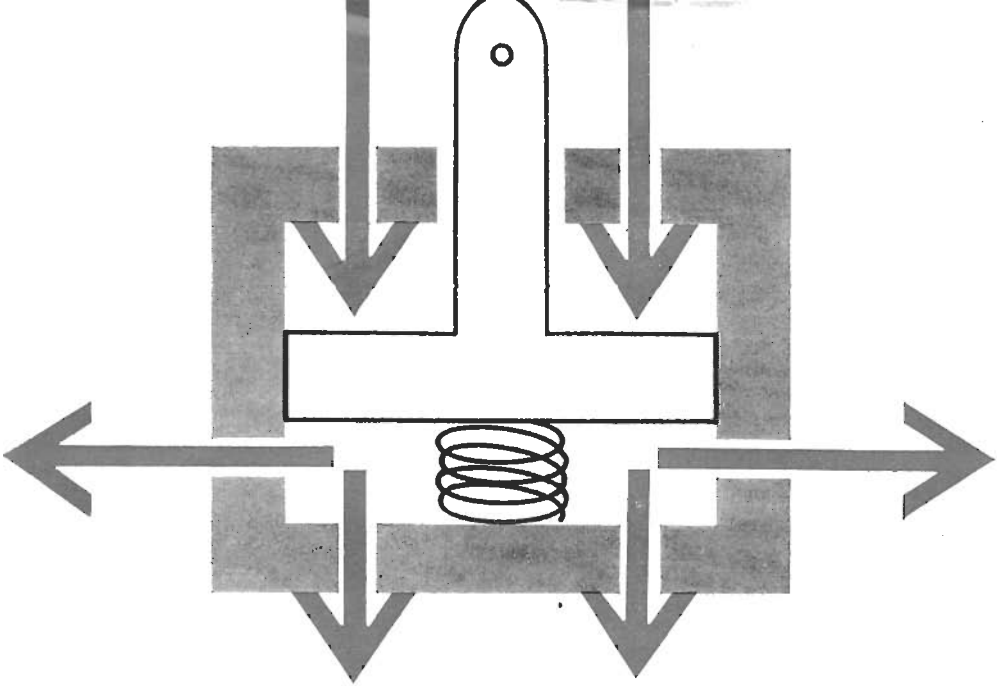


Technicians' Guide to Pneumatic Controls

By **ROBERT GARY** / **Compressed air in valves and cylinders does work automatically at bidding of electrical controls.**

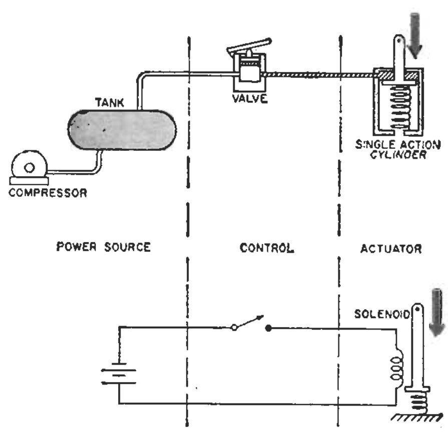


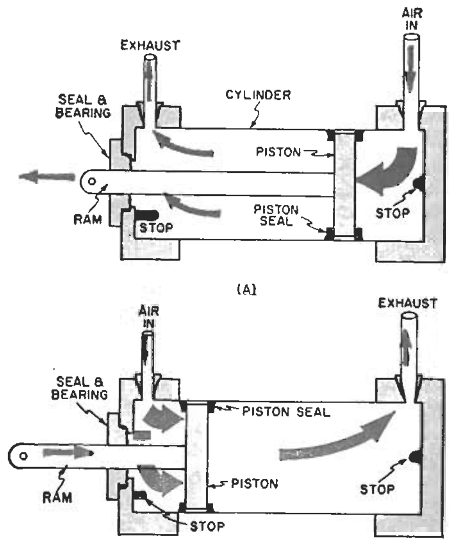
Fig. 1. The operation of a single-action, pneumatic cylinder (above) may be compared to that of solenoid below.

