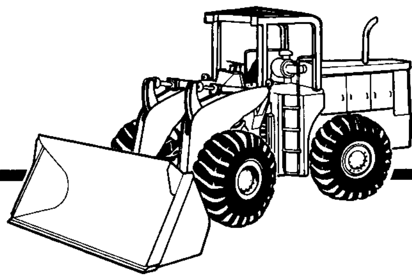
BASIC HYDRAULICS 9021

CLARK

Michigan Company



Basic Hydraulics

Basic Hydraulics, part one, has been designed as an introduction to Hydraulic Systems in general. The ability to disassemble and assemble hydraulic system components is only part of a mechanic's responsibility. Knowing the "How" and "Why" of system operation is also important. Before a service man can begin to do a good job of maintaining and troubleshooting any hydraulic system, he must have a thorough understanding of the information contained in the following pages.

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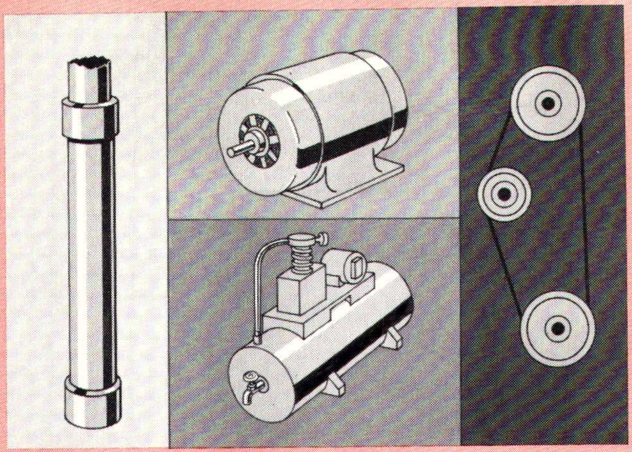
1

Why are hydraulic systems used so much in today's construction machinery instead of electrical, pneumatic or mechanical systems?



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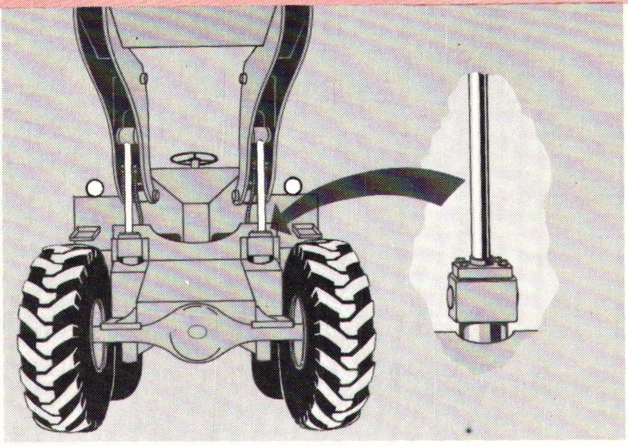
The answer is that hydraulics is one of the most versatile, efficient and simple ways of transmitting power known to man. The purpose of a hydraulic system is to change power from one form to another to perform useful work.



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There are several hydraulic systems which a piece of construction machinery must depend on. They are brakes, steering, boom and bucket, blade and ripper, elevator, grapple, transmission and winch.

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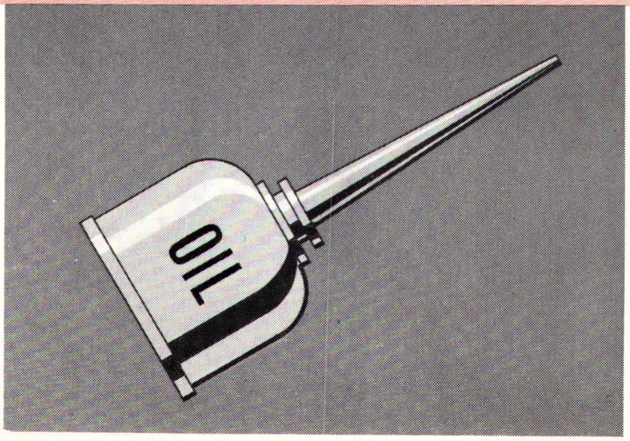
Oil is the most commonly used hydraulic fluid because it is practically non-compressible. Under 1,000 pounds of pressure per square inch it will compress only one-half of one percent. Oil has the added advantage of serving as a lubricant.



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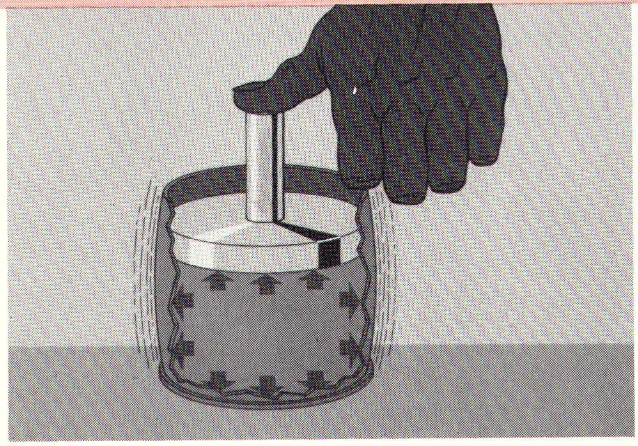
If you have ever tried to put a cork into a bottle, you've run head on into the principle of non-compressibility of liquids. If the bottle is full, you can't push the cork all the way in. Push too hard and the bottle will burst. Non-compressibility of liquids is what makes hydraulic power possible. This was discovered three hundred years ago by Blaise Pascal who made the observation now known as Pascal's law.

