a neater, more dependable package. When selecting a solenoid-operated pilot valve for an actuator, it is important to
specify that it be energized-to-open or energized-to-close. This means that the pilot valve should be ported in such a way that when voltage is applied to it (energized), it will pressurize the actuator, which in turn will operate the process valve to the open or closed position. With some integrally mounted solenoid valves, this selection is satisfied by mounting the valve in one position or 180° out of position.

To increase the speed of actuation a pilot valve with a higher flow coefficient may be used. In some cases the actuator may require modification to match the port size of a larger pilot valve. For slower actuation a variable restrictor (needle valve) may be connected to the exhaust port. Undesirable speed and operation may result if the restriction is connected to the supply pressure port.

**Limit Switches**

For a pneumatic actuator, the term limit switch may be a misnomer. The term more properly applies to electric rotary actuators that are fitted with limit switches to interrupt the power to the motor when the actuator has reached its desired limit of rotation. As a functional term, position-indicating switch is more properly applied to limit switches when they are used with pneumatic actuators. Indeed, a switch fitted to a pneumatic actuator does not limit its travel but instead indicates (through switches) when the actuator has reached, or has not reached, a specified point of rotation.

Also referred to as a switch box, the position-indicating switch encloses the switch elements, cams, and terminal strip and has a rotating input shaft that is fitted to the auxiliary shaft of the actuator to pickup rotary motion. The switch housing is composed of an input shaft that externally couples to the actuator’s auxiliary drive shaft and is fitted internally with adjustable cams, snap-acting switches that are mounted to align with the cams and a terminal strip for incoming wiring. As the actuator cycles, the input shaft of the switch box rotates and the cams actuate the switches. When the switches are used to indicate the limits of the cycle, the cams are adjusted to operate the switch when the desired position is reached.

Position-indicating switches are used for a variety of applications: light indication (powering indicator lamps on a control panel), system sequence cycling, alarms, electrical interlocking, etc. Some switch enclosures may be fitted with other devices, such as a potentiometer or position transmitter for continuous feedback of the valve’s position.

When the switches are connected to signal lights, they should be arranged so that both lights are on in mid-travel, with one or the other being extinguished at the ends of travel. This helps the operator avoid being misled by a burned-out lamp.
Switch boxes for pneumatic actuators are often specified by the type and quantity of switches required. Examples of the types of switches available are snap acting, proximity, and pneumatic switches.

**Electric limit switch configurations**

Electric switches are usually expressed in terms of the number of poles and throws they contain. A pole is a component of the switch that is moved by the switch action to make or break electric contact. The possible electric connections that can be made by a given pole are called throws. For example, the most elementary switch configuration is shown in the figure below.

There are four configurations of electric limit switches: single-pole-single-throw; single-pole-double-throw; double-pole-single-throw; and double-pole-double-throw.

**Single-pole, single-throw (SPST)** This switch has one movable component, or a single pole. It also has only one possible connection, or a single throw, for that pole. The configuration of single-pole-single-throw is often abbreviated SPST. It is usually used as an on-off switch.

**Single-pole, double-throw (SPDT)** shows a single-pole-double-throw configuration. This switch still has only one movable component, but it has two possible connections, or throws. It is often found in a switch box where the customer may select between normally open (NO) or normally closed (NC) contacts. Normally open contacts provide an open circuit when the switch is in a free position, while normally closed contacts provide a closed circuit when the switch is in a free position.

**Double-pole, single-throw (DPST)** This switch has two movable components, so it is a double pole. There is only one connection for each pole and, therefore, is a single throw. Note that the key phrase in determining the number of throws is “for each pole.” The contacts of this switch are normally closed.

**Double-pole, double-throw (DPDT)** This switch has two movable components and therefore, is a double pole. It also has two connections for each pole so it is a double throw. This type of switch is often used in a switch box to give the customer an extra set of contacts to wire indicator lights or relays. Almost any switch configuration can be identified by applying the principles outlined here.

