R E P O R T   R E S U M E S

ED 021 105 VT 005 688

AUTOMOTIVE DIESEL MAINTENANCE 2. UNIT III, AUTOMATIC TRANSMISSIONS--HYDRAULICS (PART I).

HUMAN ENGINEERING INSTITUTE, CLEVELAND, OHIO

REPORT NUMBER AM-2-3 PUB DATE 9 MAY 67

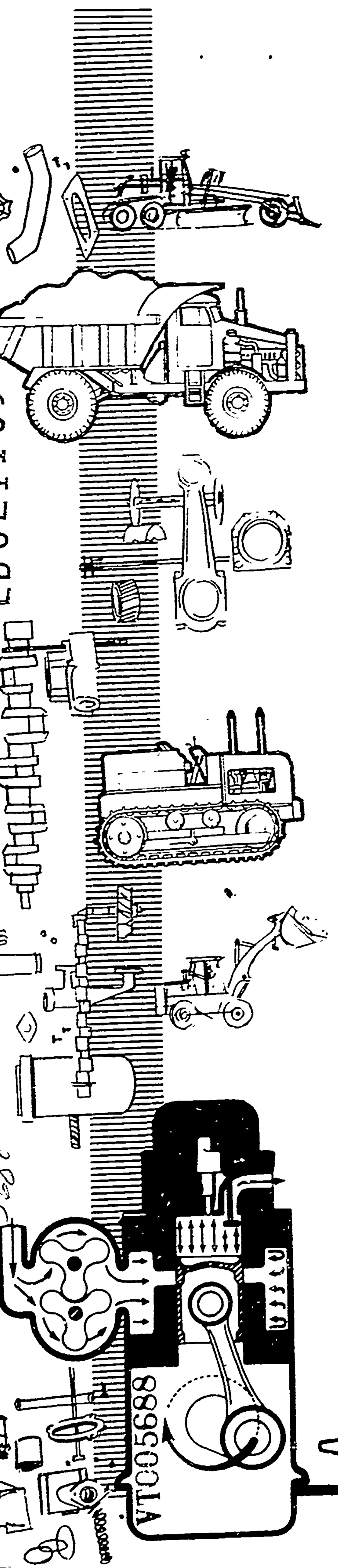
EDRS PRICE MF-$0.25 HC-$1.84 44P.

DESCRIPTORS- *STUDY GUIDES, *TEACHING GUIDES, *TRADE AND INDUSTRIAL EDUCATION, *AUTO MECHANICS (OCCUPATION), *HYDRAULICS, DIESEL ENGINES, ADULT VEHICLES, INDIVIDUAL INSTRUCTION, INSTRUCTIONAL FILMS, PROGRAMED INSTRUCTION, EQUIPMENT MAINTENANCE, KINETICS,

THIS MODULE OF A 25-MODULE COURSE IS DESIGNED TO INTRODUCE BASIC HYDRAULIC PRINCIPLES AND PROVIDE AN UNDERSTANDING OF HYDRAULIC TRANSMISSIONS USED IN DIESEL POWERED VEHICLES. TOPICS ARE WHY USE HYDRAULICS, REVIEWING BASIC PHYSICS LAWS IN RELATION TO HYDRAULICS, UNDERSTANDING THE HYDRAULIC SYSTEM, AND DEVELOPING A BASIC HYDRAULIC SYSTEM. THE MODULE CONSISTS OF A SELF-INSTRUCTIONAL PROGRAMED TRAINING FILM "BASIC HYDRAULICS" AND OTHER MATERIALS. SEE VT 005 685 FOR FURTHER INFORMATION. MODULES IN THIS SERIES ARE AVAILABLE AS VT 005 685 - VT 005 709. MODULES FOR "AUTOMOTIVE DIESEL MAINTENANCE 1" ARE AVAILABLE AS VT 005 655 - VT 005 684. THE 2-YEAR PROGRAM OUTLINE FOR "AUTOMOTIVE DIESEL MAINTENANCE 1 AND 2" IS AVAILABLE AS VT 006 006. THE TEXT MATERIAL, TRANSPARENCIES, PROGRAMED TRAINING FILM, AND THE ELECTRONIC TUTOR MAY BE RENTED (FOR $1.75 PER WEEK) OR PURCHASED FROM THE HUMAN ENGINEERING INSTITUTE, HEADQUARTERS AND DEVELOPMENT CENTER, 2341 CARNEGIE AVENUE, CLEVELAND, OHIO 44115. (HC)

STUDY AND READING MATERIALS

AUTOMOTIVE DIESEL MAINTENANCE 2



AUTOMATIC TRANSMISSIONS -- HYDRAULICS (PART I)

UNIT III

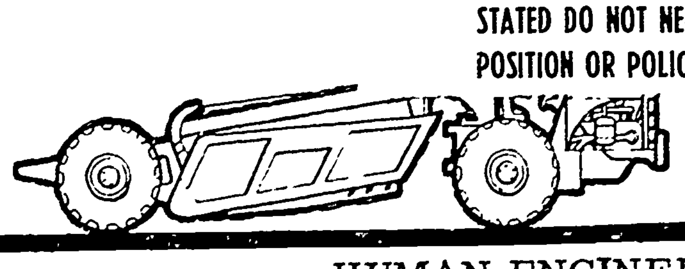
SECTION A WHY USE HYDRAULICS

SECTION B REVIEWING BASIC PHYSICS LAWS IN RELATION TO HYDRAULICS

SECTION C UNDERSTANDING THE HYDRAULIC SYSTEM

SECTION D DEVELOPING A BASIC HYDRAULIC SYSTEM

AM 2-3
5/9/67



HUMAN ENGINEERING INSTITUTE

This unit is one of several designed to familiarize the mechanic with basic hydraulics and hydraulic components. The Allison transmission, like many other parts of modern off-highway equipment, operate almost entirely by hydraulics; see Figure 1. Therefore, it is of vital importance that the mechanic have a thorough understanding of the subject.

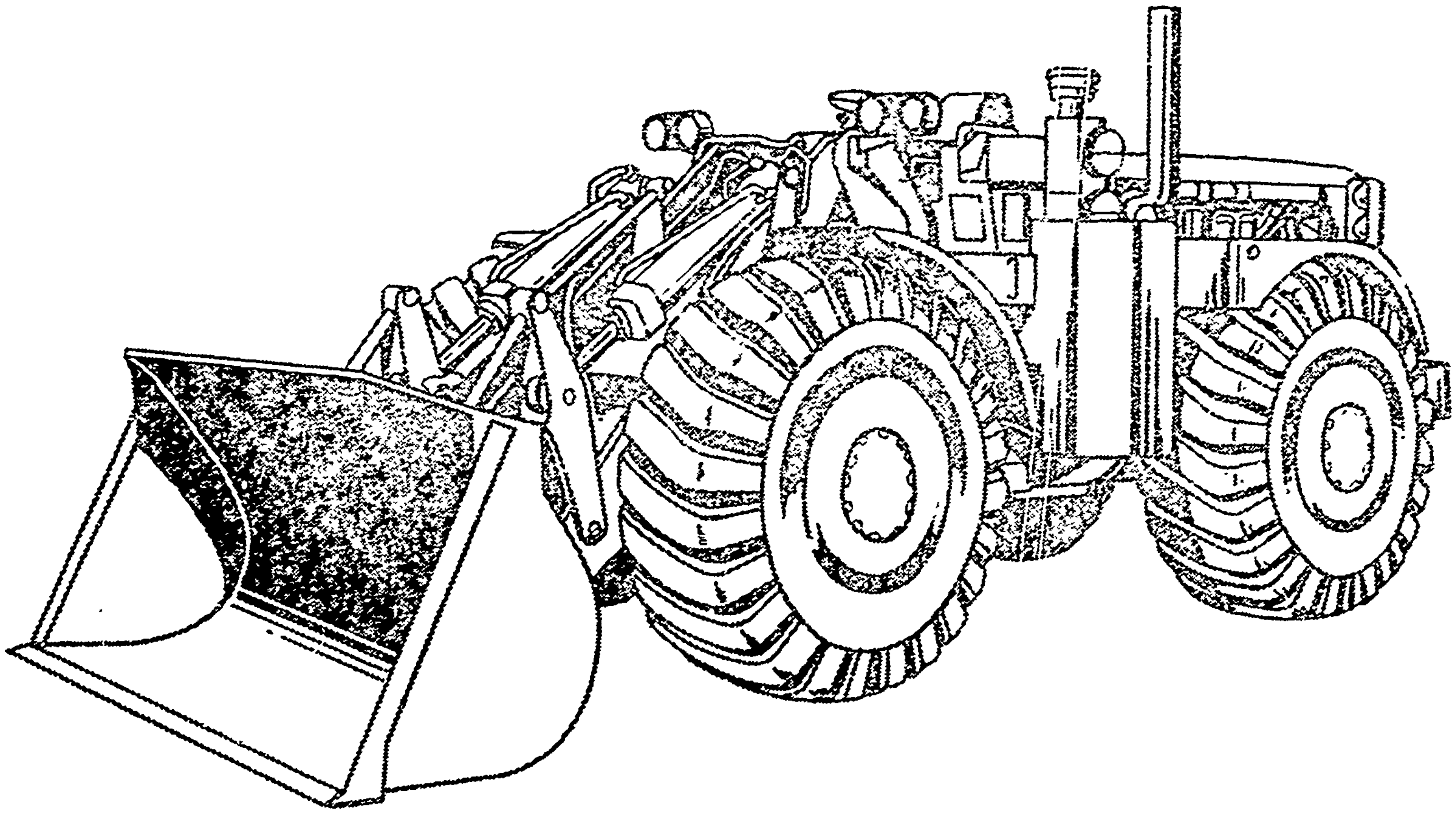


Fig. 1 Modern off-highway equipment

SECTION A -- WHY USE HYDRAULICS

Fluid under pressure used to transmit power and to control intricate motions has had its greatest development in the past two or three decades. Let's see why.

The use of a confined liquid in a closed system is one of the most versatile means known to transmit power and control motion. A liquid is almost incompressible, and yet is limitlessly flexible. It will change its shape to fit the body that resists its thrust and then be reunited to work again as a whole. It can move rapidly in one part of its length and slowly in another. No other medium combines the same degree of positiveness, accuracy and flexibility, while maintaining the ability to transmit a maximum of power with a minimum of bulk and weight.

DESIRABLE FEATURES -- When deciding on the means for the transmission and control of power, the design engineer can choose among mechanical, pneumatic, hydraulic, or the more recently developed methods of electronic control. Each of these methods has a definite field of application in industry. Mechanical and electrical methods are used widely in equipment where it is convenient to locate the source of power and its control close to the work being done. Hydraulic, pneumatic and electronic controls have the advantage of flexibility in the location of the control equipment. Hydraulics also have the added advantage that the amount of force which can be exerted is almost unlimited.

Hydraulic systems are a "natural" for use on off-highway equipment because hydraulic power may be transmitted to any point on a rig by means of flexible hoses. It can be precisely controlled by simple valves, and it affords a compact means of securing force multiplication where desired. An almost effortless flick of a control valve will pick up a load or dump it. Clutches are shifted, gears are changed, and rigs are steered by hydraulic power. One construction machine, as shown in Figure 1, uses hydraulic power exclusively for all its actuation.

The basic principle of the hydraulic system is very simple. A reservoir or tank holds a supply of oil which is forced through a system of hoses or pipes by a pump to the point where the power is to be applied. Here it may operate a piston in a cylinder or actuate a hydraulic motor to secure the desired effort. Control valves (some of which are actuated electrically), filters and pressure relief valves complete this picture -- which will be shown in detail later on in this unit.

Some of the other features of hydraulic power are:

1. Simplicity in design.
2. Extreme flexibility of location with respect to actuated parts.

3. Systems can be made completely automatic, to control a sequence of operations.

4. Simplicity of speed control.

5. Wide variety of speeds and forces.

6. Usually less maintenance required because of reduction of wear on moving parts by:

   (1) Controlled acceleration and deceleration
   (2) Automatic release of pressure at overload
   (3) Absence of vibration
   (4) Automatic lubrication

7. Efficient and economical to operate.

8. Can be used where electricity would be a fire hazard.

9. Ease of reversibility.

10. High starting torque with relatively small power unit.

11. Can be used in adverse weather where small gas-powered unit or electric motor would be likely to become damaged.

SECTION B -- REVIEWING BASIC PHYSICS LAWS IN RELATION TO HYDRAULICS

In 1653, the foundations of modern hydraulics were laid by Pascal. Pascal discovered the fundamental law of physics upon which all modern hydraulic systems are based. Essentially, PASCAL'S LAW states:

> Pressure exerted on a confined liquid is transmitted, undiminished, in all directions and acts with equal force on all equal areas.

Since liquids are essentially incompressible and are fluid, that is, flow readily, the pressure applied to the liquid at one point will be transmitted to any point the liquid reaches. Modern hydraulic systems are assemblies of units capable of accomplishing this, for they contain fundamentally units for generating force (pumps), suitable tubes or pipes for containing and transmitting the fluid under pressure, and units in which the energy in the fluid will be converted to mechanical work (cylinders).

MEANING OF POWER -- POWER is the measure of a given force moving through a given distance at a given speed. To understand this statement, we must define force.

FORCE is defined as any cause which tends to produce or modify motion. Due to inertia, a body at rest tends to remain at rest and a body in motion tends to remain in motion until acted upon by an external force. The resistance to change in speed depends upon the weight of the object and the friction between the contacting surfaces. If we wish to move an object, such as a machine tool head, we must apply force to it. The amount of force necessary will depend upon the object's inertia. Force may be expressed in any of the units of weight measure, but it is commonly expressed in pounds.

The concept of force involves the total tendency to assist or oppose the movement of an object; it does not involve a measure of this tendency at any given point of contact between opposed bodies. To equate force on the basis of unit area of contact, we need the concept of pressure. PRESSURE is force per unit area, and it usually is expressed in terms of pounds per square inch (psi) in hydraulics, although it can be pounds per any square measure, such as per square foot.

The earth's atmosphere provides an example of the relationship between force and pressure. The blanket of air enveloping the earth's surface is of such a volume that its total weight could be measured in tons. However, if we were to measure the weight of a column of this air one square inch in cross sectional area, we would find that the force exerted by the weight of this column of air would be 14.7 pounds at sea level. Thus, atmospheric pressure at sea level is 14.7 psi.

The relationship between force (F), pressure (P), and area (A) is mathematically expressed as follows:

$$F \text{ (lbs.)} = P \text{ (psi)} \times A \text{ (sq. in.)} \qquad P \text{ (psi)} = \frac{F \text{ (lbs.)}}{A \text{ (sq. in.)}}$$

The area of a rectangular surface may be determined by multiplying its width by its length: $A = W \times L$. The area of a circle is found by multiplying the square of its diameter by the constant .7854; the formula is: $A = .7854 \times D^2$.

FORCE, WORK AND POWER -- Both force and pressure are primarily measures of effort. A given force and pressure may be applied to a motionless object without moving the object, if they are not sufficient to overcome the object's resistance to movement. WORK is a measure of accomplishment. It describes the application of a force moving through a distance, and is commonly expressed in terms of inch-pounds or foot-pounds. Thus, if we apply a continuous force of 1200 pounds to move a ram 4 inches, we have accomplished work equal to 4800 inch-pounds or 400 foot-pounds. It may be expressed in a formula as follows:

$$W \text{ (work)} = F \text{ (force)} \times D \text{ (distance)}$$

When a force is applied through a rotary path of motion, it is referred to as TORQUE. Thus, a certain amount of torque may be required to properly tighten a nut, or a certain total torque may be available at the output shaft of a rotary motor. Torque is commonly expressed in terms of inch-pounds or foot-pounds.

The concept of work makes no allowance for the time factor. A person who runs up a flight of stairs accomplishes no more work than he would have had he walked up the same flight of stairs; but running is obviously more of a task than walking. To explain this difference, we must refer to the definition of power. POWER is work per unit time. The standard unit of power measurement is the horsepower. One horsepower is that amount of power necessary to raise 33,000 pounds one foot in one minute, or 550 pounds one foot in one second. Running requires more power than walking.

Since the movement of an object by force from one point to another point involves a transfer of energy from the origin of the force to the object being moved, work is actually a measure of energy transfer. In this sense, power is a measure of the rate of energy transfer.

PHYSICAL PROPERTIES OF LIQUIDS -- The three basic forms of matter are solids, gases and liquids. In all three forms, matter occupies space and possesses weight; but a given substance will vary in physical properties according to its form. Thus, ice, water and steam are identical in chemical composition, but each has its own physical properties.

A solid is characterized by its rigid molecular structure. The molecules are held at a fixed distance from each other, so that they tend to resist any change in the physical shape of the solid.

Both gases and liquids are fluids. Unlike solids, fluids are characterized by the ability of their molecules to move freely in relation to each other. In a gas, the molecules repel each other, giving the gas an expansive quality. However, this repelling force is limited, so that gases are also very compressible. In a liquid, the molecules are held in a state of balance; so that although the molecules may move in relation to each other, the distances between the molecules are fixed. Thus, a liquid combines the shape flexibility of a gas with the relative incompressibility of a solid. These two characteristics of liquids are primary factors in their ability to transmit power.

SECTION C -- UNDERSTANDING THE HYDRAULIC SYSTEM

HOW A HYDRAULIC SYSTEM WORKS -- In order to understand how a hydraulic system works, we must visualize the principles by which the two media (mechanical and fluid) work together to provide power and mechanical advantage, and thus relieve man of manual labor.

