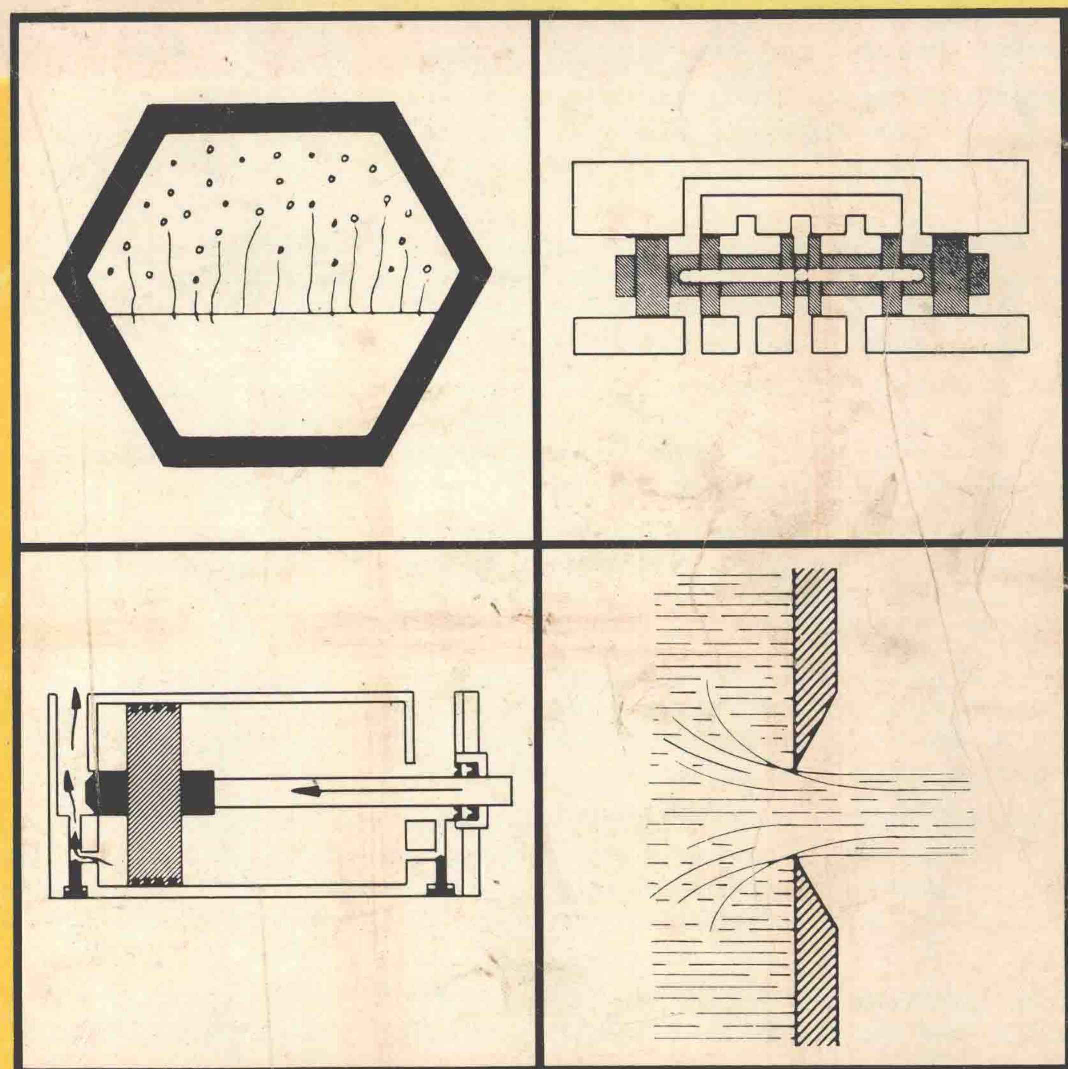
Industrial Hydraulic Technology

Bulletin 0221-B1



Parker Fluidpower

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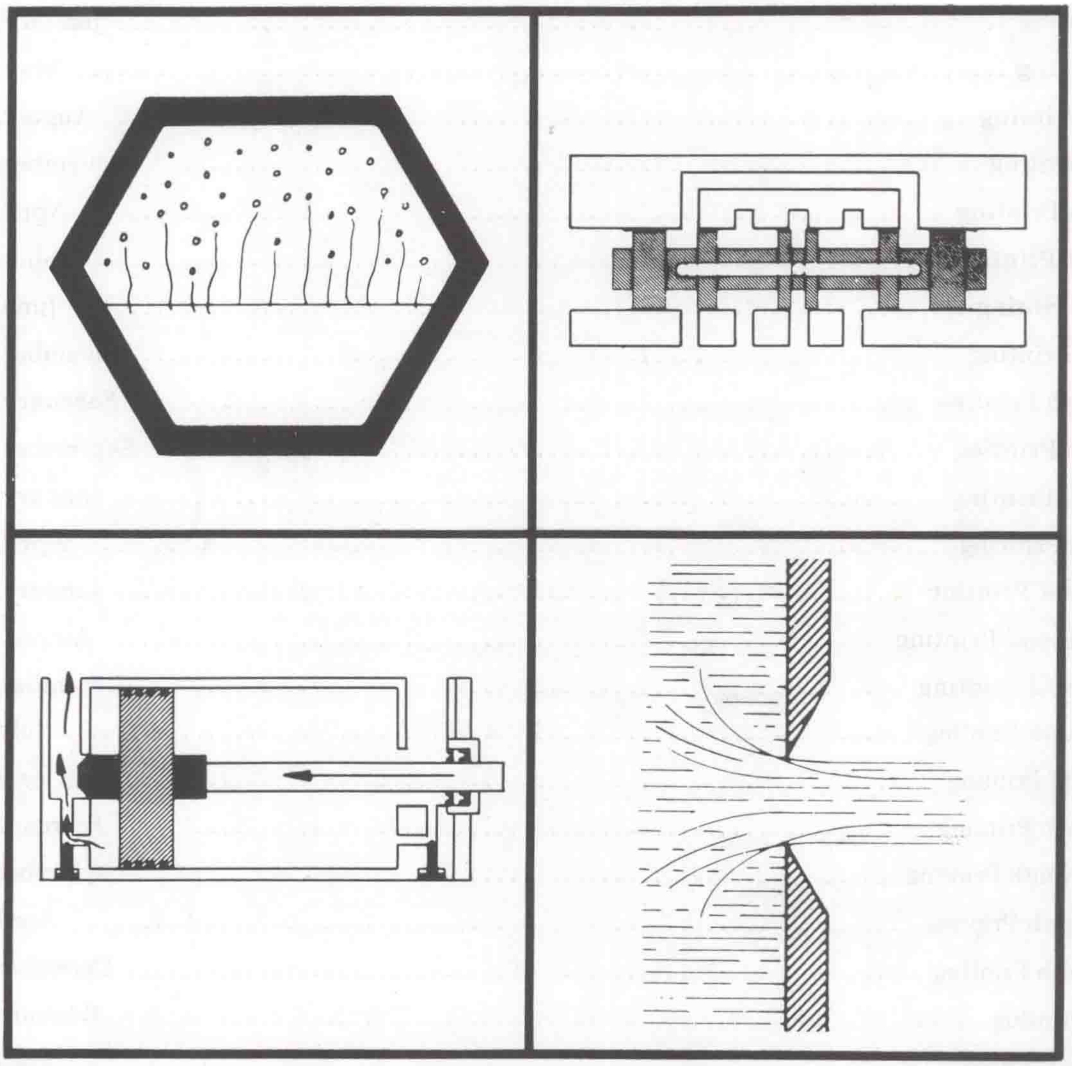

Parker Fluidpower

Training Department, Power and Controls Group

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Preface

The technology of industrial hydraulics has been developing at a high rate over the past three decades. With the beginning of World War II, hydraulics filled a need for an energy transmission system with muscle which could be easily adapted to automated machinery.

During this period, Parker-Hannifin was also growing and today has evolved into a full-line manufacturer of hydraulic components. The material in this text is a by-product of Parker-Hannifin's experience in the areas of design, manufacture, application, and servicing of hydraulic components and systems over the years. As a result, we feel the text material is pertinent and accurately describes industrial hydraulics as it is presently seen.

The organization of the text material is designed for the beginning student. Starting with "The Physical World of a Machine", the student is lead through topics ranging from basic physical concepts to component operation and its typical system application.

Excercises are placed at the end of the chapters. These exercises are designed to be a summary of the text high points and at the same time to be interesting and self-checking.

At this writing, the subject of metrication is creating considerable activity in many areas. However, since the metric system is presently just beginning to appear in industrial hydraulics, no attempt was made to incorporate this material into the text. This will be done at a later time.

We hope that the student will find the course of study logical and easily understood. If we have failed in this regard, your comments will be greatly appreciated.

