THE MASTER TECHNICIAN'S

SERVICE REFERENCE BOOK

SESSION NO. 64

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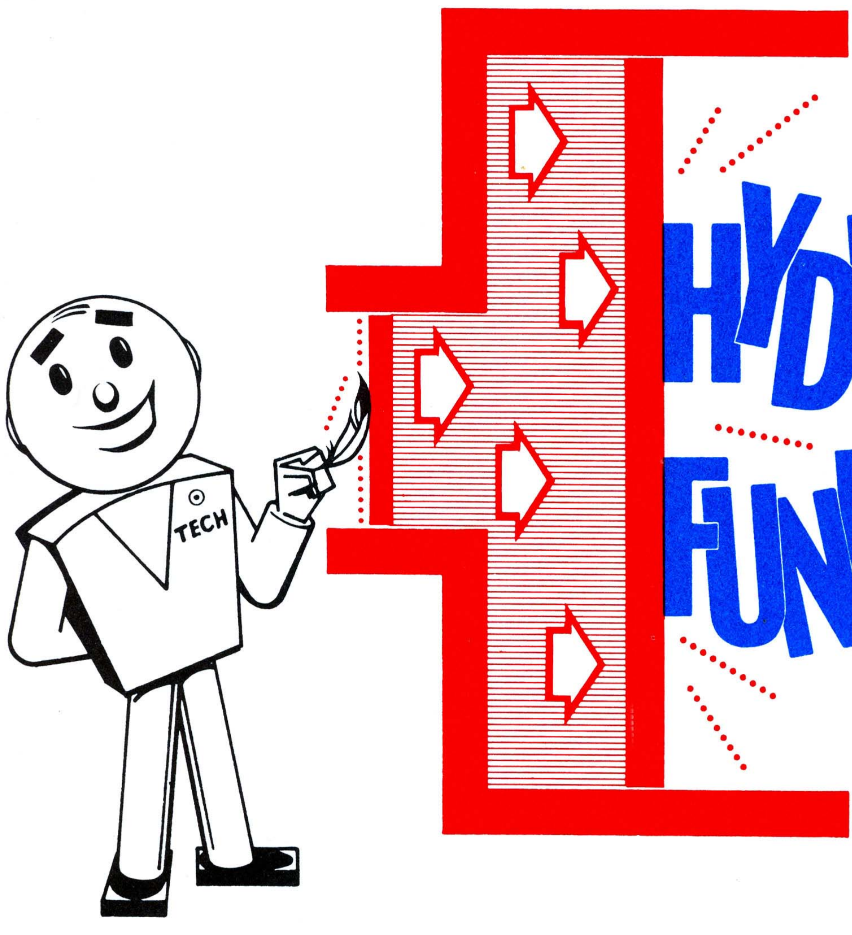

HYDRAULICS FUNDAMENTALS

MASTER TECHNICIANS SERVICE CONFERENCE
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A note from Tech

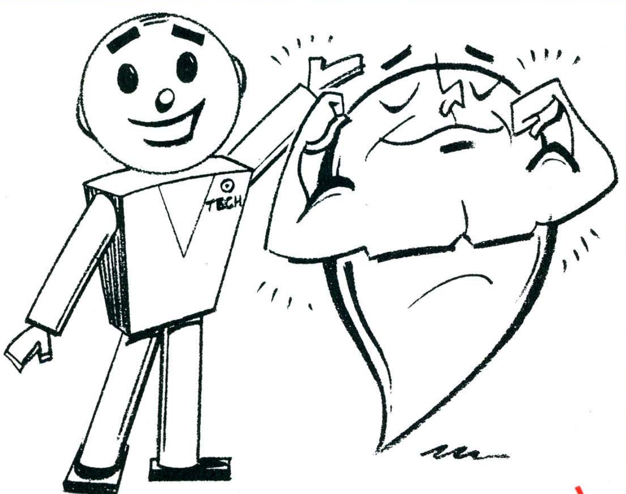
When the subject of hydraulics was suggested for an MTSC kit, your old buddy, Tech, thought right away that it was a fine idea. You know, we've been at this business for sixteen full years (this session starts our seventeenth), and we understand pretty well the workings of the hydraulic systems in our cars and how to service them. But I had to admit that hydraulics fundamentals, to me at least, were a lot of Greek.

Well, it turns out that I wasn't so dumb as I thought. Seems that the word hydraulics comes from the Greek word for water. And for an awful lot of years, the science of hydraulics was nothing but storing water and moving it from place to place, and operating waterwheels.

Now, of course, in the machine age, we use liquids to transmit force and motion, and there's a lot more to the science than the Greeks ever dreamed. Today's engineers have come up with a bunch of fancy new names for our specialized brands of hydraulics.

Let's leave those fancy names to the fancy-pants guys who devised them and define hydraulics broadly as the science of liquids in motion. Then, we'll just pick up the basic principles of pressure hydraulics and add them to our storehouse of automotive knowledge . . . making ourselves better technicians because we not only know what we're doing, but why we're doing it.

Tech



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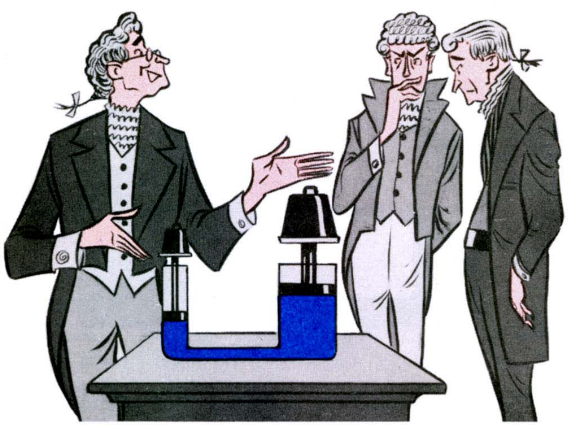
PASCAL'S LAW

In the seventeenth century, Pascal, a French scientist discovered the hydraulic lever. In laboratory experiments, he proved that force and motion could be transferred by means of a confined liquid. Experimenting with weights and pistons of varying size, Pascal also found that *mechanical advantage* or *force multiplication* could be obtained in a pressure system, and that the relationships between force and distance were exactly the same as with a mechanical lever.



From the data Pascal collected, he formulated *Pascal's Law,* which states:

> *Pressure* on a confined fluid is transmitted equally in all directions and acts with equal *force* on equal areas.

