Lesson A6–7

Using Hydraulic Systems

Unit A. Mechanical Systems and Technology

Problem Area 6. Agricultural Power Systems

Lesson 7. Using Hydraulic Systems

New Mexico Content Standard:

Pathway Strand: Power, Structural and Technical Systems

Standard: **III:** Apply principles of service and repair to mechanical equipment, structures, biological systems, land treatment, power utilization, and technology.

Benchmark: **III-C:** Evaluate performance and check maintenance manuals to service and repair hydraulic systems.

Performance Standard: **1.** Describe features, benefits, and applications of types of hydraulic systems. **2.** Describe physical principles of operation. **4.** Describe the application and operations of major components.

Student Learning Objectives. Instruction in this lesson should result in students achieving the following objectives:

1. Define hydraulics and explain its major operating systems.
2. Discuss the basic principles of hydraulics.
3. Describe the primary components of a hydraulic system.
4. Describe the advantages and disadvantages of hydraulic systems.

List of Resources. The following resources may be useful in teaching this lesson:

Recommended Resources. One of the following resources should be selected to accompany the lesson:

Johnson, Donald M., et al. *Mechanical Technology in Agriculture.* Danville, Illinois: Interstate Publishers, Inc. 1998. (Textbook, Chapter 13 and 14)

Other Resources. The following resources will be useful to students and teachers:

Herren, Ray V., and Elmer L. Cooper. *Agricultural Mechanics Fundamentals and Applications.* Albany, New York: Delmar Publishers, Inc., 2002. (Textbook, Chapter 37)

Hydraulics, Volume II. Athens, Georgia: AAVIM. (Student Manual)

List of Equipment, Tools, Supplies, and Facilities

Writing surface
Overhead projector
Transparencies from attached masters
Microcomputer
Presentation software
TV converter hardware
Hydraulic cylinder
Copies of student lab sheet

Terms. The following terms are presented in this lesson (shown in bold italics):

Connectors
Cycle time
Directional control valve
Energy
Filter
Flow rate
Hydraulic actuator
Hydraulics
Hydrodynamics
Hydrostatics
Law of Conservation of Energy
Linear actuator
Micron
Multiplication of force
Pascal's Law

Piping
Positive displacement pump
Pressure gauge
Pressure relief valve
Prime mover
Pump
Reservoir
Rotary actuator
Strainer

Interest Approach. Use an interest approach that will prepare the students for the lesson. Teachers often develop approaches for their unique class and student situations. A possible approach is included here.

Introduce the lesson by asking students if they have ever used a floor jack or driven an automobile equipped with power brakes or power steering. Most students will answer that they have. Go on to explain that these items use hydraulics to operate. Discuss the fact that hydraulics is also used widely in agriculture. Use the discussion to move into the content of the first objective.

Summary of Content and Teaching Strategies

Objective 1: Define hydraulics and explain its major operating systems.

Anticipated Problem: What is hydraulics and what are its major operating systems?

I. ***Hydraulics*** is the branch of physics dealing with the mechanical properties and practical applications of fluids in motion. Hydraulic systems do not create power, they simply transfer power from an outside source. This outside source of power is called the ***prime mover***. The applications of hydraulics can be classified into two major operating systems. An example is a tractor. A hydraulic pump on the tractor moves the fluid. However, the pump does not power itself. It is powered by the tractor's engine. In this case, the engine serves as the prime mover.

   A. ***Hydrodynamics*** is the use of liquids at high flow and low pressure to perform work. Old-fashioned gristmills operate because of hydrodynamics. The energy of the stream's moving water turns the mill wheel. The mill wheel transmits this rotating force to machinery inside the mill that grinds grain.

   B. ***Hydrostatics*** is the use of liquids at high pressure and low flow to perform work. When compared to water in a flowing stream, the oil in a tractor's hydraulic system moves at a slower rate, yet it is under a much greater pressure.

Have students read the first few pages in Chapter 13 of the recommended resource text. Follow this up by displaying TM: A6–7A. It will provide a good summary of the definitions presented in this objective.

Objective 2: Discuss the basic principles of hydraulics.

Anticipated Problem: What principles govern the use of hydraulics?