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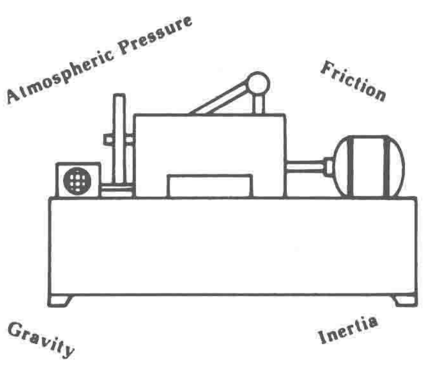
The Physical World of a Machine

Man has invented machinery to work for him. Machines are man's servants, yet most men are afraid of or puzzled by machines because they don't understand how they operate.

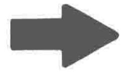
Just as all things on earth, machines are surrounded by physical elements which hinder the performance of work. To understand, then, how a machine operates, we will look at and attempt to define some of these elements, and then determine how a machine contends with them.



NOTE: The elements with which a machine deals are defined in this and the following sections. These definitions are not intended to be all inclusive, but only show in what sense these terms will be used throughout this text.

force

A force is any influence capable of producing a change in the motion of a body.



Force

pound

One unit for measuring force is the pound.

changes motion

Force, as we will deal with it, can change the motion of a body in basically two ways:

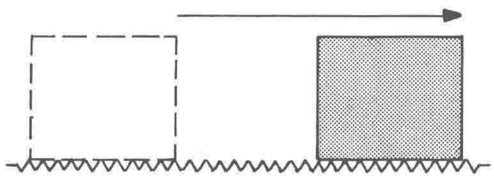
1. It can cause a body to move.
2. It can retard or stop a body which is moving.

resistance

Resistance

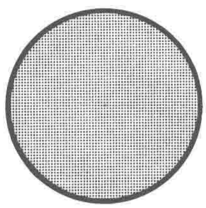
Any force which can stop or retard the movement of a body is a resistance. Examples of resistances are friction and inertia.

friction as resistance



Frictional resistance is always present between the contacting surfaces of two objects when they are moving across one another.

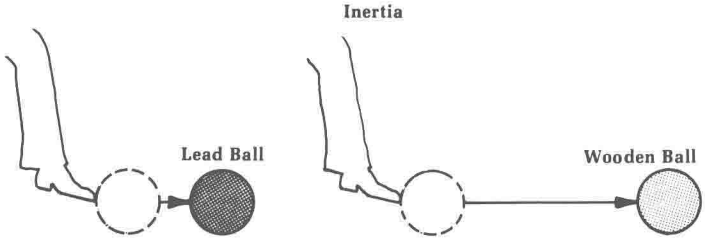
inertia as resistance



Inertia

Inertia is the reluctance of a body to a change in its motion.

Inertia is directly related to the quantity of matter in a body. The more mass or matter an object has, the heavier it is, and consequently the harder it is to move.



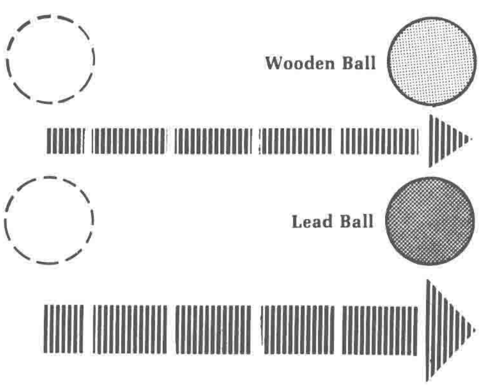
The inertia of a lead ball is greater than a wooden ball. If both balls are kicked with the same force, the wooden ball will move faster and farther than the lead ball. The lead ball has more of a resistance to be moved.

energy

Energy

A force which can cause a body to move is energy.

inertia as energy



Inertia, being the reluctance of a body to a change in its motion, can also be energy. A moving body exhibits a reluctance to be stopped, and can therefore strike another body and cause its motion.

With a wooden ball and lead ball moving at the same speeds, the lead ball exhibits more inertia since it is more difficult to stop. The lead ball has more energy than the wooden ball.

some forms of energy

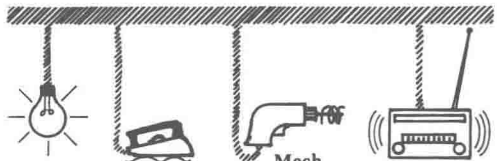
Some forms of energy are mechanical energy, heat energy, electrical energy, light energy, chemical energy, and sound energy.

law of conservation of energy

The law of conservation of energy says that energy can neither be created nor destroyed, although it may change from one form to another.

energies change form

Energy exists under various forms, and has the ability to change from one form to another. For instance, electrical energy may be changed to several forms. Depending on what device or appliance is plugged into the outlet, electrical energy changes to light energy, heat energy, mechanical energy, or sound energy.



