CHAPTER 12

Fluid Power

OBJECTIVES

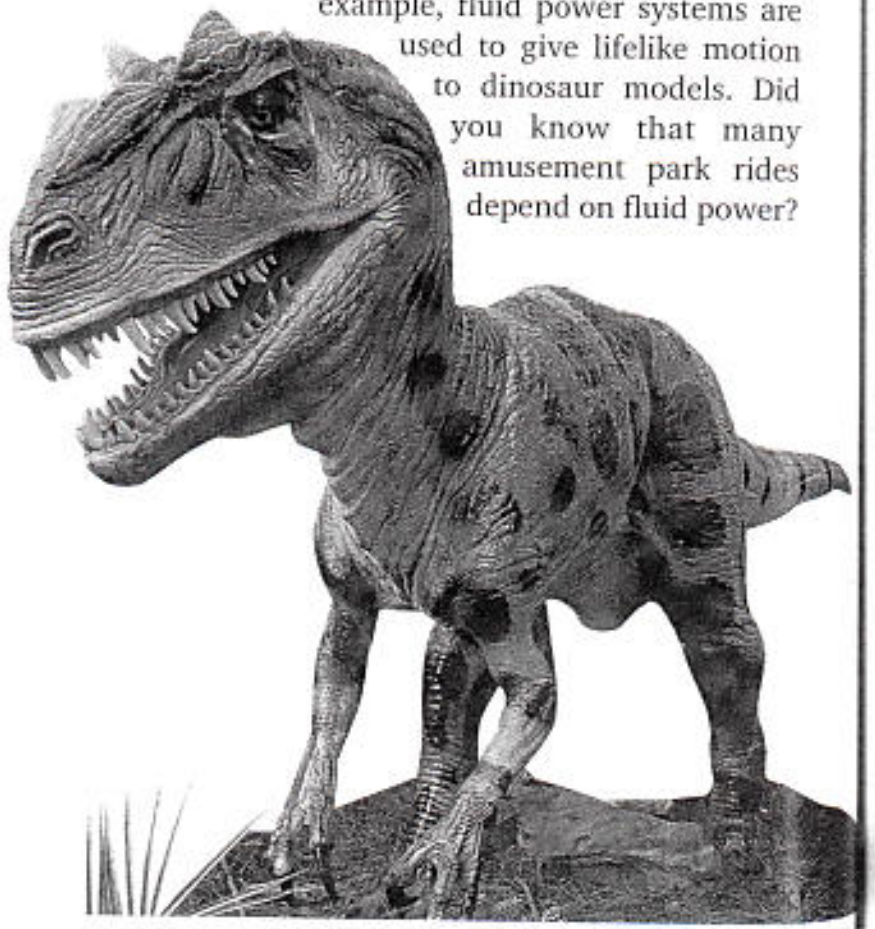
- define fluid power.
- explain the difference between hydraulic and pneumatic systems.
- identify the basic components of fluid power systems.
- give examples of how fluid power is used.
- discuss the future of fluid power.

KEY TERMS

fluid
fluid power
hydraulic systems
mechanical advantage
Pascal's Principle
pneumatic systems
pressure

How did you get to school this morning? Did you ride a bus or subway? Were you driven in a car? You probably have not spent much time thinking about fluid power. In fact, the term may be unfamiliar to you. However, fluid power helps you in many ways. Cars, buses, and subways use devices that depend on fluid power.

Fluid power is also used in entertainment. For example, fluid power systems are used to give lifelike motion to dinosaur models. Did you know that many amusement park rides depend on fluid power?



Dinamation Dinosaurs ©1997
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WHAT IS FLUID POWER?

Fluid power is the use of pressurized liquids or gases to move heavy objects and perform many other tasks. A **fluid** is any substance that flows. Liquids and gases are both fluids. When they are not moving, fluids have no power. When they are put under pressure and moved to where they are needed, fluids can perform work. Fig. 12-1.

Fluid power is one of the three basic systems used to transmit and control power: mechanical, electrical, and fluid. *Mechanical power* moves airplanes and other vehicles. *Electrical power* gives us light and operates motors.

The properties (physical characteristics) of air and water allow boats to float and airplanes to fly. Engineers take advantage of the properties of fluids to design power systems for many different purposes. In this chapter, you will learn about two types of fluid power systems: hydraulic and pneumatic.

FASCINATING FACTS

A hydraulic system built in London in the late 1800s is still in use. It is used to lift bridges, hoists, and cranes.

FLUID SCIENCE

All objects are made of matter. There are three states of matter: solids, liquids, and gases. The state in which matter exists depends on how tightly its molecules are held together. Solids have molecules that