6

Pascal said: *"Pressure exerted on a confined liquid is transmitted undiminished in all directions and acts with equal force on all areas.*



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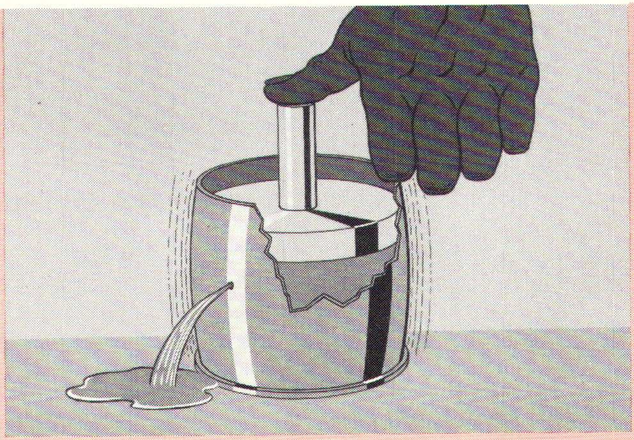
Fill a can with oil and insert a tightfitting plug. Push down. The plug will be stopped by the oil. The oil will fight back by pressing against the plug as well as against the sides and bottom of the can. If we could push hard enough, the can would burst as the bottle did.



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But you know from your own experiences that when a force is applied to a confined liquid, the liquid will take the path of least resistance. If we punch a small hole in the can, oil will spurt out as we push down on the plug.

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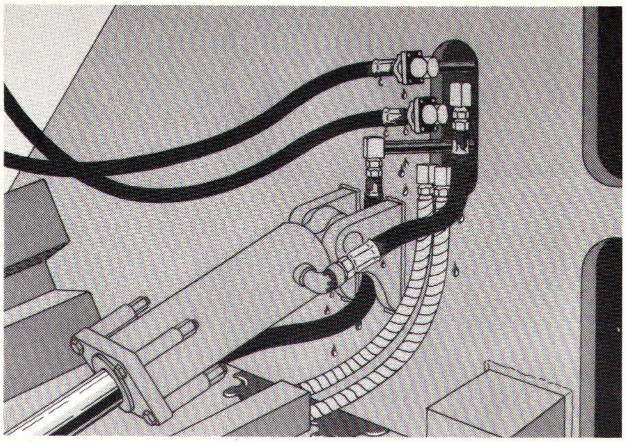
This principle that makes hydraulic fluid so useful is also the source of most hydraulic problems. Because of this law, hydraulic fluid is continually looking for the line of least resistance such as a break in a hose or through the opening around loose fittings.



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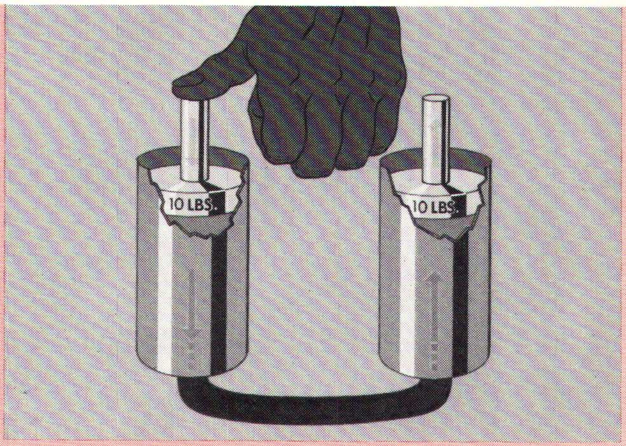
Now, let's see how the law of least resistance can work for us. The key phrase to the law is that the fluid acts with equal force on equal areas. In other words, if two identical cylinders are connected by a hose, pushing one piston down with a force of 10 pounds per square inch will cause the other to rise with a force of 10 pounds per square inch. This is because the area of each piston is equal.



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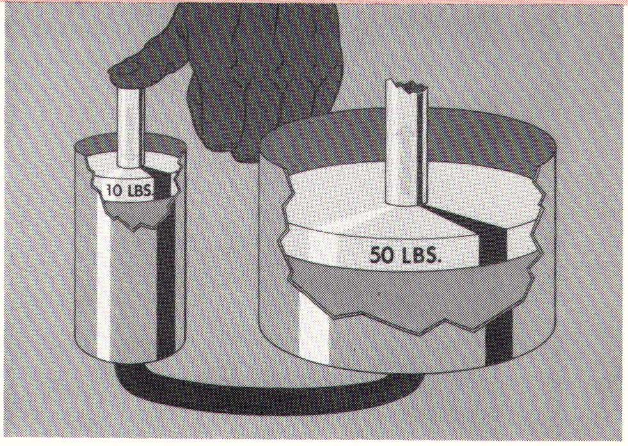
It logically follows that, if the areas are not equal, the forces are not equal. Connect the same power cylinder to a working cylinder that is five times the area. Apply 10 pounds per square inch to the power cylinder. According to Pascal's law, this applies 10 pounds to every square inch of working cylinder. . . or 10 pounds times five . . . a total force of 50 pounds.



