
INSTRUMENT ENGINEERS' HANDBOOK

Third Edition

Process Control

BÉLA G. LIPTÁK, Editor-in-Chief

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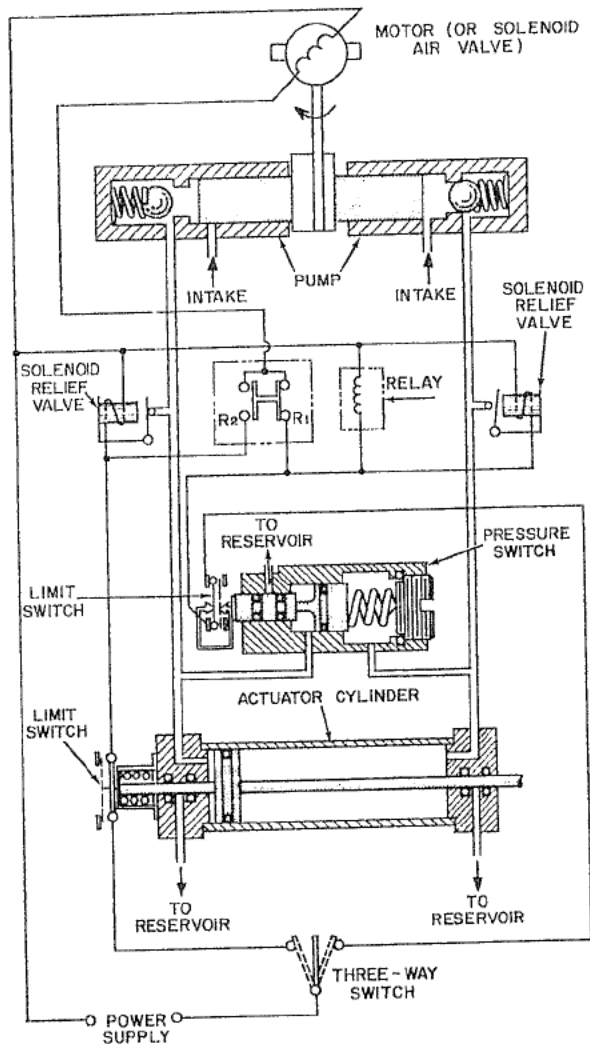


FIG. 4.1w
Two-cylinder pump-type electrohydraulic actuator.

Two-Cylinder Pump A two-cylinder pump, driven by a unidirectional motor, injects pressure into one end of a cylinder or the other, depending upon the positions of two solenoid relief valves (Figure 4.1w). The solenoid on the left is closed to move the piston to the right, with hydraulic pressure relieved through the other relief valve. Motion continues until the valve it is operating is seated. The buildup of cylinder pressure operates the pressure switch at a predetermined setting to de-energize the motor and both solenoid relief valves. This locks the hydraulic pressure in the cylinder. Switching of the three-way switch will start the motor and reverse the sequence of the relief valves to move the piston to the left. At full travel (which is the up position of a valve stem), a limit switch shuts down the unit. Open-centering the three-way switch at any piston position will lock the piston (and valve stem) at that point.

Remote control is accomplished by manipulating the open-center switch. Automatic control is acknowledge by including this open-center function, which may be solid state, in the control circuit. A potentiometer or LVDT that senses the stem position is required for feedback.

Stem output is 6000 lbf (2,727 Kgf) at a rate of 3 sec/in. (0.12 sec/mm). Stem travels up to 7 in. (175 mm) are available, although longer travels are feasible. The entire system is designed in a very compact explosion-proof package that can be mounted on a variety of valve bonnets. The speed of response to energizing and de-energizing the control circuit makes it feasible to adapt the unit to digital impulses.

