TECHNICAL PRINCIPLES OF VALVES

GENERAL

Solenoid valves are used wherever fluid flow has to be controlled automatically. They are used to an increasing degree in ever more varied types of plants and equipment. The wide variety of different designs which are available enables the user to choose a valve specifically to suit virtually any application.

CONSTRUCTION

Solenoid valves are control units which, when electrically energized or de-energized, either cut off or permit fluid flow. The actuator is an electromagnet. When the valve is energized, a magnetic field builds up which pulls a plunger or pivoted armature against the action of a spring. When de-energized, the plunger or pivoted armature is returned to its original position by the action of the spring.

VALVE OPERATION

Depending on the mode of actuation, a distinction is made between direct-acting valves, internally piloted valves, and externally piloted valves. A further distinguishing feature is the number of port connections or the number of flow paths (“ways”).

DIRECT-ACTING VALVES

In a direct-acting solenoid valve, the seat seal is attached to the solenoid core. In the de-energized condition, a seat orifice is closed, which opens when the valve is energized.

DIRECT-ACTING 2-WAY VALVES

Two-way valves are shut-off valves having one inlet port and one outlet port (Fig. 1). In the de-energized condition, the core spring, assisted by the pressure of the fluid, holds the valve seal on the valve seat, shutting off the flow. When energized, the core and seal are pulled into the solenoid coil and the valve opens. The electromagnetic force is greater than the combined spring force and the static and dynamic pressure forces of the medium.

DIRECT-ACTING 3-WAY VALVES

Three-way valves have three port connections and two valve seats. One valve seal always remains open and the other closed in the de-energized mode. When the coil is energized, the mode reverses. The 3-way valve shown in Fig. 2 is designed with a plunger-type core. Various valve operations can be performed according to how the fluid medium is connected to the working ports in Fig. 2. The fluid pressure builds up under the valve seat. With the coil de-energized, a conical spring holds the lower core seal tightly against the valve seat and shuts off the fluid flow. Port A is vented through outlet R. When the coil is energized, the core is pulled in and the valve seat at Port R is sealed off by the spring-loaded upper core seal. The fluid now flows from P to A.

Unlike versions with plunger-type cores in pivoted-armature valves, all port connections are in the valve body. An isolating diaphragm ensures that the process fluid does not come into contact with the coil chamber. Pivoted-armature valves can be used for any 3-way valve operation. The basic design principle is shown in Fig. 3. Pivoted-armature valves are provided with manual override as a standard feature.

INTERNALLY PILOTED SOLENOID VALVES

With direct-acting valves, static pressure forces increase with increasing orifice diameter, which means that the magnetic force required to overcome the pressure force becomes correspondingly larger. Internally piloted solenoid valves are therefore employed for switching higher pressures in conjunction with larger orifice sizes, so in this case, the differential fluid pressure performs the main work of opening and closing the valve.

INTERNALLY PILOTED 2-WAY VALVES

Internally piloted solenoid valves are fitted with either a 2- or 3-way pilot solenoid valve. A diaphragm or a piston provides the seal for the main

Figure 1

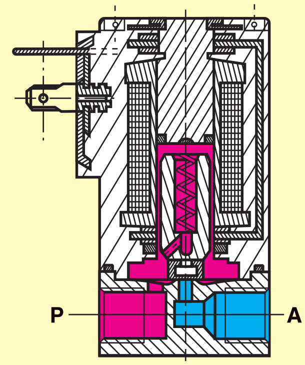


Figure 2

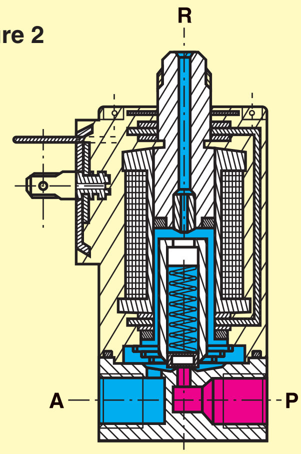


Figure 3

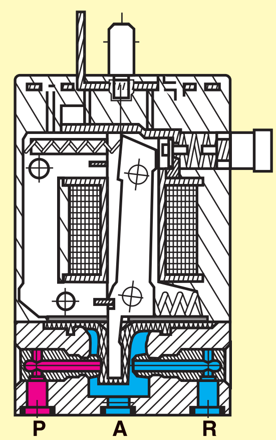
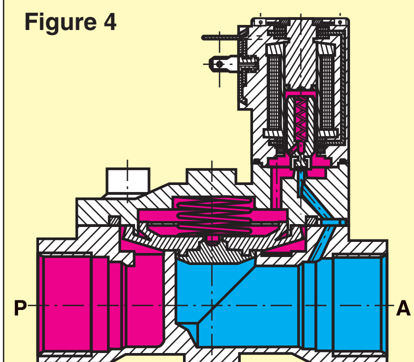


