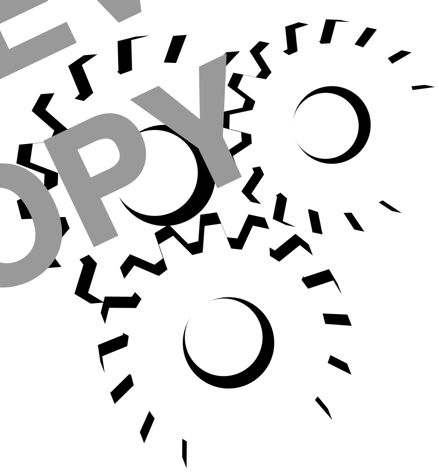
Hydraulic Troubleshooting

Table of Contents

HYDRAULIC TROUBLESHOOTING

Lesson One

Hydraulic Systems



TPC Training Systems

30801

Lesson

1 Hydraulic Systems

TOPICS

Hydraulic Systems
Pumps and Their Drive Units
Actuators
Control Valves
Conductors and Connectors
Hydraulic Fluids
Fluid Storage and Conditioning Equipment
Tracing the system
Getting to Know the System
Circuit and System Diagrams
Cutaway Drawings
Mechanical Setup
Understanding Components
Convertible Components
System Operation

OBJECTIVES

After studying this Lesson, you should be able to…

- Name the six basic elements of a hydraulic system.
- Explain the functions of hydraulic pumps, actuators, control valves, conductors and connectors, hydraulic fluid, and fluid storage and conditioning equipment.
- Describe how to trace a system.

KEY TECHNICAL TERMS

Actuator 1.06 a device at the output end of the hydraulic system that converts hydraulic power into mechanical power

Directional control 1.08 a valve that directs the path of fluid flow in the system

Flow control 1.08 a valve that controls actuator speed

Pressure control 1.08 a valve that limits hydraulic pressure

Conductor 1.09 pipe or tubing that carries the hydraulic fluid through which power is transmitted

Connector 1.09 fitting used to connect pipe or tube sections

Hydraulic fluids 1.10 blends of oils and additives

Reservoir 1.12 container where the hydraulic fluid is stored

To troubleshoot hydraulic systems, you must have a thorough knowledge of the system and the hydraulic process. With that knowledge, you will soon find it easy to determine what went wrong. Even more important, you will know what to look for during routine maintenance inspections to prevent trouble and breakdowns.

This Lesson explains how to recognize the elements of a hydraulic system and how to blend your knowledge of the individual components into a comprehensive knowledge of the entire system.

Hydraulic Systems

1.01 Hydraulic systems transmit power from one point to another. The power or energy needed to operate a machine is usually provided by an electric motor or an internal combustion engine. But, because these power sources do not always deliver their power output in a directly usable form, hydraulic systems convert the available power to usable power at the location where it is required. Consider, for instance, how much mechanical linkage would be required to provide straight-line motion to a component located 15 or 20 feet away from a rapidly rotating motor shaft. The same job is easily accomplished with hydraulics.

1.02 Almost every type of machine built today already has hydraulic equipment or can use hydraulics to power its motions. You are probably aware of several hydraulic systems in the plant.

1.03 Hydraulic equipment may seem complicated and unfamiliar at first. This may be true even if you already have made successful repairs to a hydraulic system. To understand how a hydraulic system operates, much of what you will study in this Lesson requires that you trace or follow the path of fluid flow from one component to the next, until you have traced the entire circuit or path through the system.

1.04 All hydraulic systems include six basic elements or groups of components:

- pumps and their drive units (power sources)
- actuators
- control valves
- conductors and connectors
- hydraulic fluid
- fluid storage and conditioning equipment.

Pumps and Their Drive Units

1.05 The pump drive unit is usually either an electric motor or an internal combustion engine. The drive unit, motor or engine, provides rotary motion and torque to turn the pump. The pump converts the mechanical energy input to hydraulic energy output.

Actuators

1.06 At the output end of the hydraulic system, *actuators* convert the hydraulic energy into the mechanical energy required to operate the machine. Actuators are either cylinders or fluid motors. Cylinders are used to push or pull the object to be moved.

1.07 In the case of fluid motors, the speed of the hydraulic motor can be varied to provide a variable torque or turning force even though the electric motor itself is running at a constant speed. Hydraulic motor systems operate in much the same way as a gearbox transmission, except that with hydraulics you do not need to shift gears.

Control Valves

1.08 There are three basic types of control valves: directional controls, flow controls, and pressure controls:

- *Directional controls* direct the path of fluid flow in the system.The fluid flow in turn controls the direction of actuator motion. For example, a directional control valve may be used to retract, extend, or stop a cylinder.

- *Flow controls* are used to control actuator speed—fast, slow, or moderate. They do so by limiting the volume of fluid flow.

- *Pressure controls* are used to limit hydraulic pressure. They control the force applied to an actuator. This can be the amount of force pushing or pulling a cylinder, or the amount of torque from a fluid motor.

Conductors and Connectors

1.09 *Conductors* are the pipes and tubes that carry the hydraulic fluid through which power is transmitted. *Connectors* are the fittings used to join the pipe or tube sections together, or to connect them to components such as pumps, valves, and actuators. Although conductors are extremely important, often they are not given proper attention. Pipe or tube that is too small can restrict fluid flow and rob the system of hydraulic power. Poorly fitted systems leak, creating maintenance problems and safety hazards. Leaks also decrease power.

Hydraulic Fluids

1.10 Most hydraulic fluids are carefully selected blends of oils and additives. For safety reasons, many hydraulic fluids are made fire-resistant for the areas where they are used. Many fire-resistant hydraulic fluids are formulated with glycols or a highly controlled water content. Other fire-resistant fluids are made of chlorinated hydrocarbons, generally referred to as phosphate-ester fluids.

