MOBILE HYDRAULIC TIPS DESIGN GUIDE

COMPONENT BASICS FOR MOBILE EQUIPMENT HYDRAULICS

Design engineers involved in the design, construction and maintenance of mobile hydraulic equipment need to know the basics of how the components work. The editors of *Fluid Power World* present some of the most commonly asked questions in this exclusive white paper–issues like how cylinders fail to why viscosity index is important in your systems.

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What are hydraulic cylinders used for?

Hydraulic cylinders are used for creating mechanical force in a linear motion. A hydraulic cylinder is a tube capped at either end with a rod sticking out of one side. Attached to the rod, interior to the cylinder, is a piston. The piston separates the internal rod side from the internal cap side of the cylinder. Fluid is forced into either side of the cylinder to extend or retract the piston rod.

The piston rod is attached to the part of the machine requiring motion; it could be the boom arm on an excavator or platen on a press. Literally any application requiring linear application of force is an excellent use of a hydraulic cylinder, and no other method of linear motion is so strong and efficient as a cylinder is. Hydraulic cylinders can extend with force ranging from a couple thousand pounds up to thousands of tons.

Hydraulic cylinders are used in mobile applications, such as excavators, dump trucks, loaders, graders, back hoes and dozers, which is an incomplete list to say the least. They can push, pull and lift loads of any description, and the mobile machinery industry relies nearly exclusively on hydraulic cylinders for linear motion.

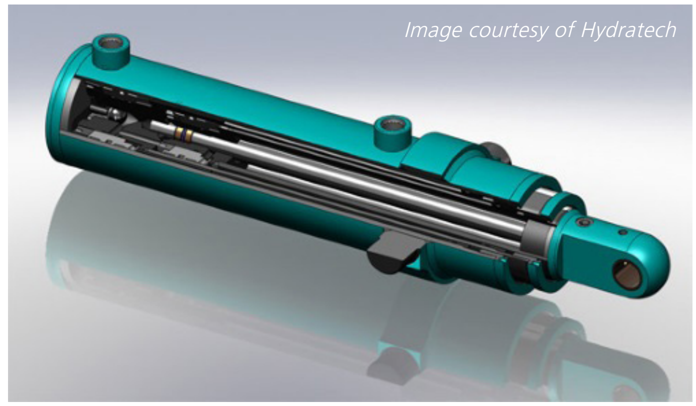
Hydraulic cylinders are also used prolifically in the industrial machinery industry. The power density of hydraulic cylinders is unmatched, making them great for presses, compactors, injection molding, forging presses, et al. Even for advances applications such as flight simulators or fatigue testing, hydraulic cylinders can be used in literally any linear motion application.

How do you specify a hydraulic cylinder?

Hydraulic cylinders are specified by the force required to be pushed and moved, and they are specified by their method of mounting. There are subordinate functions to be considered when specifying a hydraulic cylinder, such fluid type, column strength and material construction. However, 90% of cylinder applications are not exotic, and simply identifying force and mounting requirements will suffice, leaving all else standard.

The first step in specifying a hydraulic cylinder is calculate the required force. Factors required to determine force are the mass of the load, direction of cylinder travel and angle of the force vector. The mass is easiest to know, in most cases. The direction of cylinder travel is also easy to determine; will the cylinder push or pull on the load? It is important to consider the difference because a cylinder pulls with less force than it pushes, due to the area taken up on the piston by the rod. The angle the cylinder pushes on the load at affects the force required, but because this part of the discussion requires trigonometry, I'll leave it out for now. Let's just say that if you're not pushing at ninety degrees to the load, it requires more force.