MANY discussions of automation tend to concentrate on the control mechanism and skip over the actuating device. Yet this part provides the muscle of the system: it carries out the decision of the automatic control and actually moves something. In a photoelectric conveyer-belt inspection system, the actuator pushes the rejected units to the side, just as in a simple, automatic door opener there must be some "muscle" to actually push the door open and hold it there. This power device, a vital part of the complete system, must be considered in any industrial servicing work.

As a rule the electronic technician will not be expected to service the mechanical, actuating portion of the system but, in order to troubleshoot the electronic portion accurately, he must know at least some of the fundamentals of such devices. This knowledge need not be too detailed, but he should be able to read diagrams and get a general grasp of the entire operation.

The three most frequently used "muscle" systems involve hydraulic, electric, and pneumatic power. Pneumatic systems, used very widely in connection with electronic controls, are especially adaptable to rapidly operating machines which do not require very great power. The reader will be familiar with the pneumatic hammer and riveter used in construction work and, if he has ever worked in a factory, with the air-powered drill and screwdriver. Compressed air is also used to blow chips or scraps out of the way and for spraying paint. All of these pneumatic tools are powered by compressed air stored in a tank and released by valves as needed.

Fig. 2. The two possible positions of a simple, double-action cylinder, with direction of air flow in each position.



One of the features of all of these tools is that the air is piped to the device in a single hose and, when it has done its work, is released into the surrounding atmosphere. There is no need for a return line to the compressor: air, of course, is free; one merely has to pay for compressing it. This is one of the great advantages which compressed air has over hydraulic systems. It has certain disadvantages too, but these are not important in many applications.

Pneumatic "Circuitry'

A familiarity with fundamental electric circuits can be used as a starting point in understanding pneumatic circuits, since analogies are possible. A simplified pneumatic system and its electrical counterparts are shown in Fig. 1. The compressor and tank are the "power source" that can be compared with the battery or power supply, while the similarity between the valve and the switch is obvious.

As actuator we show a cylinder to be roughly equivalent to a solenoid: in each case a piston or ram is pushed upward by a spring, unless power is applied to pull it down. The piston in the single-action cylinder is forced down when compressed air enters the chamber; and the armature is attracted to the solenoid when current sets up a magnetic field. Actually, each system shown is incomplete because, both in the pneumatic and in the electric system, there is no way for the energy stored in the coil or cylinder to

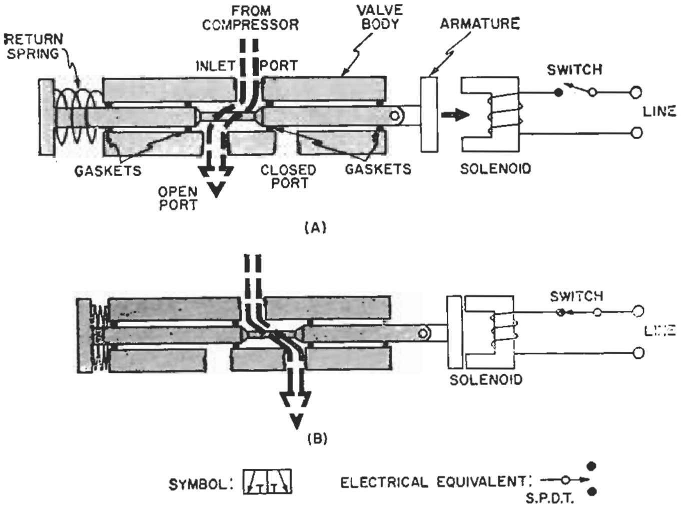


Fig. 3. The two positions of a 3-way, solenoid-operated valve. It is represented by the functional symbol below.