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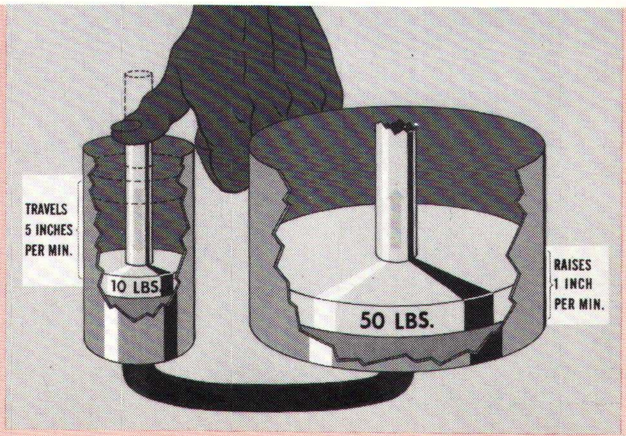
You can't gain something, without paying some sort of price and the price here is the distance the working piston moves. Force is increased five times, distance is cut five times. The reason the working piston doesn't travel as far is simple. It is five times the size of the power cylinder. Five inches of stroke by the power cylinder is required to transmit enough fluid to move the larger working cylinder a distance of one inch.



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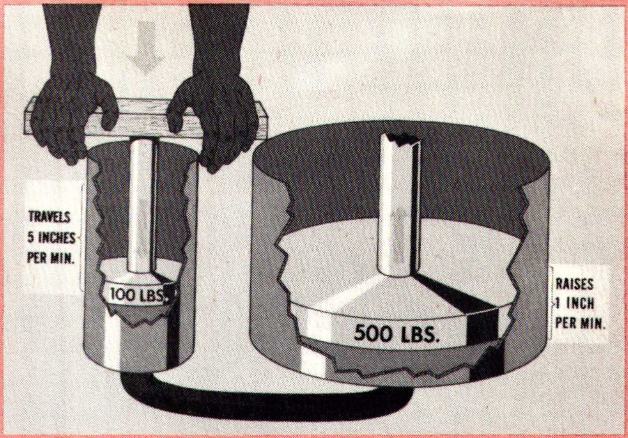
One of the common mistakes in understanding hydraulic systems is the supposition that increased cylinder pressure will increase piston speed. Not true. Increased pressure does not make a piston move faster. Increased volume of oil makes the working piston move faster. Here, we increase the pressure on the power cylinder 10 times. But, regardless of the amount of pressure we put on the cylinder, the same volume of fluid still moves from one cylinder to the other. The force increases five times as before but note that travel stays as before. The only way to increase speed of either piston is to increase the rate of flow from power cylinder to working cylinder.



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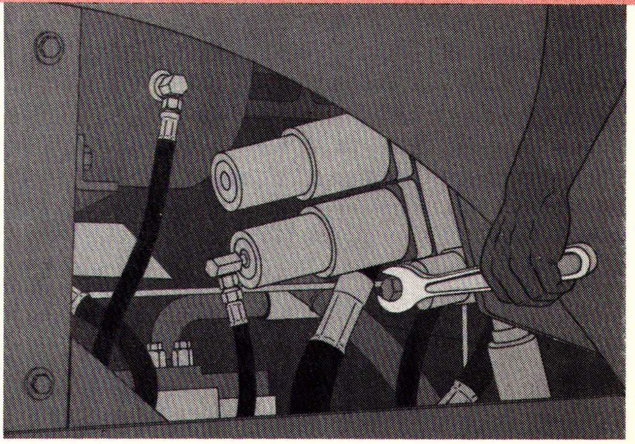
In an attempt to increase the speed of hydraulic action a mechanic sometimes will tighten the relief valve which raises the maximum pressure in the system. This does not increase the speed of action. The relief valve is meant to protect the system and its setting should never be increased over the pressure recommended by the manufacturer. Instead of tightening the relief valve, a mechanic should look elsewhere for some defect in the system.



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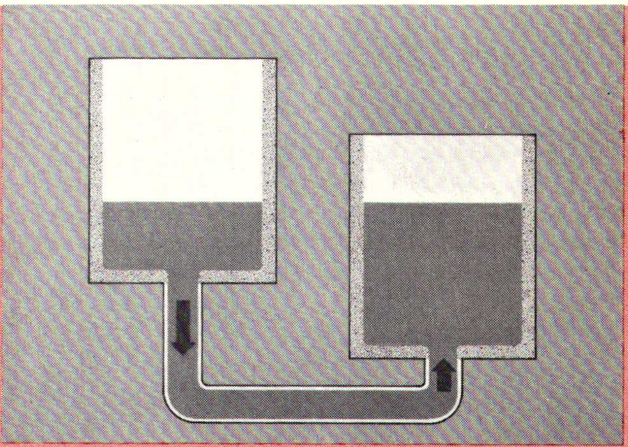
Pressure can and often does exist without flow. Gravity can be one of the causes. When gravity is the only force present, a liquid will seek its own level. We make extensive use of this natural force in hydraulic systems.