1.11 Fluid acts as the carrier of hydraulic power through the system, but it also serves the important function of lubricating the hydraulic equipment. Poor lubrication causes many breakdowns and maintenance problems. Use of good fluid is one of the maintenance man's best hydraulic maintenance tools. (Hydraulic fluids are covered in a later Lesson.)

Fluid Storage and Conditioning Equipment

1.12 The container where the fluid is stored is properly referred to as a *reservoir* (or reserve fluid chamber). Some people use the expression "hydraulic tank." A good reservoir is actually much more than a tank, because it also cleans and cools the fluid during system operation.

1.13 *Fluid-conditioning equipment* is a broad category that includes filters for cleaning the system during operation, coolers to prevent fluid from overheating, and heaters to prevent damage to the system under cold start-up conditions.

Tracing the System

1.14 If you have ever stood next to a hydraulically operated machine and wondered how the hydraulic system worked, you are not alone. Even the experts would find themselves confused if it were not for hydraulic diagram. Diagrams are the most important key to understanding hydraulic systems.

1.15 Hydraulic diagrams come in many forms: block-type, outline drawings, pictorial or cutaway views, schematic, or various combinations of these. In some cases you may have schematic diagrams of the system, but pictorial or cutaway views of each component are also available. (Diagrams, symbols, and the interpretation of drawings are covered in Lesson Two.)

Getting to Know the System

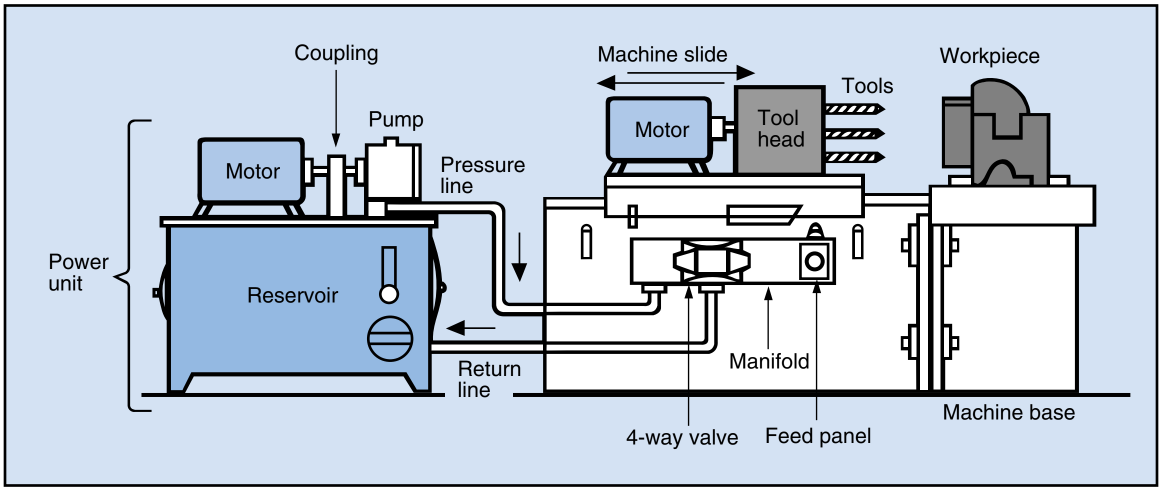
1.16 The first thing to do is to understand the operation of the basic machine or piece of equipment on which the system is installed. As an example, consider a basic machine tool used for drilling, counterboring, and similar operations (see Fig. 1-1). This machine has a hydraulic drive to feed the tools into the workpiece and retract the tool head for the next job.

1.17 The machine is basically a drill-slide unit that has a hydraulic power unit mounted alongside it. Some of the hydraulic components are on the power unit and others are on the machine itself. In each case, important hydraulic elements are out of sight—some in the power unit, and some in the machine.

1.18 In Fig. 1-2 you can see one of the hydraulic elements that is not visible in Fig. 1-1: the cylinder inside the machine base. This hydraulic circuit is referred to as a "machine tool traverse and feed circuit."

1.19 The hydraulic cylinder drive is used to move and position the tool head on the machine. When the

Fig. 1-1. Typical hydraulic power installation



machine is at rest, the cylinder retracts the slide. When actuated, the cylinder extends rapidly (rapid traverse) to move the tools toward the workpiece. The drive speed is then reduced (often referred to as "slowdown") to the slow speed used for cutting (feed rate). The slow speed is maintained until the cut is finished. Then the tools are rapidly returned to their starting position where they wait for another work cycle. This waiting period is referredto as "dwell."

1.20 During these operations, hydraulic fluid flow and pressure provide the motion and necessary force to move the slide and feed the tools into the workpiece.

Circuit and System Diagrams

1.21 Using diagrams, you can now look at the entire hydraulic system and several of its elements in more detail. Figure 1-3 on the following page is a block diagram of the system. From the diagram, you can get an idea of how the system works and what its primary components are.

1.22 To learn even more about the system, a schematic diagram can be studied. Figure 1-4 on the following page is a schematic diagram of the circuit, using JIC (Joint Industry Conference) symbols. The four-way valve diagram has been expanded to show that it is actually two valves. One small,

