PHASE 18
TABLE OF CONTENTS

PAGE

PHASE 18
TABLE OF CONTENTS

UNIVERSAL TECHNICAL INSTITUTE

LIST OF LAB PROJECTS

PHASE 18: DIESEL HYDRAULICS

INSTRUCTOR Mr. Fults

STUDENT'S NAME & NUMBER Martin Rogers 6059

DRAW GRAPHIC SCHEMATICS	2
DRAW PICTORIAL SCHEMATICS	2
DISASSEMBLE PRESSURE RELIEF VALVE	2
DISASSEMBLE DIRECTIONAL CONTROL VALVE	2
DISASSEMBLE FLOW CONTROL VALVE	2
DISASSEMBLE VANE PUMP BALANCED	3
DISASSEMBLE GEAR PUMP	3
DISASSEMBLE PISTON PUMP AXIAL	3
DISASSEMBLE PISTON PUMP RADIAL	3
TEST A PUMP G.P.M. R.P.M. P.S.I.	1
DISASSEMBLE ROTOR PUMP	3
DISASSEMBLE CYLINDERS	3
DISASSEMBLE FILTER	3
DISASSEMBLE LINES AND FITTINGS	2-1
PROJECT: 998 RESERVOIR	
PROJECT: FORK LIFT	
PROJECT: LIFT GATE	
PROJECT: LOADER	
PROJECT: SPERRY VICKER BOARD	30
TEST CYL. AREA FORCE P.S.I.	3
Sperry Vicker Test	3
Specil Project	

HYDRAULIC CIRCUIT SYMBOLS

U.S.A.S.I. (United States of America Standards Institute)
J.I.C. (Joint Industry Council)

Pumps

HYDRAULIC PUMP: FIXED DISPLACEMENT	
VARIABLE DISPLACEMENT	

Motors and Cylinders

HYDRAULIC MOTOR: FIXED DISPLACEMENT	
VARIABLE DISPLACEMENT	
CYLINDER, SINGLE ACTING	
CYLINDER, DOUBLE ACTING	
SINGLE END ROD	
DOUBLE END ROD	
ADJUSTABLE CUSHION ADVANCE ONLY	
DIFFERENTIAL PISTON	

Miscellaneous Units

ELECTRIC MOTOR	
ACCUMULATOR, SPRING LOADED	
ACCUMULATOR, GAS CHARGED	
HEATER	
COOLER	
TEMPERATURE CONTROLLER	
FILTER, STRAINER	
PRESSURE SWITCH	
PRESSURE INDICATOR	
TEMPERATURE INDICATOR	
DIRECTION OF SHAFT ROTATION (ASSUME ARROW ON NEAR SIDE OF SHAFT)	

Valves

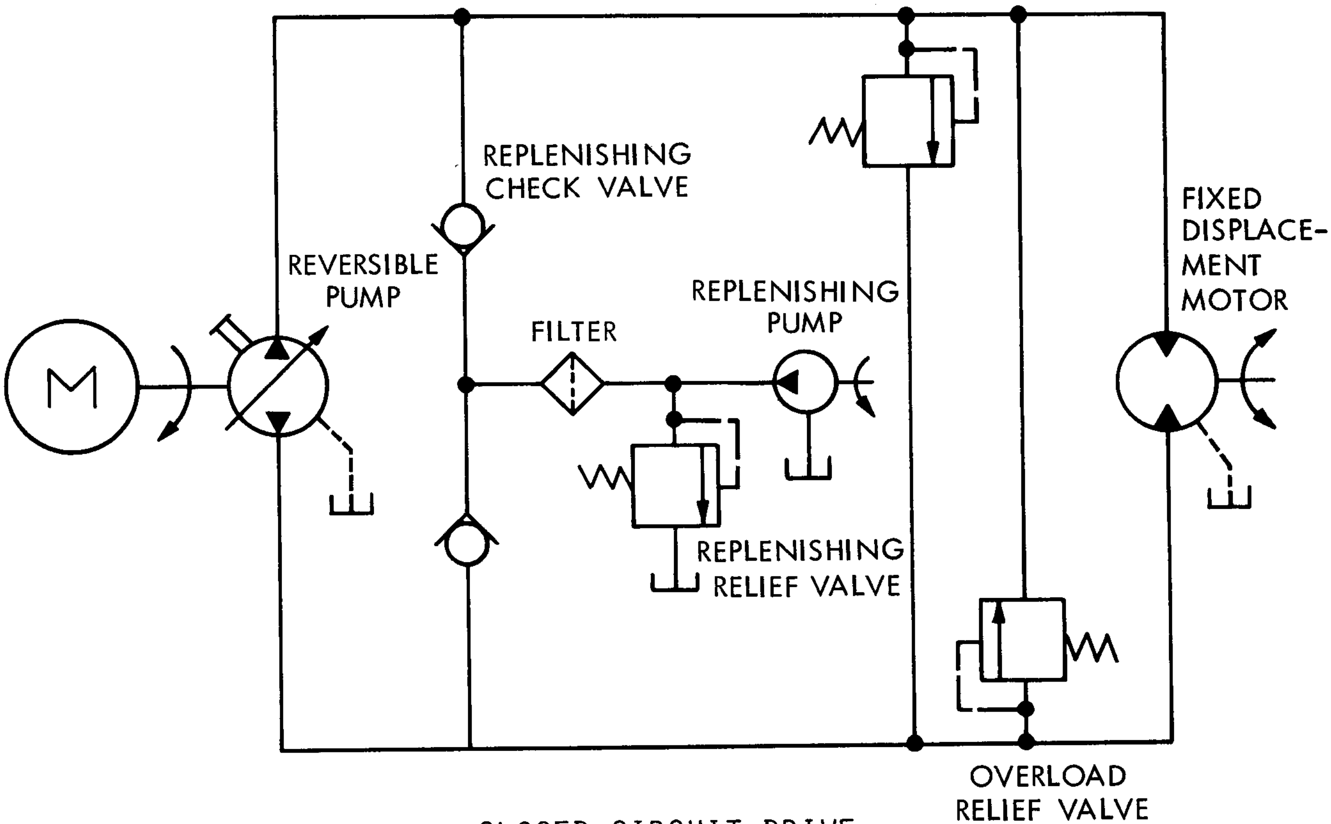
CHECK	
ON-OFF (MANUAL SHUT-OFF)	
PRESSURE RELIEF	
PRESSURE REDUCING	
FLOW CONTROL, ADJUSTABLE-NON-COMPENSATED	
FLOW CONTROL, ADJUSTABLE (TEMPERATURE AND PRESSURE COMPENSATED)	
TWO POSITION TWO CONNECTION	
TWO POSITION THREE CONNECTION	
TWO POSITION FOUR CONNECTION	
THREE POSITION FOUR CONNECTION	
TWO POSITION IN TRANSITION	
VALVES CAPABLE OF INFINITE POSITIONING (HORIZONTAL BARS INDICATE INFINITE POSITIONING ABILITY)	

Methods of Operation

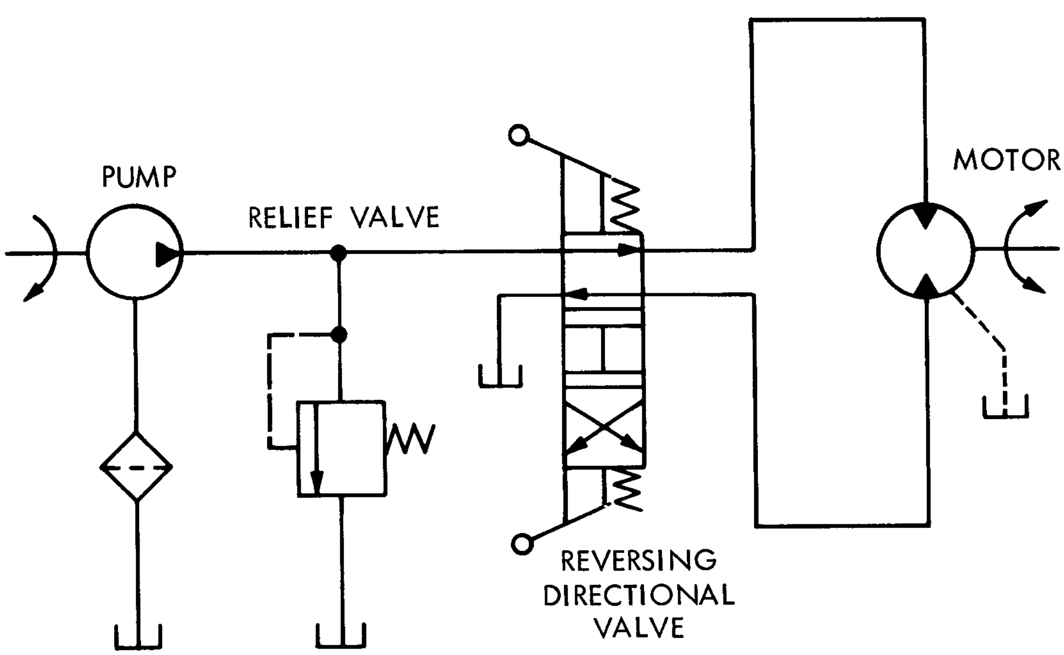
SPRING	
MANUAL	
PUSH BUTTON	
PUSH-PULL LEVER	
PEDAL OR TREADLE	
MECHANICAL	
DETENT	
PRESSURE COMPENSATED	
SOLENOID, SINGLE WINDING	
REVERSING MOTOR	
PILOT PRESSURE REMOTE SUPPLY	
INTERNAL SUPPLY	

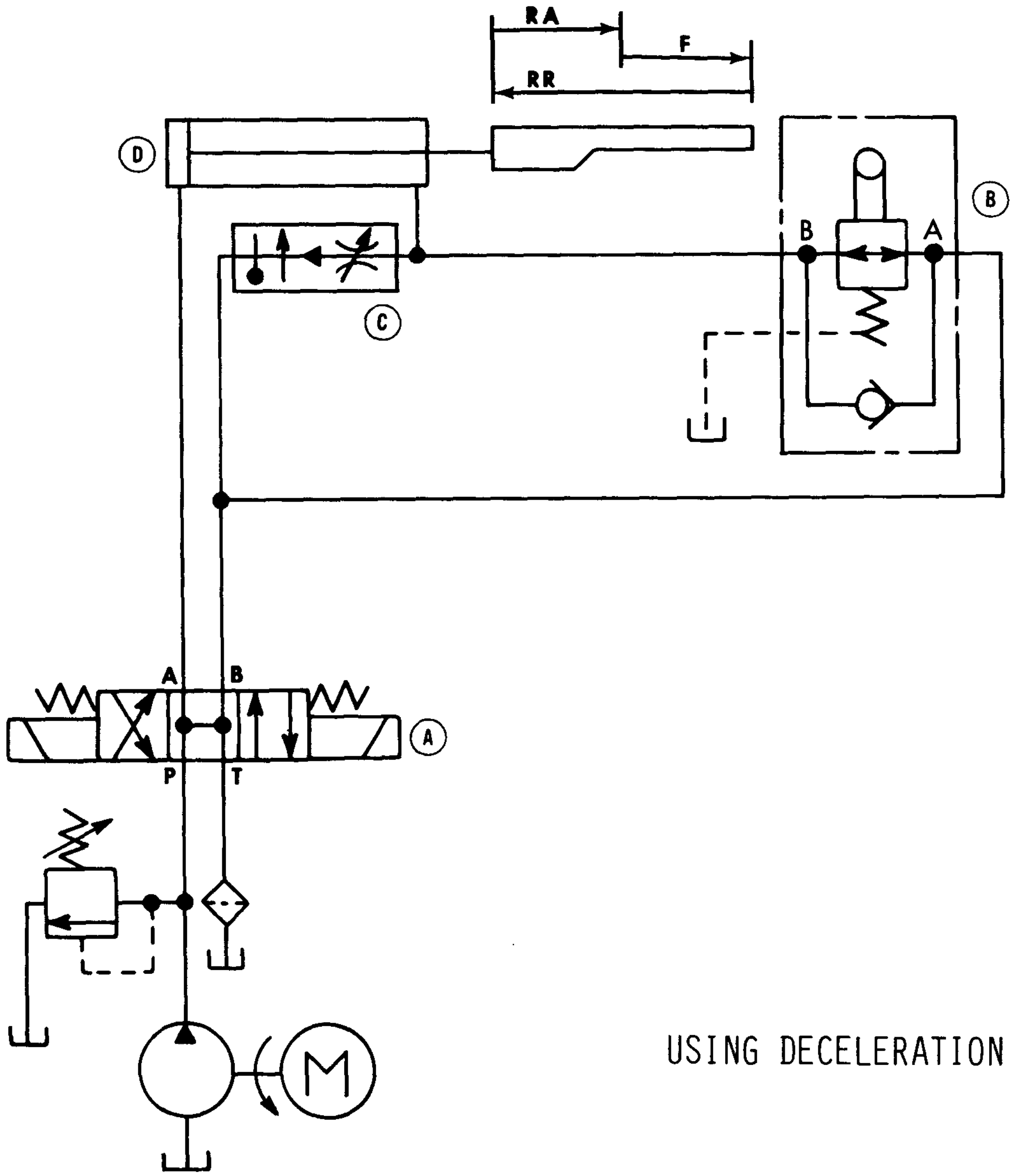
Lines

LINE, WORKING (MAIN)	
LINE, PILOT (FOR CONTROL)	
LINE, LIQUID DRAIN	
FLOW, DIRECTION OF HYDRAULIC	
FLOW, DIRECTION OF PNEUMATIC	
LINES CROSSING	or
LINES JOINING	
LINE WITH FIXED RESTRICTION	
LINE, FLEXIBLE	
STATION, TESTING, MEASUREMENT OR POWER TAKE-OFF	
VARIABLE COMPONENT (RUN ARROW THROUGH SYMBOL AT 45 deg.)	
PRESSURE COMPENSATED UNITS (ARROW PARALLEL TO SHORT SIDE OF SYMBOL)	
TEMPERATURE CAUSE OR EFFECT	
RESERVOIR VENTED	
RESERVOIR PRESSURIZED	
LINE, TO RESERVOIR ABOVE FLUID LEVEL	
BELOW FLUID LEVEL	



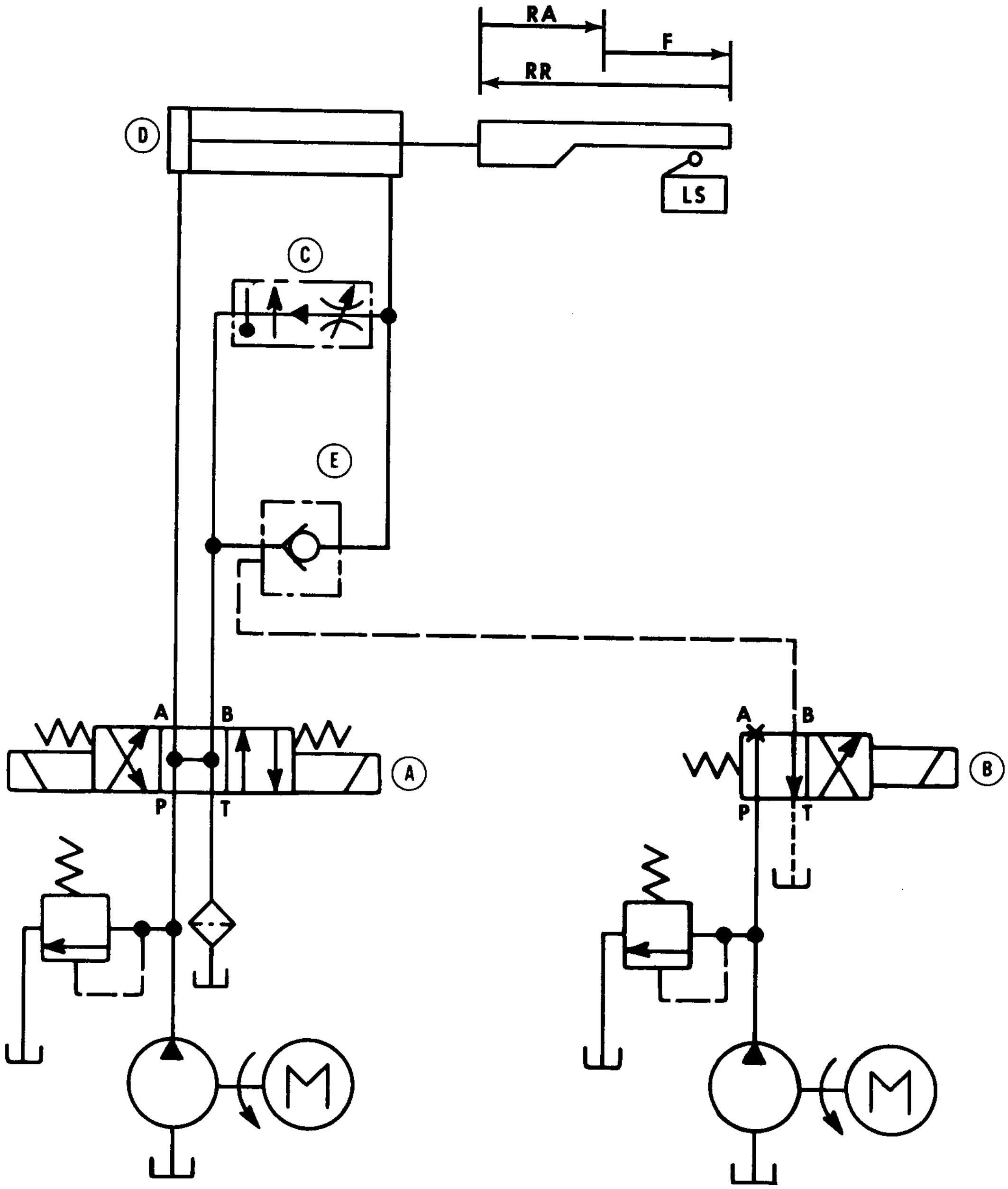
CLOSED CIRCUIT DRIVE





USING DECELERATION VALVE

Directional valve (A) is shifted to direct flow into head end of cylinder (D). Discharge from rod end of (D) flows through normally open deceleration valve (B) and freely to tank through (A) for rapid advance. At end of rapid advance, cam on (D) depresses spool of (B) to the closed position. Discharge from rod end of (D) is then metered by flow control (C) for the feed stroke. Valve (A) is reversed to direct flow through integral check valve of (B) freely into rod end of (D) for rapid return.



RAPID ADVANCE TO FEED
USING PILOT OPERATED CHECK VALVE

Directional valve (A) is shifted to direct flow into head end of cylinder (D). Directional valve (B) is shifted to direct pilot flow to remotely open pilot operated check valve (E). Discharge from rod end of (D) flows freely to tank through (E) and (A). At end of rapid advance, cam on (D) contacts a limit switch to allow (B) to spring return to its normal position. Valve (E) closes and discharge from rod end of (D) is then metered by flow control (C) for the feed stroke. Valve (A) is reversed to direct flow freely through (E) into rod end of (D) for rapid return.

HYDRAULIC FLUIDS

INTRODUCTION

The hydraulic fluid is the medium by which power is transmitted from a pump to the mechanisms which produce work such as cylinders and hydraulic motors. The fluid is just as important as any other part of a hydraulic system. In fact, it has been estimated that 70 percent of hydraulic problems stem from the use of improper types of fluids, or fluids containing dirt and other contaminants.

When we speak of a hydraulic fluid, in almost all cases we really mean a highly refined petroleum oil usually containing additives, some to suppress unwanted properties and others to give the oil desirable properties.

Here it might be well to interject a word of caution. **Never** use hydraulic brake fluid in a hydraulic system designed to use petroleum-base oils. Brake fluid is **not** a petroleum product and is completely incompatible with petroleum-base hydraulic fluids.

During the development of hydraulic equipment, engineers make careful studies of the available fluids to find one best suited to enable their product to give efficient, trouble-free operation. Sometimes it is even necessary to develop a new fluid which has just the right properties. This is why it is always essential to use the fluid recommended in the instructions that accompany a hydraulic machine or mechanism.

WHAT A HYDRAULIC FLUID MUST DO

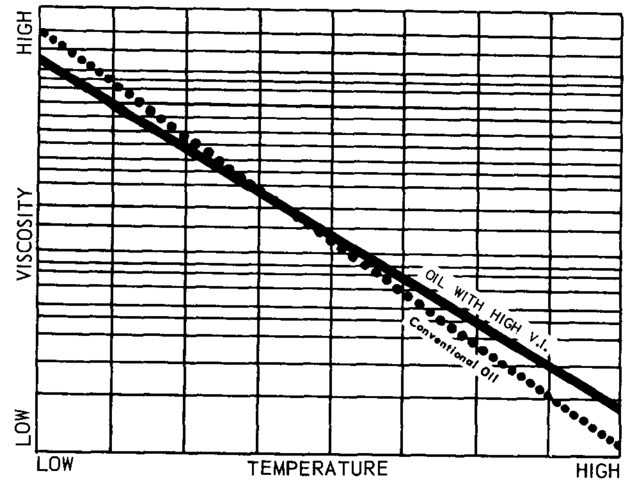
First of all, of course, a hydraulic fluid must be capable of transmitting the power applied to it. Of equal importance it must do several other things. It must provide lubrication for moving parts, be stable over a long period of time, protect machine parts from rust and corrosion, resist foaming and oxidation, and be capable of separating itself readily from air, water, and other contaminants. The fluid must also maintain proper viscosity through a wide temperature range, and finally, be readily available and reasonably economical to use.

PROPERTIES OF HYDRAULIC FLUIDS

VISCOSITY

For proper power transmission, this is a most important property. Viscosity is a measurement of a fluid's resistance to flow. Said another way, it is a fluid's "thickness" at a given temperature. Viscosity is expressed by SAE (Society of Automotive Engineers) numbers; 5W, 10W, 20W, 30, 40 etc. All petroleum oils tend to become thin as the temperature goes up, and to thicken as the temperature goes down. If viscosity is too low (fluid too thin), the possibility of leakage past seals and from joints is increased. This is particularly true in modern pumps, valves, and motors which depend on close fitting parts for creating and maintaining proper oil pressure. If viscosity is too high (fluid too thick), sluggish operation results and extra horsepower is required to push the fluid through the system. Viscosity also has a definite influence on a fluid's ability to lubricate moving parts.

Viscosity is determined by measuring the time required for 60 cubic centimeters of an oil at a temperature of 210 deg. F. to flow through a small orifice in an instrument known as a Saybolt Viscometer or another instrument called a Kimematic Viscometer. The actual SAE number is determined by comparing the time required for the oil to pass through the instruments with a chart provided by the Society of Automotive Engineers.



The Viscosity of an Oil with a High VI Contrasted with the Viscosity of a More Conventional Oil

Viscosity Index (VI)

VI	0°F	100°F	210°F
50	12,000 SUS	150 SUS	41 SUS
90	8,000 SUS	150 SUS	43 SUS

Note that the 90 VI oil is thinner at zero degrees and thicker at 210 degrees, while both have the same viscosity at 100 degrees.

This is simply a measure of a fluid's change in thickness with respect to changes in temperature. If a fluid becomes thick at low temperatures and very thin at high temperatures, it has a **low** VI. On the other hand if viscosity remains relatively the same at varying temperatures, the fluid has a **high** VI. As pointed out earlier, in a fluid with good viscosity characteristics, there is a balance between a fluid thick enough to prevent leakage and provide good lubrication while, at the same time, being thin enough to flow readily through the system. Therefore, a fluid with a high VI is almost always desirable and must be an important consideration in hydraulic fluid recommendations.

Viscosity Index Improver

Even though carefully refined oils have a good viscosity index, a substance called a viscosity index improver is often added to hydraulic fluids. This substance increases the VI of the fluid so that its viscosity change over a wide range of temperatures is as little as practical.

WEAR PREVENTION

Vane Pump Ring Worn Due to Lack of Lubrication

Most hydraulic components are fitted with great precision, yet they must be lubricated to prevent wear. To provide this lubrication, a satisfactory fluid must have good "oiliness" to get in the tiny spaces available between moving parts and hold friction between the parts to a minimum.

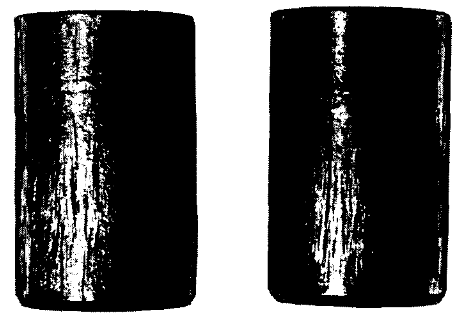
A good fluid must also have the ability to "stick" to these closely fitted parts, even when they are quite warm.

Good lubricating qualities become even more important in many modern machines where the hydraulic fluid has a double purpose - to operate the hydraulic mechanisms, and also to lubricate the transmission, differential, and other parts of the machine.

The best hydraulic fluids contain an "extreme pressure" additive which assures good lubrication of very close fitting metal-to-metal parts operating at high pressures and temperatures.

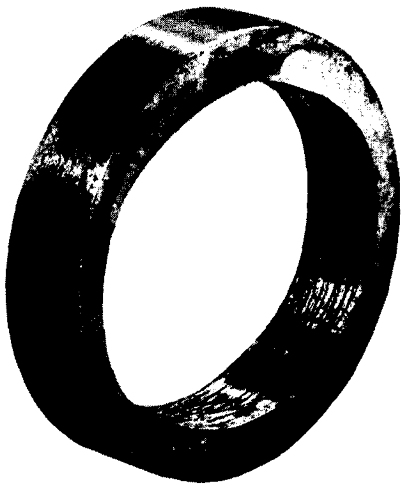
This additive reduces friction and helps to prevent galling, scoring, seizure, and wear.

RESISTANCE TO OXIDATION



Radial Pump Pistons Scored by Contaminated Fluid

Everyone is familiar with the effects of air on a piece of shiny iron, especially in the presence of water; it combines with oxygen in the air to form rust and other foreign materials. Its chemical properties are also changed. Just like the iron, all oils combine to some extent with the oxygen in the air. This changes the oil's chemical composition. Organic acids are formed which may be harmful to metal parts and many types of seals and packings in the system. In addition to the acids, sludges are often formed through the reactions between fluids and air. Both reactions are speeded up by the presence of water and other contaminants such as dust, dirt and metallic particles in the fluid. This is one reason why an efficient filtering system is so important in any hydraulic system. Heat is also a very important factor in oxidation.



Vane Pump Rotor Ring Worn and Pitted by Contaminated Fluid

It has been determined, for instance, that for every 18 deg. F. rise in temperature, the rate of oxidation doubles. Because of this, some hydraulic systems contain a cooler to hold temperatures to reasonable limits.

Fortunately, carefully refined fluids, plus the addition of a special chemical, successfully resist oxidation. With careful attention to prevent the entrance of dirt and other contaminants, most modern hydraulic fluids will operate for many hours without ill effects due to oxidation. However, oxidation can be a real problem unless high-quality hydraulic fluids, specifically recommended by the equipment manufacturer are used.

RUST AND CORROSION PREVENTION

Rust and corrosion are both related to oxidation, and a hydraulic fluid (providing it is kept clean) with good anti-oxidation qualities is likely to resist rust and corrosion. However, the possibilities of rust or corrosion developing are always present and they cannot be ignored. Rust and corrosion differ in that rusting adds to metal making the part larger while corrosion, caused by acids or local electrochemical cells, is an eating away of the metal. Either condition, of course, is highly detrimental to a hydraulic mechanism. Rust causes rough spots which damage seals and close fitting parts. It is most likely to form during storage periods, down-time, or even overnight. Corrosion affects the fit of closely machined parts and permits undesirable leakage. Both rust and corrosion cause erratic operation and untimely wear.

Good hydraulic fluids contain both rust and corrosion additives which neutralize corrosion forming acids and cling to metal parts to protect them from rusting and corroding.

RESISTANCE TO FOAMING

The proper operation of any hydraulic system is based on the fact that fluids cannot be compressed by pressures normally encountered in the system. In effect the fluid acts like a "liquid" steel rod. Any force applied to it at one end is transmitted to the other end without any "slack" due to compression. However, air which is compressible can be absorbed by the fluid. In many systems the fluid reservoir is directly exposed to the atmosphere which promotes entrance of air into the fluid. In addition, air can enter the system through defective packings, leaky lines, or if the fluid level in the reservoir is allowed to get too low.

In many systems turbulence promotes the mixing of fluid and air.

Good fluids have the capacity to "dissolve" a small amount of air. The amount of air that can be dissolved increases as pressure and temperature increase. This dissolved air has no harmful effects on operation. But if the amount of air which enters the fluid is greater than the fluid's capacity to dissolve it, bubbles form which, since air is compressible, result in mushy, unsatisfactory operation. Furthermore, some air in solution under pressure comes out of solution when pressure is released. This air creates foam which seriously affects proper action, and especially lubrication.

While most well refined oils are not subject to excessive foaming, most good hydraulic fluids contain a foam inhibitor additive which speeds up the rate at which bubbles break up. This improves the fluid's ability to do its work properly, and to increase its capacity for adequately lubricating moving parts.

ABILITY TO SEPARATE FROM WATER

Contrary to popular opinion, oil and water **will** mix. This mixture is called an "emulsification." It is almost impossible to keep all water out of a hydraulic system. Water vapor enters the reservoir where it condenses into droplets. It also may enter through tiny leaks in the system. Because of the violent agitation, churning, and continual recirculation in a typical hydraulic system, the water and fluid quickly mix to form an emulsion. Any appreciable amount of water in the fluid is highly detrimental. The emulsion promotes rust, increases oxidation which forms acids and sludges, and reduces the fluid's ability to lubricate moving parts properly. Also, emulsions often have a slimy, sticky, or pasty consistency which interferes with normal operation of valves and other parts.

LACK OF OTHER CONTAMINANTS

It should go without saying that a good hydraulic fluid should be as free as possible of contaminants such as metallic particles, dust, dirt and the like. Such materials are not only likely to damage closely fitted parts, but they also seem to help the undesirable oxidation process to take place.

Use of reliable fluids, careful storage, good filters, proper handling of fluids, and periodic cleaning of hydraulic systems all materially reduce the danger of contamination.

MAINTAINING GOOD FLUID

As has been said many times, dirt and contamination are the worst enemies of any hydraulic system. Continued, long operation at high efficency is very dependent upon proper fluid maintenance. First of all, **only** a fluid recommended by the manufacturer of the system should be used; it should be checked at the suggested intervals maintained at the correct level, properly filtered, and changed at the recommended intervals.

DRAIN SCHEDULE

Periodic drainage of the entire system is very important.

This is the only way to remove contaminants, products of oxidation such as sludge and acids, and other particles that may be injurious to the system. Actually, in modern hydraulic systems using approved fluids, the drain period is not frequent and it should work no hardship on the part of the owner to follow the manufacturer's directions. Many modern fluids are so highly refined, filtered, and fortified by additives that system flushing is not necessary. However if flushing is recommended by the manufacturer, it is always advisable to follow directions so as not to contaminate the new oil with flushing oil that cannot be drained from the system.

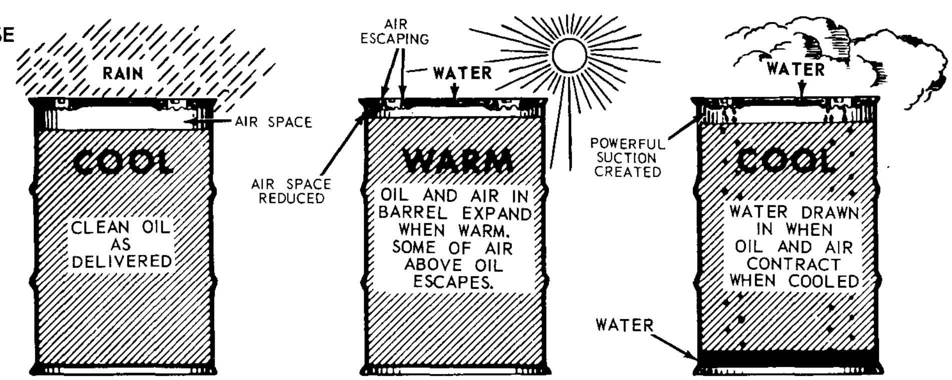
KEEPING HYDRAULIC FLUIDS CLEAN

All good hydraulic fluids, which come in cans or barrels, are delivered perfectly clean and free from contaminants. It is when the containers are opened or stored that troubles develop.

When opening a can or barrel, be absolutely certain that the area around the opening is completely free of dust, dirt, lint, or water. If a container, funnel, or hose is required to fill the system, be sure that it is spotless.

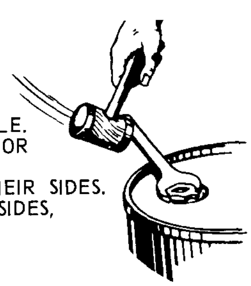
When possible, always store barrels of hydraulic fluid indoors, or at least under cover, and be sure the bung is tight. If barrels are stored in the sun without a tight bung, the fluid will expand, forcing some air from the bung. Then as the fluid cools off, the fluid contracts, drawing any rain, dew, or other moisture into the barrel and fluid. The detrimental effects of water in hydraulic fluids have already been discussed. For this reason, keep the bungs in barrels as tight as possible, and tip the barrels in such a manner that water cannot collect around the bung.

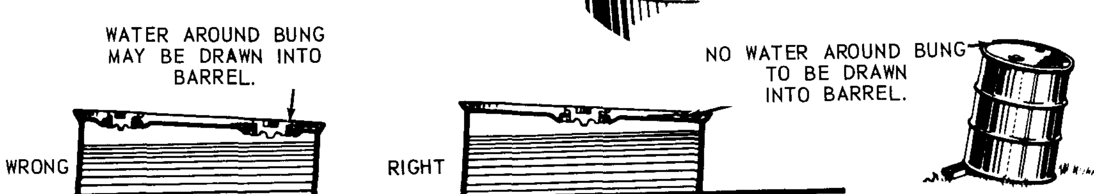
CAUSE



PREVENTION

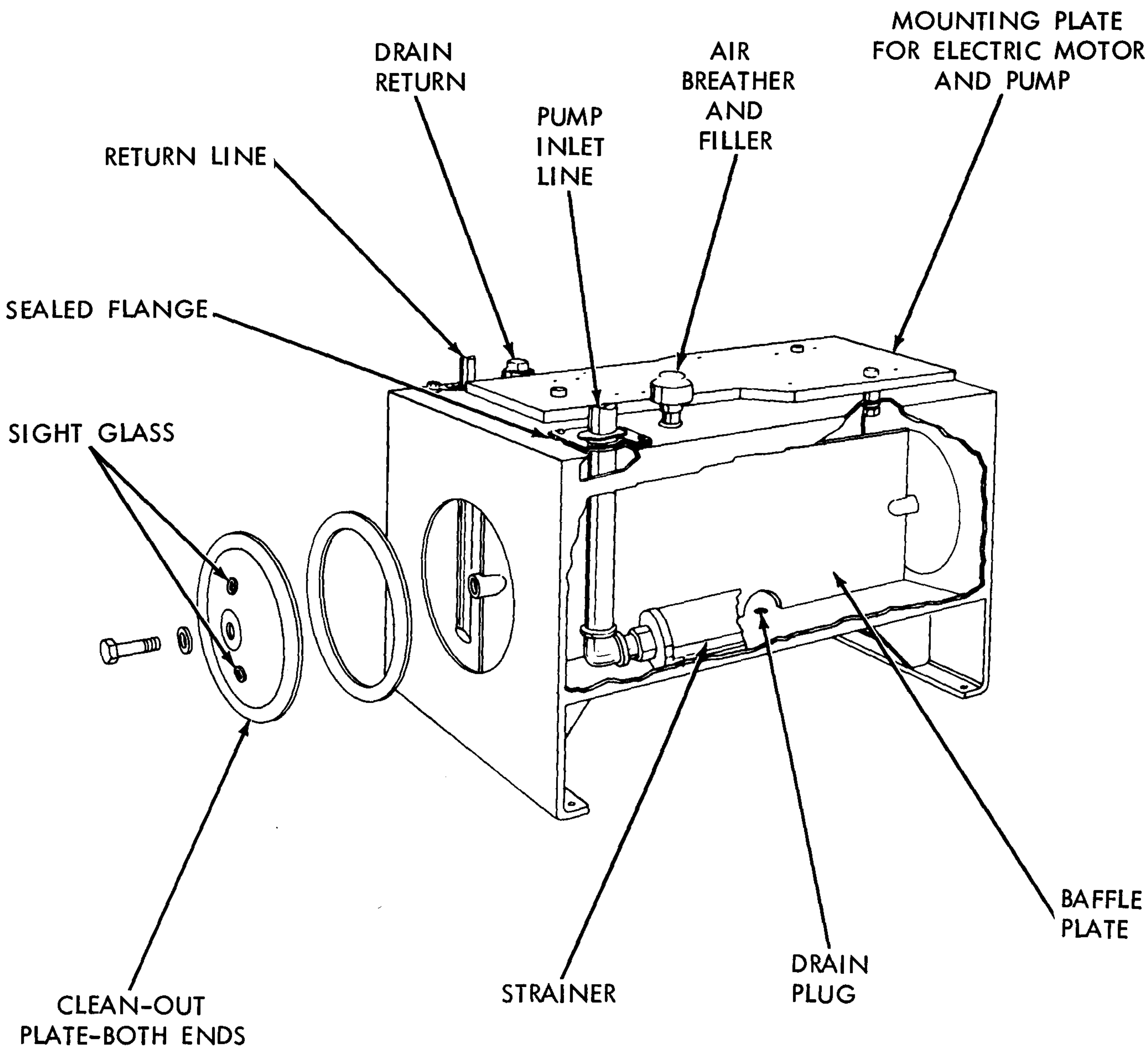
1. KEEP BUNGS DRAWN TIGHT. USE WOODEN MALLET TO MAKE SURE.
2. STORE BARRELS INSIDE WHENEVER POSSIBLE. (WARM STORAGE IN WINTER PREFERABLE) OR
3. AT LEAST UNDER COVER.
4. IF STORED OUTSIDE, LAY BARRELS ON THEIR SIDES.
5. IF BARRELS CANNOT BE LAID ON THEIR SIDES, TILT THEM SLIGHTLY AS SHOWN BELOW.