SOLENOID VALVES

Solenoids move in a straight line and therefore require a cam or other mechanical converter to operate rotary valves. These actuators are best suited for small, short-stroke on-off valves, requiring high speeds of response. Solenoid-actuated

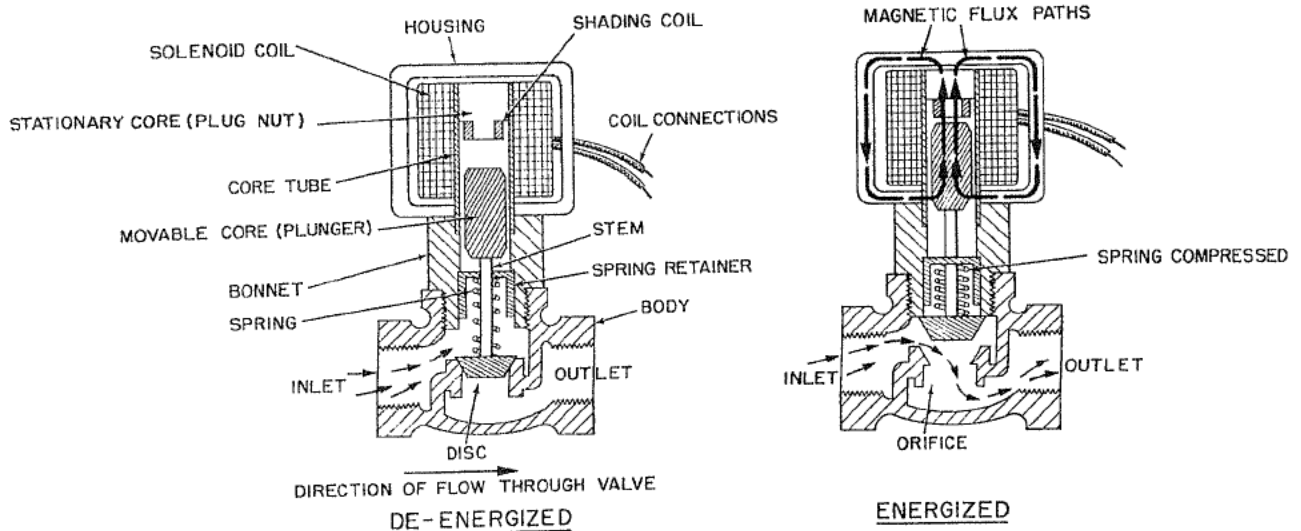


FIG. 4.1x
Direct-acting solenoid valve.

valves can open or close in 8 to 12 milliseconds. Their fast closure is not always an advantage: in water systems it can cause water hammer. They are limited to pressure drops below 300 PSID (20.7 bars), although when provided with pilots, levers, or double seats, they can handle higher pressure drops. They are available in two- or three-way designs, with power requirements ranging from 10 to 30 watts with 6 to 440 volt AC or 6 to 115 volt DC power supplies. Solenoids are reliable devices, and they can provide multimillion cycles on liquid service.

Solenoids (consisting of a soft iron core that can move within the field set up by a surrounding coil) are used extensively for moving valve stems. Although the force output of solenoids may not have many electrical or mechanical limitations, their use as valve actuators has economic and core (or stem) travel limitations, and they are expensive.

A solenoid valve consists of the valve body, a magnetic core attached to the stem and disc, and a solenoid coil (Figure 4.1x). The magnetic core moves in a tube that is closed at the top and sealed at the bottom, allowing the valve to be packless. A small spring assists the release and initial closing of the valve. The valve is electrically energized to open. Stronger springs are used to overcome the friction of packing when it is required (Figure 4.1y). Reversing the valve plug causes reverse action (open when de-energized). Increased stroking force is obtained by using the mechanical advantage of a lever with a strong solenoid (Figure 4.1z).

Using a solenoid to open a small pilot valve (Figure 4.1aa) increases the port size and allowable pressure drop of solenoid-operated valves. Small solenoid pilot valves are widely employed to supply pressure to diaphragms or

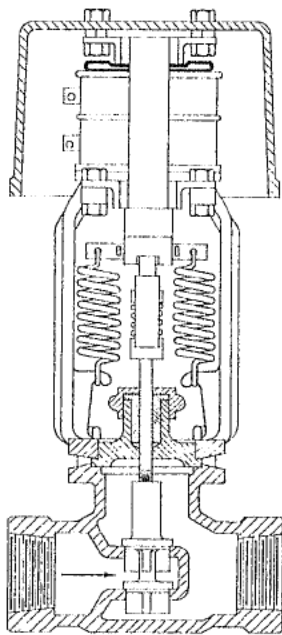


FIG. 4.1y
Solenoid valve with strong return springs.