This is admittedly a big mouthful. So let's break it down into easy-to-understand pieces, demonstrating it with the kind of equipment Pascal used in his experiments. But first, we'd better review the definitions and units of measure of force and pressure, so we don't stumble on them.

FORCE

If you look force up in a dictionary, you'll probably find a definition that only an engineer can understand. But there's at least one textbook out that defines force as *a push or pull on an object,* and this seems like a good definition for our purposes.

You're all familiar with two kinds of forces—*gravity* and *friction.* The force of gravity is nothing more than the weight of an object. If you weigh 175 pounds, you exert a downward force of 175 pounds on the floor when you're standing. (Likewise, the floor exerts an equal and opposite force on you.) To lift you off the floor, it's necessary to exert a force of 175 pounds under you and in an upward direction.

The force of friction is present when two objects move against one another. For instance, if you slide a 100-pound box along a smooth floor, it takes considerably less force than the 100 pounds needed to lift the box. But some force has to be exerted to overcome friction or the backward drag the floor exerts on the box.

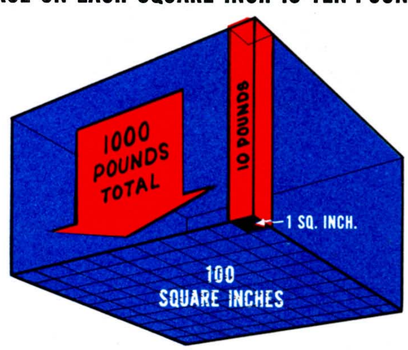
In hydraulics, you often are concerned with overcoming a third type of force—*spring force.* Spring force is the tension in a spring when it is compressed (or stretched).

As you've no doubt deduced by now, the engineering and household unit for force is the *pound.* Force can be measured, then, on any scale designed to measure weight.

PRESSURE

Pressure is force divided by area or force per

FORCE ON EACH SQUARE INCH IS TEN POUNDS



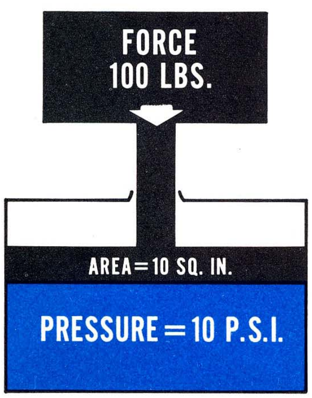
PRESSURE = 10 POUNDS PER SQUARE INCH

unit area. To illustrate pressure, suppose a uniform weight of 1000 pounds rests on a surface 100 square inches in area. The total force is 1000 pounds, the weight of the object. But the force on *each square inch* of area is 1000 pounds divided by 100 square inches, or ten pounds.

We can say then that the *pressure* on the surface is ten pounds per square inch. This is the unit for measuring pressure—*pounds per square inch*. It is abbreviated *psi*.

PRESSURE ON A CONFINED FLUID

Pressure is exerted on a confined fluid by applying a force to some area in contact with the fluid. For example, if a cylinder is filled with fluid, and a piston closely fitted to the cylinder has a force applied to it, pressure will be created in the fluid. Of course, no pressure will be created if the fluid isn't confined. It will just flow then. There must be a resistance to flow to create pressure. (In the following illustrations, the forces we are using are gravity—that is, weight applied downward. The principles are the same, no matter what direction the forces are applied.)



The pressure created in the fluid is equal to the force applied, divided by the piston area. If the force is 100 pounds and the piston area is ten square inches, pressure equals ten psi. According to Pascal's law, this pressure of ten psi is equal *everywhere* in the trapped fluid:

> *Pressure on a confined fluid is transmitted undiminished in all directions . . .*

No matter what shape the container is, no matter how large it is, this pressure will be maintained throughout, so long as the fluid is confined.

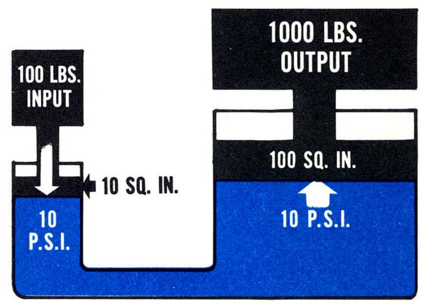
FORCE ON AN AREA

Having digested the idea that pressure equals force divided by area, let's try on another for size. Pascal also tells us that:

> *Pressure . . . acts with equal force on equal areas.*

But the greater the area, the greater the force . . . in fact, the total force on any area equals the pressure multiplied by the area.

FORCE ON LARGE PISTON = 1000 LBS.

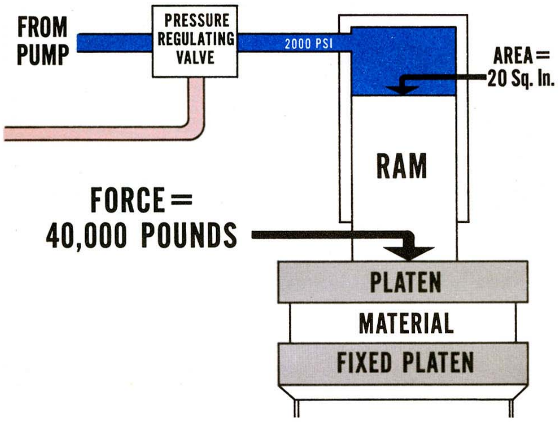


So, if we're able to take the ten psi we just created and apply it to a piston with a 100-square-inch area, we can exert a total force of ten times 100 or 1000 pounds. *Force is multiplied*—with a 100-pound input we obtain a 1000-pound output, ten times as much. And in fact, input force can be multiplied 100 to one, or even 1000 to one just by increasing the size of the output piston.

HYDRAULIC PRESS

Pascal didn't get rich on his hydraulic lever. It was more than 200 years before anyone made use of it in a practical way by inventing the hydraulic press. The hydraulic press is probably the best way to demonstrate the tremendous forces obtainable in the hydraulic lever, so let's take a quick look at how it works.

The idea is to squash or stamp out a sheet of material with a very high force—for instance, 20 tons. The material to be squeezed is placed between two platens. One is fixed and the other is attached to the end of a hydraulic ram.



Fluid is pumped into the other end of the ram and a valve in the line regulates the pressure that can be developed. If the pressure-apply area at the end of the ram is 20 square inches and the pressure developed is 2000 psi, the total force at the platen is 40,000 pounds or 20 tons.