Figure 4



valve seat. The operation of such a valve is shown in Fig. 4. When the pilot valve is closed, the fluid pressure builds up on both sides of the diaphragm via a bleed orifice. As long as there is a pressure differential between the inlet and outlet ports, a shut-off force is created because of the larger effective area on the top of the diaphragm. When the pilot valve is opened, the pressure is relieved from the upper side of the diaphragm. The greater effective net pressure from below now raises the diaphragm and opens the valve. In general, internally piloted valves require a minimum pressure differential to ensure satisfactory opening and closing. In addition, OMEGA also offers internally piloted valves designed with a coupled core and diaphragm that operate at zero pressure differential (Fig. 5).

INTERNALLY PILOTED MULTI-WAY SOLENOID VALVES

Internally piloted 4-way solenoid valves are used mainly in hydraulic and pneumatic applications to actuate double-acting cylinders. These valves have four port connections: a pressure inlet (P), two cylinder port connections (A) and (B), and one exhaust port connection (R). An internally piloted 4/2-way poppet valve is shown in Fig. 6. When de-energized, the pilot valve opens at the connection from the pressure inlet to the pilot channel. Both poppets in the main valve are thus pressurized and switch over. With port connection P connected to A, B can exhaust via a second restrictor through R.

EXTERNALLY PILOTED VALVES

In this type, an independent pilot medium is used to actuate the valve. Fig. 7 shows a piston-operated angle-seat valve with closure spring. In the unpressurized condition, the valve seat is closed. A 3-way solenoid valve, which can be mounted on the actuator, controls the independent pilot medium. When the solenoid valve is energized, the piston is raised against the action of the spring and the valve opens. A normally-open valve condition can be obtained if the spring is placed on the opposite side of the actuator piston. In these configurations, the independent pilot medium is connected to the top of the actuator.

Double-acting versions controlled by 4/2-way valves do not require a spring.

MATERIALS

All materials used in the construction of valves must be carefully selected to work best in varying types of applications. Body material, seal material, and solenoid material should be chosen to optimize functional reliability, fluid compatibility, service life and cost.

BODY MATERIALS

Neutral fluid valve bodies are made of brass and bronze. For fluids with high temperatures, *e.g.,* steam, corrosion-resistant steel is available. In addition, polyamide material is used for economic reasons in various plastic valves.

SOLENOID MATERIALS

All parts of the solenoid actuator which come into contact with the process fluid are made of austenitic corrosion-resistant steel to guarantee resistance against corrosive attack by neutral or mildly aggressive media.

SEAL MATERIALS

The particular mechanical, thermal and chemical conditions in an application determine the selection of seal material. The standard material for neutral fluids at temperatures up to 90°C (194°F) is FKM. For higher temperatures, EPDM and PTFE are employed. PTFE is universally resistant to practically all fluids of technical interest.

PRESSURE RATINGS

PRESSURE RANGE

All pressure figures quoted in this section represent gage pressures. Pressure ratings are quoted in psi. The valves function reliably within the given pressure ranges. These figures apply for the range 15% undervoltage to 10% overvoltage. If 3/2-way valves are used in a different operation, the permitted pressure range changes. Further details are contained in our data sheets.

During vacuum operation, care has to be taken to ensure that the vacuum is on the outlet side (A or B), while the higher pressure, *i.e.,* atmospheric pressure, is acting against the inlet port (P).