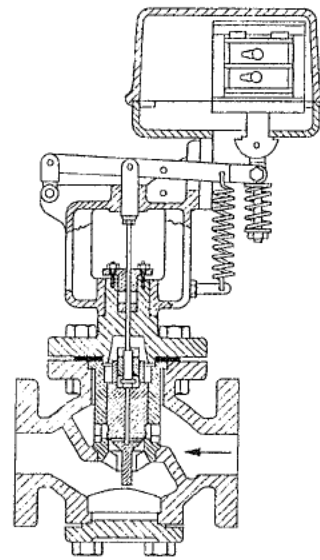


FIG. 4.1z
Solenoid valve with lever-type actuator force amplifier.

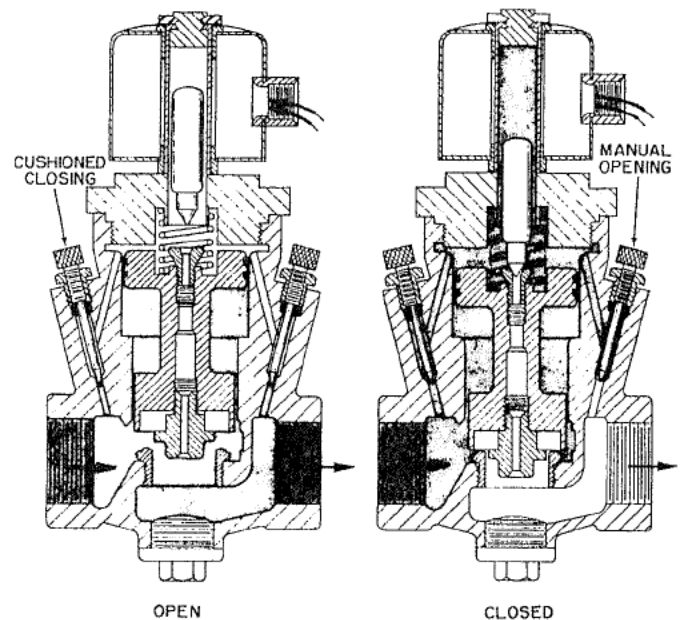


FIG. 4.1aa
Pilot-operated solenoid valve.

pistons for a wide range of output forces. Pilot operation applies pressure to a diaphragm or piston or may release pressure, allowing the higher upstream pressure to open the valve. A good example is the in-line valve (Figure 4.1bb). Most solenoid valves are designed to be continually energized, particularly for emergency shut-down service. Thus the power output is limited to the current whose I^2R -developed heat can be readily dissipated.

Using a high source voltage and a latch-in plunger overcomes the need for continuous current. The single-pulse valve-closing solenoid is disconnected from the voltage

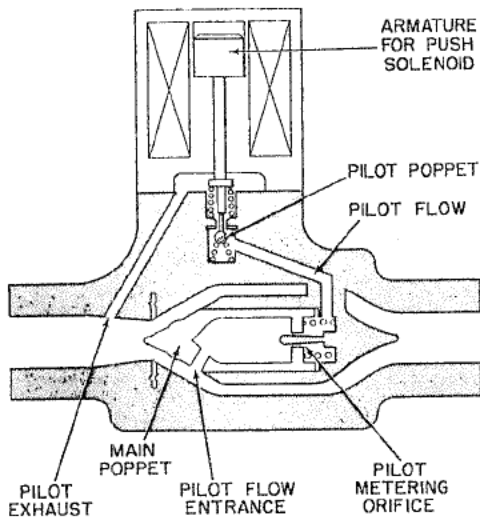


FIG. 4.1bb
Pilot-operated in-line solenoid valve.