Once the force requirement is defined, you will have to calculate the require bore of cylinder. The bore is inside diameter of the barrel, but also describes the outside diameter of the piston. The hydraulic fluid acts upon the piston, imparting force energy against it, and the larger the area of the piston or the higher the pressure you exert, the more force is generated. Are and force are calculated as such:



$A = \pi r^2$
A = Area in square inches
$\pi \approx 3.14$
r = Piston radius (1/2 diameter)

After piston area is calculated, simply multiply its area by the available system pressure:

F = P x A
F = Force in pounds
P = Pressure in psi
A = Area in square inches

Let's take an example to help with the math. We have a 4-in. bore cylinder, and our system pressure is capable of 3000 psi:

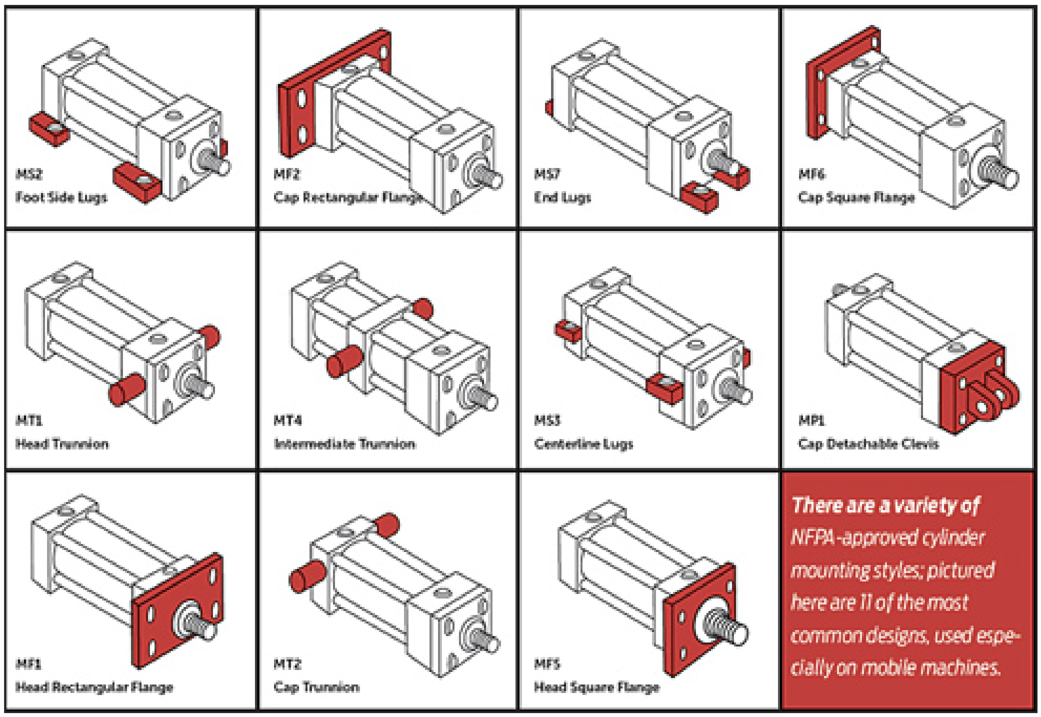
$A = 3.14 \times r^2$
$A = 3.14 \times 2^2$
$A = 3.14 \times 4$
$A = 12.56\ in^2$

F = P x A
$F = 3000\ psi \times 12.56\ in^2$
F = 37,680 pounds

How do you mount a hydraulic cylinder?

Hydraulic cylinders are available in a variety of styles and can be mounted in numerous ways. While they come in countless variations, they are usually built to certain standards. National Fluid Power Association (NFPA) and International Standards Organization (ISO) standards for hydraulic tie-rod cylinders are among the most common.

The advantage of standard tie-rod cylinders is their modular nature. Parts such as the head (rod-end block), cap (end opposite the head), barrel, tie rods and cylinder rod can be quickly assembled from off-the-shelf parts.



There are a variety of NFPA-approved cylinder mounting styles; pictured here are 11 of the most common designs, used especially on mobile machines.

NFPA and metric ISO standards that apply to mounting types and dimensions are quite similar—they even use the same three-character code to designate mounting options.