We will begin our discussion by first defining the term MECHANICAL ADVANTAGE. Mechanical advantage (MA) means that the resistance overcome exceeds the force applied. It is a measure of the number of times a machine increases the force which is applied to it. It is expressed as the ratio of the force delivered by the machine to the force required to operate it.

Mechanical advantage can be gained through leverage, either mechanical or liquid.

In MECHANICAL LEVERAGE, a lever consisting of a rod or bar is pivoted about a fixed point called a fulcrum, thereby transmitting the force. The length of the resistance arm (RA) multiplied by the resistance force (R) is equal to the length of the effort arm (EA) times the effort force required (E).

$$RA \times R = EA \times E$$

In the case of MECHANICAL LEVERAGE, the extent of advantage gained is due to the difference in the LENGTHS of the lever arms.

In Figure 2 (top), by using an effort arm (30 in.) that is twice the length of the resistance arm (15 in.), we need an activating force or Effort (10 lbs.) which is only half the resistance force.

To further reduce the effort required to perform the same work, Figure 2 (bottom), we can double the lever arm from 30 in. to 60 in. and then need only a 5 lb. force to lift the same 20 lb. load.

This means, using the equation: $MA = \frac{R}{E}$, we've gained a mechanical advantage of 20 to 5, or MA = 4.

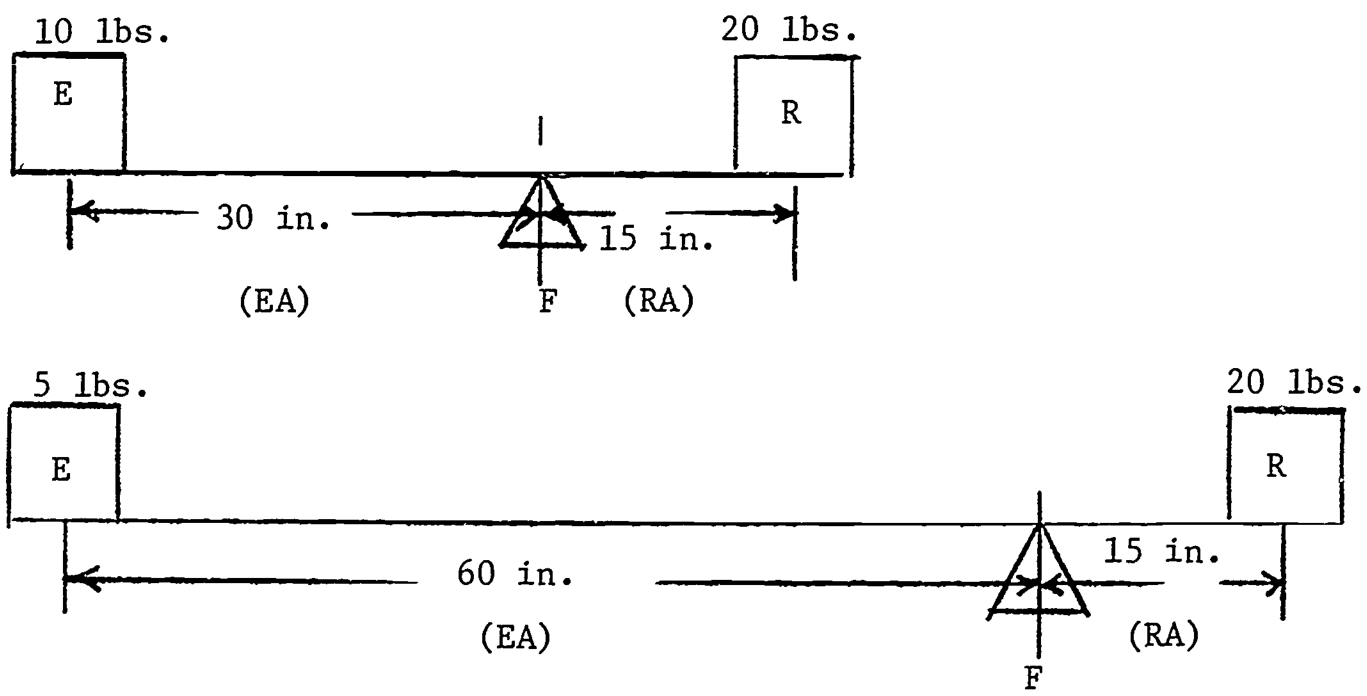


Fig. 2 Mechanical advantage through mechanical leverage

Another way of computing MA is to divide the DISTANCE through which the effort moves by the distance through which the resistance moves.

In Figure 3, the MA is found by dividing the distance through which the Effort moves by the distance the Resistance moves:

$$MA = \frac{ED}{RD} = \frac{4}{2} = 2$$

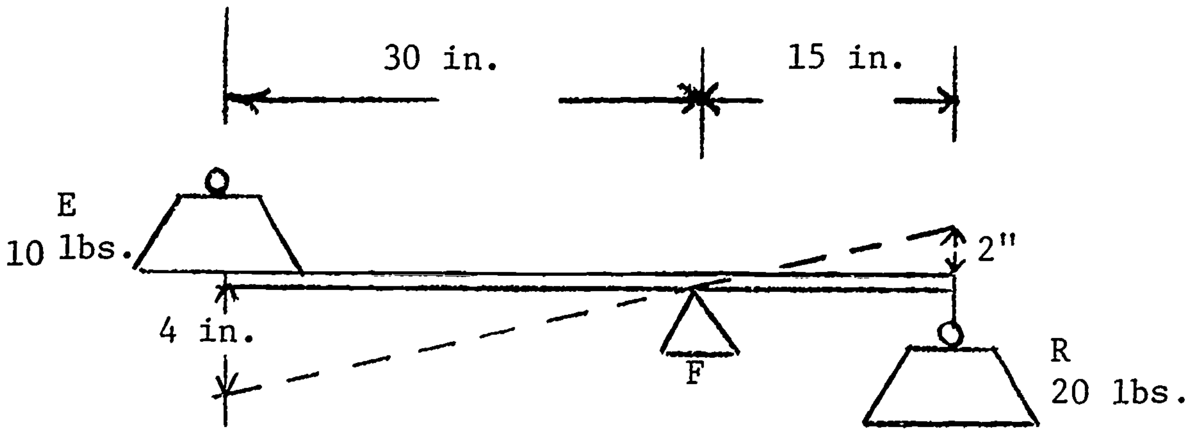


Fig. 3 Mechanical advantage computed on distance moved

We can see by this illustration that, although the mechanical advantage has given us a gain in force, we have lost in distance. The amount of total work done will be the same, since work = force x distance, or in this case:

W (10 lbs. x 4 ins.) = F (20 lbs.) x D (2 in.)

In the case of LIQUID LEVERAGE, the extent of the advantage gained is due primarily to the difference in the surface area of two movable pistons.

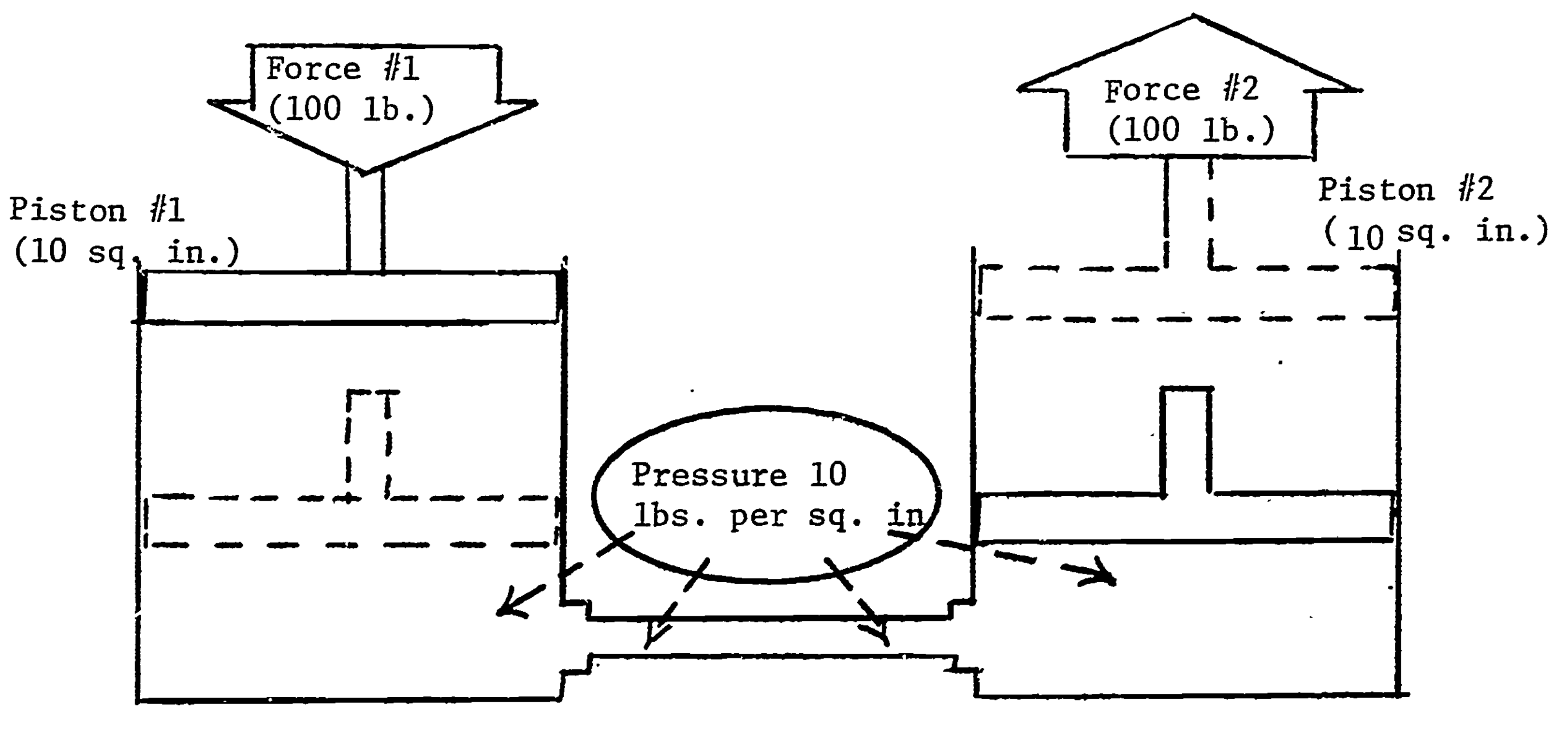


Fig. 4 Mechanical advantage through liquid leverage

With two pistons of equal size, as in Figure 4, a downward thrust of 100 lbs. pressure on piston #1 (10 sq. in. surface area*) exerts 100 lbs. upward pressure on piston #2, which is of equal size (10 sq. in. surface area). This downward movement of piston #1 forces some of the fluid from its cylinder through the pipe or tube into the cylinder, to lift piston #2 an equal distance. Thus, with pistons #1 and #2 being of equal area, a 100 lb. thrust on piston #1 permits piston #2 to lift a 100 lb. load.

---

* By surface area, we mean the area of that face of the piston which is bearing against the fluid.

With two pistons, one larger than the other, as in Figure 5, the pressure or force of 20 lbs. exerted on piston #1 (2 sq. in.) is multiplied, to exert a total force of 200 lbs. on the larger piston #2 (20 sq. in.).

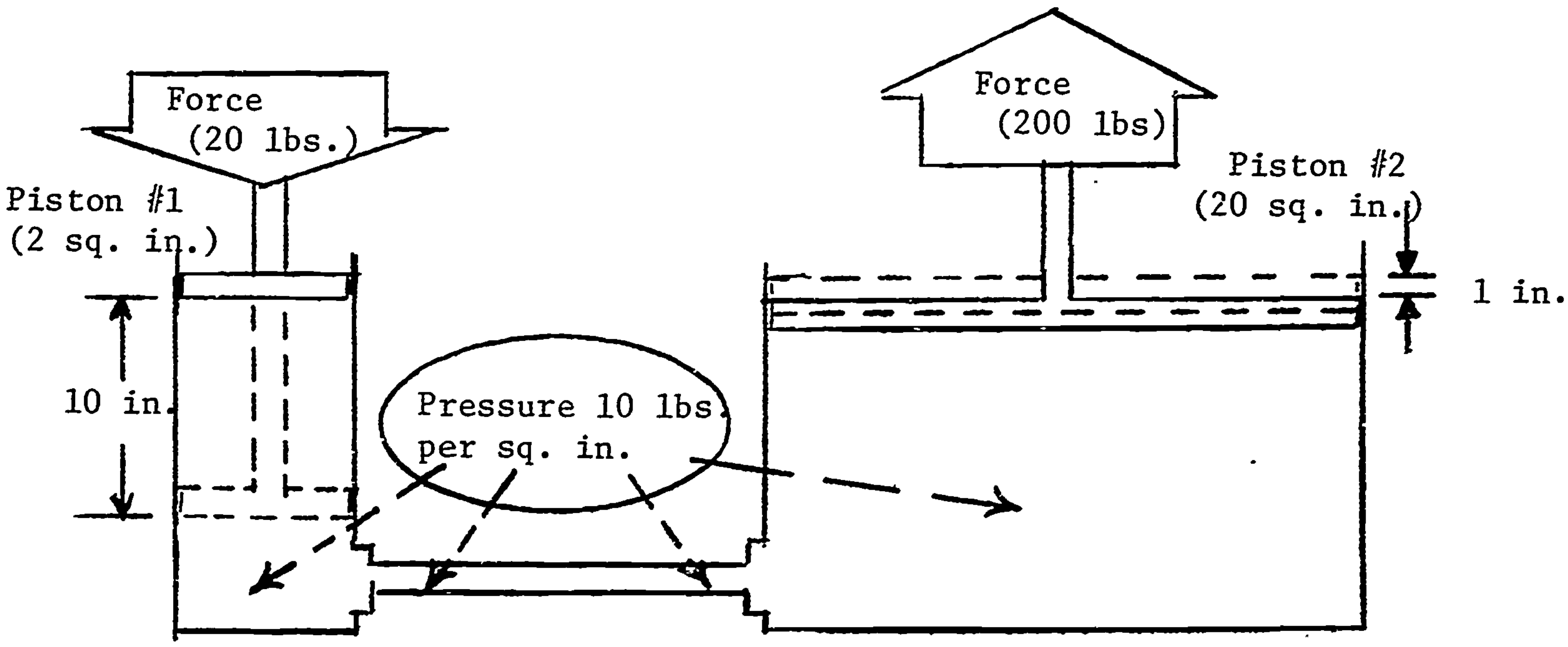


Fig. 5 Mechanical advantage through multiplication of force

The force of 20 lbs. on the smaller piston #1 is distributed over the surface area (2 sq. in.) to provide a fluid pressure of 10 lbs. per sq. in:

$$\frac{20 \text{ lbs.}}{2 \text{ sq. in.}} = 10 \text{ psi.}$$

This 10 psi of pressure is transmitted through the fluid to bear against the surface area (20 sq. in.) of large piston #2. Fluid pressure of 10 psi against the 20 sq. in. of surface of piston #2 results in a force of 200 lbs. (20 sq. in. x 10 psi = 200 lbs.) This is the load capacity of piston #2.

In other words, we have multiplied the force exerted against piston #2, and have gained a mechanical advantage (MA) of 200 to 20, or MA = 10. But, you will notice that we have lost in the distance the larger piston moves. This compares with the distance loss in our lever example.

This reaction will occur without regard of the shape and position of the container and connecting lines, as seen in Figure 6.

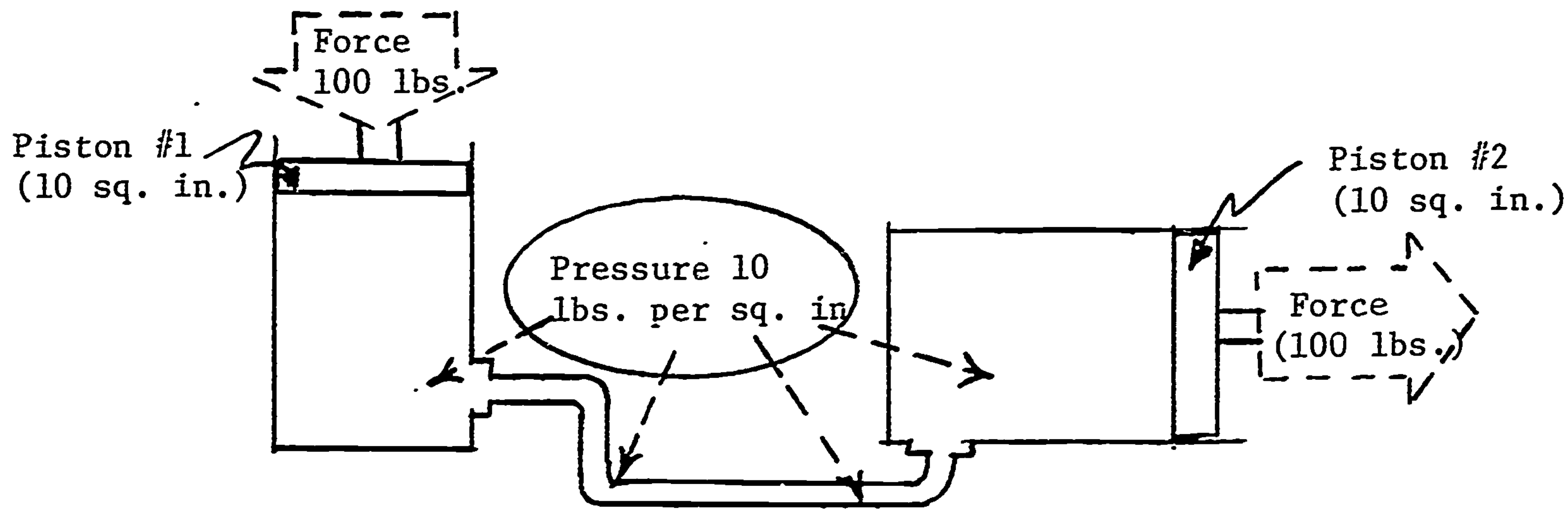


Fig. 6 Multiplication of force not dependent on shape or position of container

We can now see how mechanical advantage through liquid leverage occurs because of the principle referred to in Pascal's law. Restating this law: "Pressure exerted at any point in a confined liquid is transmitted, undiminished, in all directions, and acts with equal force on all areas."