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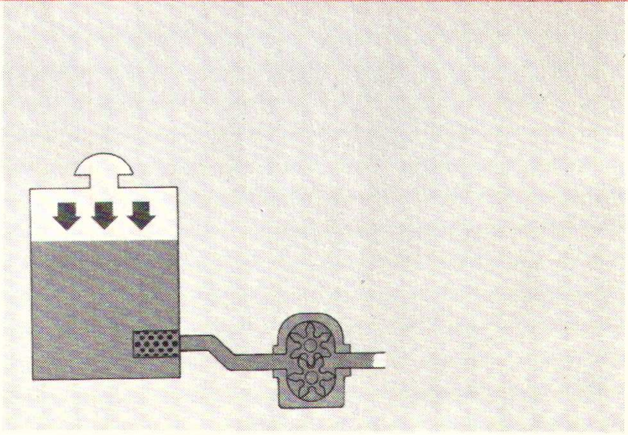
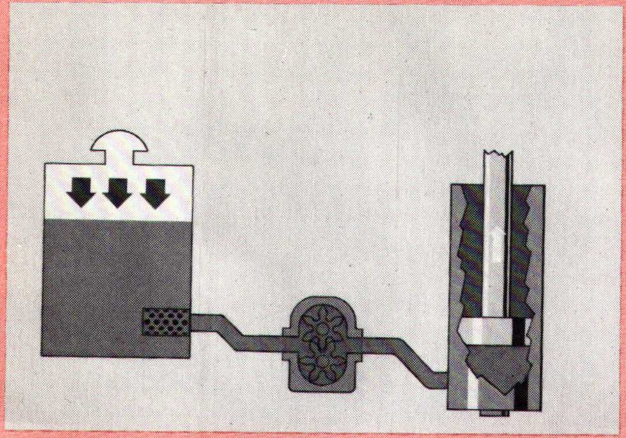
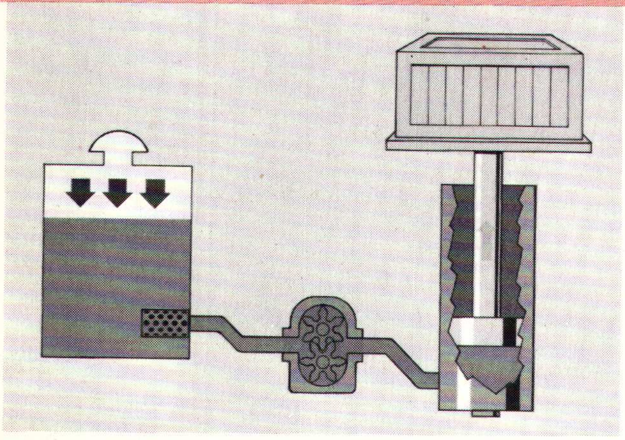
It is pressure of gravity that forces hydraulic fluid from a tank into a pump. What is commonly called the suction of a pump is really this force of gravity pushing oil into a chamber which is continually emptied by the rotating action of the pump. Another form of pressure is called working pressure. This is the pressure that when coupled with flow, will do work for us.

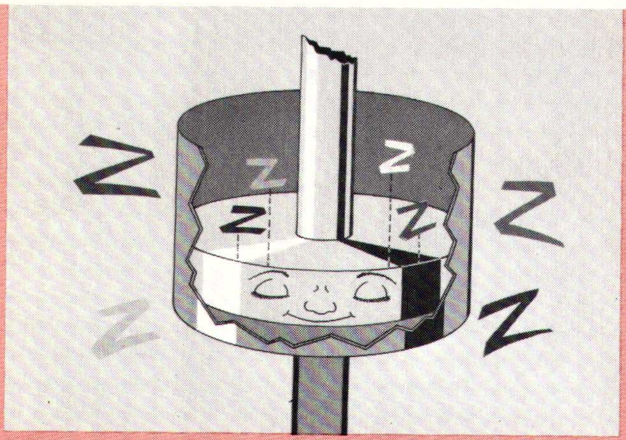




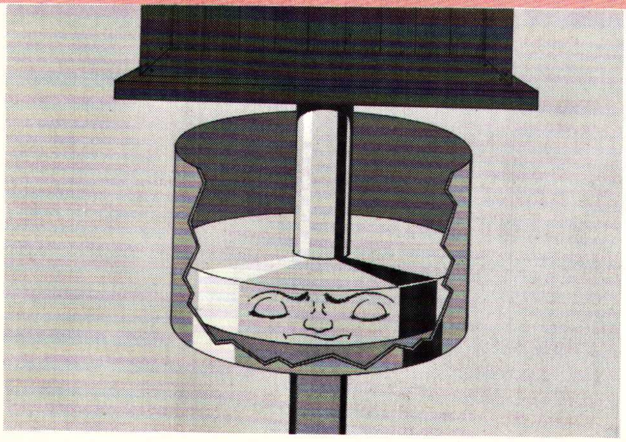
17 Let's direct flow into a cylinder to see what creates the pressure that combines with flow to make up hydraulic power. Some pressure, we have just seen, comes from the force of gravity.



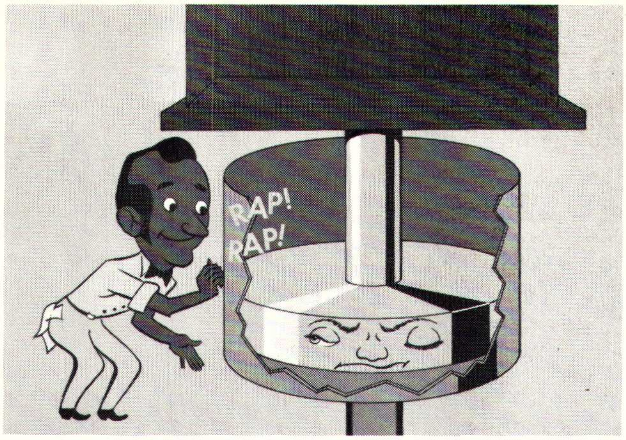
18 But most of the pressure results from the load itself. A constant supply of fluid is coming from the pump. The fluid seeks the path of least resistance which in a hydraulic system happens to be through hoses to the working cylinder.