A basic cylinder has no mounts, so users typically specify the necessary mounting type and hardware when purchasing a cylinder. Three general styles include cylinders that have:

- Fixed mounts that absorb force along the centerline of a cylinder.
- Fixed mounts that do not absorb force along the centerline.
- Pivot mounts that drive a load in a curved path.

Here’s a look at some of the most common variants.

Flange mounts: Front flange mount (designated MF1), front flange extra mount (MF5), and front head flange mount (ME5) are all methods of mounting the cylinder off of, or part of, the head itself. MF1 has a rectangular flange attached to the head, which extends from the sides of the cylinder, and the MF5 has a larger square flange extending in all directions, which provides extra strength. The ME5, instead of being mounted to the head, uses an extra thick and wide head, which itself attaches directly to the machine. These options require the cylinder to be stationary and this fixed-centerline mounting provides them with high column strength.

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Rear flange mounts (MF2, MF6 and ME6) are similar to the front flange family, except their respective locations are off the cap rather than the head. MF2 has a rectangular flange attached to the head, but extends only on the sides, the MF6 uses the same larger flange as the MF5, and the ME6 has a beefy cap containing mounting holes for direct attachment to a machine. Being fixed-centerline-type mounts, they offer the same strength advantage of the front flange versions.

Tie-rod mounts: Tie-rod mounts use extended tie rods to attach the cylinder to a machine. They include rods extended at both ends (MX1), cap end (MX2) and head end (MX3). While they provide centerline support, they're less rigid than flange mountings and often require additional support for long-stroke applications.

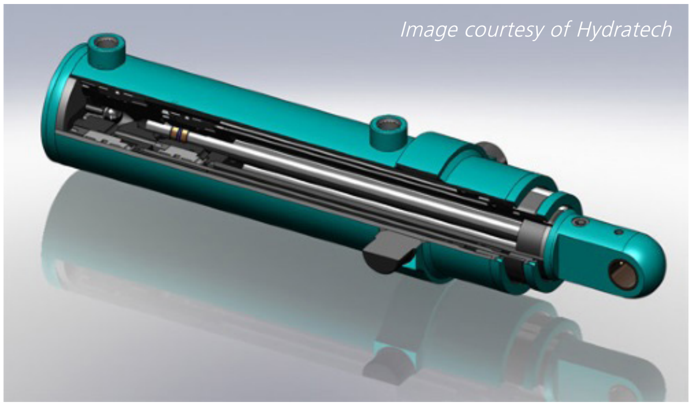
Lug mounts: Lug mounting options use rectangular tabs machined from (or welded to) the same block of steel as the head and cap. MS3 center lugs are positioned mid-way up the head and cap and support loads along the centerline of the cylinder. Foot-mounted versions include four MS2 side lugs on the bottoms of the head and cap, and MS7 end lugs mounted to front bottom of the head and back bottom of the cap. Fixed, lug style mounts can be quite rigid, but those off the cylinder centerline can cause misalignment concerns between the front and rear lugs, especially related to bending or torquing of the mounting surface.

Clevis mounts: MP1 (fixed clevis) and MP2 (detachable clevis) are common mounting options, especially in applications where the cylinder must pivot through an arc as it extends and retracts, such as with an excavator boom. The fixed clevis is a part of the cap itself. A detachable clevis is bolted to the cap. Both allow engagement to a clevis mounting bracket with a steel pin held in place with cotter pins or snap rings. Clevis mounts have the advantage of centerline mounting, but they are highly prone to side load and column strength issues.

Front, rear, and intermediate trunnion mounts (MT1, MT2 and MT4, respectively) are similar to clevis style pivots. They let the rod move through an arc as it extends and retracts, although they have a slight advantage in column strength and precision of movement over a clevis mount, especially the MT1 (front trunnion) and MT4 (intermediate trunnion). The MT2 (rear trunnion) mount is slightly weaker, especially if the rod isn't rigidly guided. Trunnion cylinders experience smoother movement because the trunnion on either side of the cylinder is fixed to the machine with special mounting brackets and bushings, and has less play in the joint compared to a clevis.