CHARACTERISTICS OF FLOW -- Pascal's law deals with the pressure characteristics of a STATIC liquid subject to an applied force. In power hydraulics, however, we must also consider the DYNAMIC factors, that is, the force present when a liquid is in motion.

As previsouly mentioned, ENERGY is the ability to perform work. For the purposes of this discussion, energy may be classified into three distinct forms: potential energy, kinetic energy, and heat energy. Potential energy is energy due to position; an object possesses potential energy in proportion to its vertical distance above the earth's surface. Kinetic energy is the energy a body possesses by reason of the velocity at which it is moving. The greater the velocity, the greater the kinetic energy that is present. Heat energy is the energy a body possesses by reason of the heat contained in it.

In hydraulics, potential energy is a static factor; kinetic and heat energy are dynamic factors.

STATIC PRESSURE VERSUS HEAT ENERGY -- Pascal's law neglected the factor of friction, because it dealt with static liquids. Friction is the resistance to relative motion between two bodies. Whenever a liquid flows in a hydraulic circuit, the friction present produces heat, so that some of the energy being transferred is lost in the form of heat energy. Although friction can never be eliminated entirely, it can be controlled to some extent. The three main causes of excessive friction in hydraulic lines are:

1. Excessive length of lines.
2. Excessive number of bends and fittings, or improper bends.
3. Excessive velocity (lines undersized).

When a liquid flows through straight piping at a low velocity, the particles of the liquid move in straight lines parallel to the direction of flow so that heat loss from friction is minimized. This type of flow is referred to as LAMINAR FLOW. If the velocity or the amount of friction is increased beyond a given point, secondary cross currents develop. Flow characterized by such secondary cross currents is referred to as TURBULENT FLOW. Figure 7 illustrates laminar and turbulent flow in the smoke of a cigarette. At first, the smoke rises in parallel columns, but at some distance from the end of the cigarette, the smoke is distributed and turbulence develops. Laminar and turbulent flows of a confined liquid follow similar patterns.

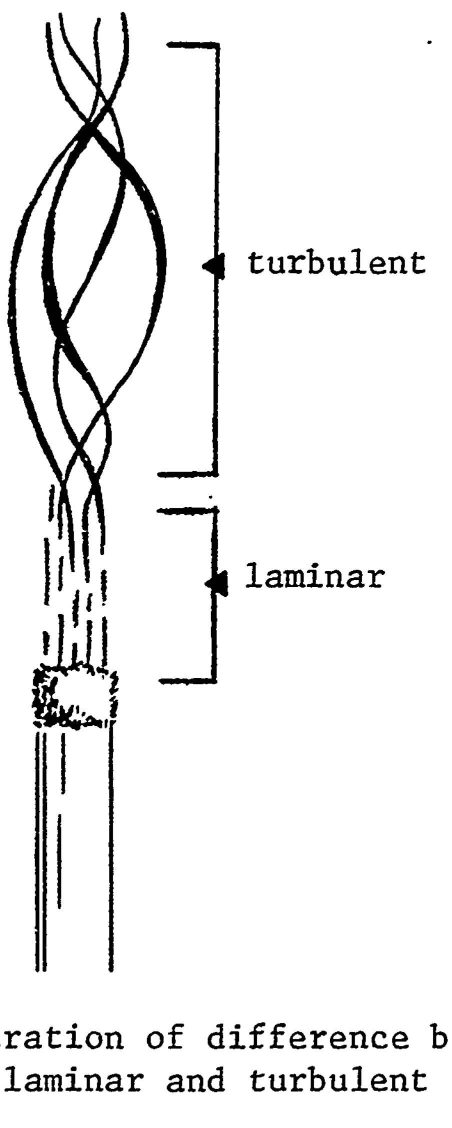


Fig. 7 Illustration of difference between laminar and turbulent flow

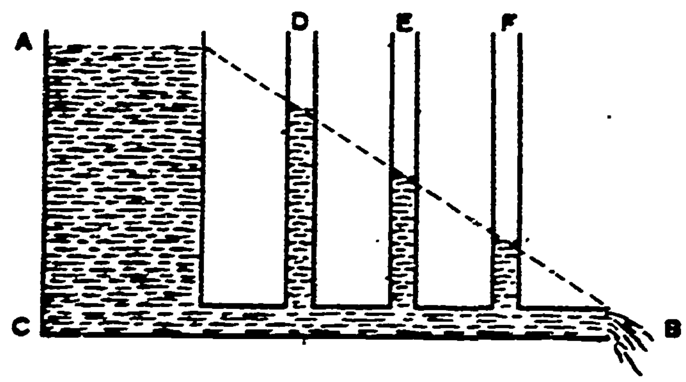


Fig. 8 Effects of friction upon pressure

Figure 8 illustrates the effect of friction upon pressure. We can assume that the liquid flowing out the end of the tube encounters no further resistance. (Flow which encounters negligible resistance is commonly referred to as "free flow.") Since pressure is a result of resistance to motion, the pressure at point (B) is zero. The amount of potential energy in tube (A) depends upon the weight per unit area of the liquid in this tube. Let us assume that the weight of the liquid and the diameter of the tube are such that a static pressure of 10 psi is created at point (C). If this is the case, flow from point (C) to point (B) has resulted in a pressure drop of 10 psi. In other words, the potential energy at point (C) is completely dissipated in moving the particles of liquid to point (B). However, energy can be neither created nor destroyed. The potential energy in tube (A) has been converted into the heat energy as a result of the friction of the liquid moving through the tubes.

The height of the liquid in tubes (D), (E) and (F) illustrates the action of friction in producing a pressure drop. In a moving liquid, the pressure drop tends to increase; and the pressure tends to decrease as the distance from the source of pressure increases. The pressure drop through an orifice of a given size will vary directly as the amount of flow passing through the orifice.

POTENTIAL ENERGY VERSUS KINETIC ENERGY -- When a force is applied to a confined liquid, the liquid assumes that force in the form of potential energy. The ability of the liquid to perform work is dependent upon the static pressure of the liquid.

We have seen that the potential energy of a moving liquid can be reduced by the amount of heat energy released. The potential energy in a moving liquid can also be reduced by a transformation of this energy into kinetic energy. Thus, a moving liquid can perform work by reason of both its static pressure and its momentum. Since momentum is a force and pressure is a function of force, the kinetic energy of a moving liquid produces a dynamic pressure in the direction of movement.

The velocity of a liquid is its rate of flow, and it is usually expressed in feet per second. Velocity should not be confused with the quantity of flow as expressed in gallons per minute (gpm) or cubic inches per minute (cipm). Velocity is a measure of the average speed at which the molecules in a moving liquid pass a given point. The quantity of flow (volumetric output) is a measure of the quantity of molecules in a moving liquid that pass a given point during a given time interval. Kinetic energy increases proportionally with the velocity of a liquid. The pressure resulting from this kinetic energy may be referred to as "velocity pressure."

BERNOULLI'S PRINCIPLE.-- Figure 9 illustrates the relationship between velocity and pressure. Let us assume that the force on piston (X) is sufficient to create a pressure of 100 psi in chamber (A), that piston (X) is being moved downward and that friction is nonexistent. All of the liquid being forced out of chamber (A) must pass through passage (C) to reach chamber (B). The velocity of the liquid will increase as it passes through passage (C), because the same quantity of liquid must pass through a smaller area in the same time. Some of the 100 psi static pressure in chamber (A) is converted into velocity pressure in passage (C) so that a pressure gauge at this point registers 80 psi. As liquid passing through passage (C) reaches chamber (B), velocity decreases to its former rate and some of the kinetic energy is reconverted into potential energy. This condition is summed up in Bernoulli's Principle which states that the static pressure of a moving liquid varies inversely as its velocity. In other words, as velocity increases, static pressure decreases.

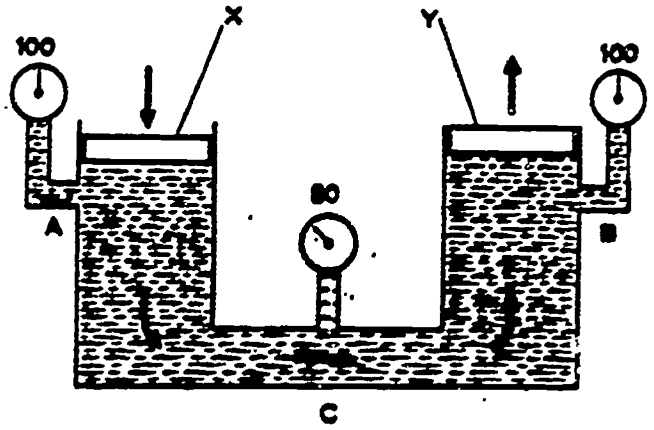


Fig. 9 As velocity increases, pressure decreases

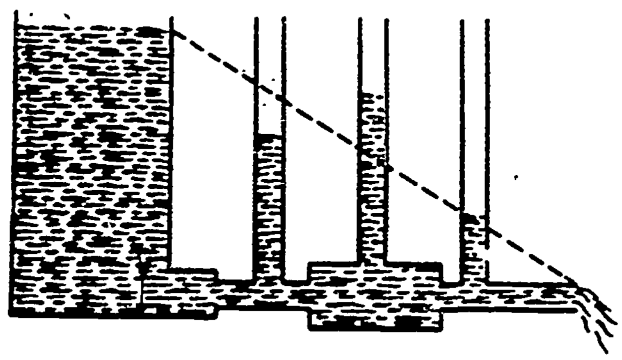


Fig. 10 Effects of friction and velocity on pressure

Figure 9 neglected the factor of pressure drop due to friction. Figure 10 illustrates the effects of both friction and velocity on pressure.

ATMOSPHERIC PRESSURE -- As previously mentioned, the atmosphere surrounding the earth produces a pressure of 14.7 psi at sea level. Atmospheric pressure also plays a vital role in most hydraulic circuits. Figure 11 illustrates the ineraction of hydraulic and atmospheric pressure under three sets of conditions.

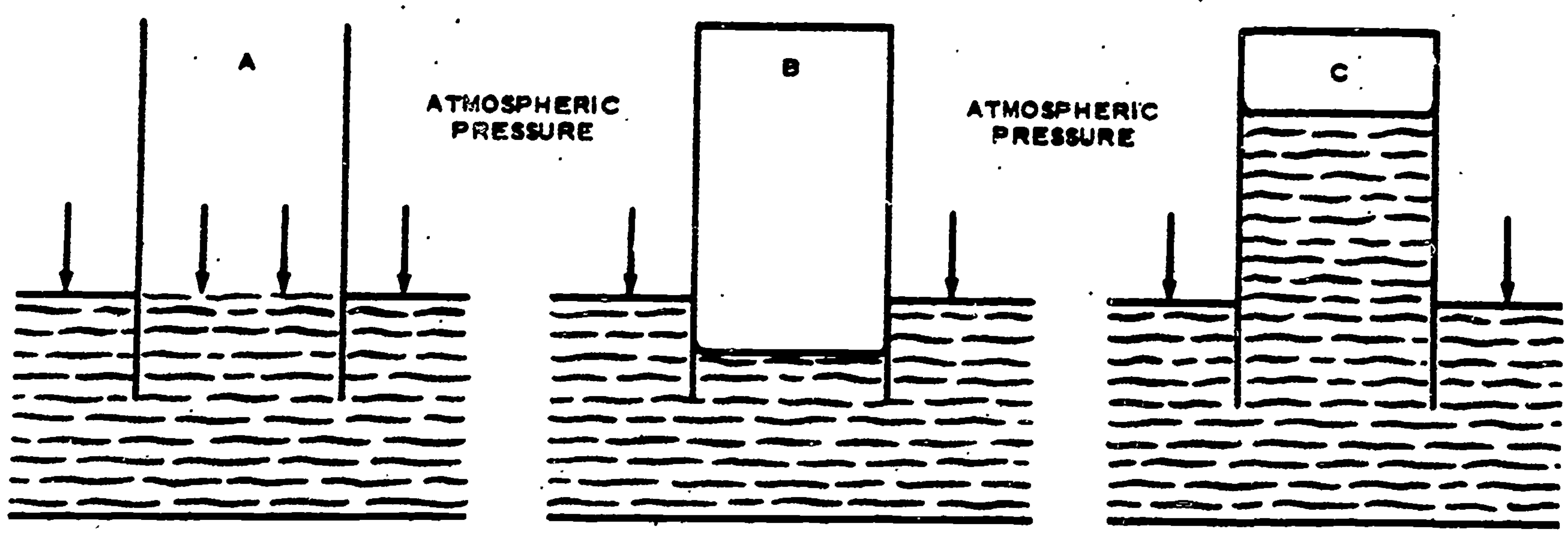


Fig. 11 Interaction of hydraulic and atmospheric pressure under three sets of conditions

Tube (A) is open at both ends. Immersing this tube in liquid has no effect on liquid level except to raise it, both inside and outside, in proportion to the amount of liquid displaced by the submerged tube wall.

Cylinder (B) is closed at its upper end. Immersing this cylinder in a liquid forces the level down within the container, because the air trapped in the container must occupy a space and, therefore, displaces liquid. The level of the liquid outside the container rises in proportion to the combined volume of the cylinder wall and the trapped air below the original liquid level. Atmospheric pressure acting on the liquid outside the cylinder cannot force it to displace the trapped air, because the trapped air transmits the downward thrust of the container to the top of the liquid within the container.

Cylinder (C) is of the same construction as cylinder (B), but some of the air has been removed so that the pressure within the cylinder is less than 14.7 psi. Such a condition is referred to as "a partial vacuum". A perfect vacuum would exist if all pressure could be eliminated; but this condition has never been attained. Since the liquid outside of cylinder (B) is subject to full atmospheric pressure, liquid will be forced up into the cylinder to satisfy the vacuum. The extent of the liquid rise will depend upon the difference in air pressure between the trapped air and the atmosphere.

ABSOLUTE PRESSURE, GAUGE PRESSURE, THEORETICAL LIFT -- Most pressure gauges used in hydraulic work are calibrated to measure liquid pressure and to disregard atmospheric pressure. This relative reading is known as "gauge pressure". The sum of gauge pressure and atmospheric pressure is known as "absolute pressure".

As illustrated in Figure 11, a partial vacuum above a portion of a liquid surface allows atmospheric pressure on the remaining surface to cause the liquid to rise. Although the process is primarily one of pushing rather than lifting, this phenomena is often referred to as "lift". Theoretical lift is the amount of lift possible with a perfect vacuum, and it is reached when a one square inch column of the upraised liquid weighs 14.7 pounds.

Thus, a perfect vacuum could cause water to rise 34 feet at sea level conditions. However, actual lift is limited to about 75% of the height because a perfect vacuum is unattainable.

SECTION D -- DEVELOPING A BASIC HYDRAULIC SYSTEM

STARTING WITH TWO CYLINDERS -- We will begin developing a workable hydraulic system by first repeating our previous illustration of two cylinders, one larger than the other. See Figure 12.

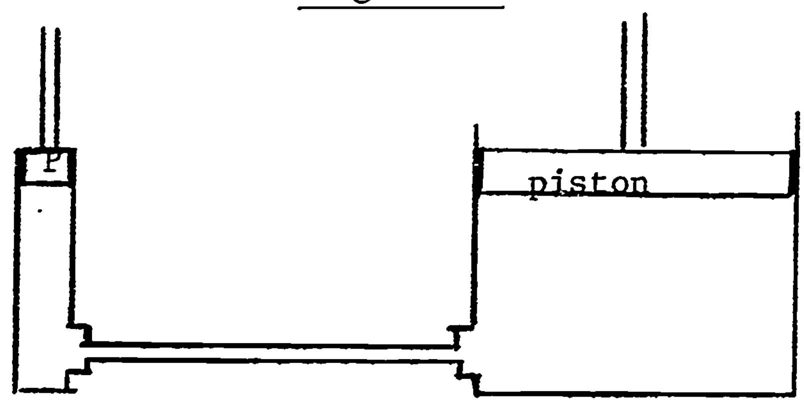


Fig. 12 Begin with two cylinders

MODIFYING THE TWO CYLINDERS -- Next we will alter the above set-up so it appears as shown in Figure 13.

Onto the piston of cylinder (A) we attach a shaft and handle, and cylinder (A) becomes a pump which can be operated by hand (dotted lines Figure 13).

On top of the piston of cylinder (B) we place a spring so the fluid will be forced to return to cylinder (A) when the operation is complete and the hand pump handle is returned to its original position.