Another example of energy changing form is a person sliding down a rope. When it comes time to stop or slow down, the rope is squeezed and some mechanical energy of the falling body is changed into heat energy, as most people are well aware.

energy states

An important consideration when dealing with energy is the state or condition in which it is found.

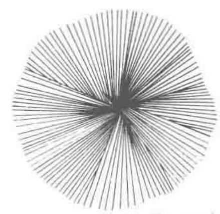
kinetic state of energy

Energy in the kinetic state is moving. It causes movement by contacting an object's surface.

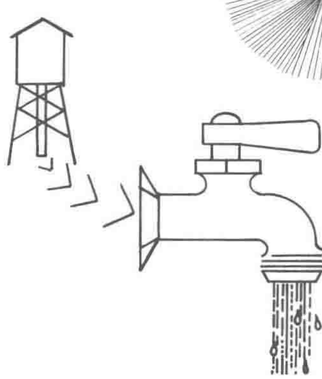
Kinetic Energy

potential state of energy

When in a potential state, energy is stored. It is waiting to spring into action, to change to a kinetic state as soon as an opportunity arises. Potential energy has the ability to become kinetic because of its physical makeup or its position above a reference point.



Potential Energy

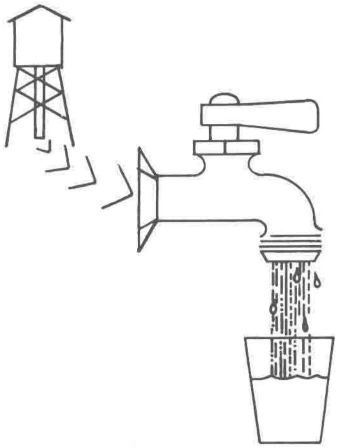


Because of its elevation, the water contained in a water tower is potential energy. It has the ability to be drawn off at a household water tap at a lower level.

A storage battery, when not connected in a circuit, is in a state of potential energy. Because of their physical makeup, the chemicals in a battery have the ability to change to electrical kinetic energy.

energies change states

As has been discussed, potential energy has the ability to change to kinetic. But, kinetic energy can change to potential as well. The water in a water tower is poten-



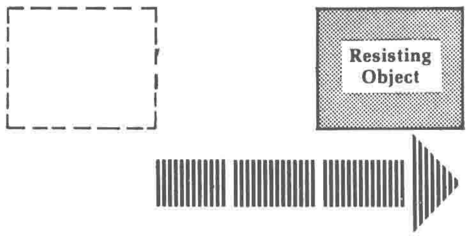
tial energy which changes to hydraulic kinetic energy at a water tap. This kinetic energy changes to a potential state while it fills a glass.

It is not only convenient that energy can change from one state to another, but most forms of energy must be in the kinetic state before any work can be done.

work

Work, as we will deal with it, is the movement of an object through a distance.

"Work" is getting things done. Machinery exists to perform work.



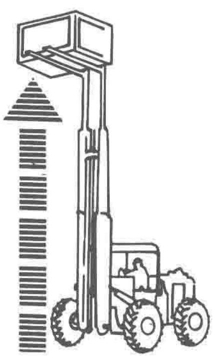
foot—pound

The unit for measuring work is the ft. lb.

description of work

The expression which describes work is:

work = (ft.lbs.)	distance moved (ft.)	x force exerted (lbs.)



An example of doing work would be a forklift loading a truck. If the forklift exerted a force of 2000 lbs. over a vertical distance of 5 ft. to load each pallet, then 10,000 ft. lbs. of work would be done per pallet.

power

All work is done within a certain time. Power is the speed or rate at which work is done.

description of power

The expression which describes power is:

$$\text{power} = \frac{\underset{(\text{ft.})}{\text{distance moved}} \times \underset{(\text{lbs.})}{\text{force exerted}}}{\text{time (seconds)}}$$

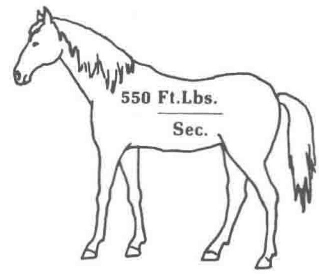
In our example of loading the truck, if the 10,000 ft. lbs. were done in 5 seconds, the rate of doing work would be

$$\frac{10{,}000 \text{ ft. lbs.}}{5 \text{ seconds}}$$

or 2000 ft. lbs. per second.