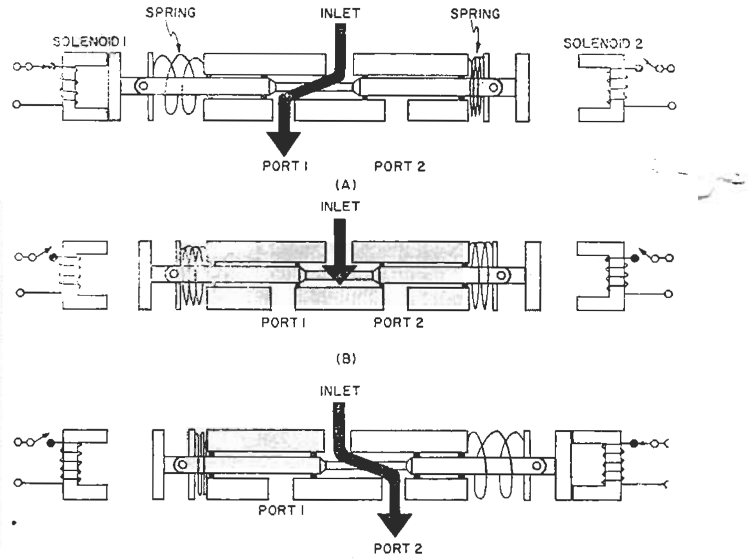


Fig. 4. The positions, including directions of air flow, for a 3-way, center-closed, 2-solenoid pneumatic valve.

dissipate when the switch is opened. However, experience teaches us that there will be an arc when the solenoid switch is opened; similarly, the valve or the cylinder will have an exhaust port to allow the spring to do its work.

To carry the analogy further, we learn that, in pneumatics, many other features of electrical systems also prevail. Comparable to meters and voltage regulators, there are special instruments—pressure gauges—which measure pressure and automatically regulate it at a fixed amount. Most pressure gauges are built into the air lines, usually near regulating valves or near the air tank. A typical air-pressure gauge may have a range from 0 to 20 or up to 120 psi in 5-lb. steps. Practically all ratings are given in psi (pounds-per-square-inch); and this means that such factors as the diameters or areas of the line, valve ports, and actuating surfaces must be known to determine the force at any given point.

A cylinder having a piston surface of 3 square inches can exert a force of 300 lbs. if a 100-psi power source is used. If the air-line diameter is small, it will take longer to push the piston out than if a lot of air can enter quickly. In a sense, we can compare the line diameter and the volume of air required to the wire diameter and the current through it in an electrical system. Losses due to leakage or high resistance due to air obstructions are also comparable troubles.

To avoid obstructions due to dirt and also to keep water away from the moving parts of valves and cylinders, special air filters are placed between the tank and the control portions of the pneumatic system. These filters must occasionally be cleaned out. Most of them use the action of the moving air itself to spin dust and dirt to the side and bottom of a bowl which also traps excess moisture. To clean out such a filter, merely open the drain cock—but keep well away from it, since the air will blow the dirt out with considerable force.

When a single air tank has to supply several, different, pneumatic devices, there may be times when all are demanding air at once, causing air pressure to drop. Conversely, back pressure may develop when none of these tools is in use. This situation is analogous to power-supply problems that occur when the load varies over a wide range.

A pneumatic regulator usually comes complete with a dial and valve which is set for the desired pressure. The valve then regulates the volume of air through the line. Some types of regulators also bleed off back pressure automatically. This regulator should not be confused with the pressure cut-off switch that turns the compressor on and off to maintain a certain pressure within the tank.

Other special-purpose devices used in air lines include lubricators to supply a thin film of oil to the valves and other wearing parts.

Some Pneumatic Components

Probably the most important type of actuator used in pneumatic systems is the cylinder. There are quite a few rotary air tools that use instead simple turbines, or paddle wheels, but in automation systems air is used mostly to provide linear motion. This is accomplished most efficiently by cylinders. The single-action cylinder shown as an example in Fig. 1 is used only for installations involving very low power. Practically all operations requiring a controlled stroke and return use the double-action cylinder of Fig. 2. This device does not rely on a spring: its motion in each direction is accurately controlled by the air entering and leaving, as shown in Figs. 2A and 2B.

Fig. 2 shows the basic elements found in any double-action cylinder, but leaves out many of the construction details. The seal and bearing which hold the moving ram, for example, is usually an elaborate combination of precision-machined parts and nylon, teflon, or special rubber gaskets. In some cases, cloth or rubber bellows extend from the bearing to the external end of the ram to prevent grit from collecting and wearing down the seal. The construction of the end stops varies greatly with cylinder design. There are also different means of connecting air lines to the cylinder, different adjustments, and different methods for lubricating the inner walls and the bearing.