Regardless of how well a hydraulic cylinder is designed and manufactured, it can fail if not mounted correctly. Proper mounting avoids problems like side loads that cause excessive seal and bearing wear, or even bend the rod or bind the load.

What is a telescopic hydraulic cylinder?



Telescopic hydraulic cylinders, sometimes called multi-stage cylinders, are a type of linear actuator consisting of a series of tubular rods called sleeves. The sleeves (usually four or five) sequentially decrease in diameter and are nested inside of each other.

Once hydraulic pressure is introduced to the cylinder, the largest sleeve (called the main or barrel) is extended first. Once the barrel has reached its maximum stroke, the next sleeve, usually referred to as a stage, begins to extend. This process continues until the cylinder reaches its last stage, called the plunger.

There are two different types of telescopic hydraulic cylinders—single-acting cylinders and double-acting cylinders. Single acting, by far the most common, work by using gravity or some other external force to retract the stages of the cylinder. As soon as pressure is released from the cylinder, the force of the load pushes oil out of the system and the cylinder retracts.

While pneumatic telescopic cylinders exist, hydraulic power is much more common, especially when heavy loads are being moved. With a collapsed length typically between 20-40% of the fully extended length, telescopic hydraulic cylinders are used when extension needs to be originated from a tight space. This extension capability creates a longer working stroke than would be possible with a single stage rod-style actuator. These capabilities, along with the power to handle very heavy loads, make dump trucks, lifts and garbage trucks some of the most common applications for telescopic cylinders.

Where are telescopic cylinders used?

Telescopic cylinders are used in applications requiring long stroke but a short retracted length. The most common telescopic cylinder application is dump beds or trailers. They can fit between the frame rails of the chassis, but can extend far enough to dump even the longest beds.

Telescopic cylinders use nested barrels, each like both a rod and a barrel at the same time. The rod end itself is often hollow. Each barrel extends in stages, and the number of stages can vary between two or up to five or more. Stroke range varies vastly, but is most often between six and twenty feet.

The first stages of a telescopic cylinder have the most surface area to work with, so telescopic cylinders produce the most force at the beginning of their stroke. The more stages a telescopic cylinder has, the better it is able to produce more force over a wider range of its stroke.

Telescopic cylinders are usually mounted with center trunnion at the base end, although sometimes with a cross tube. The rod side of the cylinder is typically mounted with a pivot pin. Telescopic cylinders can be manufactured in single or double acting variations.

How do hydraulic cylinders fail—side loads

Hydraulic cylinders are typically built to handle high loads in rugged and demanding operating conditions, and they routinely last for years. Unfortunately, cylinders used improperly face a quick demise. Mechanical issues like side loading and rod bending are two common cylinder problems that lead to premature failure.

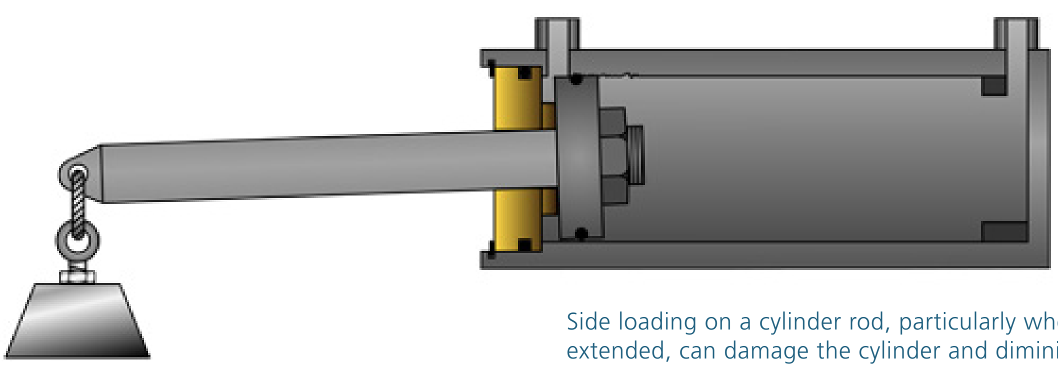
Cylinders are designed to provide linear force and motion to move a load. A cylinder works well when compression and tension forces perfectly align in the rod's axial direction. Side loading occurs when a mass or external force pushes the rod to the side, up or down.