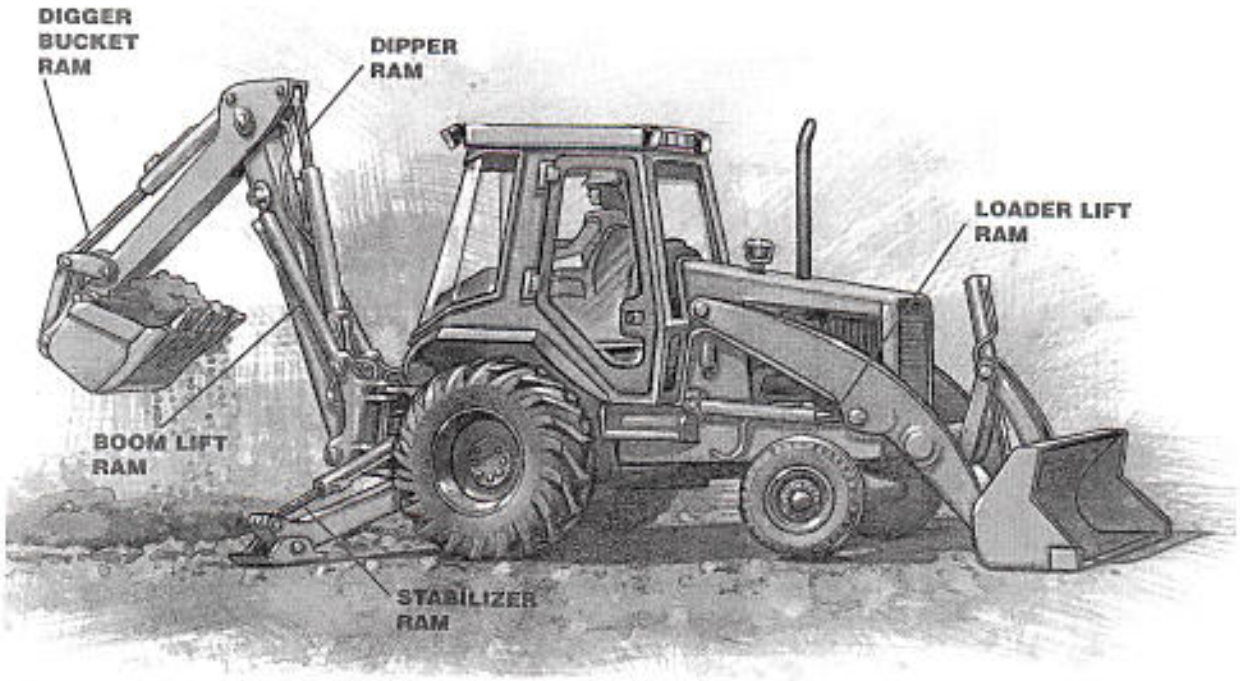


Fig. 12-1 Almost every construction job requires the use of earthmoving equipment. Vehicles such as this excavator depend on hydraulic systems. Separate rams (hydraulically-operated pistons) transfer the power of the hydraulic system to the digger bucket, boom lift, stabilizers, and loader.

are strongly linked. The molecules of liquids are loosely held together. Gas molecules can move in all directions.

Because of the space between their molecules, gases are easy to compress. Solids and liquids are not. Solids have a definite shape and occupy a certain amount of space (volume). Liquids have a definite volume and take the shape of the container they are in. Gases do not have a definite volume. They can fill a container of any shape and size. However, as pressure on a gas increases, the volume of the gas decreases. This is known as Boyle's law. Fig. 12-2.

Pressure

Pressure is the force on a unit surface area (such as a square inch). Pressure is essential in all fluid power systems. The formula for calculating pressure is:

$$\text{Pressure} = \frac{\text{Force } (F)}{\text{Area } (A)}$$

The molecules of both liquids and gases (fluids) bump into the walls of their containers. This pushing is pressure.

Blaise Pascal was a French scientist who lived in the 1600s. He found that when force is applied to a confined liquid, the resulting pressure is transmitted unchanged to all parts of the liquid. His discovery became known as **Pascal's Principle.**

FLUID POWER SYSTEM SAFETY

To use fluid power systems safely, follow these rules.

- Always wear safety glasses while operating a pneumatic or hydraulic system.
- Never blow air at yourself or another person.
- Do not place your hand in the path of a moving piston rod.

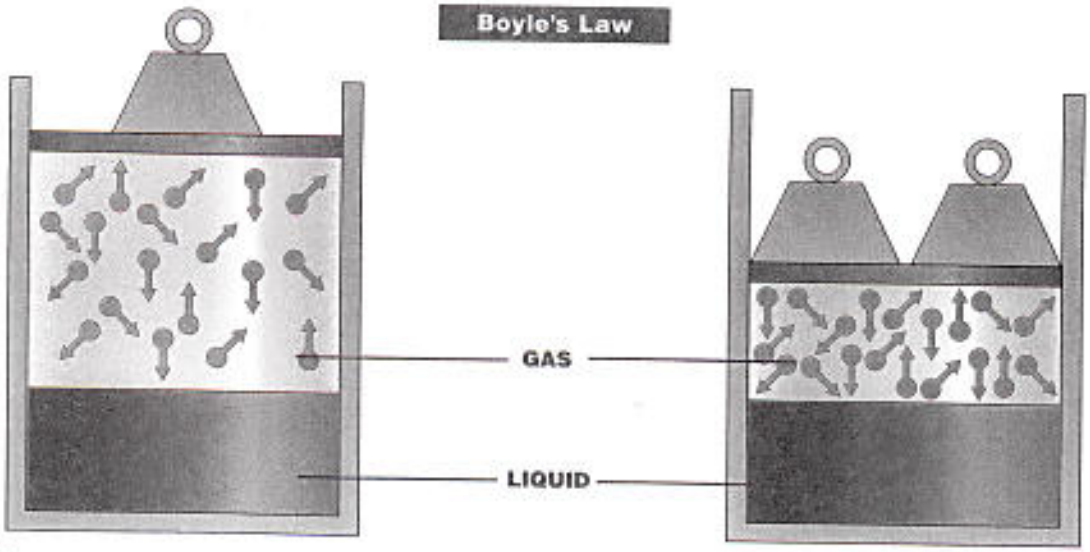


Fig. 12-2 Boyle's law states that as pressure increases, the volume of gas decreases. Note that pressure does not change the volume of liquids under constant temperature.

Explore

Design and Build a Water Squirter

Collect Materials and Equipment
flexible tubing (1/2" to 3/4" diameter)
plastic syringe units, or parts to fabricate one
corks, of a size to fit tubing
wood to use for building frame

State the Problem

Design and construct a water squirter.

Develop Alternative Solutions

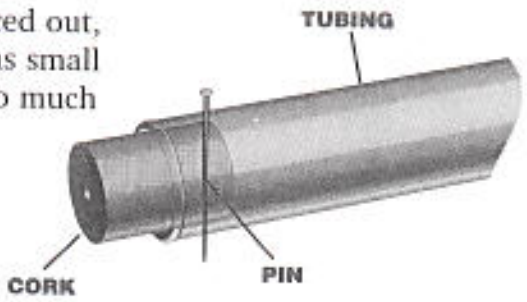
The device should project water to a distance of 3 to 10 feet. Sketch several possible designs as accurately as possible. Design the wood frame to permit comfortable, single-hand gripping, leaving one hand free to operate the piston. One basic design idea is shown here.

Select the Best Solution

Select the design that you think will be most effective.

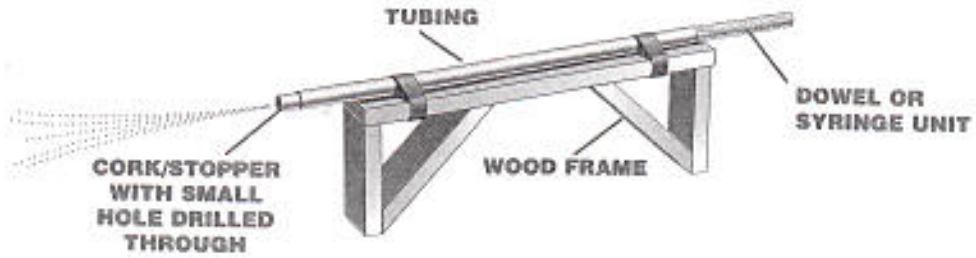
Implement the Solution

1. Build the unit.
2. Test the completed unit. If no water can be forced out, enlarge the hole in the cork. Keeping the hole as small as possible will permit the maximum range. Too much force may cause the cork to pop out. If this happens, place a pin through both cork and tubing. This will keep the cork in the tube.
3. Demonstrate the water squirter to the class.