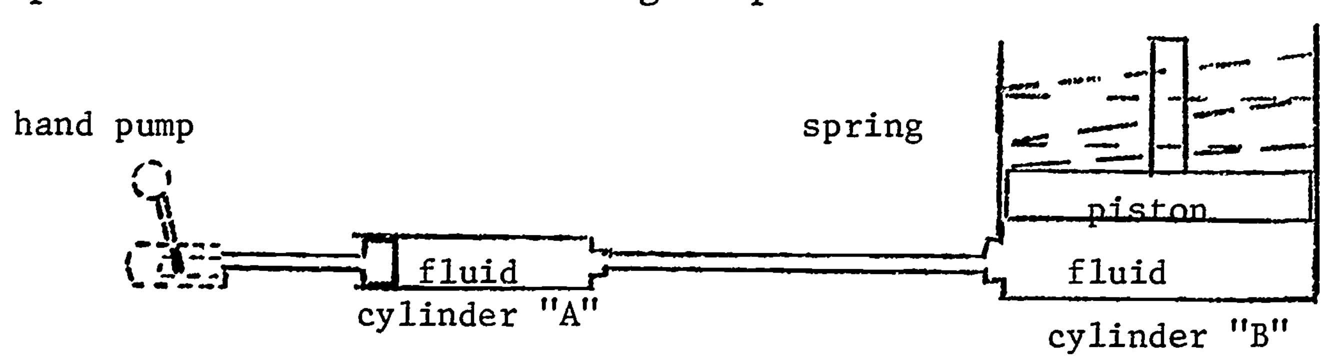


Fig. 13 Add a hand pump and spring

Any force developed by smaller cylinder (A) will be multiplied in larger cylinder (B) in the ratio equal to the difference in the working area of the pistons. The spring in cylinder (B) will never be compressed completely because there is not sufficient fluid in cylinder (A) to completely fill cylinder (B). But this can be remedied by adding additional mechanical parts to the set-up.

ADDING A RESERVOIR AND CHECK VALVES -- Next, we add a reservoir for storing additional fluid and some check valves to keep the fluid headed in the direction of cylinder (B) and to prevent it from going back through the piping. (Dotted lines Figure 14). Now we can raise the piston in cylinder (B) all the way with a few strokes of the pump.

However, now we have another problem, because there is no way to get the fluid back into the reservoir when the operation is complete. This too can be remedied by once again adding parts to our set-up.

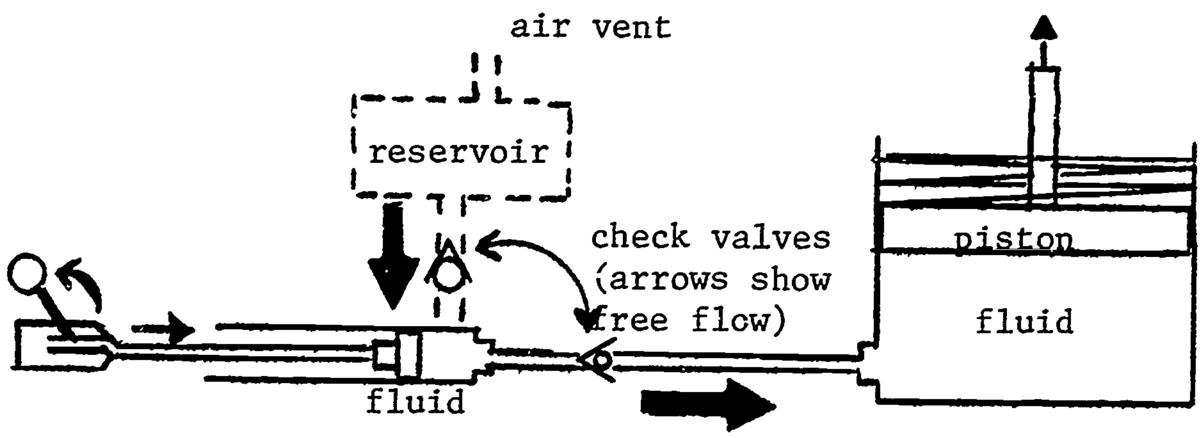


Fig. 14 Add a reservoir and check valves

ADDING A TWO-WAY DIRECTIONAL VALVE -- A two-way directional control valve is placed in the piping and a return line to the reservoir is added. (Dotted lines Figure 15).

The direction control valve is a device which directs the flow of the fluid in one of several directions. In Figure 15, the two-way valve is shown in a non-operative position.

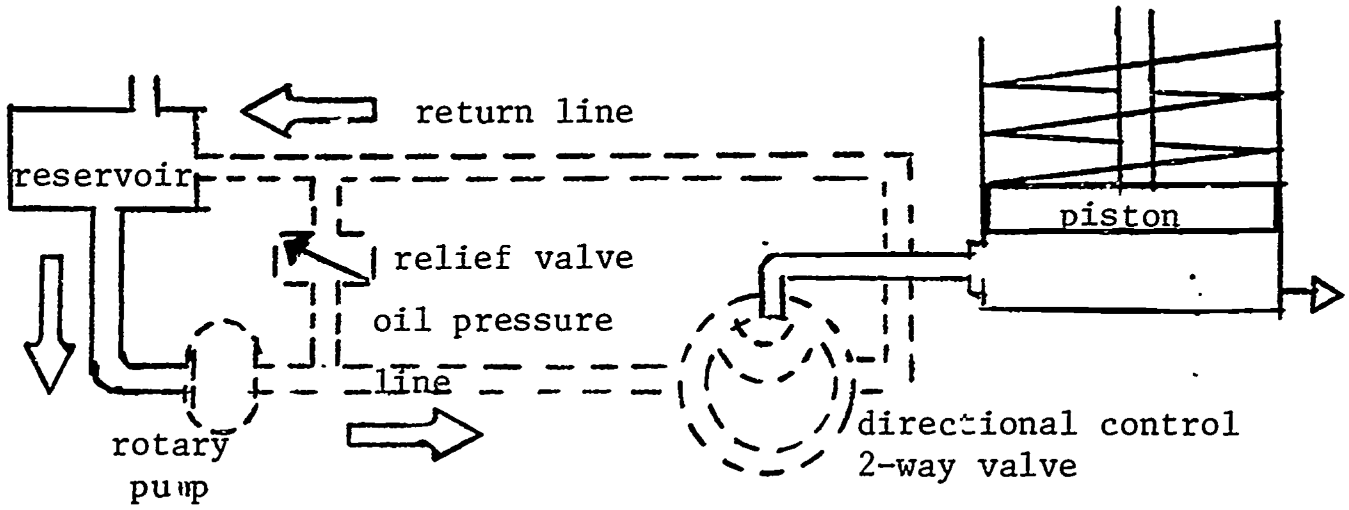


Fig. 15 Add controls

This valve can be turned to either of two positions, as shown in Figure 16. In one position, the fluid will be pumped into the large cylinder and the piston forced up. In the other position, the spring will force the piston down and the fluid will be directed into the return line and on to the reservoir.

Because it is usually desirable to operate such a cylinder at frequent intervals, a motor driven pump has been substituted for the hand pump

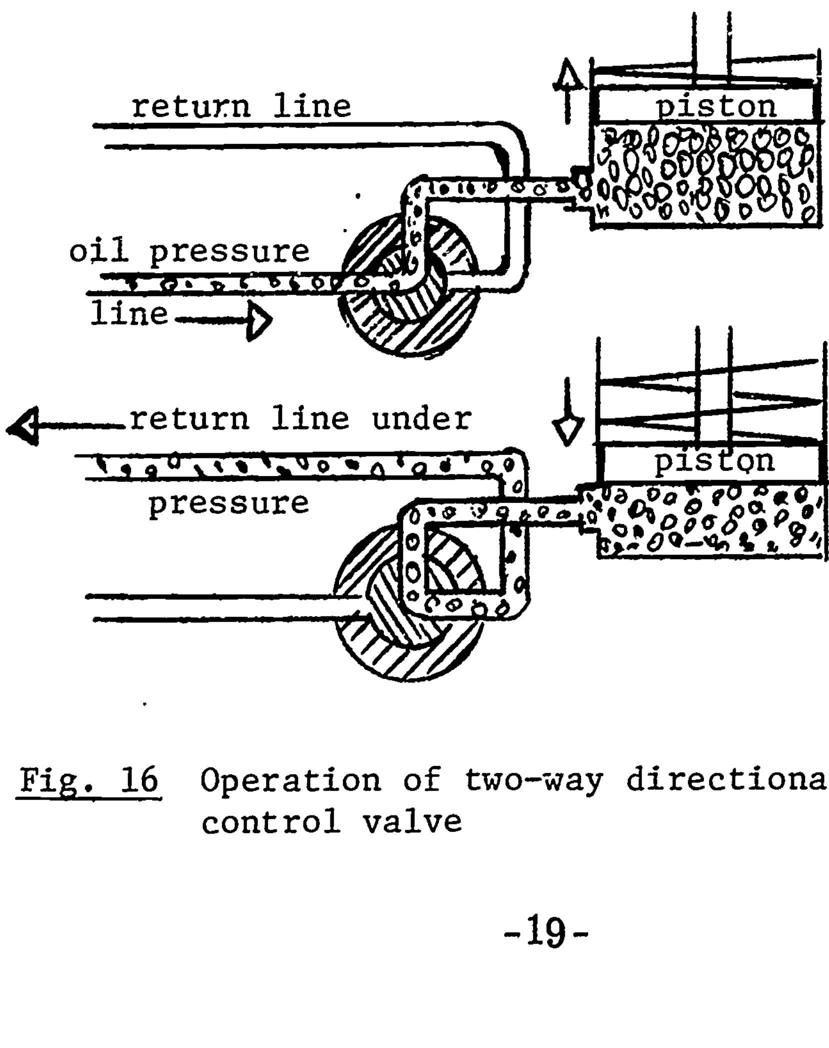


Fig. 16 Operation of two-way directional control valve

(Figure 15). Since the motor driven pump which was added was a rotary pump, that supplies fluid continuously, a relief valve is added to relieve pressure at a specified level. In this case, the relief valve has been added between the oil pressure line and the return line.

This now represents a simple hydraulic system which is operative. However, if we want to use a cylinder which does not contain a spring to move the piston in one direction, we can add additional lines and controls.

MODIFYING FOR TWO-DIRECTION HYDRAULIC MOVEMENT OF PISTON -- By adding additional lines and a four-way selector valve, fluid can be supplied to either side of the piston. The piston will be pushed in either direction hydraulically, rather than by using a mechanical spring to return it to the down position. (Dotted lines Figure 17). No matter to which side of the piston the fluid is applied, the fluid on the opposite side is free to return to the reservoir.

This, now, is the basic hook-up on which virtually all hydraulic systems are founded. Additional equipment can be made an integral part of the system, to accomplish any desired specific requirement.

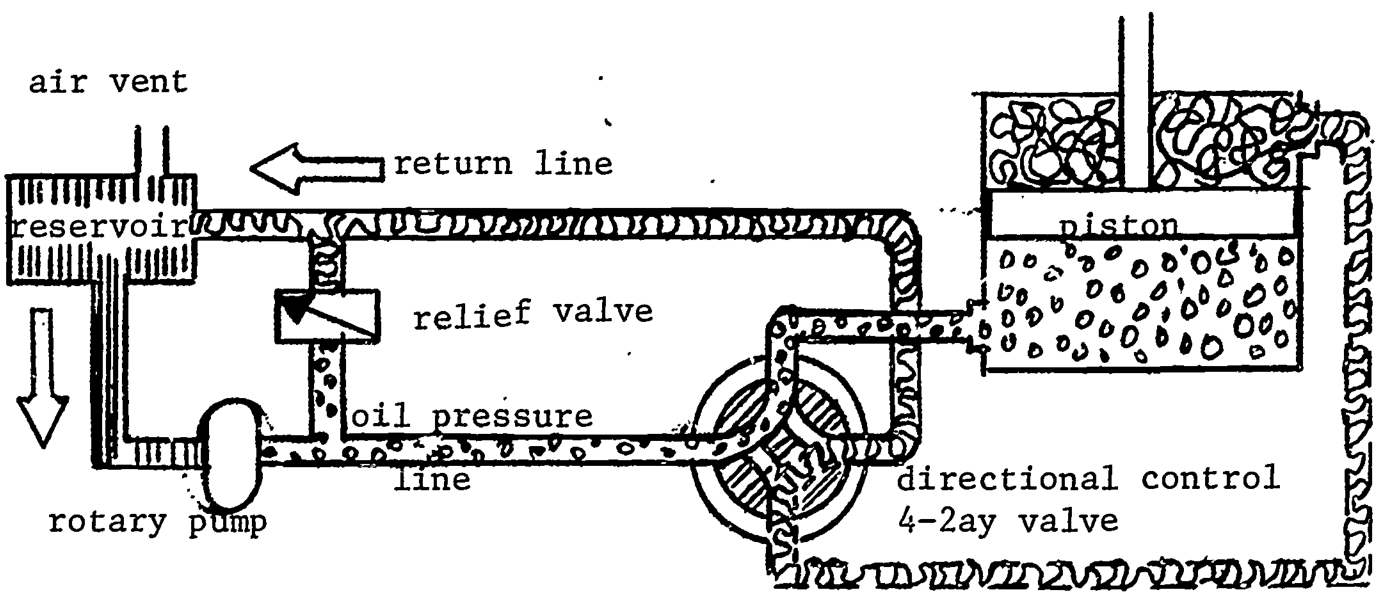
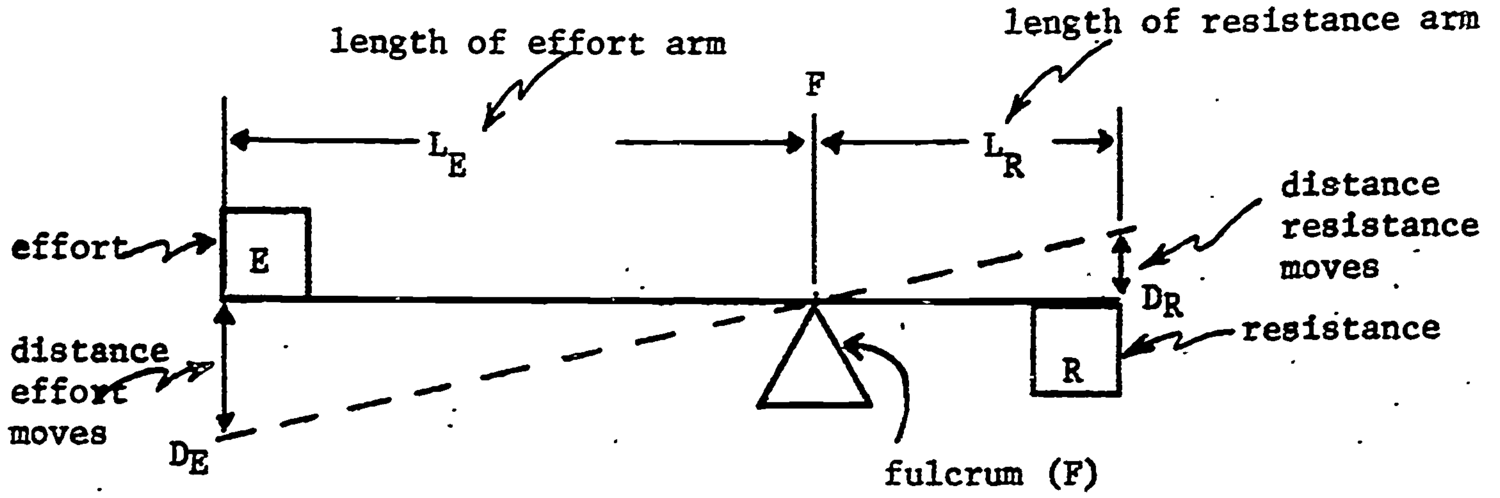


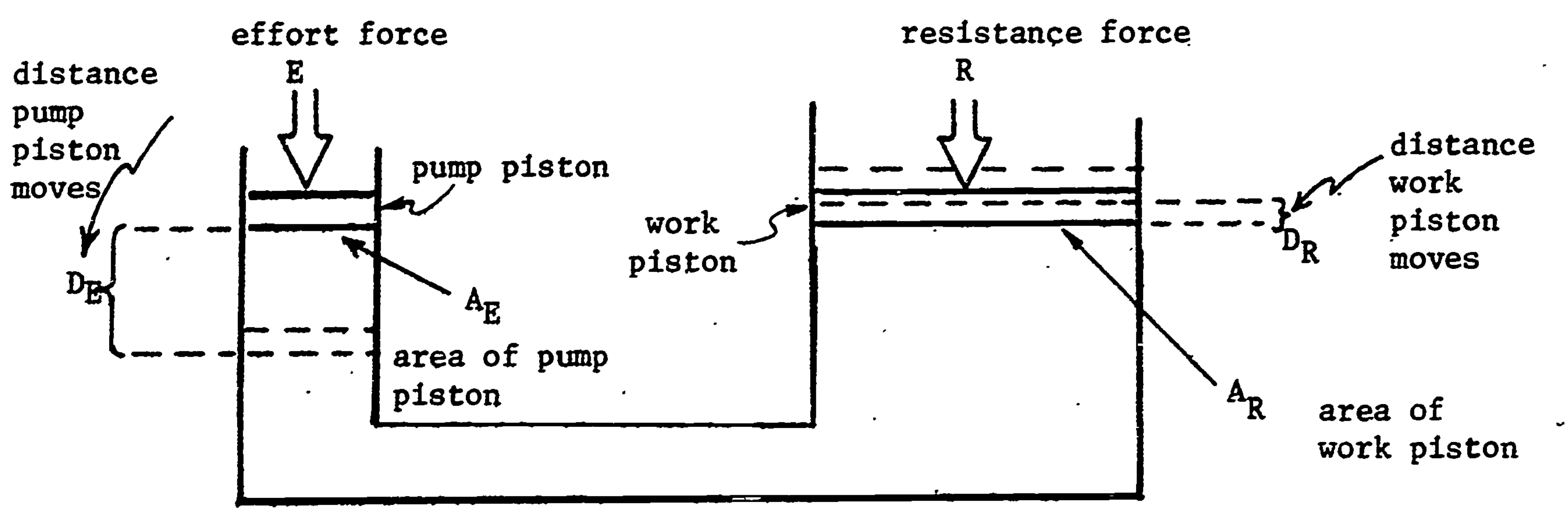
Fig. 17 Four-way directional control valve