Fig. 1-2. Position of the actuating cylinder in the machine

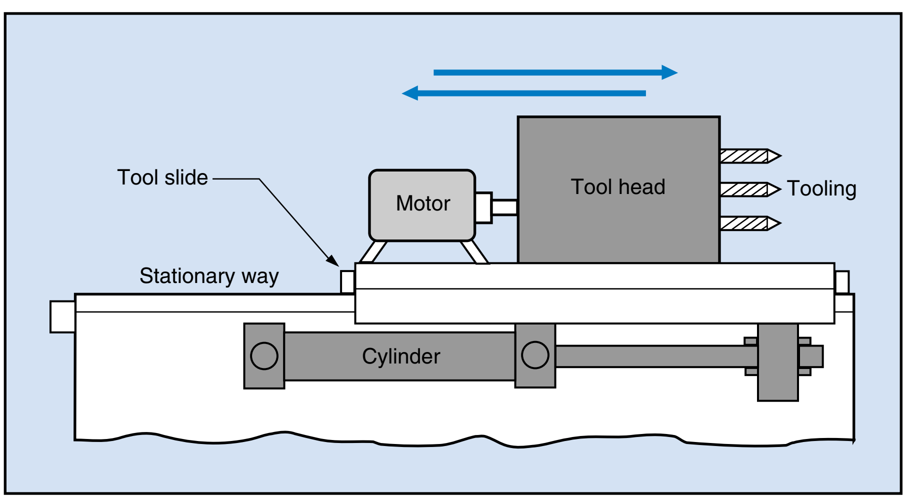
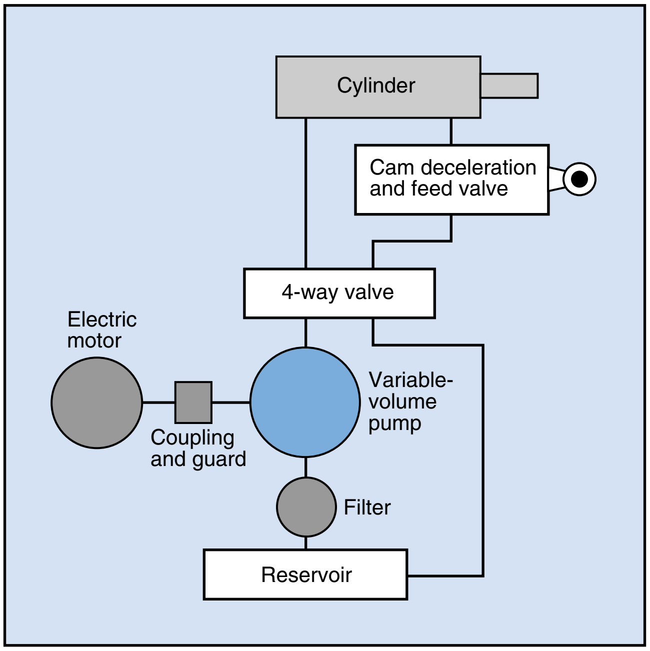


Fig. 1-3. Block diagram of a hydraulic system



solenoid-operated pilot valve directs hydraulic pressure and flow from Port P to the appropriate pilot operator of the main valve, as shown. This shifts the main valve, which controls the cylinder through ports A and B. You can see that a small, separate hydraulic circuit is included in the four-way valve. This is important to know because circuits-within-circuits are often found in hydraulic system.

Cutaway Drawings

1.23 A cutaway or pictorial drawing of the system similar to the one in Fig. 1-9 on page 14 is the kind of drawing that every maintenance craftsman wishes he had for every circuit he works on. In actual practice, you will find fewer cutaway drawings than any other type of diagram. This is true simply because the detailed drawing of all of these units requires many hours of drafting time, which in turn costs money. However, you will generally find that component manufacturers do supply cutaway views of their pumps and valves.

1.24 By putting together a JIC diagram and cutaway drawings of components, you can readily figure out how the system functions. Note that cutaway drawings are not drawn to scale. They may use big pictures for small units to make them clear and to show inside details.

1.25 Manifolds are sometimes used to complete piping and reduce the number of lines and fittings used. A manifold is a device that has several outlets for connecting one pipe with others. A manifold also