Evaluate the Solution

1. Are there any leaks? Can they be stopped?
2. Does the squirter project water accurately?
3. Is the range satisfactory?
4. What could be done to improve the water squirter's performance?



- Disconnect the air-pressure line before working with pneumatic system components.
- Position air and hydraulic lines so that they are not a hazard to yourself or others.

TYPES OF FLUID POWER SYSTEMS

There are two types of fluid power systems. **Hydraulic** (high-DRAW-lick) **systems** are fluid power systems that use oil or another liquid. **Pneumatic** (new-MAT-ick) **systems** are fluid power systems based on the use of air or another gas.

Components

Hydraulic and pneumatic systems are very similar in design. The knowledge you gain by using one system is easy to apply to the other. All fluid power systems have similar basic components, or parts:

- a fluid.
- a compressor or pump.
- a reservoir or receiver.
- control valves.
- actuators.
- flow regulators.
- transmission lines.

Refer to Fig. 12-3 as you read about these components.

For fluid, most hydraulic systems use oil to transmit power. Pneumatic systems typically use air.

The *compressor* or *pump* supplies fluid under pressure to the system. A hydraulic system uses a pump to move oil. Most pumps are motor-driven. A pneumatic system uses a compressor that draws air into a chamber. The air is then compressed or squeezed into a smaller space. The compressor can be operated by hand or motor-driven. A bicycle pump is not really a "pump." It is actually a manual compressor. Most pneumatic systems use motor-driven compressors.

The oil in a hydraulic system is pumped into a *reservoir*, where it is stored. In a pneumatic system, a *receiver* takes the air from the compressor and stores it. Later the air is released as needed.

Control valves open and close passages to direct air or liquid to the proper location in the system. They also regulate the fluid pressure and the rate of flow. Valves are used to control the actions of cylinders. Valves can be controlled manually, electrically, or by air pressure.

Actuators change pressure into mechanical motion. The actuator is usually a cylinder or motor.

Cylinders are made up of the cylinder body, piston, and piston rod. *Single-acting* cylinders are designed so that air pressure is applied to only one side of the piston. When the air pressure is released, a spring returns the piston to its original position.

Double-acting cylinders are designed so that air can be applied to either side of the piston. With this type of cylinder, air pressure can be used to extend and retract the piston.

Cylinders produce linear (straight line) or reciprocating (back and forth) motion. Applying the brakes in a vehicle is linear motion. Fluid motors produce rotary

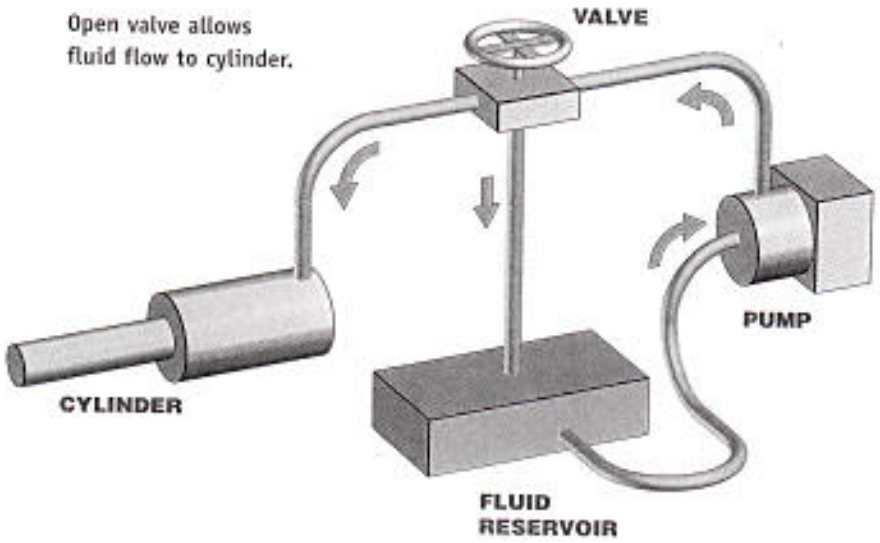


Fig. 12-3A Open valve allows fluid flow to cylinder.

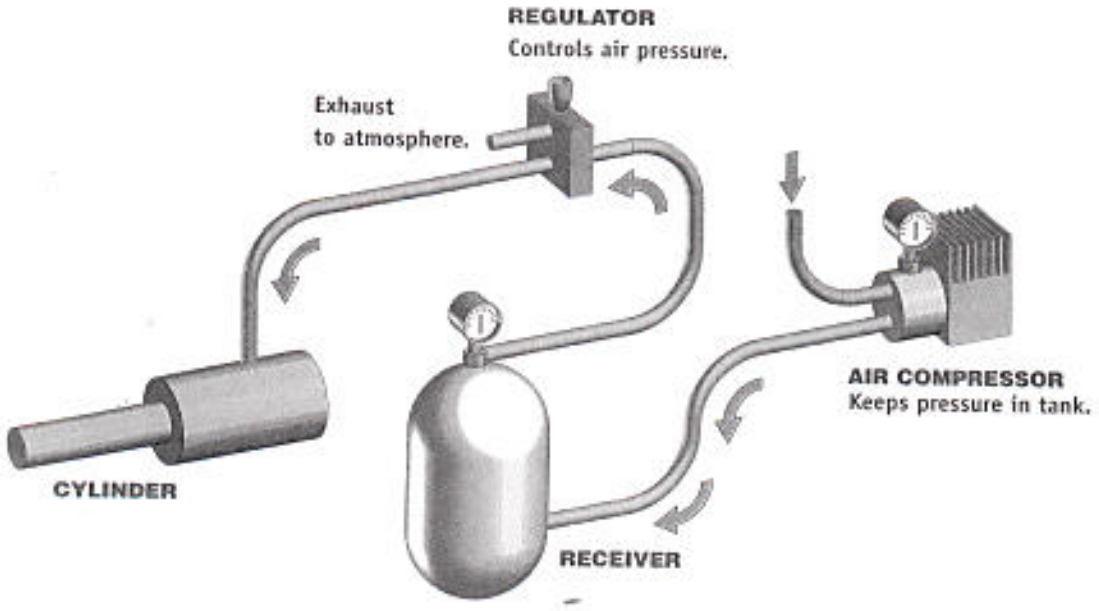


Fig. 12-3B A simple pneumatic system.