DIDACTOR PLATES FOR AM 2-3D AND MM 2-6D



$$\text{Mechanical Advantage (MA)} = \frac{R}{E} = \frac{L_E}{L_R} = \frac{D_E}{D_R}$$

Plate I Simple lever



$$\text{Mechanical Advantage (MA)} = \frac{R}{E} = \frac{A_R}{A_E} = \frac{D_E}{D_R}$$

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} \quad \text{or} \quad P = \frac{F}{A}$$

Plate II Simple hydraulic system

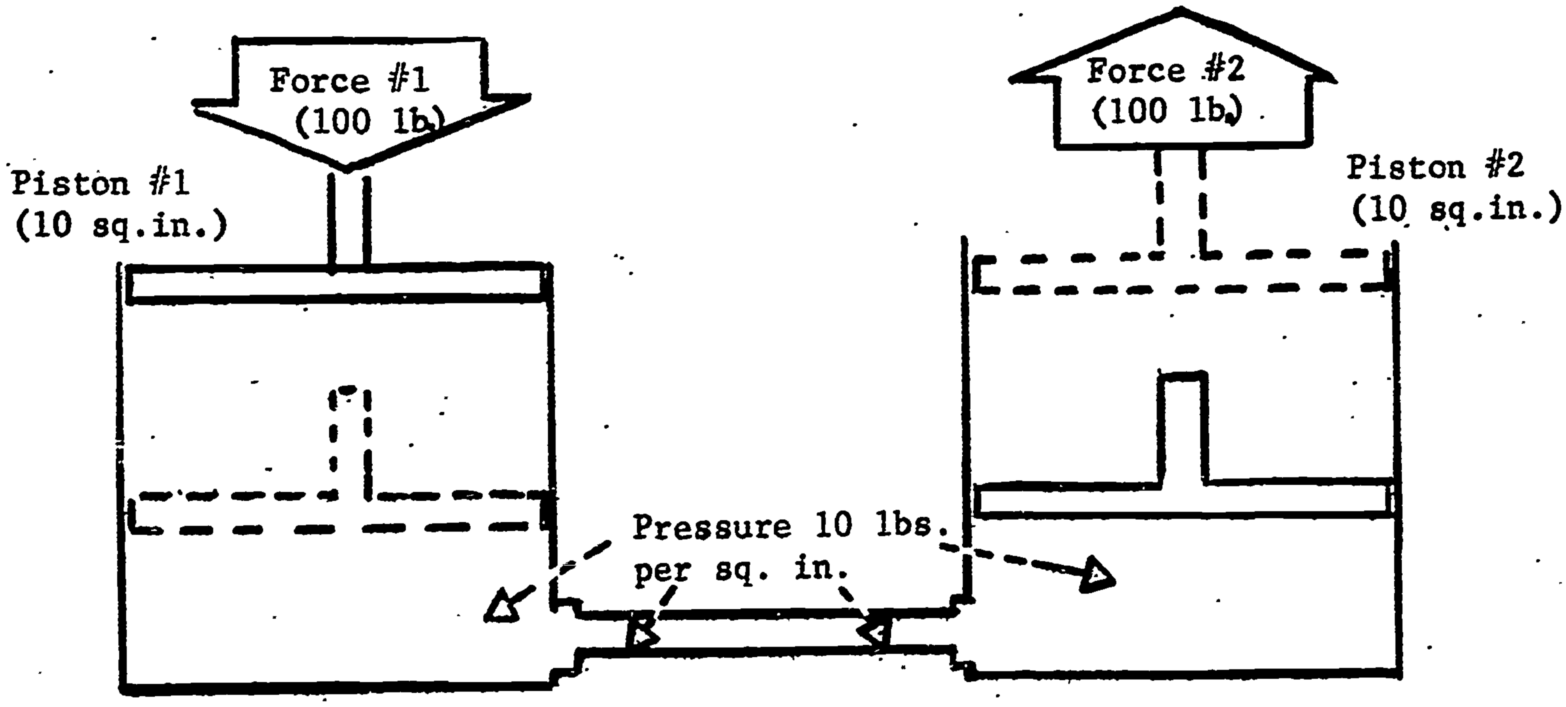


Plate III

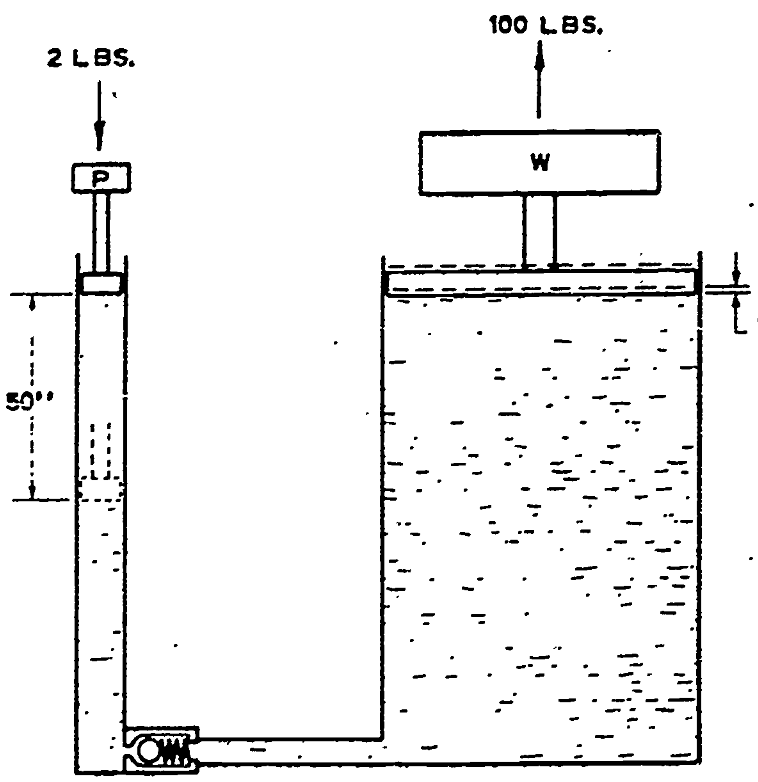


Plate IV

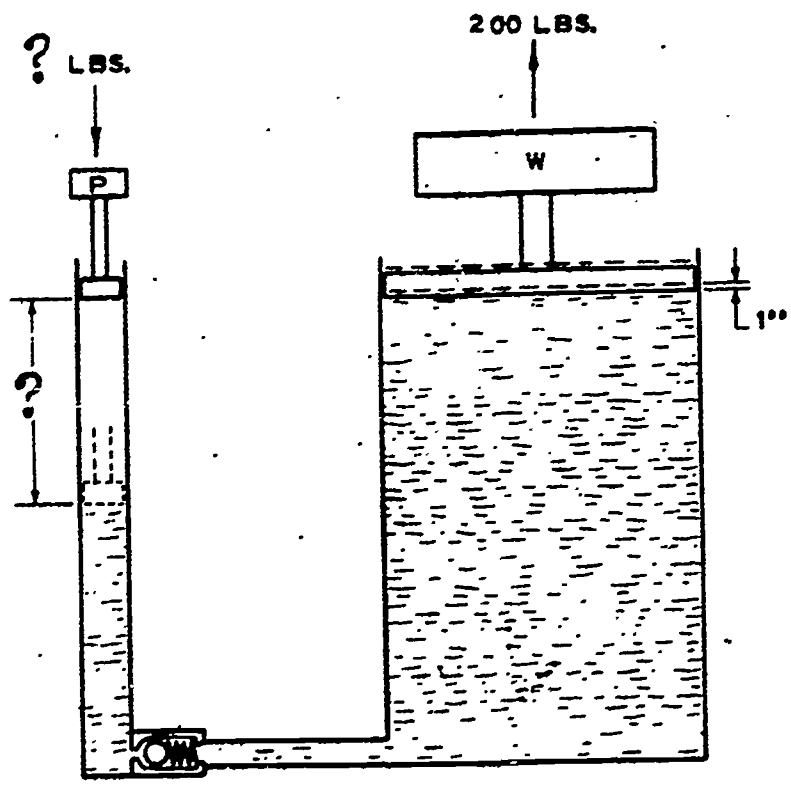


Plate V

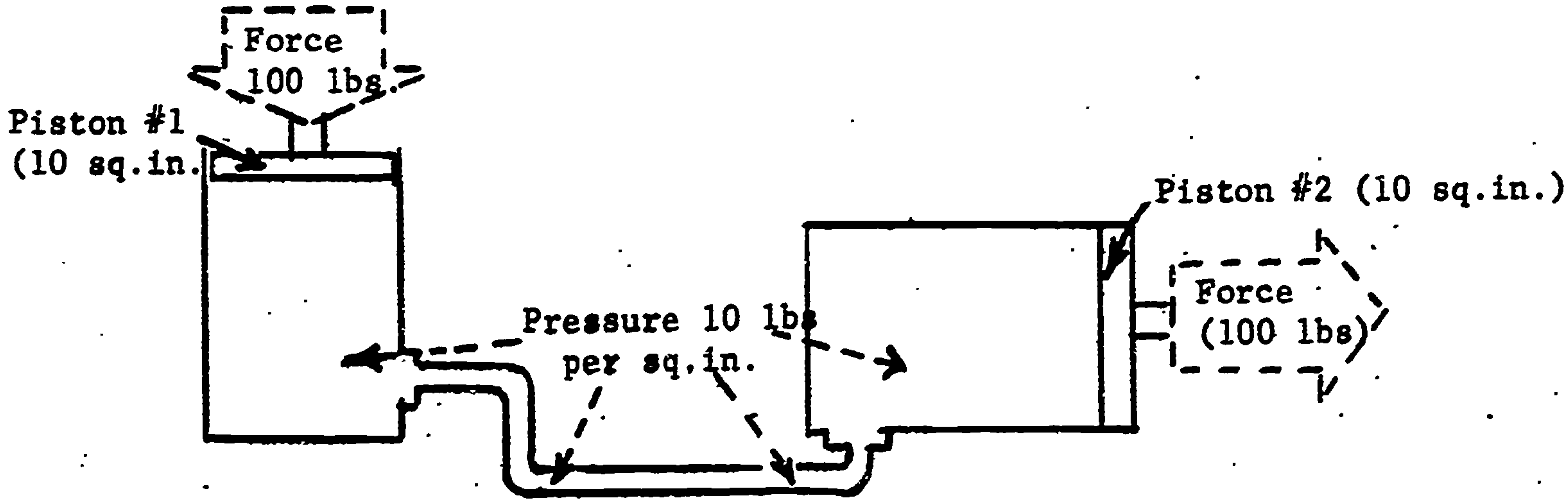


Plate VI

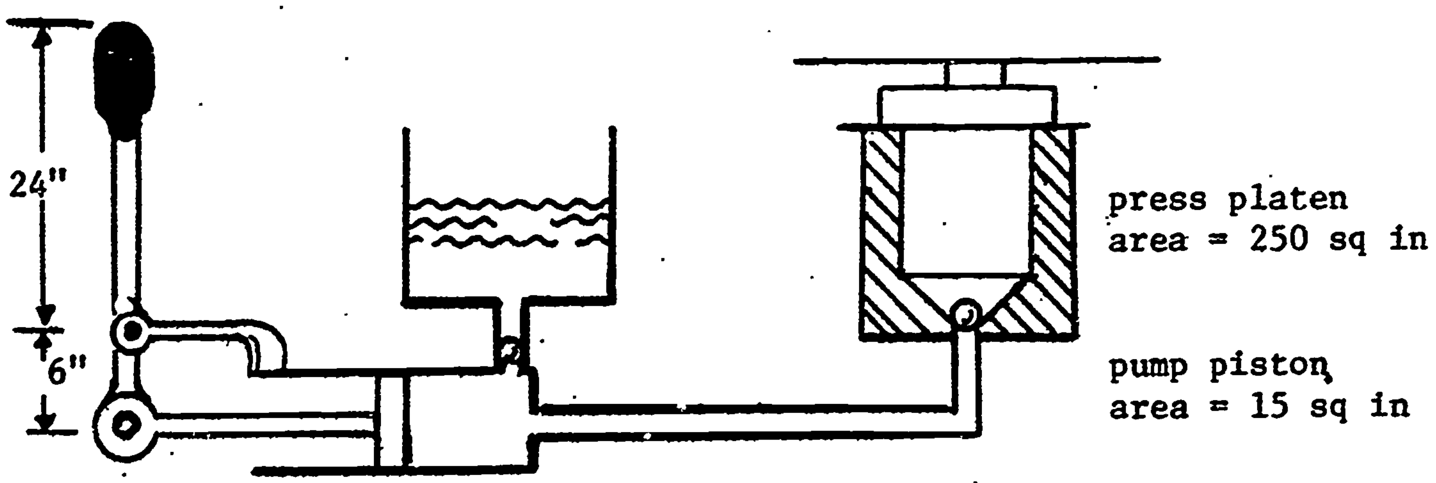


Plate VII

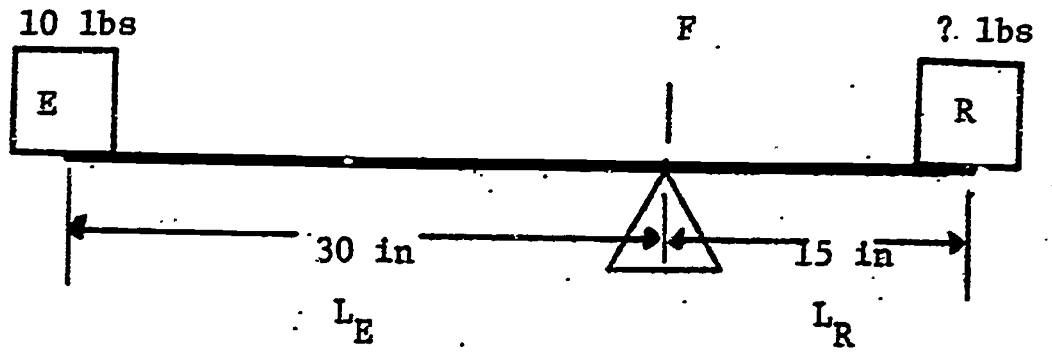


Plate VIII

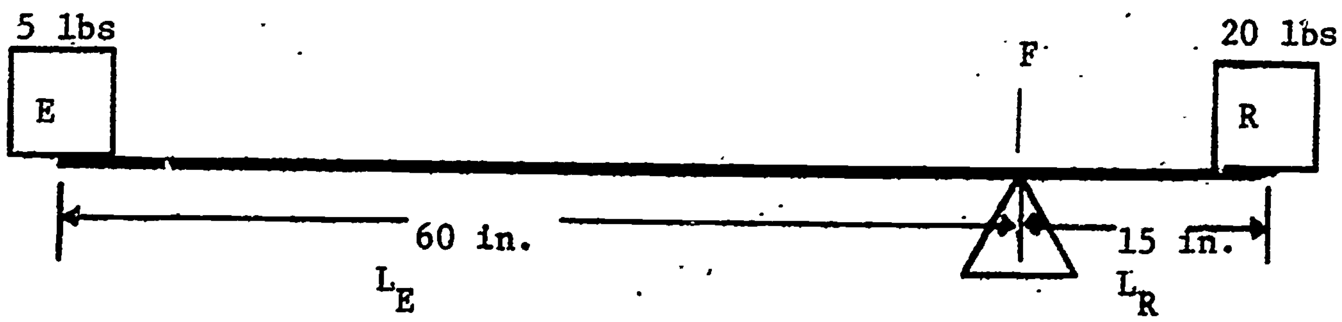


Plate IX

0

AM 2-3D
and MM 2-6D
3/2/67

BASIC HYDRAULICS

Human Engineering Institute

Press A Check to see that timer is OFF.

1-1

1

BASIC HYDRAULICS covers the physical characteristics of liquids at rest and in motion.

In this film we will study some of the basic hydraulic principles and their applications.

Applied hydraulics is the transferring of power from one location to another through the use of a liquid - oil or water - as a medium.

Press A 2

1-2

2

Before discussing applied hydraulics as a power of force and pressure, let's review some of the basic laws of Physics.

Newton's law of motion states that a body at rest remains at rest unless acted upon by an outside force, and a body in motion will remain in motion unless acted upon by an outside force.

FORCE is the push or pull that starts, increases, decreases or stops motion.

Press A 3

1-3

3

PRESSURE is a measure of force and is expressed in pounds per square inch, psi, or as gage pressure plus atmospheric pressure (14.7 psi at sea level).

WORK, in the mechanical sense of the term, is done only when a resistance is overcome by a force acting through a measurable distance. Since force normally is measured in pounds, and distance normally is measured in feet, work is measured in units called foot-pounds.

Press A 4

1-4

4

POWER is the rate of doing work, and is measured by units of time. The measurement of power depends on three factors: the force exerted, the distance the force moves and the time required. Power is commonly measured in foot-pounds per minute.