Figure 5

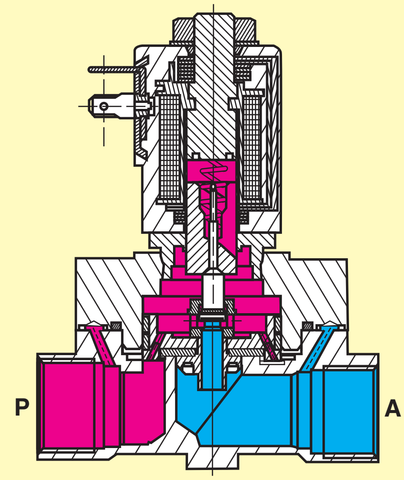


Figure 6

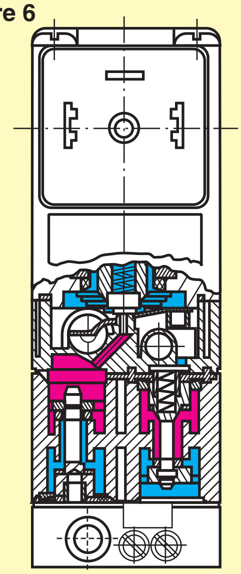
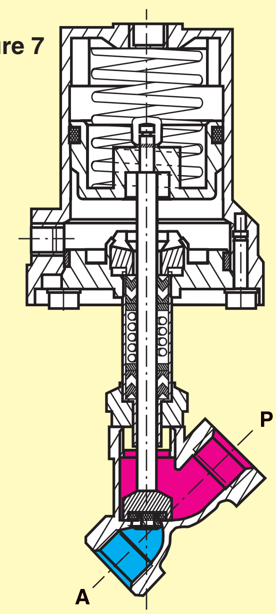


Figure 7



TECHNICAL PRINCIPLES OF VALVES

FLOW RATE VALUES

The flow rate through a valve is determined by the nature of the design and by the type of flow. The size of the valve required for a particular application is generally determined by the Cv rating. This figure is established for standardized units and conditions, *i.e.,* flow rate in GPM using water at a temperature of between 4 and 30°C (40 and 86°F) at a pressure drop of 1 psi. Cv ratings for each valve are quoted. A standardized system of flowrate values is also used for pneumatics (in this case, air flow in SCFM upstream with a pressure drop of 15 psi at a temperature of 20°C (68°F).

SOLENOID ACTUATOR

A feature common to many OMEGA® solenoid valves is the epoxy-encapsulated solenoid system. With this system, the whole magnetic circuit—coil, connections, yoke and core guide tube—is incorporated in one compact unit. This causes a high magnetic force to be contained within a minimum of space, ensuring first class electrical insulation and protection against vibration and external corrosive effects.

COILS

OMEGA coils are available in all commonly used AC and DC voltages. Low power consumption, a factor in particular in smaller solenoid systems, means that control via solid state circuitry is possible.

The magnetic force available increases as the air gap between the core and plug nut decreases, regardless of whether AC or DC is involved. An AC solenoid system has a larger magnetic force available at a greater stroke than a comparable DC solenoid system. The characteristic stroke vs. force graphs, shown in Fig. 8 illustrates this relationship.

The current consumption of an AC solenoid is determined by the unit's inductance. With increasing stroke, the inductive resistance decreases and causes an increase in current consumption. This means that, at the instant of de-energization, the current reaches its maximum value. The opposite situation applies to a DC solenoid where current consumption is a function solely of the resistance of the windings. A time-based comparison of the energization characteristics for AC and DC solenoids is shown in Fig. 9. At the moment of energizing, *i.e.,* when the air gap is at its maximum, solenoid valves draw much higher currents than when the core is completely retracted, *i.e.,* when the air gap is closed. This results in a high output and increased pressure range. In DC systems, after switching on the current, flow increases relatively slowly until a constant holding current is reached. These valves are, therefore, only able to control pressures lower than can be handled by AC valves with the same orifice size. Higher pressures can be accommodated only by reducing the orifice size and, thus, the flow capacity.

THERMAL EFFECTS

A certain amount of heat is always generated when a solenoid coil is energized. The standard version of a solenoid valve has relatively low temperature rises. It is designed to reach a maximum temperature rise of 62°C (144°F) under conditions of continuous operation (100%) and at 10% overvoltage. In addition, a maximum ambient temperature of 54°C (130°F) is generally permissible. The maximum permissible fluid temperature is dependent on the particular seal and body materials employed. These figures can be obtained from technical data.

TIME DEFINITIONS

RESPONSE TIMES

The small volumes and relatively high magnetic forces involved with solenoid valves enable rapid response times to be obtained. Valves with a wide range of response times are available for special applications. Response time is defined as the time between application of the switching signal and completion of the mechanical opening or closing.

Figure 8

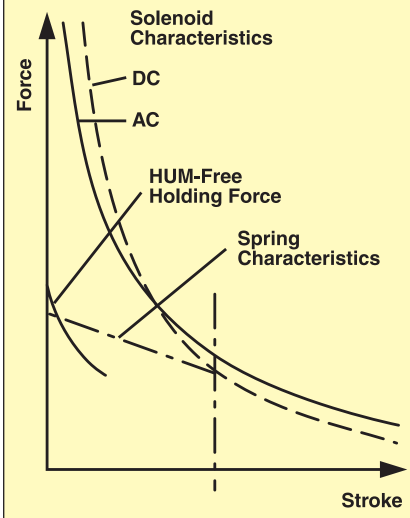
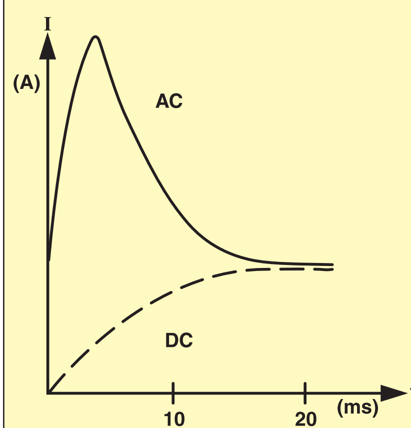


Figure 9



ON PERIOD

The "on" period is defined as the time between switching the solenoid current on and switching it off.