Linking to COMMUNICATION

Word Roots. Many words in English are based on word parts from the ancient Greek language. Two important terms in this chapter—hydraulic and pneumatic—use Greek roots. *Hydro* means "water." *Pneuma* means "blast of air." Discuss with your study group how these two root words apply to hydraulic and pneumatic. Use the dictionary to prepare a list of other words using the same root words. Be sure each word in your list refers in some way to water (hydro) or air (pneuma).

(circular or spinning) motion. Rotary motion is produced in a tool such as a drill. Complicated industrial equipment often uses combinations of the different types of motions.

Flow regulators control the speed of piston travel in a cylinder. They do this by restricting the flow of air in one direction. Two flow regulators are needed to control the motion of a double-acting cylinder.

Transmission lines are pipes and hoses. Pressurized fluid is moved through these to the other components in the system.

Hydraulic Systems

Liquids cannot be compressed. Therefore, they can be used to transfer force. Figure 12-4 shows this. The force applied to piston A puts pressure on the fluid. The fluid then exerts the same amount of pressure in all directions (Pascal's Principle). Thus the 10 pounds of force from piston A is transferred to piston B. Note that the two pistons are the same size.

Hydraulic systems can also multiply force. The increase in force gained by using a machine is called **mechanical advantage.** Figure 12-5 shows how pistons of different sizes can produce a

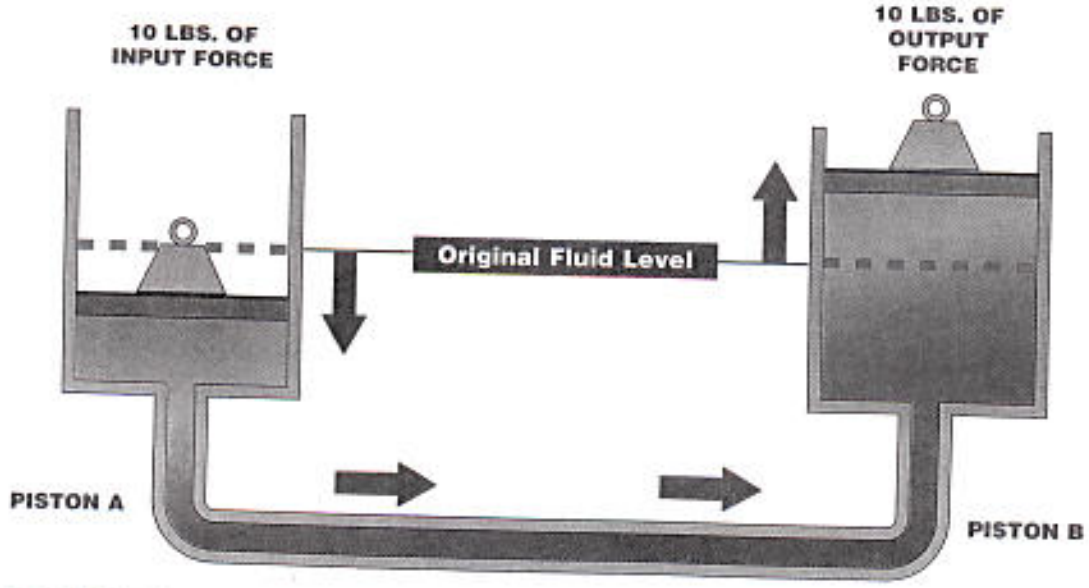


Fig. 12-4 Piston A and Piston B are the same size. When force is applied to Piston A, the force is transferred by the liquid to Piston B.

mechanical advantage. Remember that pressure is calculated by dividing the force by the area.

$$P = \frac{F}{A}$$

$$P = \frac{50 \text{ pounds}}{5 \text{ square inches}}$$

$$P = 10 \text{ pounds per square inch (psi)}$$

Piston B has an area of 10 square inches. To calculate the force applied to piston B, multiply the pressure times the area as follows:

$$F = P \times A$$

$$F = 10 \text{ psi} \times 10 \text{ square inches}$$

$$F = 100 \text{ pounds}$$

Note that 2 inches of input movement were required to produce 1 inch of output movement. A gain in force results in a loss of distance.

Automobile jacks use a simple hydraulic system. The handle must be moved up and down many times to raise the jack even a few inches.

Hydraulic systems are ideal for use when strength and accuracy are required. This is why they are used on heavy construction equipment such as backhoes and bulldozers.

Pneumatic Systems

Pneumatic systems have some advantages over hydraulic systems. The air they use is usually readily available. If a pneumatic system leaks, there is nothing to clean up. No hazardous materials are