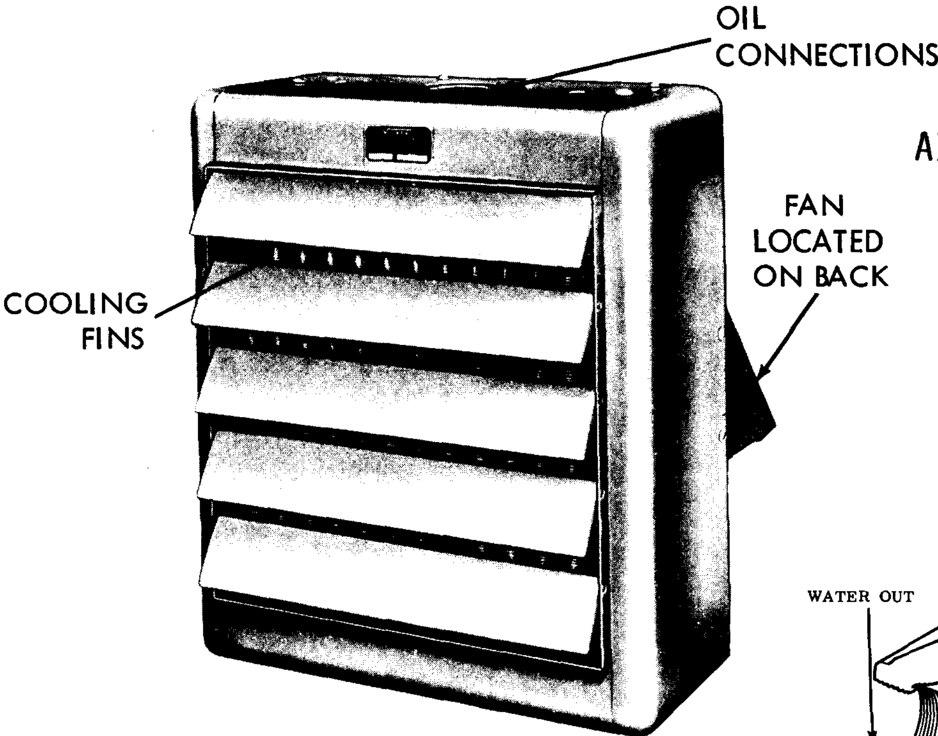


Oil Contamination Can Be Prevented By Careful Storage Practices

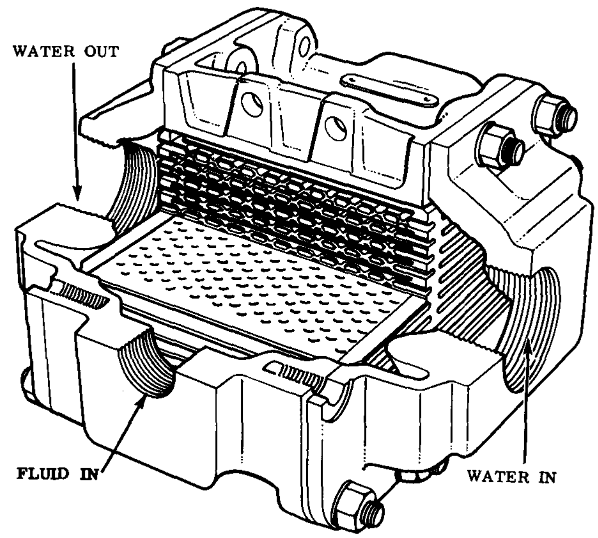
RESERVOIR CUTAWAY (TYPICAL)

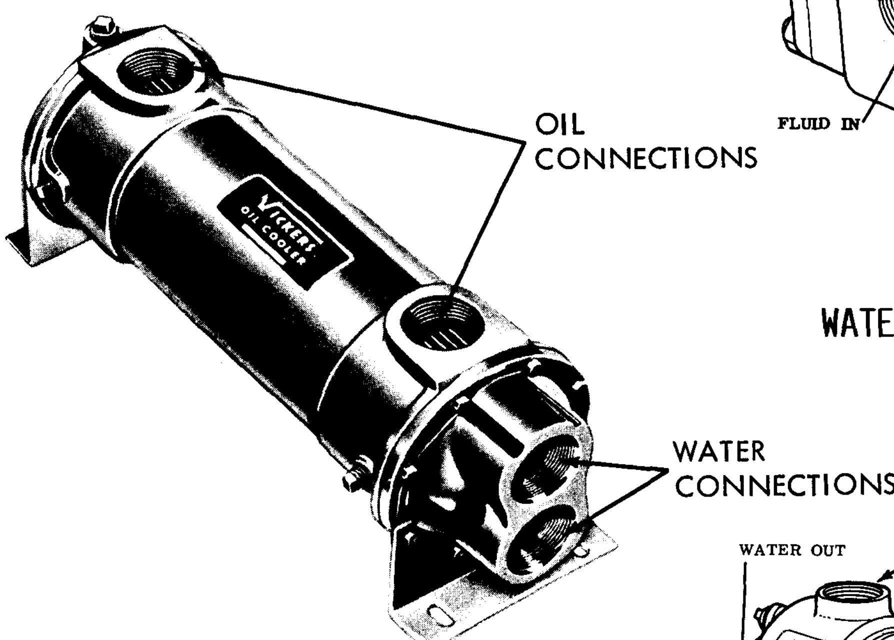


OIL COOLERS

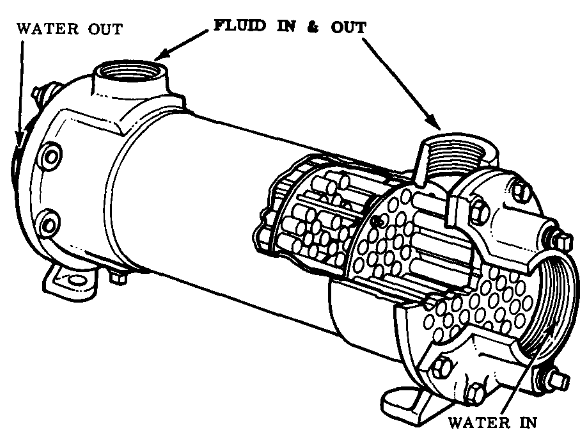


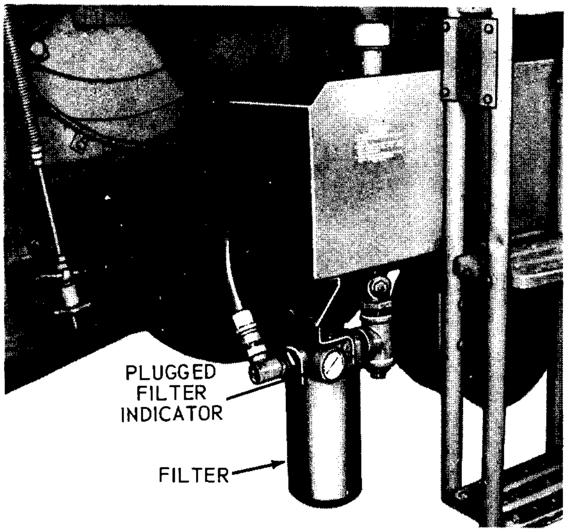
AIR COOLED TYPE



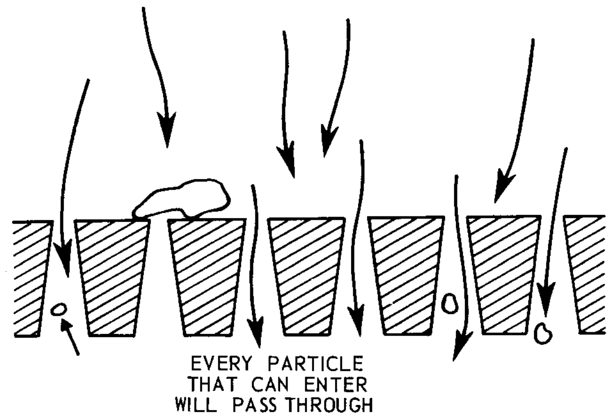


WATER COOLED TYPE

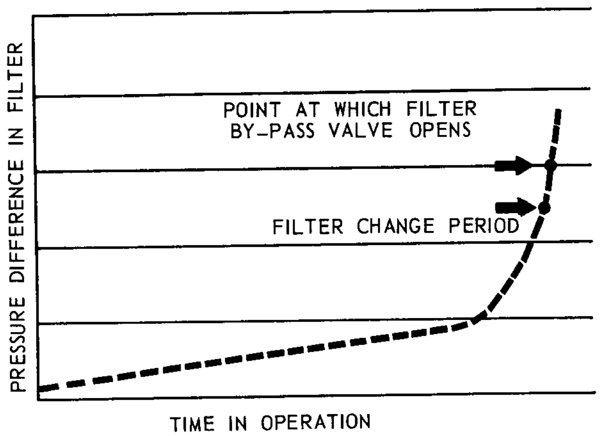




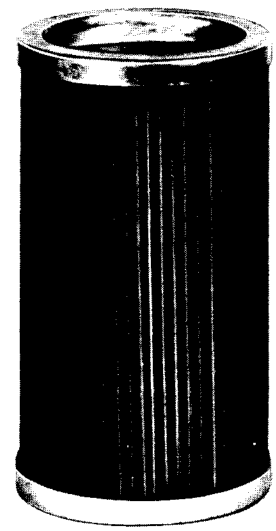
Plugged Filter Indicator



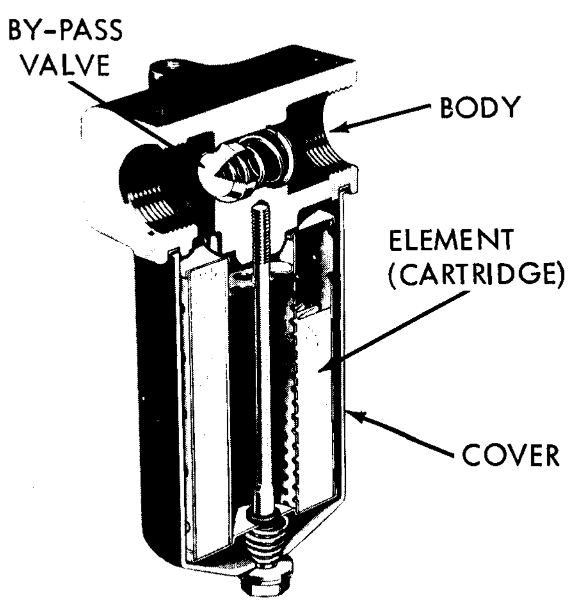
Tapered Flow Path Helps Prevent Plugging

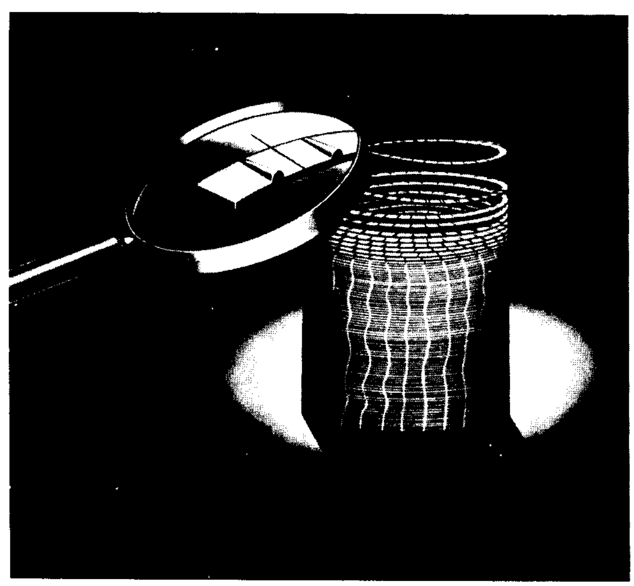


Life of a Filter Element



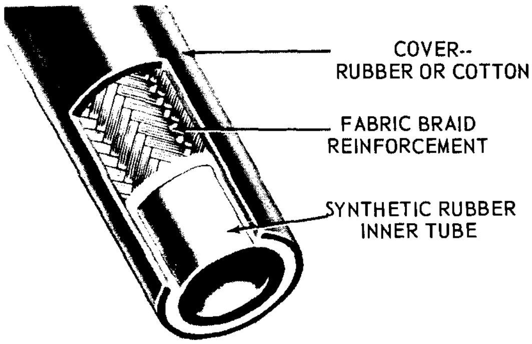
Wire Mesh Filter



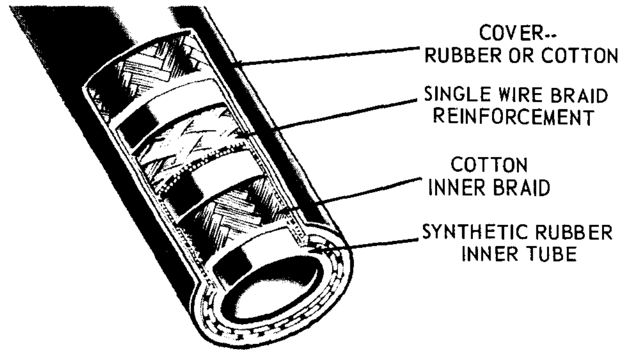


Metal Edge Filter

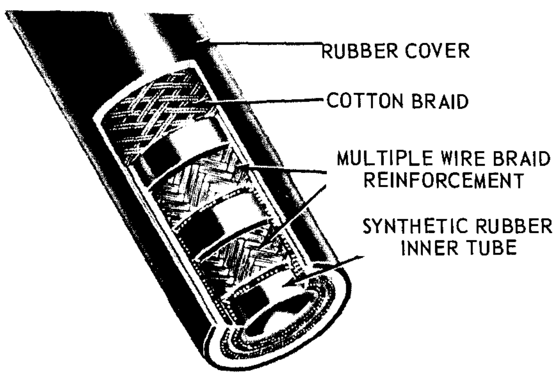
HYDRAULIC HOSES



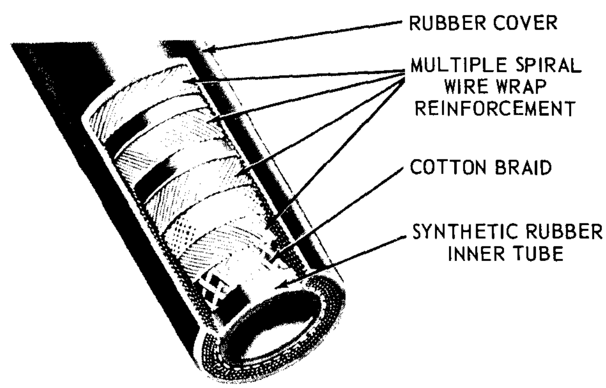
FABRIC BRAID HOSE
(For Lower Pressures)



SINGLE WIRE BRAID HOSE



DOUBLE WIRE BRAID HOSE



SPIRAL WIRE HOSE

The Four Types of Hoses

The hose pressure rating is based on the *working pressure* of the system. This must allow for the maximum "surges" of pressure during the normal operation of the system.

Temperature of the hydraulic oil is also critical in hose selection. All four types will handle the normal heat of hydraulic operation, but special hoses have been designed for extra high temperatures.

The charts which follow give the constructions and applications of the four types of hoses.

FABRIC BRAID HOSE

Construction	*Uses*
Inner Tube: Black synthetic rubber. Reinforcement: Woven fiber reinforced with spiral wire to prevent collapse. Cover: Synthetic rubber, oil- and abrasion-resistant.	Lines for Petroleum-base hydraulic oils, gasoline or fuel oil. In suction lines or in low-pressure return lines. Temperature Range: -40°F. to +250°F. Vacuum: 30 In. Hg.

FABRIC BRAID HOSE—Continued

Construction	*Uses*
Inner Tube: Black synthetic rubber, oil-resistant. Reinforcement: One-fiber braid. Cover: Black synthetic rubber, oil- and abrasion-resistant.	Hydraulic oil return lines only, or general-purpose fuel oil, gasoline, water, anti-freeze mixtures, air, and other chemicals. Temperature Range: -40°F. to +250°F.
Inner Tube: Black synthetic rubber, oil-resistant. Reinforcement: Two fiber braids. Cover: Black synthetic rubber, oil- and abrasion-resistant.	Hydraulic oil return lines only, or general purpose fuel oil, gasoline, water, anti-freeze mixtures, air, and other chemicals. Temperature Range: -40°F. to +250°F.

IMPORTANT: Fabric braid (low pressure) hoses are NOT RECOMMENDED FOR PRESSURE LINE USE IN HYDRAULICS. Therefore, they will not be included in the chart on selecting hoses which follows these charts.

SINGLE WIRE BRAID HOSE

Construction	*Uses*
Inner Tube: Black synthetic rubber. Reinforcement: Two fiber braids. Cover: Synthetic rubber, oil- and abrasion-resistant.	Hydraulic oil lines, fuel oil, anti-freeze solutions, or water lines. Temperature Range: −40° F. to +250°F.
Inner Tube: Black synthetic rubber, oil-resistant. Reinforcement: One braid of high tensile steel wire. Cover: Black synthetic rubber oil- and abrasion-resistant.	Hydraulic oil lines, fuel oil, gasoline or water. Temperature Range: −40°F. to +250° F.

DOUBLE WIRE BRAID HOSE

Construction	*Uses*
Inner Tube: Black synthetic rubber oil-resistant. Reinforcement: Two braids or more of high tensile steel wire. Cover: Black synthetic rubber, oil- and abrasion-resistant.	High-pressure hydraulic oil lines, fuel oil, gasoline or water lines.
Inner Tube: Black, synthetic rubber. Reinforcement: Two braids or more of high tensile steel wire. Cover: Synthetic rubber oil- and abrasion-resistant green color.	Hydraulic lines using phosphate ester base fluids. (Should not be used with petroleum oils.) Temperature Range: −40° F. to +200° F.

NOTE: Both single and double wire braid hoses of the first type are widely used on farm and industrial equipment hydraulic systems.

SPIRAL WIRE HOSE

Construction	*Uses*
Inner Tube: Black synthetic rubber, oil-resistant. Reinforcement: Multiple spiral of high tensile steel wire and one fiber braid. Cover: Black synthetic rubber, oil- and abrasion-resistant.	Very high-pressure hydraulic oil lines or fuel oil lines. Temperature Range: −40° F. to +200° F.

IMPORTANT: Spiral wire hose is recommended where high surge peaks are encountered. Surges can cause weak spots in the wire braids of the less-strong hoses. The spiral wire reinforced hose does not weaken under high surges.

Selecting Hoses

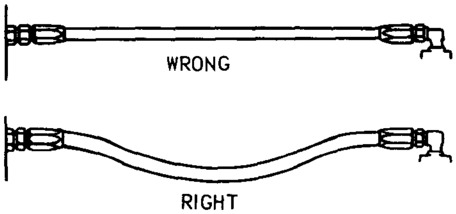
The following chart will help you to select the proper hose for any pressure application. Find the size of the hose you need and read across to the system working pressure nearest your application. If you find it in column 1, use a single wire braid hose. If in column 2, use a double wire braid hose, or in column 3 use a spiral wire hose.

SELECTING HOSE FOR VARIOUS PRESSURES

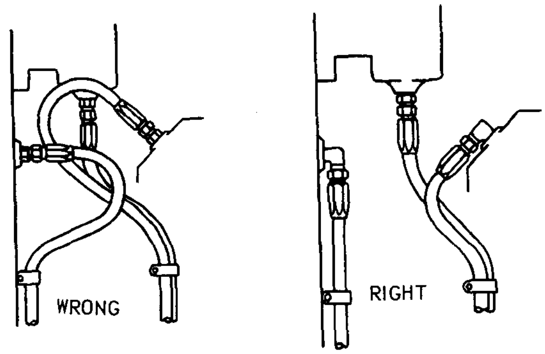
Hose Size in Inches	*1. Use SINGLE WIRE BRAID Hose if System Working Pressure Equals . . .*	*2. Use DOUBLE WIRE BRAID Hose if System Working Pressure Equals . . .*	*3. Use SPIRAL WIRE Hose if System Working Pressure Equals . . .*
1/4"	3000 psi	5000 psi	– – –
3/8"	2250 psi	4000 psi	5000 psi
1/2"	2000 psi	3500 psi	4000 psi
5/8"	1750 psi	2750 psi	– – –
3/4"	1500 psi	2250 psi	3000 psi
1"	800 psi	1875 psi	3000 psi
1 1/4"	600 psi	1625 psi	3000 psi
1 1/2"	500 psi	1250 psi	3000 psi
2"	350 psi	1125 psi	2500 psi

Note again how larger hoses are recommended for lower pressures than smaller ones of the same construction.

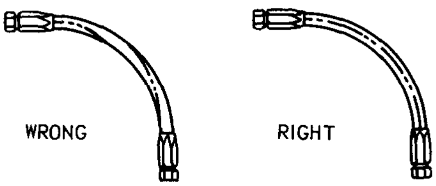
ROUTING OF HOSES



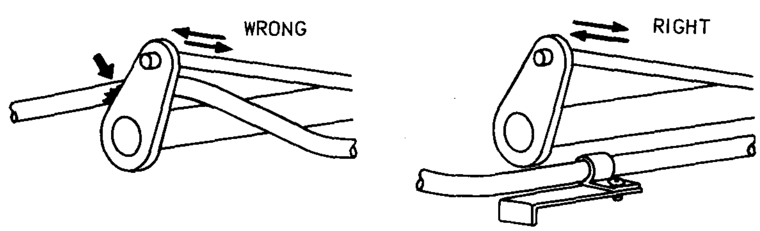
1. AVOID TAUT HOSE



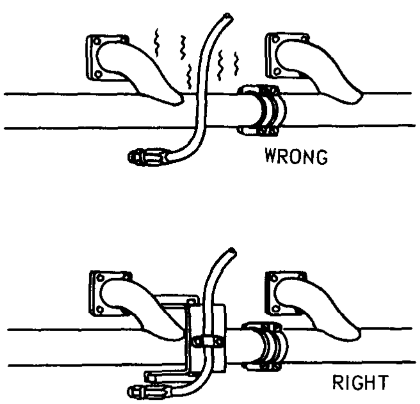
2. AVOID LOOPS



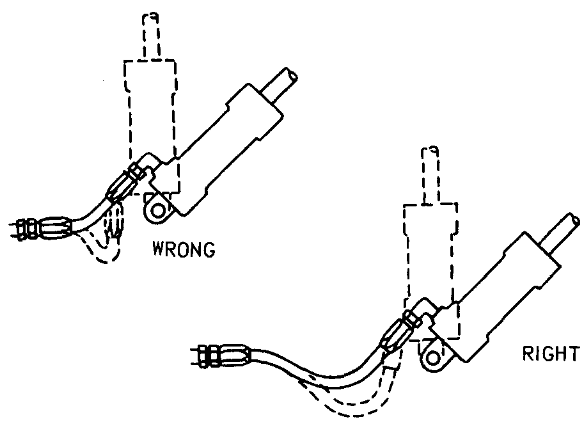
3. AVOID TWISTING



4. AVOID RUBBING

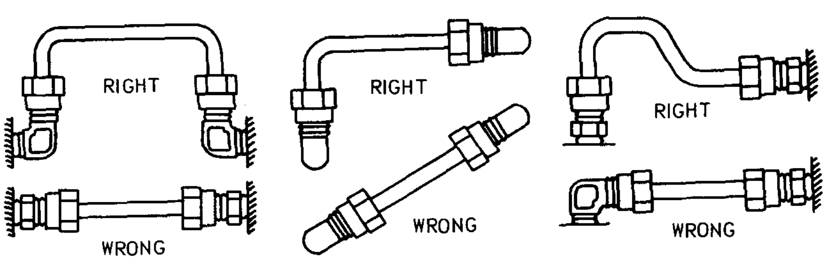


5. AVOID HEAT

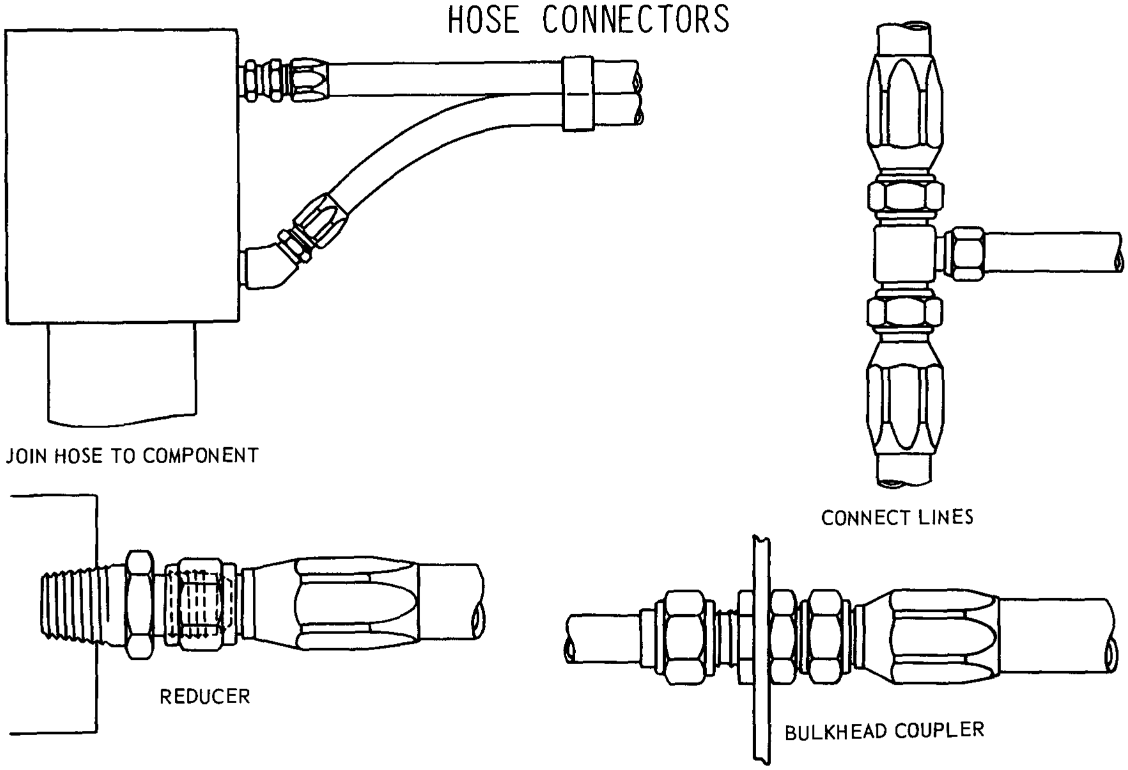


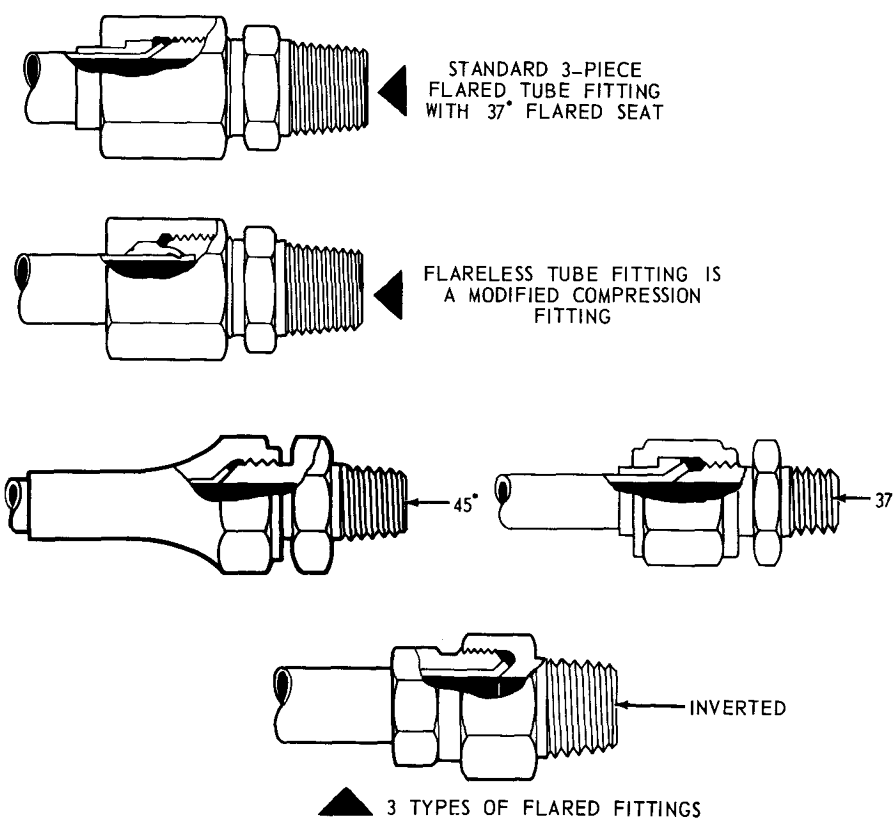
6. AVOID SHARP BENDS

ROUTING OF TUBES



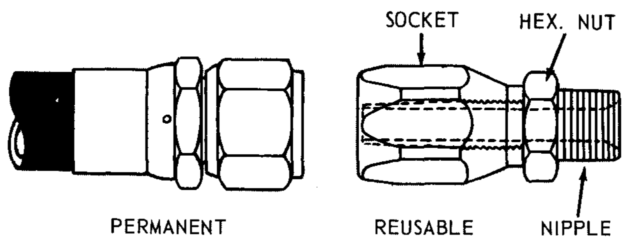
HOSE CONNECTORS

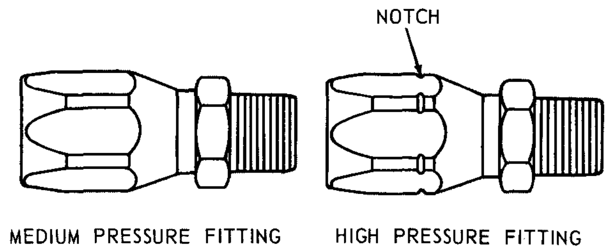




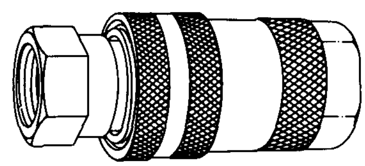
TUBE FITTINGS

HOSE FITTINGS

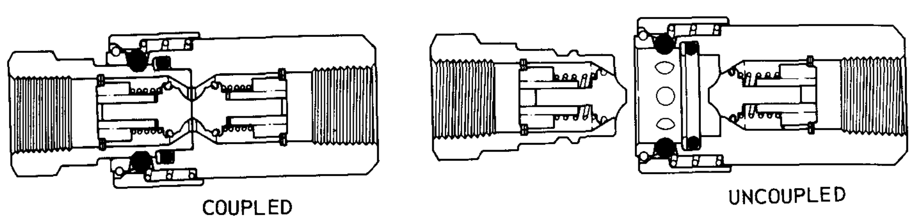


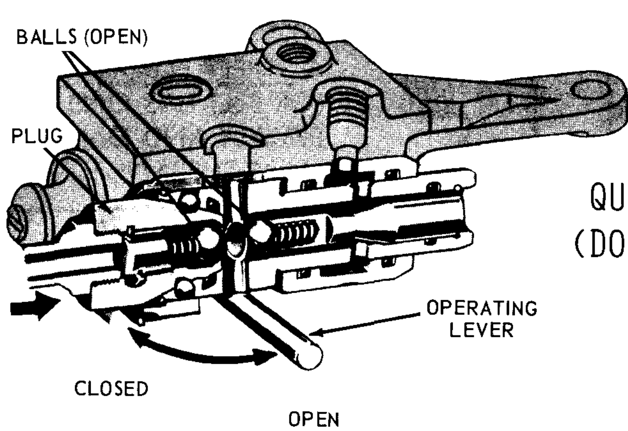


QUICK COUPLERS



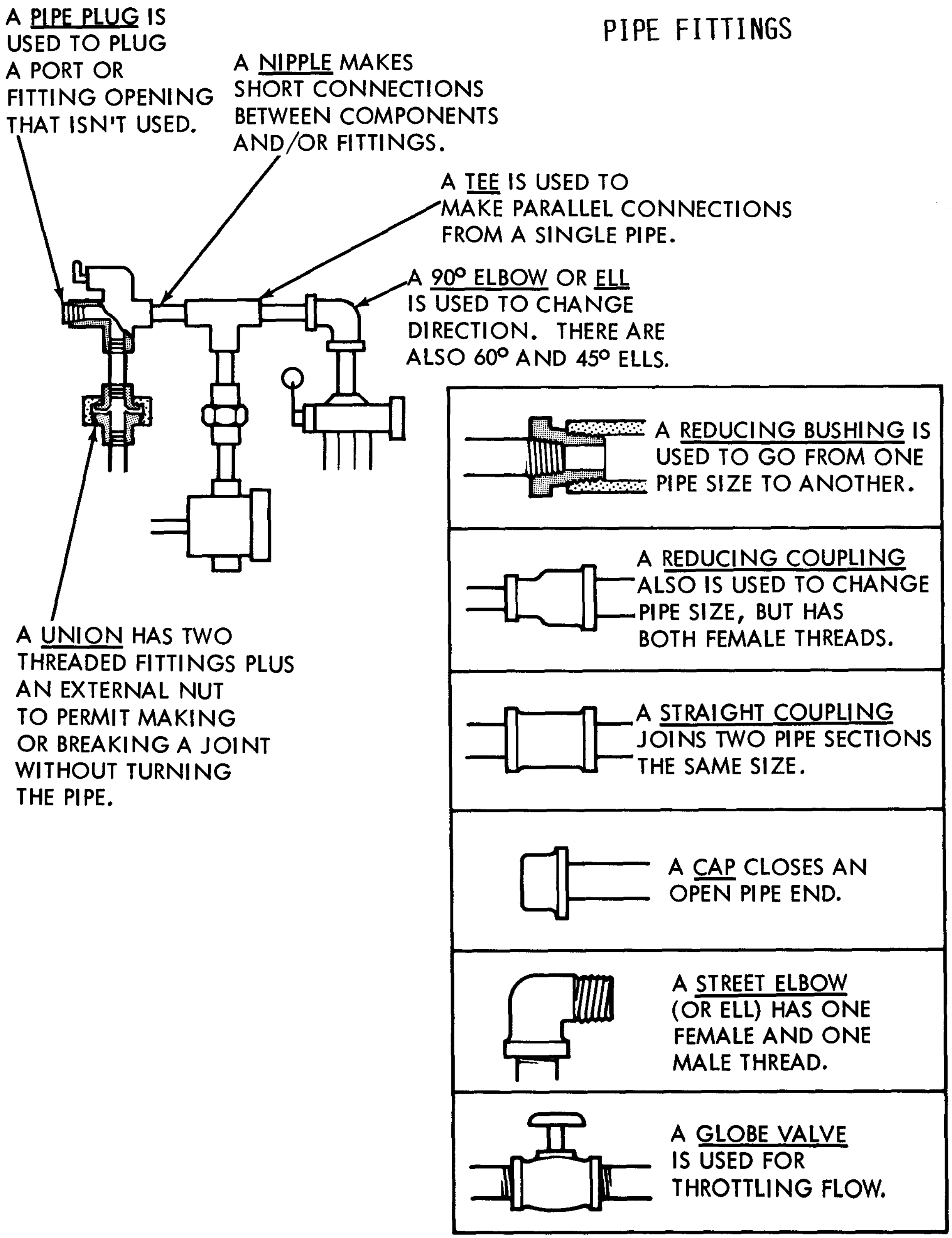
QUICK DISCONNECT COUPLER

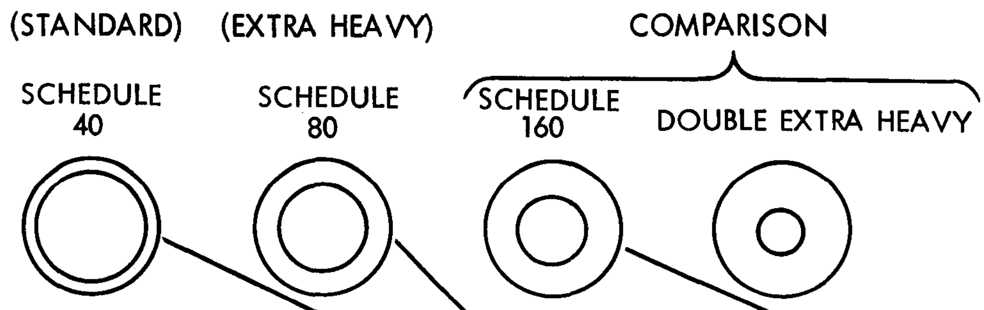




QUICK DISCONNECT COUPLER (DOUBLE ROTATING BALL TYPE)

PIPE FITTINGS





NOMINAL SIZE	PIPE O.D.	INSIDE DIAMETER									
		SCHED. 10	SCHED. 20	SCHED. 30	SCHED. 40	SCHED. 60	SCHED. 80	SCHED. 100	SCHED. 120	SCHED. 140	SCHED. 160
1/8	.405				.269		.215				
1/4	.540				.364		.302				
3/8	.675				.493		.423				
1/2	.840				.622		.546				.466
3/4	1.050				.824		.742				.614
1	1.315				1.049		.957				.815
1-1/4	1.660				1.380		1.278				1.160
1-1/2	1.900				1.610		1.500				1.338
2	2.375				2.067		1.939				1.689
2-1/2	2.875				2.469		2.323				2.125
3	3.500				3.068		2.900				2.624
3-1/2	4.000				3.548		3.364				
4	4.500				4.026		3.826		3.624		3.438
5	5.563				5.047		4.813		4.563		4.313
6	6.625				6.065		5.761		5.501		5.189
8	8.625		8.125	8.071	7.981	7.813	7.625	7.439	7.189	7.001	6.813
10	10.750		10.250	10.136	10.020	9.750	9.564	9.314	9.064	8.750	8.500
12	12.750		12.250	12.090	11.934	11.626	11.376	11.064	10.750	10.500	10.126

SCHEDULE NUMBERS FOR PIPE

OPERATING PRESSURES (0 TO 1000 psi)

Flow rate (15ft sec) gpm	*Valve size*	*Pipe schedule*	*Tubing O. D.*	*Tubing-wall thickness*
1	1/8	80	1/4	0.035
1.5	1/8	80	5/16	0.035
3	1/4	80	3/8	0.035
6	3/8	80	1/2	0.042
10	1/2	80	5/8	0.049
20	3/4	80	7/8	0.072
34	1	80	1¼	0.109
58	1¼	80	1½	0.120

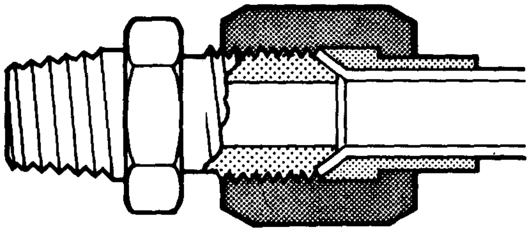
Safety factor 8 : 1

OPERATING PRESSURES (1000 TO 2500 psi)

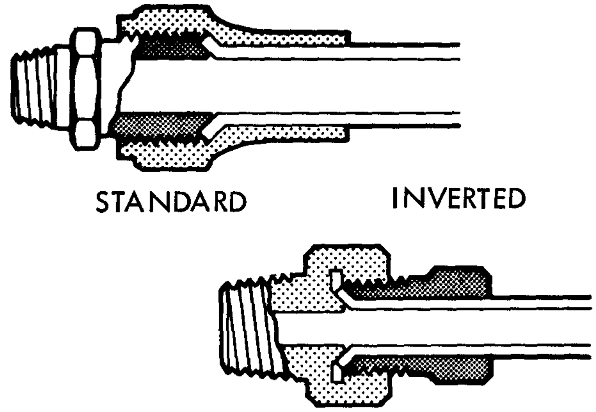
Flow rate (15ft sec) gpm	*Valve size*	*Pipe schedule*	*Tubing O. D.*	*Tubing-wall thickness*
2.5	1/4	80	3/8	0.058
6	3/8	80	5/8	0.095
10	1/2	80	3/4	0.120
18	3/4	80	1	0.148
30	1	80	1¼	0.180
42	1¼	160	1½	0.220

Safety factor 6 : 1. Above ½ in. tubing, welded flange fittings or fittings having metal to metal seals or seals that seal with pressure are recommended.