Fig. 1-4. Schematic diagram of the system

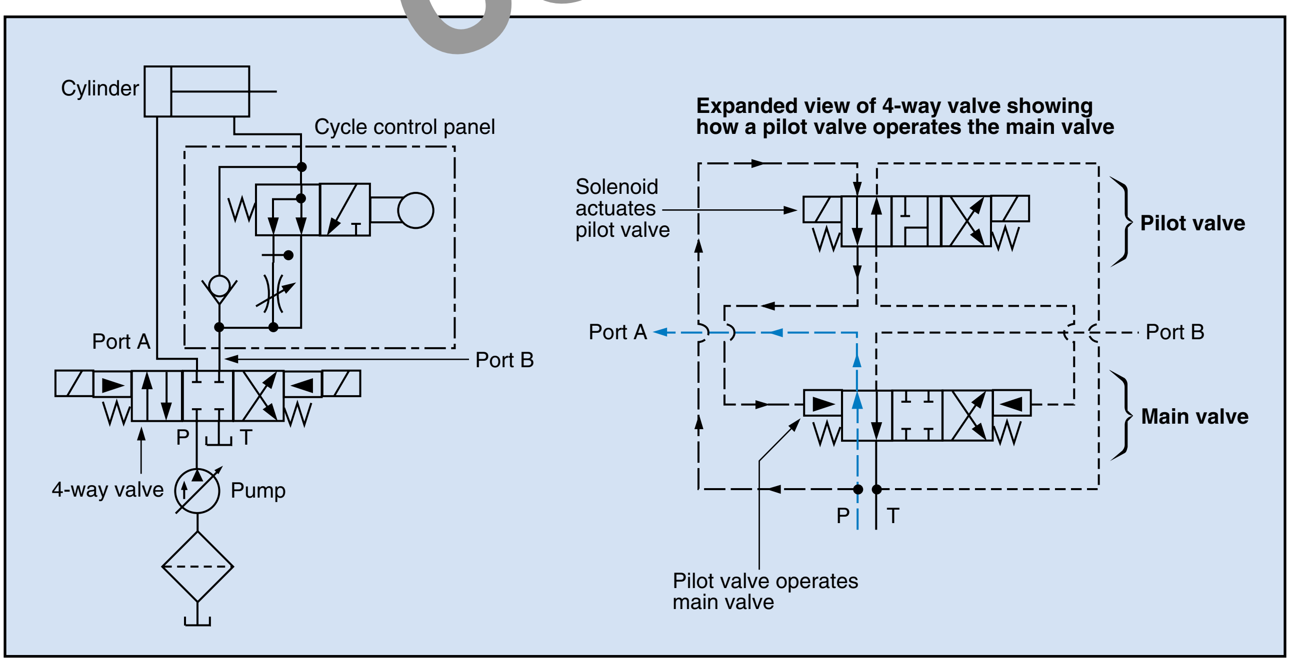
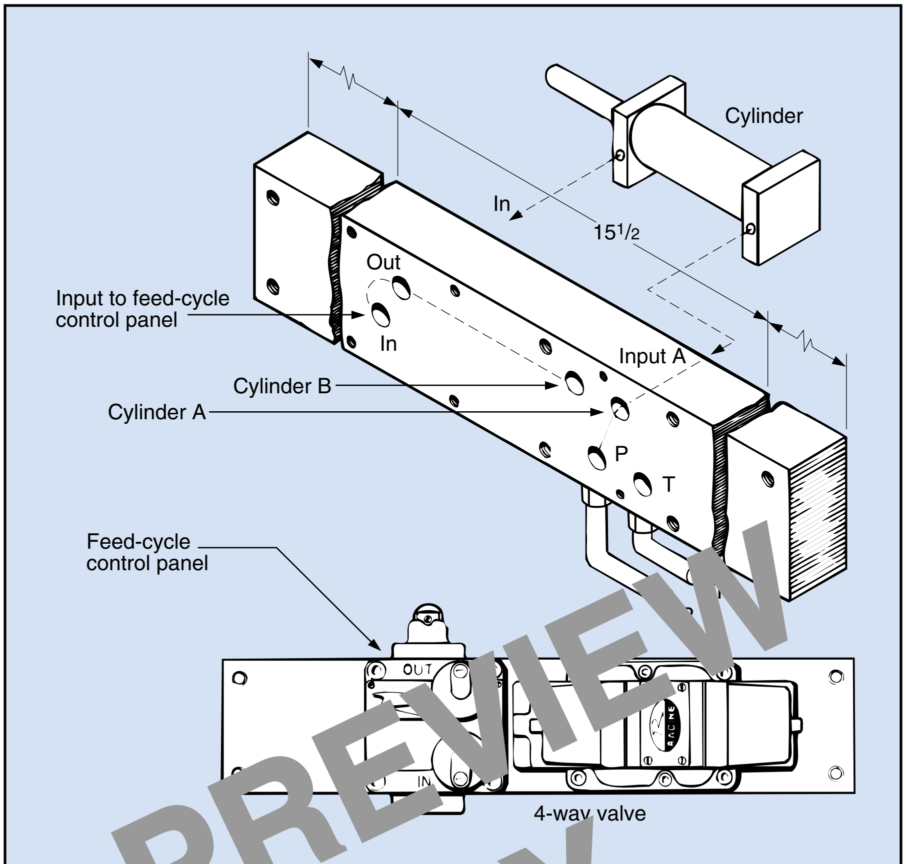


Fig. 1-5. Manifold application and circuitry



serves as a rigid mounting base for valves, and reduces leakage points. Figure 1-5 shows a manifold on which a feed-cycle control panel and a four-way valve are mounted. Without a manifold diagram, you would find it almost impossible to trace the path of fluid flow from one point to another in the manifold.

The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of your Book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

1-1. All complete hydraulic systems have ________ basic elements.	1-1. SIX Ref: 1.04
1-2. Actuators convert ________ energy to ________ energy.	1-2. HYDRAULIC; MECHANICAL Ref: 1.06
1-3. Name the three basic types of control valves.	1-3. DIRECTIONAL, FLOW, PRESSURE Ref: 1.08
1-4. In hydraulic systems, piping and fittings are referred to as ________ and ________.	1-4. CONDUCTORS, CONNECTORS Ref: 1.09
1-5. Hydraulic fluid transmits power through a system and it also ________ the system.	1-5. LUBRICATES Ref: 1.11
1-6. Name the three important functions of a hydraulic fluid reservoir.	1-6. STORE, CLEAN, COOL THE FLUID. Ref: 1.12
1-7. The quickest, most efficient way to trace a hydraulic system is to have a(n) ________ of it.	1-7. DIAGRAM Ref: 1.14, 1.15
1-8. The waiting period between work cycles for a machine tool is referred to as ________.	1-8. DWELL Ref: 1.19

Mechanical Setup

1.26 In order for the system to provide the correct hydraulic action, the valves and other components have to be installed correctly and set up in the first place. Look at the feed-cycle control panel in Fig. 1-6.

1.27 A feed-cycle control panel is a device that controls the feed rate of the tool slide. It consists of a multiposition valve and a cam roller, which is actuated by contacting a trip mechanism on the moving tool slide. As the slide passes over the roller extension, the roller is depressed, causing the control spool to change the path of the fluid flow in the panel. Fluid flow through the control dial ports is determined by the setting on the dial. The table in Fig. 1-6 shows how the volume of fluid flow through the feed panel is affected by the different positions of the cam follower. The dials provide closer fine control of the fluid.

1.28 If the cam is not set up and functioning properly, you cannot expect the hydraulic circuit to work properly. Whenever a system is not operating as it was designed to, first check out all control devices to be certain that they are operating correctly before you try to repair the equipment.

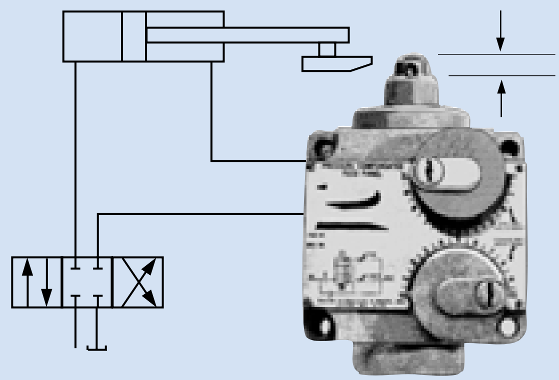
Understanding Components

1.29 To understand the complete system, it is necessary to understand fully each component in the system. There are no shortcuts.