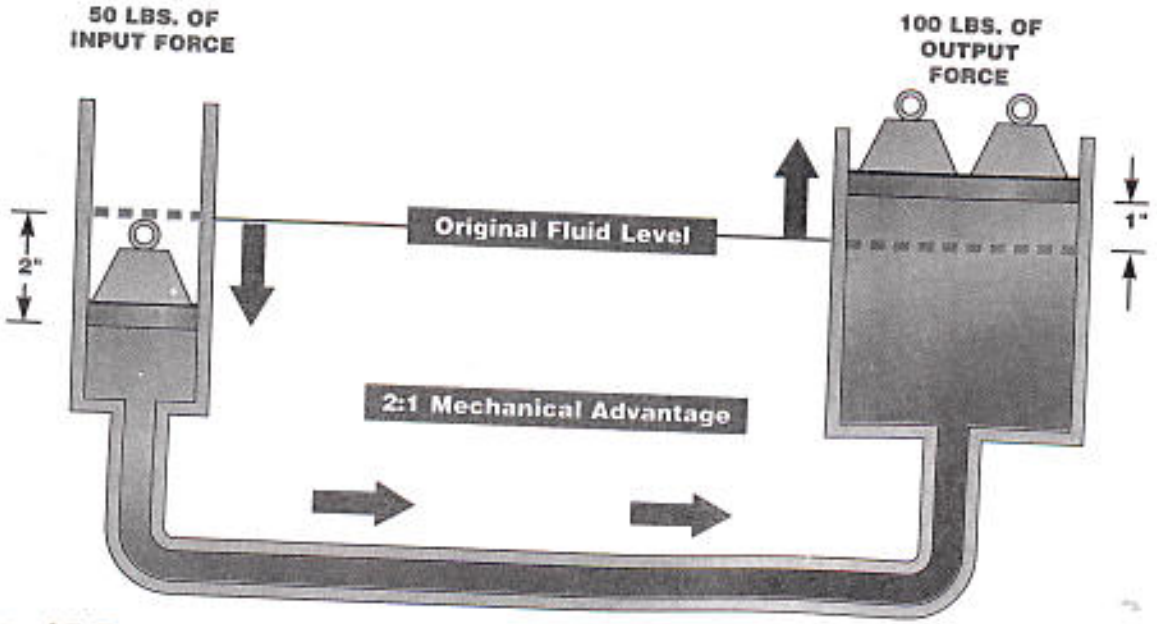


Fig. 12-5 Force can be multiplied by using pistons and cylinders of different sizes. In the system shown here, 50 lbs. of input force produces 100 lbs. of output force. The dotted line in each cylinder shows the fluid level before the application of input force.

Linking to SCIENCE

Measuring Pressure. Pressure is force per unit area. When you walk, you exert pressure on the floor. Obtain a piece of graph paper. Remove your shoe and place your foot on the paper. Draw around your foot to create its outline. Estimate the number of square inches of surface area within this outline. Use your weight to determine the pressure you exert per square inch when you stand on one foot. (Pressure equals your weight divided by the number of square inches in your foot outline.) Calculate how much pressure you exert per square inch when standing on both feet. (Double the number of square inches by which you divide.)

released. This is particularly important in the food processing industry. Pneumatic systems are also useful in locations such as spray-painting booths. Another advantage is that pneumatic systems are fast.

Pneumatic systems have some disadvantages. The energy required to compress air can be expensive. Also, many pneumatic devices are noisy.

FLUID POWER SYSTEM DIAGRAMS

Engineers plan pneumatic systems by drawing *schematic circuit diagrams*. They use symbols to represent components. Figure 12-6 shows a few of these symbols. These symbols were devised by the American National Standards Institute (ANSI). Figure 12-7 shows how some of these components are arranged to create a circuit. Fluid power system diagrams are read from bottom to top.

HOW FLUID POWER IS USED

Fluid power can be applied in a variety of ways. Many small hand tools like drills, wrenches, and sanders are operated by fluid power. So are the large machines used to crush automobiles for recycling. Fluid power is used to lift and move heavy objects. It can also open and close doors. Today most industries use fluid power.

Manufacturing

Fluid power systems are used in almost every manufacturing plant. Hydraulic lifts move materials to where they are needed. Pneumatic devices perform tasks such as painting. Many of the material-moving devices on assembly lines are hydraulic or pneumatic.

Many of the devices used to move materials in factories are powered by hydraulic or pneumatic systems. These systems are also used to power many of the tools used on assembly lines. Pneumatic systems provide an inexpensive source of energy when a lot of power is needed. For example, the tool used to tighten and remove the bolts on an automobile wheel is usually a pneumatic tool.

FASCINATING FACTS

In Paris, a system of pipes carries compressed air to users throughout the city. The system was installed in the 1880s.

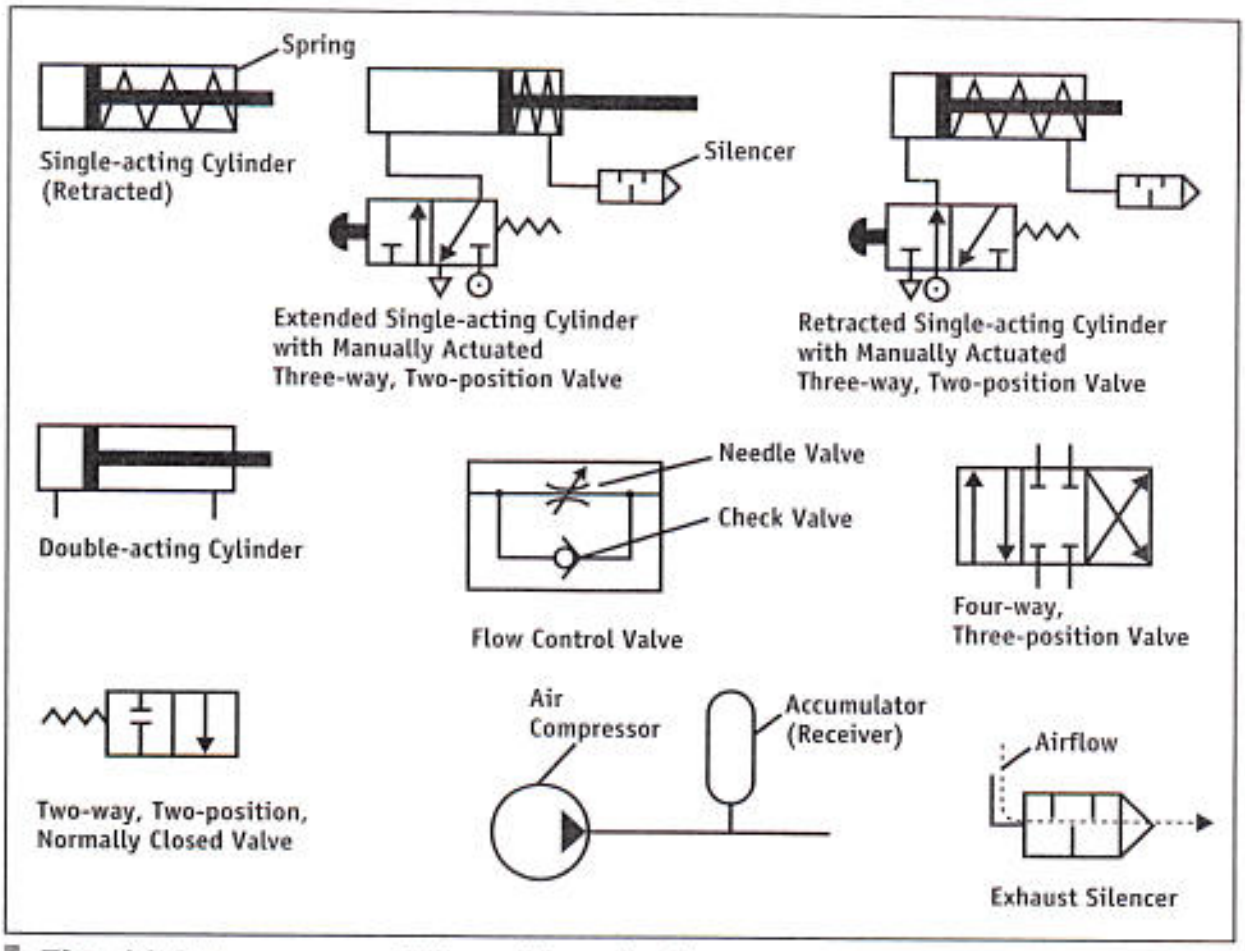


Fig. 12-6 These are some of the symbols used to diagram a pneumatic circuit.

