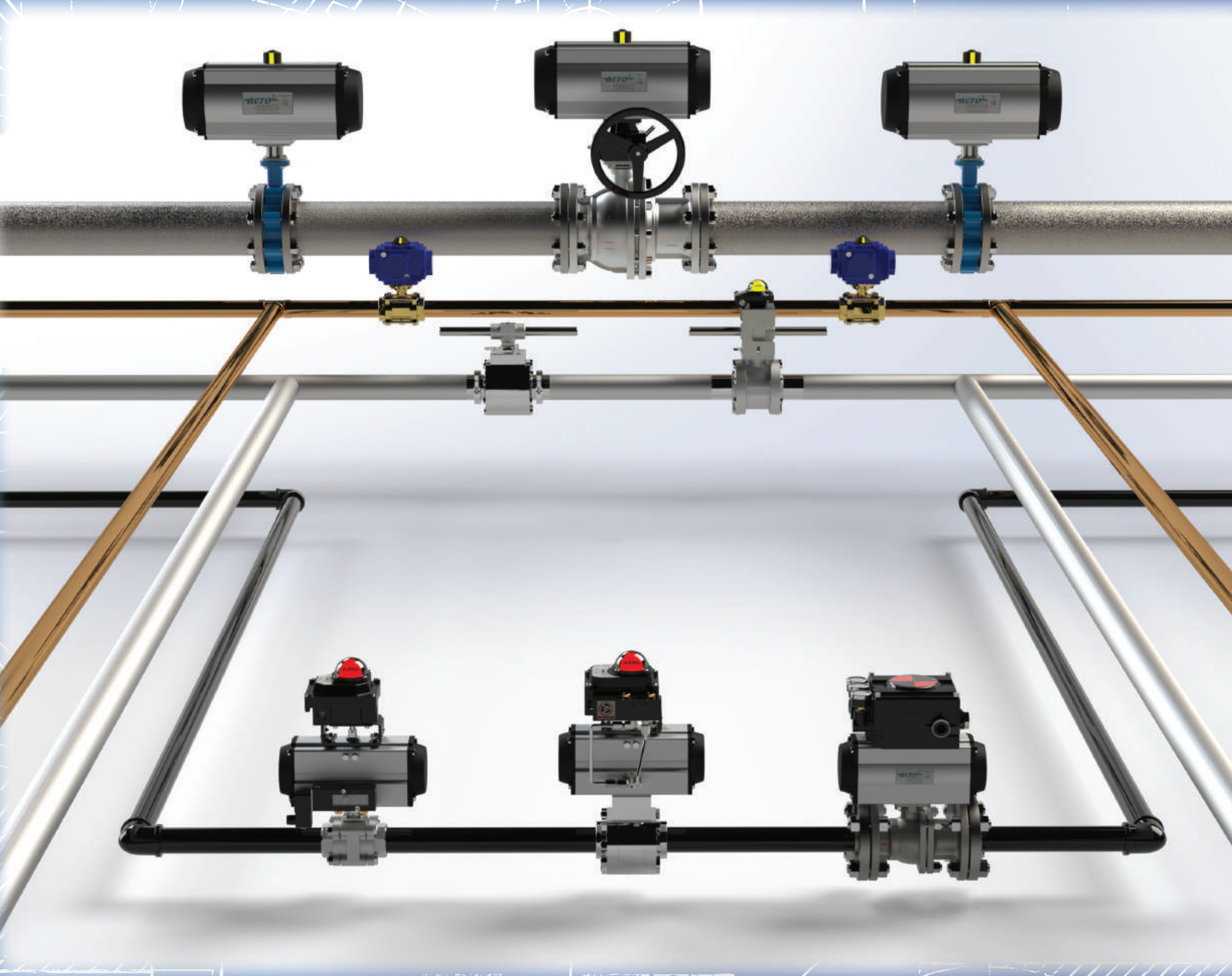
Introduction to Valves, Actuators, and Controls



An SVF Flow Controls Ebook

A Comprehensive Guide to Valves, Actuators and Controls

SVF eBook

We are pleased to share this valuable eBook that provides information for understanding valves and controls related to the processing industries. It is a collection of technical details gathered from years of field and training experience.

Delivered in 3 sections:

- Design and Selection of Valves
- Extensive Discussion on Actuators
- All About Controls and Accessories for Valve Automation

> ***"A great resource that is now in my personal technical library"***

The articles in this eBook are developed from the Technical Book: ***Valve and Actuator Technology*** by Wayne Ulanski

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Valve Selection Basics

General Introduction to Valves

The valve existed in the Egyptian, Greek, and Roman cultures centuries ago, but the modern history of the valve industry parallels the industrial revolution, when in 1705 the first industrial steam engine was invented. Because steam built up pressures that had to be contained and regulated, valves suddenly acquired a new importance. As other new inventions came along, valves became more sophisticated, more reliable, and more widely used in numerous industrial sectors.