One reason why double-action air cylinders are so widely used is that the length, the force, and even the speed of the stroke can be controlled carefully. In an automatic forming process, for example, it may be desired to move the ram rapidly for one inch; and then slowly, but with greater force, push it another half inch. The return stroke may have to be very rapid to start the next operation. This program can be achieved either by a combination of limit switches and solenoid-operated valves, or else by pneumatic time-controlled valves.

Pneumatic Valves

The cross-section of a simple three-way valve appears in Fig. 3. It consists of two main parts, both of which are round and usually machined of brass or a similar metal. The outer part is a cylinder which has three holes drilled in it, the inlet port (top) and the two outlet ports (at the bottom). These holes usually have threading so that the air-line fittings can be screwed in tight.

The inner part of the valve is a simple rod that has been turned down at one portion near its center. This permits air to pass from the inlet port to either of the two outlets, depending on the position of the rod. In a few special valves, the rod fits so tightly in the cylinder that gasket rings are not necessary, but usually such rubber or nylon rings are located as shown in the diagram to seal the valve against leakage.

A simple, single-action, solenoid-operated valve is shown in Fig. 3. When no power is applied to the solenoid, the return spring holds the inner rod in the position shown in Fig. 3A and allows air to pass from the compressor to the port on the left. As soon as the switch is closed (Fig. 3B), current passes through the solenoid. This attracts the armature, which moves the valve rod to the right, against the force of the spring. In this condition, air pressure is switched to the lower exhaust port on the right, while the lower left port is sealed off. In effect, the pneumatic power is switched much as the electrical power is switched in a single-pole, double-throw switch, the electrical equivalent of this type of valve. At the bottom of Fig. 3, we have also shown the standard pneumatic symbol for this valve. It consists of two sections, corresponding to the two possible valve positions. In each position, the arrow indicates the direction of air flow, while the "T" symbolizes a closed port.

An elaboration of the unit shown in Fig. 3 is a valve with three possible positions, as illustrated in Fig. 4. This type, actuated by two solenoids, can deliver air to either of two ports and can also close either of them or both simultaneously. Two springs are used here, to hold the inner rod in a center position when neither solenoid is actuated.

In Fig. 4A, we see the switch for solenoid 1 closed and the rod thus pulled to the left, allowing air to pass from the air line to port 1. In Fig. 4B, we show the condition where neither solenoid is actuated and the inlet opening as well as both ports are closed. In Fig. 4C, solenoid 2 is actuated and air flows from the inlet to port 2. The electrical equivalent of such a valve would be a single-pole, triple-throw switch. Its pneumatic symbol shows three sections, one for each possible position. The unit is a three-way, center-closed, two-solenoid valve.

A little reflection will show that the left and right solenoid switches should not both be closed at the same time but, by properly programming the closing and opening of the two switches, the flow of air can be arranged in a number of different sequences. All that is necessary is an electrical control circuit, possibly using a set of microswitches, actuated by a timing motor.

In addition to three-way valves such as that shown in Fig. 4, a similar arrangement of valve body and a moving center rod can be used for 4- and 5-way valves providing all sorts of combinations of positions. It is merely necessary to turn down the inner rod in several places, locate the various ports accordingly, and fit gasket rings into the proper places.

To give just one more illustration, let us consider a four-way valve that could be used directly with the double-action cylinder of Fig. 2. In one position, the valve must connect the compressor to one end of the cylinder while allowing exhausted air to leave at the other end. For the return stroke of the cylinder, these connections must be reversed. These two conditions for the cylinder, the valve, and the solenoids that control them are symbolically represented in Figs. 5A and 5B.

Now let us look at the valve itself, which is shown in Fig. 6 without the actuating solenoids. Port 5 is connected to the air compressor. Ports 3 and 4 are attached to the two openings at the top of the cylinder of Fig. 2. When one solenoid pulls the valve rod to the left (Fig. 6A), air from the compressor passes through port 3 and on into the right-hand opening of the cylinder ("air in" in Fig. 2A). At the same time, air is forced out of the "exhaust" opening in Fig. 2A, and released through ports 4 and 2 of the valve (Fig. 6A).