**Proximity switches**

These switches operate when a metallic or magnetic object is brought into close proximity to the switch sensing area. These switches are inherently protected against dust and moisture and some require a power circuit. Two types of proximity switches are the proximity sensor and reed switch.
How to Select Automation Accessories for Valves

**Proximity sensors**

Proximity sensors are switches that operate when a metallic object is brought into close proximity to the sensing face. Most proximity sensors comply with several NEMA ratings. The sensors are protected against dust, moisture, and oil. Internal solid-state circuitry prevents shock and vibration from affecting sensor operation. An inductive proximity sensor has four main components; the **Oscillator** which produces the electromagnetic field, the **Coil** which generates the field, the **Detection Circuit** which detects any change in the field when an object enters it and the **Output Circuit** which produces the output signal, either normally closed (NC) or normally open (NO). Inductive proximity switches allow for the detection of metallic objects in front of the sensor head without any physical contact of the object itself being detected. This makes them ideal for use in dirty or wet environments.

**Reed switches** Another low-current proximity switch (250 to 500 mA) is the reed switch. Action is initiated when a magnet is placed in the proximity of the sensing area. Reed switches do not require a power supply.

**Pneumatic switch**

In some instances a pneumatic valve may be used to indicate actuator position. This method is sometimes used in hazardous areas to eliminate electrical equipment. A roller and cam are used to initiate valve action. At the control panel a pressure switch or pneumatic or mechanical sensor will indicate the presence of air pressure and indicate the valve position.

**Other methods of position indication**

If continuous monitoring of an actuator’s position is required, as in modulating or "jogging" applications, a switch box may be fitted with a potentiometer. As the shaft of the switch box rotates, it likewise rotates the input shaft of the potentiometer. The continuously decreasing or increasing resistive signal may then be converted into a valve position at the control panel. When the actuator is located far from the control system, the result may be an unreliable resistive signal due to the inherent resistance of the long wire. In this case a resistance-to-current transducer circuit may be preferred. The circuit board is usually installed in the switch box with the potentiometer and provides a 4-to-20 mA signal to continuously indicate valve position.
Switch boxes designed for use in explosive environments must be able to withstand an internal explosion without igniting the explosive mixture surrounding the switch enclosure. The enclosure is thus designed to withstand the maximum expected internal explosion pressure without damage or excessive distortion and to provide venting for the pressure through channels of such dimensions that gases will be cooled below the ignition temperature before reaching the surrounding atmosphere. Thus the design of a hazardous area switch enclosure involves careful consideration of housing thickness, cover fit, and tolerances.

Many switch enclosures incorporate multiple construction standards (NEMA IV, VII, IX, etc.) to satisfy a wide range of applications. (See White Paper: About Hazardous Area Equipment.)

Pneumatic positioners
When a valve is used for throttling rather than simple on-off service, it may be considered a rotary control valve. A control valve is a process control element that varies the flow of fluid as required by a process in response to a system control signal. To provide fast, sensitive, and accurate positioning in response to a control signal, an actuator must be fitted with a pneumatic positioner. A pneumatic positioner is basically a relay that senses and compares an instrument signal and the valve stem position. Because it is usually mounted to the top of a rotary actuator it actually senses valve position through the actuator shaft.

Most basic positioners have linear characterization. This means that the input signal to output rotation is directly proportional, which enables the process engineer to select a valve that will provide system characteristics. Standard ball valves, for example, provide equal percentage flow like many other quarter-turn valves do.

Operating principle of a positioner (3- to 15 psi signal range).
Referring to the schematic illustration; with air pressure applied to the supply port of the pilot, and the instrument signal at midrange [9 psi (0.6 bar)], the unit is in force balance. The instrument signal acts upon a diaphragm assembly creating a force toward the pilot valve. An opposing force from the suppression spring counteracts this force. The cantilever range spring is in its mid-zero position. An increase in the instrument signal causes an increased force toward the pilot valve and moves it open, increasing the output pressure to the actuator. This increase causes the actuator to rotate further and rotates the cam clockwise. A cam follower rises and twists the cantilever range spring in the counterclockwise direction resulting in a force at the end of the cantilever range spring directed away from the pilot valve. The actuator continues to rotate until the force of the cantilever range springs equals the increase in the instrument signal above its midpoint. A decrease in the instrument signal from its midpoint causes the diaphragm assembly to move away from the pilot valve and open the exhaust seat. As the output pressure decreases, the actuator rotates counterclockwise and rotates the cam counterclockwise. The cam follower drops, which twists the cantilever range spring in the clockwise direction, resulting in a force directed toward the pilot valve. The actuator continues to rotate until the force of the cantilever range spring equals the decrease in the instrument signal below its midpoint.
How to Select Automation Accessories for Valves

Pneumatic positioners may be used with a variety of input control signals [3 to 15 psi, 6 to 30 psi, etc. (0.2 to 1 bar, 0.4 to 2 bar)]. To match positioner operation to these signals they are available with different range springs. This is useful when split-ranging.