Today, industry's requirements continue to force an evolution in valve design. Higher pressure, in a wider range of temperatures; exotic, hazardous, and expensive fluids; automation; response; and simplicity are all contributing to tomorrow's valve designs.

The valves most commonly used throughout industry may be categorized as linear (Multi-turn) GATE & GLOBE VALVES or rotary (Part-Turn/Quarter-Turn) BALL & BUTTERFLY VALVES.

What is a valve?

A valve is a pressure-containing mechanical device used to shut off or otherwise modify the flow of a fluid that passes through it. The action of a valve is caused by moving the closure element (ball, plug, gate, disc, etc.) which is attached to a stem located outside the body. This very basic definition of a valve is intended to reveal that indeed a valve is a very simple device. It has a body to contain the fluid pressure, a closure element to shut off or modify the flow through the body, and finally a stem to change the control position of the closure element.

In today's industrial environment valves are used to satisfy a variety of process and production requirements.

The valve user may select from many manufacturers, materials, and designs to meet flow and process requirements. What complicates things for valve manufacturers and users, however, is not the function of a valve but under what conditions it must perform. The controlled medium may be a gas, a highly corrosive liquid, toxic or radioactive material, or any of a number of other fluids. Valves must withstand pressures from vacuum to several thousand pounds per square inch as well as cryogenic to very high temperatures. Some valves must cycle in just a few seconds repeatedly over long periods of time, while others may remain in one position for 90 percent of their life. Depending on the conditions, valve life may be a few hours or many years, and maintenance may be required after a single cycle or not required for many thousands of cycles. Applications vary widely, as does valve performance.

Valve selection basics

When making a valve selection, here are some important questions to ask.

- Does the valve meet the specifications required for your process?
- What type of valve best suits your needs: gate, globe, ball, butterfly, check, pinch, etc.?
- Make sure the valve is sturdy and the stem is blowout proof.
- Will the valve be automated?
- Do you need a fail-safe capability in case of electrical or system failure?

Progress in design has put a great variety of valve and actuator types, each with some special qualification for service, at the engineer's fingertips. From these the engineer may choose the right automated valve package to provide dependable and economical performance.

Because the valve is in contact with the fluid that is either the final or intermediate product of a process, it is often the most carefully selected element of an automated valve package. But before an actuator selection is made, the valve type, material, etc., must be determined, as this may affect the amount of torque required to automate a valve. Having done this the actuator style (rotary or linear), torque (or thrust), output, and type (manual, electric, pneumatic, hydraulic, etc.) may be addressed.

Certain essential information must be known and analyzed before one can select the best valve for the job. Some important questions to ask are

- What is the function of the valve? On-off only? Control? Fail-safe? Frequent or infrequent operation?
- How will it be operated: manually, pneumatically, or electrically?
- What is the process medium? Is it corrosive or abrasive? What is its volume and velocity?
- Is the valve being considered available in all materials?
- What about pressure and temperature? Depending upon the type of material used for a given media the pressure and temperature rating may be severely limited. A completely metallic valve may be necessary to handle an extreme temperature but may not provide the shutoff required.
- What is the pipe size? Is the valve being considered available in that diameter?
- How fast must it operate? An automated ball valve can cycle dozens of times per minute, but a gate valve cannot.
- Should the valve be able to be maintained in line? Should it be a top-entry or three-piece design?
- How much should it cost? Some 1-inch (in) valves cost as much as $2000 but depending on the application they may still be considered economically feasible.
- What about weight? A gate valve can weigh as much as 10 times that of a butterfly valve.

Valve selection considerations

Pressure ratings

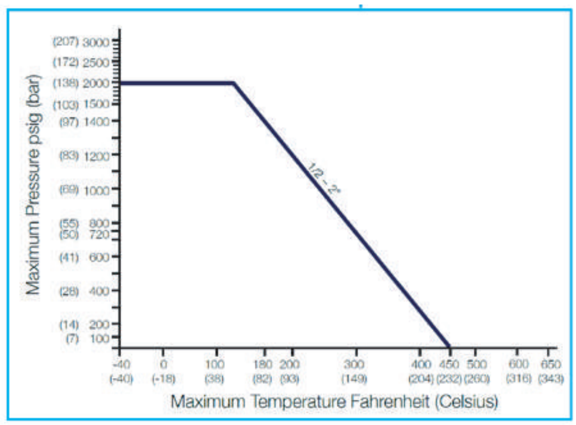
When selecting a valve for a given service, the inlet pressure and the maximum pressure drop rating of the valve must be considered. Inlet pressure ratings are generally expressed in terms of the American National Standards Institute (ANSI) class ratings and range from ANSI class 125 through 2500 depending on a valve style, size, and materials of construction including seat materials. Valves with ANSI class ratings are designed to withstand pressures greater than the nominal classifications. An ANSI class 150 valve for instance is actually rated at 285 pounds per square inch (lb/in^2) gage at 100°F. Because pressure and temperature are interactive, they must both be considered in valve ratings and selection.