1.30 The schematic diagram in Fig. 1-7 on the following page shows four circuits that include feed-cycle control panels (circled). If you were to look at each control panel from the outside, you would have to look closely to see the differences among the four, because each is much like the others in appearance. In fact, without a full understanding of what each panel is intended to do, you would probably find yourself puzzled.

1.31 The single-feed, two-port feed panel is the basic unit. In the circuit shown, it controls the rapid-traverse and cutting-feed rates. It does so as follows: with the control spool in the normal, spring-offset position, fluid enters the valve and first crosses the compensator spool. Fluid then passes through the opening of the control spool to the outlet port. This is the rapid-traverse position. As the control spool is depressed by cam action, it throttles down until it closes completely. Fluid then passes through the single feed spool to control the rate of slide travel and cutting feed, by controlling the volume of flow to the cylinder.

Fig. 1-6. Feed-cycle control panel setup data



Cam stroke and flow rate

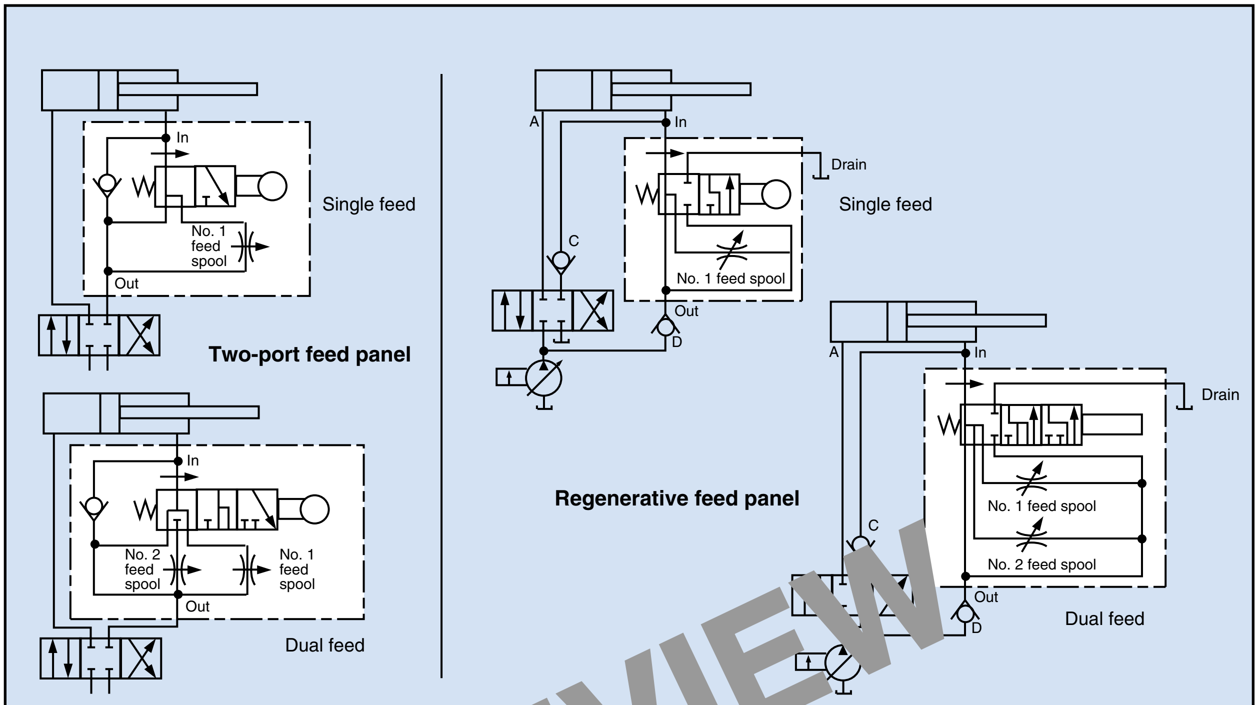
Traverse spool	Cam roller position (inches depressed)				
	0.05 in.	0.10 in.	0.15 in.	0.20 in.	0.25 in.
10 gpm	8 gpm	6 gpm	4 gpm	2 gpm	0 gpm
15 gpm	[illegible]	9	6	3	0
20 gpm	17	[illegible]	9	4	0
30 gpm	24	19	13	6	0

1.32 The dual-feed, two-port arrangement is the type shown in Fig. 1-6, where you will note that there are two feed-rate setting dials. This setup provides better and more versatile feed-rate control, because the panel now has an additional feed spool. The added feed spool provides more variable control of the slide travel rate because the volume of flow is controlled by the combined settings of the # 1 and # 2 feed spools, which are connected in parallel to the control spool.

1.33 The two lower diagrams show panels with an external drain port added. The positions of the feed spools are arranged to permit draining the hydraulic fluid back into the tank through the valve as required. The addition of the drain port permits use of the panel in what is called a regenerative circuit. A *regenerative circuit* is one in which advance travel is speeded up by adding oil from the rod end back into the cap end.

1.34 Because each of the four arrangements has a definite purpose, you must understand their differences and the purpose of each one. As in Fig. 1-7, the basic valve can

Fig. 1-7. Examples of feed-panel circuit variations



be furnished in several circuit styles and be connected in several ways. From this example you can readily understand the difficulties that can result from not knowing what each component in a system is intended to do.

Convertible Components

1.35 Almost every component shown in the circuit is a *convertible* unit. That is, the valve or pump manufacturer designs his equipment to be adaptable to many kinds of machines. In this way, a plant can stock basic spare units and parts that can be used to convert and make up many varieties of pumps and valves. The more you know about these conversion possibilities, the easier your maintenance job will be.

1.36 Figure 1-8 shows both a single-feed and a dual-feed unit. Elements of the conversion kit are also shown. All that is necessary to change the single-feed unit to a dual-feed unit is to remove a plug, install the second spool and other parts provided in the conversion kit, and change to the new nameplate which has a dial for the second spool.