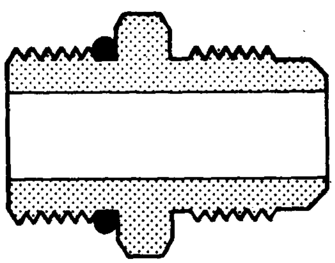
PIPE AND TUBE SIZING CHART



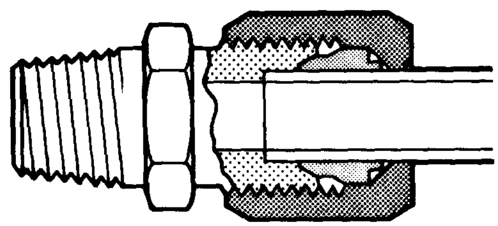
A. 37° FLARE FITTING



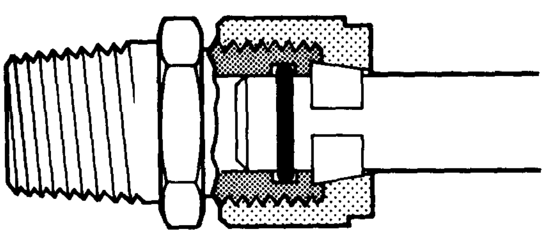
B. 45° FLARE FITTING



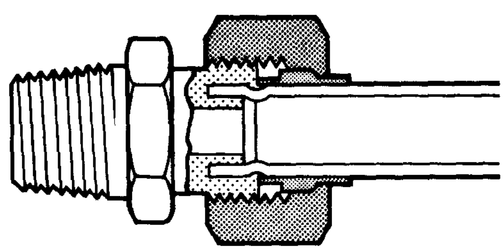
C. STRAIGHT THREAD "O" RING CONNECTOR



D. FERRULE COMPRESSION FITTING



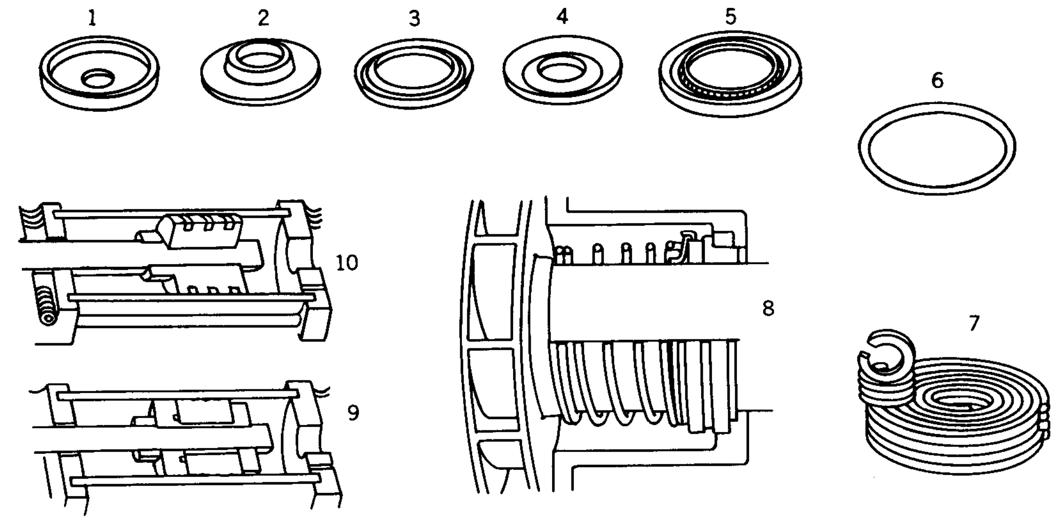
E. "O" RING COMPRESSION FITTING



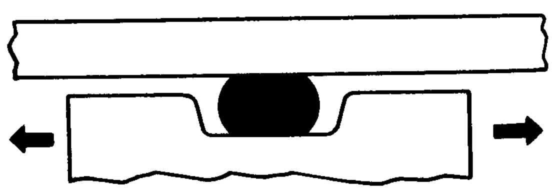
F. SLEEVE COMPRESSION FITTING

THREADED FITTINGS AND CONNECTORS USED WITH TUBING

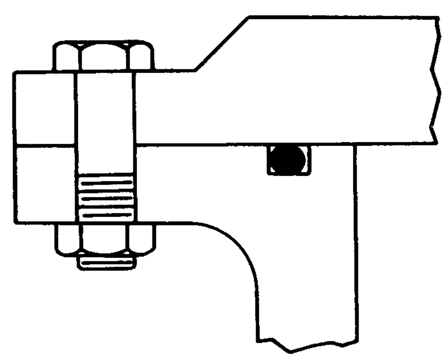
HYDRAULIC SEALS



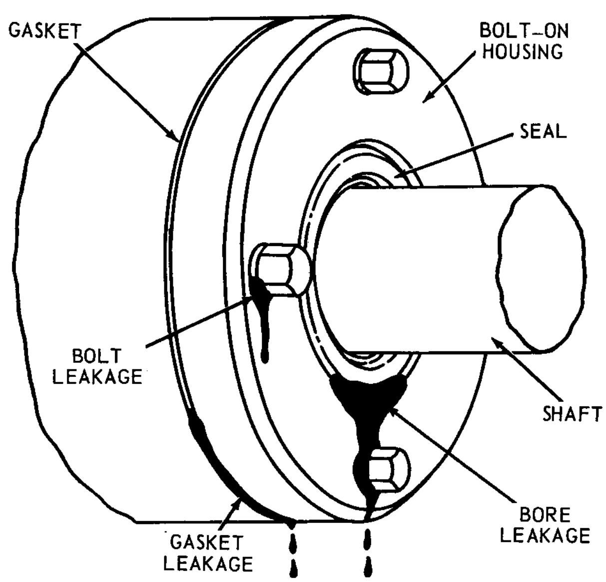
1—Cup Packing
2—Flange Packing
3—U-Packing
4—V-Packing
5—Spring-Loaded Lip Seal
6—O-Ring
7—Compression Packing
8—Mechanical Seal
9—Non-Expanding Metallic Seal
10—Expanding Metallic Seal



DYNAMIC SEAL

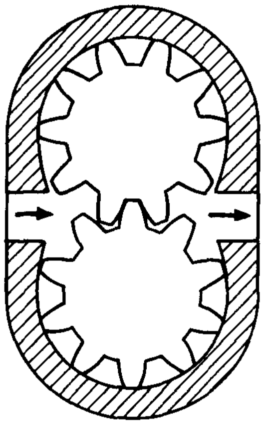


STATIC SEAL

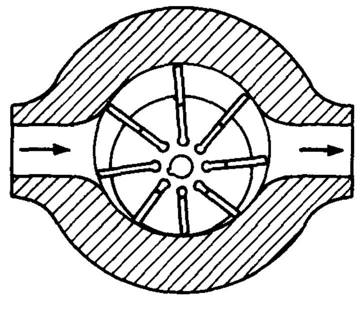


COMMON LEAKAGE POINTS

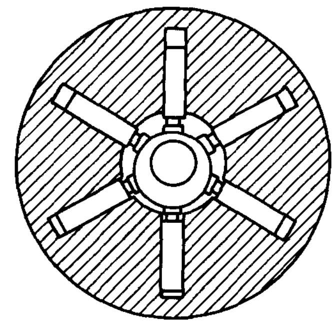
HYDRAULIC PUMPS



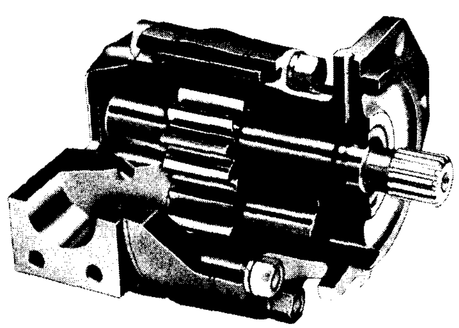
GEAR



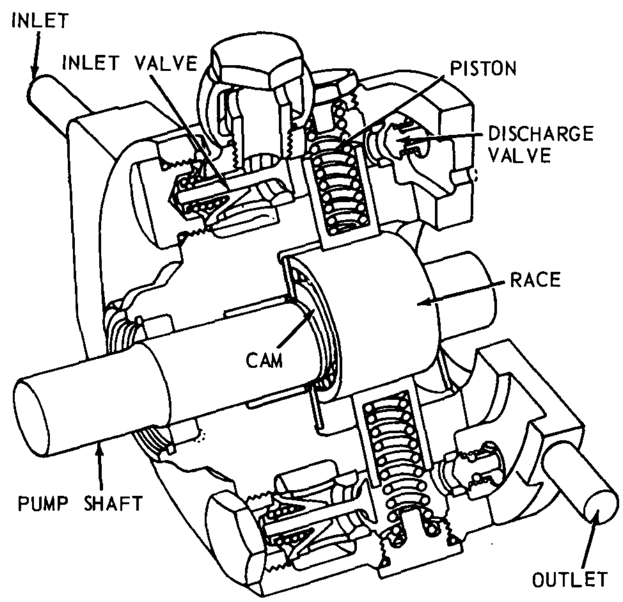
VANE



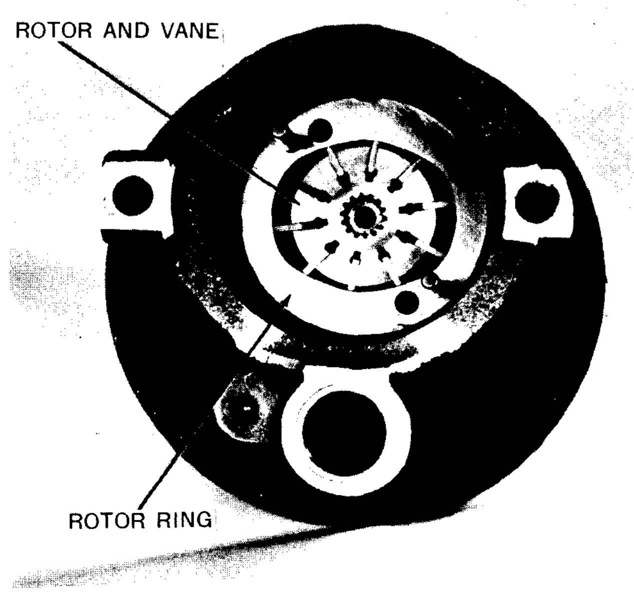
PISTON



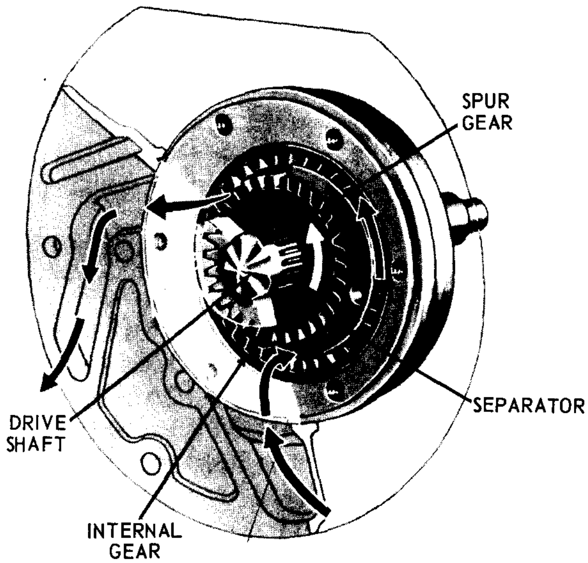
EXTERNAL GEAR TYPE



RADIAL PISTON TYPE

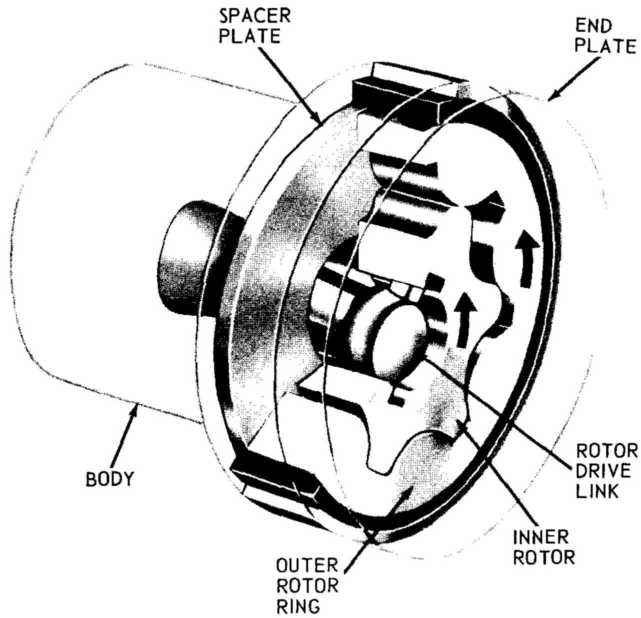


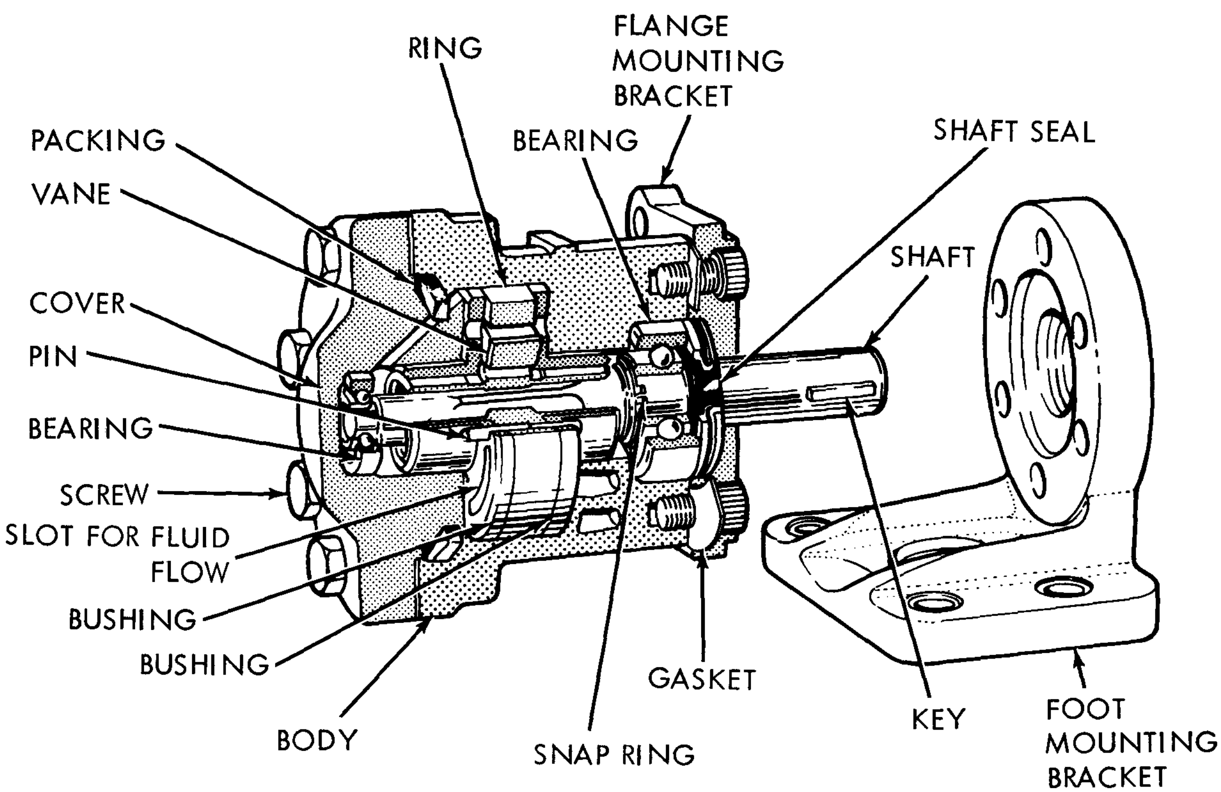
VANE TYPE



INTERNAL GEAR PUMP

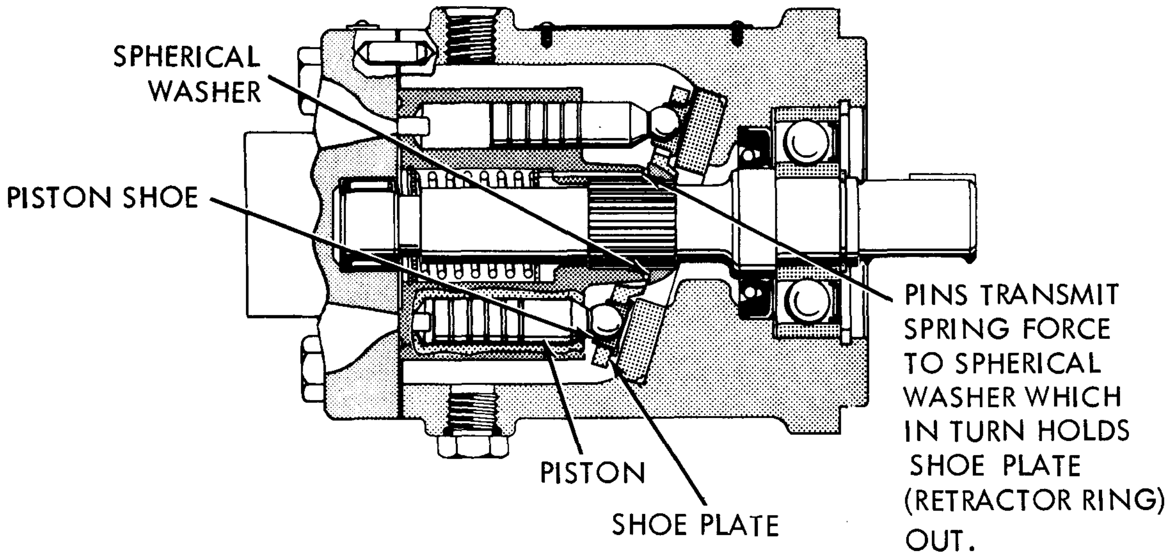
Rotor Version of Internal Gear Pump

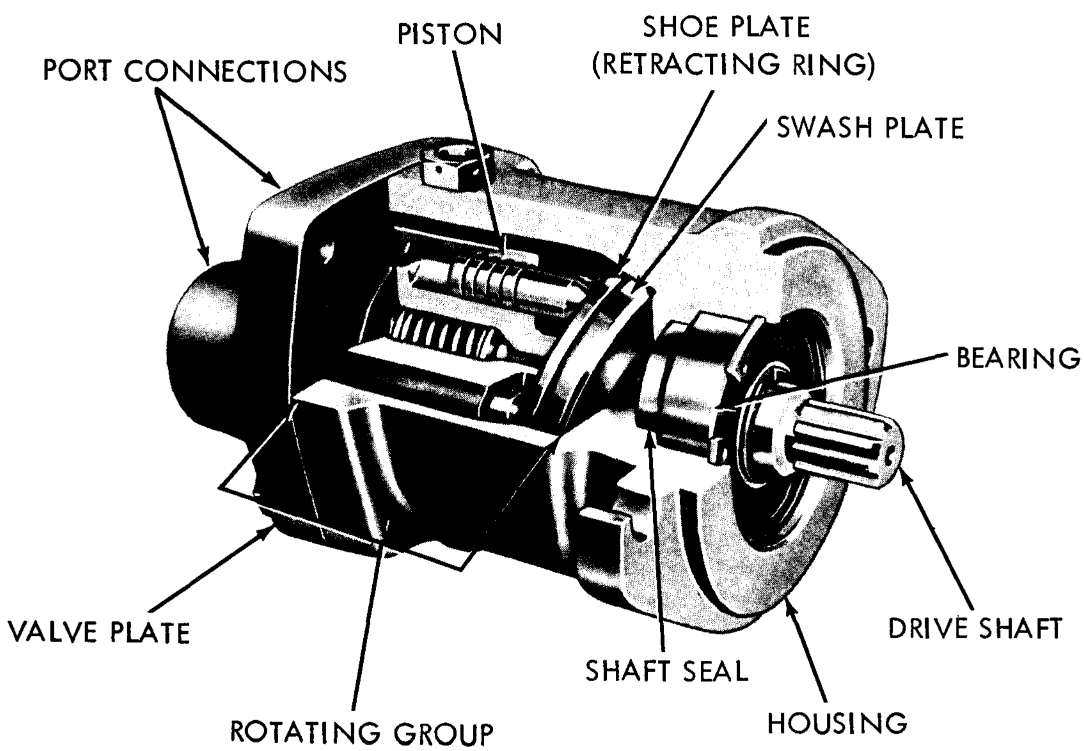


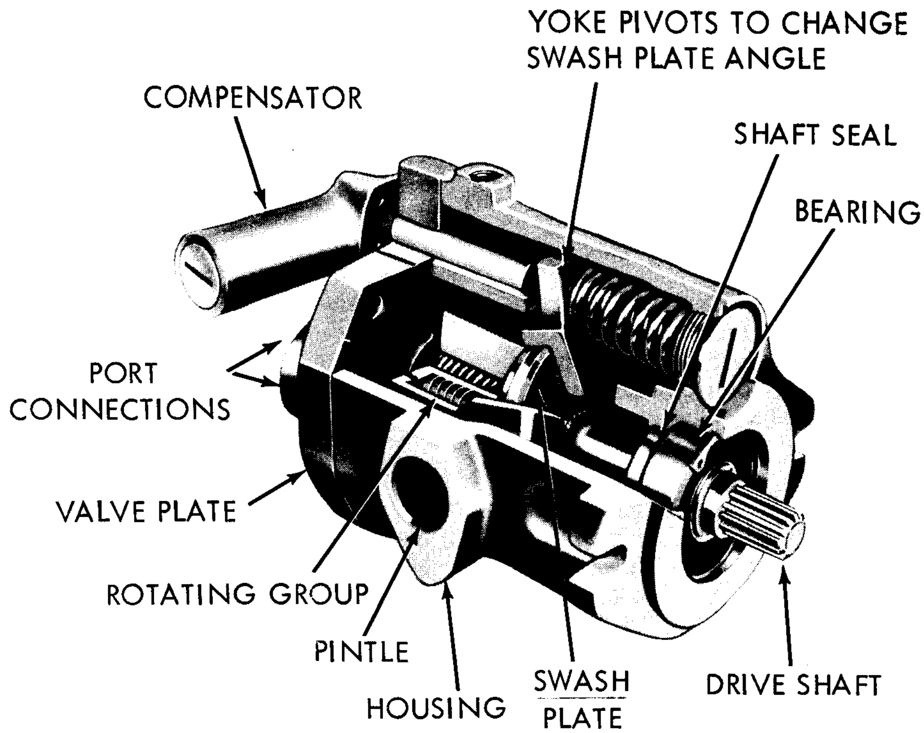


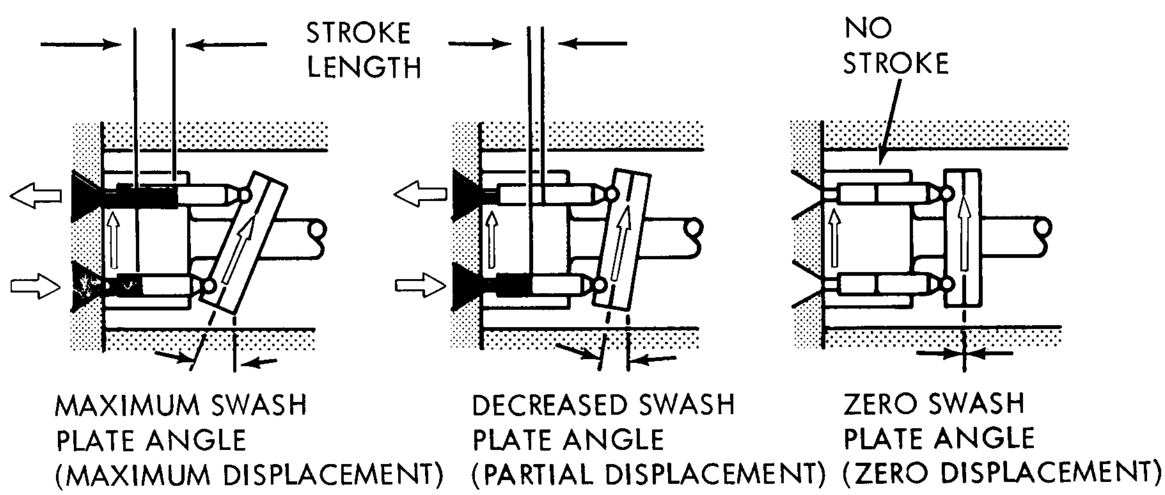
VANE PUMP (ROUND TYPE)

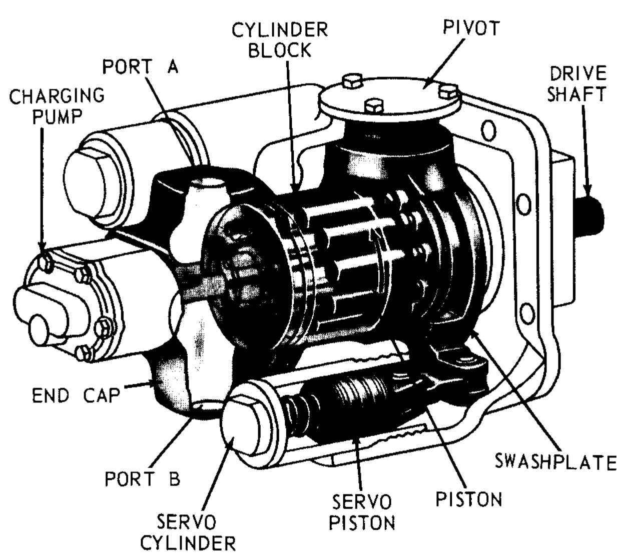
INLINE AXIAL PISTON PUMP
(FIXED DISPLACEMENT)





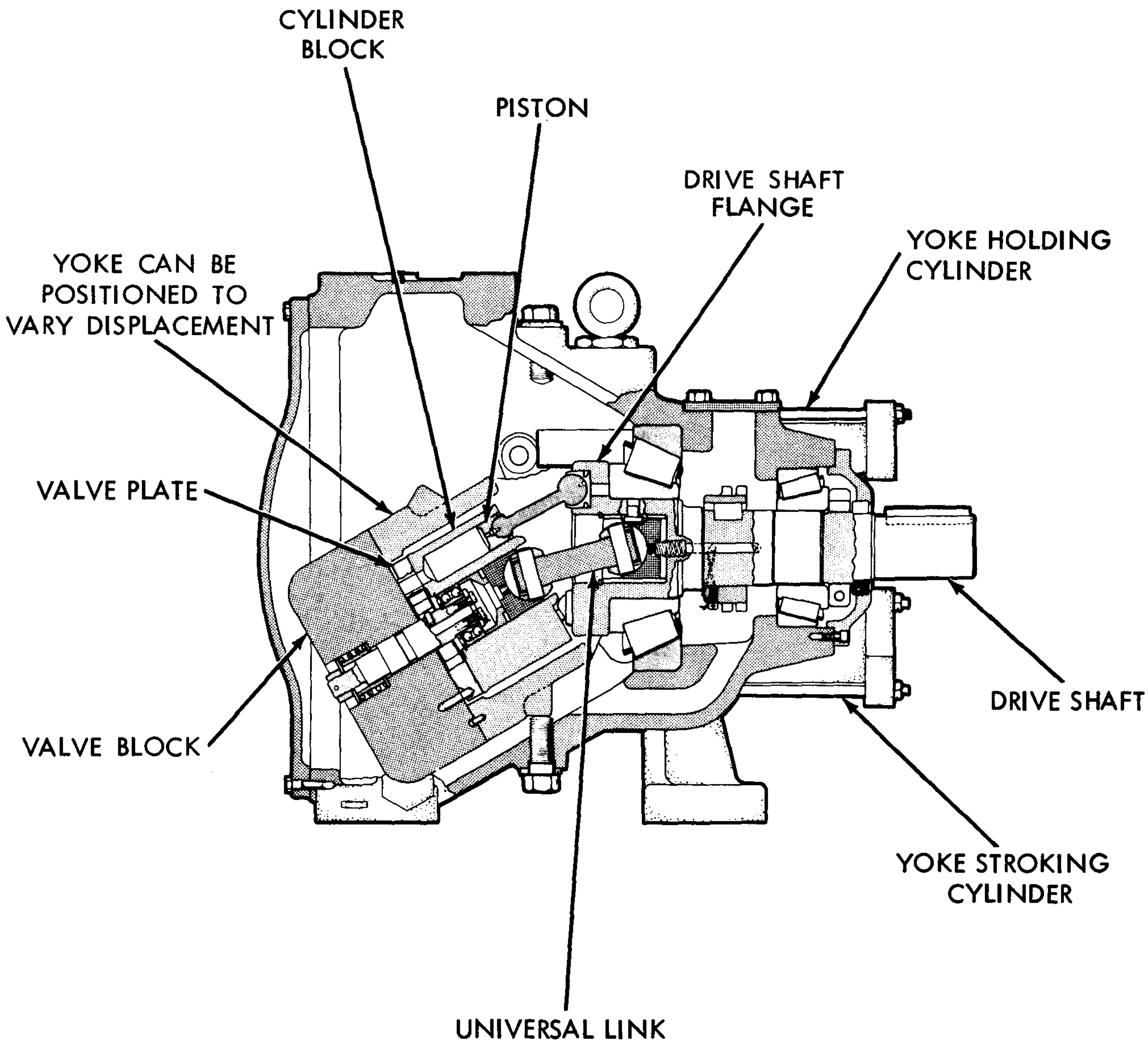




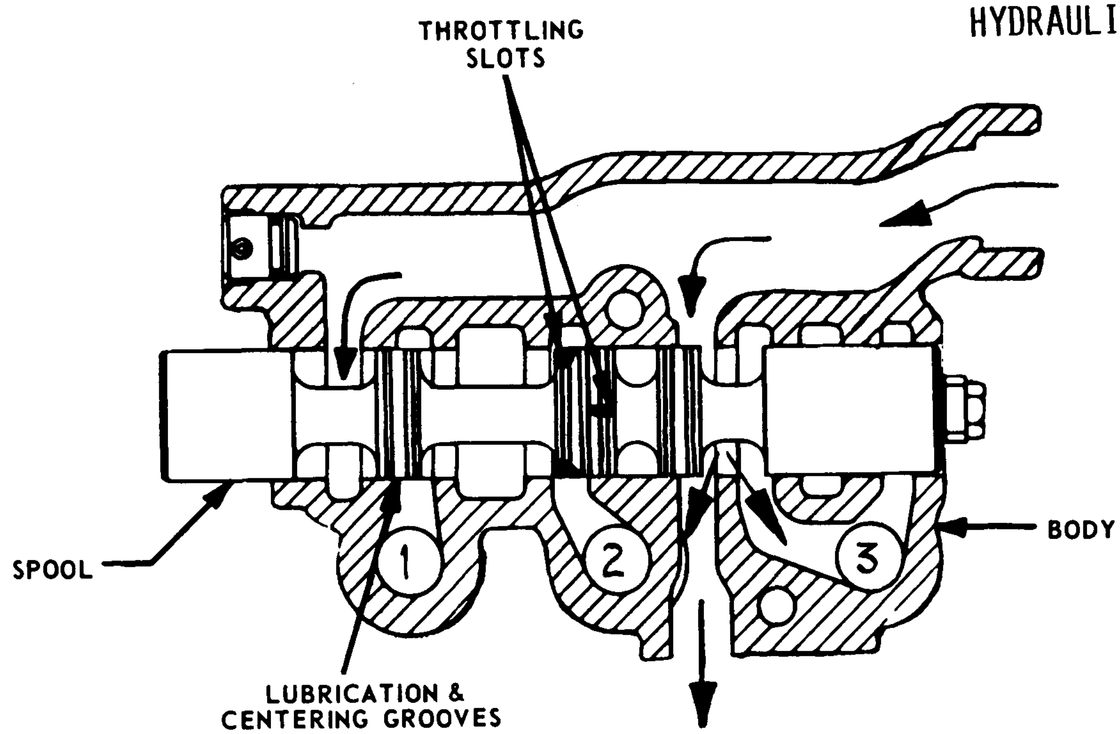


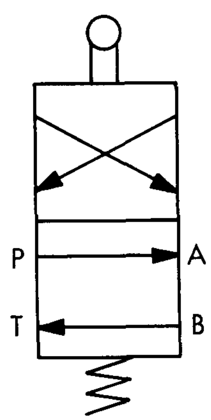
INLINE AXIAL PISTON PUMPS
(VARIABLE DISPLACEMENT)

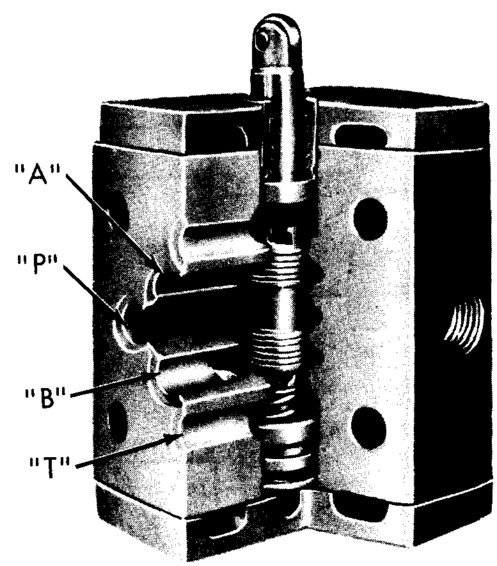
VARIABLE DISPLACEMENT BENT-AXIS PISTON PUMP