When a cylinder retracts, it normally has high resistance to side load, not only because bending forces are low, but because the rod is supported by a bushing in the head and the piston itself inside the cylinder bore. But as the cylinder extends, the piston moves closer to the head. That reduces the capacity for the piston to act as a bearing, increasing the potential lever arm and the opportunity to bend the rod.

The longer the cylinder stroke and the further the rod extends along its stroke, the higher the potential for side loading and column bending.

Fixed-mount cylinders do not function well if rod travel is out of alignment. In fact, side load is probably the most common cause of rod-bearing failure. It causes uneven wear, as the rod pushes into one side of the bushing and the piston drags with more force across one side of the barrel. Eventually, surfaces will suffer damage, resulting in shorter bearing life, fluid leaks and seal failure.

In more extreme cases side loads can bend the rod, particularly when using an undersized rod in a thrust application. The rod must be strong enough to withstand stresses imposed by the load and cylinder. Thus, correct rod size and strength are important factors in sizing a cylinder. If the piston rod diameter is too small in relation to the load column, bending failure or rod buckling is likely.



Side loading on a cylinder rod, particularly when the rod is extended, can damage the cylinder and diminish its useful life.
Image courtesy CD Industrial Group

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Fortunately, engineers can improve cylinder performance with regards to both side load and column strength. Here are some options:

- **Alignment.** There is no substitute for precision alignment. When mounting a cylinder, technicians need to check and minimize misalignment in both extended and retracted positions.
- **Guiding.** Particularly in horizontal and long-stroke applications, users must ensure that loads are properly guided and the rod has adequate support, to eliminate side loads.
- **Mounting.** One possible solution is to use a clevis or trunnion-mounted cylinder that moves with the side load. Also, note that head-style mounts provide greater column strength than comparable cap-end mounts, due to the shorter distance between mounting points.
- **Misalignment compensation.** To handle slight misalignment, a cap spherical bearing mount or spherical bearing rod eye sometimes helps. But they often require larger diameter piston rods or longer stop tubes to compensate for higher bearing stresses caused by loss of rigidity between piston rod and the moving load.
- **Larger rod.** A larger diameter rod improves overall rod strength, making it less susceptible to bending. However, stop tubes are generally more effective, less expensive, and lighter than oversized piston rods.
- **Stop tube.** Another technique is to add a stop tube. This is simply a tube inserted inside the cylinder and around the rod between the piston and head. It acts like a spacer to prevent the cylinder from extending completely. This increases the distance between the two bearing areas—the piston and rod bushing—reducing the effects of side loading and maintaining high buckling resistance. However, adding a stop tube reduces usable stroke length. Thus, users may need to opt for a cylinder with longer stroke than would otherwise be necessary.

How do hydraulic cylinders fail—contamination

Today's fluid-power users, for the most part, are well aware that keeping hydraulic fluid clean is essential in preventing premature failures and unexpected downtime. Nonetheless, contamination remains a major cause of hydraulic-cylinder failure, particularly because it leads to seal failure and leaks. And it can come from several different and unexpected sources.

Internal contamination is one obvious source. Particulate contaminants include dirt, wear particles from pumps and valves, and debris from internal breakdown of hoses. Contributing factors include clogged filters and dirty assembly areas.