Differential pressure, also called ΔP (delta P), is the difference between the upstream and downstream pressures of a valve in the closed position and is an important consideration in determining valve torque for actuator sizing.

Temperature ratings.

Temperature capabilities are essentially a function of the materials used in the construction of a valve. Temperature and pressure ratings are interactive. That is, the higher the temperature, the lower the pressure capability.

For particular material combinations it is necessary to refer to the manufacturer's specifications. An example of the pressure and temperature relationship is shown in the accompanying graph.



Material selection.

Material specification is an important step in valve selection as it has great impact on valve life, performance, and cost. Material compatibility with a given process fluid and the physical ability to withstand wear, pressure drop, corrosive and erosive fluids are basic considerations in material selection. The fluid to be handled by a valve may be broadly categorized by

- Material
- Pressure
- Temperature
- Velocity

and subcategorized as

- Clear and clean
- Viscous
- Slurry
- Corrosive
- Erosive
- Cryogenic

How they are transferred through a valve (temperature, flow rate, etc.) determines whether or not they should be considered abrasive, erosive, or clogging in nature. Finally the conditions which allow the fluid to pass through a valve or how the fluid is prepared or used in a process will determine its temperature, pressure, and flow rating.

Shutoff

Shutoff is ordinarily stated in terms of classes of seat leakage. In actual service, shutoff depends on many factors including pressure drop, temperature, and the condition of the seating surfaces. ANSI seat leakage classifications provide a basis for comparison among valves of similar configuration. Control valves are generally not required to provide complete shutoff. Block valves are intended for complete shutoff. Some terms used to describe this are leak tight, bubble tight, or positive shutoff.

ANSI publishes a standard of valve leakage specifications and classes.

LEAKAGE SPECIFICATIONS AND CLASSES

Leakage Class	Maximum Leakage Allowable	Test Medium	Test Pressure	Testing Procedures Required for Establishing Rating
I	XXX	XXX	XXX	No test required provided user and supplier so agree
II	0.5% of rated capacity	Air or water at 50-125° F (10-52° C)	45-60 psig or max. operating differential whichever is lower	Pressure applied to valve inlet with outlet open to atmosphere or connected to a low head loss measuring device full normal closing thrust provided by actuator.
III	0.1% of rated capacity	Air or water at 50-125° F (10-52° C)	45-60 psig or max. operating differential whichever is lower	Pressure applied to valve inlet with outlet open to atmosphere or connected to a low head loss measuring device full normal closing thrust provided by actuator.
IV	0.01% of rated capacity	Air or water at 50-125° F (10-52° C)	45-60 psig or max. operating differential whichever is lower	Pressure applied to valve inlet with outlet open to atmosphere or connected to a low head loss measuring device full normal closing thrust provided by actuator.
V	0.0005 ml per minute of water per inch of port diameter per psi differential	Water at 50-125° F (10-52° C)	Max service pressure drop across valve plug, not to exceed ANSI body rating.	Pressure applied to valve inlet after filling entire body cavity and connected piping with water and stroking valve plug closed. Use net specified max actuator thrust, but no more, even if available during test. Allow time for leakage flow to stabilize.
VI	Not to exceed amounts shown in following table based on port diameter.	Air or nitrogen at 50-125° F (10-52° C)	50 psig or max rated differential pressure across valve plug whichever is lower.	Actuator should be adjusted to operating conditions specified with full normal closing thrust applied to valve plug seat. Allow time for leakage flow to stabilize and use suitable measuring device.

End Connections

End connection selection is usually a simple question of whether the desired end connection style is available for the type of valve being considered. Rotary valves are generally available in threaded, welded, flanged, or wafer designs. Wafer-style bodies provide an initial cost savings compared to flanged designs. However, installing wafer-style valves requires careful centering between two line flanges.

Actuator Requirements

Another example of the importance of the valve selection process involves actuation. Consider for instance that a ball valve and a plug valve are equally acceptable for a given service. Because they are to be automated, the next natural step is to consider the operating torque of the valve. Plug valves traditionally require much more torque than ball valves. In fact, ball and plug valve manufacturers' published torque often differs significantly for the same sizes. This means that an actuator may be physically larger and more costly for a plug valve than for a ball valve.

Summary. Mixing and matching these many characteristics makes the task of valve design and selection monumental. In fact, the reason that there are so many valve types is that there are so many different requirements from the users of valves.

Basics of Valve Design (Seats and Seals)

A valve is properly considered to be a hybrid structure—pressure vessel and operating machinery. The important performance parameters of a valve are pressure-boundary integrity, operating effort, and control and/or shutoff performance.

Not all valves can handle the pressure and temperature ratings of all applications, but pressure and temperature are two basic properties of a fluid that must be considered in valve selection.

