How to Select an Actuator

As the process industry continues to achieve more efficient and productive plant design, plant engineers and technicians are faced, almost daily, with new equipment designs and applications. One product, a valve actuator, may be described by some as simply a black box, having an input (power supply or signal), an output (torque), and a mechanism or circuitry to operate a valve. Those who select control valves will quickly see that a variety of valve actuators are available to meet most individual or plant wide valve automation requirements. In order to make the best technical and economical choice, an engineer must know the factors that are most important for the selection of actuators for plant wide valve automation. Where the quality of a valve depends on the mechanical design, the metallurgy, and the machining, its performance in the control loop is often dictated by the actuator.

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

All actuators have several distinct purposes. They must:

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 multiported 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.

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 by the use of 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.

High cycle rates will require special selection and preparation of valves and actuators. A high cycle rate for pneumatic actuators is de-fined as cycling continuously in excess of 30 times per hour; electric actuators used in excess of a 25 percent duty cycle are said to have a high cycle rate. High cycle rates place additional stress and wear on the valve stem. The small amount of play between the actuator, stem, and ball increases the wear in the stem in high cycle rate applications. This is minimized with special preparation to assure long life of the valve package.
The *Data Form for Specifying Automated Valves* (see end of article) may prove helpful when gathering pertinent actuator selection information.

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:

- 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 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 250°F (-40 to 121°C) 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.

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 may be mounted and powered in a nonhazardous 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.

Where springs are not practical because of actuator size or weight, or if a double-acting unit is already installed, an accumulator tank may be installed to store air pressure.

Electric actuators are not widely available in a spring return version; however, a battery backup system is an elegant solution.

To accomplish the spring-return function an electro-hydraulic actuator is often a good choice. Electro-hydraulic actuation is achieved by energizing a hydraulic pump, which pressurizes a spring-return cylinder. Upon power failure the spring action drives the actuator to the original position. Because only an electric power supply is required for this self-contained unit it is a practical approach to fail-safe electric valve actuation.

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 device.

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	Electronydraulic actuator is a good choice for electric fail-safe function

Data Form for Specifying Automated Valves

Section I: Pneumatic Actuators and Controls for On/Off and Throttling Control
Section II: Electric Actuators and Controls for On/Off and Throttling Control

To ensure automated valve performance in today's sophisticated process control systems it is essential to develop a complete specification for each of the elements in the control package.

Though the valve actuator is the basic element in a valve automation package, pilot valves, limit switches, positioners, speed controls, transducers and other control accessories are necessary to properly communicate with the system and to characterize the performance of the automated valve to meet the process/flow control requirements.

The operating environment must also be considered and measures taken to ensure compatibility. This may include specifying the materials of construction or electrical design for area classification.

This data form is intended as a specifying aid for valve, actuator and control system elements and to focus upon the design and performance characteristics of the most common automated valve components.

The following guide is for actuators and controls only. It is assumed that the valve to be automated has already been selected based on its own unique ability to handle the service for which it is intended.

A complete valve specification for which an automated package may be specified should include:
-Valve size ___________Type _______________Mfr.___________ Model Nr._____________
-Valve Torque________________(if available)
-Service Conditions:
Line pressure ________Media Temp.________ °F Media (Slurry, Gas, etc.)___________________

Actuator Sizing

The most important step in developing an automated valve specification is to determine a sizing criteria. 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:[1]

Media and Service Factors:

Media Factors	Multiplier
Clean, particle free, non-lubricating (water, alcohol, etc)	1.00
Clean, particle free, lubricating (oils, hydraulic fluid, etc)	0.80
Slurries or heavily corroded and contaminated systems	2.00
Gas or saturated steam, clean and wet	1.00
Gas or superheated steam, clean and dry	1.30
Gas, dirty unfiltered e.g. natural gas, Chlorine	1.50
Liquid, Black Liquor, Lime Slurry	1.80
Liquid, Viscous, Molasses	1.30

Service Factors	Multiplier
Simple On and Off Operations	1.00
Manual Throttling Service	1.25
Positioner Control	1.50
Once per day operations (on/off)	1.20
Once every two days or a "Plant Critical" Operation (on/off)	1.50
Once per month or less frequently (on/off)	2.00
Applications below -20° F	1.25

NOTE: Consult the valve manufacturer for specific Safety Factor recommendations.

Data Form for Specifying Automated Valves

Section I: Pneumatic Actuator Specification Data

A. Sizing Data

-Valve Torque:________________ Ibf.in.