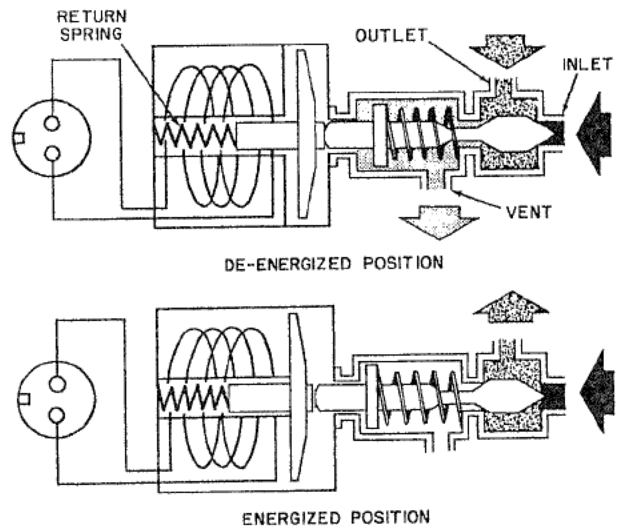


FIG. 4.1cc
Normally closed three-way solenoid valve.

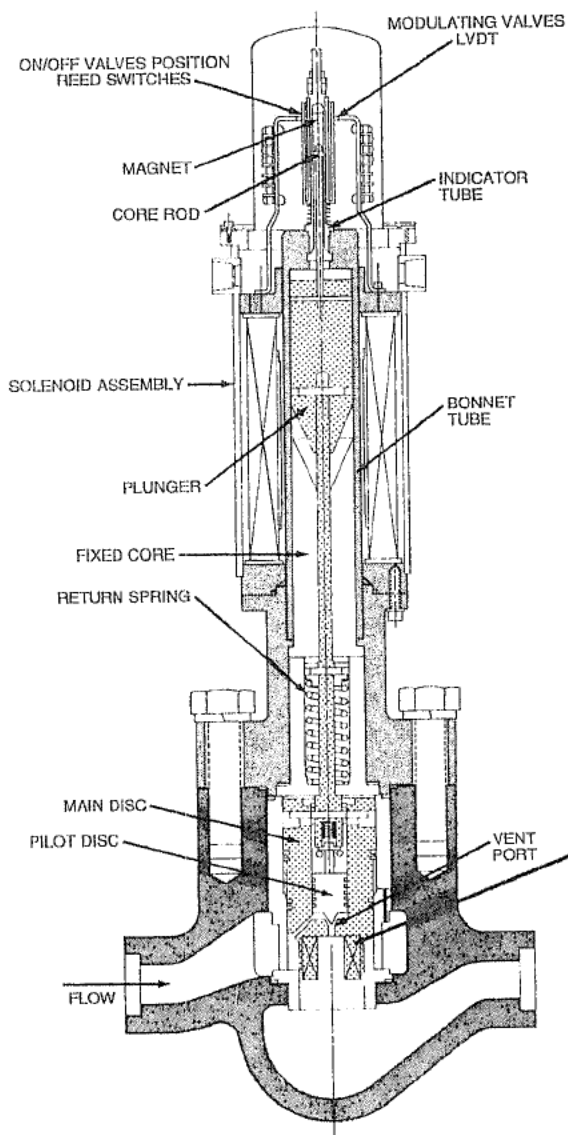
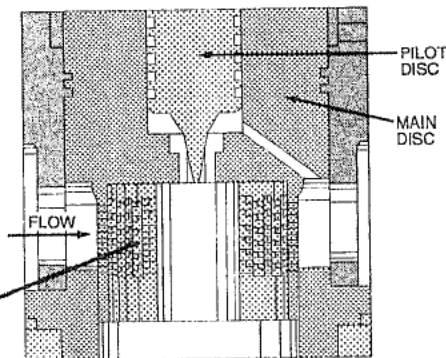
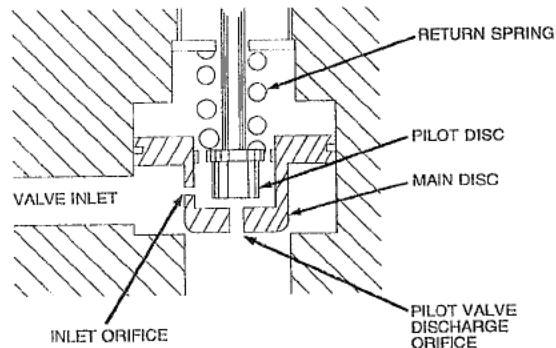


FIG. 4.1dd
*Throttling solenoid valve with LVDT-type position feedback.
(Courtesy of Target Rock Corp.)*



source by a single-pulse de-latch solenoid and hence does not heat up after it is closed. A pulse to the de-latch solenoid permits the valve to be opened by a spring.