In a pipeline there are many potential leak paths for a fluid: pipe joints, seams, equipment connections, and valves. To understand valve design as it relates to containing pressure, it is best to look at the basic components. The body is the main pressure-containing element of a valve. It also serves as the basic foundation for all the other components including the end connections. The valve body must also withstand loads generated by piping connections and the actuator. There are many considerations that must go into the design of a valve body including valve type, pressure rating, manufacturing, material, and cost. Depending on the type of valve, there may be a variety of potential leak paths through the body. There is the bonnet attachment, body seals, and stem seal as well as the pipe connection area.

Pressure-boundary integrity

Pressure-boundary integrity requires basically sound pressure parts, pressure-tight static assembly joints, and, in most cases, an effective working seal between a moving stem and the valve bonnet.

Sealing the Valve Stem

Because a valve is intended to contain the fluid that it is controlling, the basic design to meet this requirement is complicated by the need for a valve stem which penetrates the body. A very important element then for complete pressure containment of a valve is the stem seal. To contain the fluid and allow the stem to operate, valve manufacturers are continually working with new designs and materials to seal the stem area. The stem seal is the most common site for fluid leakage through a valve because it is a dynamic seal and subject to wear over time.

In terms of stem-packing leaks, all rotary-action valves offer a significant improvement over sliding stem, linear valves. Sealing the stem of a gate or globe valve is usually accomplished by filling a cylindrical chamber in the bonnet surrounding the stem with a packing material compressed in the chamber by a gland and associated bolting. In a standard globe valve, the packing acts as a wiper as the stem goes up and down. A difficult-to-hold gas, such as ammonia or chlorine, can migrate through the packing to mix with the atmosphere or cause corrosion of the stem. The alternating wet and dry stem, as it cycles, can increase corrosion and leakage and damage packing, and thus cause a more significant leak.

Another concern is in abrasive-slurry and high-temperature service. Continual up and down action can again create packing damage, causing a leak to develop. The reciprocating action of the stem against the packing in a gate or globe valve is not present in rotary valve designs, and so they tend to seal longer.

Automated quarter-turn valves are subject to premature stem seal failure when there is misalignment between the actuator drive shaft and the valve stem. This is usually caused by improperly manufactured mounting hardware. Careful selection of valve and actuator suppliers can help ensure high-quality materials and well-designed mounting hardware.

If an automated valve is in a critical service and cannot be removed for immediate maintenance, the actuator should be sized for an operating force assuming maximum packing tightness.

Valve Seats

An improperly selected valve seat material is the most common reason for internal leakage. To select the proper seat it is necessary to generate a complete fluid profile. This includes pressure and temperature but, more importantly, a classification of the fluid such as clean liquid, gas, steam, viscous, fibrous, or powder. This helps the valve manufacturer to make a seat material recommendation.

Additionally, valve operation may be affected by the fluid class. Valve manufacturers often apply actuator sizing factors or increase the valve operating torque. Use of a valve in severe throttling conditions can be harmful to valve seating surfaces and materials, and in cases where the fluid is cavitating, gross damage to the valve body and/or downstream piping may result.

Valves which remain in one position for long periods of time may be subject to some degree of reduction of operability as a result of loss of effective lubricants in threads, aging of packing, surface corrosion of moving parts, accumulation of deleterious solids, or material cold flow. In some applications it may be desirable to schedule periodic partial- or full-cycle exercising of such valves. This may be done with manual valves by cycling them periodically. When automated valves are to be exercised regularly, provisions must be made to do so. An example would be a manual override device on the pilot valve of a pneumatic actuator.

Fugitive Emissions

A fluid leaking through any part of a closed piping system is referred to as a fugitive emission. Valves, because of their sheer numbers, are the major contributor to overall fugitive emission totals in the process industries. The variables affecting emission rates are valve types and valve packing configurations.

Fugitive emissions represent a significant contribution to greenhouse gases, with atmospheric methane posing a particularly great risk due to its capacity to trap by volume 28 times more heat than carbon dioxide. Fugitive emissions from valves account for 60% of the total methane emissions from a refinery, with as much as 80% of the leakage, per valve, occurring at the valve stem.

API 641 and ISO 15848 Standards

Today, there are several different standards for low emissions certification: API 641 certification and the ISO 15848-1:2015 standard.

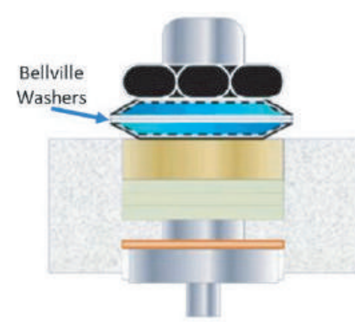
API 641 is specifically relevant to quarter-turn valves – the most common type of valve used in industry. The API 641 standard applies to all stem seal materials and dictates a stringent maximum allowable leakage of 100 parts per million by volume (ppmv).

ISO 15848-1:2015, 'Industrial valves – Measurement, test and qualification procedures for fugitive emissions', addresses both isolation and control valves, and outlines testing procedures to measure leakage for the stem/shaft seals and body seals of the valve being tested. Under this specific standard, a control valve must be cycled from 40% open to 60% open, and there are distinct ratings for tightness class, endurance class, and temperature class.