II. All areas of science are governed by laws or principles that help in explaining how concepts work. Since hydraulics is a part of physical science, it is explained by these principles. Some of the more scientific principles that explain hydraulics are:

A. Blaise Pascal was a French scientist. In 1653, he formulated Pascal's Law, which is the fundamental law that explained the operation of hydraulic equipment. ***Pascal's Law*** states that pressure applied to a confined fluid is transmitted undiminished in all directions, acts with equal force on equal areas, and acts at right angles to the walls of the container.

B. Hydraulic systems are generally used to produce a multiplication of force. ***Multiplication of force*** means that the hydraulic system takes a small input force and transforms it into a larger output force.

C. The ***cycle time*** for a hydraulic application is the amount of time required for one complete set of operations to occur. For example, if it takes 16 seconds to fully extend a hydraulic cylinder and 12 seconds to retract it, the system has a cycle time of 28 seconds. The speed with which the cylinder extends and/or retracts is dependent on the volume of the cylinder and the flow rate of the hydraulic fluid. ***Flow rate*** is the measure of how many gallons per minute of hydraulic fluid would run into a container.

D. The ***Law of Conservation of Energy*** states that energy may be changed from one form to another, but it cannot either be created or destroyed. This means that the total amount of energy within the system never changes. ***Energy*** is the capacity to do work. In hydraulics, this law dictates that one cannot get more work out of a hydraulic system that is put into the system. There is no such thing as getting something for free. The work output from a hydraulic system can never be greater than the work put into the system.

Assign students to read the Basic Principles of Hydraulics section in Chapter 13 of the recommended resource text. It contains fundamental information that will be important to more fully understanding hydraulics. Display TM: A6–7B to the class and use it to illustrate Pascal's Law.

Objective 3: Describe the primary components of a hydraulic system.

Anticipated Problem: What are the primary components of a hydraulic system?

III. A hydraulic system is made of components. Each component contributes to the operation of the system. Primary components of a hydraulic system include:

A. The ***reservoir*** supplies oil to the hydraulic pump and stores oil that returns after passing through the hydraulic circuit. The actual design of a reservoir will differ depending on the specific application. On a tractor, the reservoir is usually the sealed case that contains the tractor's transmission and differential. However, on a piece of stationary equipment, such as a hydraulic press, a separate reservoir is usually provided.

B. Hydraulic oil is kept clean by strainers and filters. Each performs similar functions through slightly different methods.

1. A ***strainer*** directs the hydraulic oil in a straight line through an element made of one or more fine mesh screens attached to a metal core. As the oil passes through the strainer, particles larger than the screen openings are caught. Strainers are usually installed in the supply side of a hydraulic circuit.
2. A ***filter*** directs the hydraulic oil in a roundabout path through one or more layers of a porous element that may trap particles as small as one micron. A ***micron*** is equal to 39 millionths of an inch. Filters are usually placed in the return side of a hydraulic circuit.

C. The ***pump*** uses mechanical power (supplied by the system's prime mover) to cause hydraulic oil to flow through the circuit. It is the heart of the hydraulic system. The function of the pump is to change mechanical power to fluid power. Pumps used in agricultural hydraulics are positive displacement pumps. A ***positive displacement pump*** delivers the same volume of oil per cycle regardless of the pressure at the pump outlet.

D. A ***pressure gauge*** measures and shows the pressure being produced in a hydraulic system. This is important on equipment where system pressure must be adjusted or changed manually.

E. The ***pressure relief valve*** limits the pressure in the hydraulic system to a preset maximum level. It is located between the pump outlet and reservoir. When system pressure reaches the relief valve setting, the valve opens and diverts some or all of the pump's output back to the reservoir. This protects the system's components from possible damage due to overloads.

F. The ***directional control valve*** controls the operation of the system's cylinders and motors by directing the flow of the fluid in the system. It accomplishes this task by opening and closing ports between the pump, reservoir, and the system's cylinders and motors.

G. A ***hydraulic actuator*** converts fluid energy into mechanical energy. The two primary types found on agricultural equipment are the hydraulic cylinder and the hydraulic motor.

1. A hydraulic cylinder is considered a ***linear actuator*** which means that the output of the cylinder occurs in a straight-line manner as the cylinder extends or retracts.
2. A hydraulic motor is considered a ***rotary actuator*** which means that it produces a rotating output force. Hydraulic motors are similar in construction to hydraulic pumps, but serve opposite purposes. Instead of using an input force to push fluid, as in a pump, a hydraulic motor is pushed by the incoming fluid and delivers a rotating output force.