1.37 The four-way valve in the system is convertible. The pump can also be changed to make several different units from one basic type. Knowledge of components and their variety is fundamental to understanding the system.

System Operation

1.38 Unless equipment units or machines are exact copies of one another, no two systems are identical. However, they are often so close to being alike that you can understand many systems without a lot of study.

1.39 Understanding the machine, knowing what is inside the hydraulic system, and being able to read circuit diagrams will prepare you for analyzing the system. Referring to Figs. 1-1, 1-2, 1-3, and 1-4, study the system in detail. Most of the following references are easier to check if you refer to Fig. 1-9 on page 14.

1.40 Here is what happens when the starting button is pushed. First, the electric motor turns the pump in the proper direction.

1.41 Atmospheric pressure in the reservoir forces hydraulic fluid through the filter and into the pump inlet, as the pump pulls in the fluid.

1.42 The rotating pump carries fluid around to the discharge side and discharges it into the system.

1.43 As shown in Fig. 1-9, the spring-centered four-way valve is blocked closed. Therefore, pressure in the system rises until the pump spring allows the pump to shift to an idling position. While idling, the pump delivers no fluid but does hold pressure. The system is now ready to operate the machine on signal.

1.44 When the machine operator selects the "forward" control position, an electrical signal is sent to the pilot-valve solenoid A. This shifts the pilot-valve spool to the right to connect system pressure through to the main-valve pilot connection A. At the same time, it connects the main-valve pilot connection B to the reservoir through a passage in the spool body. The change in pressure causes the main valve spool to shift to the left. Doing so connects the internal passages X and Y, which directs system pressure through to main-valve cylinder port A. (Designations X, Y, and Z are added for illustration only. You are not likely ever to see a valve marked like this.) At the same time, the main valve spool connects the feed-cycle panel port B to the tank through a passage in the spool body, as shown in Fig. 1-10 on page 15.

1.45 System pressure and fluid flow act together on the cylinder piston to extend the cylinder. Fluid from the rod end of the cylinder passes through the feed-panel traverse spool at full flow. At this time, the tool head is approaching the workpiece at full pump-output speed.

1.46 As the tools approach the work, the cam on the tool slide depresses the feed-panel traverse-control spool. That restricts the flow path of the fluid leaving the rod end of the cylinder. Restricting the fluid flow causes a buildup of pressure on the rod end of the cylinder. As a result, the cylinder slows down.

1.47 When the traverse flow path has been closed completely by depressing the traverse-control spool all the way, the flow passes through one or two small adjustable feed spools, which control the cutting-feed rate. The cam holds this position as the tool moves into the cut.

1.48 Near the end of the cut the cam trips a limit switch that has a time-delay relay. The switch signals the pilot valve to reverse, but action is postponed by the time delay until the slide makes contact with the positive stop which controls the depth of cut. After the time-delay relay times out, the solenoid-pilot valves reverse. That is, solenoid A becomes deenergized and solenoid