The tightness class can be measured with helium or methane as the test fluid, the latter being more relevant to the topic of greenhouse gas emissions, and defines standards for the maximum allowable leakage at each class rating.

Today's plant personnel must not only concern themselves with the type of packing material to put into their valves but with the sealing effectiveness of the packing technique. One option is to employ the live-loading technique. This concept, originally used to pack valves in nuclear service, is now prevalent in every type of industry.

Live loading of valve packing is accomplished by storing energy in spring washers (Belleville). This technique puts a compressive force on the packing and maintains a relatively leak-tight seal around the stem while allowing the stem to move as necessary during opening and closing. The number of springs varies according to the valve configuration, but it usually is possible to design a group of springs that maintains about 80 percent of the original design load, even when the packing has seen some consolidation while in service.



Live Loaded Stem Packing

Properly designed live-loaded valve packing improves the control of emissions leakage; increases reliability of packing, providing an additional safety factor in areas not accessible during normal operations; and saves on packing by increasing its life expectancy and decreasing total erosion.

The use of springs to live-load a valve also provides a guide to help the user determine if there is sufficient bolt torque on the packing. The visual flat position of the spring will indicate that the springs are fully loaded. The visual position of the spring being opened indicates torque loss or insufficient torque loading on the packing. Any valve that has a packed stem, sufficient clearance, and a gland stud long enough to hold the springs can be live-loaded. The springs produce a constant force against the packing that can be more than 20 times greater than could be applied manually with a gland nut. Even with the use of only one spring, the stored energy available to maintain the force on the packing is 4 times greater than the manual force normally used on the gland nut to maintain packing load.

The following types of valve situations would benefit from the enhanced packing design used with severe service valves.

- Valves that are subjected to a high degree of thermal cycling
- Motor-operated, air-operated, and manually operated valves that are frequently actuated
- Critical valves with a possible high volatility
- Certain types of valves that have been particularly troublesome from past experience

Valve Materials

A valve can achieve no more than its material will allow. With each new development in materials or their properties the ability of valves to handle more severe applications is improved. Typically, valves are constructed of two types of materials that may be referred to as hard and soft. All the components that contain the fluid pressure make up the valve body. The body and the trim (ball, stem, gate, etc.) are constructed of hard materials. Hard materials must withstand the mechanical stresses of fluid pressure, abrasion, bolting, threading, weight, and piping stresses as well as the corrosive condition of not only the surrounding environment but certainly the fluid that it contains.

Soft materials are those whose properties make them useful as seats, seals, and liners. Various compositions of fluorocarbons, fibers, graphites, and elastomers provide for an incredible selection of material properties to satisfy most applications.

Material selection is often quite simple for nonaggressive fluids. But even water must be carefully analyzed before a material is selected. For instance, stainless steel type 17-4 pH is corrosion resistant. It will not corrode in ordinary tap water, but it will corrode in pure demineralized water. Titanium is dangerous for dry chlorine but excellent for wet chlorine. But the opposite is true for copper.
Each combination of body, trim, and seal materials may provide desirable performance on one hand but undesirable performance on the other. For instance, where desirable corrosion resistance is achieved, undesirable pressure or temperature limitations may exist. When cost is a consideration, one may accept a stiff purchase price for the offsetting longer performance life of a specific valve. Fortunately there are plenty of materials from which to choose.

Valve bodies and closure elements may be constructed of just about any material that may be cast, forged, molded, or welded. This includes iron, steel, aluminum, bronze, nickel, titanium, and many other metals and alloys. They may also be made from a variety of plastics and even ceramics. Some valve types and sizes are not available in all materials. In some cases a corrosion-resistant metal may prove inadequate or too costly for a particular service. Oftentimes a plastic or elastomer lining may be available. The strength of an iron or steel body in combination with the unique properties of the liner material is sometimes an excellent cost-saving alternative. Some examples of these valves are diaphragm valves and fully lined ball, plug, and butterfly valves.

It pays to know the range of materials from which valves are usually made and to understand the pressure, temperature, and structural limitations of each material. It may be highly unsafe to use materials for services they are not recommended for.

This white paper is derived from the technical book, Valve and Actuator Technology by Wayne Ulanski

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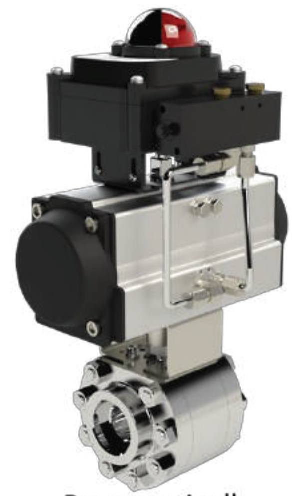
Understanding Valve Actuator Selection

Making the decision

The decision to automate a valve is usually based on one or all of the following considerations.