Three-way solenoid valves with three pipe connections and two ports are used to load or unload cylinders or diaphragm actuators (Figure 4.1cc). Four-way solenoid pilot valves are used principally for controlling double-acting cylinders.

Modulating Solenoid Valves

Modulating magnetic valves (Figure 4.1dd) utilize spring-loaded low-power solenoids to provide throttling action. The only moving part in this design is the valve stem, which has the valve plug attached to one end and an iron core attached to the other. The valve opening is thereby a function of the voltage applied across the solenoid. (Figure 4.1ee illustrates the change in plunger force as a function of applied voltage and plunger air gap.) Such throttling solenoids are frequently used in the HVAC industry and in other applications where the valve actuators do not need to be very powerful. The actuator thrust requirements are lowered by balancing the inner valve through the use of pressure equalization bellows or floating pistons. The positive failure position of these valves is provided by spring action.

Throttling solenoids are typically available in ½ in. to 8 in. (12 mm to 200 mm) sizes and are limited by the pressure difference against which they can close. They are available in two- or three-way designs and can handle water flows up to 5000 GPM (20 m³/m).

The use of throttling solenoids can completely eliminate the need for instrument air in the control loop. These valves

offer a higher speed and better rangeability than their pneumatic counterparts. Some manufacturers claim a rangeability of 500:1 and a stroking time of 1 second. The design illustrated in Figure 4.1dd can be driven directly from microprocessor-based building automation systems.

The design shown in Figure 4.1dd also includes a separate positioner which accepts a 4 to 20 mA DC input from a controller and delivers a DC output signal to the throttling solenoid. Valve position feedback is obtained through the use of a linear variable differential transformer (LVDT) mounted directly on the valve.

References

1. Scott, A.B., "Control Valve Actuators: Types and Application," *InTech*, January 1988.
2. Price, V.E., "Smart Valve Intelligence Takes Many Forms," *InTech*, August 1992.

Bibliography

- Barnes, P.L., "Protect Valves with Fire-Tested Actuators," *Instruments and Control Systems*, October 1982.
- Baumann, H.D., "Trends in Control Valves and Actuators," *Instruments and Control Systems*, November 1975.
- Berris, R., Hazony, D., and Resch, R., "Discrete Pulses Put Induction Motors into the Stepping Mode," *Control Engineering*, Vol. 29, No. 1, 1982, p. 85.
- Carey, J.A., "Control Valve Update," *Instruments and Control Systems*, January 1981.
- Colaneri, M.R., "Solenoid Valve Basics," *Instruments and Control Systems*, August 1979.
- Fernbaugh, A., "Control Valves: A Decade of Change," *Instruments and Control Systems*, January 1980.
- Fitzgerald, W.V., "Loop Tuning and Control Valve Diagnostics," Paper #91-0500, 1991 ISA Conference, Anaheim, California, October 1991.
- Hammit, D., "How to Select Valve Actuators," *Instruments and Control Systems*, February 1977.
- Hocr, D., "Low-Power DC-Solenoid Valves," *M&C News*, September 1992.
- Howleski, M.F., "Adapting Electric Actuators to Digital Control," *Instrumentation Technology*, March 1977.
- Kervin, D., "Zero-Crossing Triac Drivers Simplify Circuit Design," *Control Engineering*, Vol. 29, No. 3, 1982, p. 76.
- Koehnner, Q.V., "Characterized Valve Actuators," *Instrumentation Technology*, March 1977.
- Liantonio, V., "High Pressure Modulating Solenoid Valve for Steam/Gas Service," *InTech*, January 1988.
- Lipták, B.G., "Control Valves in Optimized Systems," *Chemical Engineering*, September 5, 1983.
- Lockert, C.A., "Low Load Technique Controls Motor Energy Losses," *Control Engineering*, Vol. 29, No. 2, 1982, p. 142.
- Price, V.E., "Smart Valve Intelligence Takes Many Forms," *InTech*, August 1992.
- Pyotsia, J., "A Mathematical Model of a Control Valve," 1992 ISA Conference, Houston, October 1992.
- Scott, A.B., "Control Valve Actuators: Types and Application," *InTech*, January 1988.
- Shinsky, F.G., "Dynamic Response of Valve Motors," *Instruments and Control Systems*, July 1974.
- Usry, J.D., "Electric Valve Actuators Can Fail Safe," *Instruments and Control Systems*, May 1980.
- Usry, J.D., "Stepping Motors for Valve Actuators," *Instrumentation Technology*, March 1977.
- "Valve Actuator Roundup," *InTech*, January 1988.