CYCLE PERIOD

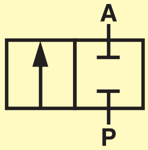
The total time of the energized and de-energized periods is the "cycle period." Preferred cycle periods are 2, 5, 10 or 30 minutes.

RELATIVE DUTY CYCLE

The relative duty cycle (given in %) is the ratio of the energized period to the total cycle period.

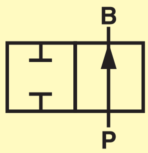
Continuous operation (100% duty cycle) is defined as continuous operation until steady-state temperature is reached.

Operation A



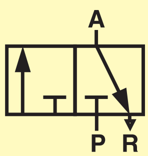
2/2-way valve, normally-closed

Operation B



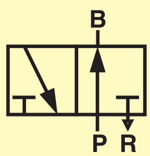
2/2-way valve, normally-open

Operation C



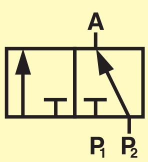
3/2-way valve, in rest position outlet A exhausted

Operation D



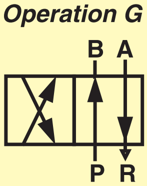
3/2-way valve, in rest position outlet B pressurized

Operation E



Mixer valve, in rest position pressure inlet P_2 open, P_1 closed

Operation G



4/2-way valve, in rest position pressure inlet P connected to outlet B, outlet A exhausted

VALVE OPERATION

The coding for a valve operation always consists of a capital letter. The summary at left details the codes of the various valve operations and indicates the appropriate standard circuit symbols.

VISCOSITY

The technical data is valid for viscosities up to the figure quoted. Higher viscosities are permissible, but at such levels the voltage tolerance range is reduced and response times are extended.

TEMPERATURE RANGE

Temperature limits for the fluid medium are always detailed. Various factors, *e.g.,* ambient conditions, cycling, speed, voltage tolerance, installation details, etc., can influence temperature performance, however. The values quoted herein should therefore be used only as a general guide. In cases where operation at extremes of the temperature range are involved, you should seek advice from OMEGA's Engineering Department.

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Technical Terms

Solenoid Valve—A valve that is opened or closed by an electromagnet. This action is achieved by the movement of a magnetic plunger to seal off or open a port when voltage is applied.

Electromagnet—A device consisting of an iron or steel core which is magnetized by electric current applied to a coil which surrounds it.

Solenoid—An electrical conductor, such as a wire, that is wound as a tight spiral; current flowing through it establishes a magnetic field.

General Purpose Valve—A normally closed valve intended to control the flow of a fluid, but not depended upon to act as a safety valve.

Direct-Acting—A solenoid valve where all flow passes through an orifice that is opened directly by an electromagnet and plunger.

Pilot Operated—A solenoid valve that operates by means of a minimum and maximum pressure differential and uses a small orifice to control the opening and closing of a piston or diaphragm.

Normally Closed Solenoid Valve—A valve in which the inlet port is closed when the solenoid coil is de-energized and open when the solenoid coil is energized.

Two-Way Valve—A valve that has a single orifice which can be normally open or normally closed.

Two-Way Normally Closed Valve—A valve in which the orifice is closed in the de-energized position and no flow is possible between the inlet and outlet ports.

Continuous Duty—Rating given to a valve that can be energized indefinitely without overheating or failing under normal operating conditions.

Cv Factor—The quantity of water at 16°C (60°F), expressed in gallons per minute, which will flow through a valve with a one psi pressure drop.

Flow Capacity—The amount of flow through a valve in reference to pressure drop and rate, given in gallons per minute or cubic feet per minute, as measured at the outlet of the valve.

Flow Rate—The measure of the amount of fluid that passes a given point in a given period of time.

Port—An opening or passageway for the inlet or outlet of fluid or gas in a valve.

Inlet Port—The port which provides a passage from the source of fluid or gas.

Outlet Port—The port where the fluid or gas leaves the valve.

Pressure, Differential (Drop) or Delta-P (ΔP)—The difference in pressure measured between two given points.

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