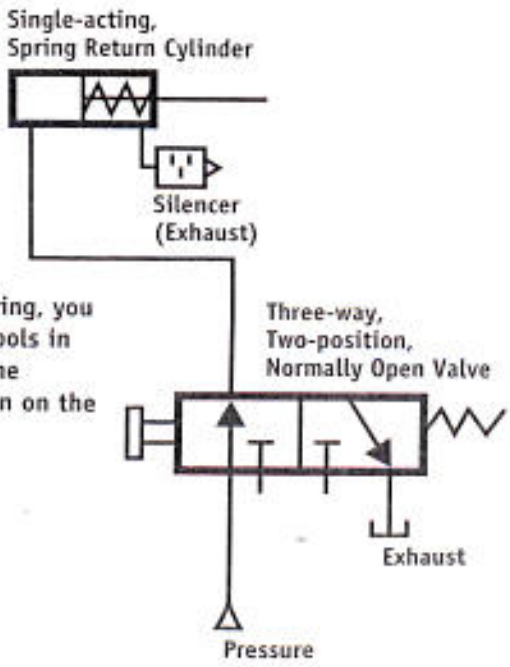


Fig. 12-7 To be able to read a schematic drawing, you need to know what each symbol represents. The symbols in Fig. 12-6 will help you identify the components of the circuit shown here. What will happen when the button on the left is pushed?

Explore

Design and Build an Air Cushion Vehicle

Collect Materials and Equipment
corrugated cardboard
compass
scissors
pencil
hot glue gun
balloons in assorted sizes and shapes
empty thread spools
pennies

State the Problem

Air cushion vehicles (ACVs) use a pneumatic system to provide lift as they travel. Design and build a model ACV capable of transporting as many pennies as possible.

Develop Alternative Solutions

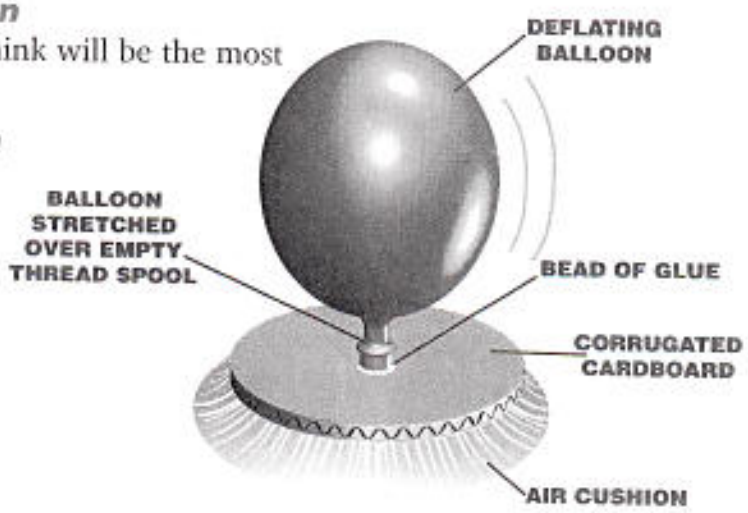
A simple ACV is shown here.. A model built with this design will work. How can you modify this design to lift and move as many pennies as possible? Sketch several possible designs.

Select the Best Solution

Select the design that you think will be the most effective.

Implement the Solution

1. Make your first ACV using a 4" diameter base. Use the pencil to make a hole in the center of the base.



Transportation

Fluid power systems make automobiles steer easily, ride smoothly, and stop. The equipment used to repair flat tires is hydraulic and pneumatic. Protective air bags work because they are pneumatic.

The controls that pilots use to guide airplanes, helicopters, and even the space shuttle are fluid-powered. Aircraft landing gears are lowered and raised hydraulically. Also, hydraulic shock absorbers built into landing gears make landing safer and more comfortable.

2. Center the thread spool over the hole. Attach it to the base using hot glue. Allow to dry.
3. Inflate the balloon and stretch it over the spool. Pinch the balloon at its base so that the air cannot escape. Place the ACV on the floor and release it.
4. Add several pennies to the top of the ACV and repeat the test.
5. Repeat the test using balloons of various sizes and shapes. You might also use bases of different sizes. Determine how these changes affect lifting power.

Evaluate the Solution

1. Make a table to record the results of each test. Include information about the size and shape of the balloon, the size of the base, and the number of pennies moved.
2. Which combination of balloon and base worked best?
3. What might be done to improve control of the ACV?
4. Describe one use of an ACV in business or industry. How might the design of such an ACV differ from the design of your model?

Construction

In home construction, pneumatic nailers are replacing hammers. Pneumatic framing, roofing, and trim nailers have greatly increased the amount of work a carpenter can complete in a day. The lifting, pushing, and digging mechanisms on heavy construction equipment are hydraulically operated. Fig. 12-8.

Fig. 12-8 The enormous force developed by a hydraulic system is demonstrated here. This truck is delivering several tons of rock.

Agriculture

Hydraulic devices are used in agriculture on the equipment used for planting and harvesting. Pneumatic power systems are commonly used in factories that wash, can, and package food. Fig. 12-9.

Health Care

Fluid power devices are also important in health care. Your dentist uses a high-speed pneumatic drill. The dental chair is raised and lowered by a hydraulic system.

Medical personnel can now use pneumatic devices to give injections. These devices force vaccines through the skin without piercing it.

Pneumatic artificial kidney machines are used by thousands of people every day. These machines are controlled by a computer.