Such contamination results in scored rods and cylinder-bore surfaces and excessive seal wear. This causes leaks past the cylinder rod and head and into the environment. And it can increase internal leakage past the piston seals, which reduces efficiency. It can even exacerbate erosion problems, where contaminants abrade the seal as media travels from the high-pressure to low-pressure side of the seal.

Damaged cylinder rods and bores can usually be repaired, but users should first determine the root cause or the problem will soon return. Proper filtration keeps fluid clean and helps prevent problems due to internal contamination.

Also ensure proper flow through the cylinder. If the volume of oil in a cylinder exceeds that of the hose between the cylinder and directional valve, it may not flow efficiently to the reservoir for filtration. Instead, particulates remain in the cylinder and attack the seals. Here, a fix is to mount the valve closer to the cylinder to ensure efficient circulation. Proper installation and alignment of the cylinder will also reduce the rate at which the cylinder itself generates fluid contaminants, by minimizing seal and bearing wear.

External contaminants are another consideration. Hydraulic cylinders are constantly exposed to external contaminants ranging from dust, mud and abrasive grit to metal chips and weld spatter. Fluid contaminants include coolants, washdown water and rain. Dirt and fluid contaminants can be drawn into a cylinder during rod retraction via a faulty wiper seal, so the proper specification and installation of a rod wiper/scraper is recommended. Likewise, a well-designed tank breather/filter keeps water and dirt out the system.

Under particularly dirty conditions, consider installing boots or bellows over the moving rod. A pleated bellows/boot can protect finished rod surfaces from wear-causing elements, reduce downtime and lengthen cylinder life. These protective devices are often made of elastomer-covered fabric, as well as flexible vulcanized and injection-molded materials. The covers can be held in place by collars and hose clamps or flanges.

Water is a common contaminant in petroleum-oil based systems that degrades fluid-performance properties and accelerates oxidation and additive depletion. Exposing some seal materials to water—especially at elevated temperatures—also lowers their physical properties. That

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translates to seals that lose strength, harden, crack or even disintegrate.

Polyurethane seals, for example, are subject hydrolysis effects in high-water-content fluids at temperatures above 50°C. That leads to loss of hardness and tensile strength, in turn allowing fluid leakage past the rod seal.

Users should ensure that seal materials are compatible with the fluid and system operating temperature. And experts recommend that users minimize water ingression through suitable wipers and desiccant-style breathers. Finally, maintenance technicians should routinely test for the presence of water in the hydraulic fluid. Water-removal filters or dehydrators are recommended to control water content.

Air is often overlooked as a fluid contaminant. Hydraulic fluid always contains some dissolved air that causes no problems. However, if air mixes with the hydraulic fluid and forms bubbles, that's another story, as it can physically damage the seals. Causes include air drawn past the rod seals; rapid decompression; high flow through an undersized port, generating turbulence; and overrunning loads.

Air bubbles can lead to scoring, nibbling and other physical damage to the seal. Pressure shocks, particularly in cylinders cycling at high speeds, can cause air bubbles to become heated, a condition often referred to as dieseling. The combination of high temperature and high pressure can ignite oil fumes inside the bubble and burn the seal face, and consequently lead to leaks and quick cylinder failure. Minimizing aeration of the fluid through proper design and operation, as mentioned above, is a helpful option.

Why is viscosity important in hydraulic fluids?

Viscosity, according to Webster's Dictionary, is the property of fluids and semi-fluids that defines its internal resistance to flow and shear.

Or, in more simple terms, how thick or thin a fluid is. For example, water is less viscous than tar. (Fluids that have no resistance to shear stress are known as ideal fluids or "superfluids." Zero viscosity is observed only at extremely low temperatures.)

Viscosity is a critical property of hydraulic oil, as it affects the performance and efficiency of complete systems as well as the wear rates of individual components like pumps and valves.