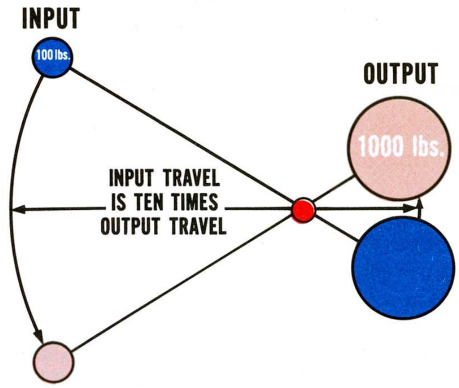
HYDRAULIC BRAKES

A less startling example of Pascal's law is the hydraulic brakes you're all so familiar with. The force input to the brake system is to the relatively small area of the master cylinder piston. The output is through eight wheel-cylinder pistons, which have a much larger combined area. The total force at the brake shoes then is much greater than at the master cylinder.

CONSERVATION OF ENERGY

The old law of conservation of energy says that *energy can neither be created nor destroyed*. The only way to get a large output force with a small input force is to make the input force travel farther.

We can illustrate this in a mechanical setup by taking the 100-pound weight and using it to move the 1000-pound weight with a lever. You know that to get an output ten times the input with a lever, the input lever arm has to be ten times as long. It's easy to see then that for every foot the 1000-pound weight moves, the 100-pound weight has to move ten feet.

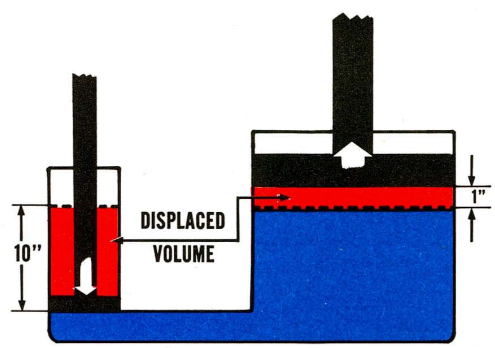


MEASURING ENERGY

We can measure the energy that is transferred in this system in *foot-pounds*. The 100-pound weight moves ten feet so the energy is 1000 foot-pounds. The 1000-pound weight moves one foot, so the energy there is 1000 foot-pounds, too. In other words, if we ignore friction, 1000 foot-pounds of energy is transferred in the system with no loss or gain. So the law of conservation of energy proves out.

PISTON TRAVEL

Returning to our small and large pistons, we find the same weight-to-distance relationship as with the lever. Remember, that to use 100 pounds of force to raise 1000 pounds, we had to have an output piston area ten times the input piston area. So the input piston has to travel *ten* inches to displace enough fluid to move the output piston *one* inch. (In this example, you can measure the energy transfer in

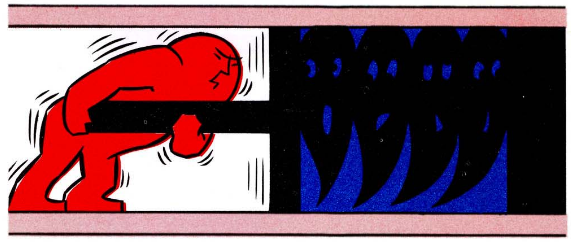


inch-pounds. It works out to 1000 inch-pounds at each piston, if you ignore friction loss in the system.)

PRESSURE vs. IMPACT

Before we go into hydraulic systems, let's make a distinction between *pressure* hydraulics and *impact* hydraulics. The principles we're dealing with apply to force on a confined fluid, and everything that's accomplished in a pressure system is through *pushing* the fluid. You are also familiar with the *turbine* or *waterwheel* where motion is generated by *impact* of a fluid against blades or vanes. Entirely different principles apply to this branch of hydraulics, which we are not considering.

PRESSURE DOES THE WORK



HYDRAULIC SYSTEMS

Now that we've been over the principles of the hydraulic lever, we can look at some of the systems that use it and how they work. Every pressure hydraulic system has certain basic components. Let's see what these components are and what they do in the system right now. Later, we'll go into more detail on how various components work.

FIRST A RESERVOIR

The reservoir (or sump) is a storehouse for fluid until it's needed in the system. In some systems where there is constant circulation of the fluid, the reservoir aids cooling by transferring heat from the fluid to the atmosphere.

In a brake system, the reservoir is part of the master cylinder. The power steering reservoir surrounds the pump housing and the Torque-Flite control system reservoir is the oil pan.

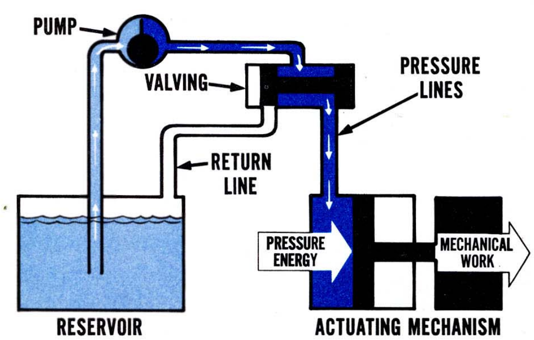
THEN A PUMP

The pump creates *flow* and applies *force* to the fluid. It pushes the fluid into the system and pressure is built up when the fluid encounters resistance.

Now this is an important point. The pump *cannot* create pressure by itself—it can only create flow. If the flow doesn't meet any resistance, it's referred to as *free flow*, and there is no pressure built up. There must be a blind alley of some sort, or a resistance to flow in the system, to create pressure.

Pumps can be the *reciprocating piston* kind (as is a brake master cylinder) or they can be *rotary*. In hydraulics, piston pumps are usually operated manually and rotary pumps are driven by an engine or electric motor.

LINES CONNECT COMPONENTS



THEN VALVING

Valving regulates and directs the fluid. Some valves just interconnect passages, telling the fluid where to go and when. Other valves control or regulate pressure and flow. In a brake system, for instance, valving is done by the piston and ports in the master cylinder.

AN ACTUATING MECHANISM

The working or actuating mechanism changes pressure energy to mechanical force. This is where the flow from the pump runs into a dead end and causes pressure to build up. The pressure works against some surface area and causes a force to be applied. In a brake system, there are eight actuating mechanisms – the wheel cylinder pistons. In TorqueFlite, there are four – two band servos and two clutches.

FINALLY THE LINES

Naturally, we must have tubing, hoses and passages to interconnect the components, and these lines must be built to withstand whatever pressures will be generated in the system. Pressure lines carry fluid from the pump to the actuating mechanisms and return lines release fluid to the sump when pressure is released. In many systems, such as brakes, the same lines perform both functions.