The formula for work is ____________.

5 A. $W = \frac{F}{D}$

6 B. $W = F \times D$

5 C. $W = F + D$

where: W = Work
F = Force
D = Distance

1-5

5

No. Work is done when a resistance is overcome by a force acting through a measurable distance:

$$W = F \times D$$

$W = \frac{F}{D}$ is the opposite of the correct procedure.

$W = F + D$ is not correct either.

Press A 6

1-6

6

Right.
If you apply a continuous force of 1200 pounds to move a ram 4 inches, __________ foot-pounds of work have been accomplished.

A. 300 7
B 400 8
C. 1204 7
D. 4800 7

1-7

7

No. You either used the wrong formula or forgot to divide by 12 inches to change the distance to feet.

The formula for work is $W = F \times D$.

Try the question again. Press A 6

1-8

8

Right. 400 ft-lbs of work.

A man running up a flight of stairs does not accomplish any more work than he would by walking up the same stairs. This statement is ________.

A. True 10

B. False 9

1-9

9

Sorry; the statement is true.

Running, obviously is a harder task than walking. But it does not involve any greater amount of work. To express the difference between walking and running, we use the expression power.

Running requires more power than walking because the same amount of work is accomplished in a shorter period of time. The definition of power is work per unit of time.

Press A 10

1-10

10

True.

Power relates to the rate of doing work or work per unit of time.

The formula for power is ________.

A. $W = F \times D$ 11

B. $P = W \times T$ 11

C. $P = \frac{F \times D}{T}$ 12

D. $P = \frac{W}{T}$ 12

1-11

11

No. Work is defined as force times distance. Power is defined as work per unit of time.

Try the question again. Press A 10

1-12

12

Right. Power is work per unit of time.

$$P = \frac{F \times D}{T} = \frac{W}{T}$$

The movement of an object by force from one point to another point involves the transfer of energy from the origin of the force to the object being moved.

Work is, therefore, actually a measure of energy transferred.

In this sense, power is a measure of the rate of energy transfer.

Press A 13

1-13

13

All matter is composed of molecules of fluids or solids. Fluids may be gases or liquids.

Power is easily transmittable through hydraulics because the relative cohesion of molecules in any fluid is less than in solid matter.

In a solid, the force of cohesion is very great. Molecules in any solid matter are so firmly held in place that they do not change their relative positions to any marked degree.

Press A 14

1-14

14

In fluids, molecules have less cohesion than they have in solids. The molecules can slide over each other, and the liquid can take the shape of its container. Gas also can take the shape of its container, but gas is compressible. (In gas, molecules have even less cohesion than they have in a liquid.)

Since a liquid is not compressible, it has the same capability as a solid to absorb and transmit force, in the form of power, to another point. Movement of power hydraulically through a liquid is very rapid.

Press A 15

1-15

15

Liquids have certain characteristics that make them well suited for the transfer of power hydraulically.

Liquids have ___(1)___ molecular cohesion than solids and ___(2)___ than gases.

A. (1) less (2) less 13

B. (1) greater (2) greater 13

C. (1) greater (2) less 13

D. (1) less (2) greater 16

1-16

16

Right. Liquids have less molecular cohesion than solids and greater molecular cohesion than gases.

Molecules in a liquid are in a state of balance. Although the molecules may move in relation to each other, the distance between the molecules remains fixed.

A liquid subjected to a force will seek the path of least resistance. If the force is gravity, liquid will seek "its own level".

1-17

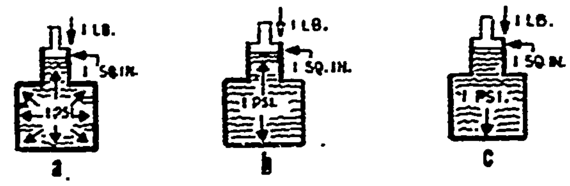
Press A 17

17

Pascal's law, a basic law of hydraulics states:

> Pressure applied anywhere to a body of confined or enclosed liquid is transmitted with undiminished force in every direction. This pressure acts at right angles to every portion of the surface of the container, with equal force upon equal areas.

Sketch ______ correctly illustrates Pascal's law.



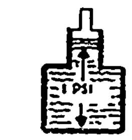
a. b c

20 18 15

1-18

18

No. This illustration shows pressure in only two directions. Pascal's law states that pressure is equal in all directions within the container. Since this pressure is undiminished. the one (1) pound per one (1) square inch of force is equal in all directions.



Try the question again. Press A 17

1-19

19

No. This illustration shows that the one (1) pound per one (1) square inch of pressure is being applied directly to the bottom of the container. (This could happen only if there was no liquid in the container and the solid piston was forced all the way to the bottom.)

However, we are compressing a liquid, which exerts pressure in all directions. Try this question again.

1-20

Press A 17

20

Right. This is the correct illustration of Pascal's law. Pressure exerted on an enclosed liquid is transmitted with equal strength in every direction. The liquid provides the mechanical advantage and acts as a transmitter of force.

Press A 21

1-21

21

The mechanical advantage (MA) of a lever is relatively easy to explain and understand. The same basic principles apply to hydraulics.

We will cover the principles of mechanical leverage first. then apply them to liquid leverage (hydraulics).

In a simple first class lever the fulcrum is located between the effort and the resistance. A seesaw is a good example of the first class lever.

2-1

Press A 23

xc 22

22

One or more questions in this sequence have not been answered correctly.

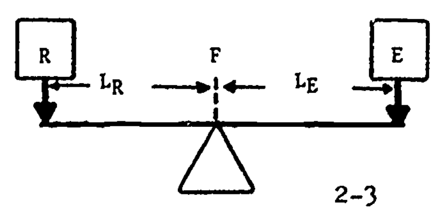
Before continuing, you should review these frames. Read the questions carefully before answering them. Take your time. Press A →1

2-2

23

MECHANICAL ADVANTAGE is the force multiplication gained by use of a lever or a hydraulic system.

This illustration is a balanced first class lever: The effort (E) applied, times the length of the effort arm (L_E), always is equal to the resistance (R) to be overcome - the load to be moved - times the length of the resistance arm (L_R):



$E \times L_E = R \times L_R$

Press A 24

2-3

24

The mechanical advantage (MA) of a lever is equal to the resistance divided by the effort, or the effort arm length divided by the resistance arm length.

$$MA = \frac{R}{E} = \frac{L_E}{L_R}$$

The mathematical equation for a simple lever is ________.

26 A. $L_E \times E = L_R \times R$

25 B. $\frac{R}{E} = \frac{L_R}{L_E}$

25 C. $\frac{L_E}{L_R} = \frac{E}{R}$

25 D. $L_R \times E = L_E \times R$

2-4

25

No. Refer to Plate I. The effort arm length (L_E) divided by the resistance arm length (L_R) equals the resistance (R) divided by the effort (E).

$$\frac{L_E}{L_R} = \frac{R}{E} \quad \text{or} \quad L_E \times E = L_R \times R$$

The mechanical advantage gained is due to the difference in length of the lever arms. The greater the effort arm length is, compared to the resistance arm length, the greater the mechanical advantage will be:

$$MA = \frac{L_E}{L_R}$$

Press A 26

2-5

26

Right. The mechanical equation for a lever is

$$\frac{L_E}{L_R} = \frac{R}{E}$$

In the illustration in Plate VIII, R equals ________.

A. 10 25

B. 20 27

C. 30 25

2-6

27

Right. 20 lbs resistance.

The MA is ________ for the illustration on Plate VIII.

A. .5 28

B. 1 28

C. 2 29

D. 3 28

2-7

28

No. MA (mechanical advantage) is equal to the resistance divided by the effort, or is equal to the effort arm length divided by the resistance arm length:

$$MA = \frac{R}{E} \quad \text{or} \quad MA = \frac{L_E}{L_R}$$

Refer to Plate I.

Try the question again. Press A 27

2-8

29

Right. The MA is 2.

The mechanical advantage (MA) of the Plate IX illustration is ________ times greater than the MA of Plate VIII illustration.

A. 1 30

B. 2 31

C. 3 30

D. 4 30

2-9

30

No. The MA of Plate VIII is 2 and the MA of Plate IX is 4. Therefore, the MA of Plate IX is twice as great as the MA of Plate VIII.

Press A 31

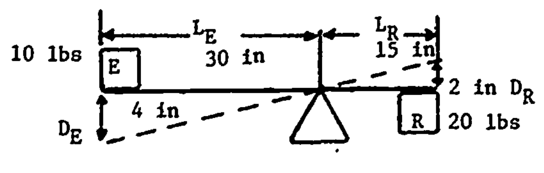
2-10

31

The MA of a lever can be found by dividing the DISTANCE (D_E) through which the effort moves by the DISTANCE (D_R) through which the resistance moves.

$$MA = \frac{D_E}{D_R}$$

You will find by the illustration that although the mechanical advantage gives us a gain in force from 10 lbs to 20 lbs, we have lost in distance moved, from 4 inches to 2 inches.



Press A 32

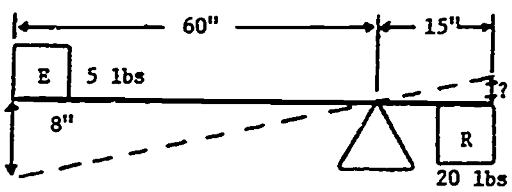
2-11

32

In a balanced lever problem, the work accomplished on one side of the fulcrum must balance the work accomplished on the other side.

If the effort in the sketch is moved through 8 inches, the resistance will move through ________ inches.

A. 2 34
B. 3 33
C. 4 33
D. 8 33



2-12

33

No. Did you forget that $MA = \frac{D_E}{D_R} = \frac{R}{E} = \frac{L_E}{L_R}$, that $W = F \times D$ and that the work has to be equal on both sides of the fulcrum? Since we are looking for the distance (D_R) the resistance moved, let's use:

$$\frac{D_E}{D_R} = \frac{R}{E}$$

where: D_E = 8 inches, R = 20 lbs, E = 5 lbs

$$\frac{8}{D_R} = \frac{20}{5}$$

$$20\,D_R = 40$$

$$D_R = 2$$

Press A 34

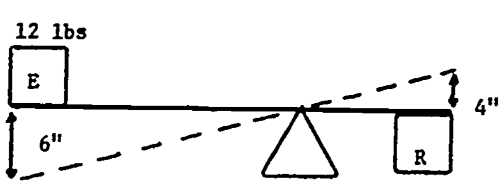
2-13

34

Right. D_R = 2 inches.

In the sketch, R equals ________ pounds.

A. 18 36
B. 24 35
C. 48 35
D 72 35



2-14

35

No. What were you looking for?

Right: the resistance R. Use a formula that has all the known values plus the unknown R.

$$\frac{D_E}{D_R} = \frac{R}{E}$$

Now substitute the known values for the letters and solve for R.

Try the question again. Press A 34 2-15

36

Right. The resistance (R) is 18 lbs.

A comparison of the MA of the lever system and a hydraulic system may help make it easier to understand the hydraulic system operation.

Press A 36.1

2-16

36.1

The MA of a lever system equals:

Resistance (R) divided by effort (E).

Or length of effort arm (L_E) divided by length of resistance arm (L_R).

Or distance the effort arm moves (D_E) divided by distance the resistance arm moves (D_R).

$$MA = \frac{R}{E} = \frac{L_E}{L_R} = \frac{D_E}{D_R}$$

2-17

Press A 37

37

The MA of a simple hydraulic system equals the:

Resistance (R) divided by effort (E).

Or the area of resistance (work) piston (A_R) divided by the area of effort (pump) piston (A_E).

Or the distance the pump piston travels (D_E) divided by distance the work piston travels (D_R).

or $MA = \frac{R}{E} = \frac{A_R}{A_E} = \frac{D_E}{D_R}$

3-1

See Plate II. Press A 39

XC → 38

38

One or more questions in this sequence have not been answered correctly.

Before continuing, you should review these frames. Read the questions carefully before answering them. Take your time. Press A →21

3-2

39

In a hydraulic system we normally associate work and force with the pressure applied by the fluid, since the energy is transmitted from the pump piston to the work piston by the fluid.

Pressure in a fluid is defined as the normal force exerted by the fluid per unit area and is usually measured in pounds per square inch.

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} \quad \text{or} \quad P = \frac{F}{A}$$

3-3

Press A 40

40

Liquid leverage describes the advantage gained by reason of the difference in surface area (area of piston bearing against the liquid) of two movable pistons in a closed system.

Refer to Plate III. A downward thrust of piston (1) of 100 lbs. (10 sq. in. of surface) exerts a pressure of 10 psi against piston (2). Since piston (2) has the same area as piston (1), movement of the fluid from cylinder (1) to cylinder (2) will lift 100 lbs. of load a distance equal to the travel of piston (1).

3-4

Press A 41

41

The mechanical advantage (MA) of the system in Plate IV is __(1)__. If the large piston (W) has an area of 50 sq. in., the pressure applied by the fluid is __(2)__ psi. The area of the small piston (P) is __(3)__ sq. in.

42	A. (1) 25	(2) 4	(3) 1/2
42	B. (1) 25	(2) 2	(3) 1
50	C. (1) 50	(2) 2	(3) 1
42	D. (1) 100	(2) 1	(3) 2

3-5

41.1

You seem to be having trouble understanding this material. Take your time, read each frame completely before going to the next frame. Read the questions completely before answering them, and always pick the best answer.

Press A 42

3-6

42

No. The MA of a simple hydraulic system equals the resistance (R) divided by the effort (E): $MA = \frac{R}{E}$

The MA also equals the area (A_R) of the resistance (work) piston divided by the area (A_E) of the effort (pump) piston:

$$MA = \frac{A_R}{A_E}$$

The MA also equals the distance (D_E) the pump piston travels divided by the distance (D_R) the work piston travels: $MA = \frac{D_E}{D_R}$

Refer to Plate II.

Press A 43

3-7

43

Pressure in a fluid is defined as the normal force exerted by the fluid per unit area and usually is measured in pounds per square inch (psi).

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}, \quad P = \frac{F}{A}$$

Pressure can be calculated from the effort force (E) divided by the pump piston area (A_E), or from the resistance force (R) divided by the work piston area (A_R).

$$\text{Pressure} = \frac{E}{A_E} \quad \text{or} \quad \text{pressure} = \frac{R}{A_R}$$

3-8

Press A 44

44

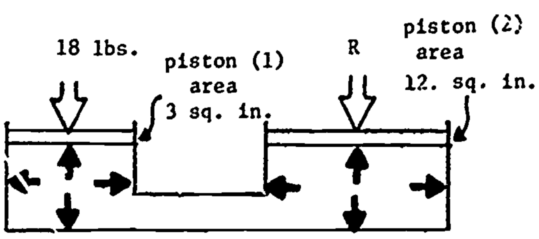
In this system the fluid is exerting a pressure of ___ psi on all enclosed surfaces.

45 A. 3

46 B. 6

45 C. 12

45 D. 18



3-9

45

No. Pressure equals force divided by area.

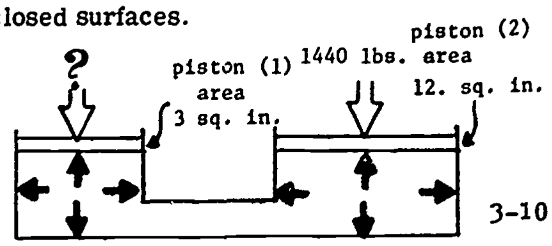
$$P = \frac{F}{A} = \frac{\text{18 lbs (force on piston 1)}}{\text{3 sq. in. (area of piston 1)}} = 6 \text{ psi}$$

In this system, the fluid is exerting a pressure of _____ psi on all the enclosed surfaces.

43 A. 12

43 B. 36

46 C. 120

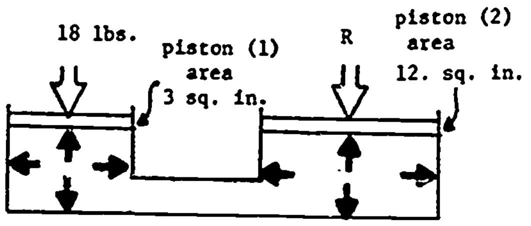


3-10

46

Right.
The force applied to the piston (2) is ________ lbs.

47 A. 6
47 B. 12
47 C. 54
48 D. 72
47 E. 216



3-11

47

No. Resistance force equals the mechanical advantage times the effort force:

$R = MA \times E$ or $R = \frac{12}{3} \times 18 = 72$

Resistance force equals the pressure times the area of the work piston:

$R = P \times A_R$ or $R = \frac{18}{3} \times 12 = 72$

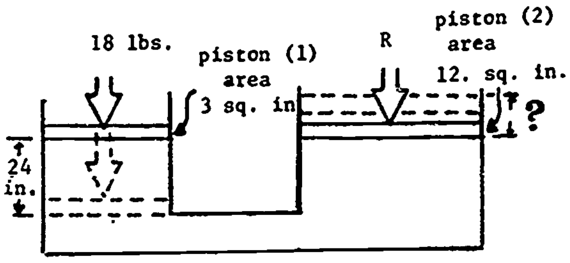
3-12

Press A 41.1

48

Right.
Piston (2) will move ________ inches if piston (1) moves 24 inches.

49 A. 4
50 B. 6
49 C. 8
49 E. 76



3-13

49

No. Work piston movement (D_R) equals the pump piston movement (D_E) divided by the MA :

$D_R = \frac{D_E}{MA} = \frac{24}{4} = 6$ inches.