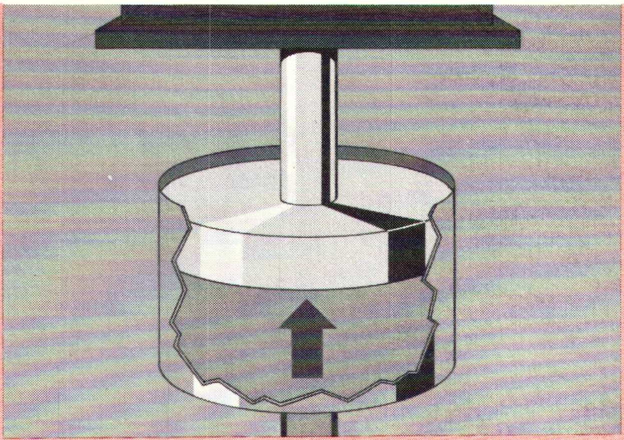
19 The piston in the working cylinder doesn't really want to move. According to the law of inertia, a body at rest tends to remain at rest.



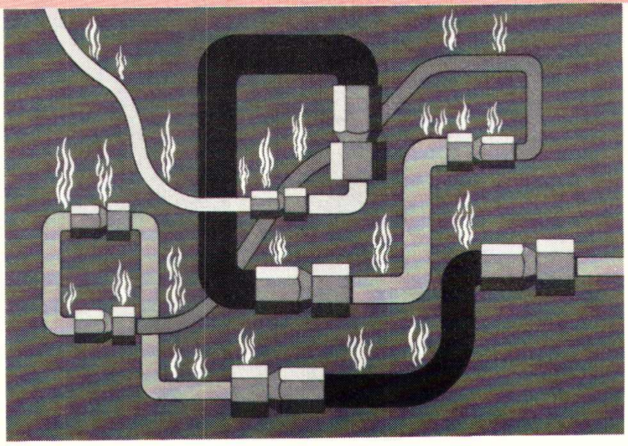
20 But the working piston has an especially good reason for not wanting to move. It is supporting a heavy load, the load you want to lift.



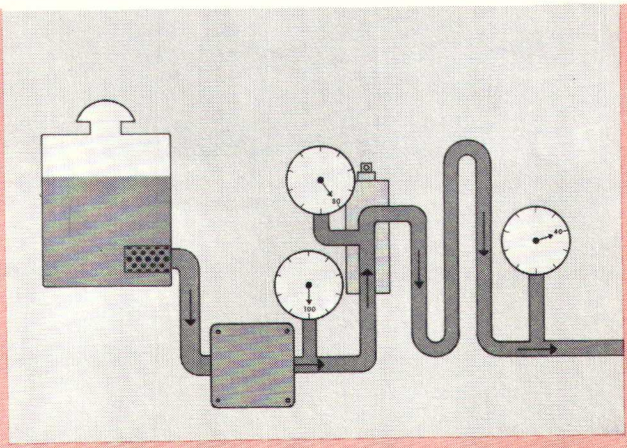
21 The flow of fluid keeps coming from the pump. The working piston, weighted down by the load, resists the flow. Pressure results. Something has to give. If the force against the piston is greater than that caused by the weight of the load, the working piston will have to go to work.



22 It will be forced upward in the cylinder and, as it lifts, the load will lift. Flow and pressure have combined to perform useful work. This is hydraulic power in action.



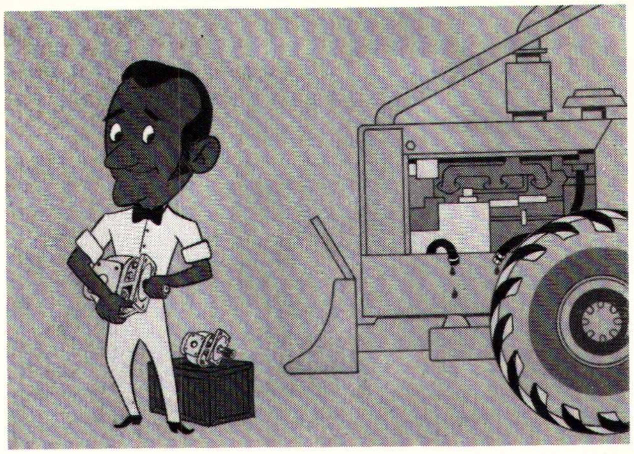
23 We mentioned, in passing, another important factor in hydraulics: RESISTANCE to flow. Fluid in motion creates certain effects which are important to the understanding of hydraulic circuits. Each fitting, each valve, each opening through which fluid must flow, each inch of line creates a resistance to flow. All of them together use up pressure merely moving oil from one place to another before actually getting a job done. This wasted pressure manifests itself in the form of heat.



24 In this diagram, resistance to flow robs the fluid of power as it moves through the tubes. Note how the further you go from the power source, the more lines, valves and fittings your oil goes through, the greater the resistance and the greater the pressure drop due to friction.

25

Increased flow also adds to resistance. If the flow rate for a given set of hoses and valves is doubled, resistance may be increased about four times. In actual practice, if you install a larger hydraulic pump than was called for by the specifications of your machine. . . .