THE COMPLETE SYSTEM

These, then, are the basic components of any system, whether it is simple or complex. An understanding of how these components work, and of some basic facts about hydraulic systems, will let you approach any system with confidence. No matter how many lines and how many valves the system has, each has a basic function and can be studied apart from the rest.

FLOW IN A CIRCUIT

Flow is something we've mentioned several times now without saying just what it's all about, so let's do that now. Flow is what's coming out of the pump when it's pumping and you measure it in gallons per minute or cubic inches per revolution.

As you'll see later, if the system output is *force and motion,* there is continuous flow to the actuating mechanism.

If the output is *force only,* there is *very little flow in the system*, only enough to maintain pressure and make up for leakage. The pump is still delivering fluid, but it is bypassed to sump by a regulator valve.

In any pressure hydraulic system, the components are kept full of fluid at all times. Thus, response to flow, or pressure buildup, is instantaneous. This is one reason that air, which is compressible, can't be tolerated in a pressure system and must be bled out for proper operation.

ATMOSPHERIC PRESSURE

You and I and everything around us are subject to a pressure because of the weight of the air around us. If you could isolate a one-square-inch column of air as high as our atmosphere goes, you would find that it weighs about 15 pounds. Since air is a fluid and it is confined to the earth's atmosphere, 15 pounds per square inch is exerted equally over everything on the earth's surface.

(Atmospheric pressure does vary with altitude and weather conditions, but 15 psi is a close enough figure for our purposes.) A pressure of 15 psi is often referred to as *one atmosphere*. The pressure gauges we use read zero at one atmosphere, because for most purposes, we ignore atmospheric pressure. However, it is important to us today in the part it plays in getting fluid into a pump.

VACUUM

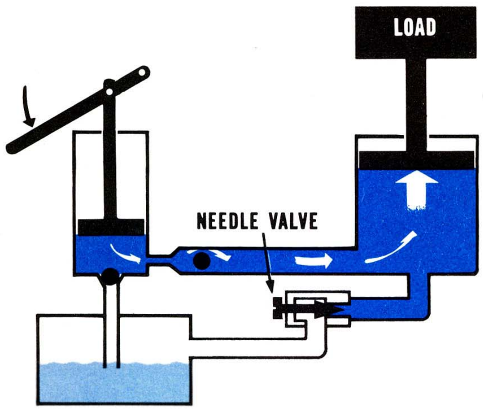
Technically, a vacuum is the absence of pressure. Actually, we refer to any condition where pressure is less than one atmosphere as a vacuum. When you sip on a soda straw, you create a void in it—what you are doing, really, is lowering the pressure in the straw below one atmosphere. The liquid in your glass, though, is still at atmospheric pressure, and it's the *pressure difference* that forces the liquid up through the straw.

The same thing happens in a pump. The action of the pump mechanism creates a void at the pump inlet. The sump is open to atmosphere *(vented)* and atmospheric pressure on the fluid forces it into the pump inlet.

THE HYDRAULIC JACK

Now we're ready to go back to our small and large pistons and make them into a hydraulic jack circuit. The small piston will be our pump and the large piston, our actuating mechanism. Since we are using the large piston to raise a load, its output will be *force and motion*. So we will make use of *pressure* and *flow* in this system—pressure to supply force and flow to supply motion.

Now we need a reservoir and valving to permit repeated stroking of the pump, raising the output piston another notch with each stroke. Two check valves are needed—one to keep the load from lowering on the intake stroke; the other to prevent pressure loss on the power stroke.



INTAKE STROKE

As the pump piston is stroked upward, a partial vacuum is created below it. Atmospheric pressure in the reservoir forces fluid in past the reservoir check valve, which is unseated by the flow. The load is prevented from coming down by high pressure seating the load check valve and preventing any back flow.

POWER STROKE

When the pump piston is stroked downward, pressure builds up below it, seating the reservoir check valve and preventing return of the fluid to sump. The load check valve opens and fluid is forced under the large piston, raising the load another notch.

LOWERING

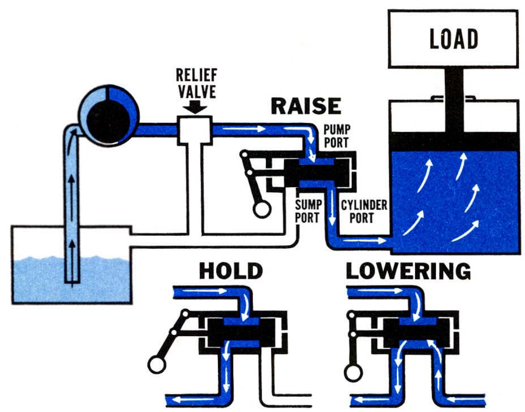
To lower the load, we connect a third valve, this time a manually controlled needle valve, between the large piston and the reservoir. The load is trying to push fluid back past the needle valve to the sump. Opening the needle valve slightly, *meters* the fluid back to the reservoir permitting gravity to bring the load down.

HYDRAULIC HOIST

The hydraulic hoist is another simple system similar to the hydraulic jack. The hoist uses a rotary pump driven by an electric motor instead of the hand-powered piston pump. This gives a smooth, constant flow of fluid. One three-position spool-type valve controlled by the operator, raises, holds and lowers the load, depending on the valve position.

The valve has three ports that are connected to the pump output, the hoist cylinder and the sump. In one position of the valve handle, flow from the pump is directed under the cylinder. The weight of the load causes pressure to develop and the hoist is raised. The reservoir port is blocked by a valve land.

In another position of the valve, the line to the hoist cylinder is blocked by one of the valve lands. This prevents the hoist from lowering or raising. The reservoir port is uncovered here and pump delivery is bypassed to tank.



In a third position, all three ports are open to each other. Pump delivery is bypassed to the reservoir along with the fluid under the hoist cylinder and gravity lowers the load.

RELIEF VALVE

A relief valve is needed in this system to protect the system from overloading. If, for instance, the control valve is left in the raise position when the cylinder is all the way up, there's no place for any more fluid to go. But the pump is still pumping and, if no relief is provided, pressure increases until something breaks or the motor stalls. The relief valve bypasses pump delivery to the reservoir and maintains pressure under the cylinder so it doesn't come down.

These simple examples should give you an idea of what goes on in a circuit. Now we can move on to a more detailed look at pumps and valves.

ROTARY HYDRAULIC PUMPS

There are many different kinds of rotary pumps used in pressure hydraulic systems, but they all work on the same basic principle. Fluid is trapped in chambers that are constantly expanding and contracting—expanding at the pump inlet to draw fluid into the pump and contracting at the outlet to force fluid into the system under pressure.