Refer to Plate II.

Press A 41.1

3-14

50

Right.
In the illustration on Plate V, piston (W) has an area of 50 sq. in. and piston (P) has an area of 2 sq. in.

A force of __(1)__ lbs on piston (P) traveling through a distance of __(2)__ inches will move the 200 lbs of piston (W) a distance of 1 inch.

41.1 A.	(1) 4	(2) 50
51 B.	(1) 8	(2) 25
41.1 C.	(1) 8	(2) 50

3-15

51

Right. Refer to Plates II and V.

$MA = \frac{R}{E} = \frac{D_E}{D_R} = \frac{A_R}{A_E}$

$MA = \frac{A_R}{A_E} = \frac{50 \text{ sq. in.}}{2 \text{ sq. in.}} = 25$

$E = \frac{R}{MA} = \frac{200 \text{ lbs}}{25} = 8$ lbs (force applied to piston (P))

$D_E = D_R \times MA = 1$ in. x 25 = 25 in.
(distance piston (1) travels)

3-16

Press A 52

52

Reaction in hydraulic cylinders will occur regardless of their shape or position. With the illustration on Plate VI you now may see how mechanical advantage takes place because of the principles of Pascal's law: "Pressure exerted at any point in a confined liquid is transmitted undiminished in all directions and acts with equal force on all areas."

Press A 53

3-17

53

In Plate VII a hand pump with a piston area of 15 sq. in. is used to operate the press with a platen area of 250 sq. in. A force of 1250 lbs is required to press a bearing 3/4 inches into a housing.

A force of ________ lbs has to be applied to the pump piston.

54 A. 2.2
54 B. 5
54 C. 16.7
54 D. 18.8
55 E. 75

3-18

54

No. $MA = \frac{\text{Press platen area}}{\text{Pump piston area}} = \frac{250 \text{ sq. in.}}{15 \text{ sq. in.}} = 16.7$

$\text{Force applied} = \frac{\text{Force required}}{MA} = \frac{1250 \text{ lbs.}}{16.7} = 75 \text{ lbs.}$

Press A 55

3-19

55

Right. The MA equals $\frac{50}{3}$ or 16.7. The total force required (1250 lbs.) divided by the MA (16.7) equals the force applied (75 lbs.). Force applied $= \frac{1250}{16.7} = 75$ lbs.

The pump piston will have to travel ______ inches in order to press the bearing into the housing 3/4 inches.

A. 12.5 57
B. 18.8 56
C. 75 56

3-20

56

No. The distance the pump piston travels equals the distance the press platen travels times the mechanical advantage:

$\text{Pump piston travel} = \frac{3}{4} \text{ inches} \times 16.7 = 12.5 \text{ inches}$

3-21

Press A 57

57

In Plate VII the pump piston is exerting 75 lbs of force on the liquid. A force of ________ lbs is required on the pump handle.

A. 4 58
B. 12.5 58
C. 18.8 59
D. 75 58

3-22

58

No. You seem to have forgotten the operation of a lever Mechanical advantage of a lever equals the length of the effort arm divided by the length of the resistance arm:

$$MA = \frac{L_E}{L_R} = \frac{24}{6} = 4$$

Effort force equals the work force divided by the MA:

$$E = \frac{R}{MA} = \frac{75}{4} = 18.8 \text{ lbs.}$$

3-23

Press A 59

59

Right. A force of 18.8 lbs has to be applied to the pump handle to produce 75 lbs of force by the pump piston.

Your problems so far have been with liquids in a static condition. Force has been applied to an enclosed liquid. The liquid transmitted this force as an equal pressure on all surfaces. Negligible movement of the liquid is encountered.

Press A 60

3-24

60

In power hydraulics, energy is always present. Energy is the ability to do work. This ability has three classifications, potential energy, kinetic energy and heat energy.

When a force is applied to a confined liquid, the liquid assumes that force in the form of potential energy.

The ability of the confined liquid to perform work is dependent upon the static pressure (lbs per sq. in.) of the liquid.

4-1

Press A 62

XC → 61

61

One or more of the questions in this series have been answered incorrectly. Try the questions again. Take your time, and read the questions carefully. Press A 41.1

4-2

62

When a liquid is in motion, the dynamic factors of hydraulics problem have to be considered. These are kinetic energy and heat energy.

Kinetic energy is the energy a body possesses by virtue of the velocity at which it is moving. The greater the velocity, the greater the kinetic energy will be.

Heat energy is the energy a body possesses by virtue of its heat. In hydraulic systems heat energy generally is created by friction and is not wanted.

4-3

Press A 63

63

The velocity of a liquid is its rate of flow, usually expressed in feet per second. Velocity is a measure of the average speed at which the molecules in a moving liquid go past a given point.

Kinetic energy increases proportionally as the velocity of the liquid. The pressure resulting from this kinetic energy may be referred to as velocity pressure.

Press A 64 4-4

64

The quantity of flow (volumetric output) is a measure of the quantity of molecules in a moving liquid that passes a given point during a given time interval.

The quantity of flow (volume) is expressed in gallons per minute (gpm) or cubic inches per minute (cipm).

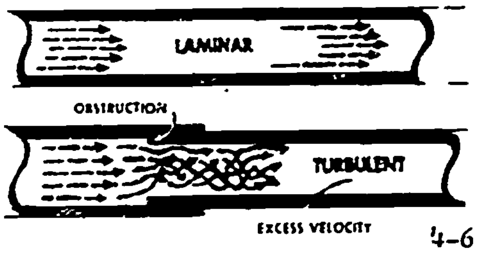
There are two types of flow in fluid power operations--LAMINAR (straight line) and TURBULENT.

Press A 65 4-5

65

Laminar flow is a smooth movement of fluid through the system as a result of the proper fluid selection, a properly designed system and the correct fluid velocity.

Turbulent flow is caused by excess velocity, rough internal surfaces of piping, obstructions and an excessive number of elbows or bends.



Press A 66 4-6

66

With reference to a liquid ____(1)____ is rate of flow and ____(2)____ is quantity of flow.

A. (1) volume (2) velocity 67
B (1) velocity (2) speed 67
C (1) velocity (2) volume 68

4-7

67

No. Velocity refers to how fast, or the speed at which, the liquid or fluid is moving.

Volume refers to how much, or the quantity, of liquid or fluid that has moved.

Press A 68 4-8

68

Right. Velocity is the rate of flow and volume is the quantity of flow.

Flow of a liquid through tubing is classed as ____(1)____ flow or ____(2)____ flow.

A. (1) pressure (2) viscosity 69
B. (1) velocity (2) volume 69
C. (1) laminar (2) turbulent 70

4-9

69

No. Laminar and turbulent are the correct answers.

Laminar flow is smooth movement of liquid through tubing or piping.

Turbulent flow is rough flow or movement, due to obstructions or excess velocity.

Press A 70 4-10

70

Right. Laminar flow is smooth flow and turbulent flow is rough flow.

When a liquid is in motion, friction occurs. Friction is the resistance to motion between two bodies.

In hydraulics, FRICTION occurs between the liquid and the inner wall of the tubing or piping through which the liquid is flowing. This friction generates heat.

4-11

Press A 71

71

Three main causes of excessive friction in hydraulic lines are:

1. Excessive length of lines
2. Excessive number of bends and fittings, or improper bends
3. Excessive velocity (lines undersize).

Let's assume we have eliminated excess fittings and bends, improper bends, undersize lines and lengthy lines. With a minimum of frictional loss, the system should now be very efficient and should have a low heat energy loss.

4-12

Press A 72

72

Liquid in motion, such as water moving through a pipe, does not have the same pressure at equal depth below the surface as a liquid at rest has.

In hydraulics _________ occurs between fluid in motion and the inner walls of its container.

A. heat 73
B. friction 74
C. velocity 73

4-13

73

No.

Velocity is the speed of motion of a fluid or object. The motion of the fluid through a container causes a boundary layer of turbulence to occur between the inner wall of the container and the fluid. The higher the velocity of the fluid the greater will be the friction and turbulence.

Friction occurs between the fluid in motion and the wall of the container as the fluid passes through it. This friction generates heat which is known as heat energy loss.

4-14

Press A 74

74

Right. Friction occurs between fluid in motion and the inner walls of its container.

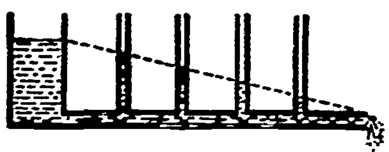
A stream of water moving through a pipe of uniform diameter, has pressure decreasing uniformly in the direction in which the water is moving. The pressure will be greatest where the water enters the pipe. Water piped from a spring also has the greatest pressure at the spring: where the pipe enters the house, pressure is lower. At a low point of pressure in hydraulics, a pump is used to step up pressure to meet requirements.

4-15

Press A 75

75

To show how pressure continues to constantly become less, at various points along the liquid flow, we have placed glass tubes vertically in this pipe. The pressure at each point is indicated by the height of water visible in each glass. The height of the liquid decreases uniformly in the direction of liquid flow. Friction is the cause of this gradual pressure drop.



4-16

Press A 76

76

Now you might imagine that the pressure in a liquid, moving through a tube, would be greatest where its speed is greatest; but this is not true. The pressure is least where the speed of the liquid is greatest.

Bernoulli's principle states that: "As fluid flows through a restriction it gains speed but loses pressure; as it emerges from the restriction it loses speed but gains pressure"

Press A 77

4-17

77

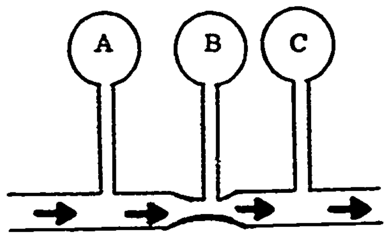
In Bernoulli's principle there is a proportionate relationship between cross sectional area of a passageway and velocity of flow. In a system, the volume of flow will always be the same through any passage line. A given volume will pass through a given distance in the same time regardless of the cross sectional area of the supply lines. However, the pressure will vary, depending on variations in the size (cross sectional area) of the pipe and fittings.

4-18

Press A 78

78

With fluid flowing from left to right in this pipe, gauge ________ will indicate the lowest pressure.



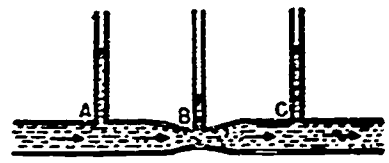
4-19

79 80 79

79

No. In a pipe whose inside passageway, or opening, is smaller at some places than at others, the fluid will flow more rapidly through the smaller sections than through the larger ones. In the figure, the fluid is moving faster at (B) than at either (A) or (C).

But the pressure in the wide parts of the pipe at (A) and (C) is greater than the pressure in the small part of the pipe at (B).



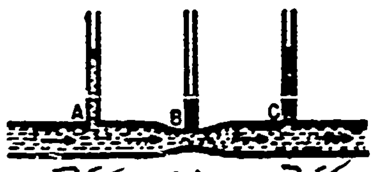
4-20

Press A 80

80

Right! The pressure is lowest at the small part of the pipe.

With fluid flowing from left to right in the pipe, the velocity of the fluid is greatest at point ________.

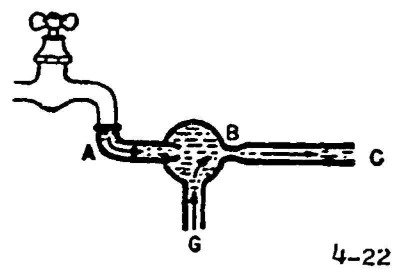


78 81 78

4-21

81

Right.
Bernoulli's principle is shown in this sketch of a water jet pump which is used to pump water from a basement sink. This pump is connected to a water faucet. As water from the faucet rushes through the tube, it travels faster through the narrow part at (B). The lessened pressure at (B) creates a suction which pulls water up through tube (G). Water from the faucet and water from the basement flow out together through tube C.



Press A 83

4-22

x C → 82

82

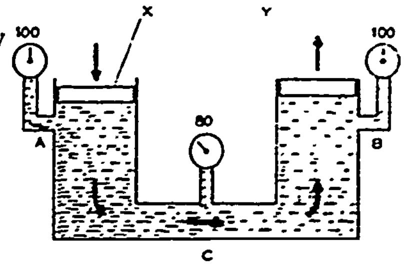
Velocity of the fluid is greatest at point (B).

Since you have missed one or more questions in this sequence, a review may help clear up any misunderstandings you may have. Read each question completely before selecting an answer. Press A 60

4-23

83

Bernoulli's principle is illustrated in this figure. As velocity increases, pressure decreases. Any force on piston (x) sufficient to move it and to create a pressure of 100 psi in chamber (A) will force liquid through passages so it will reach chamber (B). The velocity of the liquid will increase as it passes through passage (C), because the same quantity of liquid must pass through a small area at the same time.

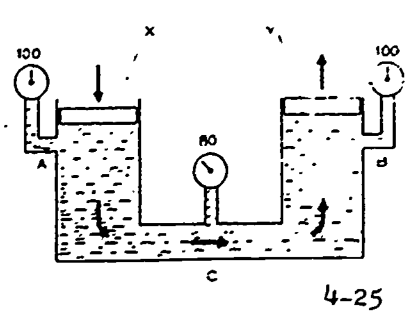


Press A 84

4-24

84

Now some of the 100 psi static pressure in chamber (A) is converted into velocity pressure in passage (C) so that a pressure gauge at this point registers 80 psi. As liquid passing through chamber (C) reaches (B), velocity decreases to its former rate and the kinetic energy is reconverted into potential energy. This is indicated by a static pressure gauge reading of 100 psi on the gauge.



Press A 85

4-25

85

A hydraulic system should be considered whenever the transmission of power through a small distance can aid the work to be accomplished.

The power of flowing fluid under pressure can be applied directly to a load and can produce linear or rotary motion -- without gears, commutators, chains, belts or magnets. It is the direct application of force by an incompressible, virtually frictionless fluid that makes hydraulic transmission of power so efficient.

4-26

Press A 86

86

Since fluids are nearly incompressible, the oil or other fluid in a hydraulic line behaves almost as if it were a steel rod. Applying power to one end of the line causes equal power to be applied at the other end. Because liquids assume the shape of their containers, hydraulic tubes or hoses can go around corners or across rooms, and the fluid and power will follow.

4-27

Press A 87

87

Hydraulic components lubricate themselves, run cool and have high power-to-size ratio.

Since the most commonly used hydraulic filud is oil, most components are self lubricating. Any heat generated is absorbed by the fluid and is dissipated in the supply reservoir.

Because they require little or no cooling and lubricating devices, hydraulic pumps and motors can be very small, compared to their power output.

4-28

Press A 88

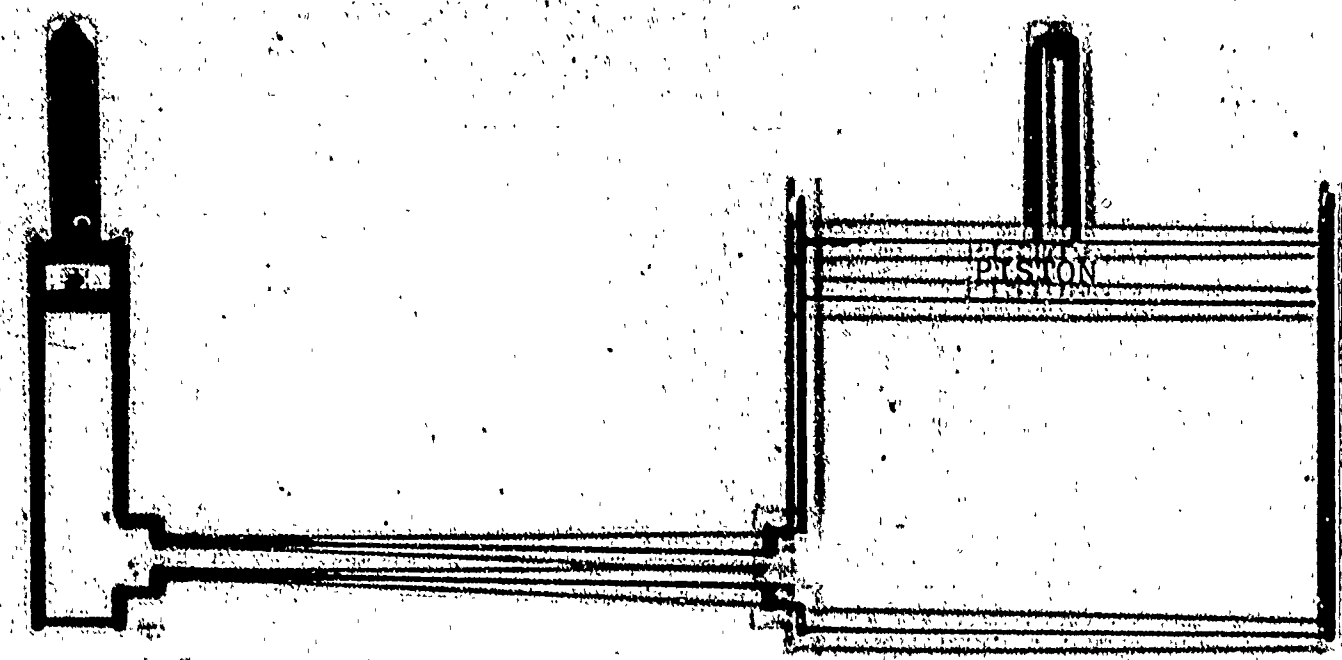
88

Congratulations! You have completed this film on "BASIC HYDRAULICS".