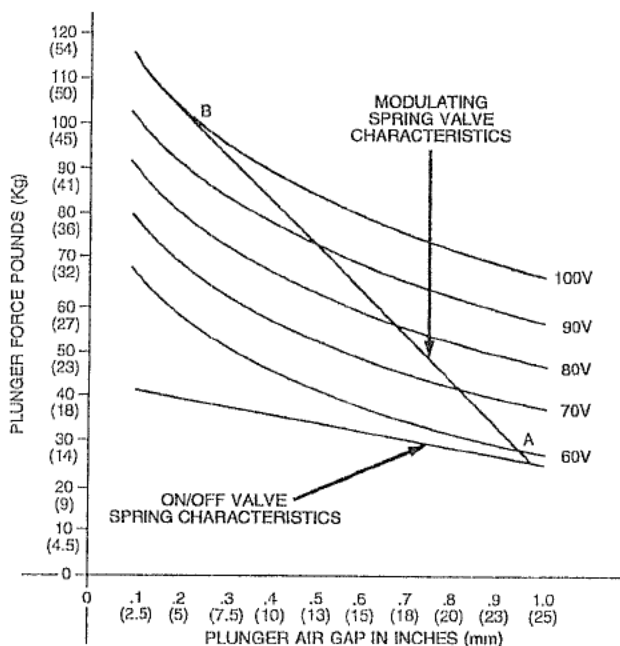


FIG. 4.1ee

The force available to the pilot plunger of a throttling solenoid depends on the voltage and the air gap. (Courtesy of Target Rock Corp.)

The use of air filters is always recommended. They should be installed in the air supply serving the positioner and should be designed for the pressure of the air supply. Their purpose is to remove moisture, oil, and all particles that are 5 microns or larger.

LIMIT SWITCHES

Switches are installed on electric motor driven valves to open the circuit and stop driving the motor when the valve is at its limit (fully open or closed) or on motor over-torque. The name "limit switch" is also used to describe switches installed to signal when a valve is at or beyond a predetermined position. These switches are used for operator information, interlock inputs, or computer feedback. It is necessary to consider mounting problems, electrical classification of area, electrical characteristics of circuit, over-travel of actuating arm, and corrosive nature of the area. Usually, it is easiest to purchase the valve complete with the required switches already installed. Because of environmental problems, some users have been using sealed magnetically actuated or proximity switches. Note that it is difficult to adjust limit switches closer than ± 5 to 10% and that dead bands of 2 to 5% can occur.

Plantwide standardization on limit switch makes will reduce spare part storage and increase maintenance personnel familiarity. When specifying the limit switches, one should state the required contact ratings, the contact configurations (SPDT, DPDT, etc.), and the type of housing required. Typical choices include weatherproof, explosion-proof, or hermetically sealed explosion-proof.

Figure 4.3s illustrates a proximity switch installed on a linear actuator. The maximum spacing allowable between the switch and the sensed surface is 0.11 in. (3 mm). The switch is available in UL- and CSA-approved explosion-proof designs.

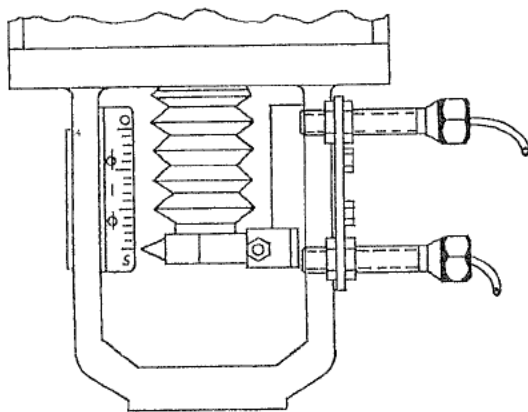


FIG. 4.3s
Open- and closed-position detecting proximity switches installed on a linear valve actuator. (Courtesy of Valtek)

SOLENOID VALVES

The solenoid valve as a control valve accessory is used (1) to operate on/off pneumatic actuators or (2) to interrupt the action of modulating valves by switching air or hydraulic pressures. It is common practice to use a solenoid valve as the pilot for a pneumatically operated on/off valve because of the wide choice of features and capabilities available in the pneumatic valve.