Terms associated with positioners

- Direct acting-Increasing input signal opens the valve (increases flow).
- Reverse acting-Increasing input signal closes the valve (decreases flow)
- Resolution-The smallest possible change in valve position.
- Deadband-The maximum range through which the input signal can be varied without initiating change in valve position.
- Hysteresis-The maximum difference in valve position for a given input signal during a full range traverse in each direction.

Transducers A transducer is a device that converts one signal type to another. In the case of control instrumentation, a current-to-pneumatic transducer accepts an analog milliamp control signal from a field instrument and converts it to a proportional pneumatic signal for the positioner. The most common conversions used with control valves are

For systems being controlled and monitored with electronic instrumentation but with pneumatically actuated control valves, the use of a transducer is the most practical method for interfacing the two types of equipment. As an electromechanical device, a transducer must be carefully selected for environmental compatibility, hazardous areas, sensitivity, vibrations, etc.

One drawback of transducers is that it is sometimes difficult to locate them near the positioner, which may then require long runs of wire or pneumatic tubing. To satisfy this, some manufacturers have integrated the transducer into the positioner. These hybrids are known as electro-pneumatic positioners.

Standard instrument signals

Instrument signals are used to interface between various elements in the control process. Information may be transmitted from a sensor to a controller, or a controller to an actuator, etc. Standard instrument signals allow a wide variety of products made by different manufacturers to work together. Common standard instrument signal ranges are shown below. The high end of a standard instrument signal range is usually 5 times the value of the low end. For instance, 20mA is 5 x 4 mA, 15 psi is 5 x 3 psi, etc.

<table>
<thead>
<tr>
<th>Input</th>
<th>Output, psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 to 20 mA</td>
<td>3-15, 3-9, 9-12</td>
</tr>
<tr>
<td>0 to 10 V dc</td>
<td>6-30, 6-18, 18-30</td>
</tr>
</tbody>
</table>

The low end usually does not have a value of zero. This provides a positive method of determining the difference between a device that is indicating the low end of a range and a device that is not functioning. This is known as live zero.
The main exceptions to these conventions are resistance-type inputs which usually have a low end of zero and various values of high ends. Split ranges are usually fractions of standard instrument signals. For example, 3 to 15 psi is often split into 3 to 9 psi and 9 to 15 psi, each of which is half of the standard range.

In pneumatic devices, pressure [psi (bar)] is the usual variable for instrument signals. In electric devices, the variable may be current (mA), dc voltage (V dc), or resistance [ohms (Ω)]. The following table gives instrument signal ranges for pneumatic and electric devices.

### Instrument Signal Ranges

<table>
<thead>
<tr>
<th>Range type</th>
<th>Pneumatic (pressure), psi</th>
<th>Electric DC voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Current, mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VDC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Resistance, Ω</td>
</tr>
<tr>
<td>Standard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-15</td>
<td>4-20</td>
<td>1-5</td>
</tr>
<tr>
<td>10-50</td>
<td>1-10</td>
<td>0-10,000</td>
</tr>
<tr>
<td>Split</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-9</td>
<td>4-12</td>
<td>1-3</td>
</tr>
<tr>
<td>9-15</td>
<td>12-20</td>
<td>3-5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10-30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30-50</td>
</tr>
</tbody>
</table>

**Uses of a pneumatic positioner** The following are some uses of a pneumatic positioner.
- Temperature control
- Level control
- Split ranging
- Loops with slow response
- Reverse action relative to actuator

**Split ranging** is a process by which the input signal range [3 to 15 psi (0.2 to 1 bar)] is used to pilot two control valves. In practice, the first control valve cycles through its full stroke in the range 3 to 9 psi (0.2 to 0.6 bar), and the second valve strokes through the 9- to 15 psi (0.6- to 1 bar) range.

Positioners are available in a variety of materials of construction, accessories, characterized cams, position transmitters, and integral transducers.
How to Select Automation Accessories for Valves

Manual override devices for pneumatic valve actuators
In this era of automation, it is possible to have more control over a process system than ever before. In fact, when the decision is made to automate a valve for a specific function or functions in a system, one important reason is to have even more complete control over the process by providing feedback, sequencing, and rapid response and by eliminating human error.