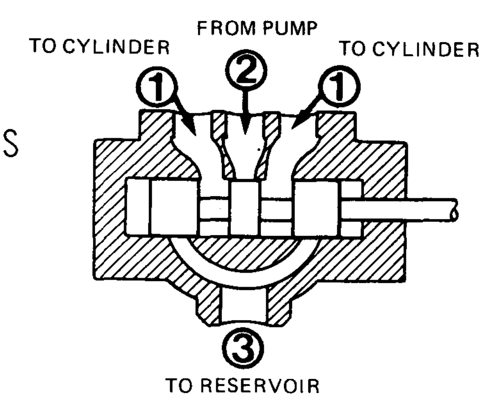
HYDRAULIC VALVES

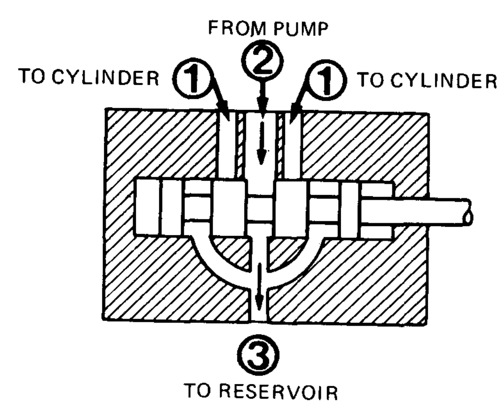




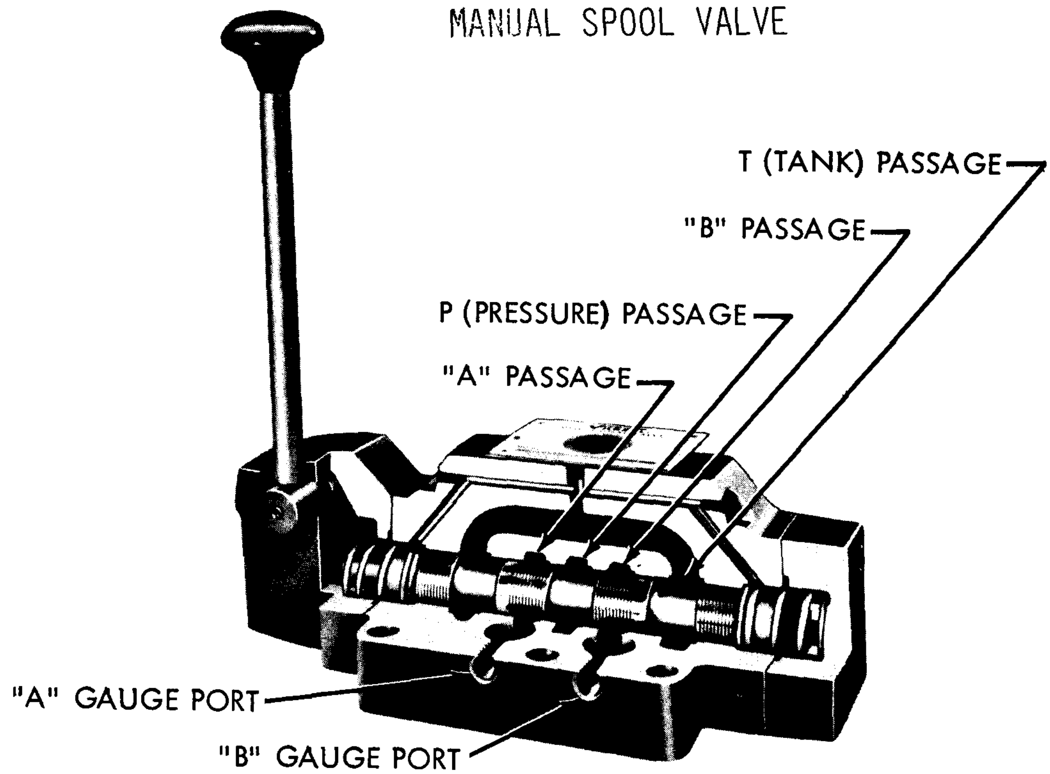


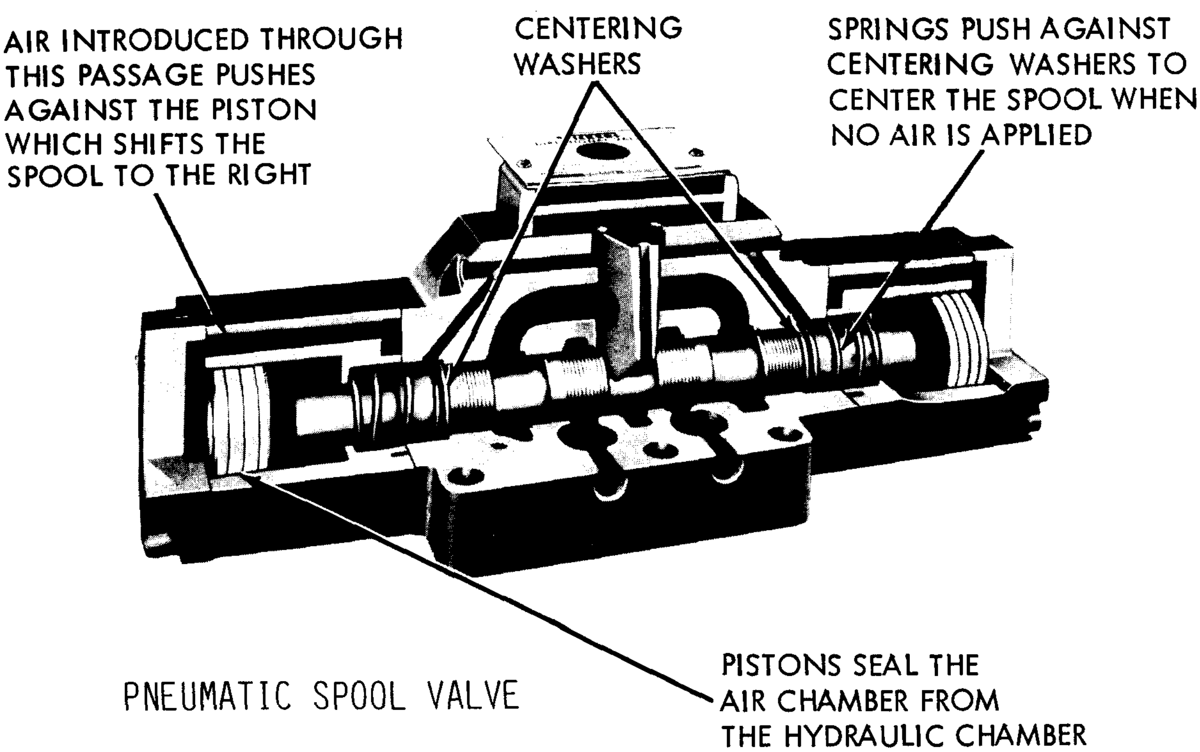
SPOOL VALVES





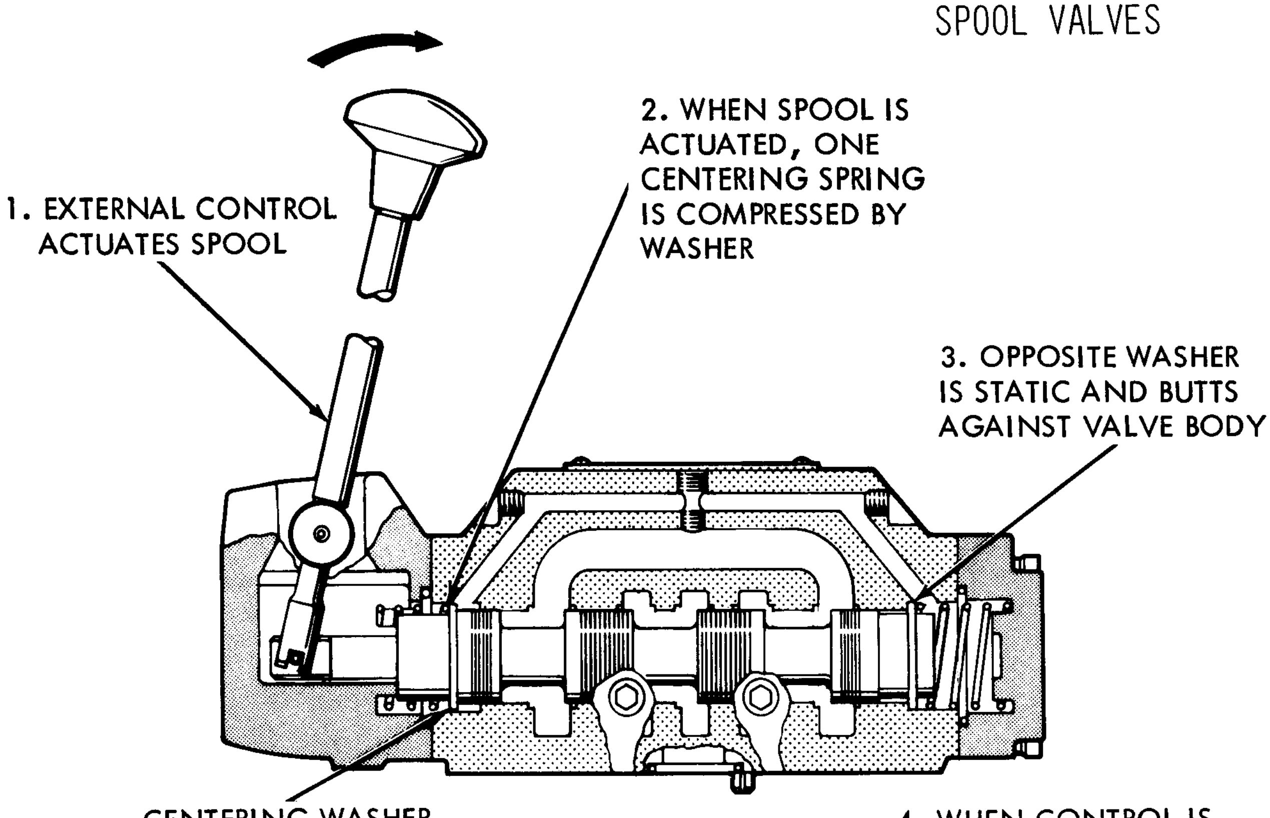
MANUAL SPOOL VALVE



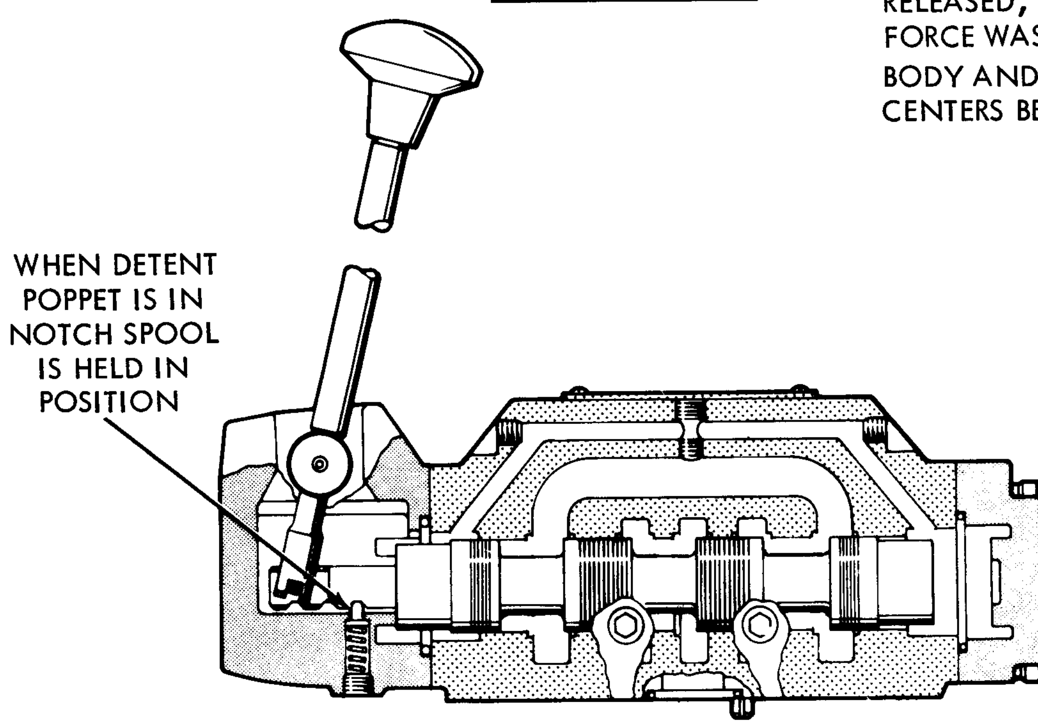


PNEUMATIC SPOOL VALVE

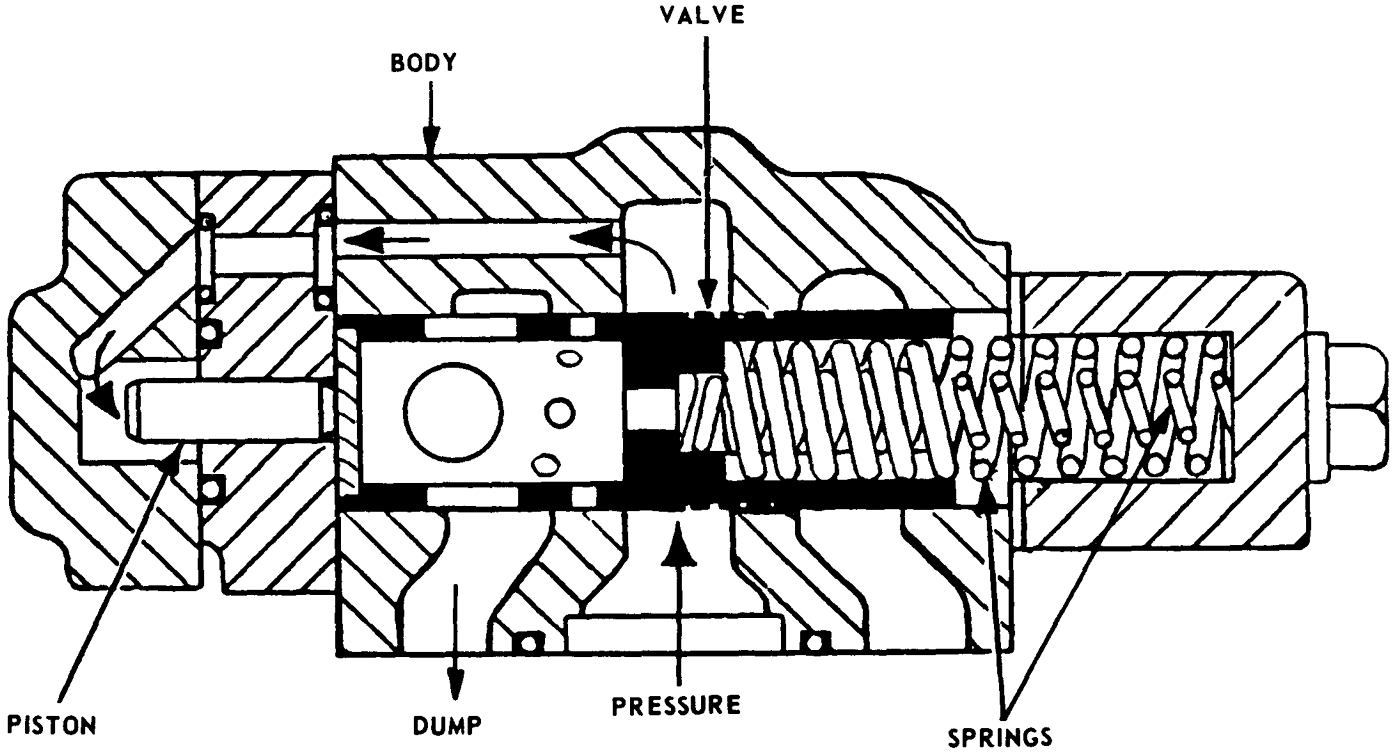
METHODS OF CENTERING SPOOL VALVES



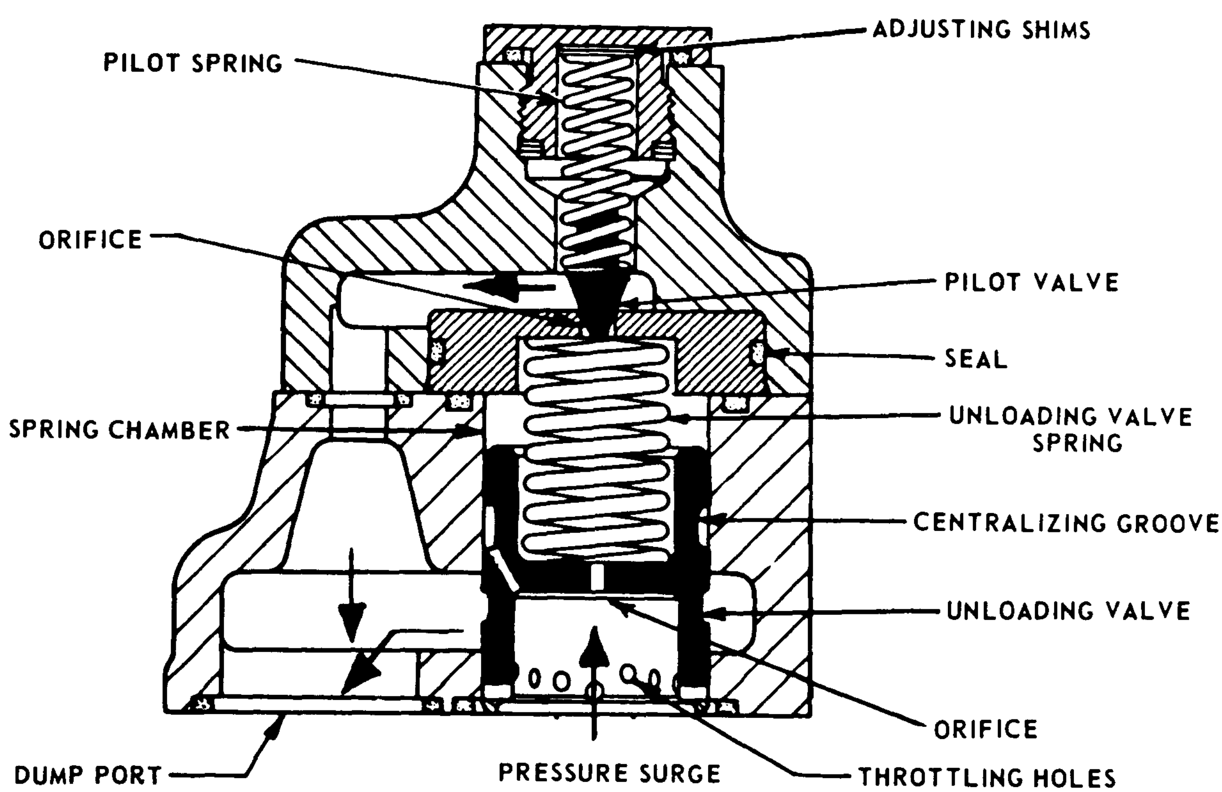
SPRING CENTERED



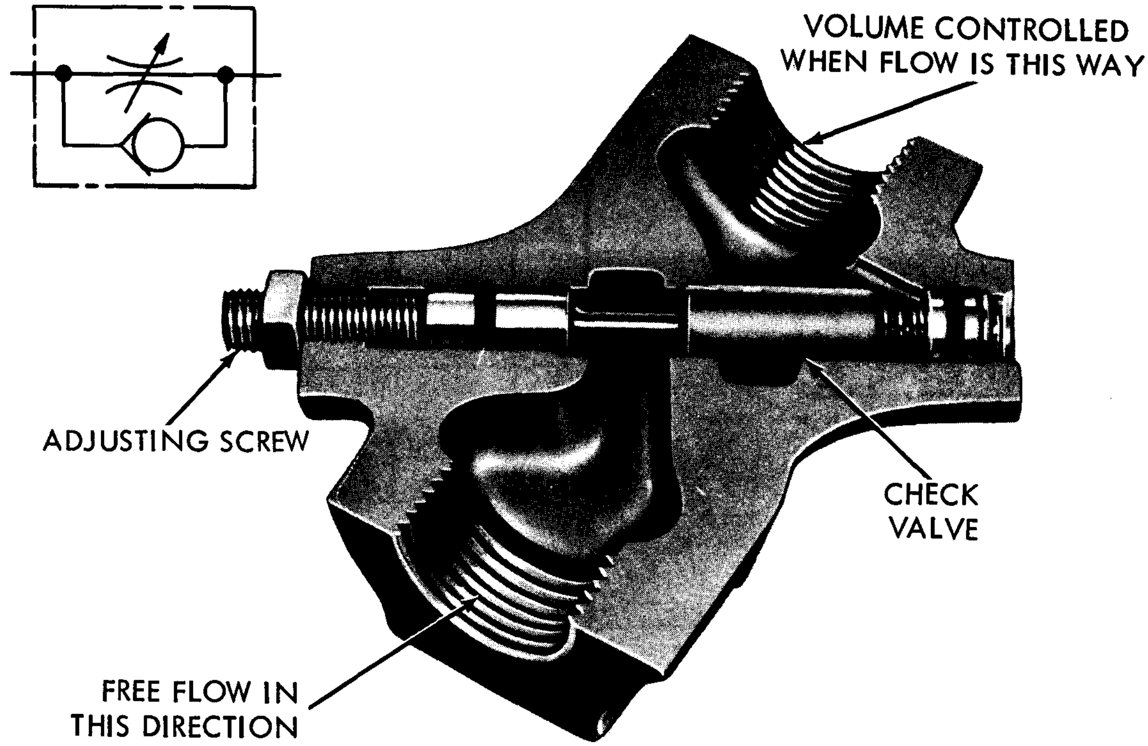
DETENTED



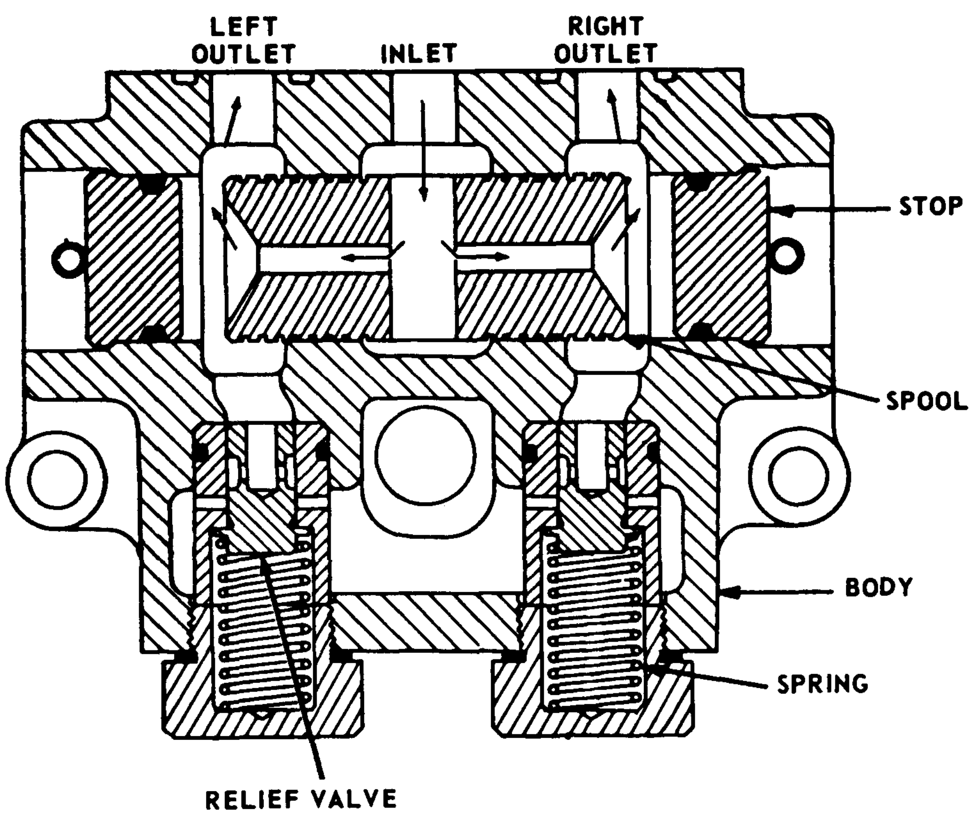
PISTON OPERATED RELIEF VALVE



PILOT OPERATED RELIEF VALVE



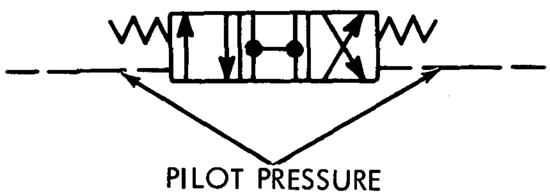
FLOW CONTROL VALVE



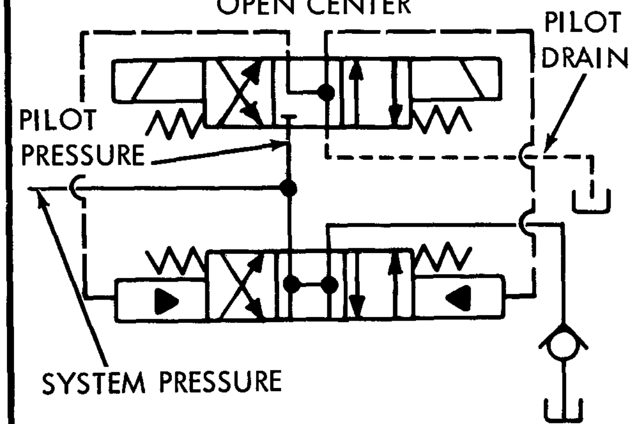
FLOW DIVIDER VALVE

DG3 (PILOT OPERATED VALVE)	DG5 (PILOT OPERATED-SOLENOID CONTROLLED)

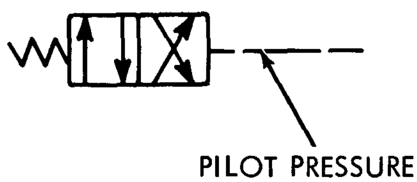
SPRING CENTERED
OPEN CENTER



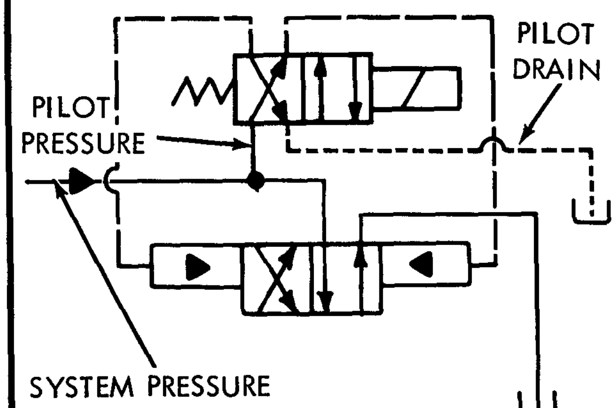
SPRING CENTERED
OPEN CENTER



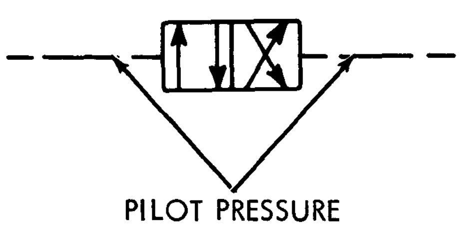
SPRING OFFSET



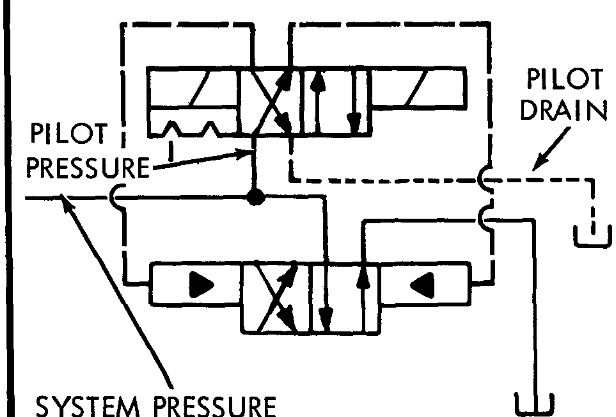
SPRING OFFSET

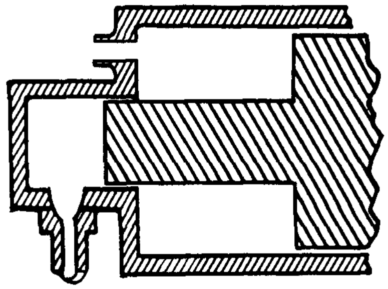


NO SPRING

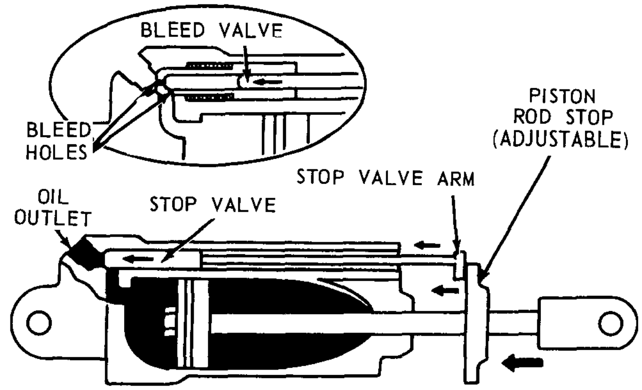


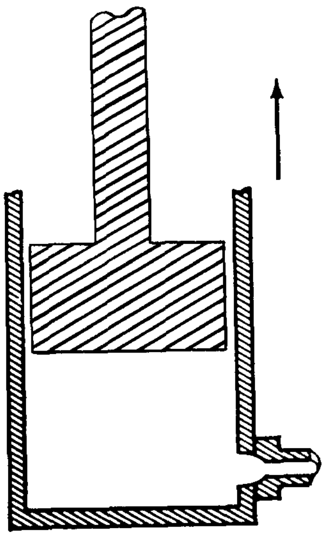
NO SPRING DETENTED



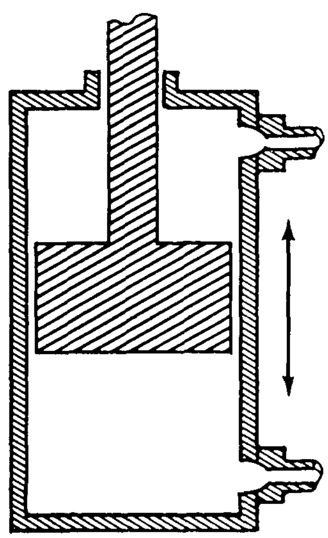


A "stepped piston" type cylinder.

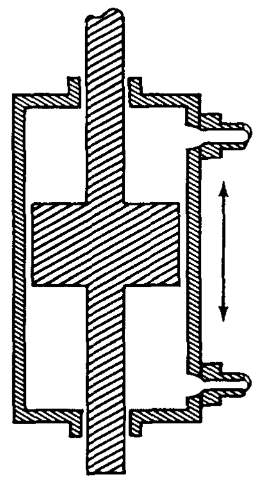




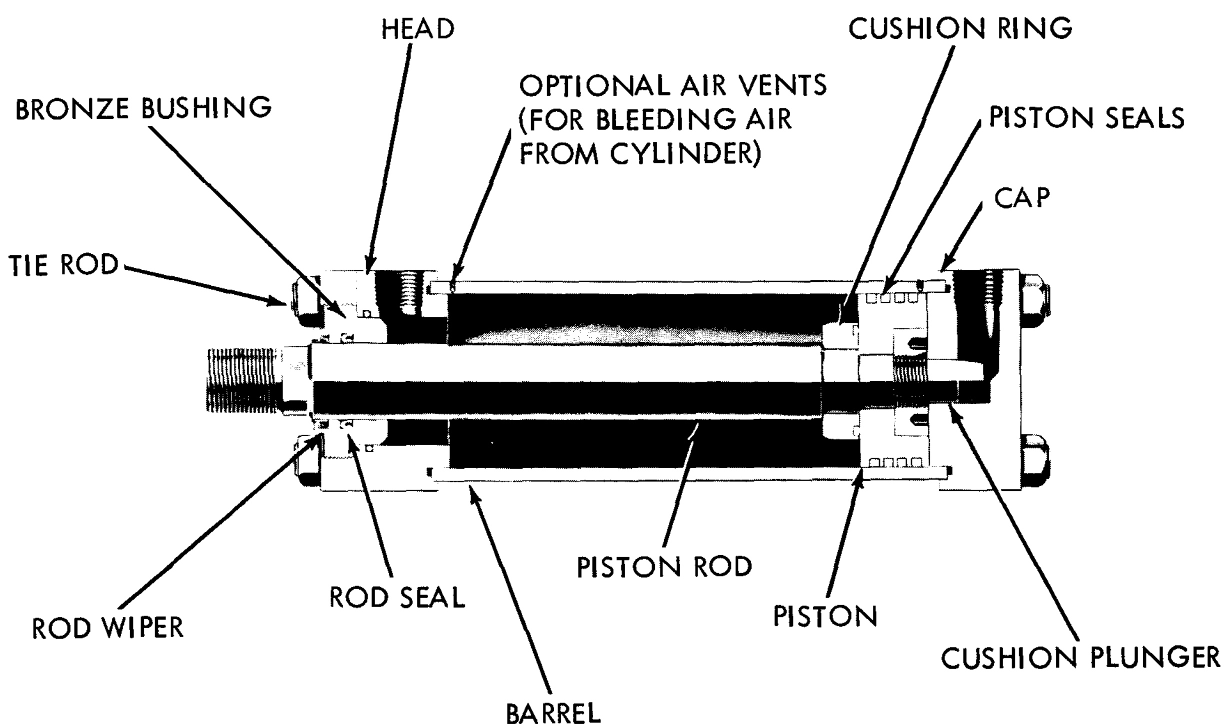
A single acting hydraulic cylinder.

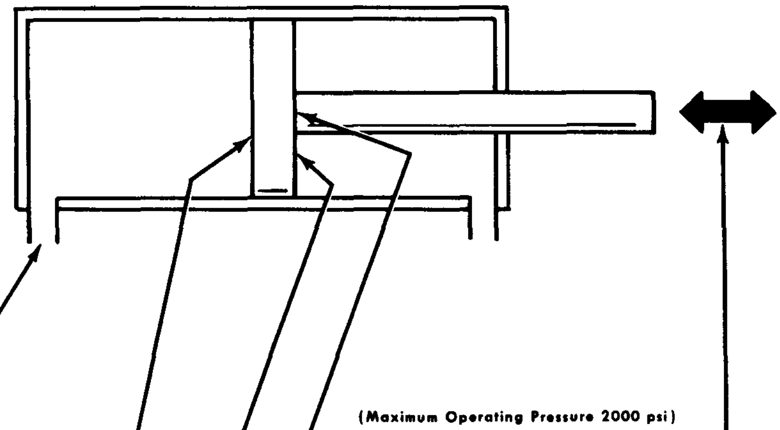


A double acting hydraulic cylinder.



A piston modified to provide equal force in both directions.





(Maximum Operating Pressure 2000 psi)

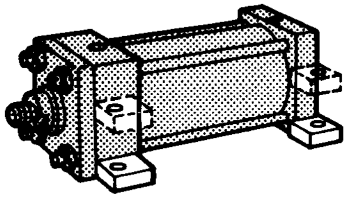
CYLINDER BORE	PORT SIZE N.P.T. THREAD	PORT SIZE *STRAIGHT THREAD	ROD O.D.	**PISTON AREA (SQUARE INCH) FULL BORE	ANNULUS	ROD	RATIO FULL BORE TO ANNULUS AREA	† APPROXIMATE OUTPUT FORCE—POUNDS 500 PSI PUSH	500 PSI PULL	1000 PSI PUSH	1000 PSI PULL	1500 PSI PUSH	1500 PSI PULL	2000 PSI PUSH	2000 PSI PULL
1½	1/2"	5/8" TUBE OD (7/8-14 THD.)	5/8" STD.	1.767	1.460	.307	1.21/1.00	884	730	1767	1460	2651	2190	3534	2920
			1" HVY.		.982	.785	1.80/1.00		491		982		1473		1964
2	1/2"	5/8" TUBE OD (7/8-14 THD.)	1" STD.	3.142	2.357	.785	1.33/1.00	1571	1178	3142	2357	4713	3535	6284	4714
			1-3/8" HVY.		1.657	1.485	1.90/1.00		828		1657		2485		3314
2½	1/2"	3/4" TUBE OD (1-1/16-12 THD.)	1" STD.	4.909	4.124	.785	1.19/1.00	2455	2062	4909	4124	7364	6186	9818	8248
			1-3/8" INT'MED.		3.424	1.485	1.43/1.00		1712		3424		5136		6848
			1-3/4" HVY.		2.504	2.405	1.96/1.00		1252		2504		3756		5008
3¼	3/4"	3/4" TUBE OD (1-1/16-12 THD.)	1-3/8" STD.	8.296	6.811	1.485	1.22/1.00	4148	3405	8296	6811	12444	10216	16592	13622
			1-3/4" INT'MED.		5.891	2.405	1.41/1.00		2945		5891		8836		11782
			2" HVY.		5.154	3.142	1.61/1.00		2577		5154		7731		10308
4	3/4"	3/4" TUBE OD (1-1/16-12 THD.)	1-3/4" STD.	12.566	10.161	2.405	1.24/1.00	6283	5080	12566	10161	18849	15241	25132	20322
			2" INT'MED.		9.424	3.142	1.33/1.00		4712		9424		14136		18848
			2-1/2" HVY.		7.666	4.900	1.64/1.00		3833		7666		11500		15332
5	3/4"	1" TUBE OD (1-5/16-12 THD.)	2" STD.	19.635	16.493	3.142	1.19/1.00	9818	8246	19635	16493	29453	24739	39270	32986
			2-1/2" INT'MED.		14.735	4.900	1.33/1.00		7367		14735		22102		29470
			3-1/2" HVY.		10.014	9.621	1.96/1.00		5007		10014		15021		20028
6	1"	1" TUBE OD (1-5/16-12 THD.)	2-1/2" STD.	28.274	23.374	4.900	1.21/1.00	14137	11687	28274	23374	42411	35061	56548	46748
			3-1/2" INT'MED.		18.653	9.621	1.52/1.00		9326		18653		27979		37306
			4" HVY.		15.708	12.566	1.80/1.00		7854		15708		23562		31416
7	1-1/4"	1-1/2" TUBE OD (1-7/8-12 THD.)	3" STD.	38.485	31.416	7.069	1.23/1.00	19242	15708	38485	31416	57728	47124	76970	62832
			4" INT'MED.		25.919	12.566	1.48/1.00		12959		25919		38878		51838
			5" HVY.		18.850	19.635	2.04/1.00		9425		18850		28275		37700
8	1-1/2"	1-1/2" TUBE OD (1-7/8-12 THD.)	3-1/2" STD.	50.265	40.644	9.621	1.24/1.00	25133	20332	50265	40644	75398	60966	100530	81288
			4-1/2" INT'MED.		34.361	15.904	1.46/1.00		17180		34361		51541		68722
			5-1/2" HVY.		26.507	23.758	1.90/1.00		13253		26507		39760		53014

*Straight thread connections available upon request.

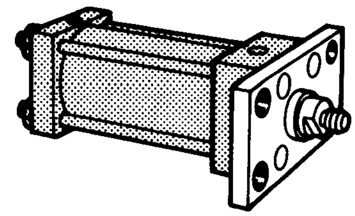
† "Pull" force values apply in both directions for cylinders with double-ended piston rods.

**Fluid displacement per inch of stroke is the same value (in cubic inches) as piston area (in square inches).

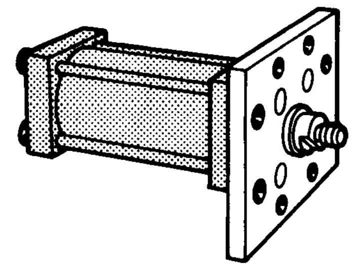
CHANGE	SPEED	EFFECT ON OPERATING PRESSURE	OUTPUT FORCE AVAILABLE
Increase Pressure Setting	No Effect	No Effect	Increases
Decrease Pressure Setting	No Effect	No Effect	Decreases
Increase GPM	Increases	No Effect	No Effect
Decrease GPM	Decreases	No Effect	No Effect
Increase Cylinder Diameter	Decreases	Decreases	Increases
Decrease Cylinder Diameter	Increases	Increases	Decreases



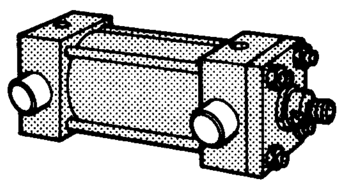
FOOT AND
CENTERLINE
LUG MOUNTS



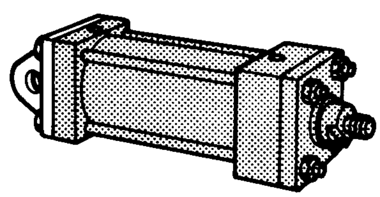
RECTANGULAR
FLANGE MOUNT



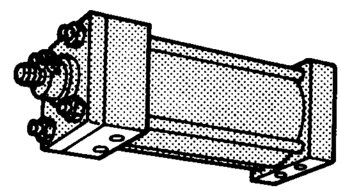
SQUARE FLANGE
MOUNT



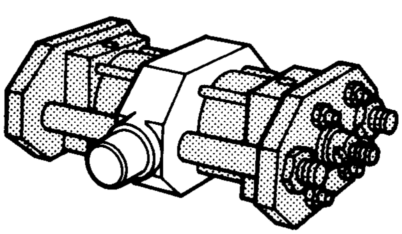
TRUNNION
MOUNT



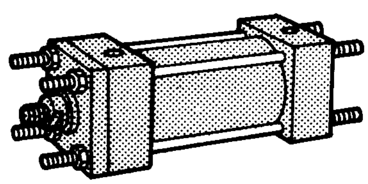
CLEVIS MOUNT



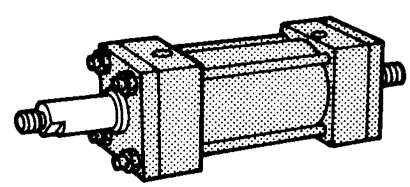
FLUSH SIDE
MOUNT



INTERMEDIATE
TRUNNION
MOUNT

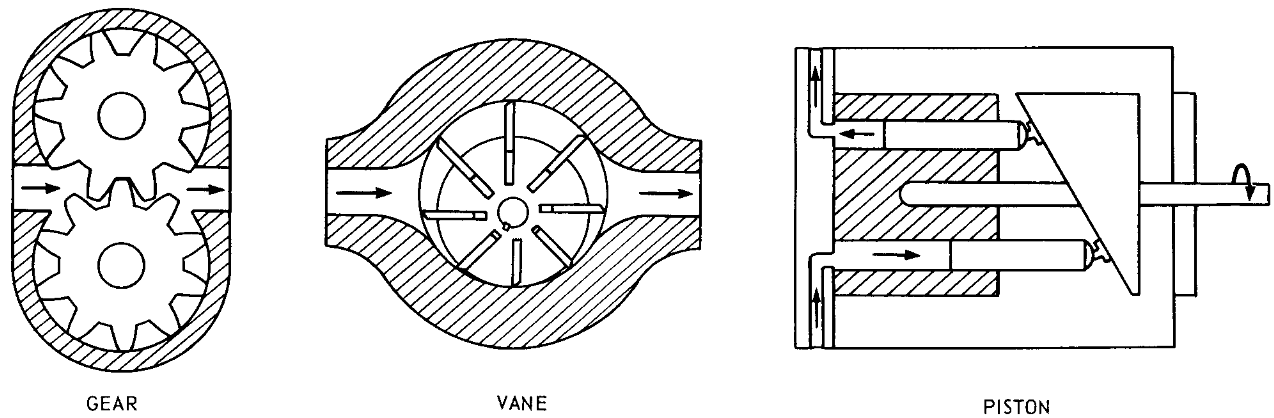


EXTENDED
TIE ROD



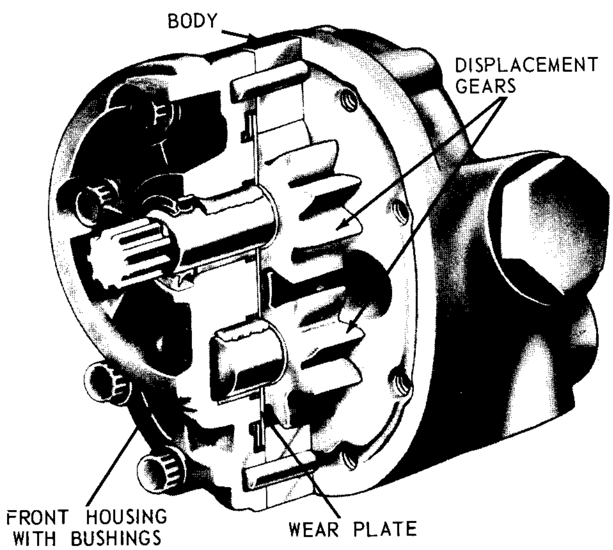
DOUBLE ROD END

CYLINDER MOUNTINGS

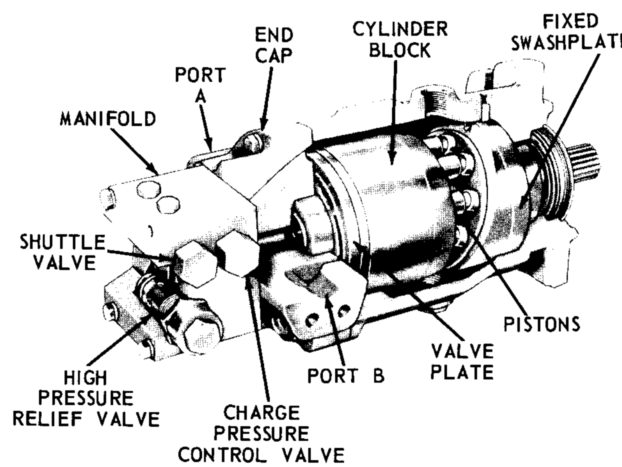


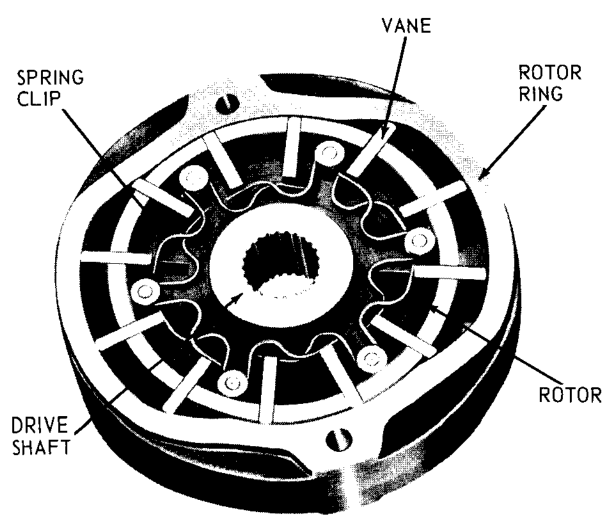
Three Types of Hydraulic Motors

EXTERNAL GEAR MOTOR



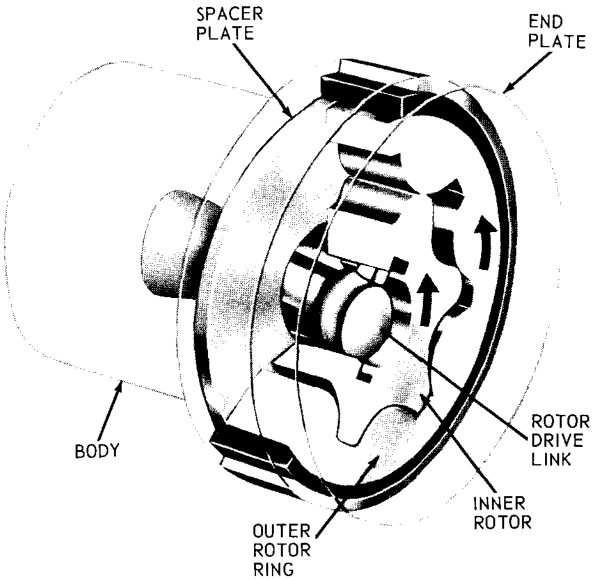
AXIAL PISTON MOTOR

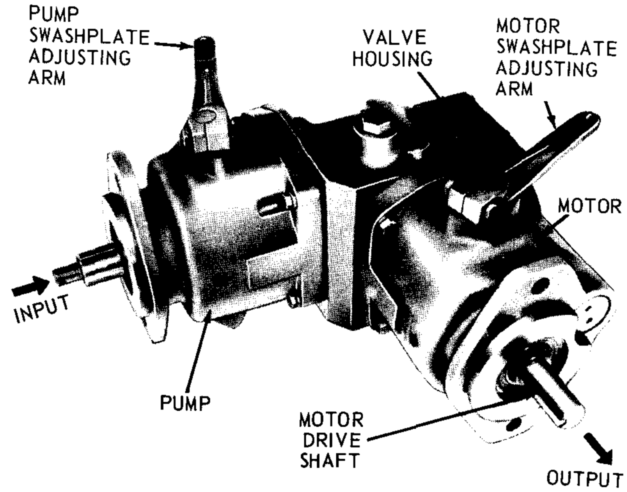




Vane Motor (Balanced Type)

INTERNAL GEAR MOTOR





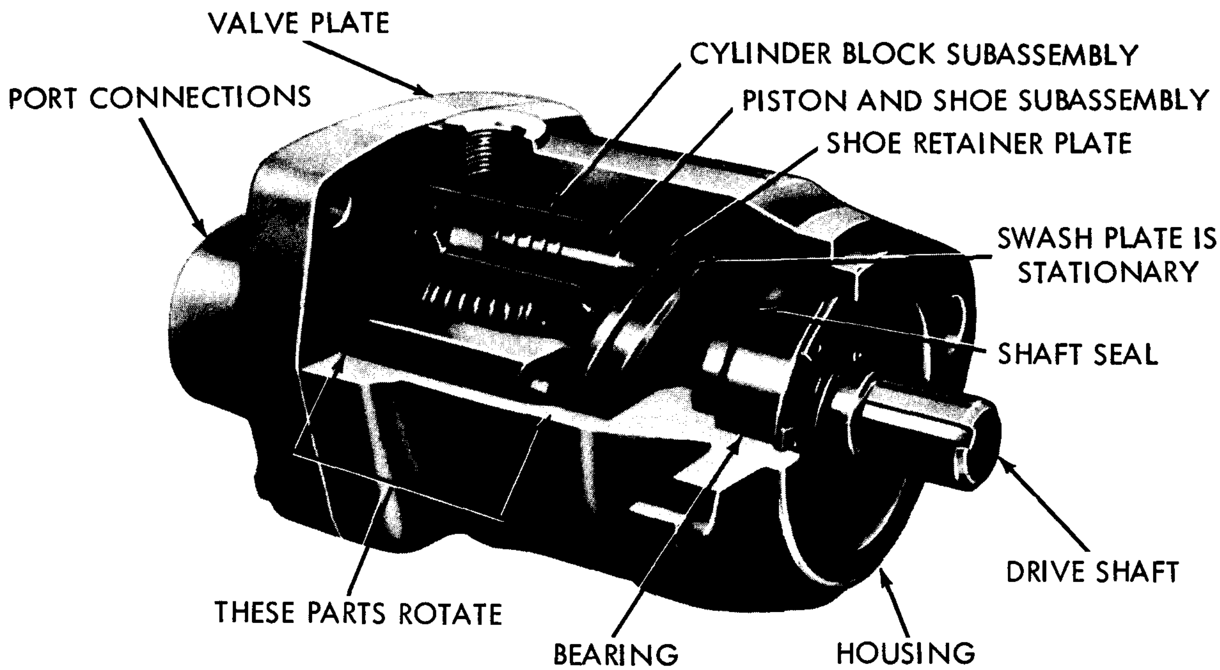
Axial Piston Motor with Variable Displacement
(Pump-Motor Drive Unit Shown)

MOTOR COMPARISON CHART

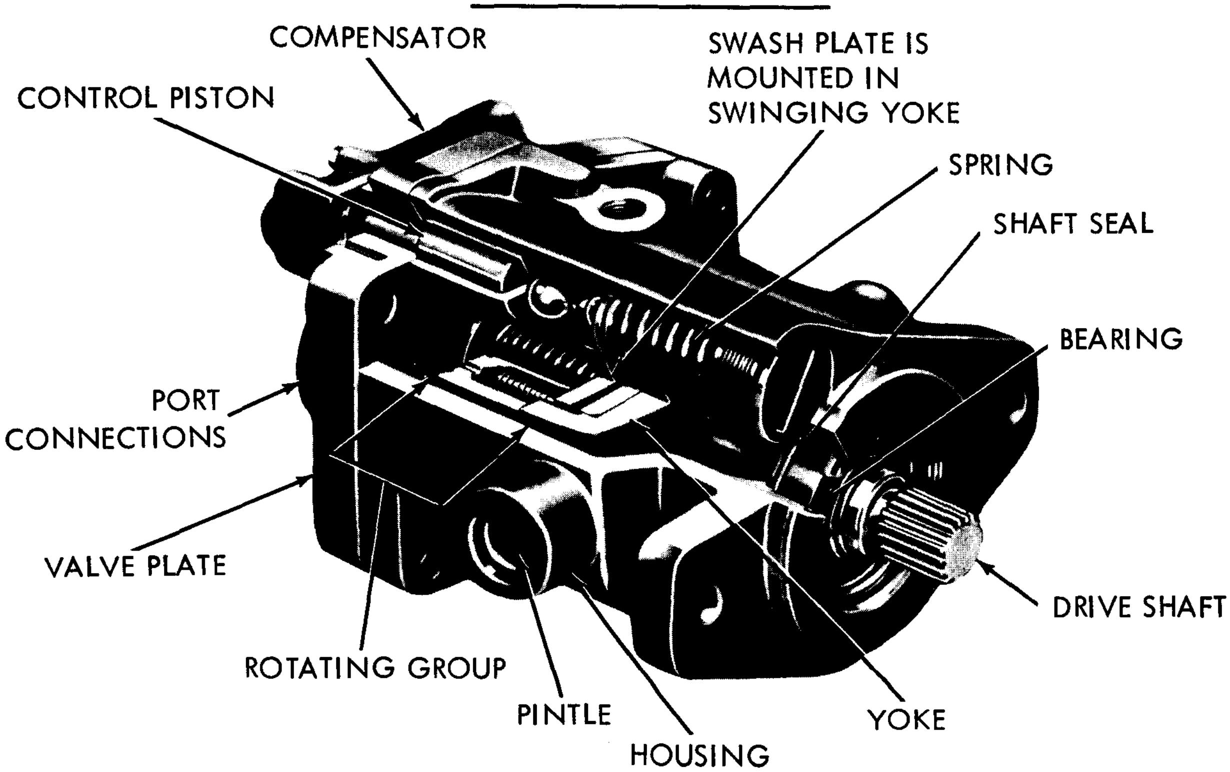
	GEAR MOTORS **External**	**Internal**	VANE MOTORS **(Balanced)**	PISTON (AXIAL) MOTORS **Fixed Displ.**	**Var. Displ.**
Physical Size	Small to Medium	Small to Medium	Small to Medium	Medium to Large	Medium to Large
Average Weight to Power Ratio-lb/hp	0.9	0.9	1.0	1.4	3.2
Pressure Range (psi)	100-2000	100-2000	100-2500	100-5000+	100-5000+
Speed Range (rpm)	100-3000	100-5000	10-3000	10-3000	10-3000
Actual Torque (% of Theoretical)	80-85	80-85	85-95	90-95	90-95
Starting Torque (% of Theoretical)	70-80	75-85	75-90	85-95	85-95
Momentary Overload Torque (% of Actual)	110-120	115-130	120-140	120-140	120-140
Volumetric Efficiency (%)	80-90	85-90	85-90	95-98	95-98
Over-all Efficiency (%)	60-90	60-90	75-90	85-95	85-95
Estimated Bearing Life (hrs.) @½ load	5000-10000	5000-10000	7000-15000	15000-25000	15000-25000
Displacement	Fixed	Fixed	Fixed	Fixed	Variable
Reversibility	Possible	Possible	Possible	Very Good	Very Good
How Operates as a Pump	Good	Good	Good	Very Good	Very Good
Average Initial Cost ($/hp)	2.90	3.35	3.60	5.67	8.40
Average Maintenance Costs ($/year/hp)	0.37	0.32	0.32	0.18	0.22
Estimated Bearing Life (hrs) @ full load	2000-5000	2000-5000	3000-6000	7000-15000	7000-15000

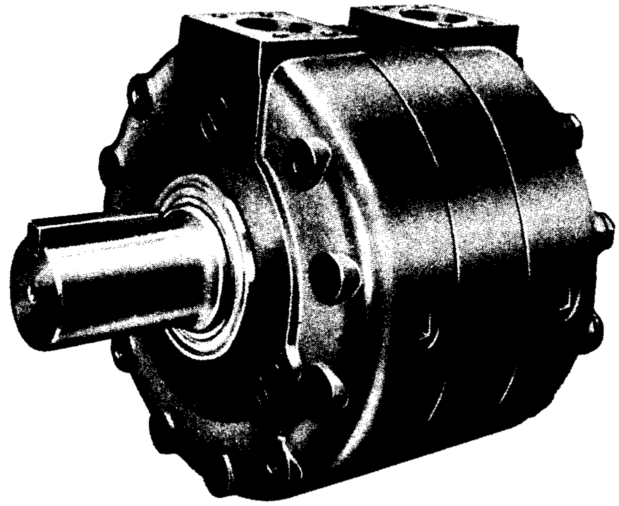
NOTE: Remember that the values in this chart are not absolute. They may vary with each particular model of motor.