When the other solenoid pulls the valve rod to the right (Fig. 6B), air from the compressor passes through port 4 and enters the cylinder as shown in Fig. 2B. Meanwhile the cylinder exhausts air through ports 3 and 1 of the valve.

The electrical equivalent of such a four-way valve is a double-pole, double-throw switch, and the electrical

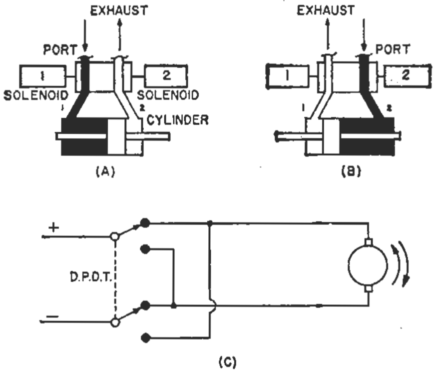
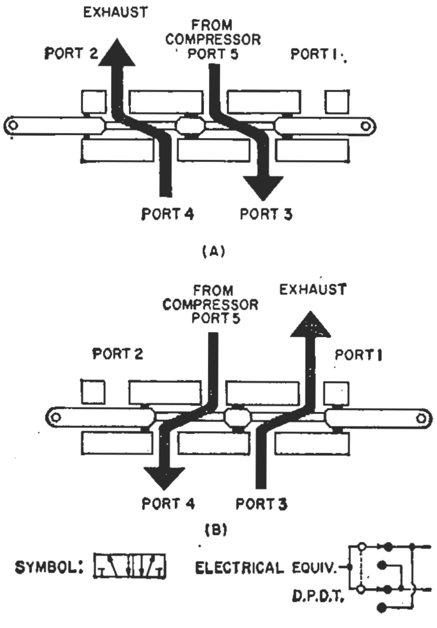


Fig 5. Four-way valve (A, B) used with cylinder of Fig. 2. Electrical equivalent (C) of function performed.

Fig. 6. Operation of 4-way valve of Fig. 5. It controls strokes, in both directions, of the cylinder in Fig. 2.



analogue of this entire pneumatic circuit, including the cylinder, can be represented as the polarity-reversing circuit for a d.c. motor, shown in Fig. 5C.

Although solenoids have been shown moving the rods of valves, the same principles of operation hold true when other means are used. This motion may be controlled by human beings, as by the hand or foot of an operator. The rod may also be moved by a small amount of air pressure.

The latter scheme is used in so-called "pilot valves." These resemble the valves already described except that, in place of the solenoids, another, small, air cylinder actuates the valve rod. This air cylinder, in turn, is controlled by still another valve, which is located remotely. Such a system may seem like an unnecessarily involved and indirect way of obtaining the action desired, but an electrical analogy again comes to the rescue by pointing up the logic involved. Often a small, manual switch is used to control current through a heavy-duty, power relay. The latter, in turn, controls power machinery. In each case, regulation of large amounts of power from a remote point is achieved by using relatively small wires (or air lines).

There are many specialized valves available, some of which use a rotary motion to perform the same actions as the cylinder-and-rod arrangement described above. Such configurations are sometimes used to allow a controlled amount of air leakage, which serves to slow down the valve action and thereby provide some time delay. Other special valves provide a controlled exhaust pressure, while still others combine pressure-regulating and indicating instruments with the regular valve elements.

Conclusion

Once the basic operation of pneumatic valves and cylinders is understood, the difficulty in tackling the more specialized types of pneumatic components is largely overcome. Compressed air furnishes muscle power for many automated installations, especially where controlled linear motion is required. Pneumatic cylinders are very useful, for example, in operations that involve hammering, riveting, or die punching, since these cylinders can be controlled closely by a variety of pneumatic valves.

Pneumatic circuitry has many features which are analogous to electrical circuitry. The electronic technician will therefore find that he may facilitate his understanding by analyzing the unknown in terms of the known. It helps to remember that valves generally correspond to switches or relays, and the variety of different valves is almost as great as that of switch combinations. Where solenoid-operated valves are concerned, the timing and sequencing of the pneumatic-circuit operation is usually determined by the electrical circuitry that controls the solenoid valves. —30—