-Sizing Safety Factor:___________%

-Double Acting or Spring Return:

-Fail Open:___ _____________ Fail Closed:____________________

-Fail on: Electric only __________________Pneumatic only_______ Electric or Pneumatic_________

-Operating Temperature Range:________ to____________°F

-Min/Max Operating Speed (if critical) _________sec/90° (open)_________sec/90° (close)

(Also important to consider in pneumatic actuator sizing is the minimum air pressure available to power the actuator. If a range of pressure is available (60 - 90 psig for example) the minimum should always be specified for actuator sizing).

-Minimum air pressure ________psig.

-Materials of Construction/Environmental Specs (i.e., caustic wash, aggressive fumes, etc.)

B. Pilot Valve

Pneumatic actuators are usually piloted by a solenoid valve. The actuator manufacturer will size the valve flow rate to provide adequate speed of operation and economy. If faster or slower speeds are critical to a process this must be specified for more accurate pilot valve sizing. The following valve types are generally used for piloting actuators:

-Double Acting Actuator 4 way, 5 ported, single coil__________

-Spring Return Actuator 3 way, 3 ported, single coil__________

Except where noted the following specification guideline applies to both 3-way and 4-way valves:
-Remote, local or direct mount:

Remote: Located away from the actuator in a control panel or on a manifold.

Local: Located at the actuator and adapted to the supply port of the actuator with tubing and fittings.

Direct: Some actuator manufacturers offer an integral air manifold to which a solenoid valve may be direct mounted to eliminate tubing and fittings. (NAMUR Standard)

-Materials of construction (aluminum, bronze, stainless steel) (aluminum is standard)

Coil Specifications -

-Coil voltage: ______ AC/DC (standard: 110, 24,12 VAC/DC)

-Class A (230 degrees F):____________

-Class F (310 degrees F):____________

-Class H (350 degrees F):________

Data Form for Specifying Automated Valves

Section I: Pneumatic Actuator Specification Data (continued)

-Area classification: (NEMA IV [weatherproof], VII [hazardous], etc)____________

-Energize to (open or close)____________

(When the pilot valve is energized will it drive the process valve open or closed?)

Pilot Valve Options -

-Manual Override: Maintained _________________Momentary _________Lock___________

-Air Pilot: yes ___no _____ (pilot valve action initiated by air pressure signal)

-Single or Dual Coil:___________(Dual coil available on 4 way valves only)

Speed control -

The speed of operation of a pneumatic actuator can be regulated in one or both directions of a cycle. Most pilot valves are designed with NPT exhaust ports that may be fitted with a needle valve or speed control valves.

-Specify: Open direction seconds __________________Close direction _________seconds

C. Limit Switches

Limit switches are used with pneumatic actuators to indicate the open, closed, or intermediate position(s) of the process valve. As an electrical device limit switches are enclosed in a housing designed to meet area classifications.

-NEMA Rating: NEMA 4 ____, NEMA 7 _____, NEMA 4-X,_____
-Switch styles: SPDT______, DPDT _____, SPST_____ , etc.
-No. of switches: Open ______________Close _________other
-Electrical Rating: (expected current draw, voltage) ______ amps _____Volts
-Visual Indicator required?: yes ___no_______
-Switch designs:

Snap acting (mechanical switches/dry contact)
Hermetically sealed reed switches
Non-contact (proximity type)
Others-consult actuator supplier

D. Positioners

Positioners are used with piston actuators and some diaphragm actuators to convert a control signal to a valve position in modulating service. There are two basic styles of positioners: pneumatic and electro-pneumatic.

1. Pneumatic Positioners
-Input control signal: _______________ 3 -15 psig etc._________psig
-Signal/position: valve open ______________________psig valve closed ______________psig
-Cam Style:* linear _____quick opening ____other__________
-Visual Indicator required? Yes ______no_____________

Data Form for Specifying Automated Valves

Section I: Pneumatic Actuator Specification Data (continued)

2. Electro-Pneumatic Positioners

-Input control signal: 4 - 20 maDC etc.

-Signal/position:

-valve open ________________maDC

-valve closed ______________maDC

-Cam Style: * linear _______quick opening ____other______

-Agency approvals (if necessary): (FM, etc.) ____________Area Classification;_________

-Options:

-Gauge set___________

-Internal limit switches______________

*Most off-the-shelf quarter turn valves have equal percentage flow characteristics. This is generally acceptable for most applications. If other characteristics are required a replaceable characterized cam may be used with most positioners.