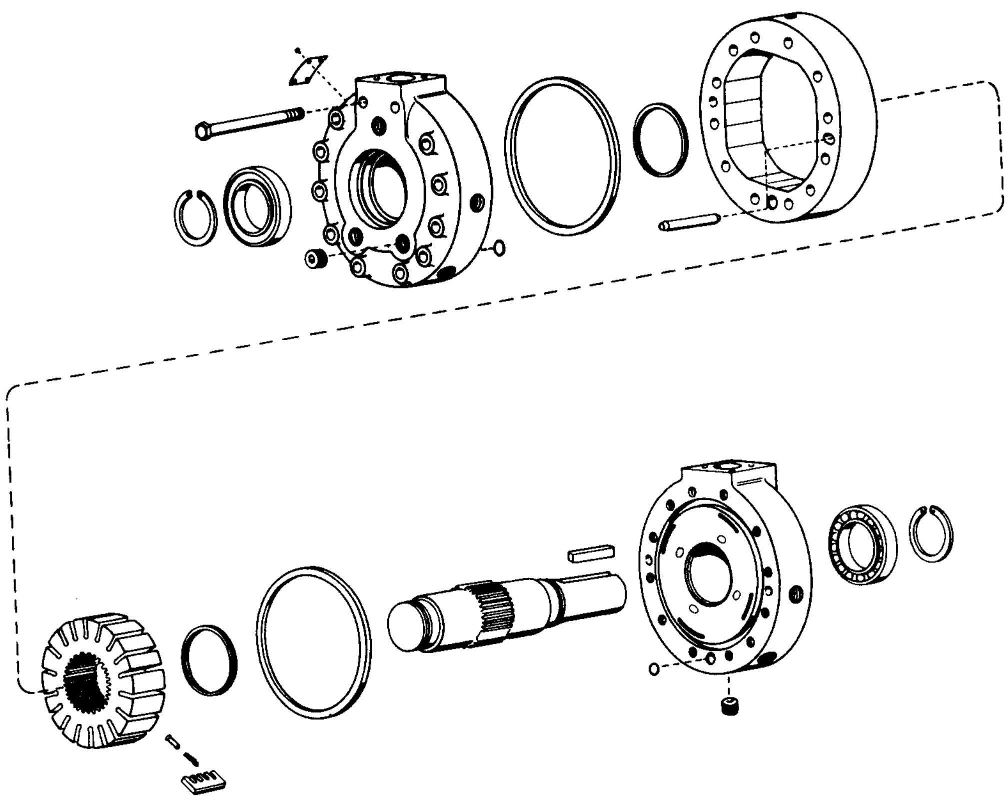
FIXED DISPLACEMENT



VARIABLE DISPLACEMENT

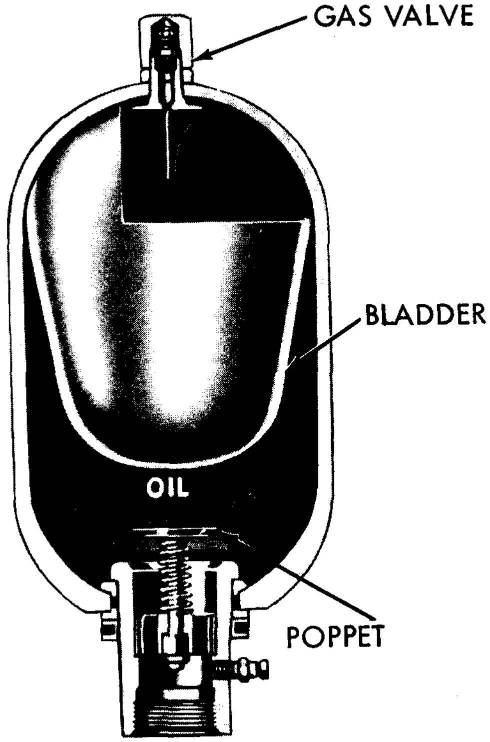




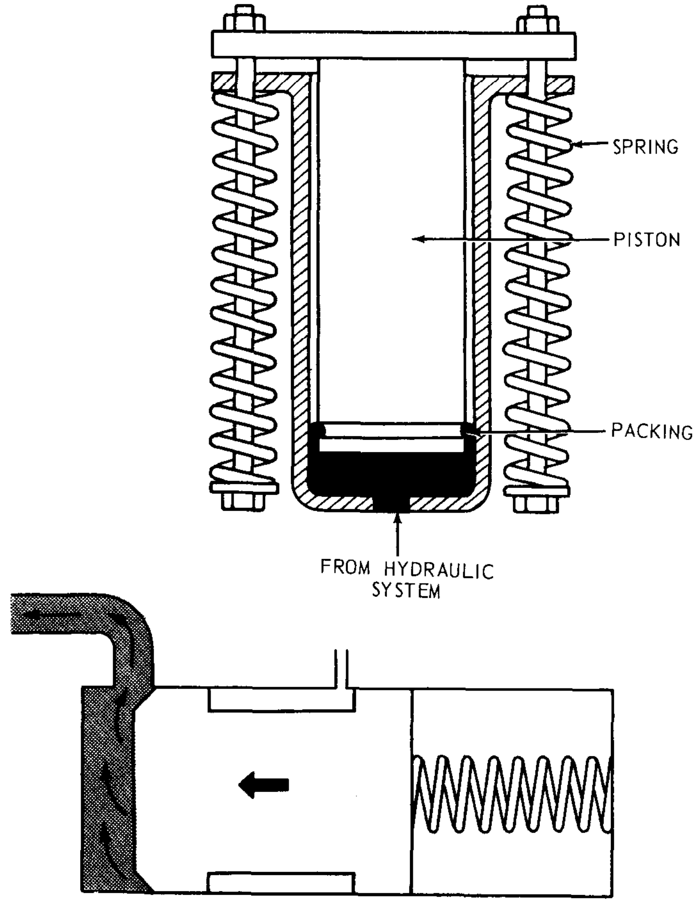


HIGH TORQUE VANE MOTOR

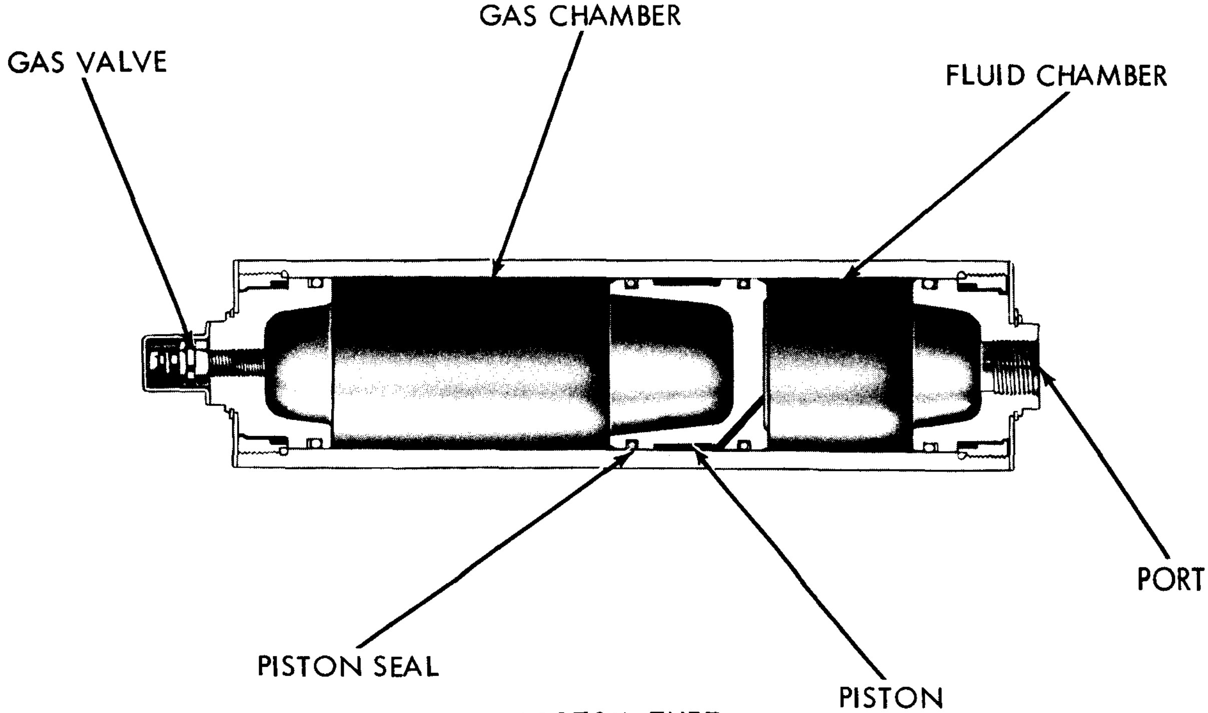
ACCUMULATORS



PNEUMATIC BLADDER TYPE

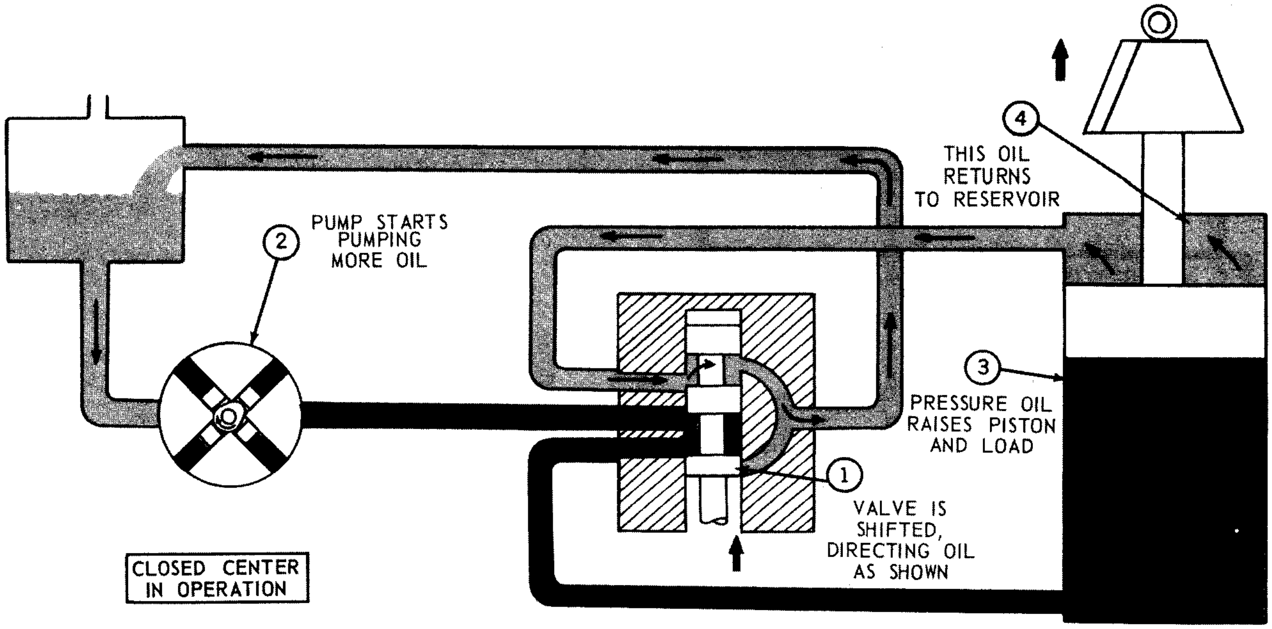


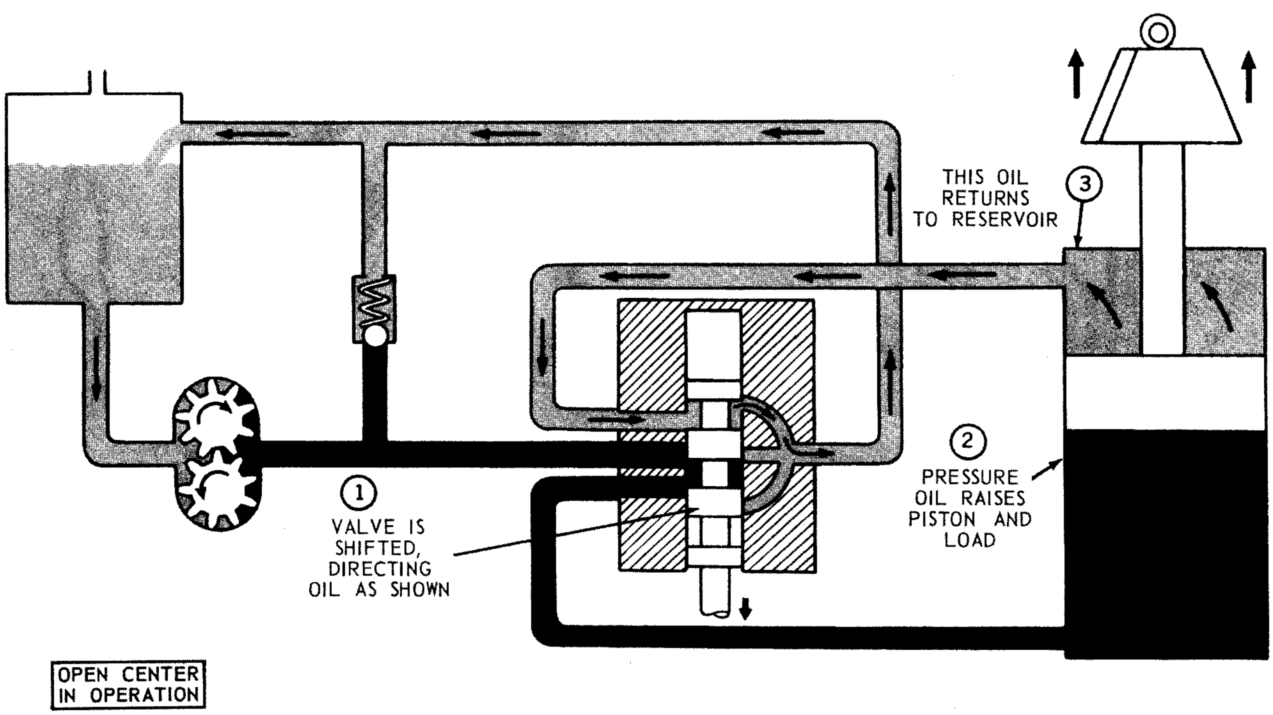
SPRING LOADED TYPE

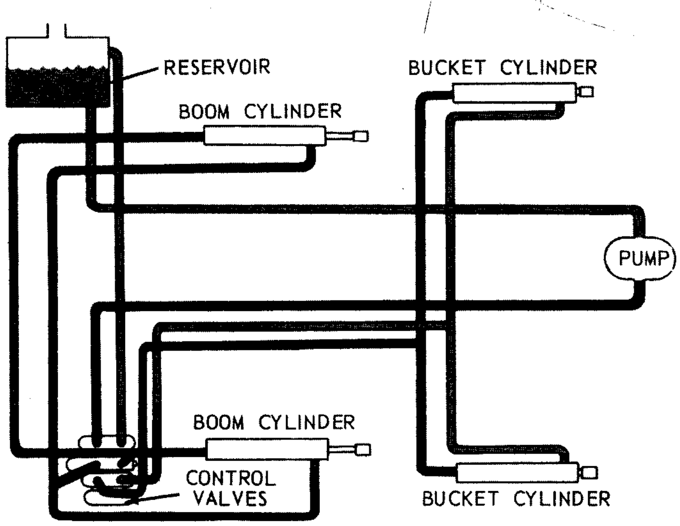


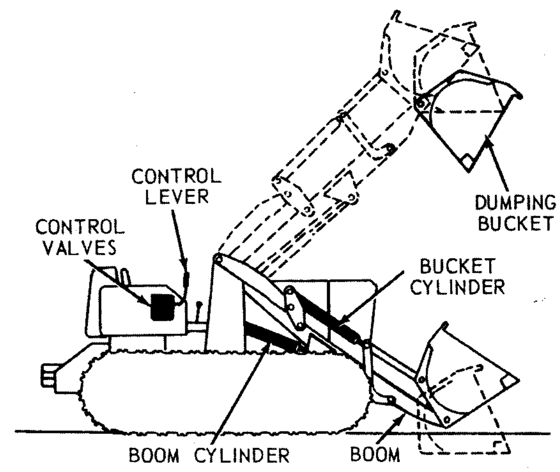
PISTON TYPE

TYPICAL HYDRAULIC APPLICATIONS

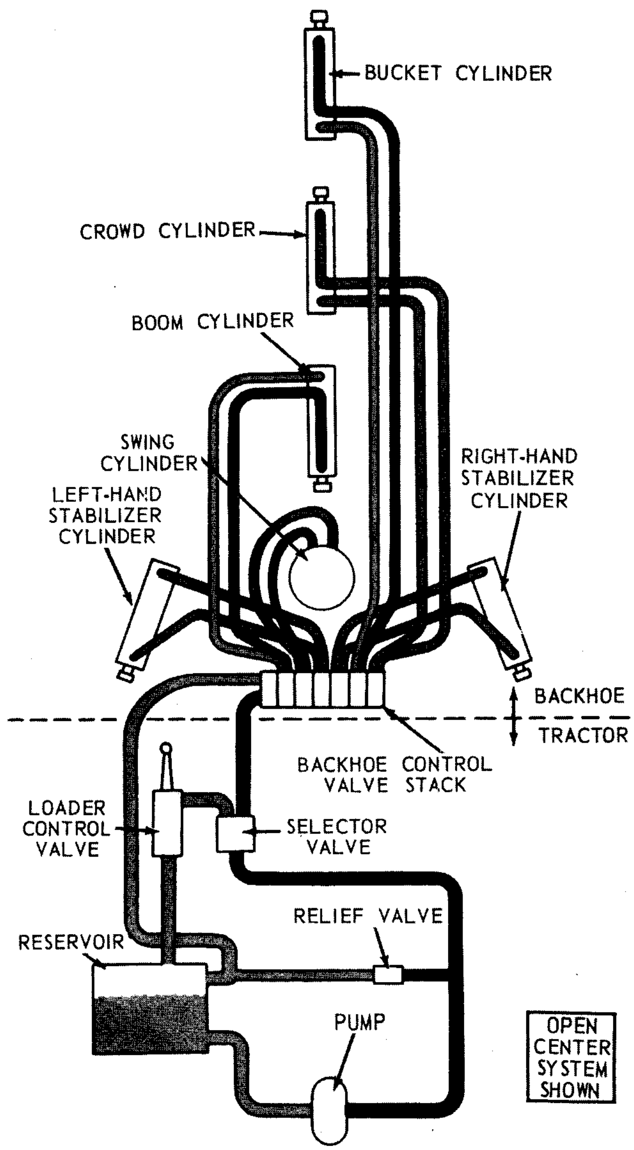


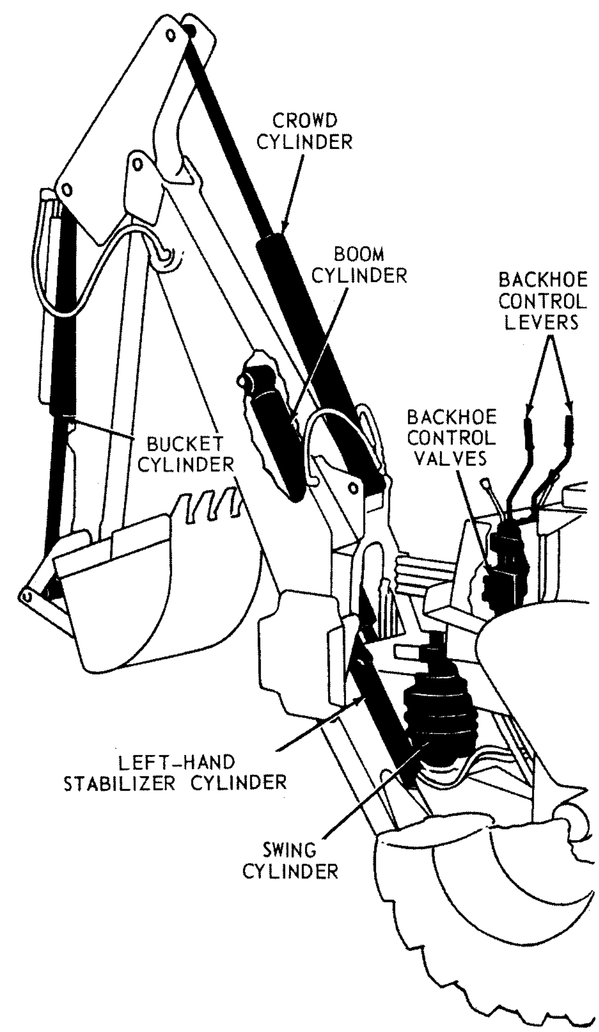




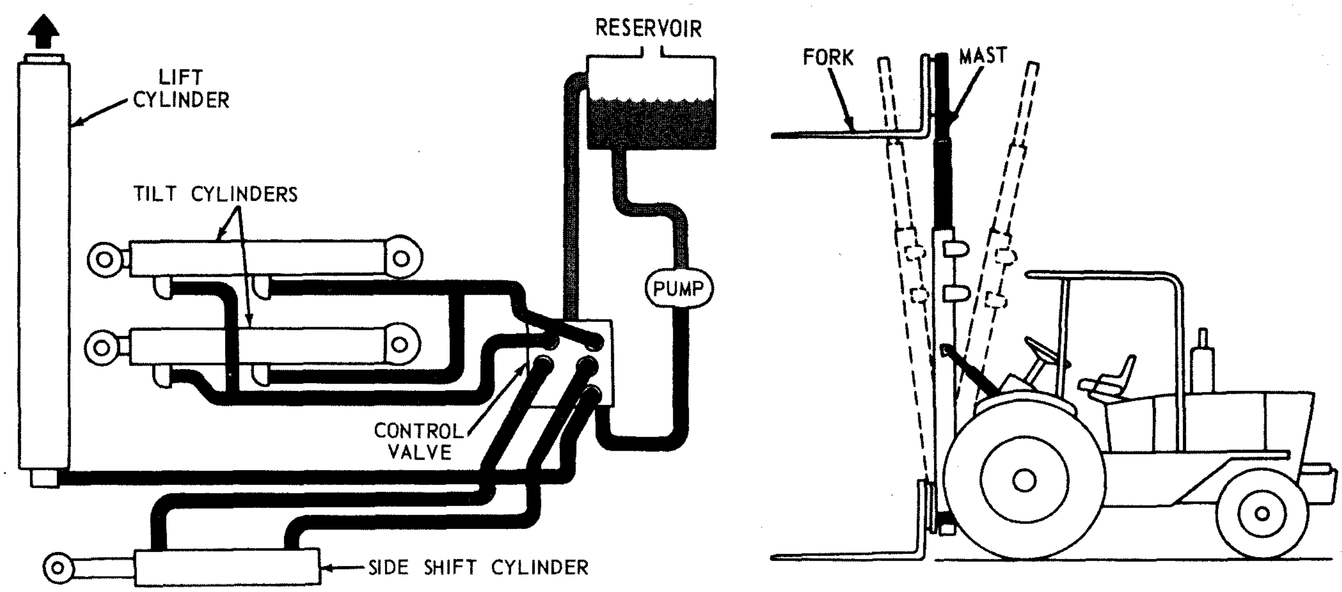


Loader Operation

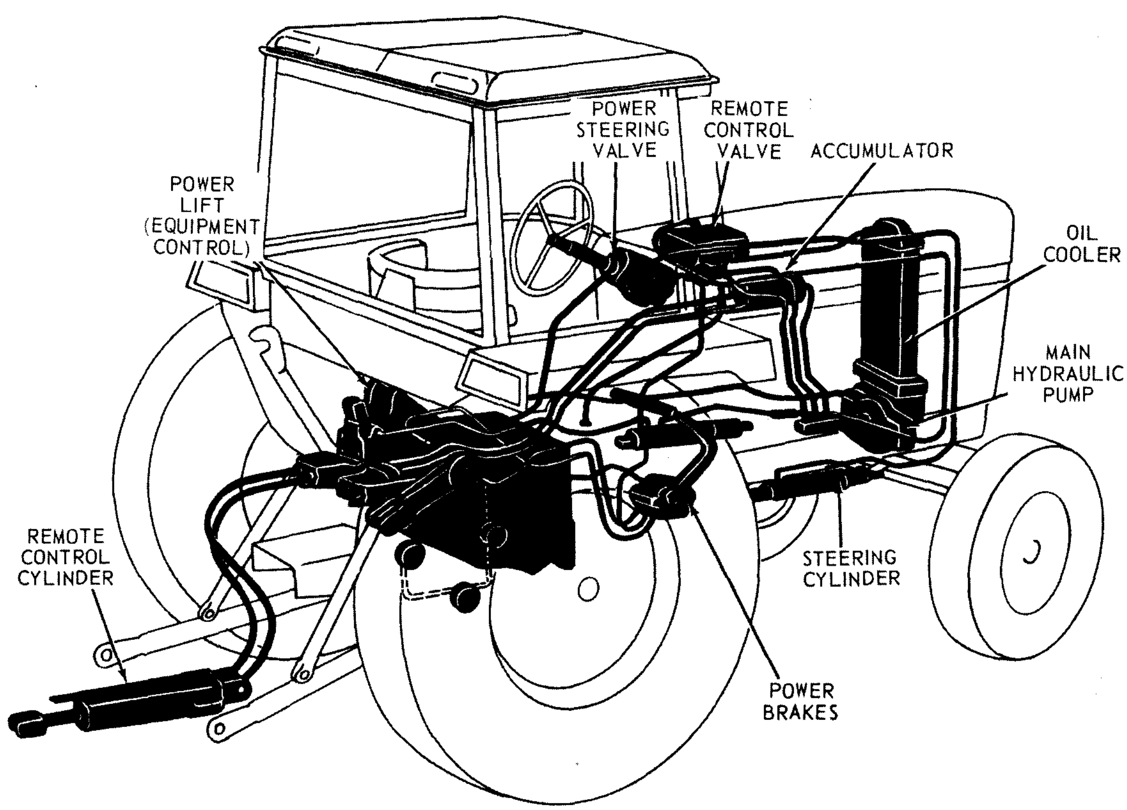




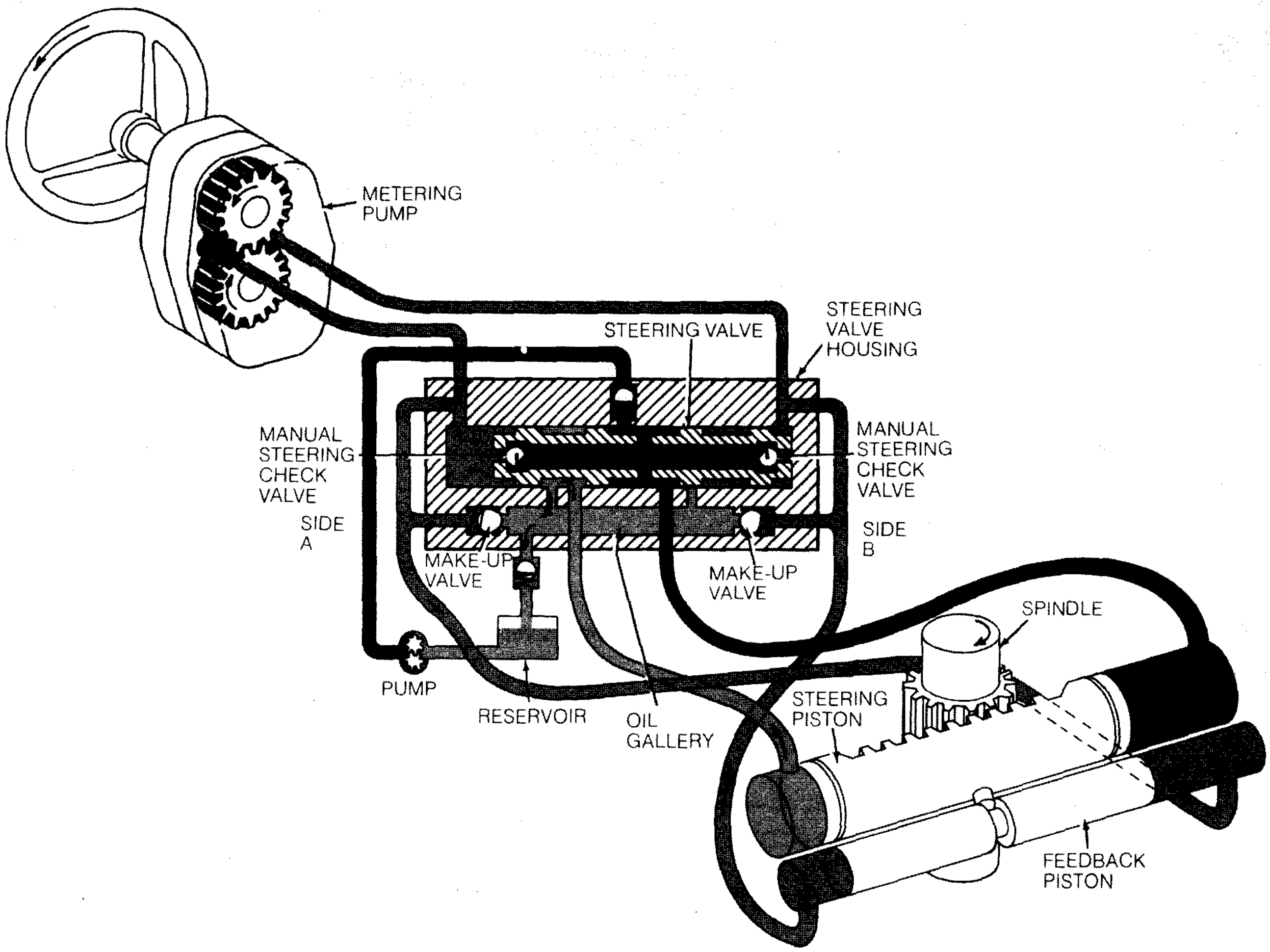
Backhoe Operation (When Used With Loader Unit)



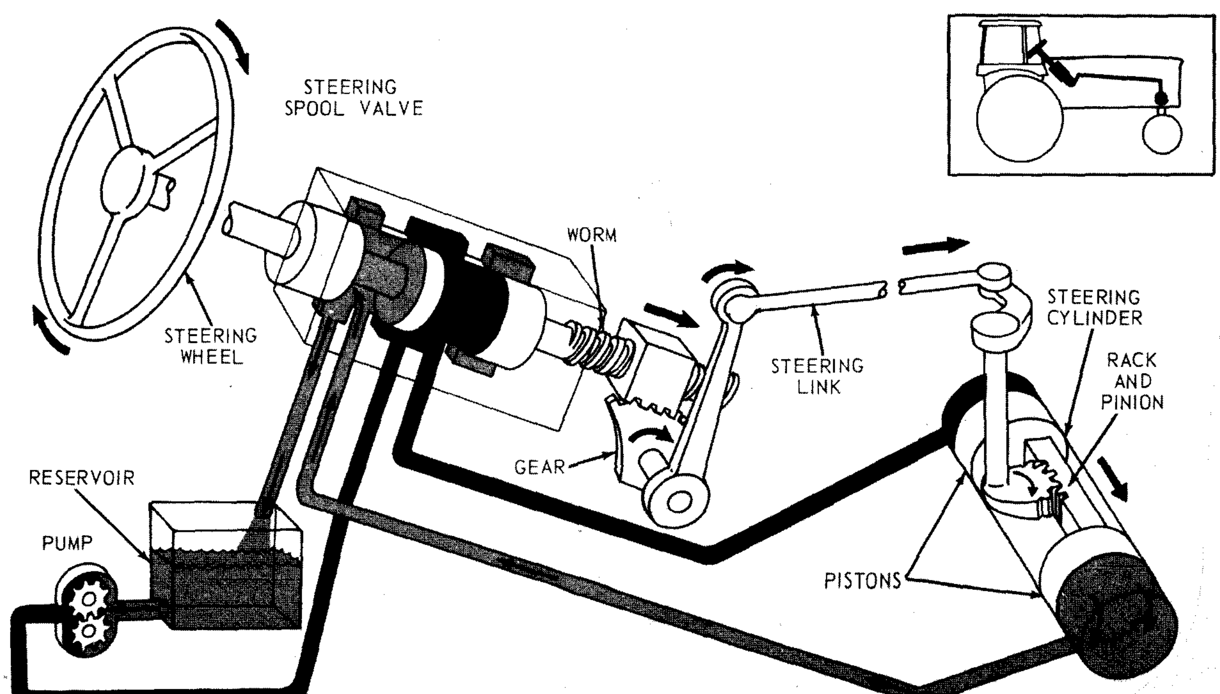
Forklift Operation



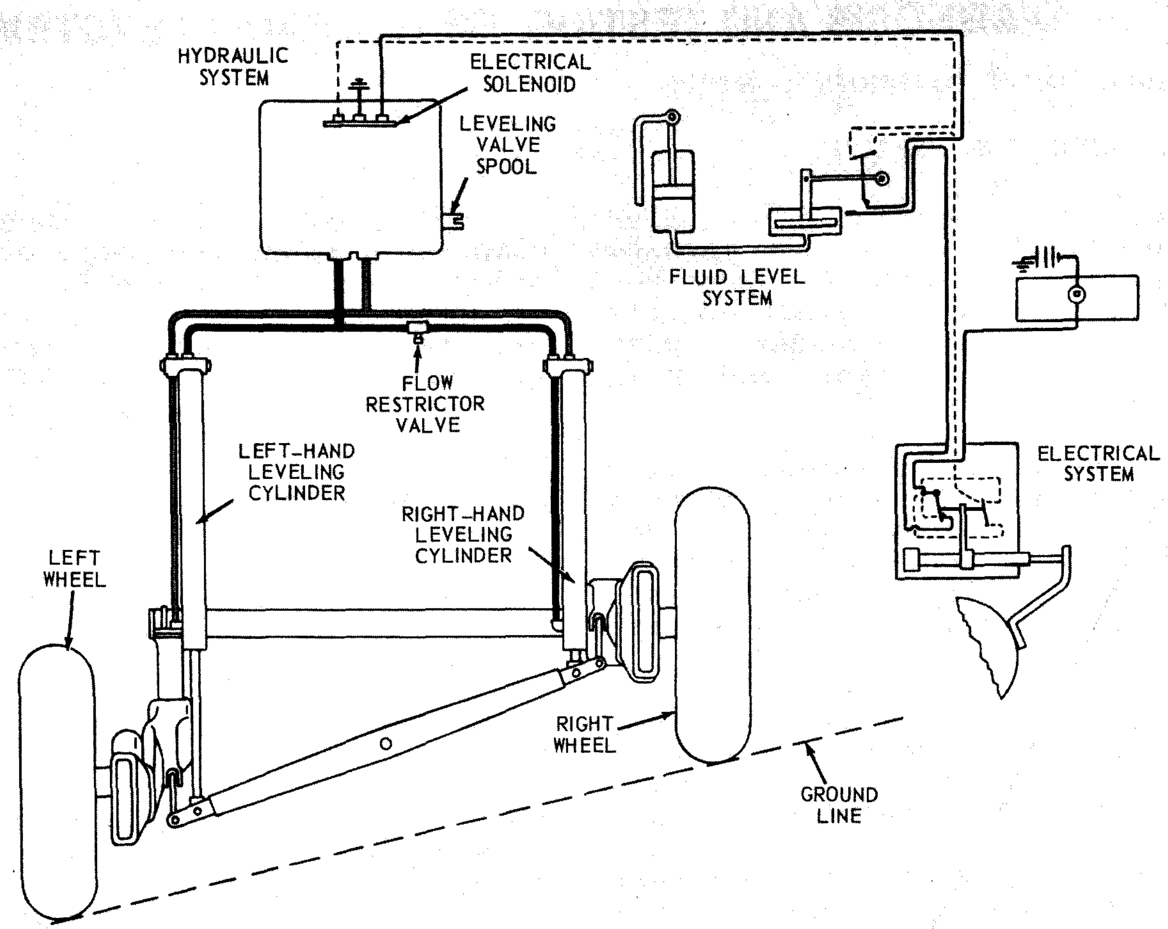
A Modern Tractor With Full Hydraulics (Closed-Center System Shown)



Metering Pump Steering During a Right Turn



Hydraulic Steering During A Right Turn



Automatic Leveling System (Hillside Combine)

NOTES

DIAGNOSIS AND TESTING OF HYDRAULIC SYSTEMS

SEVEN BASIC DIAGNOSTIC STEPS

1. KNOW THE SYSTEM

In other words, "Do your homework." Study the machine technical manuals. Know how the system works, whether it's open- or closed-center, what the valve settings and pump output should be.