Fig. 1-8. An example of component convertibility

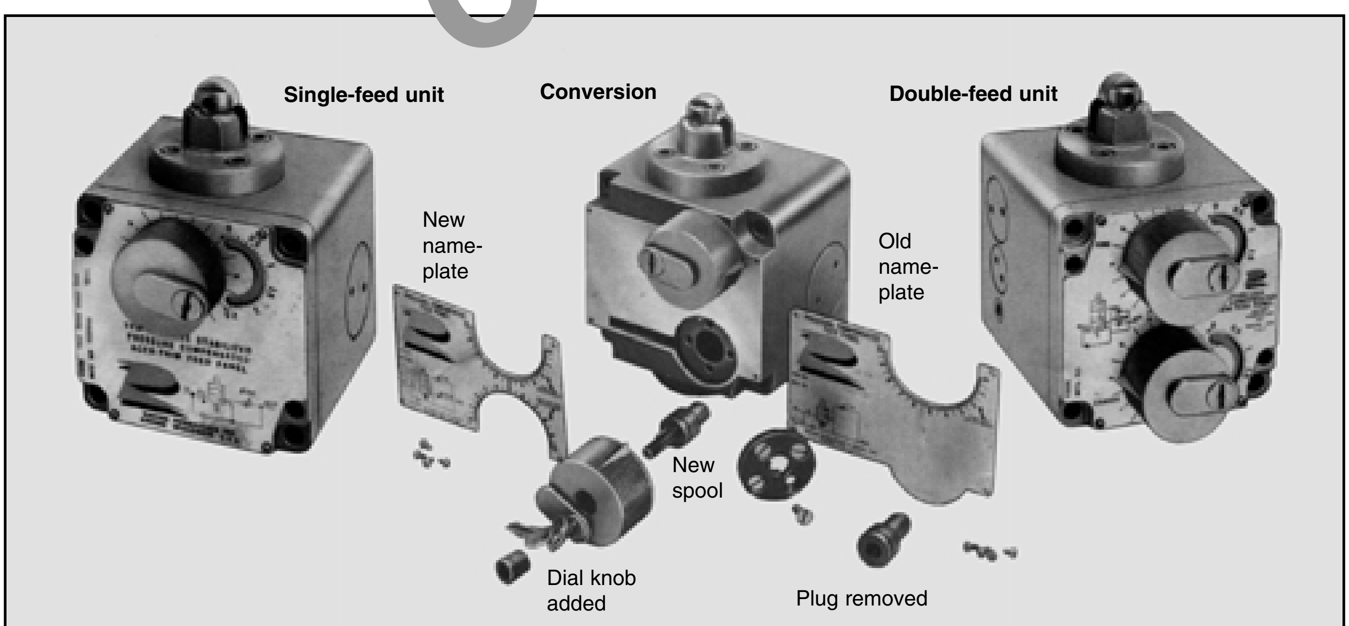


Fig. 1-9. Pictorial view of the system

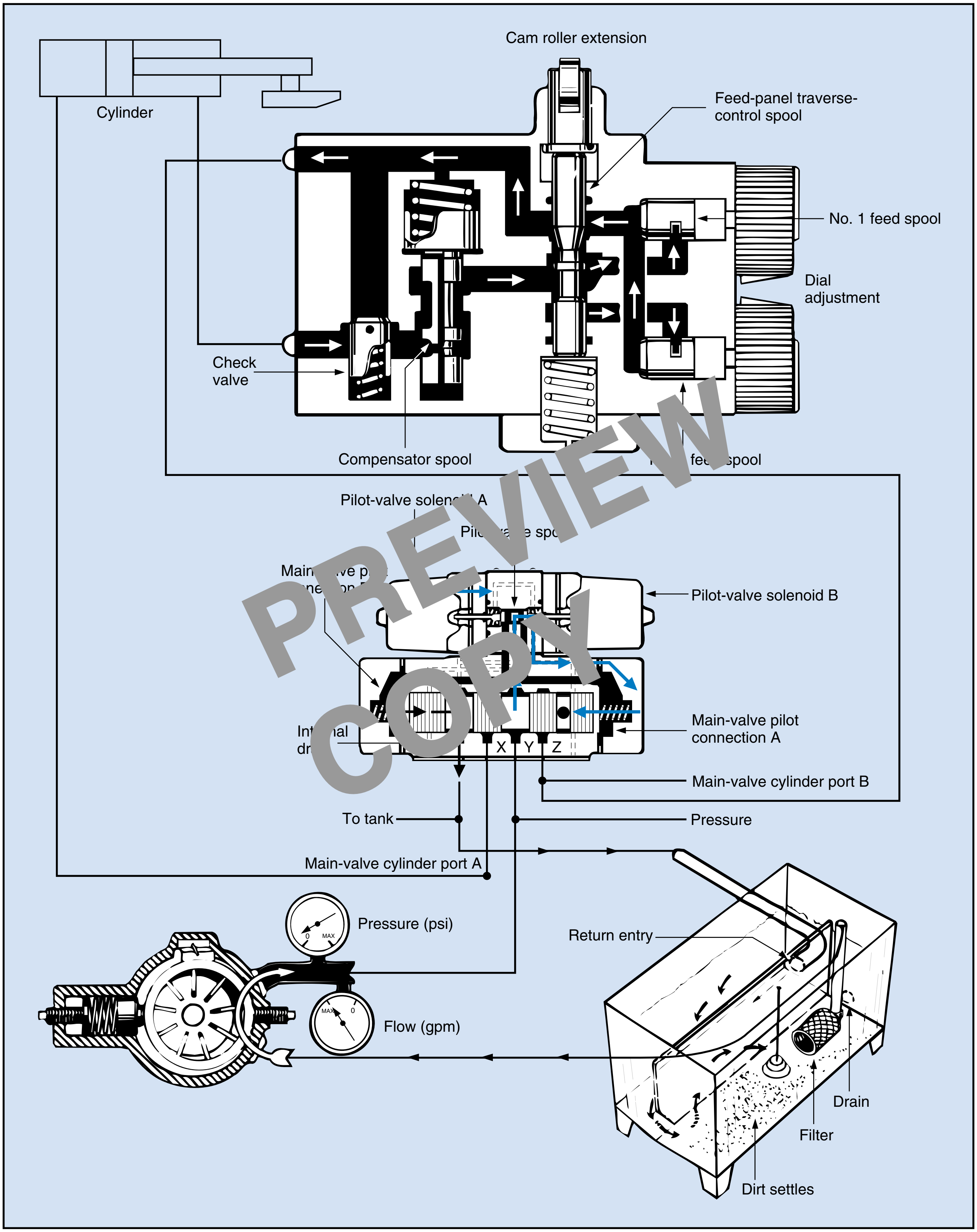


Fig. 1-10. Shifting the main valve spool

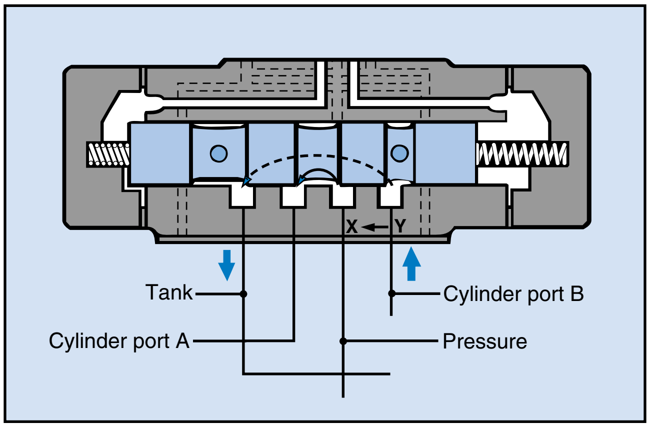
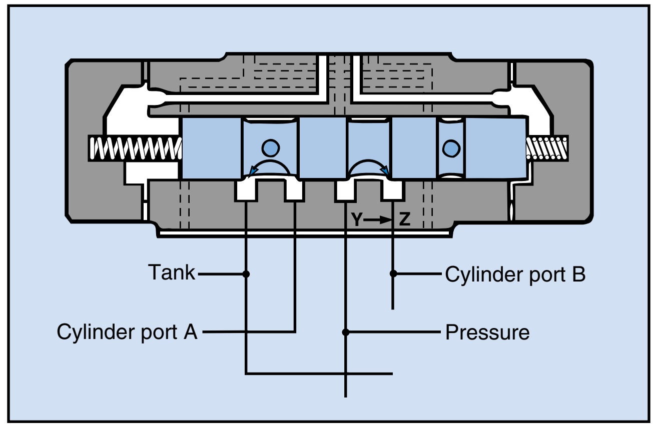


Fig. 1-11. Reversing the main valve spool



B is energized. This action also reverses the main valve spool by reversing the pilot fluid flow.