H. Piping and Connectors—***Piping*** is the general term for the fluid conducting lines that connect the various components of a hydraulic system. For both safety and efficiency, hydraulic piping must withstand extremely high fluid pressures. ***Connectors*** are used to join one piece of piping to another, or to hydraulic system components such as a cylinder or directional control valve. Similar to piping, connectors must withstand extremely high pressures without leaking or failing.

Have students read Chapter 14 in the recommended resource text. It presents detailed information on the primary components in a hydraulic system. Use TM: A6–7C to illustrate the primary components of a hydraulic system. Display TM: A6–7D to provide an example of a pressure relief valve. TM: A6–7E will provide a good basic example of the primary parts of a typical cylinder.

Objective 4: Describe the advantages and disadvantages of hydraulic systems.

Anticipated Problem: What are the advantages and disadvantages associated with hydraulic systems?

IV. The fact that hydraulics are widely used in agriculture indicates that it has a number of advantages. Despite those advantages, hydraulics do have some associated disadvantages.

A. Hydraulic systems have a number of advantages over mechanical systems. Some of these advantages include:

1. Increased flexibility—Hydraulic hoses can be routed around obstructions while mechanical drive components cannot.
2. Variable Speed—The speed at which a hydraulic cylinder or pump operates can be infinitely varied by controlling the flow rate of the pump.
3. Multiplication of force—Using hydraulics, a small input force can be multiplied to create a large output force. Although multiplication of force can be achieved with a mechanical power transmission system, it is a much simpler process using hydraulics.
4. Reduced wear—Since hydraulic systems involve less metal-to-metal contact and since hydraulic fluid lubricates parts, less wear occurs in a hydraulic system.
5. Reversibility—Hydraulic systems can be designed so that cylinders and motors may be reversed, or operate in either direction.

B. Despite their many advantages, hydraulic power transmission systems do have some disadvantages. These disadvantages include:

1. High pressures—Hydraulic systems operate under extremely high pressures. These pressures require heavy tubing and hoses, tight joints, and careful maintenance.
2. Need for cleanliness—Hydraulic components operate under high pressures and close tolerances. The components can easily be damaged by dirt, rust, or corrosion. Cleanliness is essential to the system's effective operation.
3. Safety hazards—Because hydraulic systems operate under high pressures, they pose unique safety hazards. A pinhole sized puncture in a hose can release fluid that is under enough pressure to puncture the skin. Never attempt to locate a leak by feeling with your hands. Always wear appropriate personal protective equipment when checking for leaks. Seek medical care immediately if hydraulic fluid is injected into a human's body.

Assign students to read the first few pages of Chapter 13 in the recommended resource text. It presents a fairly comprehensive list of the advantages and disadvantages of hydraulics. Since safety is of primary con-

cern, divide the class into groups of four or five students. Have them contact local equipment dealers to more fully research the safety practices and procedures that are specific to the use of hydraulic equipment.

Review/Summary. The review and summary of the lesson may be accomplished by viewing the transparency masters with the students. A discussion should be performed with students before proceeding with the laboratory activities and testing.

Application. Students can apply the lesson's content by completing the following lab sheet.

Primary Parts of a Hydraulic System—LS: A6–7A

Evaluation. Objectives should be reviewed by the students. Laboratory activities should be performed before the written test is given to students.

Answers to Sample Test:

Part One: Matching

1 = g, 2 = k, 3 = c, 4 = l, 5 = a, 6 = i, 7 = d, 8 = e, 9 = h, 10 = j, 11 = f, 12 = b

Part Two: Completion

1. pressure relief valve
2. prime mover
3. strainer
4. reservoir
5. micron

Part Three: Short Answer

1. Objective 3. III.A
2. Objective 3. III.B

Sample Test Name_____

Test

Lesson A6–7: Using Hydraulic Systems

Part One: Matching

Instructions. Match the term with the correct response. Write the letter of the term by the definition.

a. Connector	b. Directional control valve	c. Filter
d. Pressure relief valve	e. Gear pump	f. Hydraulic actuator
g. Hydraulics	h. Hydrodynamics	i. Hydrostatics
j. Positive displacement	k. Piping	l. Rotary actuator

_____ 1. Is the branch of physics dealing with the mechanical properties and practical applications of liquids in motion.