Please press REWIND.

4-29

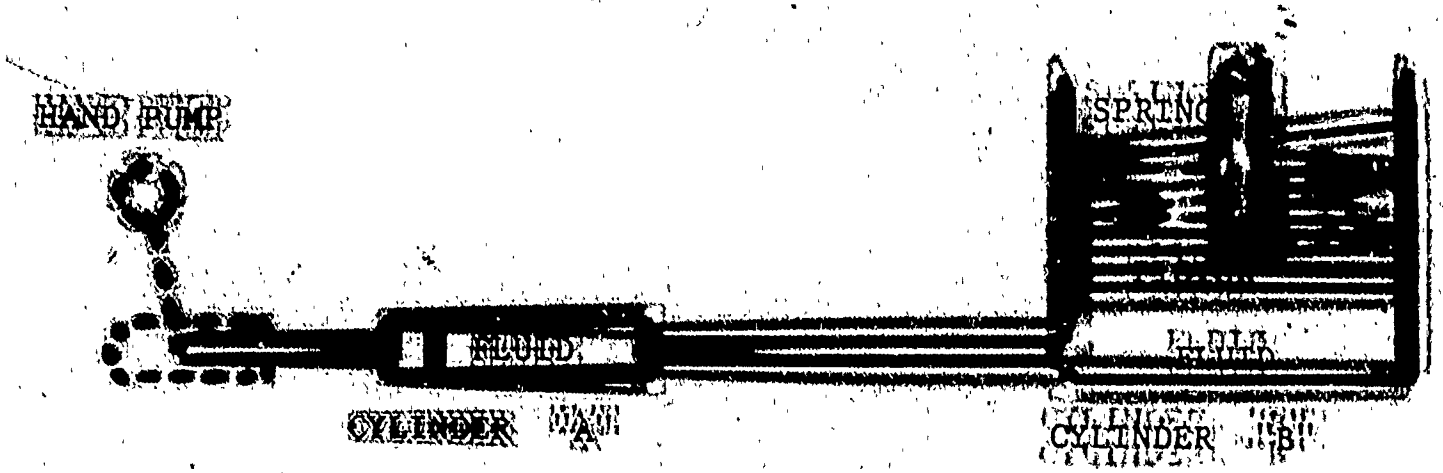
AM 2-3 (1)



[illegible] TWO CYLINDERS

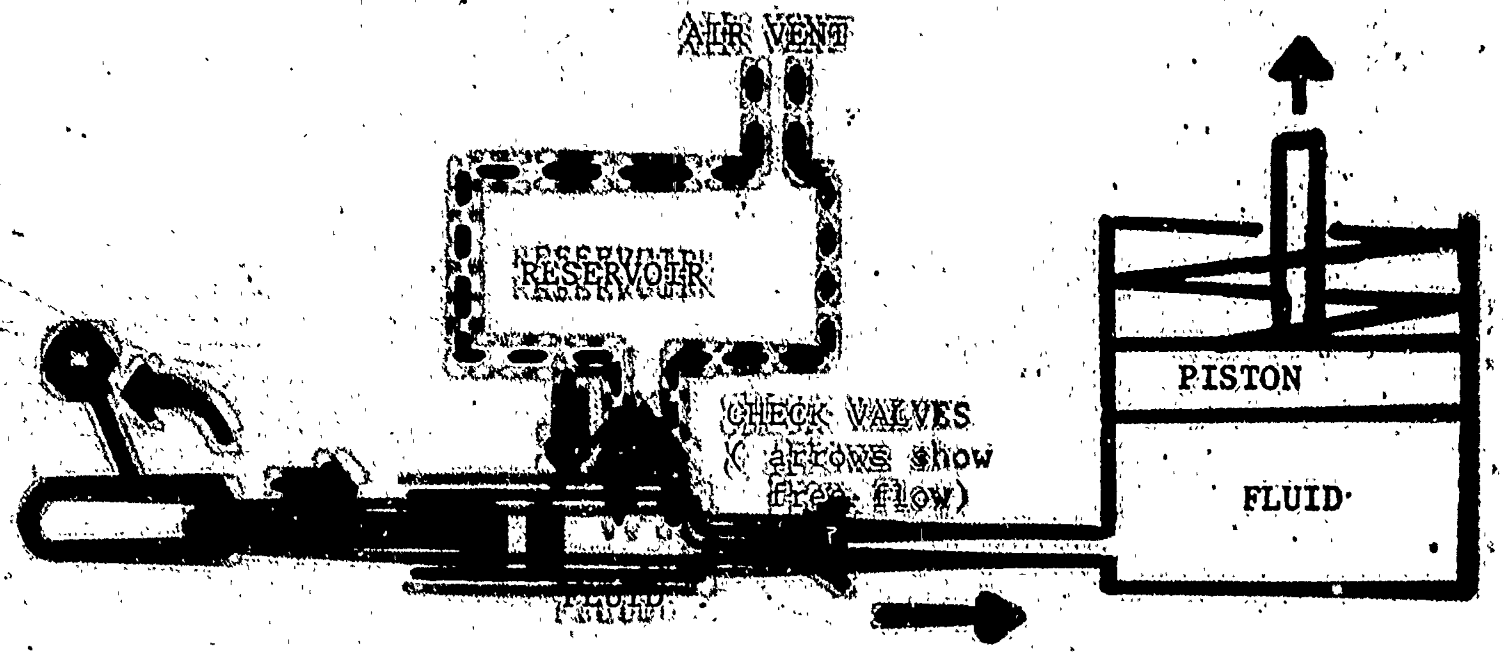
HUMAN ENGINEERING INSTITUTE
2341 Carnegie Ave
Cleveland, Ohio 44115

AM 2-3 (2)



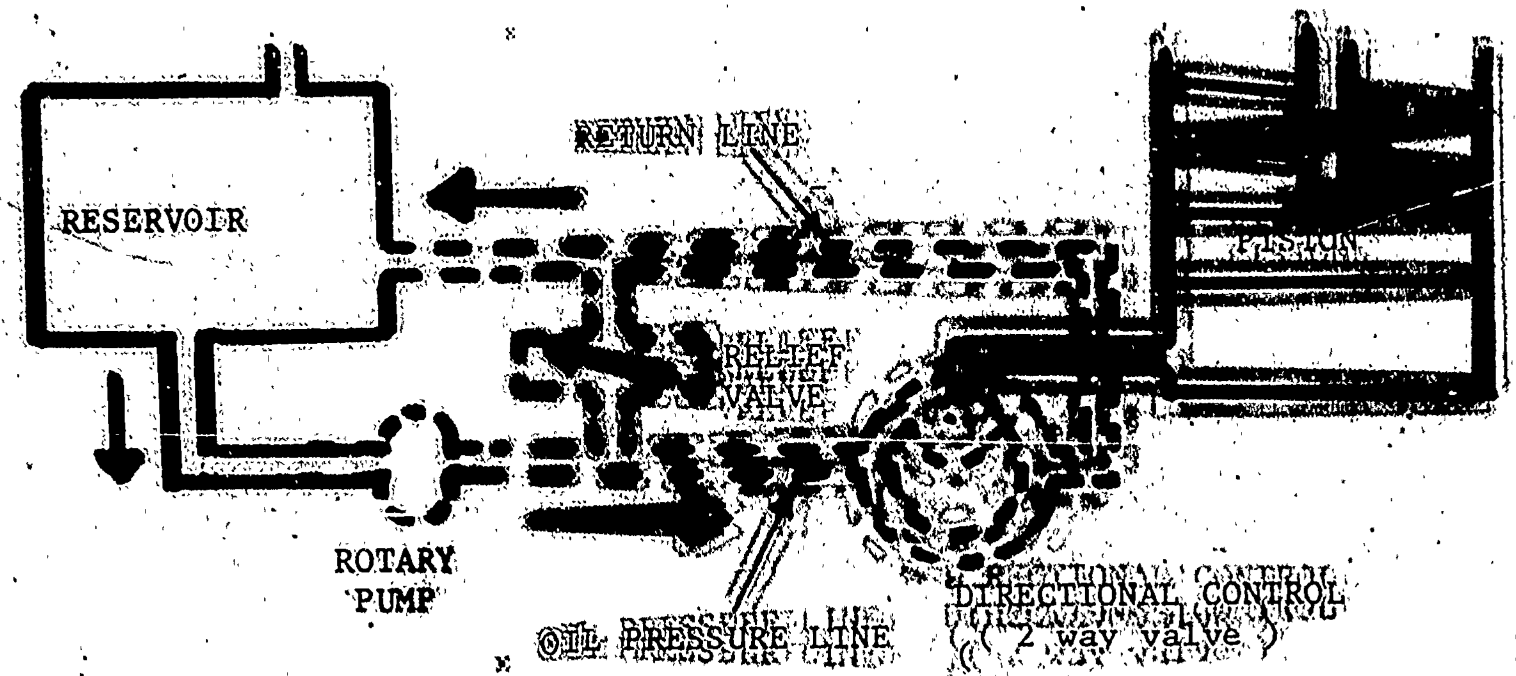
ADD A HAND PUMP AND SPRING

AM 2-3 (3)



ADD A RESERVOIR AND CHECK VALVES

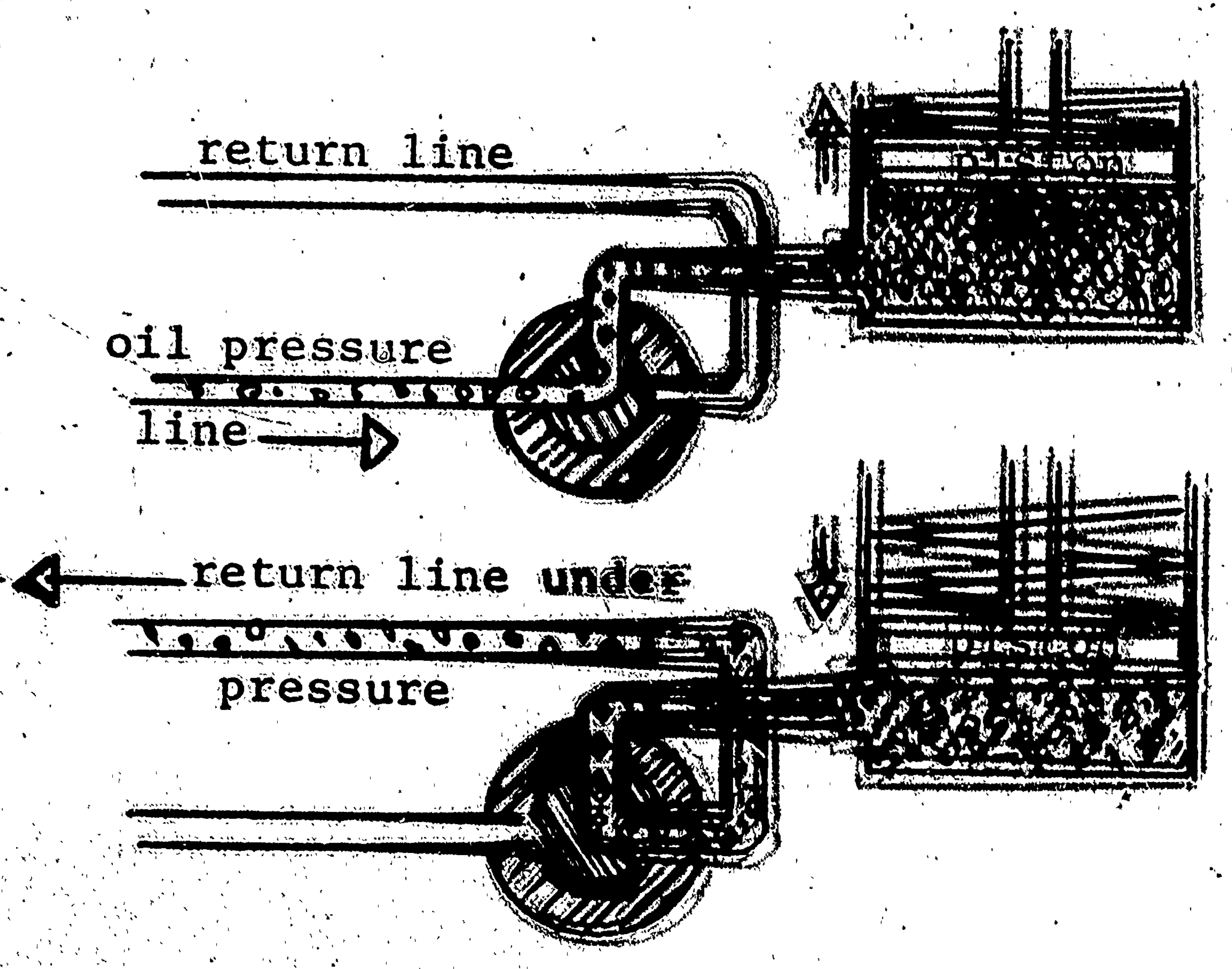
AM 2-3 (4)



FINALLY, WE ADD CONTROLS

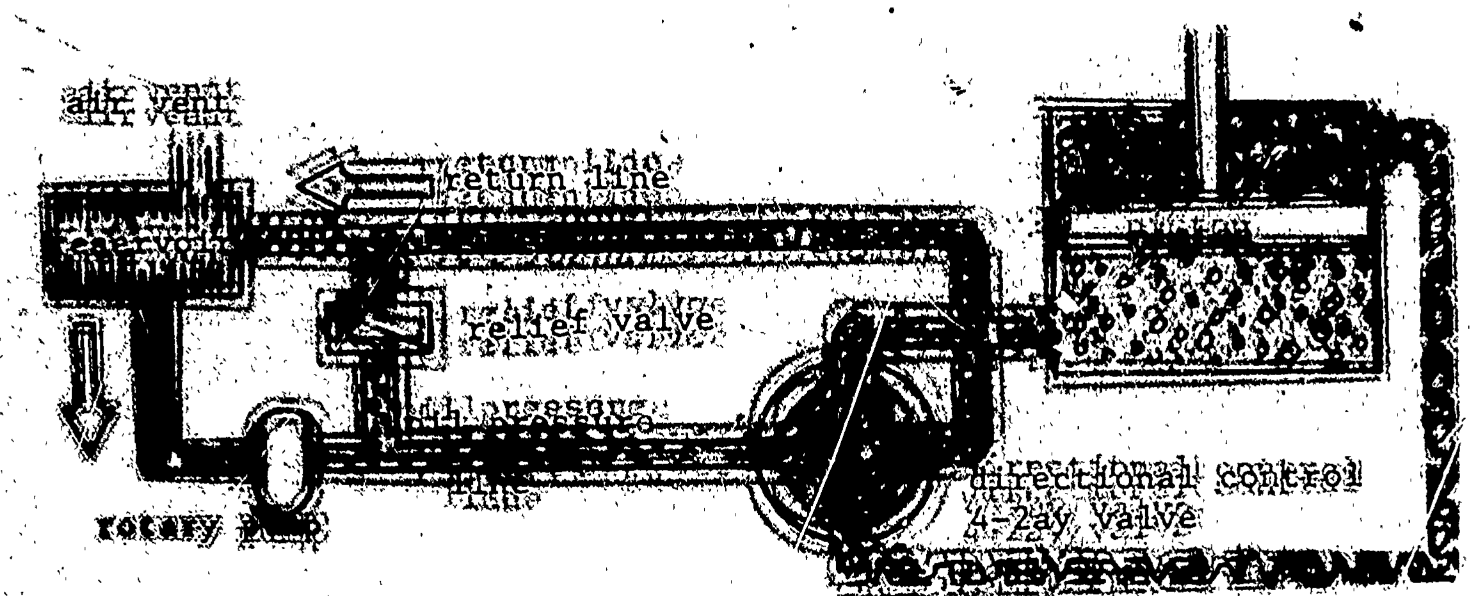
HUMAN ENGINEERING INSTITUTE

AM 2-3 (5)



Operation of two-way directional control valve

AM 2-3 (6)



Four-way directional control valve

HUMAN
ENGINEERING
INSTITUTE

2341 Carnegie Ave
Cleveland Ohio 44115

INSTRUCTOR'S GUIDE

Title of Unit: AUTOMATIC TRANSMISSIONS -- HYDRAULICS (PART I)

AM 2-3
5/9/67

OBJECTIVES:

To introduce the student to basic hydraulics by reviewing facts he has had before, plus some new concepts. This unit is designed to give the student a basic understanding of hydraulics in preparation for the units on the Allison Transmission.

LEARNING AIDS suggested:

VU CELLS:

- AM 2-3 (1) (Begin with two cylinders)
- AM 2-3 (2) (Add a hand pump and spring)
- AM 2-3 (3) (Add a reservoir and check valves)
- AM 2-3 (4) (Add controls)
- AM 2-3 (5) (Operation of two-way directional control valve)
- AM 2-3 (6) (Four-way directional control valve)

QUESTIONS FOR DISCUSSION AND GROUP PARTICIPATION:

1. Why are hydraulic controls better for off-highway equipment than electric?
2. What is a basic hydraulic system composed of?
3. What is Pascal's law in relation to a confined liquid?
4. Why should the word FORCE be understood before the concept of POWER can be comprehended?
5. What is PRESSURE in relation to force?
6. What does 14.7 psi mean to you?
7. What is meant by mechanical advantage through mechanical leverage?
8. How is it possible to gain MA (mechanical advantage) through liquid leverage?
9. How does friction affect liquid pressure?
10. What is meant by theoretical lift?
11. What are check valves used for?
12. What is the difference between a two-way direction valve and a four-way directional valve?