ELECTRICAL CONTROL-

of Fluid Power

Electric and Electronic Control of
HYDRAULIC & AIR SYSTEMS

ELECTRICAL CONTROL
OF FLUID POWER

THIRD EDITION

Electric and Electronic Control Circuits for Hydraulic and Air Fluid Power Systems

Prepared by Charles S. Hedges
Assisted by the Technical Staff of Womack Machine Supply Company

Sponsored by Robert C. Womack
Member Fluid Power Society and Fluid Power Educational Foundation

Published by

Womack Educational Publications

Department of Womack Machine Supply Company

2010 Shea Road • Dallas, Texas 75235 • Phone: 214-357-3871
Mailing address: P. O. Box 35027, Dallas, TX 75235 • Telefax 214-350-9322

Publisher's Information

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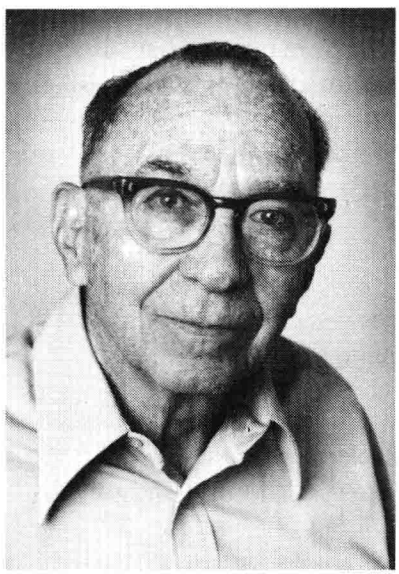
Third Edition ©1987 by Womack Machine Supply Company — All Rights Reserved
This is the Fifth Printing of the Third Edition — September 1992
Library of Congress Catalog Card No. 77-156777
ISBN No. 0-9605644-9-7
Printed in the U.S.A.



Mr. Charles S. Hedges holds an engineering degree from the University of Kansas. He has worked in industry as an electrical and mechanical designer. Since 1953 until his retirement in 1991 he has been associated with Womack Machine Supply Company where he has written the Womack textbooks on fluid power; worked with customers on a variety of fluid power applications; prepared and published many design data sheets and technical bulletins; taught fluid power classes in the larger cities of Texas, Oklahoma, and Louisiana; and has helped train new salesmen in fluid power applications and circuitry.

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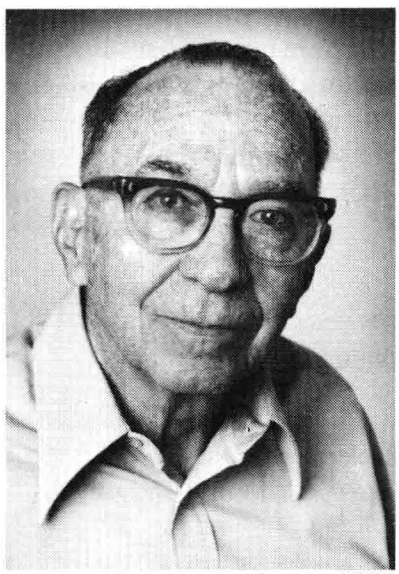

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CHAPTER 1

Popular Fluid and Electrical Components

In most air and hydraulic fluid power circuits, three kinds of valves are used to (1), control direction of fluid flow; (2), rate of fluid flow; and (3), to limit maximum level of pressure in either the pump line or in a branch circuit. Control valves for these functions can be purchased with solenoid actuators, and it is the purpose of this book to present electrical circuits for directional, speed, and pressure control of cylinders and fluid motors. With electrical control, machine cycles can be set up for automatic sequencing of various parts of the machine, and operator control can be exercised from a remote location.

For directional control, 4-way solenoid valves are the ones most often used, although combinations of two or more 2-way or 3-way valves can be used. For speed control, deceleration, step level pressure control, pump unloading, and pressure control, 2-way solenoid valves are primarily used.

Four-way air valves and 4-way hydraulic valves operate in much the same way but electric control circuits for the two media are usually different because different kinds of valves are used. For example, most air circuits use single solenoid valves or may use double solenoid valves without a center neutral. A center position is undesirable for most air circuits. Hydraulic 4-way valves, on the other hand, are nearly always the double solenoid type with a center neutral position.

In this section we will briefly describe some of the electrical components (switches, relays, etc.) for controlling fluid power. The ones described here, while being the more popular ones, are only a part of the wide variety available to a designer. The physical appearance of each component will vary with the brand, size, and type, and we cannot cover the full range of brands available.