- Safety
- Reliable operation
- Control and process system performance
- Inaccessible or remote valve location
- Cost
- Excessive valve torque
- Emergency response and whether it is fail-safe



Pneumatically actuated ball valve
(Courtesy SVF Flow Controls)

The distinct purpose

All actuators have several distinct purposes that include:

1.**Move the valve** closure member (disc, ball, or plug) to the desired position. Not only must the actuator provide enough torque or thrust to move the closure member under the most severe conditions, it must also be fitted with the appropriate controls to direct it.

2.**Hold the valve** closure member in the desired position. Particularly in throttling applications where fluids may create a dynamic torque, actuators should have adequate spring or fluid power or mechanical stiffness to overcome this phenomenon.

3.**Seat the valve** closure member with sufficient torque to provide the desired shutoff specification. A butterfly valve for instance is fully seated (closed) when the disc is positioned in a resilient liner (seat). In this rotary position the valve stem torque is at its highest. Actuator sizing for torque-seated butterfly valves may require special accessories particularly on electric actuators to ensure that sufficient torque is sustained in the closed position.

4.**Provide a failure mode** in the event of system failure. This may be fully opened, closed, or as-is depending upon the application. Certain failure mode requirements may eliminate electric actuators yet be ideal for pneumatic or electrohydraulic units.

5.**Provide the required rotational travel** (90°, 180°, etc.). Valves requiring more than 90° of rotation include multi-ported valves. A few pneumatic actuator manufacturers offer 180° actuators. For greater than 180°, electric actuators are usually preferred because they are electrically, not mechanically, limited in rotation.

6.**Provide the required operating speed.** All actuators may be regulated in cycle speed depending on the control circuit elements used.

Fast cycle speeds (less than one-half the standard actuator cycle time) require careful valve selection. The physical shocks associated with fast cycling can damage the valve parts—especially when combined with high cycle rates. Special preparation of pneumatic actuators—including special solenoids, piping, and quick-exhaust valves—may be required to achieve high cycle speeds.

Because they are geared motors, the cycle speeds of electric actuators cannot be increased, only slowed. This is easily accomplished with the specification of either special cycle times or with the addition of an electronic speed control card.

Special cycle times are achieved with a different gearing mechanism which also affects output torque. The electronic speed control is infinitely adjustable and can reduce the effective actuator speed up to 20 times without the need for special gearing. Output torque of the actuator is not affected where speed cards are used.

Pneumatic actuators can be slowed using speed control valves in the air piping. One speed control valve will slow speed in one direction, while two are required to slow speed in both directions. Speed controls do not affect the output torque of pneumatic actuators.

Pneumatic and electric actuators compared

At times it is necessary for a process engineer to choose between a pneumatically or an electrically actuated valve for a process system. There are advantages to both styles, and it is valuable to have data available to make the best choice.

Compatibility (Power Source)

First and foremost, in the selection of an actuator type (pneumatic or electric) is to determine the most effective power source for the actuator. Points to consider are:

Electric Actuators are Geared Motors
(Courtesy SVF Flow Controls)

- Power source availability
- Torque at the valve stem
- Failure mode
- Control accessories
- Speed of operation
- Frequency of operation
- Plant environment
- Size of valve
- System component costs
- System maintenance

The most practical pneumatic actuators utilize an air pressure supply of 40 to 120 psi (3 to 8 bar). Generally, they are sized for a supply pressure of 60 to 80 psi (4 to 6 bar). Higher air pressure is usually difficult to guarantee (even potentially dangerous) and lower pressures require a very large diameter piston or diaphragm to generate desirable operating torque.

Electric actuators are often used with a 110 VAC power supply but are available with a wide variety of AC and DC motors in single phase and three phase.

Temperature range

Both pneumatic and electric actuators may be used in a wide temperature range. The standard temperature range of a pneumatic actuator is from -4 to 174°F (-20 to 80°C) but may be extended to -40 to 250oF (-40 to 121oC) with optional seals, bearings and grease. If control accessories are used (limit switches, solenoid valves etc.) they may not have the same temperature rating as the actuator, and this should be considered in all applications.

In low temperature applications the quality of the supply air in relation to dew point should be considered. Dew point is the temperature at which condensation occurs in air. Condensate may freeze and block air supply lines making the actuator inoperable.

Electric actuators are available in a temperature range of -40 to 150°F (-40 to 65°C). When used outdoors an electric actuator should be sealed from the environment to prevent the introduction of moisture to the internal workings. Condensation may still form inside, if drawn from the power supply conduit, which may have captured rainwater prior to installation. Also, since motors warm the inside of the actuator enclosure when it is operating and cools it when it is not, temperature fluctuations may cause environmental "breathing" and condensation. For this reason, all electric actuators used outdoors should be fitted with a heater.

Hazardous Areas

It is sometimes difficult to justify the use of electric actuators in a hazardous environment, but if compressed air is not available or if a pneumatic actuator will not provide the operating characteristics required, then an electric actuator with a properly classified enclosure may be used.