horsepower

The unit for measuring power is horsepower. James Watt, the inventor of the steam engine, wanted to compare the amount of power his engine could produce against the power produced by a horse. From experimentation, Watt discovered that a horse could lift a 550 pound load one foot in one second. He thus said that one horsepower is equal to 550 ft. lbs. per second.



description of horsepower

The expression that describes horsepower is:

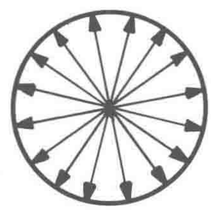
$$\text{HP} = \frac{\text{distance moved (ft.)} \times \text{force exerted (lbs.)}}{\text{time (seconds)}} \div 550$$

Using the example of loading the truck once again, the 2000 ft. lbs./sec. rate of doing work would translate into 3.6 horsepower.

pressure

Pressure is a measure of a force's intensity.

Many times, the intensity of a force is of more interest and of greater concern than the actual force itself. To determine pressure--the intensity of a force--the total force is divided by the area (usually square inches) on which it is acting. The result is the pressure (amount of force per square inch).



Pressure

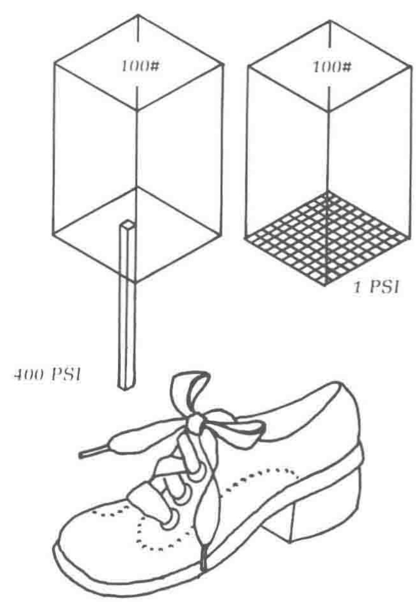
description of pressure

The expression used to describe pressure is:

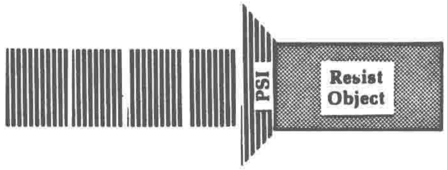
$$\text{pressure} = \frac{\text{total force (lbs.)}}{\text{area on which total force acts (in.}^2\text{)}}$$

A 100 pound weight with a base area of 100 sq. in. exerts a pressure of one pound per square inch on the surface which it is laid.

The same 100 pound weight placed on a square steel rod with a base area of ¼ sq. in. exerts a pressure of 400 PSI. The total forces are equal, but the intensities differ greatly.



An example of this from everyday life would be the difference in pressures generated by heels of various styles of shoes. Anyone who has had his foot stepped on by a woman wearing high-heel shoes knows how painful it can be. The same woman wearing low, flat-heel shoes would probably cause little discomfort.



working energy

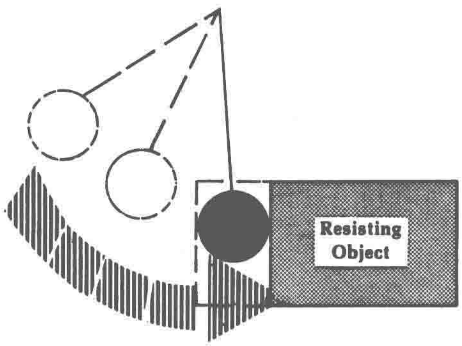
Kinetic energy used by a machine is usually in a working form which is characterized by an accompanying pressure. The pressure is the result of the force of kinetic energy being applied to a surface of an object.

Working energy is the combination of kinetic energy and pressure.

working energy changes form

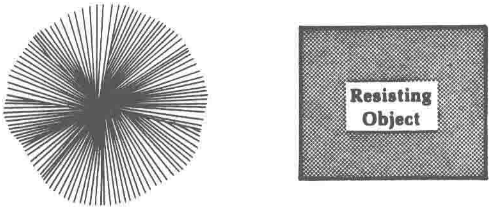
Common sense tells us that we can't get something for nothing. Something must happen to the energy in moving an object.

A swinging wrecking ball is an example of kinetic energy. If it is applied to a resisting object like a stone block, it will result in a movement of the block through a distance. (Assuming that the ball has sufficient inertia and will not rebound.) After this work is done, both the ball and object will stop.



What happens is that working energy is transformed. If the object moves along the same level, working energy changes to heat because of friction at the sliding surface of the object. If the object is raised to a higher level, as in the case of a forklift raising a pallet, working energy changes to potential energy.