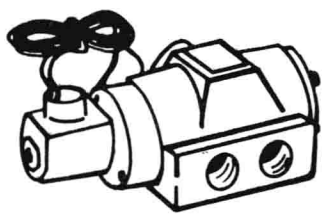
Directional Control Valves – 4-Way . . .

A directional control valve is defined as one which controls the direction of flow in a fluid, either liquid or air in the case of fluid power. This is usually for the purpose of controlling the direction in which an output actuator moves, extension or retraction in the case of a cylinder, and clockwise or counter-clockwise in the case of a fluid motor. Except in special applications, one directional valve is required for each cylinder, or group of cylinders, connected in parallel to the same mechanism.

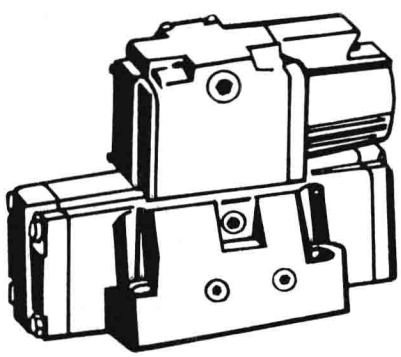
Four-way directional valves are usually considered standard for operation of double-acting cylinders. A 4-way valve has four connections to the circuit – a pressure inlet, an exhaust, and two work ports. They are built in a wide range of sizes and pressure ratings according to the volume of fluid to be handled and to the pressure level required in the system. Many will vary in appearance from the sketches shown here.

Solenoid controlled directional valves respond to an electrical signal for shifting their spool or poppet, to provide a choice of flow paths through the internal passageways to the outlet or work ports. Most directional valves are 4-way, and some can be optionally used as 2-way, 3-way, and even 5-way valves. For a more detailed description, refer to the Womack Industrial Fluid Power textbooks listed inside the rear cover.

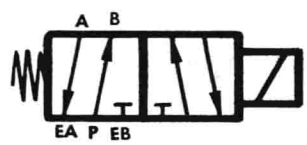
Single Solenoid 4-Way Valves. Figure 1-1. On this type, one solenoid is used. The valve spool shifts when the solenoid is energized, and will remain shifted as long as current is maintained on the solenoid. It will return to normal position by spring force when the solenoid is de-energized. The valve has "maintained" electrical action. Circuits designed for its use must maintain current on the solenoid to keep the spool shifted. It is not possible to have a center neutral position.



A. Typical Single Solenoid Air Valve.

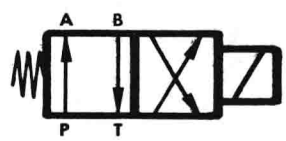


B. Typical Single Solenoid Hydraulic Valve.

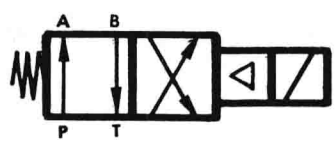


C. Single Solenoid Air Valve
Direct-Acting Type

D. Single Solenoid Air Valve
Pilot-Operated Type



E. Single Solenoid Hydraulic Valve
Direct-Acting Type



F. Single Solenoid Hydraulic Valve
Pilot-Operated Type

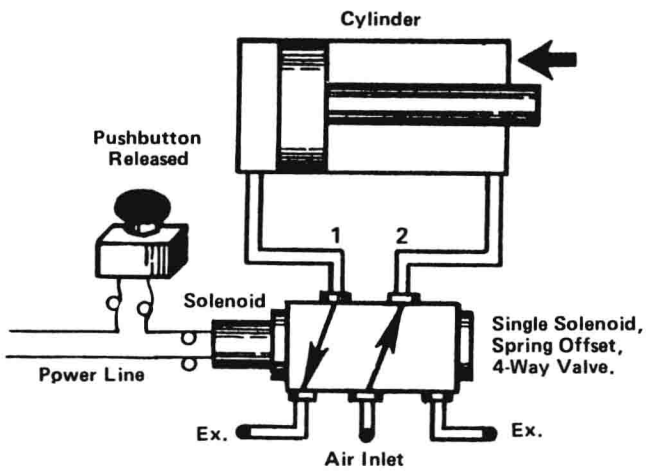
P is the pressure port; T is tank return on hydraulic valves; E is exhaust on air valves; 1 and 2 are cylinder (work) ports.

FIGURE 1-1. Examples of single solenoid valves.