Interfacing an automated valve with a control system may require that an actuator be equipped with a solenoid-actuated pilot valve, positioner, limit switches, a mechanical position indicator, transducer, and so many other control accessories that if there is a loss of power to the actuator, or if the actuator fails to operate for any reason, it may be rendered inoperable and therefore useless, becoming a potential hazard or causing an unnecessary shutdown of the production process. In effect, control of the valve and possibly the entire process may be lost.

The simplest and most reliable method for guaranteeing the continued operability of an automated valve in the event of a system failure is to use a manual override device. As more quarter-turn valves are being incorporated into expanded process control systems, there is an increased concern over the ability to operate these traditionally manual valves in the event of actuator or power failure. This concern has been recognized and addressed by actuator manufacturers. There are currently a number of manual override provisions available for pneumatic quarter-turn actuators.

Wrench override
A wrench override is simply a handle with an engagement provision that fits to the auxiliary drive shaft of the actuator. Upon failure, the wrench may be applied to the flats of the shaft to manually override the actuator. This method should be used only with double-acting actuators as it is difficult to override and hold spring-return actuators in position. Torque should be limited to about 1500 lbf-in (170 Nm).

The wrench is usually attached to the actuator or mounting bracket with a cable or chain to prevent loss. It may also be available with a locking provision to hold smaller spring-return actuators in position until the problem is resolved. A wrench override should never be permanently attached to the drive shaft of the actuator because, when it operates automatically, it may cause injury to personnel working near the equipment.
Disengageable gear manual override

The disengageable gear override is a modular component that fits between the valve and the actuator and offers simple, reliable manual positioning (see Fig. 6.35). The self-locking worm gear design provides for safe and easy operation and positive manual positioning even with spring-return actuators. Rotating the clutch lever, located at the base of the handwheel, 180° immediately engages the worm gear with the output drive sleeve to permit operation. Manual override modules may be adapted in the field to existing control valves with a slight modification to the actuator.

Manual overrides have proven to be an accessory requiring greater consideration in many applications. Modular construction, immediate operation, and adaptability to standard actuators are important to consider.

Two-Wire Control (As-I)

An increasingly common technique for controlling and communicating with automated valves in process areas is Two-Wire Control.

Based on various bus protocols (DeviceNet, As-I etc.) there are a variety of systems that cover simple on/off valve control to full system integration, diagnostics and control. The choice becomes a plant/platform-wide decision.

AS-Interface (Actuator Sensor Interface, AS-I) is designed for connecting simple field I/O devices (such as actuators and valve position sensors) in discrete process applications using a single 2-conductor cable. AS-Interface is an 'open' technology supported by a multitude of automation equipment vendors. AS-Interface is a networking alternative to the hard wiring of field devices. It can be used as a partner network for higher level fieldbus networks such as Profibus, DeviceNet, Interbus and Industrial Ethernet. It offers a low-cost remote I/O solution.

Applications: Systems that utilize 8 or more valve actuators can benefit from Bus Technology. Typically these systems have automated valves controlled by a programmable logic controller (PLC).

AS-Interface vs. Conventional System

AS-Interface is a versatile, low cost alternative to traditional hard wired I/O. It can replace traditional point-to-point wiring with a better, more flexible solution that is easier to install, operate and maintain and easier to re-configure.
How to Select Automation Accessories for Valves

Conventional system
Typical batching valve wiring networks attach each of the inputs and outputs (I/O) to a central location resulting in multiple wire runs for each field device. Large expenditures are needed for cabling conduit, installation and I/O points. Space for I/O racks and cabling must be accommodated in order to attach only a few field devices.

AS-Interface network
A simple gateway interfaces the network into the field communication bus. Data and power are transferred over the two-wire network to each of the AS-Interface compatible field devices.

Each valve communication module contains an AS-Interface ASIC and other electronics to gather open or closed position status and power solenoid or other ancillary devices on or off. Other AS-Interface modules are available to gather inputs and switch power outputs.

AS-Interface features
- Ideally suited for on/off batch process valves and other discrete applications
- 62 field devices per network master
- Simple electronics for economical and robust performance
- Transfer medium is unshielded two-wire cable for both data and power supply
- Signal transmission has high tolerance to EMI
- Easy to install providing the greatest cost savings with the least complexity
- Free choice of network topology allows optimized wiring network
- Variety of gateways available to seamlessly tie into high level bus networks