Keep up with the latest service bulletins. Read them and then file in a handy place. The problem on your latest machine may be in this month's bulletin, giving the cause and remedy.

You can be prepared for any problem by knowing the system.

2. ASK THE OPERATOR

A good reporter gets the full story from a witness - the operator.

He can tell you how the machine acted when it started to fail, what was unusual about it.

Try to find out, too, if any do-it-yourself service was performed. (You may find out later that the trouble is somewhere else. But you should know if any valves were tampered with, etc.)

Ask about how the machine is used, when it is serviced. Many problems can be traced to poor maintenance or abuse of the machine.

3. OPERATE THE MACHINE

Get on the machine and operate it. Warm it up and put it through its paces. Don't completely trust the operator's story - check it yourself.

Are the gauges reading normal? (If not, it may be hydraulic trouble or it may mean the gauges are faulty.)

How's the performance? Is the action slow, erratic, or nil?

Do the controls feel solid or "spongy"? Do they seem to be "sticking"?

Smell anything? Any signs of smoke?

Hear any funny sounds? Where? At what speeds or during what cycles?

4. INSPECT THE MACHINE

Now get off the machine and make a visual check. Use your eyes, ears, and nose to spot any signs of trouble.

First inspect the oil in the reservoir. How is the oil level? Is the oil foamy? Milky? Does it smell scorched? Does it appear to be too thin or too thick? How dirty is it?

If the oil is very dirty, also check the filters for clogging.

Feel the reservoir and lines. Are they hotter than normal? Are they caked with dirt and mud? Is the paint peeled off from heat? Check the pump inlet line for restrictions. Check for collapsed hoses.

Follow the circuit and keep on checking. Look for oil leaks at the line connectors. Watch for air leaks at loose clamps, etc.

Check the oil cooler. Is it free of trash and mud?

Look closely at the components. Inspect for cracked welds, hairline cracks, loose tie bolts, or damaged linkages.

While you inspect, make a note of all the trouble signs.

5. LIST THE POSSIBLE CAUSES

Now you are ready to make a list of the possible causes.

What were the signs you found while inspecting the machine? And what is the most likely cause?

Are there other possibilities? Remember that one failure often leads to another.

6. REACH A CONCLUSION

Look over your list of possible causes and decide which are most likely and which are easiest to verify.

Use the Trouble Shooting Charts at the end of this chapter as a guide.

Reach your decision on the leading causes and plan to check them first.

7. TEST YOUR CONCLUSION

Now for the final step: Before you start repairing the system, test your conclusions to see if they are correct.

Some of the items on your list can be verified without further testing. Analyze the information you already have:

Were all the hydraulic functions bad? Then probably the failure is in a component that is common to all parts of the system. Examples: pump, filters, system relief valves.

Was only one circuit bad? Then you can eliminate the system components and concentrate on the parts of that one circuit.

Now your list is beginning to narrow so that you can point your tests at one or two components.

The next part of this chapter will tell you how to test the system and pinpoint these final troubles.

But first let's repeat the seven rules for good trouble shooting:

1. Know the System
2. Ask the Operator
3. Operate the Machine
4. Inspect the Machine
5. List the Possible Causes
6. Reach a Conclusion
7. Test Your Conclusion

TROUBLESHOOTING
INTRODUCTION

Use the charts on the following pages to help in listing all the possible causes of trouble when you begin diagnosis and testing of a machine.

Before starting any testing, first check for external oil leaks, return lines and passages for excessive heat due to internal oil leaks, and unusual noises in the system.

Once you have located the cause, check the item in the chart again for the possible remedy.

The technical manual for each machine supplements these charts by giving more detailed and specific causes and remedies.

HYDRAULIC OIL CONDITION
Oil milky or dirty.

Water in oil, (milky).
Filter failures, (dirty).
Metal particles, (mechanical failure).

Oil discolored or has burned odor.

Kinked pipes.
Plugged oil cooler.
Wrong oil viscosity.
Internal leaks.

SYSTEM INOPERATIVE
No oil in system.

Fill to "full" mark.
Check system for leaks.

Oil low in reservoir.

Check level and fill to "full" mark. Check system for leaks.

Oil of wrong viscosity.

Refer to specifications for proper viscosity.

Filter dirty or plugged.

Drain oil and replace filters. Try to find source of contamination.

Restriction in system.

Oil lines could be dirty or have inner walls that are collapsing to cut off oil supply. Clean or replace lines. Clean orifices.

Air leaks in pump suction line.

Repair or replace lines.

Dirt in pump.

Clean and repair pump. If necessary, drain and flush hydraulic system. Try to find source of contamination.

Badly worn pump.

Repair or replace pump. Check for problems causing pump wear such as misalignment or contaminated oil.

Badly worn components.

Examine and test valves, motors, cylinders, etc. for external and internal leaks. If wear is abnormal, try to locate the cause.

Oil leak in pressure lines.

Tighten fittings or replace defective lines. Examine mating surfaces on couplers for irregularities.

Components not properly adjusted.

Refer to machine technical manual for proper adjustment of components.

Relief valve defective.

Test relief valves to make sure they are opening at their rated pressure. Examine seals for damage that could cause leaks. Clean relief valves and check for broken springs, etc.

Pump rotating in wrong direction.

Reverse to prevent damage.

Operating system under excessive load.

Check specifications of unit for load limits.

Hoses attached improperly.

Attach properly and tighten securely.

Slipping or broken pump drive.

Replace couplers or belts if necessary. Align them and adjust tension.

Pump not operating.

Check for shut-off device on pump or pump drive.

SYSTEM OPERATES ERRATICALLY

Air in system.

Examine suction side of system for leaks. Make sure oil level is correct. (Oil leak on the pressure side of the system could account for loss of oil.)

Cold oil.

Viscosity of oil may be too high at start of warm-up period. Allow oil to warm up to operating temperature before using hydraulic functions.

Components sticking or binding.

Check for dirt or gummy deposits. If dirt is caused by contamination, try to find the source. Check for worn or bent parts.

Pump damaged.

Check for broken or worn parts. Determine cause of pump damage.

Dirt in relief valves.

Clean relief valves.

Restriction in filter or suction line.

Suction line could be dirty or have inner walls that are collapsing to cut off oil supply. Clean or replace suction line. Also, check filter line for restrictions.

SYSTEM OPERATES SLOWLY

Cold oil.

Allow oil to warm up before operating machine.

Oil viscosity too heavy.

Use oil recommended by the manufacturer.

Insufficient engine speed.

Refer to operator's manual for recommended speed. If machine has a governor, it may need adjustment.

Low oil supply.

Check reservoir and add oil if necessary. Check system for leaks that could cause loss of oil.

Adjustable orifice restricted too much.

Back out orifice and adjust it. Check machine specifications for proper setting.

Air in system.

Check suction side of the system for leaks.

Badly worn pump.

Repair or replace pump. Check for problems causing pump wear such as misalignment or contaminated oil.

Restriction in suction line or filter.

Suction line could be dirty or have inner walls that are collapsing to cut off oil supply. Clean or replace suction line. Examine filter for plugging.

Relief valves not properly set or leaking.

Test relief valves to make sure they are opening at their rated pressure. Examine valves for damaged seats that could leak.

Badly worn components.

Examine and test valves, motors, cylinders, etc. for external and internal leaks. If wear is abnormal, try to locate the cause.

Valve or regulators plugged.

Clean dirt from components. Clean orifices. Check source of dirt and correct.

Oil leak in pressure lines.

Tighten fittings or replace defective lines. Examine mating surfaces on couplers for irregularities.

Components not properly adjusted.

Refer to machine technical manual for proper adjustment of components.

SYSTEM OPERATES TOO FAST

Adjustable orifice installed backward or not installed.

Install orifice parts correctly and adjust.

Obstruction or dirt under seat of orifice.

Remove foreign material. Readjust orifice.

OVERHEATING OF OIL IN SYSTEM

The operator holds the control valves in the power position too long, causing the relief valve to open.

Return the control lever to the "neutral" position when not in use.

Using incorrect oil.

Use oil recommended by manufacturer. Be sure oil viscosity is correct.

Low oil level.

Fill reservoir.
Look for leaks.

Dirty oil.

Drain and refill with clean oil. Look for source of contamination.

Engine running too fast.

Reset governor or reduce throttle.

Incorrect relief valve pressure.

Check pressure and clean or replace relief valves.

Internal component oil leakage.

Examine and test valves, cylinders, motors, etc. for external and internal leaks. If wear is abnormal, try to locate cause.

Restriction in pump suction line.

Clean or replace.

Dented, obstructed or undersized oil lines.

Replace defective or undersized oil lines. Remove obstructions.

Oil cooler malfunctioning.

Clean or repair.

Control valve stuck in partially or "full open" position.

Free all spools so that they return to "neutral" position.

Heat not radiating properly.

Clean dirt and mud from reservoir, oil lines, coolers, and other components.

Automatic unloading control inoperative, (if equipped).

Repair valve.

FOAMING OF OIL IN SYSTEM
Low oil level.

Fill reservoir.
Look for leaks.

Water in oil.

Drain and replace oil.

Wrong kind of oil being used.

Use oil recommended by manufacturer.

Air leak in line from reservoir to pump.

Tighten or replace suction line.

Kink or dent in oil lines, (restricts oil flow).

Replace oil lines.

Worn seal around pump shaft.

Clean sealing area and replace seal. Check oil for contamination or pump for misalignment.

PUMP MAKES NOISE
Low oil level.

Fill reservoir.
Check system for leaks.

Oil viscosity too high.

Change to lighter oil.

Pump speed too fast.

Operate pump at recommended speed.

Suction line plugged or pinched.

Clean or replace line between reservoir and pump.

Sludge and dirt in pump.

Disassemble and inspect pump and lines. Clean hydraulic system. Determine cause of dirt.

Reservoir air vent plugged.

Remove breather cap, flush, and clean air vent.

Air in oil.

Tighten or replace suction line. Check system for leaks. Replace pump shaft seal.

Worn or scored pump bearings or shafts.

Replace worn parts or complete pump if parts are badly worn or scored. Determine cause of scoring.

Inlet screen plugged.

Clean screen.

Broken or damaged pump parts.

Repair pump. Look for cause of damage like contamination or too much pressure.

Sticking or binding parts.

Repair binding parts. Clean parts and change oil if necessary.

PUMP LEAKS OIL

Damaged seal around drive shaft.

Tighten packing or replace seal. Trouble may be caused by contaminated oil. Check oil for abrasives and clean entire hydraulic system. Try to locate source of contamination. Check the pump drive shaft. Misalignment could cause the seal to wear. If shaft is not aligned, check the pump for other damage.

Loose or broken pump parts.

Make sure all bolts and fittings are tight. Check gaskets. Examine pump castings for cracks. If pump is cracked, look for a cause like too much pressure or hoses that are attached incorrectly.

LOAD DROPS WITH CONTROL VALVE IN "NEUTRAL" POSITION

Leaking or broken oil lines from control valve to cylinder.

Check for leaks. Tighten or replace lines. Examine mating surfaces on couplers for irregularities.

Oil leaking past cylinder packings or O-rings.

Replace worn parts. If wear is caused by contamination, clean hydraulic system and determine the source.

Oil leaking past control valve or relief valves.

Clean or replace valves. Wear may be caused by contamination. Clean system and determine source of contamination.

Control lever not centering when released.

Check linkage for binding. Make sure valve is properly adjusted and has no broken or binding parts.

CONTROL VALVE STICKS OR WORKS HARD

Misalignment or seizing of control linkage.

Correct misalignment.
Lubricate linkage joints.

Tie bolts too tight, (on valve stacks).

Use manufacturer's recommendation to adjust tie bolt torque.

Valve broken or scored internally.

Repair broken or scored parts. Locate source of contamination that caused scoring.

CONTROL VALVE LEAKS OIL

Tie bolts too loose, (on valve stacks).

Use manufacturer's recommendation to adjust tie bolt torque.

Worn or damaged O-rings.

Replace O-rings (especially between valve stacks). If contamination has caused O-rings to wear, clean system and look for source of contamination.

Broken valve parts.

If valve is cracked, look for a cause like too much pressure or hoses that are attached incorrectly.

CYLINDERS LEAK OIL

Damaged cylinder barrel.

Replace cylinder barrel.
Correct cause of barrel damage.

Rod seal leaking.

Replace seal. If contamination has caused seal to wear, look for source. Wear may be caused by external as well as internal contaminants. Check piston rod for scratches or misalignment.

Loose parts.

Tighten parts until leakage has stopped.

Piston rod damaged.

Check rod for nicks or scratches that could cause seal damage or allow oil leakage. Replace defective rods.

CYLINDER LOWERS WHEN CONTROL VALVE IS IN "SLOW RAISE" POSITION

Damaged check valve in lift circuit.

Repair or replace check valve.

Leaking cylinder packing.

Replace packing. Check oil for contamination that could cause wear. Check alignment of cylinder.

Leaking lines or fittings to cylinder.

Check and tighten. Examine mating surfaces on couplers for irregularities.

POWER STEERING DOES NOT WORK, STEERS HARD, OR IS SLOW

Air in system.

Bleed system.
Check for air leaks.

Internal leakage in system.

Components may not be adjusted properly. Parts may be worn or broken. Check for cause of wear.

System not properly timed.

Time according to manufacturer's instructions.

Worn or damaged bearings.

Check and replace bearings in steering components.

Insufficient pressure.

Check pump and relief valves. Contamination could cause valves to leak or pump to wear.

POWER BRAKES MALFUNCTION

Heavy oil or improper brake fluid.

Warm up fluid or change to one of lighter viscosity. Use proper oil or brake fluid, (see machine operator's manual).

NOTE: Many brake circuits use brake fluid instead of hydraulic oil. **DO NOT MIX.**

Air in system.

Bleed brake system.
Find out where air is coming from.

Contaminated oil.

This may cause components to wear or jam. Clean and repair system and check for cause of contamination.

Brake pedal return restricted.

Clean dirt from moving parts.
Check linkage for damage.

Accumulator not working, (if equipped).

Check accumulator precharge. If accumulator is defective, repair or replace it.

DIAGNOSING MOTOR FAILURES

The following trouble shooting charts are given as a general guide to some of the common motor failures, what the cause might be, and the possible remedy.

I. MOTOR WON'T TURN

Possible Cause	Possible Remedy
1. Shaft seizure due to:	
a. Excessive loads.	a. Check load and load capacity of the motor.
b. Lack of lubrication.	b. Check fluid level and quality. Check operating pressure and temperature.
c. Misalignment.	c. Correctly align shaft with work load.
2. Broken shaft.	2. Replace shaft. Find reason for breakage.
3. No incoming pressure.	3. Check and repair clogged, leaking, or broken lines or passages.
4. Contaminated fluid.	4. Check and clean entire hydraulic system. Find source of contamination. Install clean fluid of proper quantity and quality.

II. SLOW MOTOR OPERATION

1. Wrong fluid viscosity.	1. Install clean fluid of proper quantity and quality.
2. Worn pump or rotor.	2. Check pump and motor specifications. Repair or replace if necessary.
3. High fluid temperature.	3. Check for line restrictions, wrong fluid viscosity, or low fluid level.
4. Plugged filter.	4. Check cause of plugging, and clean or replace filter.

III. ERRATIC MOTOR OPERATION

1. Low pressure.	1. Check for air or fluid leaks.
2. Inadequate fluid flow.	2. Check for air or fluid leaks. Check system capacity.
3. System controls failing.	3. Check pump and control valves for proper operation.

IV. MOTOR TURNS IN WRONG DIRECTION

Possible Cause	Possible Remedy
1. Pump-to-motor connections wrong.	1. Reconnect pump and motor.
2. Wrong timing.	2. Check manufacturer's specifications.

V. MOTOR SHAFT NOT TURNING

Possible Cause	Possible Remedy
1. Excessive work loads.	1. Check motor load specifications.
2. Internal motor parts worn.	2. Replace parts or complete motor as necessary.

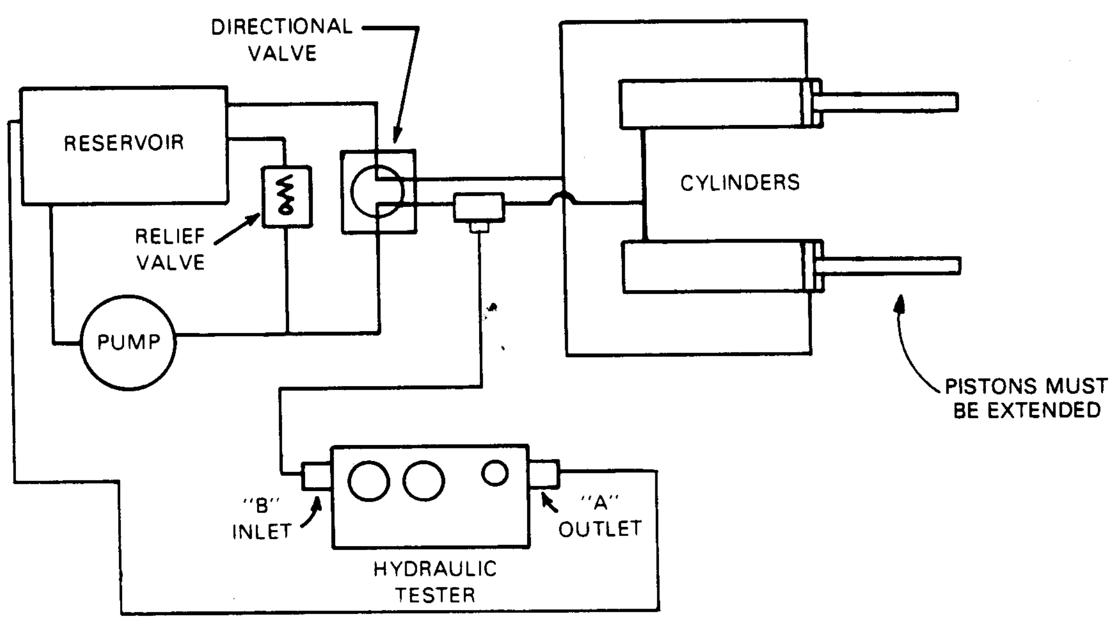
NOTES

TESTING WITH A "TEE" CONNECTION

Illustrated is a method of testing overall circuit performance. Connect line (A) between the hydraulic tester outlet port and the system reservoir. Connect line (B) from the tester inlet port to a "tee" connection in the circuit as shown, (between the control valve and the cylinder); open the tester's pressure control valve. Turn the dampener knob counterclockwise several times, start the pump, set the engine R.P.M. for the rated speed of the pump. After the operating temperature has been reached, (per the manufacturer's specifications), shift the directional control valve from "neutral" to the cylinder extend position.

Close the tester's pressure control valve partially to allow the cylinders to extend and "dead-end".* Oil will flow to the reservoir either through the tester or through leaks in the components of the circuit. Read the flow at "no load". Increase the load on the circuit by slowly closing the tester's pressure control valve and read the flow at pressure, slightly below the relief valve setting. Maintain the required engine R.P.M. at all pressure check points. The difference in readings indicates oil lost because of leaks somewhere in the circuit.

*If the design characteristics of the cylinder make a "dead-end" inadvisable, a load greater than capacity can be put on the unit to simulate "dead-ending".



TESTING THE PUMP

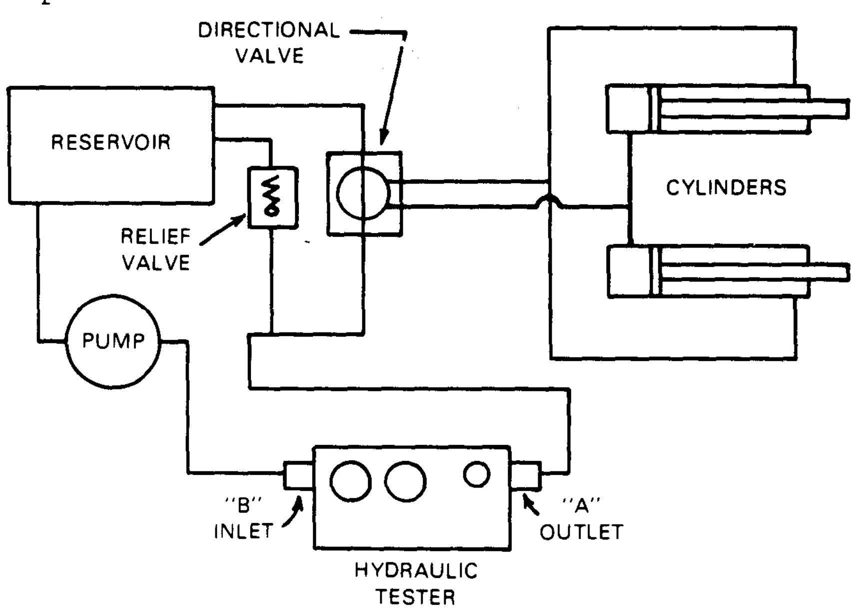
An in-line pump test can be made by disconnecting the line between the pump and the relief valve. Connect line "A" to the pressure port of the relief valve and connect line "B" to the discharge port of the pump. Make sure the directional control valve is in the "neutral" position.

Open the tester's pressure control valve. Turn the dampener knob counterclockwise several turns. Start the pump, set the engine R.P.M. for the rated speed of the pump, (equipment is at the manufacturer's specific R.P.M. level for a given rate of flow). If the action of the gauges is erratic and severe pulsation occurs, even after the dampener knob has been adjusted, cavitation of the pump may be indicated . . . check the oil level, filter, and suction line.

Induce a load on the pump with the flowtester pressure control valve at approximately 50% of maximum system pressure.

Increase the pressure gradually by turning the pressure control valve clockwise. The pressure readings are made from the tester's pressure gauge. When normal operating temperature is reached, (per the manufacturer's specification), open the tester's pressure control valve by turning the handle counterclockwise and refer to the flowmeter readings, recording the volume at low pressure. Increase the pressure by turning the handle clockwise, maintain the required engine R.P.M. at all pressure check points, and record the volume at increments up to maximum pressure. Open the pressure control valve, and shut off the pump. Now, check the results against the manufacturer's specifications. If the results are low, the trouble is in either the pump, suction line, or filter. If the results check, the trouble is beyond the pump. Check the relief valve next.

NOTE: Do Not allow the tester pressure gauge reading to exceed the maximum allowable relief valve pressure, or serious damage to the pump may result.



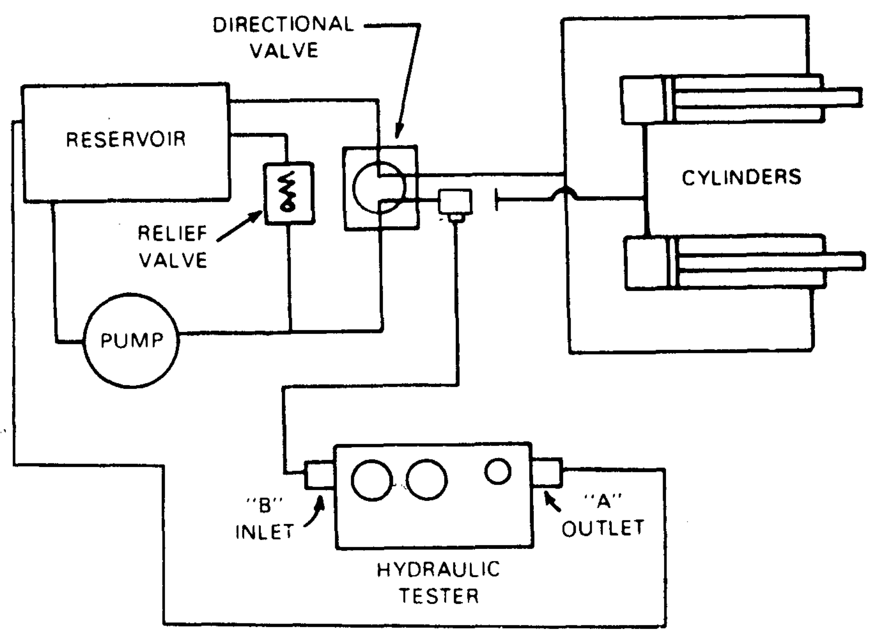
TESTING THE DIRECTIONAL VALVE

Disconnect the line from the cylinder to the "tee" and plug port on the "tee". Line "B" should be connected to the outlet port on the directional control valve and line "A" should go to the reservoir.

Open the tester's pressure control valve. Turn the dampener knob counterclockwise several turns. Start the pump, set the engine R.P.M. for the rated speed of the pump. After operating temperature has been reached, (per the manufacturer's specifications), shift the directional valve from "neutral" to the "advance" or "lift" position so oil will be directed to line "B" or the inlet port of the tester.

Record the pressure and volume at various increments. Maintain the required engine R.P.M. at all pressure check points. If full volume and pressure cannot be obtained, the directional valve is the cause of the problem, and must be repaired or replaced. If full rated volume at full pressure is recorded, the trouble is in the cylinder.

Both sides of the directional valve should be checked.

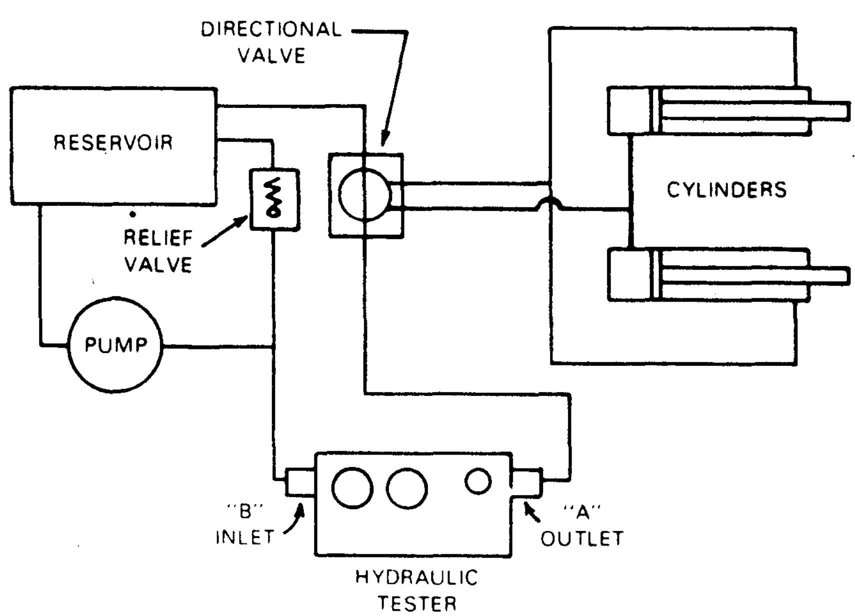


TESTING THE RELIEF VALVE

An in-line test can be made by disconnecting the line between the relief valve and the directional control valve. Connect line "A" to the pressure port of the directional control valve and connect line "B" to the discharge line after the relief valve. Make sure the directional control valve is in the "neutral" position.

Open the tester's pressure control valve. Turn the dampener knob counterclockwise several turns. Start the pump, and set the engine R.P.M. for the rated speed of pump. After the operating temperature has been reached, (per the manufacturer's specifications), maintain the required engine R.P.M. at all pressure check points, recording the volume and pressure at various increments to maximum pressure.

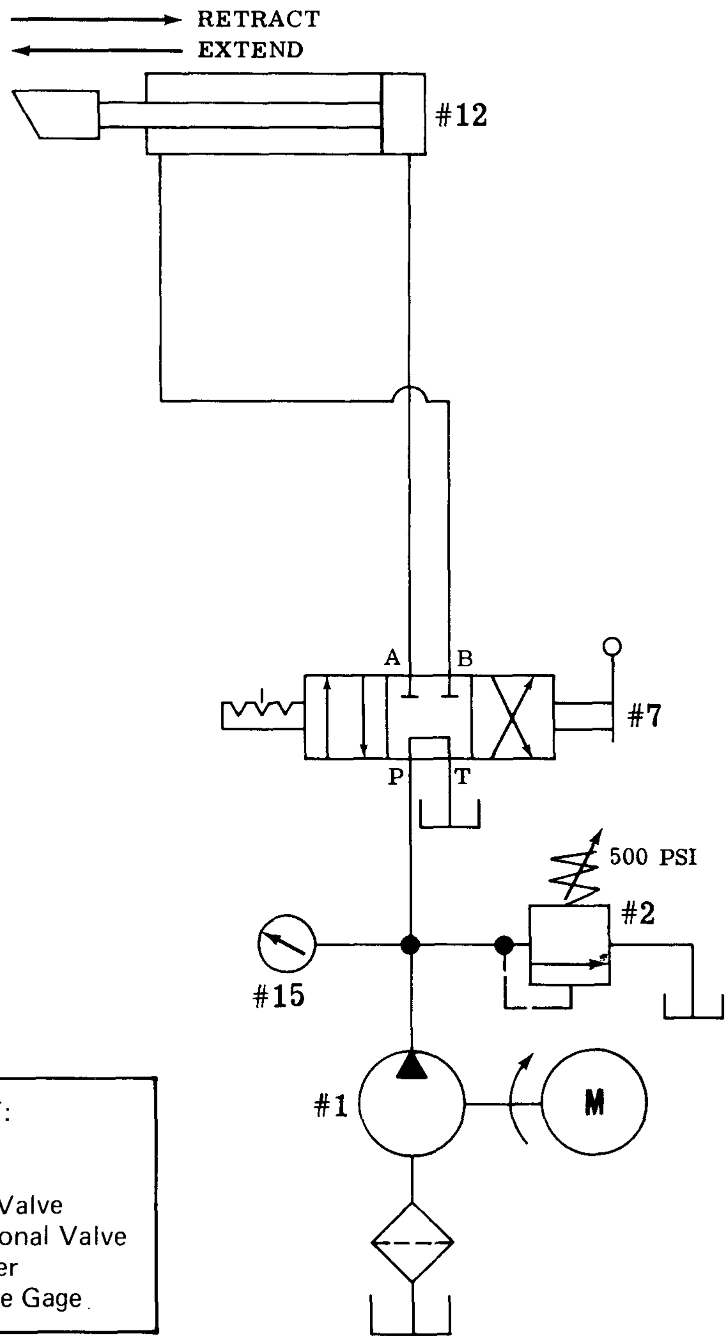
The pressure at which the flow falls off to "0" is the relief pressure. If this pressure is below maximum operating pressure, the relief valve should be adjusted. Up to relief pressure, the flow should be the same as that of the pump. If not, this is an indication that the relief valve is leaking and should be repaired. If the trouble does not lie in the relief valve, the directional valve must be tested next.



TYPE: BASIC HYDRAULIC CIRCUIT (LINEAR)

OPERATION: EXTEND, RETRACT AND STOP

CIRCUIT NO. 1

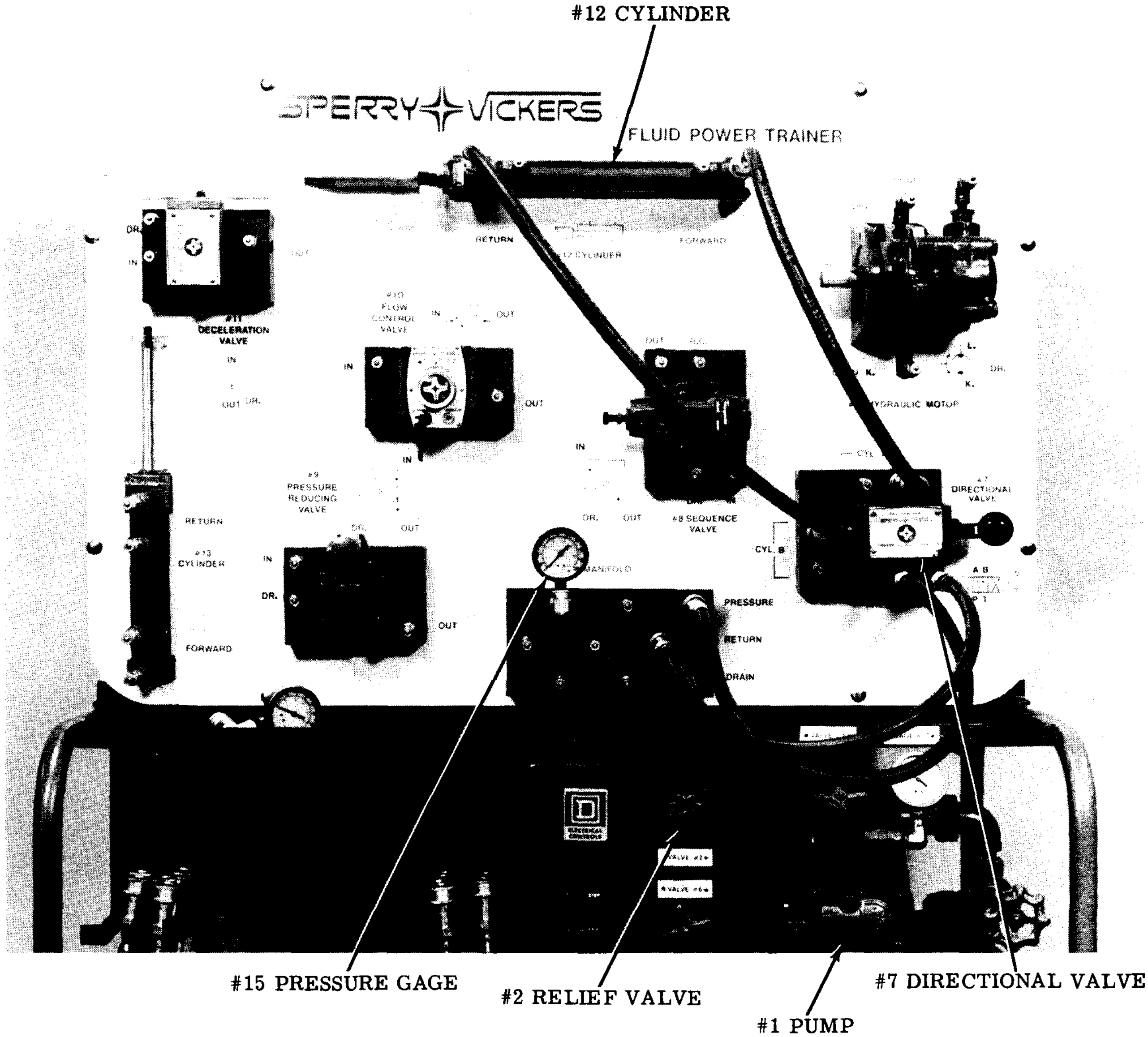


EQUIPMENT:

- #1 Pump
- #2 Relief Valve
- #7 Directional Valve
- #12 Cylinder
- #15 Pressure Gage

This system could be used for positioning a work table or other machine element. Direction of cylinder movement is controlled by shifting the handle of directional valve #7. When shifted to the left, oil flows from the pump (#1) through the valve, P to A, and to the cap end of cylinder #12, causing the cylinder rod to extend. Oil from the rod end of the cylinder flows back through the four-way directional valve, B to T, and to the reservoir.

continued



When the handle of the valve is shifted to the right, oil from the pump is directed through the valve, P to B, and to the rod end of the cylinder, causing the rod to retract. Discharged oil from the cap end of the cylinder is directed back to the reservoir through the directional valve, A to T.

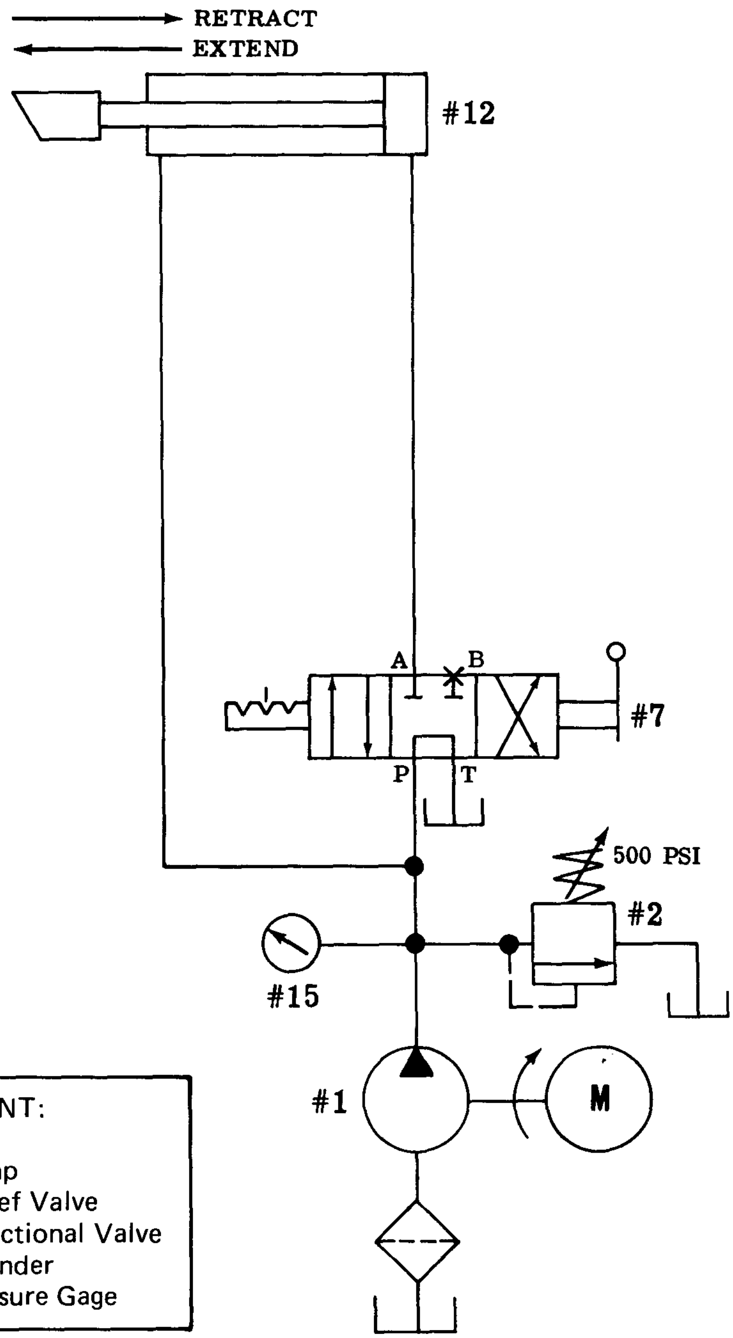
When the cylinder rod reaches either end of its stroke, pressure in the system will build up to the setting of relief valve #2. The relief valve will then open and by-pass the pump's volume back to the reservoir, while at the same time holding pressure on the cylinder equal to the relief valve setting.

In the neutral position (as shown), cylinder ports A and B of the directional valve are blocked and pressure port P is open to tank. Oil is trapped between the cylinder and directional valve, thus preventing any cylinder movement. However, oil delivered by the pump can flow freely through the directional valve, P to T, and back to the reservoir. This unloads the pump at little or no pressure.