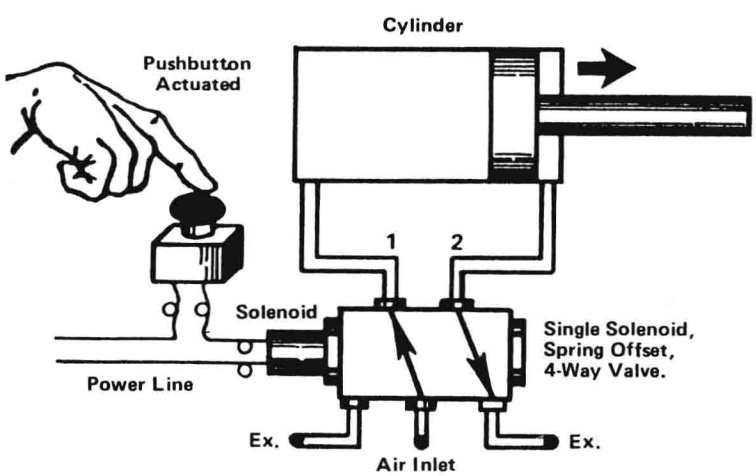
Action of Single Solenoid Valve. Figure 1-2. The basic action of a single solenoid valve in controlling a standard double-acting cylinder is shown in the two illustrations below. A pushbutton is wired in series with the valve coil to the 115v A-C (or other) power source. During the time the button is not actuated (upper sketch), the valve spool is held in its normal position by an internal spring, and fluid pressure is directed to the rod end of the cylinder, causing it to retract, then to hold against the rear end cap with full pressure. Note: If fluid lines 1 and 2 connecting valve to cylinder were to be reversed, the cylinder would return to fully extended position.

When the button is pressed, Part B of Figure 1-2, the solenoid will shift the valve spool to its opposite side position, and fluid pressure will be directed to the blind end of the cylinder causing its piston rod to extend, eventually holding the piston against the front (or rod end) cap with full pressure. However, if at any point in the piston stroke the button is released, the valve spool will be returned to its normal position and the cylinder will immediately start its retraction stroke even though its forward stroke has not been completed.

Since there can be no neutral position on a single solenoid valve, there is no electrical means by which the piston can be stopped between its extremes of travel.



A. Cylinder retracts when normally open electric pushbutton is released.



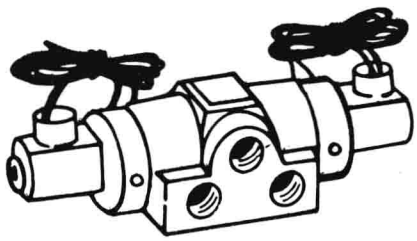
B. Cylinder extends when normally open electric pushbutton is pressed.

FIGURE 1-2. Pushbutton control of an air cylinder with a 4-way single solenoid valve.

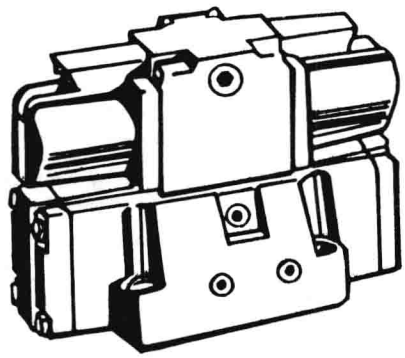
Double Solenoid 4-Way Valve. Figure 1-3. A double solenoid valve can be identified by its having two solenoid coils, usually on opposite ends of the valve body. However, a visual inspection may not reveal whether the valve has 2 positions or 3 positions with a center neutral. This can be determined by its model number as listed in the manufacturers catalog, or by a physical inspection, removing an end

cap to look for centering springs.

Valves with no centering springs on the main spool are called "2-position, no-spring" models. Those with centering springs are called "3-position, spring centered". However, some large hydraulic valves may use hydraulic pressure instead of springs to center the main spool.



Typical Air Valve

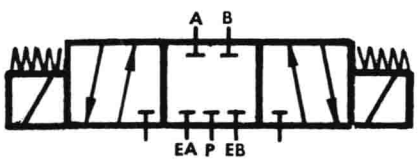


Typical Hydraulic Valve

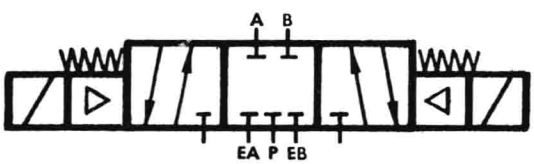
FIGURE 1-3. EXAMPLES OF DOUBLE SOLENOID 4-WAY VALVES

Two-Position, Direct-Acting Type

Two-Position, Pilot-Operated Type

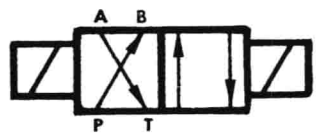


Closed-Center, 3-Position, Direct-Acting Type



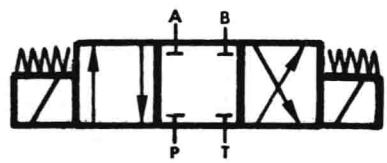
Closed Center, 3-Position, Pilot-Operated Type