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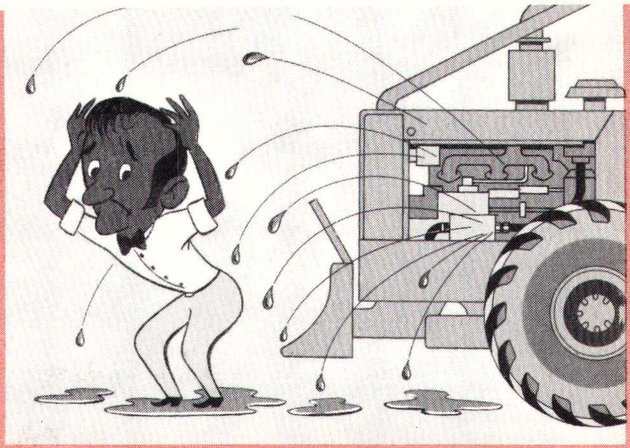
. . . you could add to your hydraulic troubles instead of solving them.



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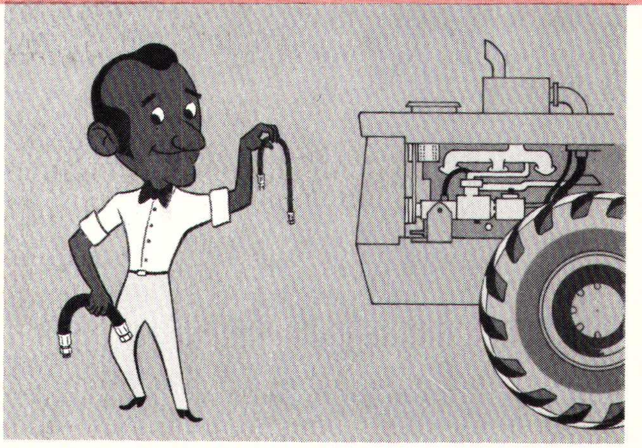
Hoses of the wrong diameter can also cause trouble. Sometimes mechanics will install smaller diameter hoses than were furnished as original equipment, simply because they were lying around. The result again is a pressure drop because the smaller hose increases resistance while flow rate from the pump remains the same.



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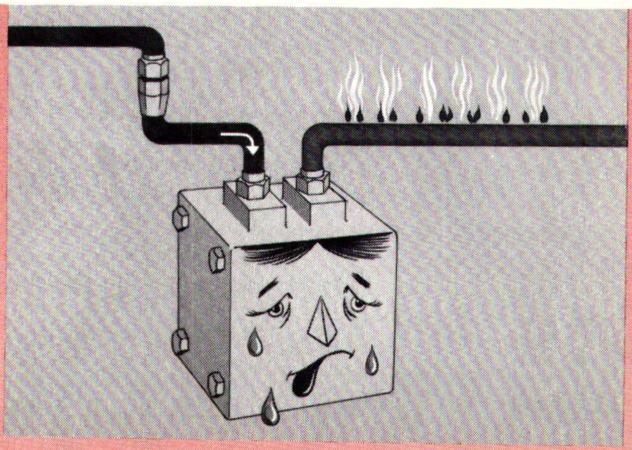
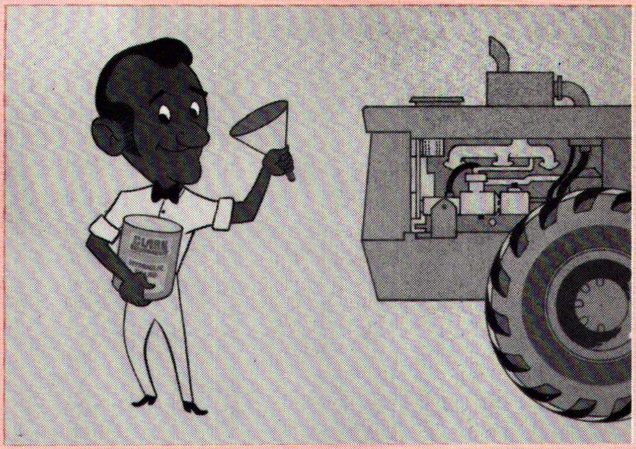
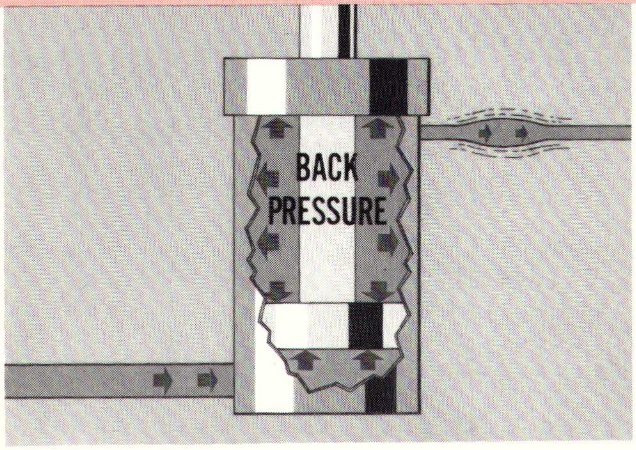
Any increase in the rate of flow, any increase in oil viscosity, any increase in length of hose — any changes like these — have a tendency to increase resistance and cause over heating.

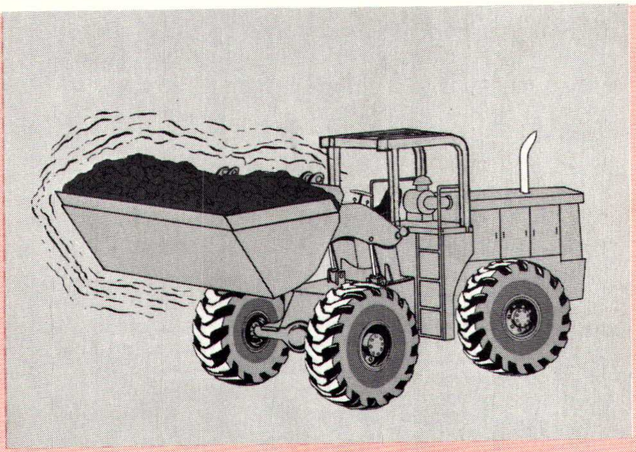




29 To avoid these troubles, it pays to use the hydraulic fluid specified by the equipment manufacturer. Replacement parts should also be identical to original equipment.