NEMA guidelines

The National Electrical Manufacturers Association (NEMA) has set up guidelines for the construction and installation of electric actuators (and other electrical devices) for use in hazardous areas. The NEMA VII guideline reads:

VII Hazardous Location Class I (Explosive Gas or Vapor) Meets application requirements of National Electrical Code; conforms with specifications of Underwriters' Laboratories, Inc., used for atmosphere containing gasoline, hexane, naphtha, benzene, butane, propane, acetone, benzol, lacquer-solvent vapors, and natural gas.

Almost all electric actuator manufacturers have an option for a version of their standard product line that conforms with NEMA VII. Another source for hazardous area guidance is available from ATEX

On the other hand, pneumatic actuators are inherently “explosion-proof”. When electric controls are used with pneumatic actuators in hazardous areas, they are generally more cost effective than electric actuators. Solenoid-operated pilot valves (which are electrical devices) may be mounted and powered in a non-hazardous area and piped to the actuator. Limit switches -for position indication- may be housed in a NEMA VII enclosure. The inherent safety of pneumatic actuators in hazardous areas makes them a practical choice in these applications.

Spring Return

Another safety accessory widely specified in the process industries on valve actuators is the spring-return (fail-safe) option. Upon power or signal failure a spring-return actuator drives the valve to a pre-determined safe position. This is a practical and inexpensive option with pneumatic actuators and is an important reason for the wide use of pneumatic actuators throughout the industry.

Electric Actuator with Optional Spring Pack.
(Courtesy SVF Flow Controls)

Electric actuators are available with a spring return option or a battery backup system to provide predictable “failure” positioning.

Performance characteristics

Before specifying a pneumatic or electric actuator for valve automation it is important to consider a few of the key performance characteristics of each.

Duty cycle

Pneumatic actuators have a 100 percent duty cycle. In fact, the harder they work, the better they work. Electric actuators are most commonly available with 25 percent duty cycle motors. This means that to prevent overheating in high cycle applications the motor must rest frequently. Because most on-off automated valves remain idle 95 percent of the time duty cycle is not usually an issue. With optional motors and/or capacitors an electric actuator may be upgraded to 100 percent duty cycle.

Stalling

Pneumatic actuators may be stalled indefinitely without overheating.
Electric actuators should not be stalled. Stalling an electric actuator draws excessive current, which generates heat in the motor and can cause damage. Torque switches or heat and current sensors are often installed in electric actuators to protect the motor.

Speed control

The ability to control the speed of a pneumatic actuator is an important advantage of the design. The simplest way to control the speed is to fit the actuator with a variable orifice (needle valve) at the exhaust port of the air pilot. Since electric actuators are geared motors it is impossible to make them cycle faster unless a gearing change is made. For slower operation a pulsing circuit may be added as an option.

Modulating control

In modulating service an electric actuator interfaces well with existing electronic control systems and eliminates the need for electro-pneumatic controls. A pneumatic or electro-pneumatic positioner is used with pneumatic actuators to provide a means of controlling the valve position.

Torque-to-weight ratio

Electric actuators have a high torque-to-weight ratio above 4,000 lbf.in. (450 Nm). Pneumatic actuators have an excellent torque-to-weight ratio below 4,000 lbf.in.

Summary of pneumatic and electric actuators

This table of characteristics summarizes the comparison of pneumatic and electric actuators.

PNEUMATIC		ELECTRIC
Simple, accurate, and inexpensive speed control		A pulsing circuit may be added to slow the operating speed
Inherently explosion-proof, spark-proof		Available with a NEMA VII enclosure for hazardous areas
Not subject to overheating; not sensitive to wet environment		Motor designed to prevent current or temperature damage
		Must be sealed from moisture; heater and thermostat required
100% duty cycle		25% standard duty cycle. May be upgraded
May be stalled indefinitely		Should not be stalled
Torque-to-weight ratio averages 123:1 at 1500 lbf • in (170 N • m)		Torque-to-weight ratio averages 44:1 at 1500 lbf • in (170 N • m)
Spring-return (fail-safe) option is practical and economical		Available in Spring Return or Battery Backup configurations

Actuator Sizing

The most important step in developing an automated valve specification is to determine a sizing criterion. If a valve is to operate in a process handling clean liquids at moderate pressures and temperatures, the manufacturer's published operating torque is usually adequate for actuator sizing. Under certain conditions, however, the torque required to operate a valve may increase. In this case a sizing safety factor may need to be applied based on the following guidelines:

MEDIA AND SERVICE FACTORS			
MEDIA FACTORS	**MULTIPLIER**	**SERVICE FACTORS**	**MULTIPLIER**
Clean, particle free, non-lubricating (water, alcohol, etc)	1	Simple On and Off Operations	1
Clean, particle free, lubricating (oils, hydraulic fluid, etc)	0.8	Manual Throttling Service	1.25
Slurries or heavily corroded and contaminated systems	2	Positioner Control	1.5
Gas or saturated steam, clean and wet	1	Once per day operations (on/off)	1.2
Gas or superheated steam, clean and dry	1.3	Once every two days or a "Plant Critical" Operation (on/off)	1.5
Gas, dirty unfiltered (natural gas, Chlorine)	1.5	Once per month or less frequently (on/off)	2
Liquid, Black Liquor, Lime Slurry	1.8	Applications below -20° F	1.25
Liquid, Viscous, Molasses	1.3		

NOTE: Consult the valve manufacturer for specific Safety Factor recommendations

About the author.
Wayne Ulanski is the president of SVF Flow Controls and has been an influential member of the valve and actuator community for many years. SVF Flow Controls is the engineered flow control division of Matco-Norca LLC.