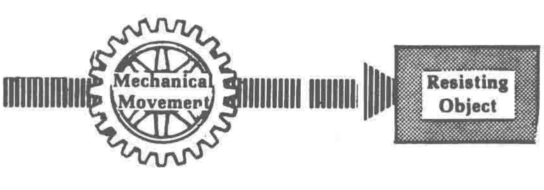
In all instances of machines doing work, working energy is not destroyed, but changes form. Machines effect energy transformation in the process of doing work.



transmission of energy

Usually the source of energy for a machine is not at the point where it is to do work. Energy must be transmitted to the resisting object. This is usually done mechanically, electrically, pneumatically, or hydraulically.

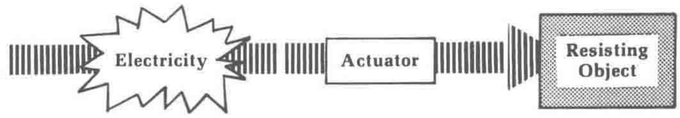
mechanical transmission of energy



In mechanical transmission, energy in the form of mechanical movement is transmitted and controlled through levers, chains, pulleys, belts, cams, and gears to the point where the work is to be done.

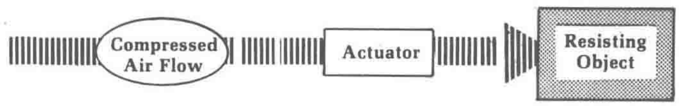
electrical transmission of energy

In electrical transmission, energy in the form of electricity is transmitted and controlled through wire, to an electrical actuator where the work is to be done.



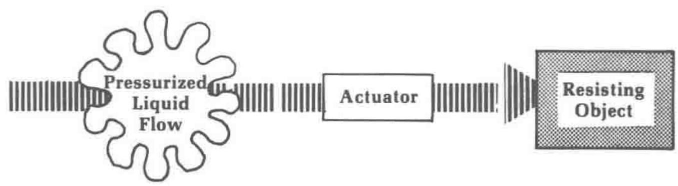
pneumatic transmission of energy

In pneumatic transmission, energy in the form of compressed air flow is transmitted and controlled through piping, to a pneumatic actuator where the work is to be done.

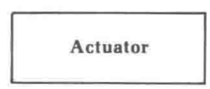


hydraulic transmission of energy

In hydraulic transmission, energy in the form of pressurized liquid flow is transmitted and controlled through piping, to a hydraulic actuator to the point of work.



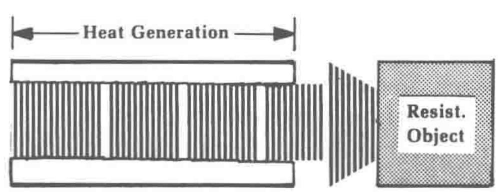
For almost all machines, the energy that does the work is mechanical energy. Even other forms of energy transmission result ultimately in mechanical energy. For this reason, they require an actuator before the point of work. Actuators transform electrical, pneumatic, and hydraulic energy into mechanical energy.



Each method of energy transmission has its own advantages and disadvantages. For this reason, a machine may be equipped with a combination of mechanical, electrical, pneumatic, and hydraulic systems.

inefficiency

The objective of the various transmission systems is to perform useful work; that is, move a resisting object through a distance. Useful work is performed by the application of kinetic energy to a surface of the resisting object. This we defined as working energy.