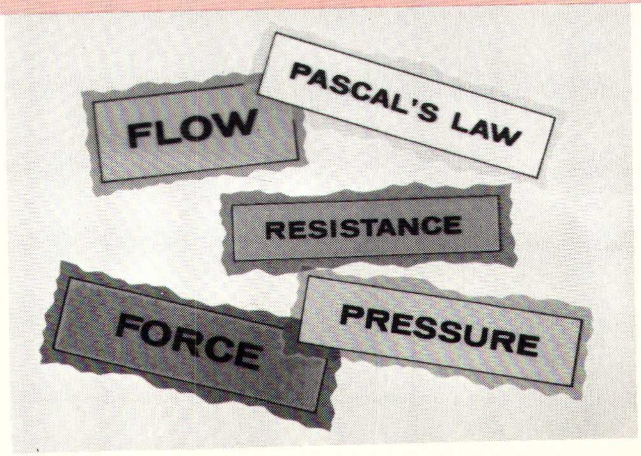
30 Back pressure is an additional resistance which the pump must overcome. A common example of back pressure is that caused by the pressurized liquid on the outlet side of the piston in a double-acting cylinder. If this fluid does not leave as fast as the liquid coming into the inlet side of the piston, there is resistance to movement. This reduction in flow may be caused by the same things that cause other resistances — hoses of the wrong diameter, hoses that are too long, pinched hoses, or other faulty parts.



31 Still another problem is air. Air can be introduced into hydraulic fluid in many ways.

For example, suppose the inlet line to the pump becomes restricted in some way. Oil can't flow into the pump as fast as it is pumped out and this creates a vacuum in the pump inlet system. To fill the void, atmospheric pressure forces air in through fittings and seals. Also, air, normally in the oil, expands. This creates a condition we call "cavitation". In time, cavitation will damage the pump.

The introduction of air into the hydraulic system causes the fluid to become aerated — full of bubbles like foam rubber. The oil will act like foam rubber too, causing bouncing and jerky piston travel.



32 We've briefly covered the theory of hydraulics. We know from Pascal's law that when pressure is applied to a liquid in a confined space, the pressure is exerted undiminished in all directions. We know that hydraulic fluid, as it flows under pressure, will seek the course of least resistance, which is the usual cause of leaks. We've found out, too, that we can multiply a force of, say, 10 pounds on a given power cylinder to 50 pounds on a working cylinder five times larger. Of course, we have to pay a price of less movement in the working cylinder. We pay an additional price in the form of resistance caused by every component in the system. And, we have learned that too much resistance causes heat and reduces power.

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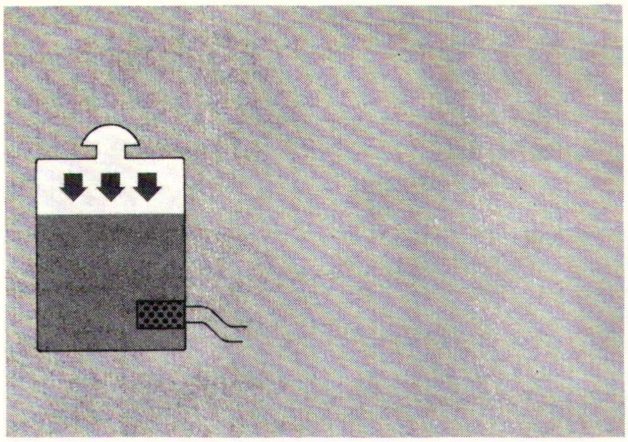
Now we are ready for the practical side of hydraulics. Let's assemble a simple hydraulic system. First, we need a reservoir or sump for the hydraulic fluid.



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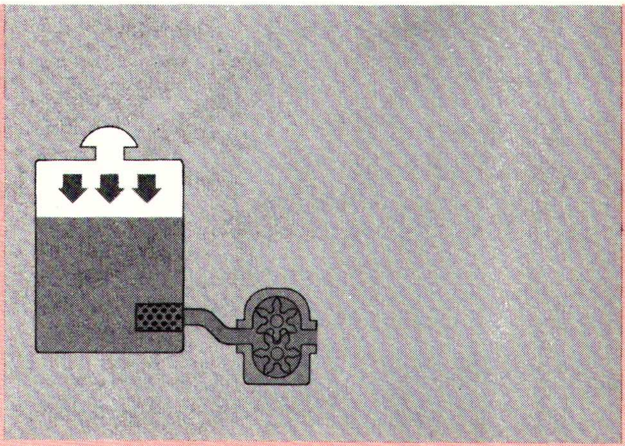
Next, we need a pump to make the fluid flow. Again, because it is so important to the understanding of hydraulics, let us point out that the pump does not "suck" the fluid out of the reservoir. Instead, atmospheric pressure forces fluid into the pump.