IMPACTS

People have used fluid power for thousands of years. Windmills have been used to pump water. Waterwheels were used to turn millstones to grind grain. Many of the devices that make our life easier depend on fluid power. Today, fluid power systems perform important tasks in manufacturing, transportation, construction, agriculture, and health care.

Some have said that certain uses of fluid power have had a negative impact on our environment. As examples, they point to the building of dams on rivers. Dams are built for several reasons. For example, they are built to help prevent or control flooding. Dams are also built to generate electric power. The fluid power of the water through the dam powers generators.

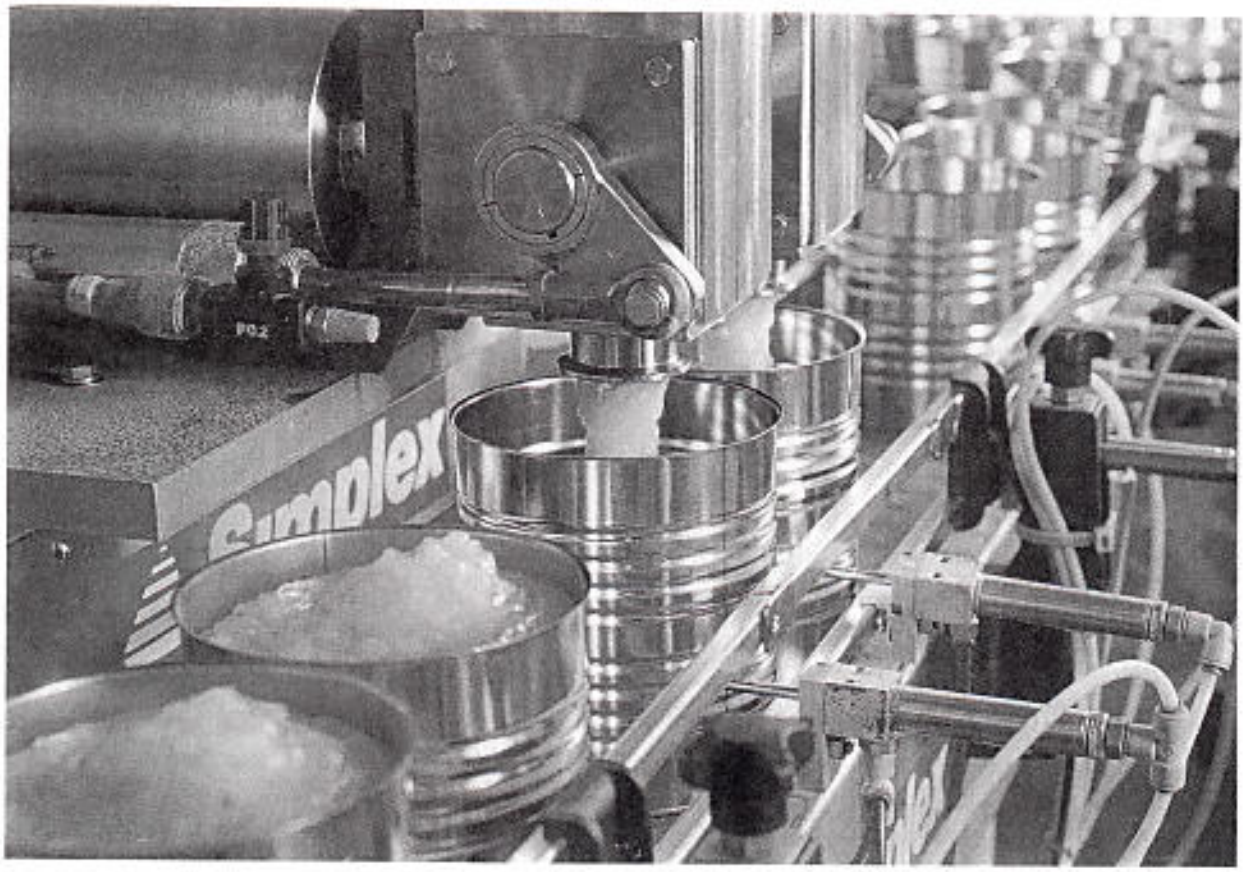


Fig. 12-9 Pneumatic systems are used in all phases of agriculture and food processing. Many of the machines used in food canning are powered by pneumatic systems.

Some have been critical of such dam building. They argue that the damming of rivers has impacted the reproduction cycle of fish such as the salmon. They also point out that such construction alters the landscape. They point out that the advantages gained by building a dam do not outweigh the negative impacts.

Linking to MATHEMATICS

Figuring Area. Apple cider is juice that has been pressed from apples. A large commercial cider press uses hydraulic power to press the juice from the ground-up apples. Assume that a cylinder with a diameter of 4" is used. Figure the area in square inches of the 4" diameter cylinder. Use the formula $A = \pi r^2$. A stands for Area; π has a value of 3.14; r stands for radius.

THE FUTURE

The fluid power industry will continue to develop new uses for pneumatic and hydraulic control systems. In the future, individual components are expected to be smaller, lighter, and less expensive.

Engineers will continue to develop new uses for fluid power in manufacturing and other industries. Microprocessors will combine fluid and computer control. These devices will play an important role in automated systems.

Design and Build a Gameboard

Collect Materials and Equipment

- thin building material for top panel and base
- insulation board
- wood or plastic
- marble
- plastic syringes
- tubing for syringes