_____ 2. The general term used for the steel pipe, steel tubing, and rubber hose (fluid conducting lines) connecting the various components of the hydraulic system.

_____ 3. Directs the oil in a roundabout path through layers of a porous element that traps particles as small as one micron.

_____ 4. A hydraulic motor which produces a rotating output force.

_____ 5. A device used to attach hydraulic piping to another pipe or component.

_____ 6. Use of liquids at high pressure and low flow to produce power.

_____ 7. Limits the pressure in the hydraulic system to a preset maximum level.

_____ 8. Causes fluid to flow by carrying the fluid between the teeth of two meshed gears.

_____ 9. The use of liquids at high flow and low pressure to perform work.

_____ 10. The pump delivery rate stays the same regardless of the pressure.

_____ 11. Converts the fluid energy into mechanical energy.

_____ 12. Controls the system by directing the flow of fluid between the internal ports and the pump.

Part Two: Completion

Instructions. Provide the word or words to complete the following statements.

1. Protection in the system is provided by the _____ _____ _____ which limits the pressure to a preset maximum.

2. The _____ _____ is an external power source used to operate the hydraulic pump.
3. A _____ directs the hydraulic oil in a straight line through an element made of one or more mesh screens attached to a metal core.
4. The _____ supplies oil to the hydraulic pump and stores oil that returns after passing through the hydraulic circuit.
5. A _____ is equal to 39 millionths of an inch.

Part Three: Short Answer

Instructions. Provide information to answer the following questions.

1. List three advantages of hydraulic power:

2. List three disadvantages of hydraulic power:

IMPORTANT TERMS

Hydraulics—the branch of physics dealing with the mechanical properties and practical applications of fluids in motion; hydraulic systems do not create power, they simply transfer power from an outside source.

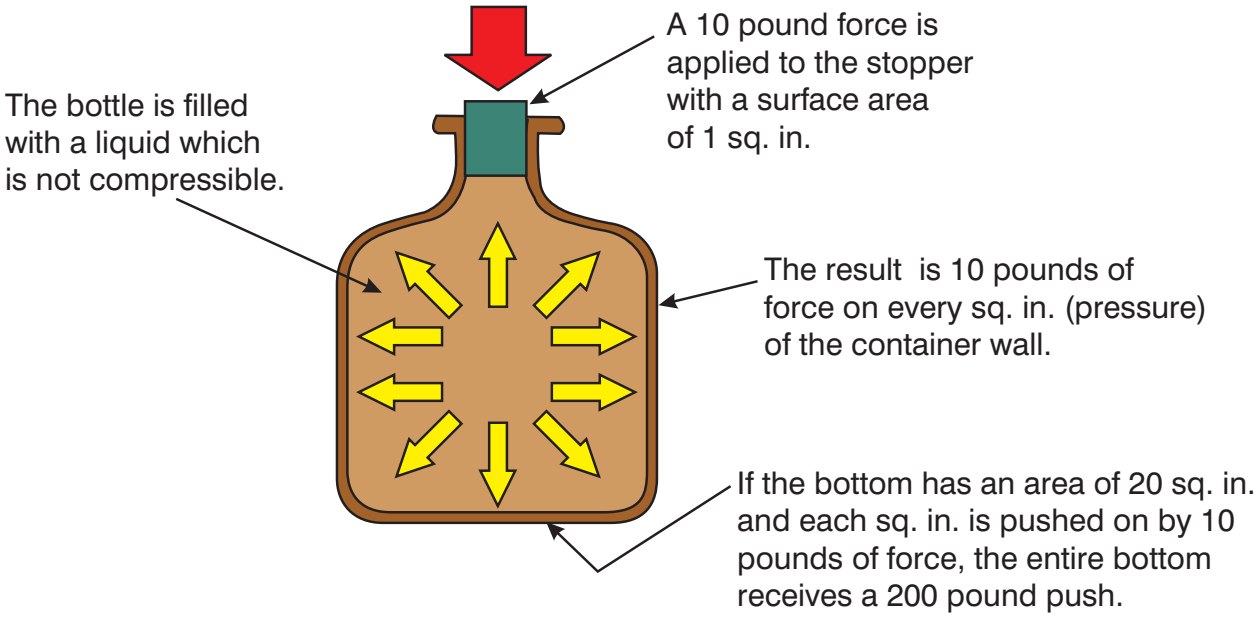
Prime mover—the outside source of power.