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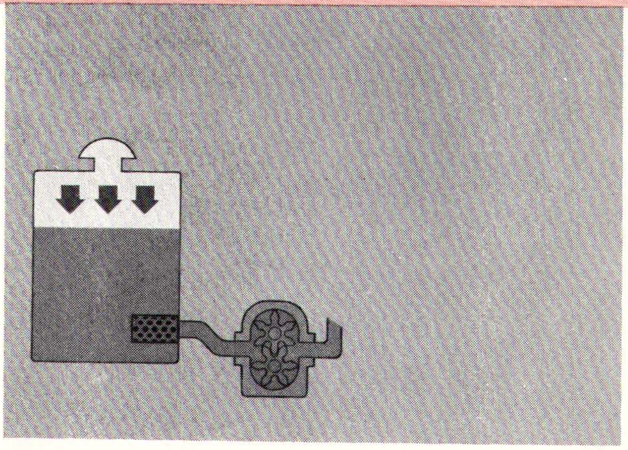
As the pump rotates, it moves a small quantity of fluid along with each rotation. This compares to the power in the earlier illustrations. An important point to remember here is that a pump pumps volume only. It is this volume that determines the maximum speed of the hydraulic action. Pressure is caused by a load and is not created by a pump.



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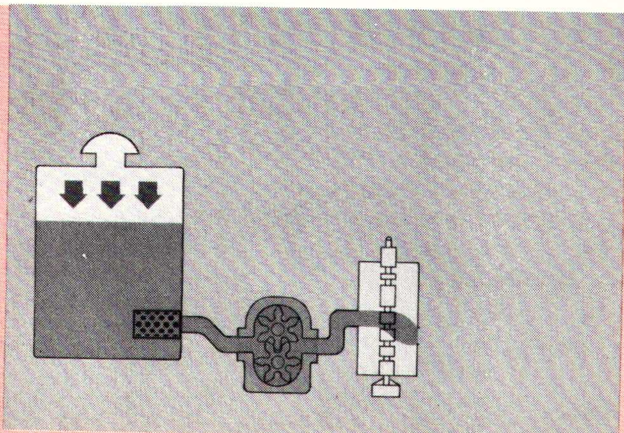
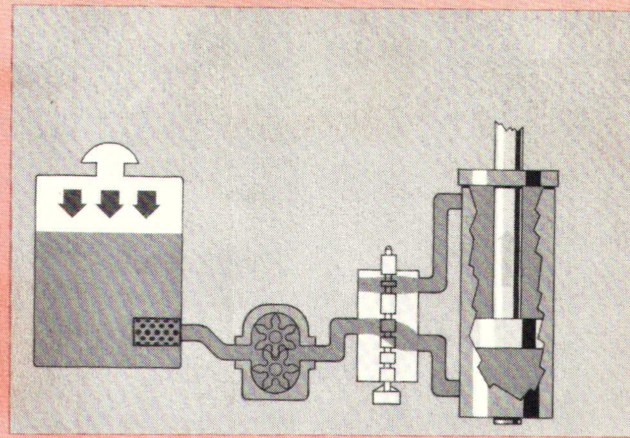
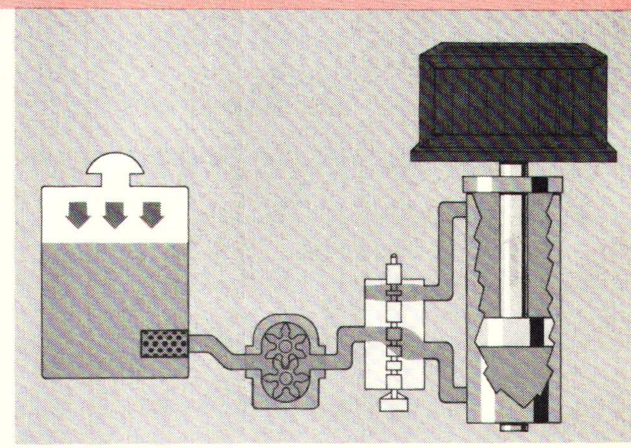
From the pump, a hose carries the flowing fluid through a hydraulic control valve. The valve either directs fluid flow to the tank or cylinder, or motor.



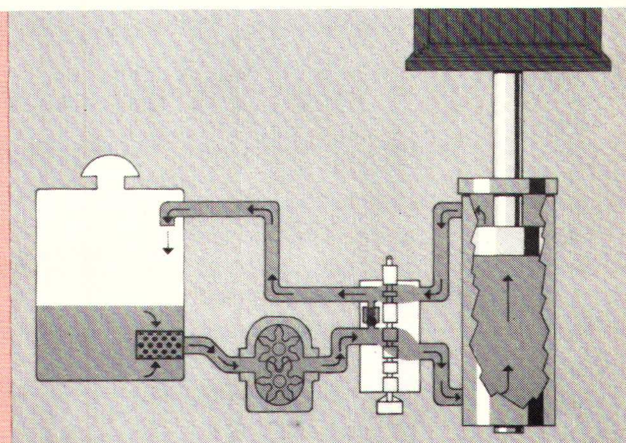
37 Next, we connect a cylinder which actually does the work.



38 The load, causes most of the resistance to flow which creates pressure.



39 Still, our hydraulic system is not complete. All components must be protected from damage in case of a sudden overload or other trouble. Even if something goes wrong with the system, the pump will continue to rotate and fill the system with oil. Unless the fluid has some place to go, pressure will build up until something breaks. To prevent damage, we install a spring-loaded relief valve between the control valve and the pump. The relief valve is built right into the control valve. Normally, it remains closed. But when pressure in the system exceeds a pre-determined amount, the relief valve opens, allowing oil to flow back into the sump.



40 Tank, pump, control valve, cylinder, relief valve — these components make up the basic hydraulic system. Every component is a necessary functional item.