TYPE: REGENERATIVE CIRCUIT

OPERATION: TO PROVIDE EQUAL SPEED AND FORCE WHILE EXTENDING AND RETRACTING, THROUGH THE USE OF A CYLINDER WITH 2 TO 1 AREA RATIO

CIRCUIT NO. 2



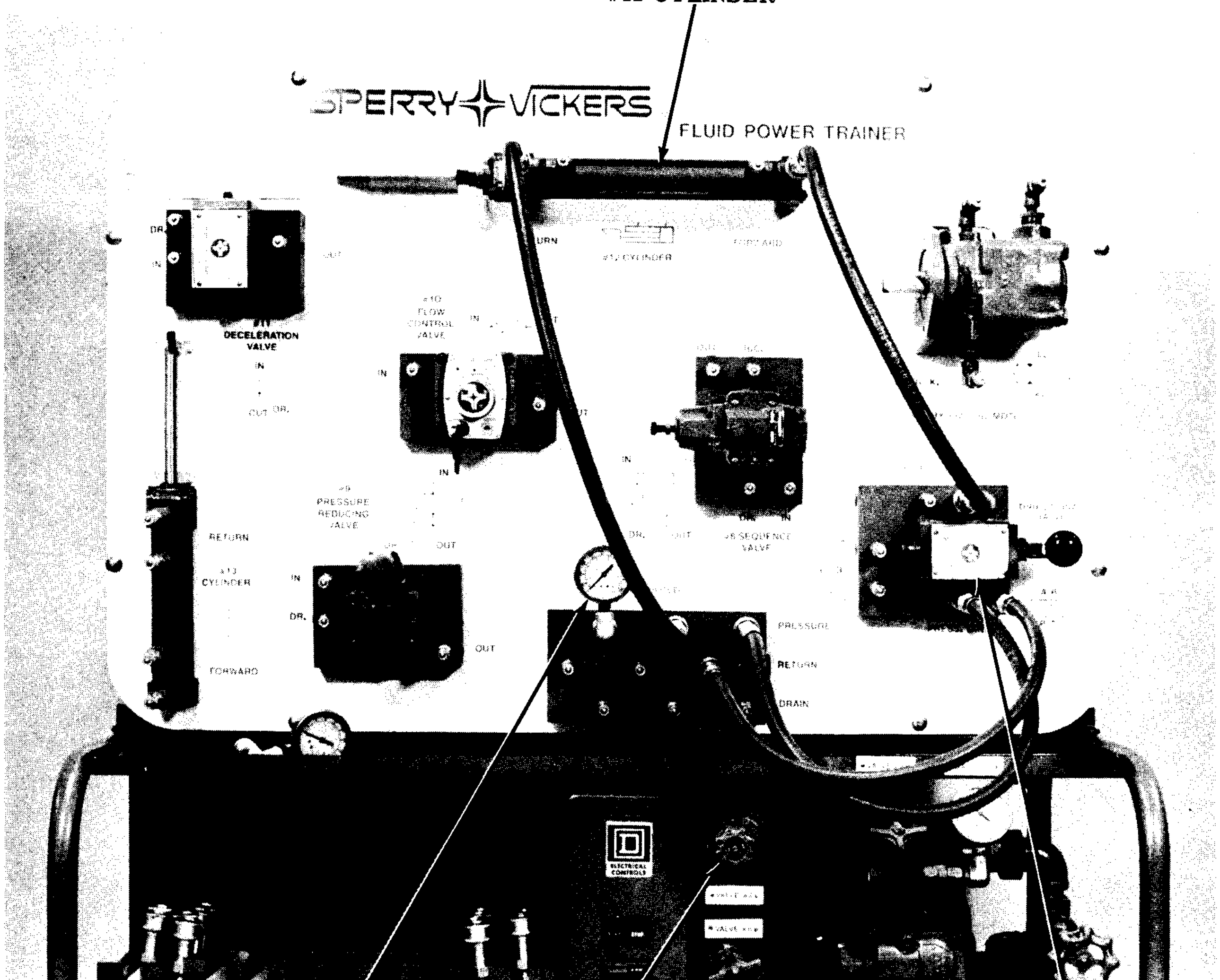
EQUIPMENT:

- #1 Pump
- #2 Relief Valve
- #7 Directional Valve
- #12 Cylinder
- #15 Pressure Gage

Single rod cylinders move slower when extending than when retracting because of their differential piston areas. In the case of a 2 to 1 cylinder, such as cylinder #12, the area of the cap end is twice as great as the annular area* around the rod at the rod end of the cylinder. Consequently, it will move only half as fast when the rod is extending as it does when the rod is retracting.

* Annular area = full area of piston minus area of the rod.

continued



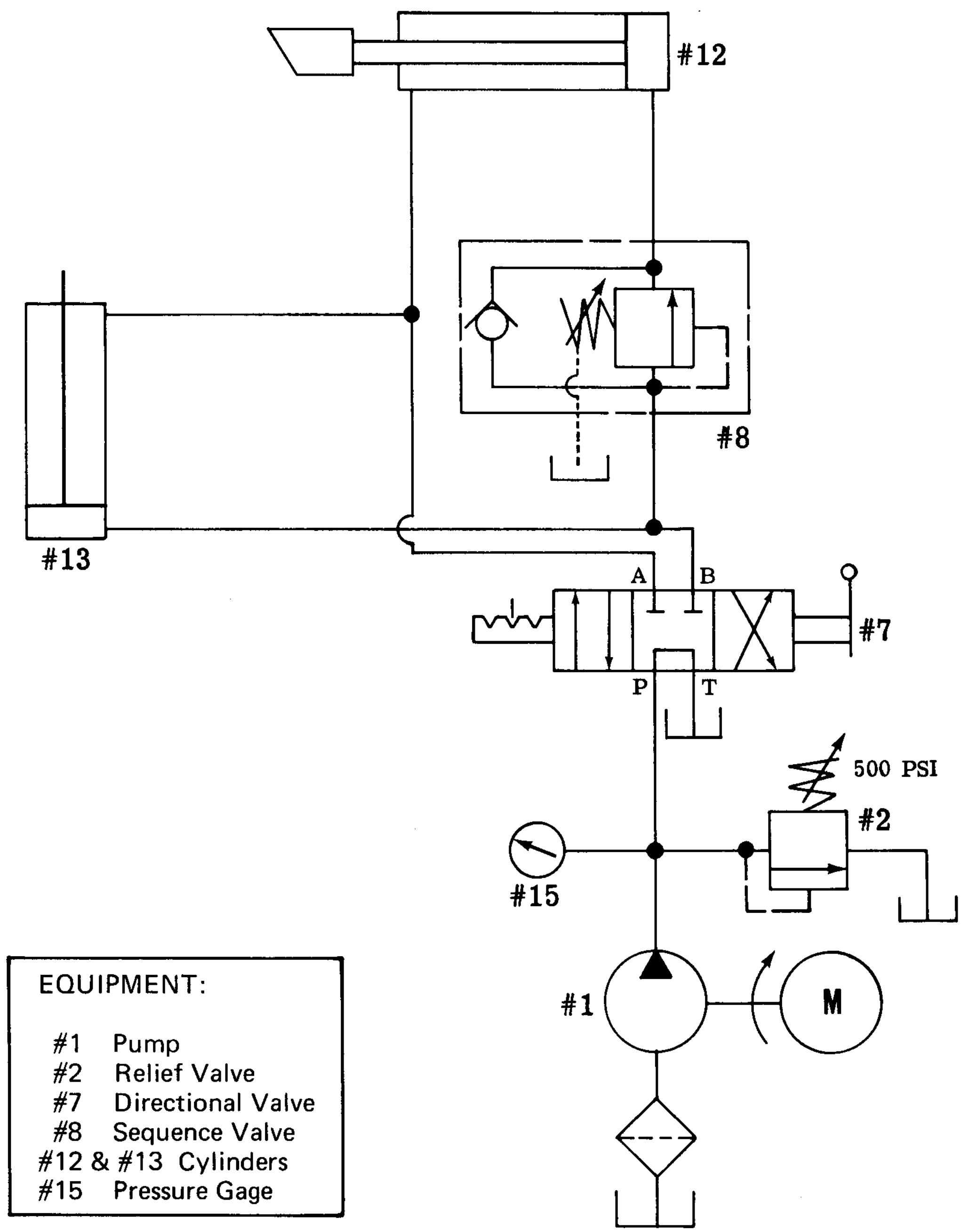
Occasionally, equal speed and force in both directions are required. This can be accomplished with a regenerative circuit. In this circuit, the rod end of cylinder #12 is piped into the main pressure line from the pump. When the handle of directional valve #7 is shifted to the right connecting P to B, the oil is blocked at port B by a check valve in the quick-disconnect. Thus, the pump's volume is directed to the rod end of the cylinder, causing it to retract. Discharged oil from the cap end of the cylinder is directed back to the reservoir through the directional valve, A to T. The speed at which the cylinder rod retracts is determined by the pump volume and the annular area of the cylinder, which is one-half the area of the cap end of the cylinder.

When the handle of the directional valve is shifted to the left, the volume of the pump is directed to the cap end of the cylinder, from P through A. Oil from the rod end of the cylinder joins the pump volume and also flows to the cap end of the cylinder through the directional valve, P to A. The combination of these two volumes is exactly equal to twice the volume of the pump (due to the 2 to 1 area ratio) which results in the cylinder rod extending at exactly the same speed that it retracted. In a circuit such as this, speed and force are the same in both directions.

TYPE: SEQUENCING CIRCUIT

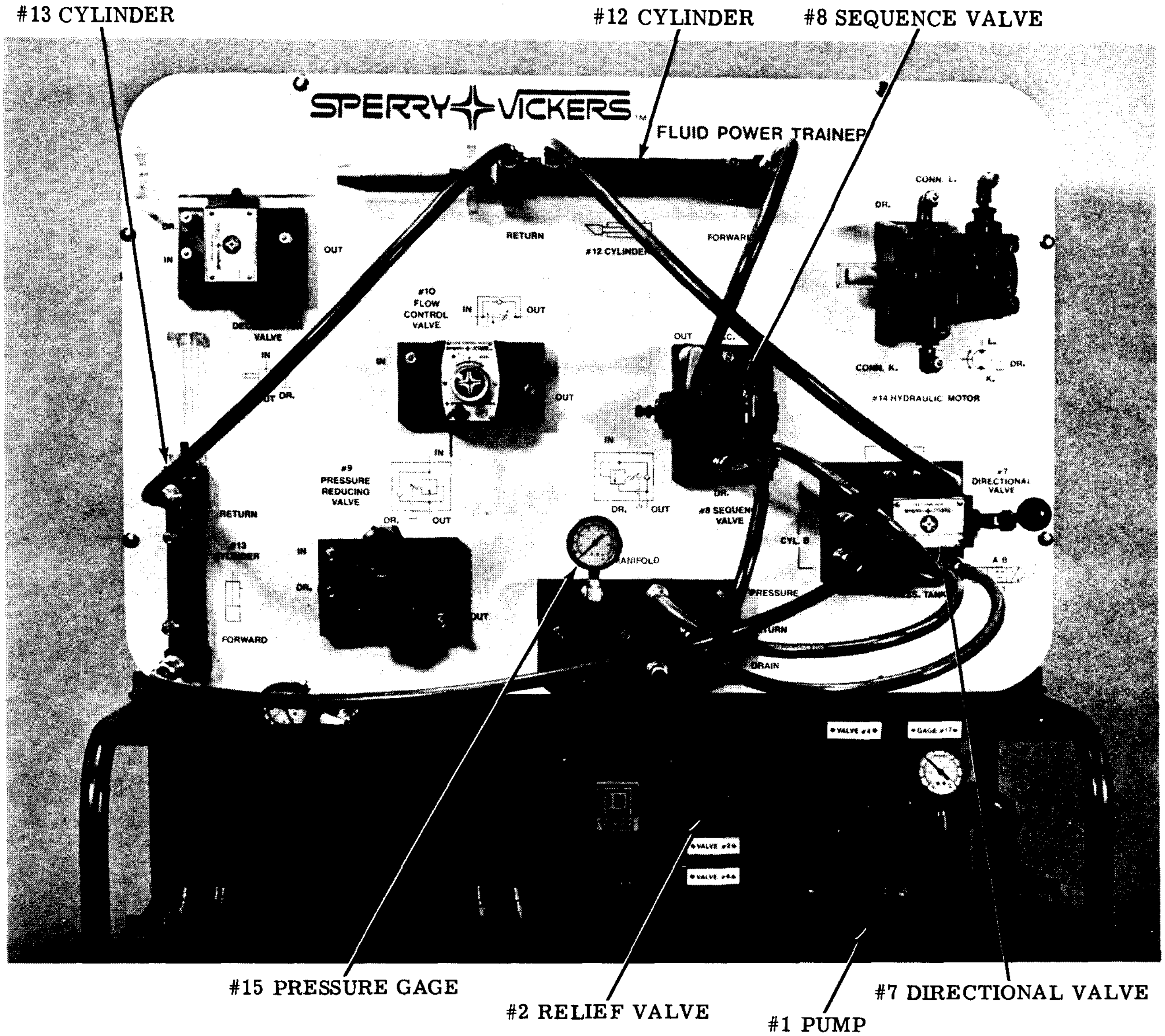
OPERATION: TO HAVE ONE OPERATION OCCUR BEFORE ANOTHER

CIRCUIT NO. 3



Hydraulic cylinders must often function in sequence. For example, it would be necessary to clamp a workpiece before performing some operation such as drilling or milling. In this circuit, when the handle of directional valve #7 is shifted to the right, oil from port B flows to both the cap end of cylinder #13 and to the inlet port of sequence valve #8. The sequence valve is spring loaded to remain closed until cylinder #13 is extended and clamps the work.

continued



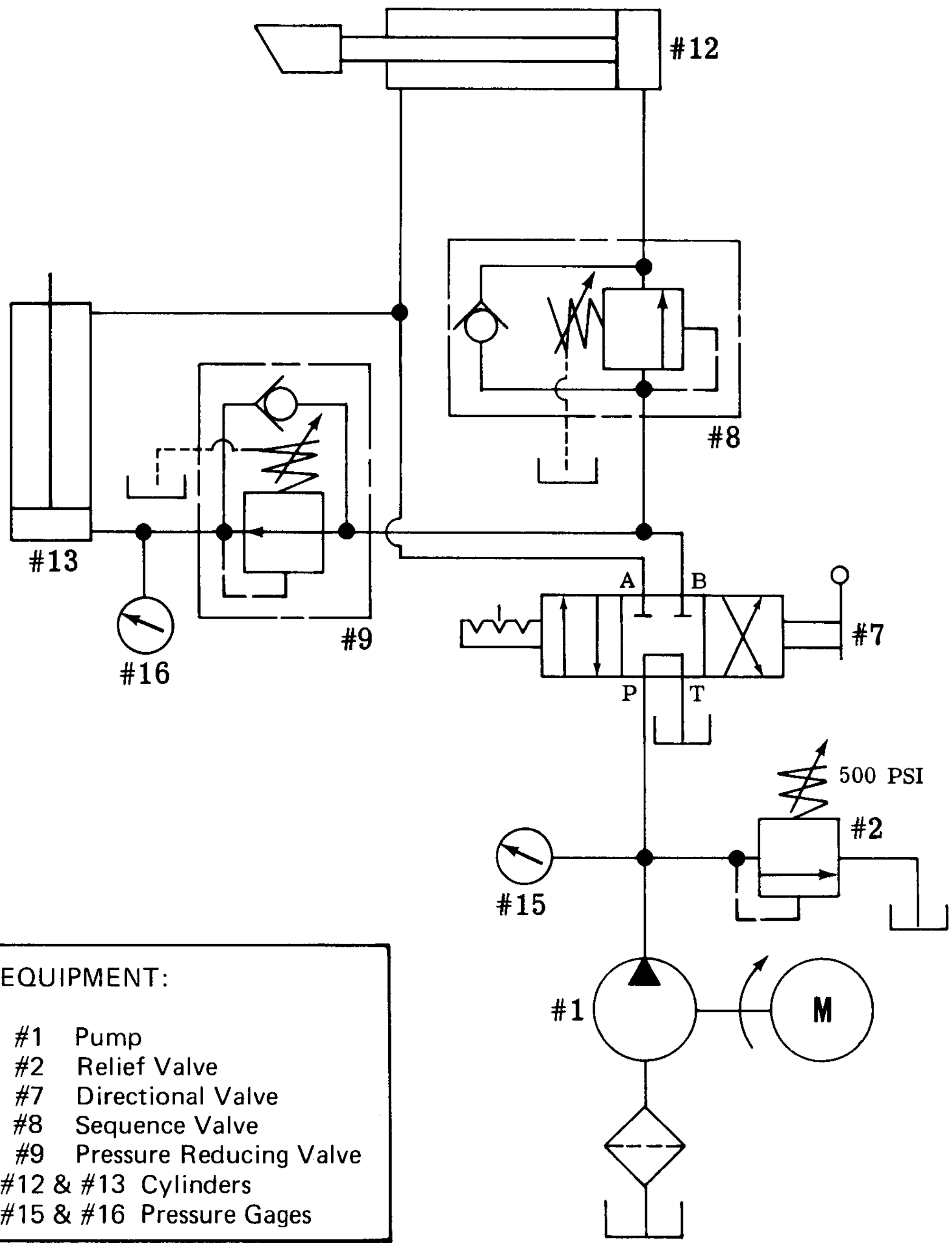
When pressure has built up sufficiently to overcome the spring setting, valve #8 will open, allowing the pump's volume to flow to the cap end of cylinder #12. Pressure at the cap end of cylinder #13 will never be less than the sequence valve setting while cylinder #12 is extending. In most cases, the setting of the sequence valve should be approximately 150 psi below that of the pressure relief valve for proper circuit operation.

When the handle of the directional valve is shifted to the left, oil from the pump flows through the valve, P to A, and to the rod end of both cylinders. An integral check valve in sequence valve #8 permits oil from the cap end of cylinder #12 to join with the discharged oil from the cap end of cylinder #13 and freely flow back to the reservoir through valve #7, B to T. No provision is made in this circuit to retract the cylinders in sequence.

TYPE: SEQUENCING CIRCUIT WITH LIMITED CLAMPING PRESSURE

OPERATION: TO HAVE ONE OPERATION OCCUR BEFORE ANOTHER AND TO LIMIT MAXIMUM PRESSURE ON THE FIRST OPERATION

CIRCUIT NO. 4

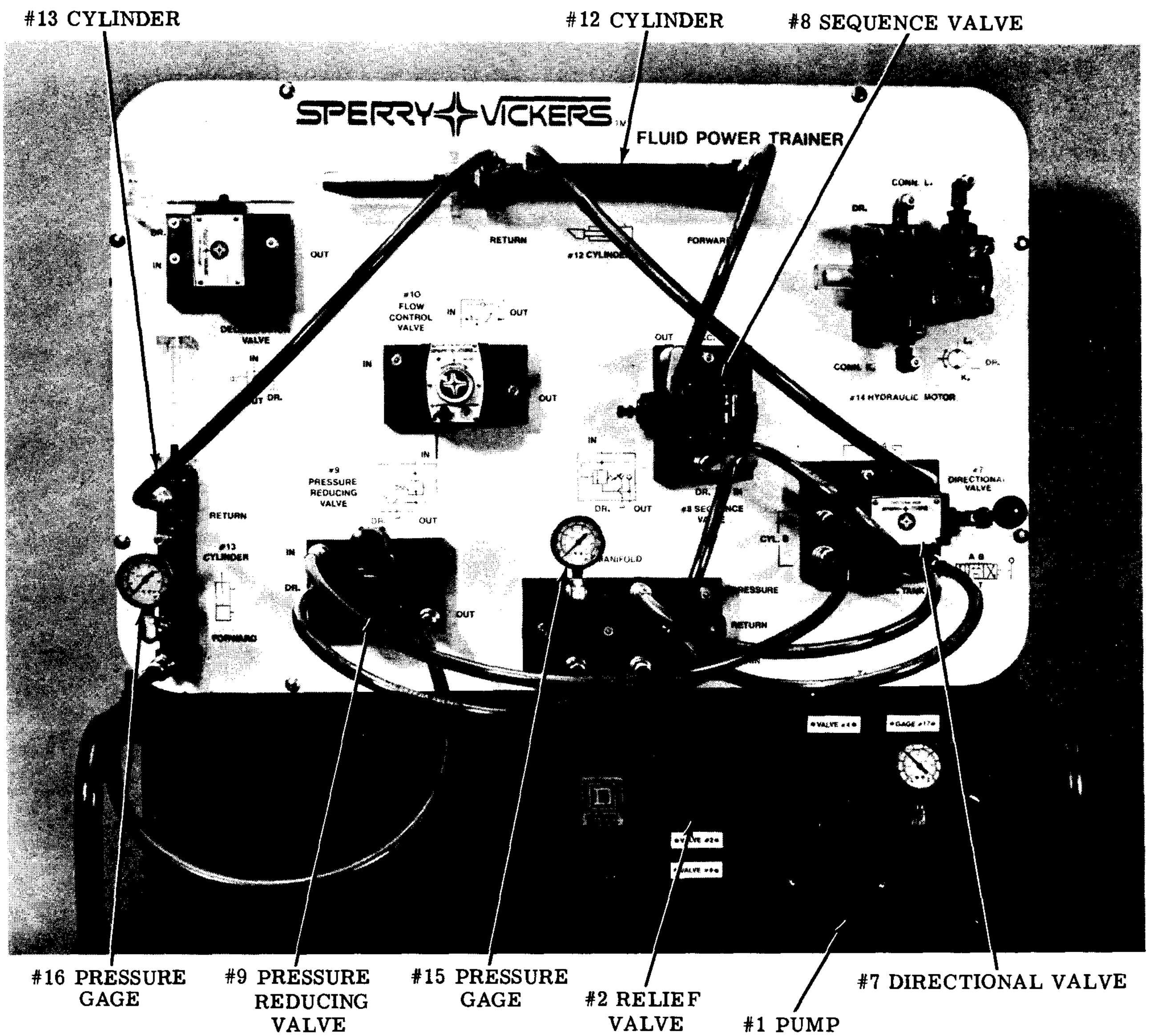


EQUIPMENT:

#1 Pump
#2 Relief Valve
#7 Directional Valve
#8 Sequence Valve
#9 Pressure Reducing Valve
#12 & #13 Cylinders
#15 & #16 Pressure Gages

This circuit is similar to Circuit No. 3. In Circuit No. 3, sequence valve #8 assures that cylinder #13 advances before cylinder #12 begins its motion and maintains a predetermined minimum pressure on the cap end of cylinder

continued



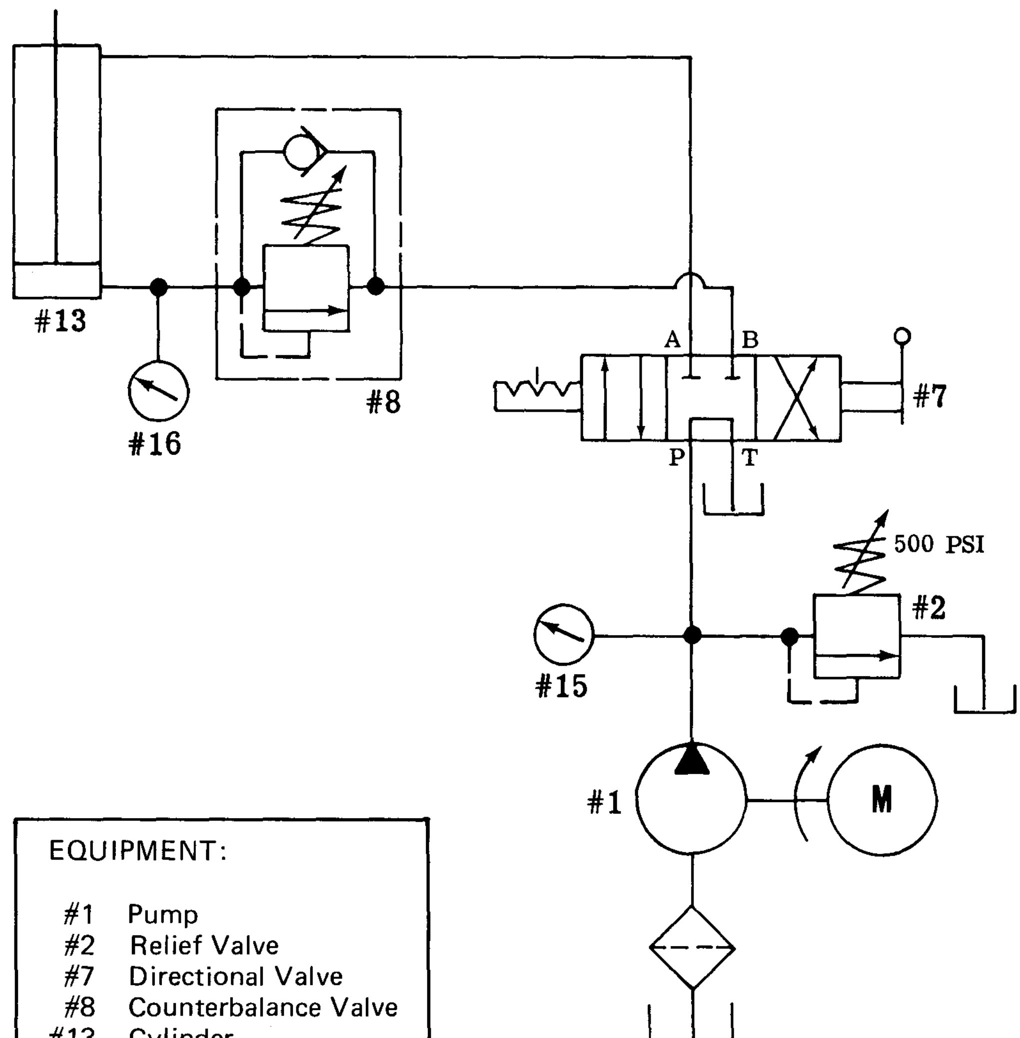
#13. It would not, however, prevent excessive pressure build-up on the cap end of cylinder #13 if pressure required for the second operation (at cylinder #12) was higher than that desired for clamping.

The addition of pressure reducing valve #9 permits a separate and adjustable control of pressure in the cap end of cylinder #13. This valve is spring-loaded to remain open. When pressure in cylinder #13 builds up sufficiently to overcome the spring setting, additional flow to the cylinder is prevented. The pressure reducing valve has a built-in check which allows free flow of the oil from the cap end of cylinder #13 to join with the free flow of the oil from the cap end of cylinder #12 and back to the tank through directional valve #7, B to T.

TYPE: COUNTERBALANCE CIRCUIT

OPERATION: TO IMPOSE A HYDRAULIC RESISTANCE ON A CYLINDER AND PREVENT UNCONTROLLED LOAD DROP

CIRCUIT NO. 5

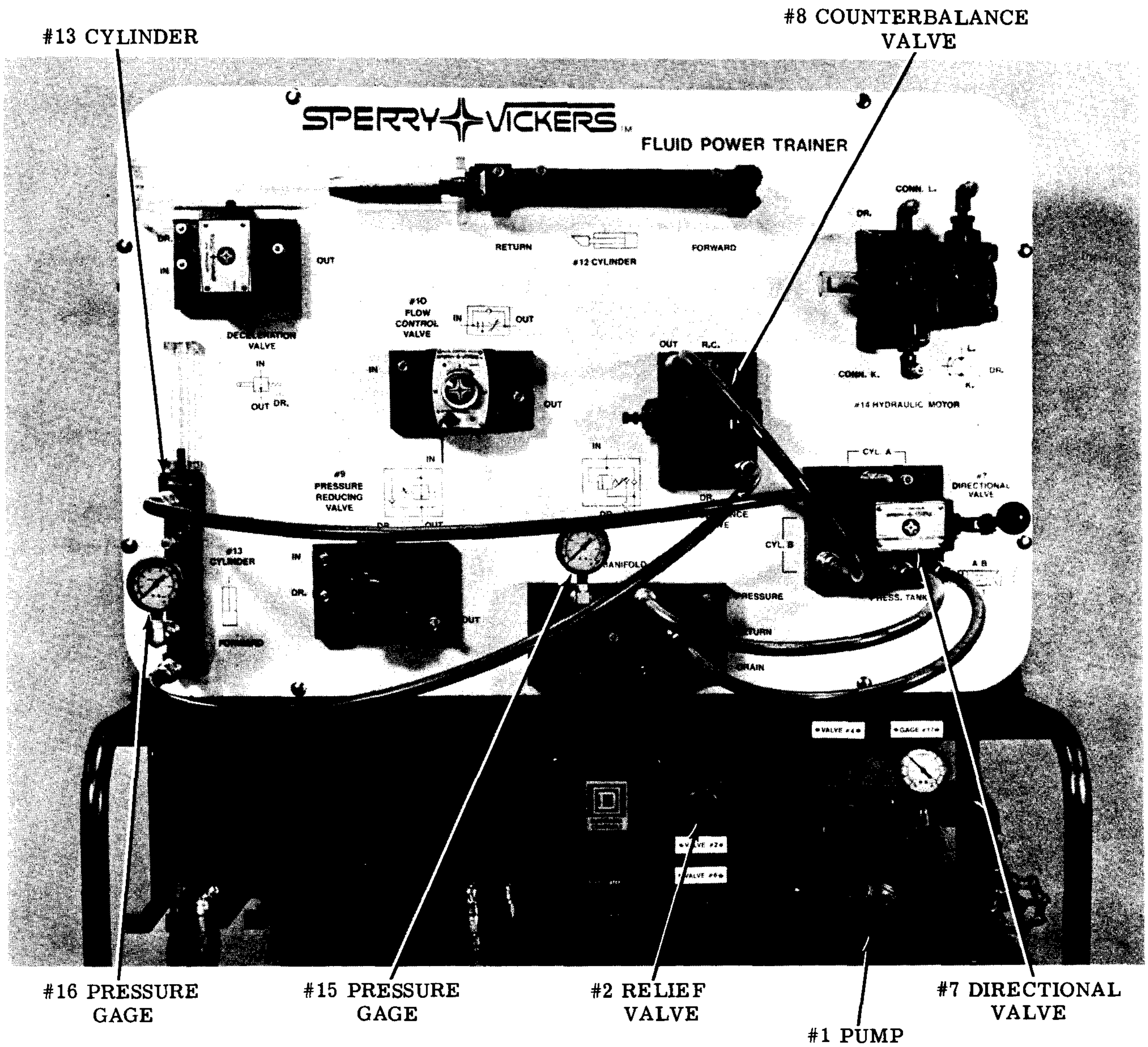


EQUIPMENT:

- #1 Pump
- #2 Relief Valve
- #7 Directional Valve
- #8 Counterbalance Valve
- #13 Cylinder
- #15 & #16 Pressure Gages

A counterbalance circuit provides a means of supporting a load and preventing uncontrolled load drop. With counterbalance valve #8 in the circuit and the handle of valve #7 shifted to the left, oil from the pump is directed to the rod end of cylinder #13, P to A. Discharged oil from the cap end of the cylinder is blocked at valve #8 which is set to open at a pressure slightly higher than that generated by the load. Thus, an additional force is needed to open valve #8 and permit the load to be lowered.

continued



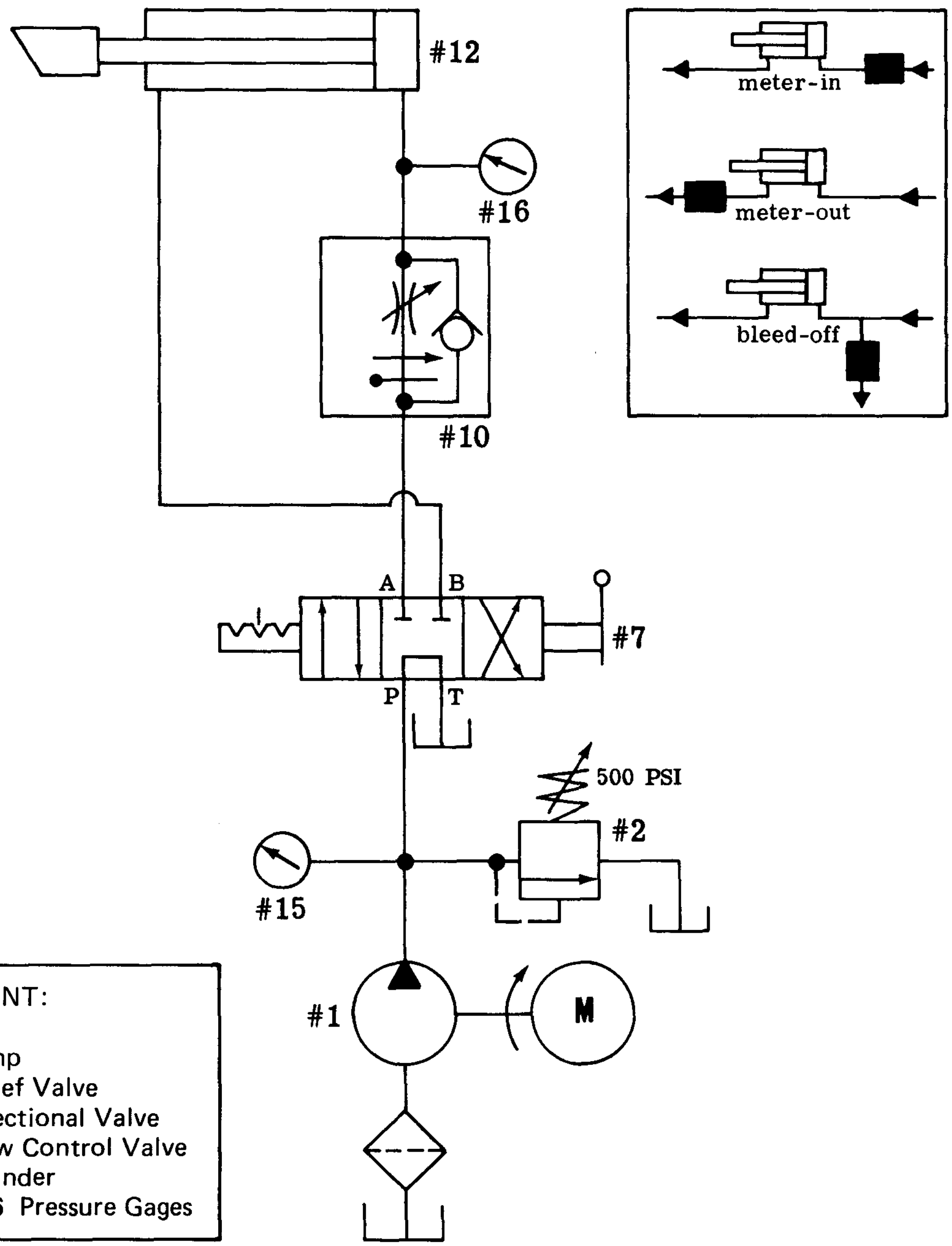
As more oil is directed to the rod end of the cylinder, pressure will build up and cause valve #8 to open. So long as the pump maintains pressure on the rod end of the cylinder, valve #8 will remain open, allowing the cylinder to be forced down under positive control. A check valve in valve #8 permits unrestricted flow from the pump to the cap end of the cylinder when it is being raised (i. e., valve #7 shifted right).

Assume, briefly, that counterbalance valve #8 is omitted from the circuit. With valve #7 in the neutral position, the blocked cylinder ports would support any load that could be raised. However, if the handle of valve #7 was shifted to the left, the oil discharged from the cap end of the cylinder could flow freely back to the reservoir through valve #7, B to T, allowing the load to fall.

TYPE: HYDRAULIC CIRCUIT WITH SPEED CONTROL

OPERATION: EXTEND (AT CONTROLLED SPEED RATE), RAPID RETURN AND STOP

CIRCUIT NO. 6



EQUIPMENT:

- #1 Pump
- #2 Relief Valve
- #7 Directional Valve
- #10 Flow Control Valve
- #12 Cylinder
- #15 & #16 Pressure Gages

Some machining operations require that the workpiece, or tool, move at a controlled feed rate. The temperature and pressure compensated flow control valve #10 in this circuit has been installed to meter oil into cylinder #12 to control its rate of travel. This is called a meter-in circuit and is used where the load always opposes the cylinder forward travel, as for table feeds on grinding, welding and milling machines.

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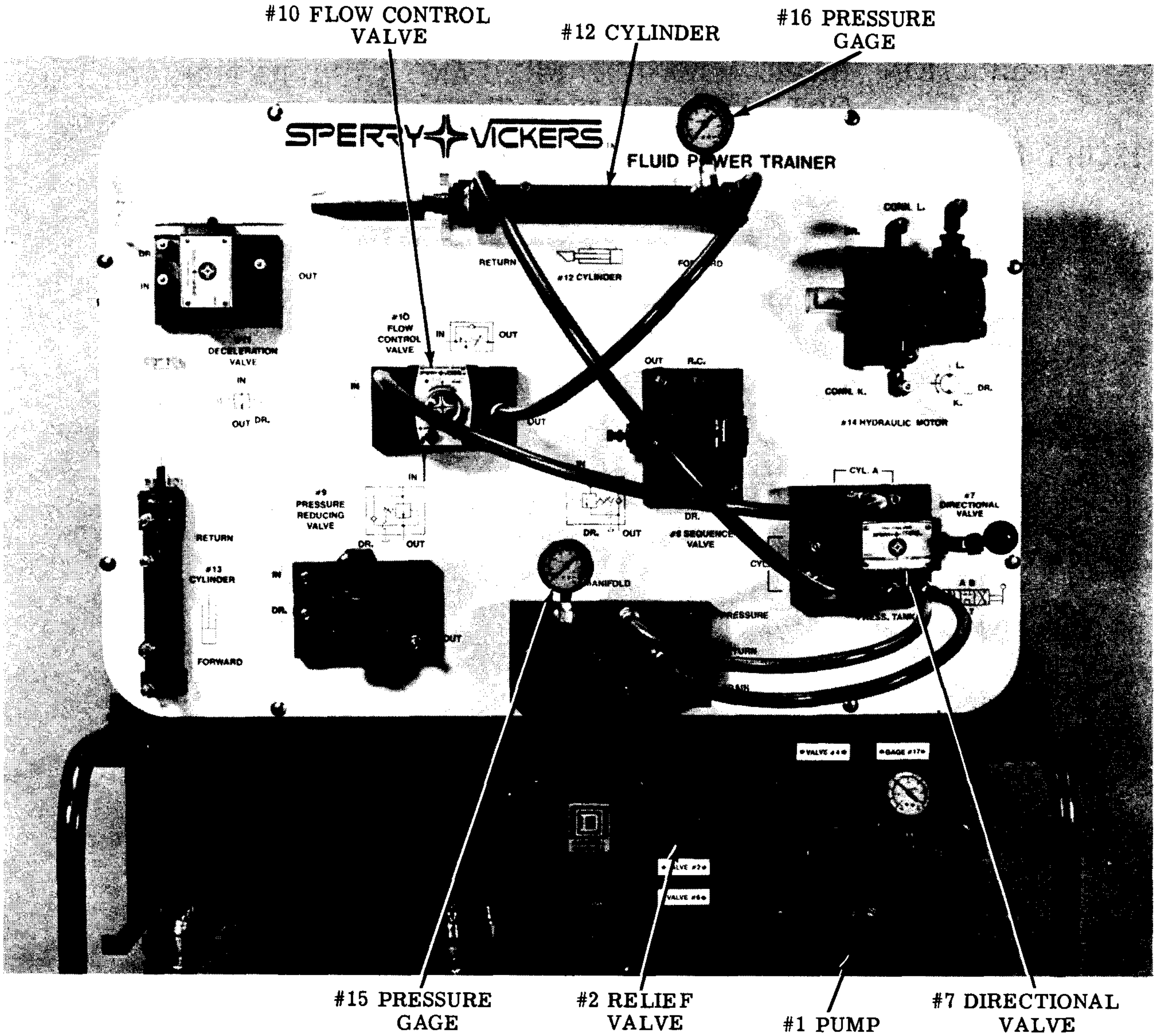


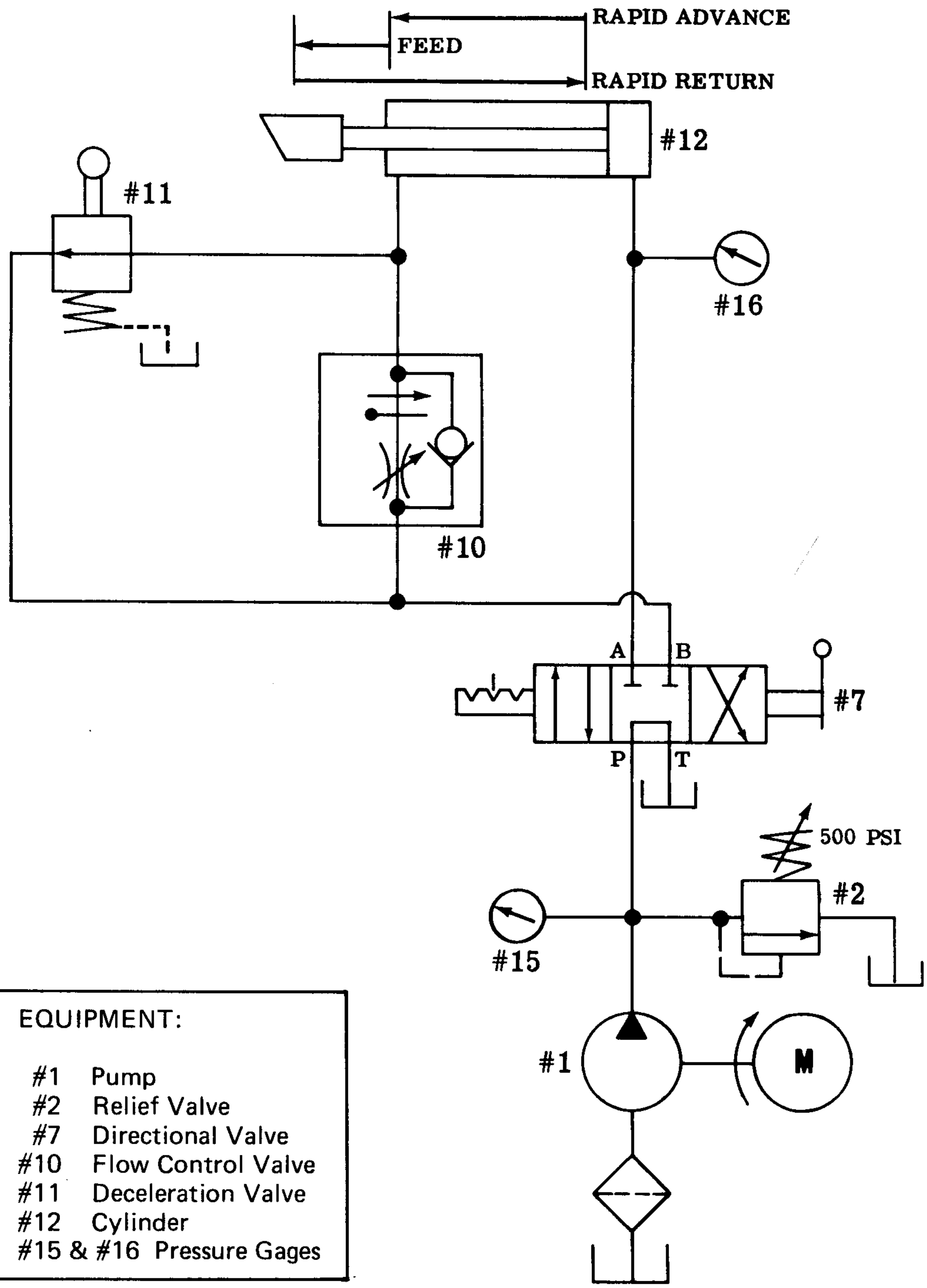
Where the load tends to "run away" or pull the cylinder, as may happen on drilling, reaming and boring machines, a meter-out circuit should be used. In this case, the flow control valve would be installed in the cylinder discharge line to meter oil from the rod end. The feed rate could never exceed that set by the flow control valve.