How to Select Automation Accessories for Valves

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 pneumatic 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 control 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 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 through 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.

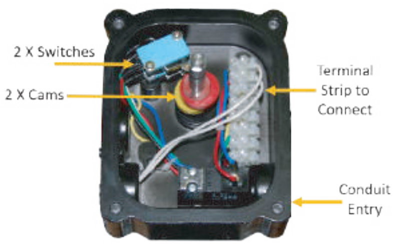
A four-way valve has a pressure port, two output ports, and an exhaust function. The two output ports will pressurize one or the other chambers of a double-acting cylinder and so it is used with these types of pneumatic actuators.

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" (or Feedback 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 box 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 pick up 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.

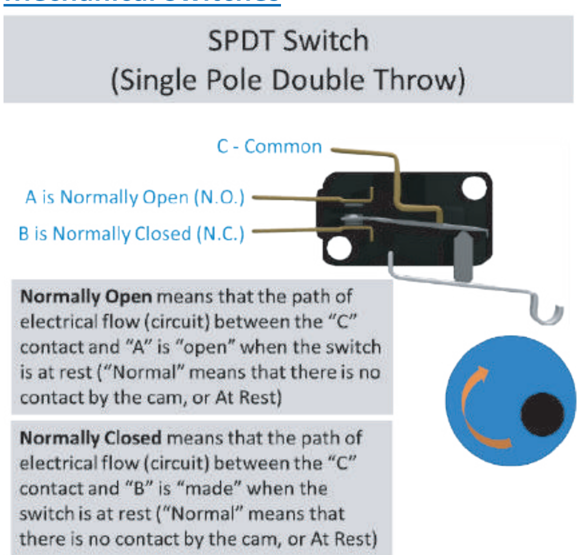


Position-indicating switches are used for a variety of applications: light indication (powering indicator lamps on a control panel), system sequence cycling, alarms, electrical interlocking, etc. Some switch enclosures may be fitted with other devices, such as a potentiometer or position transmitter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

Mechanical Switches



These switches are also called "Snap Acting" switches as there is a distinct sound (snap) as the contacts shift within the switch.

Mechanical 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.

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.

Proximity Switches

These switches/sensors operate when a metallic or magnetic object is brought into proximity with 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.

Inductive sensors

Inductive sensors are switches that operate when a metallic object is brought into proximity with the sensing face. Most inductive 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. They require power to operate as the sensing area is a field of electro-magnetism.

Reed switches

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

<u>Major advantages of reed switches</u>

- Fully hermetically sealed metal contact.
- Reed switches can operate in moist and dust ambient conditions
- Temperature variation from -60°C to +155°C. (-76°F to 311°F)
- Zero power to operate

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. See “Transducers” below.

Electrical Enclosures

Switch boxes designed for use in explosive environments (hazardous areas) 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 that are listed by the National Electrical Manufacturers Association (NEMA IV, VII, IX, etc.) to satisfy a wide range of applications. Hazardous area device selection and area definitions are also covered by ATEX.

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 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.

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 × 4 mA, 15 psi is 5 × 3 psi, etc. 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. <u>This is known as live zero.</u>

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. 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.

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

Instrument Signal Ranges

Range Type	Pneumatic Pressure (PSIG)	Electric DC Current, mA	Voltage VDC	Resistance, Ohms
Standard	3 to 15	4 to 20	1 to 5	0-10k
			10 to 50	0-5k
				0-135
Split	3 to 9	4 to 12	1 to 3	
	9 to 15	12 to 20	3 to 5	
			10 to 30	
			30 to 50	

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.

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.

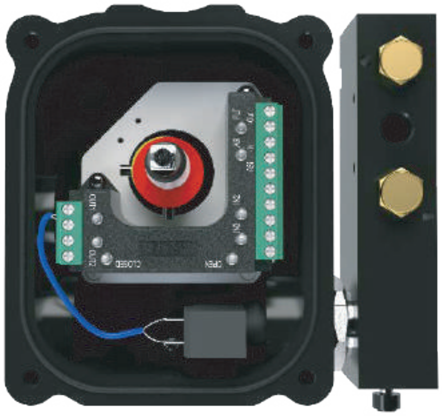
Disengageable gear manual override

The disengageable gear override is a modular component that fits between the valve and the actuator and offers simple, reliable manual positioning. 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.
It is a networking alternative to the hard wiring of field devices, and 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.

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

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