Solenoid valves are primarily used as parts of start-up or shutdown systems, interlock, or batch systems to cause the control valve to take some predetermined action under certain conditions. Two philosophies are in common use. In the first, the 3 to 15 PSI (0.2 to 1.0 bar) signal to the positioner is blocked and the downstream tubing either vented or connected to some other preset pressure (Figure 4.3t). This approach is reliable because the solenoid valve is lightly stressed, the positioner and valve have been in continuous use, and any failure or poor operation should have been detected during normal operation. With this scheme, the substituted signal can be any value over the operating range, the valve will go to the desired opening, and the advantages of the positioner are retained. If the actual positioner input is fed back to the controller external feedback connection, then a smooth return to normal control may be expected when the control loop is returned to normal operation.

In the second philosophy, the solenoid valve is installed in the tubing between the positioner and the actuator (Figure 4.3u). Solenoid valves with adequate pressure rating and flow capacity are required. Only three control valve actions

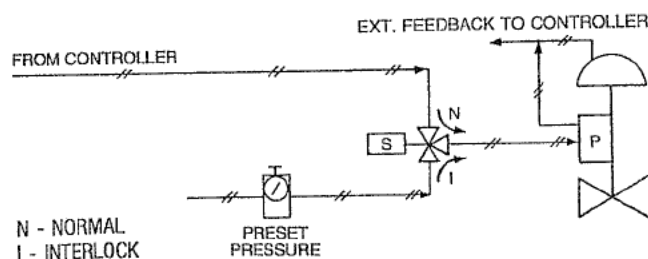


FIG. 4.3t
Interlock solenoid valve in signal tubing.

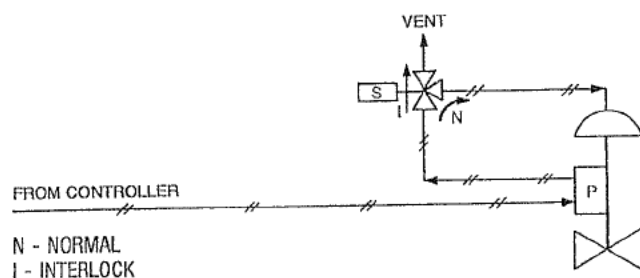


FIG. 4.3u
Interlock solenoid valve controlling actuator directly.

are possible: fully closed, fully open, or lock-up existing pressures.

For interlock safety applications, it is desirable for the solenoid valve to be continuously energized for normal operation so that deenergization, failure, loss of power, or a broken wire will cause shutdown. As a control valve accessory, usually a three-way (three connections) solenoid valve is required. Some designs require that pressure be always applied to one certain port and that another certain port always be the vent. This does not always suit the required logic, but valves can be found rated for "universal" operation. Also, note that clean, dry, oil-free instrument air provides no lubrication, and some types of solenoid valves (spool type) will have a short life without lubrication.

For on-off cylinder-operated valve actuators, four-way solenoids are often used (Figure 4.3v). They are fast, provide positive operation, and are available for a variety of AC or DC voltage services and with Class F coils for up to 310°F (154°C) temperature services.

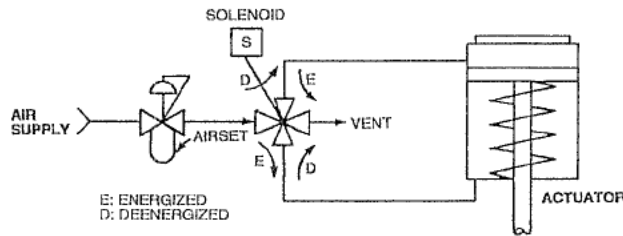


FIG. 4.3v

On-off cylinder actuator operated by four-way solenoid.