Hydrodynamics—the use of liquids at high flow and low pressure to perform work.

Hydrostatics—the use of liquids at high pressure and low flow to perform work.

TM: A6–7B

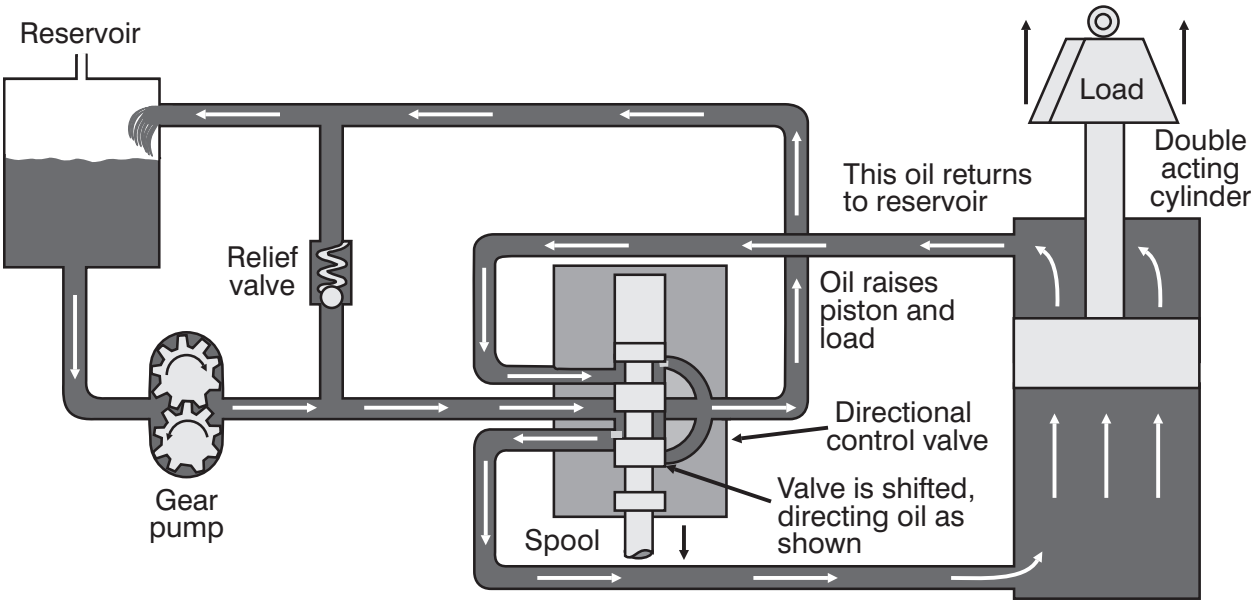
A SIMPLE APPLICATION OF PASCAL'S LAW



(Courtesy, Interstate Publishers, Inc.)