FIGURE 1-4. Graphic Symbols for Air Valves

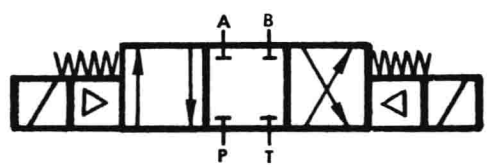


Two-Position, Direct-Acting Type

Two-Position, Pilot-Operated Type



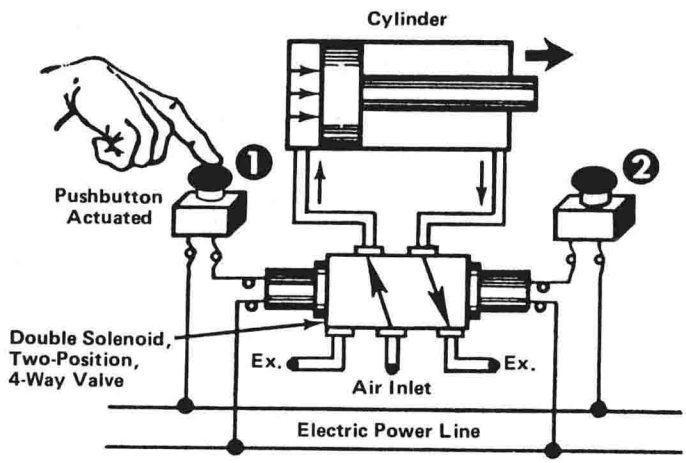
Closed Center, 3-Position, Direct-Acting Type



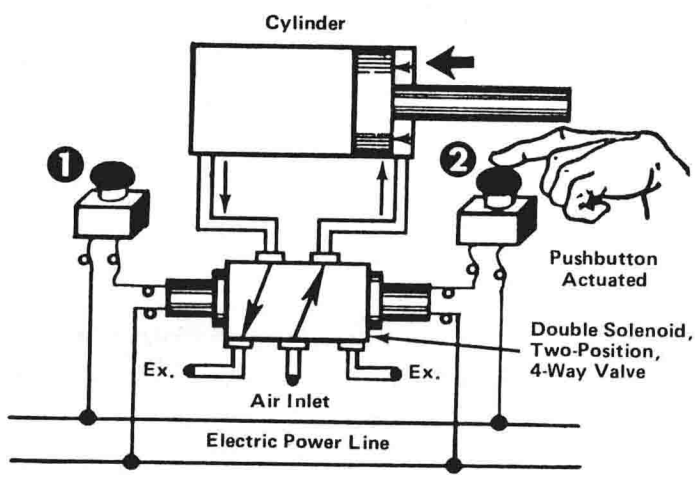
Closed Center, 3-Position, Pilot-Operated Type

FIG. 1-5. Graphic Symbols for Hydraulic Valves

Action of Double Solenoid Air Valve. Figure 1-6. The illustrations on this page show the action of a 2-position double solenoid valve in operating a standard cylinder, air or oil. A 2-position valve is said to require a "momentary" electrical impulse for its operation. Once the valve spool has been shifted by the solenoid, it will remain in that position, even though the solenoid is de-energized, until the opposite solenoid is energized. Most valves will shift reliably on a signal duration as short as 1/10th second.



A. Cylinder extends when electric pushbutton on the left is pressed.*



B. Cylinder retracts when electric pushbutton on the right is pressed.*

Part A, Figure 1-6. When the left pushbutton, 1, is momentarily pressed, the valve spool is shifted to its opposite position, directing inlet air to the back side of the cylinder piston, causing it to move forward. It will continue to travel until it stalls against the work or against its front end cap, even though the button has been released.

Part B, Figure 1-6. Pressing the pushbutton on the right shifts the valve spool back to its original position which directs air flow into the rod end of the cylinder. The piston retracts until reaching stall against its rear end cap.

Reversal can be made to take place at any point in the piston stroke while the piston is traveling. But since the valve has only two working positions, there is no electrical means by which the piston can be stopped at any intermediate point in its travel.

Design Note: All spool-type 4-way valves should preferably be mounted with spool in a horizontal plane to avoid the possibility of self-shift due to excessive air flow or vibration.

FIGURE 1-6. Pushbutton control of a cylinder with a 2-position double solenoid valve.

**Some brands of double solenoid valves may have reverse action: energizing left solenoid may cause cylinder to retract.*

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