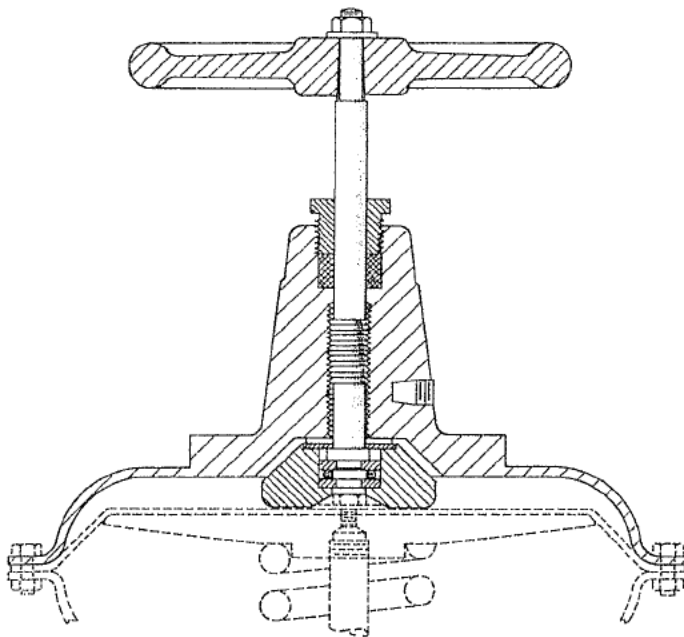


FIG. 4.3w

Top-mounted handwheel for spring-opposed pneumatic actuator.

HANDWHEELS

Handwheels are available as accessories to provide for partial or complete control of the valve to override the pneumatic actuator. Some, mounted on top of the actuator (Figure 4.3w) can only push on the valve stem to close (or

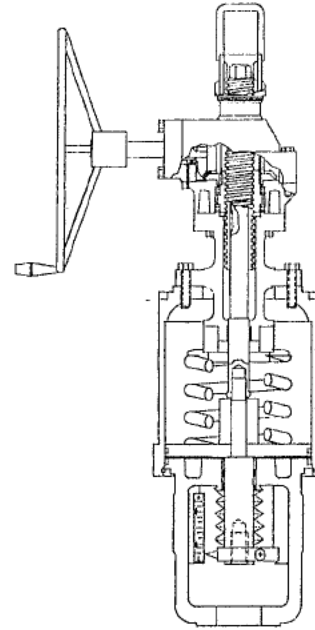


FIG. 4.3x

Top-mounted, continuously operated bidirectional handwheel. (Courtesy of Valtek)

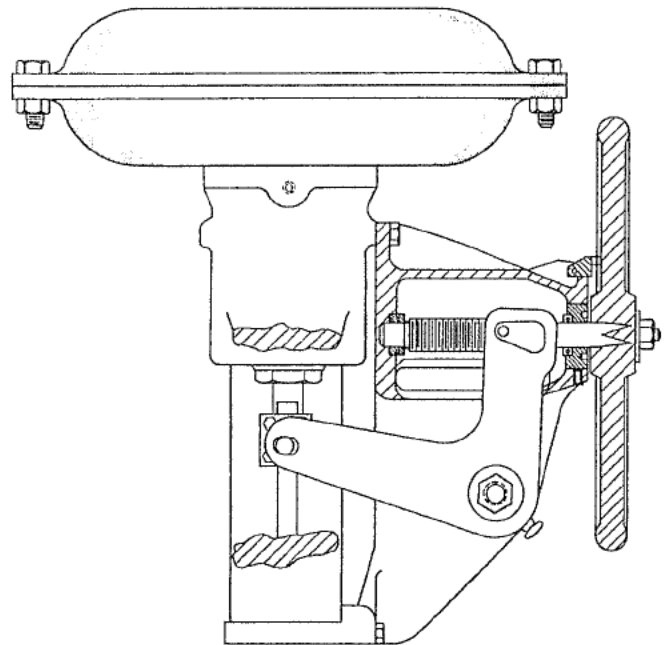


FIG. 4.3y

Side-mounted handwheel for spring-opposed pneumatic actuator.