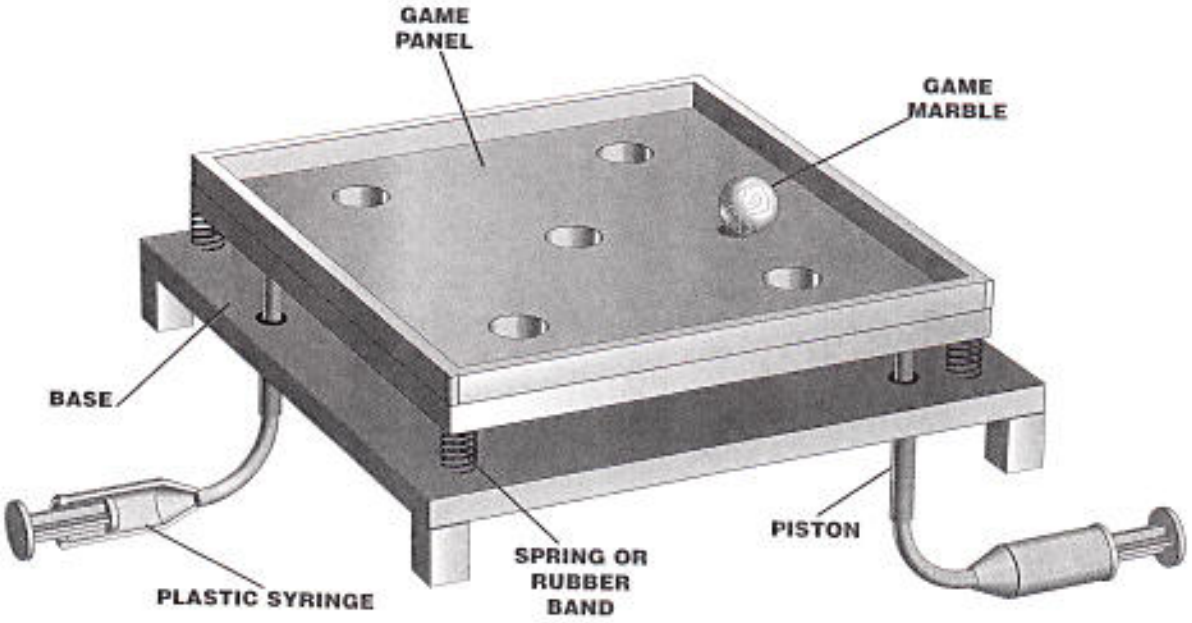
State the Problem

Design and build a game that uses pneumatic power.

Develop Alternative Solutions

A player should be able to move the marble from hole to hole using the pneumatic syringe hookups (possibly one in each corner). The panel may be held down with springs or rubber bands.

The basic setup is a flat panel (perhaps 8" x 10") with several holes. Each hole must be smaller than the marble that will be used in the game. Sketch several possible designs. Note that smaller holes will allow the marble to move from hole to hole more easily. It might look similar to the gameshown here.



Select the Best Solution

Select the design that you think will be most effective.

Implement the Solution

1. Prepare the game panel.
2. Cut and assemble the parts for the base.
3. Mount the game panel on the base.
4. Mount the syringes. It is often a good idea to mount the syringes in a secure holder to allow one-hand operation.
5. Present your finished game to the class. Explain what problems were encountered and how they were solved.

Evaluate the Solution

1. Does the game work as intended?
2. Is the game reasonably easy to operate?
3. Is the game made solidly enough to be used again and again?
4. Changing the angle of a horizontal panel in small stages through the use of pneumatic power (such as supplied by plastic syringes) is a difficult task. Making small, gradual motions takes practice and skill to achieve. How could this game be redesigned so that it would require less skill to play?
5. How do you think a game such as this could be made using other sources of power? Why might it be convenient to control motion using fluid power?

CAREERS IN
Fluid Power

WASTE WATER PLANT OPERATOR

Industrial wastewater treatment plant needs operator with mechanical aptitude and competence in basic math. Two-year degree and certification required. Will perform tests, keep records and do repairs and maintenance. Send resume to: Burlington Industries, 903 West Town Street, Athens, NE 63205.

NUCLEAR ENGINEER

Engineer needed to monitor nuclear tests and examine operations of facility utilizing radioactive material. Direct operations and maintenance activities. Degree in nuclear engineering required. Competitive salary and benefits package. Submit resume to: Tennessee Nuclear Plant, 3355 Kingston Parkway, Knoxville, TN 32204.

PETROLEUM RESEARCH ENGINEER

Oil refining company seeks petroleum research engineer for designing new petroleum blends and troubleshooting. Bachelor's degree in chemistry or chemical engineering required. Internship or summer job experience helpful. Work in lab setting. Computer skills a must. Send resume to: Clark Oil Company, Human Resources Director, 1800 King Drive, Oklahoma City, OK 77320.

PRECISION INSTRUMENT TECHNICIAN

Technician needed to inspect and repair mechanical systems used at power generating plant. Involved in all facets from regular inspection and preventive maintenance, to actual adjustment or replacement of faulty parts. Two-year training required. Knowledge of hydraulics, digital electronics and electricity required. To apply, submit resume to: Personnel Department, Blue Water Power, 1415 Lakeside Drive, Alcoa, TN 33956.

HYDRAULIC REPAIRER

Manufacturing company needs hydraulic repairer to inspect, maintain and repair robotics equipment. Knowledge of hydraulics and mechanical ability required. Computer skills helpful. Apply in person to: North Start Industries, 900 Stafford Parkway, Kewanee, IL 64302.

AUTOMOBILE TECHNICIAN

Expanding auto repair shop needs technicians with own tools. ASE Certification preferred. Two years of formal training required with knowledge of electronics. Numerous benefits with high hourly pay. For more information, call Joe at (212) 473-4500.

Linking to the WORKPLACE

The job ads listed above describe openings that an employer has written. They tell you what's needed for a person to get that job—the job requirements. Read the jobs listed above and write down all the different requirements you find. Even if you are not sure what a requirement means, write it down anyway. Were some of the listed skills needed in more than one job? What are the requirements for the job you are most interested in at this time?

Chapter 12 Review

SUMMARY

- Fluid power is the use of pressurized liquids and gases to perform work.
- There are two types of fluid power systems. Hydraulic systems use oil or another liquid. Pneumatic systems use air or another gas.
- All fluid power systems have similar basic components: a fluid, a compressor or pump, a reservoir or receiver, control valves, actuators, and transmission lines.
- Hydraulic systems are used when strength and accuracy are required. Pneumatic systems are well suited for food processing and spray-painting situations.
- Fluid power systems are used in most industries.
- Industry will continue to develop new uses for fluid power control systems.

CHECK YOUR FACTS

1. Define fluid power.
2. Describe the two main types of fluid power systems and explain the difference between them.
3. Identify the basic components of a fluid power system.
4. What part of a fluid power system changes pressure into mechanical motion?
5. What is the proper name of the drawing used to represent a fluid power system? How is the drawing read?
6. Name at least four industries that use fluid power systems. Give one example of how fluid power is used in each industry.

CRITICAL THINKING

1. Explain some of the important differences between the two types of fluid power systems.
2. Describe how the molecules of solids, liquids, and gases differ.
3. Use an example to explain how a hydraulic system can multiply force.
4. Plan a simple pneumatic system using the proper symbol for each component.
5. Do research to find out how fluid power devices are used in your community and nearby areas.
6. Do research to find out how fluid power might be used in the future.