3. Rotary Position Transmitter

A position transmitter provides continuous feedback of the valve position with a resistive or current output signal.

-Resistive Feedback is achieved through a potentiometer but may not be accurate over long distances due to the inherent resistance of the wire.

-Specify resistive range/90^0 of rotation: zero to _______ohms.

-Current Feedback is achieved through a resistance-to-current conversion circuit (RI) and is generally preferred for transmission over long distances. Output is 4-20 maDC over 90° of rotation.

-NEMA 4 ____________NEMA 7 _____________

Notes:

Data Form for Specifying Automated Valves

Section II: Electric Actuator Specification

Electric rotary actuators are basically geared motors with a variety of electrical accessories (limit switches, heater, circuit boards) that may be specified to meet the exact valve automation requirements of a process control system. As an electrical device it is housed in an enclosure designed for specific area classifications {NEMA Classification}.

A. Specification Checklist:

-Weatherproof (NEMA 4):______Hazardous (NEMA 7)[1]:_________
-Motor Voltage: 12_____24_____ 110____ 220____VAC or VDC
3-phase____________________ specify voltage[2]
-Compartment heater: yes________ no___________
[1]Specify: Class_______Division_______Groups_______
[2]3-plase motors require a reversing starter and/or transformer that may be located:
Remote_______or integral_______Specify Control Voltage for reversing starter_______VAC

B. Torque Switches

Torque switches are recommended on electric actuators with an output torque of 800 inch pounds and higher to protect the automated valve and motor. They are also necessary for tight closure of torque seated valves.

-Torque switch: Open yes ________no________
Close yes ________no________

C. Manual Override

A manual override is designed to provide manual valve operation in the event of electrical failure or for start-up and setup procedures. The handwheel should not rotate during electrical operation.

-Manual override? yes _______no___________

D. Separate Controls

-Single Phase motor:
Local/Remote Switch___________________
3 Position Rotary Switch ________(open/stop/close)
- 3-Phase Motor
Local/Remote Switch___________________
3 Pushbuttons __________(open/stop/close)

E. Electronic Speed Control

As a geared motor an electric actuator has a fixed speed of output rotation that is a function of the layout of the gear train. Some manufacturers offer their products with a rotary output speed of 2 seconds but most are in the range of 5 to 25 seconds for 90° depending upon the model. If a cycle time greater than what is available is necessary an electronic speed control should be specified.

- Electronic speed control: yes ___no ________________Speed of operation __________sec/90°min.

Data Form for Specifying Automated Valves

Section II: Electric Actuator Specification (continued)

F.Position Transmitter

A position transmitter provides continuous feedback of valve position.
-Slide wire (potentiometer) only ______Resistance ___________ohms/90°
-2-wire 4-20 maDC output ___________________(integral power supply)
-4-wire 4-20 maDC output __________________(requires a power supply)

G. Limit Switches

Limit switches are used to provide the necessary number of electrical contacts in the open, close or intermediate position. Standard electric actuators have two SPDT limit switches, one for the open position and one for the closed position to control rotary travel as desired.

Specify the number of additional contacts required in each position:
-Open _________contacts (make)
_________contacts (break)
-Close _________contacts (make)
_________contacts (break)

-Intermediate position:
Specify rotary position in degrees________°
Then ________contacts(make)________contacts (break)

H. Positioner

Positioners are used with electric actuators to position the valve in response to a control signal.
- Input signal: _______________ maDC _________________ VDC or ____________Ohms
-Position transmitter required: yes ___________no____________

I. Control Options for Electric Actuators

One of the most appealing characteristics of electric rotary actuators is its inherent versatility. Electronic control cards, switches and wiring are easily re-configured to meet the control system needs.

-3-position control package provides 0-90-180 rotation for multi-ported, 3-position valves.
-3-position options: yes ______no_____
-mid position stop from both / either extreme.
If either, then from: CW _______ CCW________________

Integral Local Control Station - mounts directly to actuator housing and includes Local / Remote switch plus open/close switch for local operation.
-Local Control Station: yes _____no____
-Options: Key lock _____Open/Close lights__________

J. Other Electric Actuator Options

Interposing Relay:____________Plug & Socket Connector_______
______DC Motor / Battery Backup for Fail-Safe Operation_____________Special Coatings: _____________
(Specify)

NOTES:

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