1.49 With the main valve spool reversed, the path of fluid flow through the whole system is reversed. Pressure from the system is now ported to the main-valve cylinder port B of the four-way valve (Y to Z). It passes through the free-flow return check valve in the feed panel and into the rod end of the cylinder. At the same time, flow from the cap end of the cylinder is ported from cylinder port A of the four-way valve back to the reservoir, as shown in Fig. 1-11.

1.50 As the slide is retracted, removing the tool head from the workpiece, it trips another limit switch, which deenergizes the solenoid-pilot valve. Because neither solenoid is energized, the pilot-valve springs center the pilot valve. When the solenoid-pilot valve is fully centered, the pilot connections of the main valve are interconnected through internal passageways in the main valve body and open to the tank. This allows the main valve to center, which stops the slide. Now the unit is ready for another start command signal.

1.51 Note that when the machine is decelerating, feeding slow, or is stopped, the pump supplies only enough flow to hold proper, spring-adjusted pressure levels. This feature conserves power.

1.52 The description given is just one possibility. Many other arrangements can be used. Some machines, for example, use manually operated lever valves rather than solenoid units.

1-9. A feed-cycle control panel controls the ________ of a tool slide or similar device.	1-9. FEED RATE Ref: 1.27
1-10. When troubleshooting a system that is not operating properly, first check all its ________ devices.	1-10. CONTROL Ref: 1.28
1-11. To understand a complete hydraulic system, you must first understand ________.	1-11 THE INDIVIDUAL COMPONENTS Ref: 1.29
1-12. A regenerative circuit is one in which the pressure source is simultaneously connected to the ________ end and the ________ end of the cylinder.	1-12. ROD; CAP Ref: 1.33
1-13. Most valves and pumps are adaptable to many installations because they are ________.	1-13. CONVERTIBLE Ref: 1.35
1-14. Except in duplicate installations, no two hydraulic systems are ________.	1-14. IDENTICAL Ref: 1.38
1-15. A cylinder is extended by the combined action of the system ________ and the fluid _______.	1-15. PRESSURE; FLOW Ref: 1.45
1-16. For control purposes, hydraulic systems may use manually operated ________ valves rather than solenoids.	1-16. LEVER Ref: 1.52

Answer the following questions by marking an "X" in the box next to the best answer.

1-1. Which of the following elements is basic to all complete hydraulic systems?

- ☐ a. Filters
- ☐ b. Fluid storage and conditioning equipment
- ☐ c. Pressure gauges
- ☐ d. Thermal sensors

1-2. What hydraulic device can easily vary speed to provide high torque?

- ☐ a. Fluid motor
- ☐ b. Manifold
- ☐ c. Compensator
- ☐ d. Linear actuator

1-3. What type of valve is used to regulate actuator speed?

- ☐ a. Solenoid
- ☐ b. Flow control
- ☐ c. Pressure control
- ☐ d. Directional control

1-4. With which of the following are some hydraulic fluids formulated to make them fire-resistant?

- ☐ a. Alcohol
- ☐ b. Foaming agents
- ☐ c. Water
- ☐ d. Spindle oils

1-5. A hydraulic fluid that has poor lubricating qualities can cause

- ☐ a. pressure loss
- ☐ b. excessive noise level
- ☐ c. system breakdown
- ☐ d. fluid foaming

1-6. What is the purpose of the filters, coolers, and heaters in a hydraulic system?

- ☐ a. To condition the fluid
- ☐ b. To lubricate the system
- ☐ c. To control viscosity
- ☐ d. To provide a variable torque

1-7. The point in an operating cycle where the moving member is at rest is called the

- ☐ a. dwell
- ☐ b. deceleration
- ☐ c. withdrawal
- ☐ d. slowdown

1-8. What is the result of hydraulic fluid flow and pressure?

- ☐ a. Quiet system operation
- ☐ b. Motion and force
- ☐ c. Variable speed control
- ☐ d. Greater fluid-carrying capacity

1-9. The number of lines and fittings in a system can be reduced by using a

- ☐ a. hydrojunction
- ☐ b. mixing valve
- ☐ c. four-way junction
- ☐ d. manifold

1-10. To analyze a hydraulic system properly for the purpose of troubleshooting, you must do all of the following EXCEPT

- ☐ a. understand the installation
- ☐ b. read the circuit diagrams
- ☐ c. know what each component does
- ☐ d. obtain a cutaway drawing of every component

SUMMARY

Hydraulic systems convert power into useful forms and transmit it to the proper location on the machine. Although hydraulic systems may be different from one another in detail, each one is made up of the six basic elements described in this Lesson. In order to understand hydraulic systems, you must have proper diagrams of the system, knowledge of mechanical relationships, and a thorough understanding of the system components.

Components often contain circuits or subsystems within themselves. Components come in a wide variety of units which look alike but have small differences that affect circuit hook-up and operation.

When you understand a hydraulic system, you should be able to follow a description of its operation from start to finish, using the steps given in this Lesson. This becomes easier with experience and practice, but it is always necessary to study the system carefully before you begin to work on it.

Answers to Self-Check Quiz

1-1. b. Fluid storage and conditioning equipment. Ref: 1.04

1-2. a. Fluid motor. Ref: 1.07

1-3. b. Flow control. Ref: 1.08

1-4. c. Water. Ref: 1.10

1-5. c. System breakdown. Ref: 1.11

1-6. a. To condition the fluid. Ref: 1.13

1-7. a. Dwell. Ref: 1.19

1-8. b. Motion and force. Ref: 1.20

1-9. d. Manifold. Ref: 1.25

1-10. d. Obtain a cutaway drawing of every component. Ref: 1.39

Contributions from the following sources are appreciated:

Figure 1-5. Racine Hydraulics
Figure 1-6. Racine Hydraulics
Figure 1-7. Racine Hydraulics
Figure 1-8. Racine Hydraulics
Figure 1-9. Racine Hydraulics