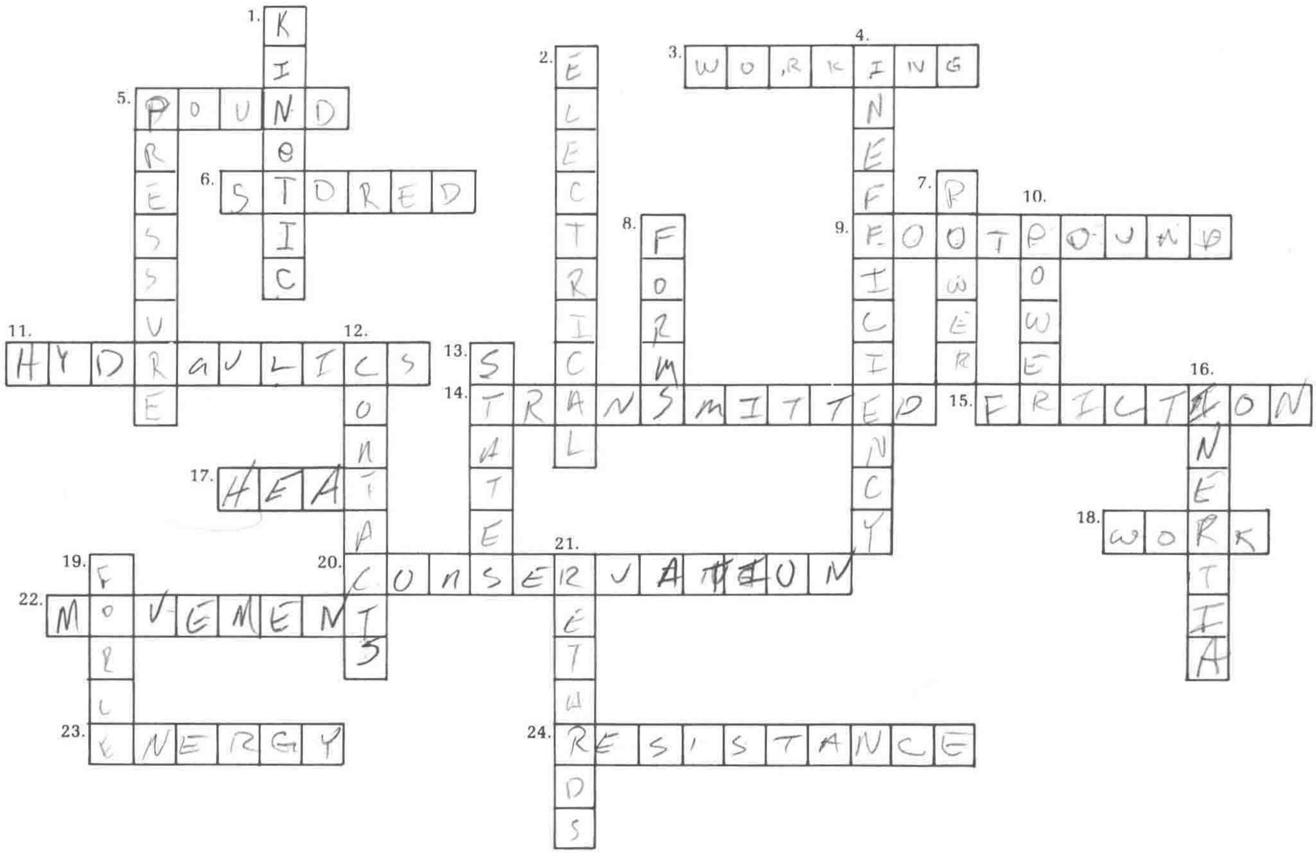
Energy transmitted through the various systems is also working energy. The conductors of energy in each system are physical objects with surfaces which also act as a resistance. The kinetic energy applies a pressure to the conductor's surface. This is working energy. But energy that performs non-useful work since no resisting object is moved.

Traveling through the system, the pressure of the working energy becomes less and less as it gets to the point of work. This pressure is not destroyed, but changes to the form of heat energy because of friction. The degree to which this happens is a measure of a system's inefficiency.

exercise

the physical world of a machine
50 points

Instructions: Complete the crossword puzzle.



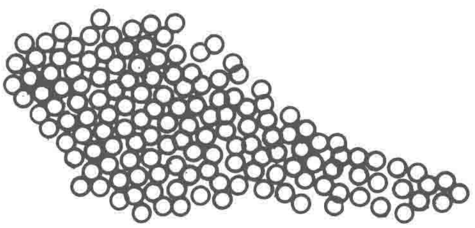
Across

3. Kinetic energy accompanied by pressure is ____________________ .
5. A force measure.
6. Potential energy is __________ energy.
9. A work measure.
11. A means of energy transmission.
14. Since the source of kinetic energy for a machine is not at the point of work, it must be ______________ .
15. Kinetic energy changes to heat when this resistance is overcome.
17. An energy form. HEAT
18. Moving an object through a distance.
20. Energy cannot be created or destroyed, so says this law.
22. What is present when work is done.
23. Force which causes movement. energy
24. Friction is a Resistance .

Down

1. A state of energy which can do work.
2. One type of energy transmission system.
4. The degree to which a system's working energy decreases is a measure of a system's ____________________ .
5. Force intensity.
7. A form of kinetic energy.
8. Energy has many of these.
10. Term indicating how long it takes to do work.
12. Kinetic energy does work as it __________ an object's surface.
13. Condition of various energies.
16. Can be energy or resistance. Kinetic
19. It influences motion.
21. Resistance ______________ motion.

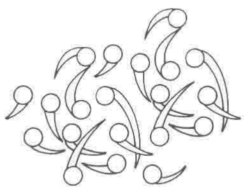
Hydraulic Transmission of Force and Energy



Before dealing with energy transmission through a liquid, it will help our understanding of hydraulics to first concentrate on some characteristics of a liquid, and then how a force is transmitted through a liquid.