A hydraulic fluid's viscosity is defined primarily by the size and structure of its molecule chains—the larger the molecules, the thicker the fluid. The hydrocarbon molecules in mineral oil vary in size, while synthetic oils have a more-consistently sized make-up. Also, as hydraulic fluid ages or experiences shear stress, oil molecules can break down and that lowers the viscosity.

The most common unit of measure for viscosity is kinematic viscosity, which gages how easily oil flows under the force of gravity. It's usually shown in spec sheets at temperatures of 40° and 100° C. Viscosity is measured in centistokes or mm2/sec, where 1 cSt = 1 mm2/sec.

Manufacturers of hydraulic fluid provide various products with different viscosities. The fluids are most-often labeled in terms of ISO number or grade, where common grades for hydraulic circuits include ISO VG 32, 46 and 68. They are generally selected based on the oil's viscosity for use in a certain type of equipment operating over a specific temperature range.

Determining the right fluid viscosity is a balancing act. As oil temperature rises, viscosity drops and it flows more easily—to a point. If the oil gets too thin, volumetric efficiency suffers and the system becomes less responsive and can lead to overheating, high wear and shorter component life. At the other extreme, if fluid viscosity is too high, mechanical efficiency is low and that leads to friction during startup, sluggish operation and, in the worst case, cavitation and mechanical failure.

The viscosity of a hydraulic fluid is a critical element in the transfer of hydraulic power. The ideal viscosity range for a fluid—and thus its highest efficiency—is usually between 10 and 100 mm^2/sec, depending on the application. If in doubt, always consult the equipment manufacturer's recommendations.

What is viscosity index?

Viscosity index is a dimensionless number that represents how the viscosity of a hydraulic fluid changes with temperature. (It also applies to fluids like engine and automatic transmission oils, gear lubricants, and power-steering fluids.) The greater the viscosity index (VI), the smaller the change in fluid viscosity for a given change in temperature, and vice versa. Thus, a fluid with a low VI will experience a relatively large swing in viscosity as temperatures change. High-VI fluids, in contrast, are less affected by temperature changes.

Typical mineral-oil fluids used in hydraulics have a VI of around 100, although products range from below 100 to well beyond 200.

The best oils with the highest VIs remain stable and don't vary much in viscosity over a wide temperature range. That, in turn, means consistent, high performance from a machine.

Standard ASTM D2270 calculates VI in part by measuring a fluid's kinematic viscosity at 40° and 100° C. Highly refined mineral oils with few contaminants tend to have higher VIs, all things being equal. Synthetic oils usually have a higher VI than do mineral oils.

Fluid manufacturers can improve the VI of base oils by using polymer additives to form multigrade-viscosity oils. These modifiers are temperature sensitive. At low temperatures, the polymer chains in the modifiers contract or fold and don't have much effect on fluid viscosity. But at higher temperatures, the polymers expand and that helps increase viscosity.

However, viscosity improvers can be susceptible to mechanical shearing. Such action can, over time, break down the polymers and degrade fluid viscosity. Experts often recommend shear-stable additives to ensure high-VI fluids work as intended.

Also remember that it's important to use a fluid with the recommended viscosity when running a machine. When viscosity is too low and fluid too thin, users will see problems like higher wear and overheating. Too thin and the machine is hard to start and has low mechanical efficiency, and can even lead to problems like cavitation.

Although oil viscosity changes with temperature, that's not so important in machines that run at constant load and speed and at constant temperatures. Here, the VI is not so important: Just choose the suitable monograde viscosity recommended for the application. But when conditions are not constant—such as in mobile equipment that must operate from winter cold to desert heat—and loads, speeds and temperatures vary, many OEMs recommend high-VI fluids that help maintain near-optimum viscosity over a wider temperature range. High-VI fluids can also improve the energy efficiency of a machine.

How does an O-ring seal work?