A third method to control rate of cylinder travel is by means of a bleed-off circuit. In this circuit, the flow control valve is teed off the pressure line between the pump and the cap end of the cylinder. Oil which is "bled off" from the main pump supply is directed back to the reservoir. Increasing the amount of oil bled off through the valve will decrease the rate of cylinder travel and vice versa. The bleed-off circuit is not as accurate as meter-in or meter-out, since the measured flow is to tank rather than to or from the cylinder.

TYPE: TRAVERSE AND FEED CIRCUIT

OPERATION: RAPID ADVANCE, FEED AND RAPID RETURN (METER-OUT FLOW CONTROL WITH DECELERATION)

CIRCUIT NO. 7



EQUIPMENT:

#1	Pump
#2	Relief Valve
#7	Directional Valve
#10	Flow Control Valve
#11	Deceleration Valve
#12	Cylinder
#15 & #16	Pressure Gages

A typical machine tool operating sequence involves rapid advance of the tool to the work, changeover to a slower feed speed, then rapid return to the starting position. Rapid advance and return motions help to increase machine productivity. In this circuit, with directional valve #7 shifted to the

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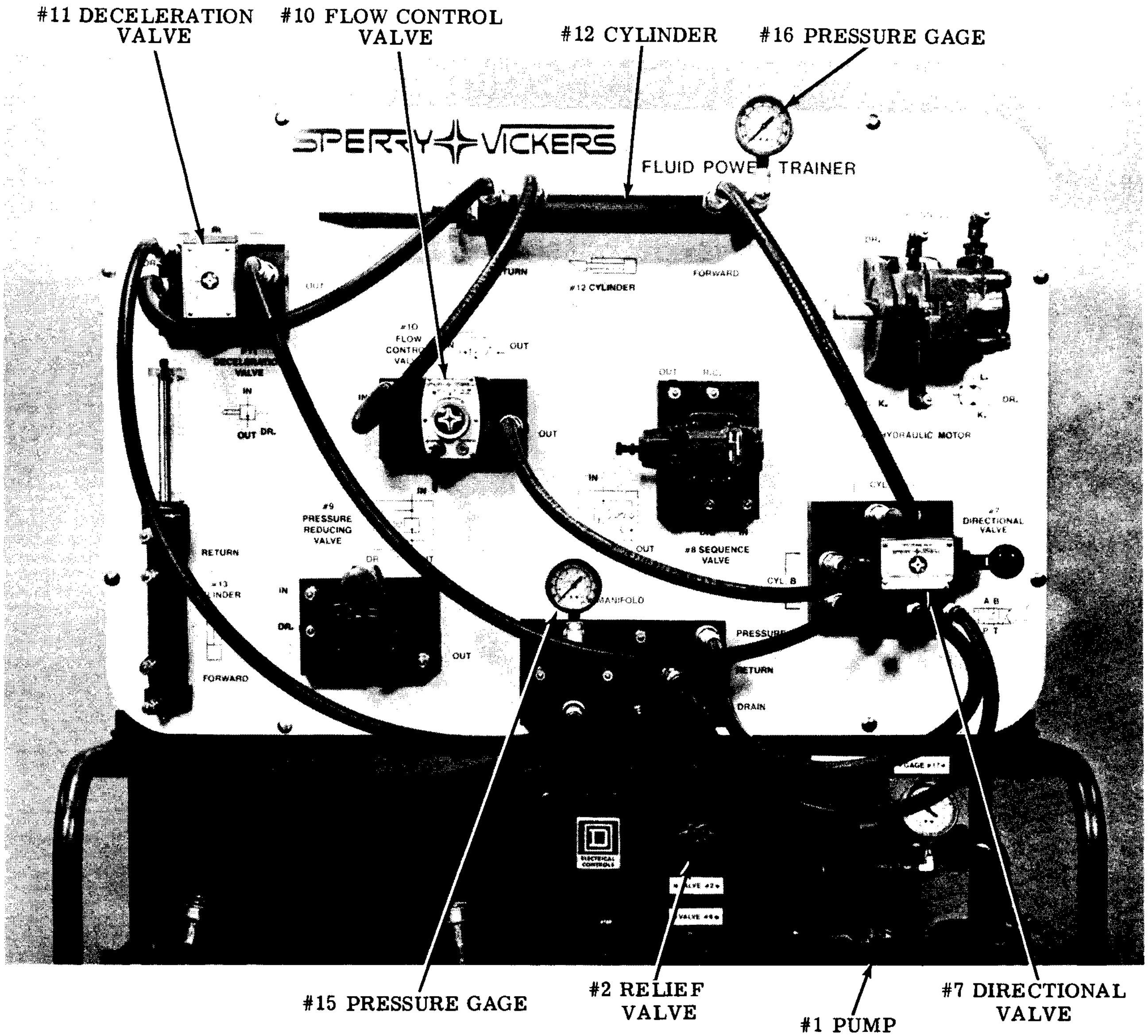
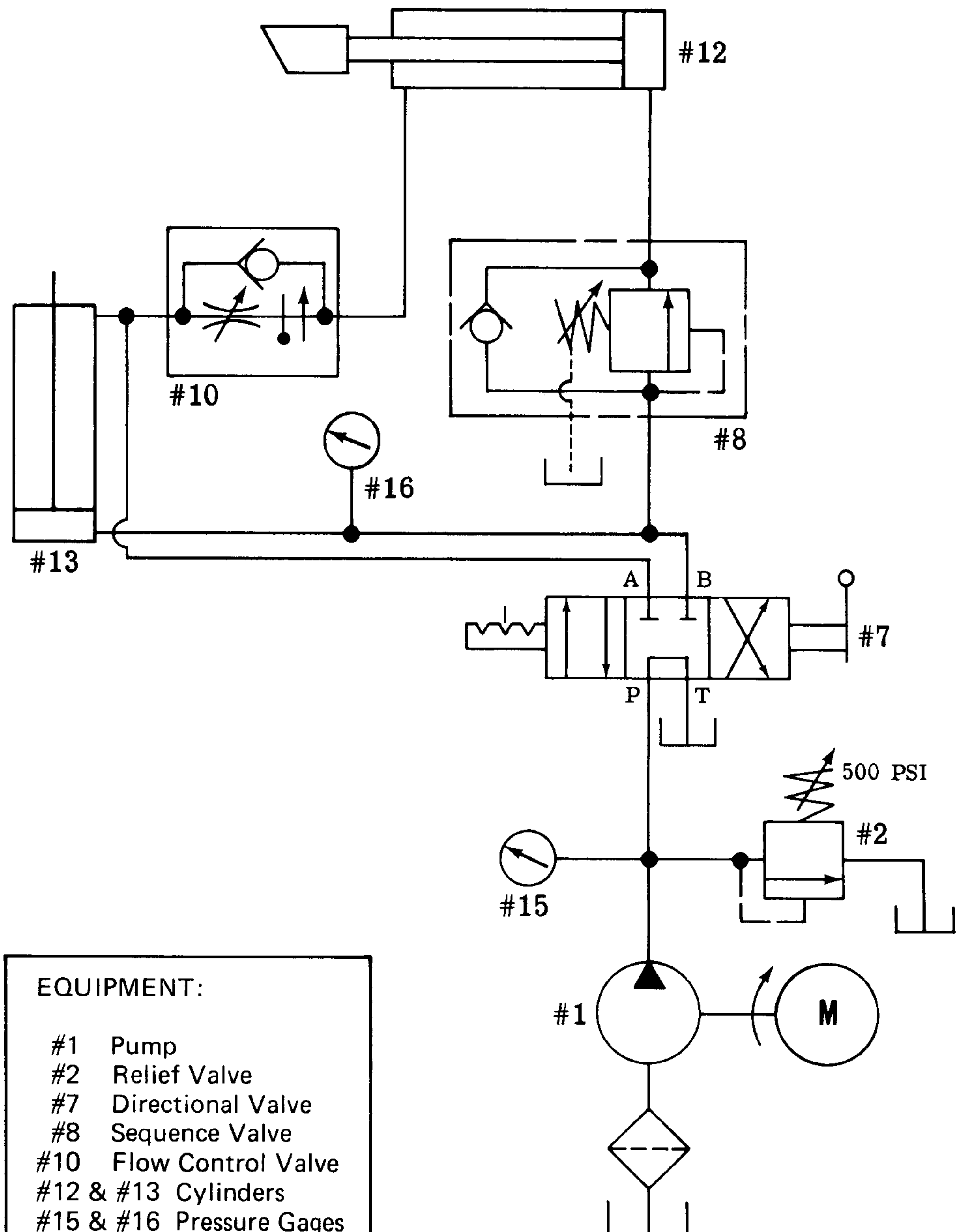


left, the meter-out flow control #10 is by-passed by the cam-operated shut-off valve (deceleration valve #11) during the rapid advance portion of the cycle. When the cam actuates valve #11, oil from cylinder #12 must pass through flow control valve #10. Feed rate can be adjusted at this valve. When valve #7 is shifted to the right, oil flows through the integral check valve in valve #10 and to the rod end of the cylinder, permitting rapid return.

TYPE: SEQUENCING CIRCUIT WITH SPEED CONTROL

OPERATION: TO HAVE ONE OPERATION OCCUR BEFORE ANOTHER, AND TO HAVE ADJUSTABLE SPEED IN THE SECOND OPERATION ONLY

CIRCUIT NO. 8



EQUIPMENT:

- #1 Pump
- #2 Relief Valve
- #7 Directional Valve
- #8 Sequence Valve
- #10 Flow Control Valve
- #12 & #13 Cylinders
- #15 & #16 Pressure Gages

In addition to controlling the sequencing of two cylinders, it may be necessary to control the rate of travel of one of them. Assuming in this circuit that cylinder #13 is to be used for clamping, sequence valve #8 assures that

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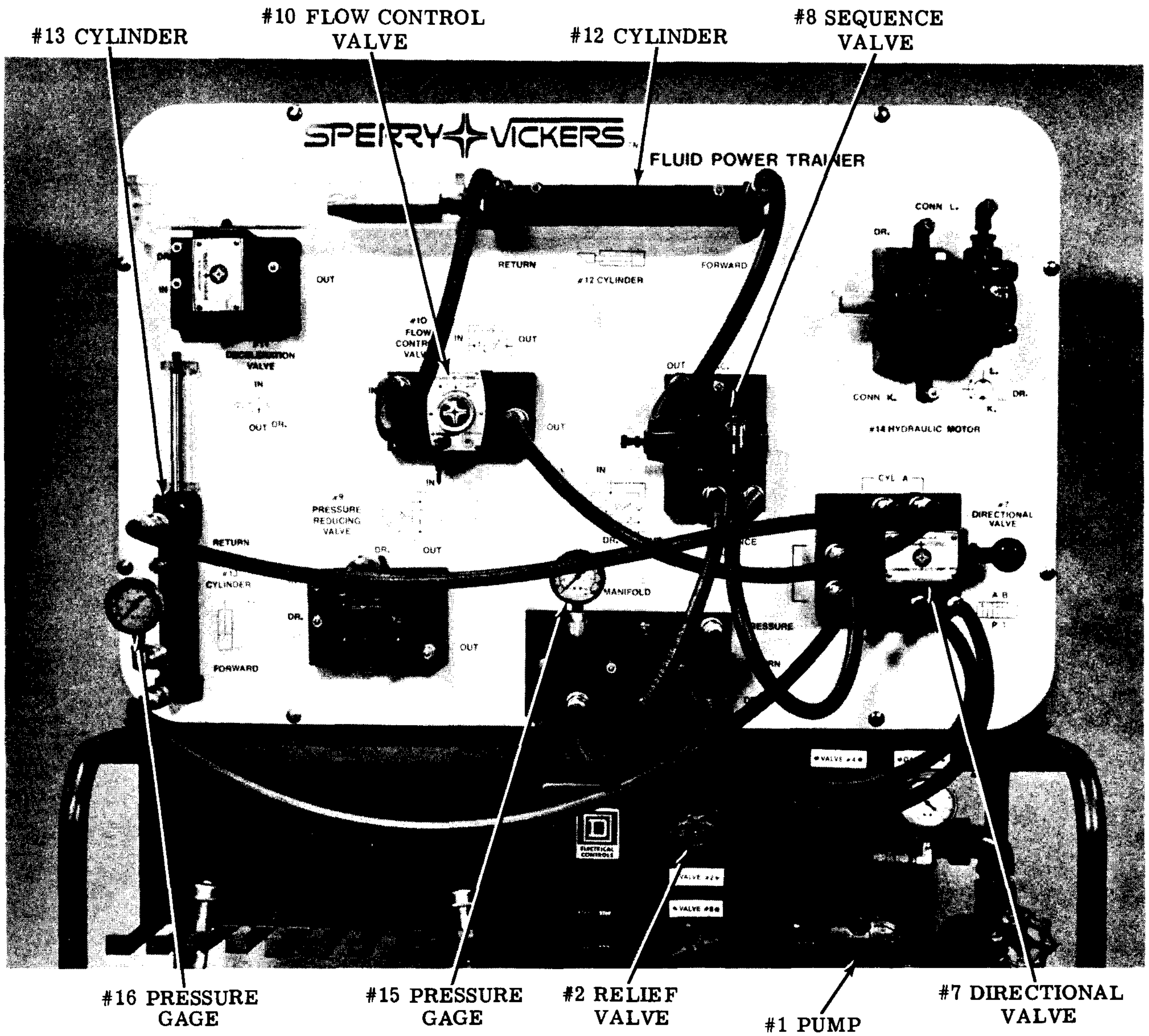


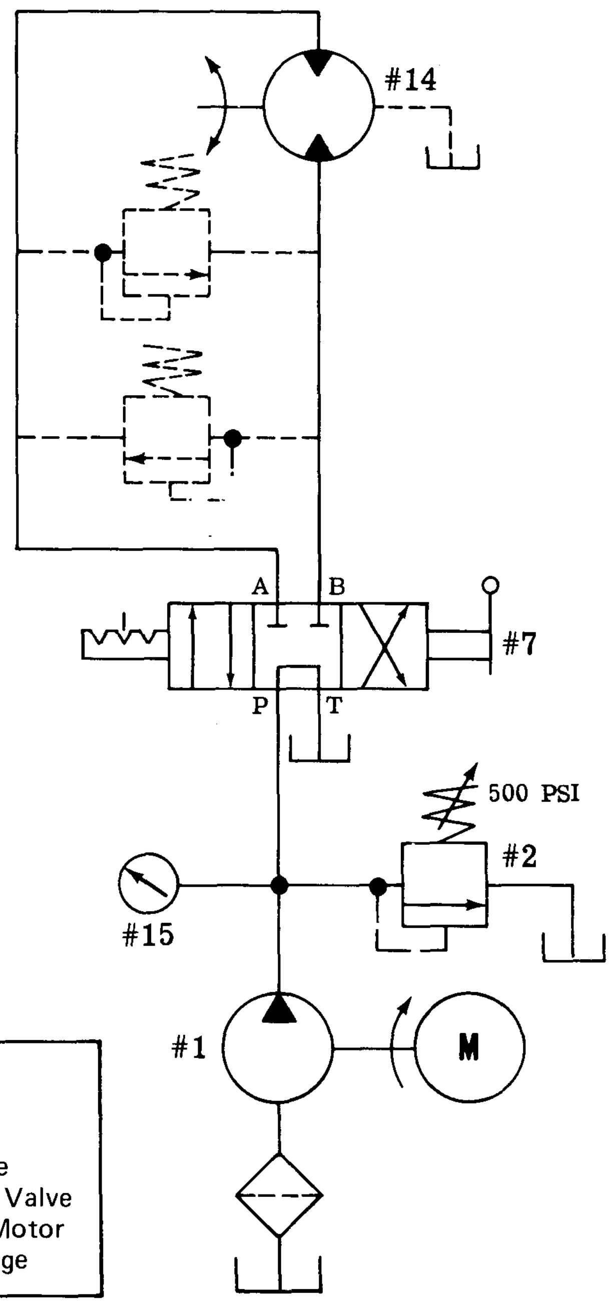
it will move first, when valve #7 is shifted to the right. When pressure in the cap end of cylinder #13 exceeds the spring setting of valve #8, the valve will open and admit oil to the cap end of cylinder #12.

The forward speed of cylinder #12 can be regulated by flow control valve #10 located in the discharge line in a meter-out arrangement. When valve #7 is shifted left, integral check valves in valves #8 and #10 permit both cylinders to return at maximum speed.

TYPE: BASIC HYDRAULIC CIRCUIT (ROTARY MOTION)

OPERATION: TO PROVIDE REVERSIBLE ROTATION AND STOPPING OF HYDRAULIC MOTOR SHAFT

CIRCUIT NO. 9



EQUIPMENT:

#1 Pump
#2 Relief Valve
#7 Directional Valve
#14 Hydraulic Motor
#15 Pressure Gage

Where rotary motion is required, a hydraulic motor is used instead of a cylinder. In this circuit, directional valve #7 permits hydraulic motor #14 to rotate in either direction, but prevents motor rotation when in the neutral position. Where a high inertia load on the motor shaft could cause excessive

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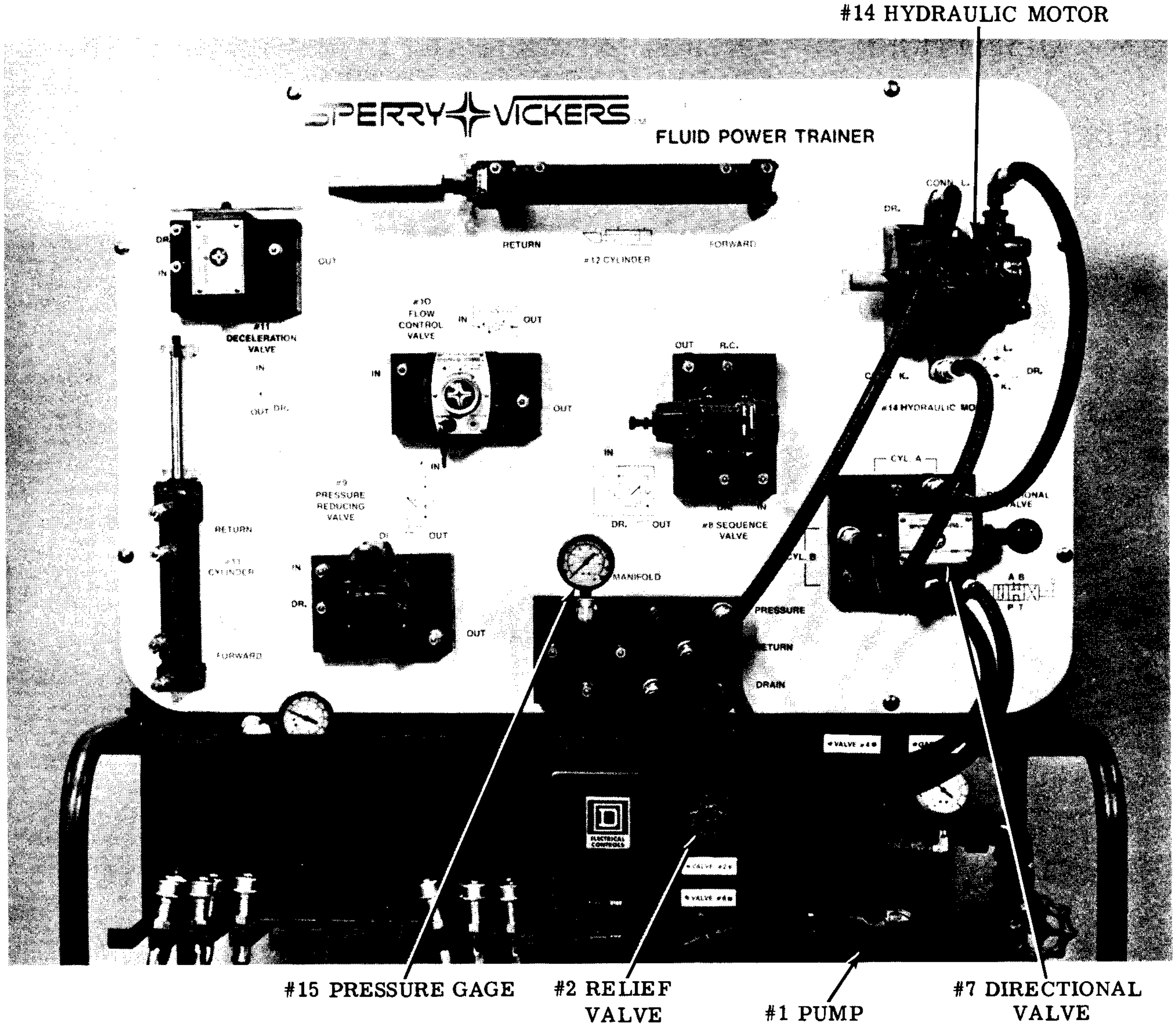
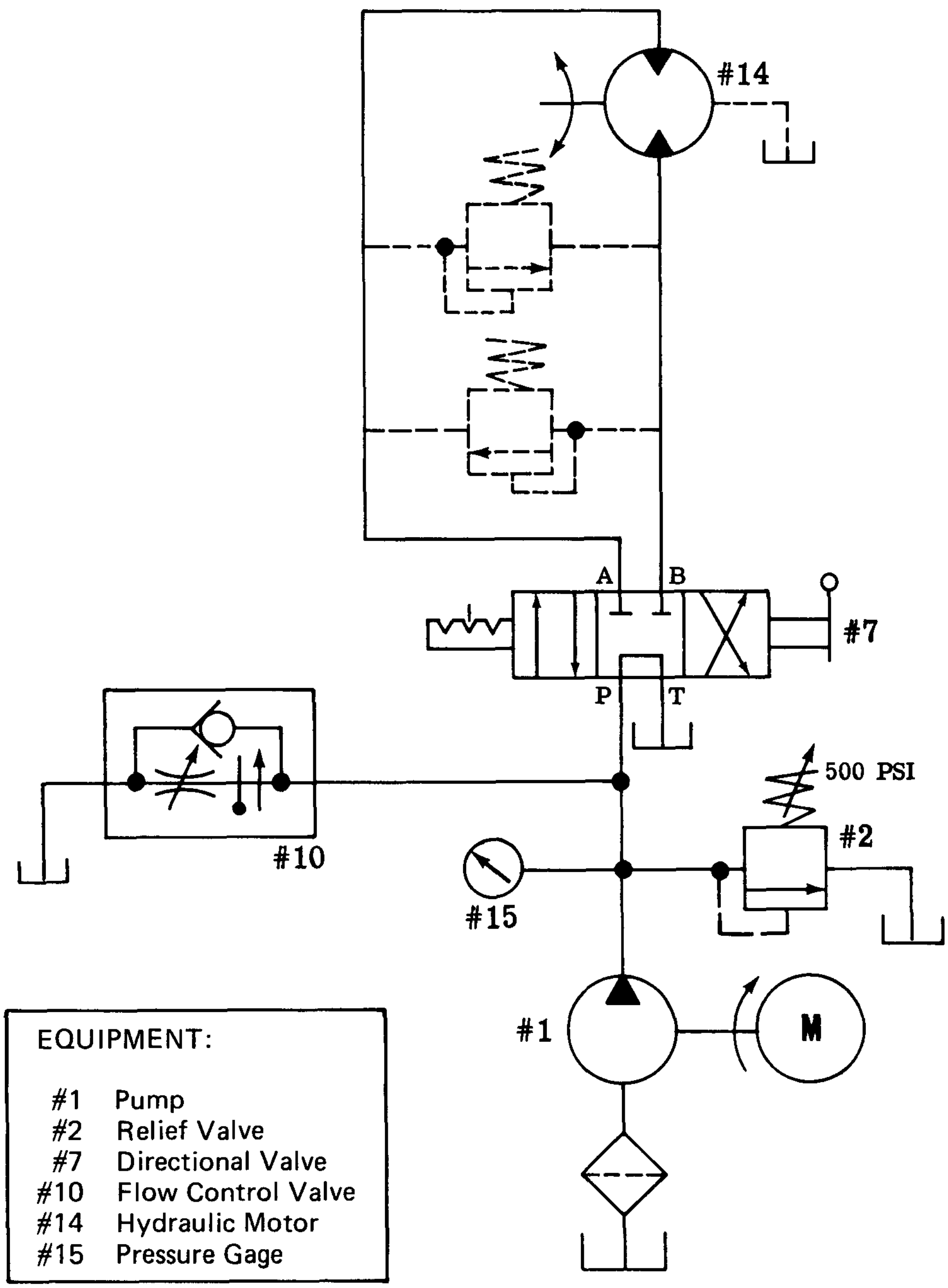


pressure build-up when the directional valve is shifted to neutral position for stopping, some means of overload protection may be required. Cross-line relief valves are often used for this purpose. Although not provided on the trainer, they are indicated in the circuit drawing by dotted lines.

TYPE: HYDRAULIC ROTARY DRIVE WITH SPEED CONTROL

OPERATION: TO CONTROL MOTOR SPEED IN EITHER DIRECTION WITH BLEED-OFF FLOW CONTROL

CIRCUIT NO. 10



In this circuit, speed regulation of hydraulic motor #14 is accomplished through the use of flow control valve #10. Bleeding off fluid from the supply line permits the pump to operate at the pressure required to drive the motor and controls speed in both directions. It would not, however, control over-

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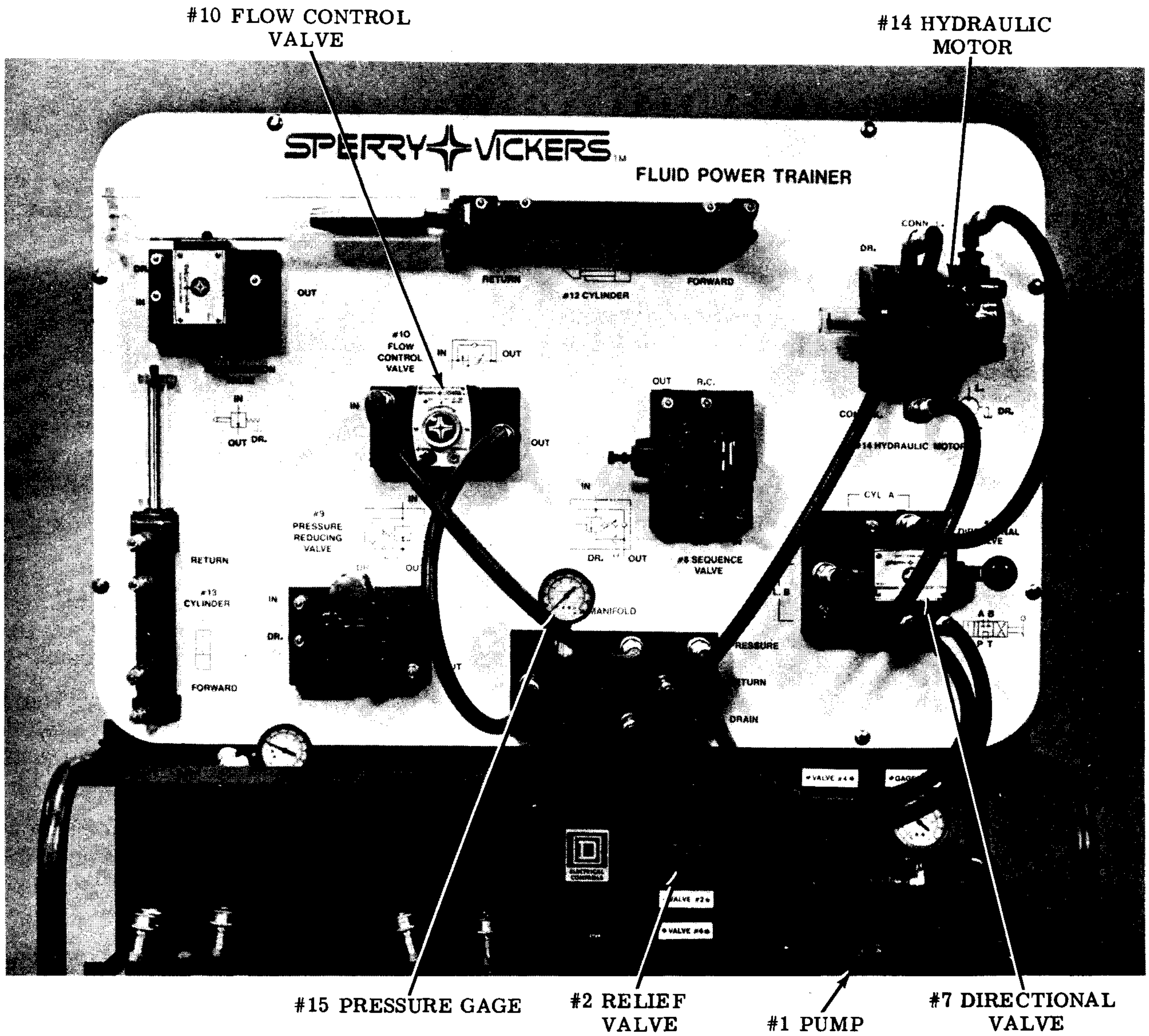

speeding in the event of an overhauling load. Should this be a problem, a meter-out circuit could be used; that is, one in which a flow control and check valve would be installed between the hydraulic motor and the directional valve.

DEFINITIONS OF TERMS

A

ACCUMULATOR—A container which stores fluids under pressure as a source of hydraulic power. It may also be used as a shock absorber.

ACTUATOR—A device which converts hydraulic power into mechanical force and motion. (Examples: hydraulic cylinders and motors.)

B

BLEED—The process by which air is removed from a hydraulic system.

BYPASS—A secondary passage for fluid flow.

C

CAVITATION—Air pockets in the oil circuit (as at the pump inlet).

CIRCUIT—A series of component parts connected to each other by fluid lines or passages. Usually part of a "system."

CLOSED CENTER SYSTEM—A hydraulic system in which the control valves are closed during neutral, stopping oil flow. Flow in this system is varied, but pressure remains constant.

COOLER (Oil)—A heat exchanger which removes heat from a fluid. (See "Heat Exchanger.")

CUSHION—A device sometimes built into the end of a cylinder which restricts outlet flow and thereby slows down the piston.

CYCLE—A single complete operation of a component which begins and ends in a neutral position.

CYLINDER—A device for converting fluid power into linear or circular motion. An "actuator". Basic design types include piston and vane units.

Double-Acting Cylinder—A cylinder in which fluid force can be applied to the movable element in either direction.

Piston-Type Cylinders—A cylinder which uses a sliding piston in a housing to produce straight movement.

Rotary Cylinders—A cylinder in which fluid force is applied to produce circular motion.

Single-Acting Cylinder—A cylinder in which fluid force can be applied to the movable element in only one direction.

Vane-Type Cylinder—A cylinder which uses a turning vane in a circular housing to produce rotary movement.

D

DISPLACEMENT—The volume of oil displaced by one complete stroke or revolution (of a pump, motor, or cylinder).

DRIFT—Motion of a cylinder or motor due to internal leakage past components in the hydraulic system.

E

ENERGY—Three types of energy are available in modern hydraulics (of the normal hydrostatic type):

1. *Potential Energy*—Pressure energy. The *static* energy of oil which is standing but is pressurized and ready to do work. Example: oil in a loaded accumulator.

2. *Heat Energy*—Friction or resistance to flow. (An energy *loss* in terms of output.) Example: friction between moving oil and the confines of lines or passages produces heat energy.

3. *Kinetic Energy*—The energy of the moving liquid. Varies with the velocity (speed) of the liquid.

F

FILTER (OIL)—A device which removes solids from a fluid.

FLOW METER—A testing device which gauges either flow rate, total flow, or both.

FLOW RATE—The volume of fluid passing a point in a given time.

FLUID POWER—Energy transmitted and controlled through use of a pressurized fluid.

FORCE—A push or pull acting upon a body. In a hydraulic cylinder, it is the product of the pressure on the fluid, multiplied by the effective area of the cylinder piston. It is measured in pounds or tons.

FRICTION—The resistance to fluid flow in a hydraulic system. (An energy loss in terms of power output.)

H

HEAT EXCHANGER—A device which transfers heat through a conducting wall from one fluid to another. (See "Cooler, (Oil)".)

HORSEPOWER — The work produced per unit of time.

HOSE—A flexible line.

HYDRAULICS—The engineering science of liquid pressure and flow. (In this manual, our main interest is in *oil* hydraulics as applied to produce work in linear and rotary planes.)

Hydrodynamics—The engineering science of the *energy* of liquid pressure and flow.

Hydrostatics—The engineering science of the energy of liquids *at rest*. (All the systems covered in this manual operate on the *hydrostatic* principle.)

L

LINE—A tube, pipe, or hose for conducting a fluid.

M

MANIFOLD—A fluid conductor which provides many ports.

MOTOR (Hydraulic)—A device for converting fluid energy into mechanical force and motion—usually rotary motion. Basic design types include gear, vane, and piston units.

O

OPEN CENTER SYSTEM—A hydraulic system in which the control valves are open to continuous oil flow, even in neutral. Pressure in this system is varied, but flow remains constant.

ORIFICE—A restricted passage in a hydraulic circuit. Usually a small drilled hole to limit flow or to create a pressure differential in a circuit.

P

PACKING—Any material or device which seals by compression. Common types are U-packings, V-packings, "Cup" packings, and O-rings.

PIPE—A line whose outside diameter is standardized for threading.

PISTON—A cylindrical part which moves or reciprocates in a cylinder and transmits or receives motion to do work.

PORT—The open end of a fluid passage. May be within or at the surface of a component.

POUR POINT—The lowest temperature at which a fluid will flow under specific conditions.

POWER BEYOND—An adapting sleeve which opens a passage from one circuit to another. Often installed in a valve port which is normally plugged.

PRESSURE—Force of a fluid per unit area, usually expressed in pounds per square inch (psi).

Back Pressure—The pressure encountered on the return side of a system.

Breakout Pressure—The minimum pressure which starts moving an actuator.

Cracking Pressure—The pressure at which a relief valve, etc., begins to open and pass fluid.

Differential Pressure—The difference in pressure between any two points in a system or a component. (Also called a "pressure drop.")

Full-Flow Pressure—The pressure at which a valve is wide open and passes its full flow.

Operating Pressure—The pressure at which a system is normally operated.

Pilot Pressure—Auxiliary pressure used to actuate or control a component.

Rated Pressure—The operating pressure which is recommended for a component or a system by the manufacturer.

Static Pressure—The pressure in a fluid at rest. (A form of "potential energy.")

Suction Pressure—The absolute pressure of the fluid at the inlet side of the pump.

Surge Pressure—The pressure changes caused in a circuit from a rapidly accelerated column of oil. The "surge" includes the span of these changes, from high to low.

System Pressure—The pressure which overcomes the total resistances in a system. It includes all losses as well as useful work.

Working Pressure—The pressure which overcomes the resistance of the working device.

PULSATION—Repeated small fluctuation of pressure within a circuit.

PUMP—A device which converts mechanical force into hydraulic fluid power. Basic design types are gear, vane, and piston units.

Fixed Displacement Pump—A pump in which the output per cycle *cannot* be varied.

Variable Displacement Pump—A pump in which the output per cycle *can* be varied.

R

REGENERATIVE CIRCUIT — A circuit in which pressure fluid discharged from a component is returned to the system to reduce flow input requirements. Often used to speed up the action of a cylinder by directing discharged oil from the rod end to the piston end.

REMOTE—A hydraulic function such as a cylinder which is separate from its supply source. Usually connected to the source by flexible hoses.

RESERVOIR—A container for keeping a supply of working fluid in a hydraulic system.

RESTRICTION—A reduced cross-sectional area in a line or passage which normally causes a pressure drop. (Examples: pinched lines or clogged passages, or an orifice designed into a system.)

S

SOLENOID—An electro-magnetic device which positions a hydraulic valve.

STARVATION—A lack of oil in vital areas of a system. Often caused by plugged filters, etc.

STRAINER—A coarse filter.

STROKE—

1. The length of travel of a piston in a cylinder.

2. Sometimes used to denote the changing of the displacement of a variable delivery pump.

SURGE—A momentary rise of pressure in a hydraulic circuit.

SYSTEM—One or more series of component parts connected to each other. Often made up of two or more "circuits".

T

THERMAL EXPANSION—Expansion of the fluid volume due to heat.

TORQUE—The turning effort of a hydraulic motor or rotary cylinder. Usually given in inch-pounds (in-lbs) or foot-pounds (ft-lbs).

TUBE—A line whose size is its outside diameter.

V

VALVE—A device which controls either 1) pressure of fluid, 2) direction of fluid flow, or 3) rate of flow.

Bypass Flow Regulator Valve—A valve which regulates the flow to a circuit at a constant volume, dumping excess oil.

Check Valve—A valve which permits flow in only one direction.

Closed Center Valve—A valve in which inlet and outlet ports are closed in the neutral position, stopping flow from pump.

Directional Control Valve—A valve which directs oil through selected passages. (Usually a spool or rotary valve design.)

Flow Control Valve—A valve which controls the rate of flow. (Sometimes called a "volume control valve.")

Flow Divider Valve—A valve which divides the flow from one source into two or more branches. (Includes "priority" and "proportional" types.)

Needle Valve—A valve with an adjustable tapered point which regulates the rate of flow.

Open Center Valve—A valve in which the inlet and outlet ports are open in the neutral position, allowing a continuous flow of oil from pump.

Pilot Valve—A valve used to operate another valve or control.

Pilot Operated Valve—A valve which is actuated by a pilot valve.

Poppet Valve—A valve design in which the seating element pops open to obtain free flow in one direction and immediately reseats when flow reverses.

Pressure Control Valve—A valve whose primary function is to control pressure. (Includes relief valves, pressure reducing or sequencing valves, and unloading valves.)

Pressure Reducing Valve—A pressure control valve which limits outlet pressure.

Pressure Sequence Valve—A pressure control valve which directs flow in a preset sequence.

Priority Flow Divider Valve—A valve which directs oil to one circuit at a fixed rate and dumps excess flow into another circuit.

Proportional Flow Divider Valve—A valve which directs oil to all its circuits at all times.

Relief Valve—A valve which limits the pressure in a system, usually by releasing excess oil.

Rotary Directional Valve—A valve designed in a cylindrical shape. When the valve is turned, it opens and closes drilled passages to direct oil.

Selector Valve—A valve which selects one of two or more circuits in which to direct oil, usually operated manually.

Shuttle Valve—A connecting valve which selects one of two or more circuits because of flow or pressure changes in these circuits.

Shutoff Valve—A valve which operates fully open or fully closed.

Spool Directional Valve—A valve designed as a spool which slides in a bore, opening and closing passages.

Thermal Relief Valve—A valve which limits the pressure in a system caused by heat expansion of oil.

Two-, Three-, Four-, or Six-Way Valve—A valve having 2, 3, 4, or 6 ports for direction of oil flow.

Unloading Valve—A valve which allows a pump to operate at minimum load by dumping the pump's excess oil at a low pressure.

Volume Control Valve—A valve which controls the rate of flow. Includes flow control valves, flow divider valves, and bypass flow regulators.

V

VALVE STACK—A series of control valves in a stack with common end plates and a common oil inlet and outlet.

VELOCITY—The *distance* which a fluid travels per unit time. Usually given as feet per second.

VENT—An air breathing device in a fluid reservoir.

VISCOSITY—The measure of resistance of a fluid to flow.

VOLUME—The amount of fluid flow per unit time. Usually given as gallons per minute (gpm).

ABBREVIATIONS

ASAE—American Society of Agricultural Engineers (sets standards for many hydraulic components for agricultural use)

°F—degrees Fahrenheit (of temperature)

ft-lbs—foot-pounds (of torque or turning effort)

gpm—gallons per minute (of fluid flow)

hp—horsepower

I.D.—inside diameter (as of a hose or tube)

O.D.—outside diameter (as of a hose or tube)

psi—pounds per square inch (of pressure)

rpm—revolutions per minute

SAE—Society of Automotive Engineers (sets standards for many hydraulic components)

NOTES

NOTES