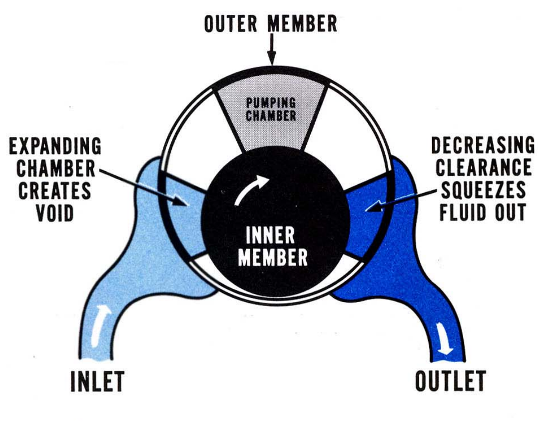
ECCENTRIC PUMP MEMBERS

Most of these pumps have two round members, with the inner member turning inside the outer. The members are on different centers, so at one point there is no clearance between them, and the clearance varies through a half revolution to the point of maximum clearance.

The pumping mechanisms – slippers, vanes, lobes or gears – form sealed chambers between the members. These pumping chambers are carried around by rotation of one or both members.

PUMPING ACTION

At the point where clearance begins to increase, the pumping chamber expands in size, creating a void. So the inlet is located here, and atmospheric pressure in the sump forces fluid into this void.

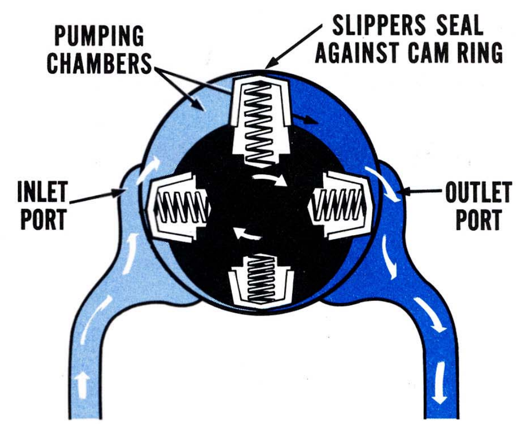


The size of the chamber continues to increase until rotation carries it past the inlet to the point of maximum clearance. For a few degrees of travel here, the chamber neither increases nor decreases.

The outlet is located where the clearance is decreasing. Here the pumping chamber decreases in size and fluid is squeezed out into the system under pressure. By having succeeding chambers follow each other closely, a smooth continuous output is obtained.

SLIPPER PUMPS

In the slipper pump used in power steering, the inner member is a notched rotor which carries four spring-loaded slippers. The slippers move in and out of the rotor notches and follow the surface of the stationary outer member or *ring*.

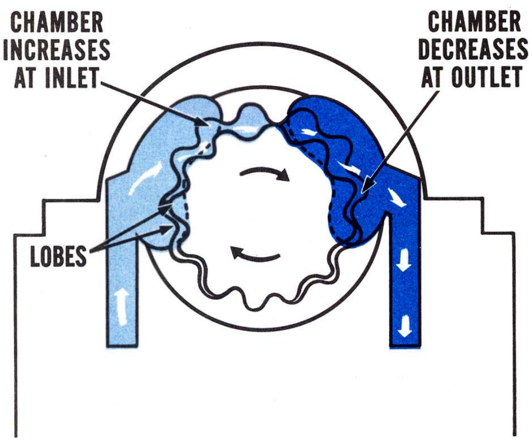


Pumping chambers are formed between two slippers, which seal against the ring. The chambers are carried from the inlet to the outlet by the rotor turning.

ROTOR PUMPS

The TorqueFlite control system pumps are the lobed-rotor design. Both members are rotors which turn together. The inner rotor is driven and carries the outer rotor by meshing of the lobes.

A pumping chamber is formed between four lobes. As the lobes separate from mesh, the chamber increases at the inlet. At the outlet,



the lobes are meshing again, decreasing the chamber size and squeezing the fluid out into the system. The inlet is sealed from the outlet by the close clearance between the lobe tips at the point of maximum displacement.

POSITIVE DELIVERY

These pumps are classified as *positive delivery* or *positive displacement*. This just means that the pump delivers against pressure no matter how high the pressure. The output depends on the speed it is driven at, rather than the pressure in the system.

This is why the relief valve is always needed to protect against pressure overloads.

EFFICIENCY

Of course, as pump parts become worn or damaged, fluid can leak back from the contracting (output) chambers to the expanding (intake) chambers, causing loss of efficiency.

Efficiency is the actual pump output with respect to displacement. Thus, if a pump has a displacement of 100 cubic inches per revolution but twenty cubic inches are leaked internally, its efficiency is eighty percent.

Loss of efficiency doesn't mean pressure is lost, because pressure will build up so long as some fluid is being pumped and isn't leaking off somewhere else in the system. But loss of efficiency often does *slow down* the application of pressure and the movement of working mechanisms.

HYDRAULIC VALVES

Hydraulic valves can be divided generally into two classes — those that *direct* flow and pressure and those that *regulate* or control flow and pressure.

Valves that direct flow and pressure can be likened to an on-off switch. They simply connect or disconnect passages, without restricting the fluid in any way while the passages are connected. These valves are usually called *directional* or *relay* valves.

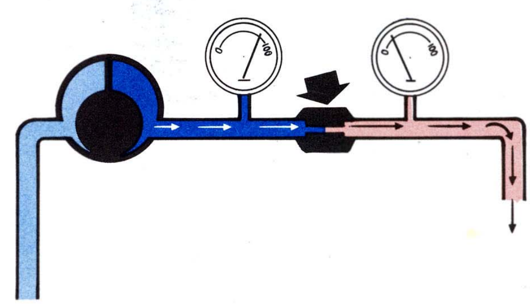
Regulator valves operate by metering fluid, or permitting passage of a restricted flow. In other words, the control is effected by always keeping the door partly open (or partly closed).

ORIFICE

The simplest means of controlling flow and pressure is the *orifice*. An orifice is a restriction. It slows down fluid flow—either to create back pressure or to delay pressure buildup downstream.

When fluid is pumped up to an orifice, there isn't room for it all to go through at once, and a *back pressure* is created on the pump side. If there is a flow path on the downstream side, a *pressure difference* is maintained across the orifice. That is, pressure is lower on the downstream side than on the pump side. This is the reason for an orifice in many applications.

