Section 10
BASIC HYDRAULICS

Proportional valves are usually operated by special solenoids. The solenoids found on ordinary directional valves exert a variable force over the length of stroke for a given current; proportional solenoids, on the other hand, exert a fairly constant force over the length of stroke for the same signal (Fig. 46). As the proportional-valve solenoid armature moves, it pushes on a pin that pushes on the spool of the valve. The spool is centered by springs when the valve is de-energized so the force of the solenoid is opposed by a spring. Because springs push back harder the further they are compressed, a given current on the solenoid will translate directly into a specific position of the valve spool, assuming no hysteresis. When hysteresis occurs because of friction, a given electrical signal may produce different valve positions, depending on whether the signal was increasing or decreasing as it approached its present value (Fig. 47). Various means are employed to overcome this phenomenon, one of which is feedback on the spool itself; usually, a linear variable differential transformer (LVDT) transducer is attached to the spool to assure that nothing interferes with spool position.

Although the differences between servo and proportional valves are becoming blurred, some differences remain between them. For example, servos operate at higher frequency response than proportionals; in addition, because they are machined to tighter tolerances for greater accuracy than proportionals, they are more sensitive to dirt.

When fluid compressibility was discussed at the beginning of this Section, it was indicated that with normal "bang-bang" hydraulics, fluid compressibility is a negligible concern. With servo and proportional valves, however, depending on the frequency response of the system, fluid compressibility may be a problem. If there is a long column of fluid between the valve and actuator, the natural sponginess of the fluid may cause the actuator movement to lag far behind the valve movement. One way of minimizing this lag is to mount the valve very close to the actuator, sometimes even attach it to the actuator.

The foregoing is only a cursory description of servo and proportional valves. The reader is urged to obtain more detailed information from the list of references at the end of this Section.

Logic Cartridges

Using manifolds to eliminate much of the piping in hydraulic systems is increasingly popular, and any valve that
Hysteresis causes the same input signal to produce a different amount of spool movement when the signal is increasing compared to when it is decreasing.

Fig. 47-Hysteresis curve (Courtesy of Vickers, Inc.).

Fig. 48—"Slip-in" cartridge valve (Courtesy of Vickers, Inc.).

can be mounted on a subplate or be mounted on the outside of a manifold. However, for even more compact designs, valves of all types are being redesigned to thread into a manifold instead of fastening to the outside. External manifolds (fastened to the outside) provide passageways for P, T, A and B. When the second type (threaded inside) provides poppet seats, the manifold effectively includes some features of the valve itself.

Another type of valve insert, called a "logic element," includes a poppet sleeve, a spring and a bolted cover; some are available in the threaded style described above (Fig. 48). Logic elements are pilot-controlled by small, externally mounted solenoid-operated valves; they can be combined in various ways for many operating modes. Although they can duplicate any of the valves discussed earlier, they are generally utilized in directional valve applications because they offer two important advantages over conventional spool-type directional valves. The first is that with a spool-type valve, you are locked into the center condition cut into the spool (if it is a three-position valve); logic valves allow you to change this simply by changing the electrical sequencing. The second advantage is that you can send a considerably larger fluid flow through a poppet-type logic element; this feature permits significant downsizing of valve stands.

To demonstrate the flexibility of logic cartridges, Fig. 49 shows how four normally-closed elements might be operated by two small solenoid valves. Potential alternatives are suggested by the table showing operating modes for various combinations of solenoid actuation.

**Basic Circuits**

Fig. 50 illustrates a conventional circuit that includes a fixed-displacement, single-direction pump; a relief valve and a three-position, four-way manually operated with a spring-centered, blocked center directional valve operating a co-acting, differential area cylinder. You will note the omission of certain information, such as: the type of pump used, the type of prime mover and the reason for using a blocked center valve. Nevertheless, because the purpose of the drawing is to show function only, it provides sufficient information to troubleshoot any problems with the circuit. This circuit is probably not a practical circuit because unloading the fixed-
displacement pump is not provided for. You will recall that "unloading" directs pump flow back to tank at low pressure during idle periods. The blocked center on the valve tells us that the cylinder can be stopped in intermediate positions, and that there is no danger of an external force hitting the rod (in either direction) and causing high internal pressures. If there were such a danger, the valve center could be changed to the type shown in Fig. 51 to dissipate external forces. Of course, other means would be required if the cylinder were to remain stationary. If the cylinder should be depressurized when at rest and the pump unloaded, a spool center like the one shown in Fig. 52 could be used. Selection of the spool center is based on the condition desired by the designer when the actuator is at rest.

If it is not pressure-compensated, unloading the pump is an important part of any circuit design, and there are several ways of accomplishing it. Fig. 53 shows a variation of the high-low method (discussed later) that includes a check valve, a combination relief-unloading valve and an accumulator, all between the single pump and the directional valve. The check valve and combination relief-unloader are often built into the same housing. When the actuator is idle (directional valve centered), pressure begins to build up as the accumulator is filled. When pressure reaches the relief setting minus 150 psi, the unloading valve opens and pump flow goes to tank. The check valve prevents the pressurized fluid in the accumulator from leaking back to tank. The unloading valve operates on some differential pressure, and when the pres-
sure finally subsides to the low operating point of the unloader, the unloader closes and the process starts all over again. The pressure in the accumulator bleeds off eventually because all hydraulic valves, especially spool-type directional valves, leak internally, to some extent. The relief valve does not open during the unloading cycle.

The pilot-operated relief unloading method shown in Fig. 54 employs a pressure switch, an accumulator and a two-position, two-way directional valve. This method relies on the presence of a plug in the pilot section of most compound relief valves. When the plug is removed, the pressure above the main spool cannot be contained, and the spool must unseat completely, allowing pump flow to return to tank. In this circuit, a tube is run from that plugged hole to the solenoid valve, which is normally open. When the system is turned on, low pressure on the pressure switch sends a signal that activates the relief valve: this is analogous to replacing the plug in the hole. Flow fills the accumulator and pressure builds to the high setting (the unload pressure) on the pressure switch, at which time the electrical signal to the solenoid is discontinued. The small two-position, two-way valve opens to "vent" the relief, converting it to an unloading valve. As flow from the pump returns to tank at very low pressure, the check valve prevents the accumulator contents from doing the same thing. As the pressure beyond the check valve dissipates over time to the low setting on the pressure switch (the load-up pressure), the pressure switch once again signals the solenoid valve to close, restoring the relief valve to its original status, and the process repeats. Incidentally, with both of these methods, a low gas charge on the accumulator makes the load/unload process (when the cylinder is idle) faster than usual. The pump sound during load and unload is distinctly different, so one can easily tell when a gas charge may be needed.