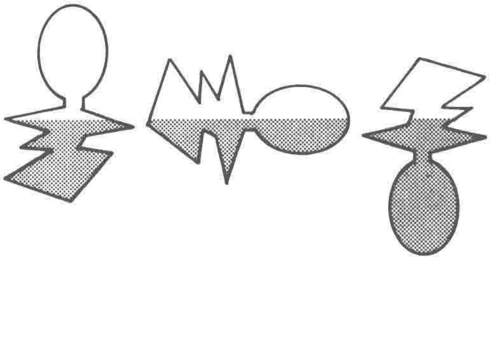
liquids

A liquid is a substance made up of molecules. Unlike a gas, these molecules are closely attracted to one another. Also, unlike a solid, these molecules are not so attracted to each other that they are in a rigid position.



molecular energy

Liquid molecules are continuously moving. They slip and slide past one another even when the liquid is apparently at rest. This movement of molecules is molecular energy.



liquids take any shape

Since this slipping and sliding action is continuously taking place, a liquid is able to take the shape of any container.

liquids are relatively incompressible

With molecules in close contact with one another, liquids exhibit a characteristic of

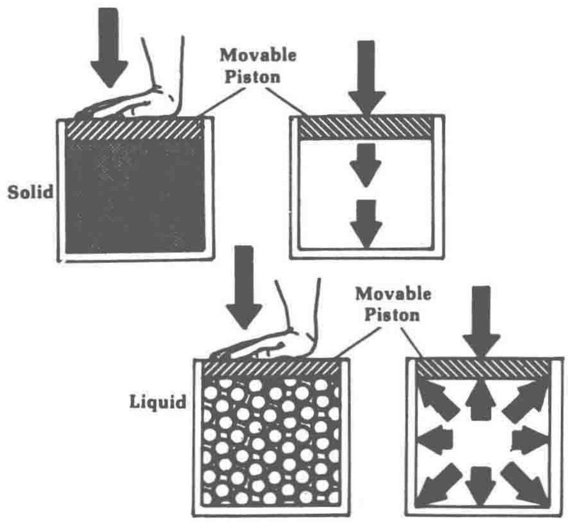
solids. Liquids are relatively unable to be compressed.

This is the reason a diver tries to "knife" his way into the water and avoid a belly smacker.

Since liquids are relatively incompressible and can take the shape of any container, they possess certain advantages for transmitting a force.

force transmission

The four methods of energy transmission (mechanical, electrical, hydraulic, pneumatic) are capable of transmitting a static force (potential energy) as well as kinetic energy. When a static force is transmitted in a liquid, it happens in a special way. To illustrate, we will compare how it is transmitted through a solid and through a confined liquid.

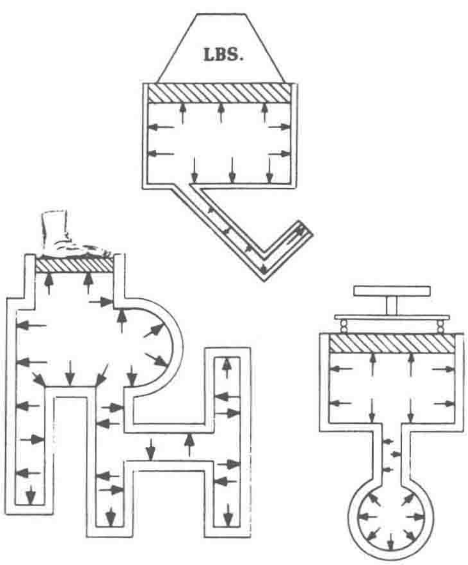


force transmitted through a solid

A force transmitted through a solid is transmitted basically in one direction only.

If we pushed on a solid block, the force would be transmitted to the opposite side only.

force transmitted through a liquid



Unlike a solid, a force applied to a confined liquid is transmitted equally throughout the liquid in the form of hydraulic pressure.

If we pushed on a container filled with liquid, the pressure of the applied force would be transmitted equally throughout the liquid.

A confined liquid will transmit pressure in the same manner regardless of how it is generated. As far as the liquid is concerned, an applied force results in pressure whether the application of force comes from a hammer, by hand, weight, fixed or adjustable spring, compressed air, or any combination of forces.

Since fluid can take the shape of any container, pressure will also be transmitted regardless of the shape of the container.

pascal's law

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

The property of a liquid to transmit pressure equally throughout itself is known as