ORIFICE CREATES DIFFERENCE IN PRESSURE



When flow is blocked on the downstream side, Pascal's law takes over and pressure equalizes on both sides of the orifice. But the pressure *doesn't equalize until flow across the orifice stops*. So the orifice can also be used to delay the application of pressure.

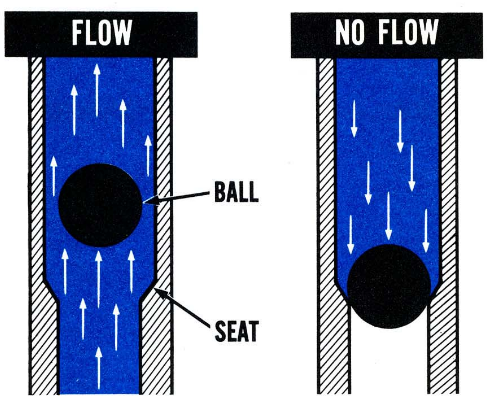
CHECK VALVES

A check valve in its simplest form is a one-way directional valve. It permits flow in one direction and blocks it in the other direction. The two commonest kinds of check valve are ball checks and poppet checks.

BALL CHECK VALVE

The ball check valve consists simply of a steel ball and a seat, though there may be a light spring to hold the ball against the seat when no pressure is applied. When pressure is applied on the seat side, the ball is forced off the seat and permits flow. Pressure on the opposite side holds the ball against its seat and blocks flow.

BALL CHECK VALVE

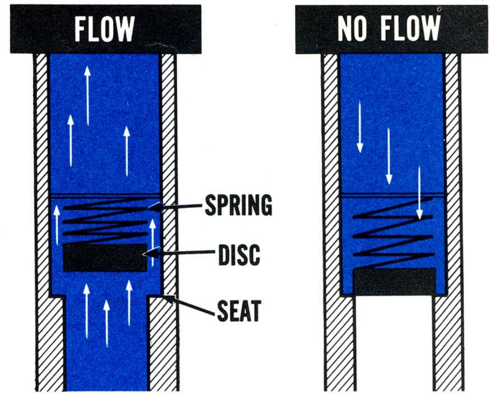


In the TorqueFlite valve body, there are several ball check valves with two seats connected to different pressure chambers. In this type of valve, the ball is seated by the higher pressure and blocks the lower pressure.

POPPET CHECK VALVE

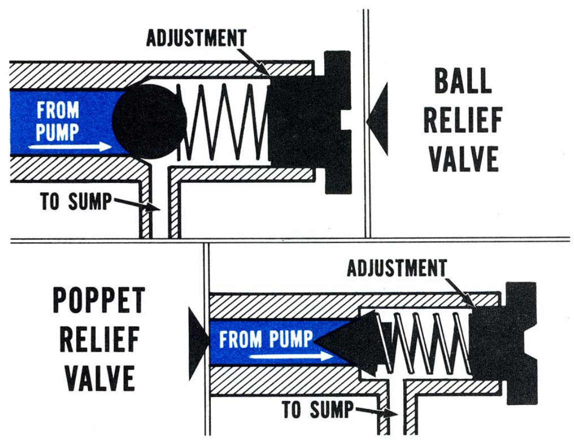
The poppet check valve used in TorqueFlite is a flat disc that seals around a hole smaller than the disc. A light spring guides the disc and holds it seated when no pressure is applied. Otherwise, operation is the same as a simple ball check valve.

POPPET CHECK VALVE



RELIEF VALVES

A simple relief valve is used to limit maximum pressure in a system which uses a positive delivery pump. It is always connected between the pump outlet and sump and it meters pump delivery to sump when the desired pressure has been reached in the system.

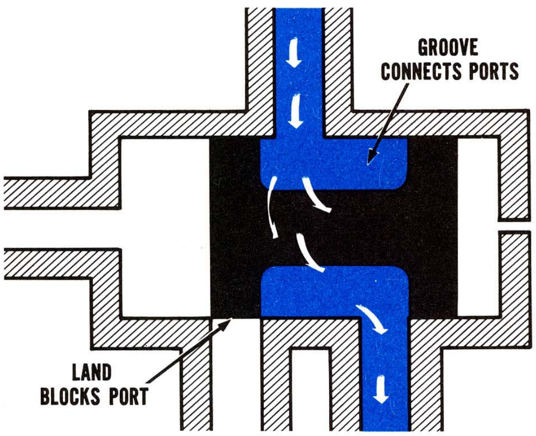


A relief valve is like a check valve in construction, except that it has a heavier spring to hold it seated against pressure. An adjusting screw can be turned in or out to vary spring tension, and thereby vary the pressure at which the valve relieves. Most simple check valves use a ball to seal against pressure, but a cone-shaped poppet also is common.

In operation, the spring holds the valve seated and blocks pump delivery from sump until system pressure is high enough to overcome the spring. Then, the valve unseats, and meters fluid from the pump to sump. It adjusts itself automatically so just enough fluid goes to the system for actuating movement and leakage and to maintain pressure.

SPOOL VALVES

So far, we've seen the operation of the simplest kinds of valves, which are very limited in means of control and number of flow paths. Where a valve function is to interconnect several passages, or to react to more than one pressure, a *spool valve* is usually called for.



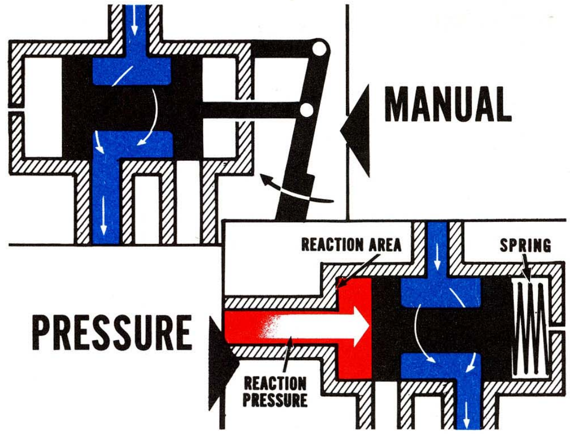
A spool valve is cylindrically shaped, with two or more lands and with annular grooves between the lands. The valve is closely fitted to a round bore and slides in the bore on a pressurized film of fluid. Fluid passages are open or closed to each other, depending on the valve land positions.

Spool valves have to be handled carefully so burrs won't be raised on the sharp edges of the lands. The edges shouldn't be rounded off, because this will let a particle of dirt get wedged between the land and bore. Then, if the valve doesn't stick, there will be some scoring that becomes a leakage path.