TM: A6–7C

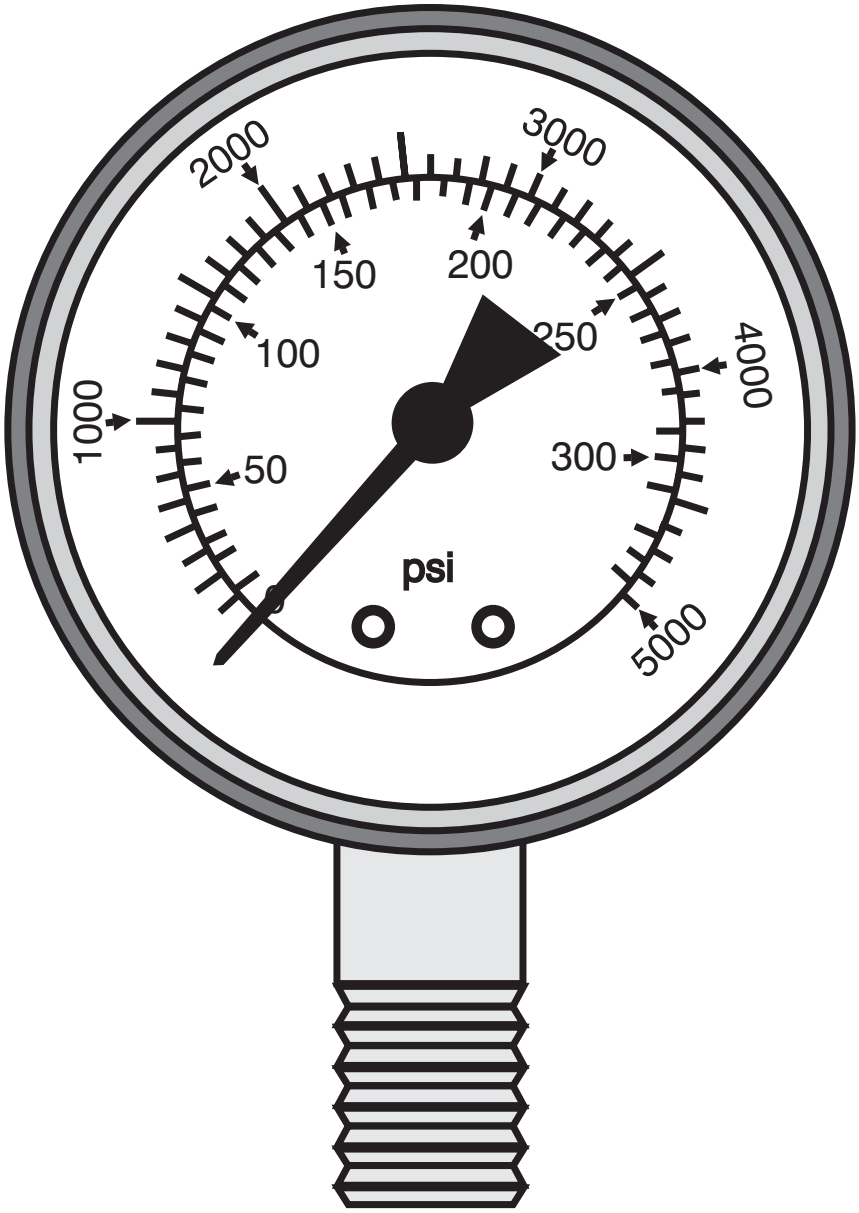
PRIMARY COMPONENTS OF A HYDRAULIC SYSTEM



(Courtesy, Interstate Publishers, Inc.)

TM: A6–7D

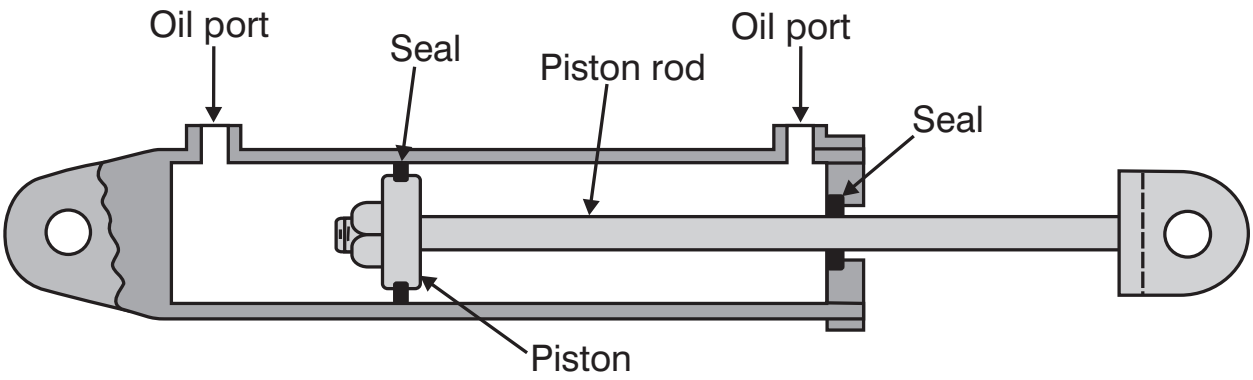
A BOURDOIN TUBE PRESSURE GAUGE



(Courtesy, Interstate Publishers, Inc.)

TM: A6–7E

PRIMARY PARTS OF A TYPICAL CYLINDER



(Courtesy, Interstate Publishers, Inc.)

LS: A6–7A Name _____

Lab Sheet

Primary Parts of a Hydraulic System

Instructions: Label the following parts on the diagram below:

1. Reservoir
2. Relief valve
3. Gear pump
4. Cylinder
5. Directional control valve
6. Load