POSITIONING SPOOL VALVES

Spool valves can be positioned manually, by springs and by pressure.

When a valve is acted on by a spring and by pressure, the spring exerts force in one direction, and the pressure opposes the spring. A pressure that opposes the spring is called a *reaction pressure,* and the area on which it acts is called a *reaction area.* Pressure can be

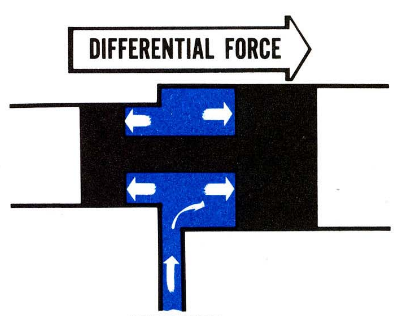


resolved into force by multiplying the pressure and reaction area. The valve will always move in the direction of the greater force.

Suppose a valve has a reaction area of one-half square inch and a spring with a 20-pound force. If the reaction pressure is 25 psi, the force from this pressure is 25 psi multiplied by one-half square inch or twelve and one-half pounds. This is less than spring force, so the spring holds the valve closed. If reaction pressure rises to 50 psi, its force is then 25 pounds. This will overcome the spring and the valve will shift.

DIFFERENTIAL AREAS

When two adjacent lands of a spool valve have different diameters, and pressure is applied between the lands, a differential force results. The force on the larger land is greater than on the small land, so the resultant or *differential force* is in the direction of the large land.

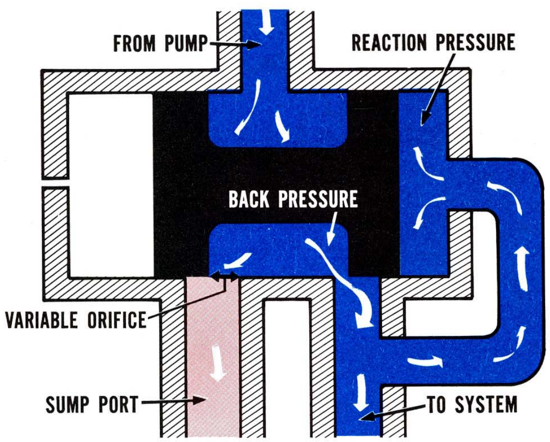


REGULATOR VALVE

A regulator valve used to control pressure has one function in common with a relief valve. It meters fluid from the pump to sump and maintains a pressure in the system. Where the difference comes in is that a relief valve controls pressure at a set value depending on spring tension, but a regulator valve can change the pressure in response to other hydraulic pressure signals.

Here's a simplified example of regulator valve operation. The valve has connections from the pump; to the system; to sump; and from the system to a reaction area that is opposite the valve spring. Thus, any pressure in the system will oppose the spring.

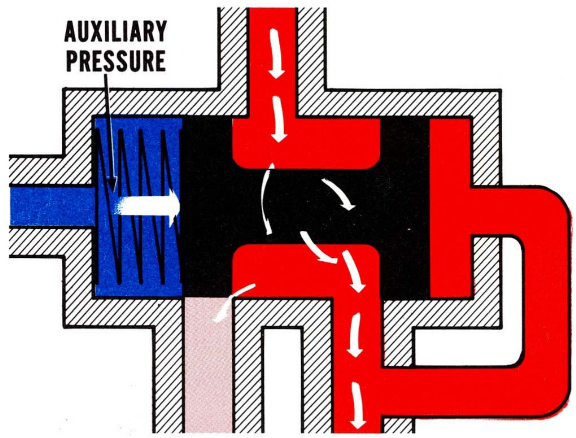
Before fluid begins to flow, there is no reaction pressure. The spring is the only positioning force and it holds the valve so the sump port is blocked. All the pump delivery goes to the system until pressure begins to build up.



As pressure builds up in the system, it reacts against spring force. The valve moves to uncover the sump port, letting part of the pump flow go back to sump. If pressure then tends to decrease, it allows the spring to force the valve back to block pump delivery again. A condition of equilibrium occurs with spring force and reaction pressure balanced. The valve is poised between the two. The valve land and sump port act as a variable orifice which meters flow back to sump. The back pressure created on the pump side of the orifice is the system pressure, and it's determined by the spring force. An adjustment screw is provided to change the spring force if system pressure doesn't fall within specifications.

AUXILIARY PRESSURE

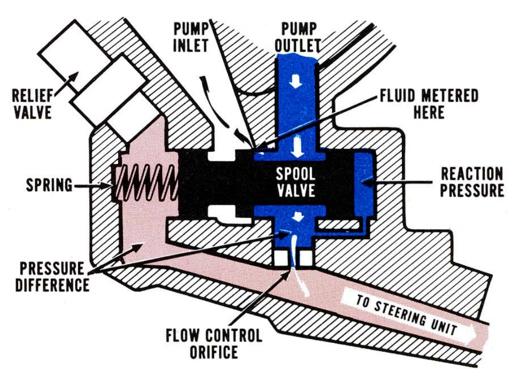
So far, the valve is just acting like a relief valve. But now we can add another pressure signal to change the system pressure. If this auxiliary pressure opposes the spring, it simply *subtracts* from the spring's effective force and *decreases* the regulated pressure. If the auxiliary pressure assists the spring, the regulated pressure is increased.



The auxiliary pressure can be applied to plugs at the valve spool ends or to differential areas in the valve grooves.

FLOW CONTROL VALVE

In the power steering flow control valve, a spring-loaded spool valve operates with a fixed orifice to control flow rate to the system at approximately two gallons per minute. This valve has a reaction area that is exposed to pressure on the pump side of the orifice. Pressure on the system (downstream) side of the



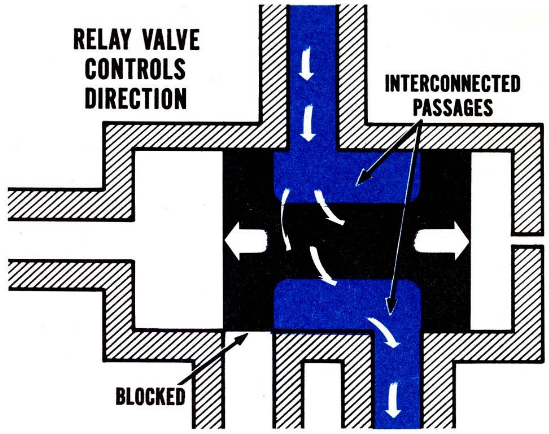
orifice is ported to the spring end of the valve and assists the spring in holding the valve closed.

Fluid flowing through the orifice then creates a pressure difference between the reaction area end and the spring end of the spool. Up to two g.p.m. (gallons per minute) flow, this pressure difference is not enough to overcome the spring and the valve stays closed. But when flow reaches two g.p.m., the pressure difference becomes high enough to overcome the spring. The valve opens and all pump delivery in excess of two g.p.m. is metered back to the pump inlet.

The flow control valve also recirculates pump delivery back to inlet when the relief valve is operating. In this case, there is just enough flow through the relief valve to create the pressure difference needed to shift the flow control valve.

RELAY VALVES

Relay valves have two positions—on and off.



They are like a traffic cop, telling the fluid "stop here" or "now you can go". They are held in one position by spring force. When pressure opposing the spring rises high enough, the valve shifts and connects ports. Auxiliary pressures can be applied to relay valves, too, but the valves are designed so they don't meter—they just open and close.

HYDRAULIC FLUIDS AND SEALS

What's so special about hydraulic fluid? Probably the best answer to this is the many things a good fluid has to do. The most important thing the fluid does is *transmit force*—and it has to do it immediately.

This rules out air and other gases which, technically speaking, are fluids. Actually, a hydraulic fluid must be a *liquid,* because it must be non-compressible. The term *fluid* came to be applied to the particular liquids used in hydraulics so they wouldn't be confused with ordinary lubricating oils.

LUBRICATION

Most hydraulic fluids are lubricating oils, and they are distilled from crude petroleum oil, just as engine oil is. The hydraulic fluid, with very few exceptions, provides all the lubrication of all the hydraulic system components. Pumps, valves, and actuating mechanisms all have slight leakage paths designed in so the system is self-lubricating. Of course, most practical lubricating liquids have petroleum bases. And additives can be and are incorporated in petroleum oil to further improve lubricating ability.

VISCOSITY

Viscosity is the measure of a fluid's resistance to flow. Thin fluid flows easy, so viscosity is low; a fluid that is thick or heavy-bodied has a high viscosity.

Viscosity of the fluid is important for lubrication, for minimizing friction and for sealing. The fluid must be light enough to flow easily, but must have enough viscosity to lubricate and seal. Too much viscosity, though, increases friction, so viscosity has to be closely controlled for each system.

VISCOSITY INDEX

As oil is heated, viscosity decreases, and as it cools viscosity increases, but the change in viscosity with temperature change is not the same for all oils. *Viscosity index* or *VI* is the measure of *viscosity stability*. If a liquid has little change in viscosity with temperature change, it is a *high VI* liquid.

Hydraulic fluid in a car is exposed to wide temperature ranges and is usually not changed seasonally, so its VI must be comparable with the multi-viscosity engine oils. In fact, hydraulic fluids had this desirable property long before the oil companies thought of putting it in engine oil.

Viscosity stability is put in a fluid by special refining techniques and additives.

OXIDATION, RUST AND CORROSION RESISTANCE

You remember from the MTSC session "Lubrication Services" that high temperatures and the pressure of impurities, such as moisture, caused oxidation of engine oil; rust and corrosion.

The same things can happen in hydraulic systems, so fluids have to be compounded with oxidation and corrosion inhibitors. Where there is heat in the system, the fluid also must resist the formation of varnish, which does as good a job of sticking spool valves as it does hydraulic valve lifters or piston rings.

AIR IN THE FLUID

Air in the fluid can't be tolerated. It makes operation of the system spongy and it causes loss of control and lubrication. So automatic transmission fluid is compounded to quickly disperse any air in the fluid when it gets back to sump.

EFFECT OF SEALS

Seals can swell or shrink; harden or soften, depending on what's in the fluid. MoPar and Chryco automatic transmission fluids, for instance, are compounded for compatibility with the special neoprene seals used in Torque-Flite. Other fluids may work as well, but won't necessarily promote long seal life.

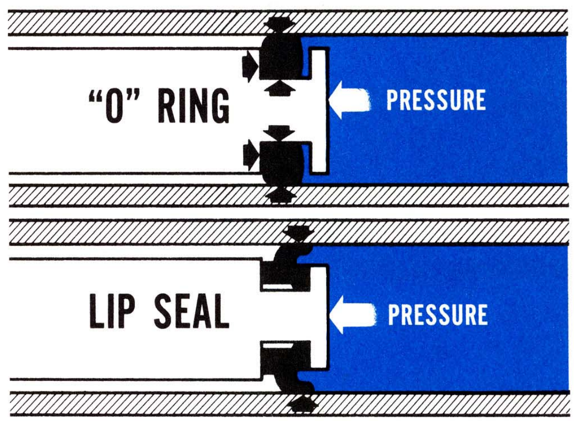
You know now that the compounding of a hydraulic fluid is a mighty fussy business and that it's important to use the best fluid available. MoPar and Chryco automatic transmission fluid, power steering fluid, and brake fluid are compounded for maximum safety and long life. It just makes good sense not to mix fluids or to take a chance on any other product. It also makes good sense *not* to add anything to the fluid, except approved MoPar and Chryco additives.

CLEANLINESS OF FLUID

The fluid also has to seal and lubricate between closely fitted parts where dirt can cause scoring and sticking. And foreign material speeds up undesirable chemical processes like rust, corrosion and fluid oxidation. This means that dirt, water, and other foreign material can cause a lot of damage in the system. So keep the fluid clean whenever you handle it and don't let dirt or water in the system. When you overhaul a system, be sure to clean it thoroughly and keep it clean when it's reassembled.

SEALING FLUID

Sealing applications can be classified as static or dynamic. In a static application, the parts being sealed don't move in relation to each other. In dynamic applications, there is rotating or reciprocating motion between the parts.



"O" rings are used effectively where motion is limited to seal closely fitted parts. They seal in both directions and take up little space. When the mating parts are assembled together, the "O" ring is squeezed at the inside and outside diameters. Pressure on either side of the "O" ring forces it against the side of its groove providing a positive seal on three sides.

The lip-type seal is also a positive seal and can be used to seal high-pressure in dynamic applications. The seal lip is installed toward the pressure source and pressure against the lip balloons it out and aids sealing.

Metal seals are not positive. They are used to seal rotating shafts that carry fluid under pressure and need some leakage fluid to lubricate the shaft journals. Metal seal rings are also used where high temperatures are encountered.

Litho in U.S.A.