O-rings are probably the most common fluid power seals. They're made by the billions by manufacturers all around the world, and they prevent leaks in everything from pumps and valves to cylinders and connectors. The compact, economical components handle both static and dynamic operations, in pneumatic and hydraulic applications.

These simple seals consist of a donut-shaped ring (technically, a toroid) with a circular cross section. They're typically made of elastomers like Buna N, Neoprene or silicone, but they also come in plastics like PTFE, metals and other materials. Sizes range from fractions of an inch in diameter to several meters across.

O-rings seal by mechanical deformation that creates a barrier to a fluid's potential leak path between two closely mated surfaces. O-rings are typically installed in a groove that's machined or molded in one of the surfaces to be sealed. Their rubber-like properties let the devices compensate for dimensional variations in the mating parts.

When properly sized, the clearance between the surfaces is less the OD of the O-ring. Thus, as the two surfaces contact, forming a gland, they compress the O-ring, which deforms the round cross section. This diametrically squeezes the seal, and the resulting force ensures surface contact with the inner and outer walls of the gland.

With little or no pressure, the natural resiliency of the elastomer compound provides the seal and keeps fluid from passing by. Increasing the squeeze (say, by using a larger diameter O-ring in the same-size groove) increases deformation and sealing force. But that can lead to problems in higher-pressure dynamic applications.

Applying fluid pressure pushes the O-ring against the groove wall on the low-pressure side, increasing the sealing force. Interference between the seal and mating surfaces lets the O-ring continue to operate leak-free. At higher pressures, the O-ring deforms to a somewhat "D" shape, and contact area between elastomer and gland surfaces may double from initial zero-pressure conditions. Due to the elastomer's resiliency, releasing pressure lets the O-ring return its original shape, ready for the next pressure cycle. It also lets properly designed O-rings seal in both directions.

Extreme pressures, however, can force elastomer material into the small clearance between the mating surfaces just beyond the groove. Ultimately, the O-ring material shears and flows into the so-called extrusion gap, and the seal fails. Dynamic applications can hasten seal extrusion. But even in

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static applications, high pressure can stretch assembly bolts and open the extrusion gap sufficiently to permit leakage.

While O-rings are relatively straightforward seals, there are still a number of design considerations when specifying them. For starters, they come in a wide range of materials and countless compounds and variations. Matching the material to the application, however, lets them provide excellent fluid compatibility, withstand various operating environments and handle temperature extremes. Other considerations include static versus dynamic (rotary or axial) conditions, operating pressure, and whether the system sees pressure spikes. These, in turn, let engineers specify design parameters like proper gland dimensions, gland surface finishes, seal cross-section diameter, material hardness, initial compression, clearance gaps, and even how much the seal expands or contracts in relation to its mating surfaces as temperatures change. Properly designed, O-rings provide long, trouble-free life in countless applications.

What is a Hydraulic Valve?

Asking "what is a hydraulic valve?" is like asking "how long is a piece of string?" The variations available to the hydraulic designer are absolutely astounding, not only because of the myriad types of valves on the market, but also because of the numerous manufacturers making them.

The most basic description of a valve is a mechanical device that opens and closes, most often to control the flow of fluid—liquid or air. Valves exist in nearly every industry, from automobile engines to the foundries that cast the engine's valves; yes, there are valves on the machines that make valves.

This article isn't about the poppet valves in your 1999 Civic SI VTEC. This article is about hydraulic valves. Hydraulic valves are unique because they must be capable of withstanding 3,000 psi or more of fluid pressure, which require them to be manufactured from strong (and often heavy) steel and iron. Their construction must be such that hydraulic pressure is entirely contained, yet able to function smoothly and accurately, without being prevented from functioning because of the high forces imposed by that pressurized fluid.

So a hydraulic valve is just a device that opens and closes to allow the flow that will move actuators and loads. It sounds simple, but there are various techniques used in hydraulics to allow this to occur. Valves can be mechanically operated (by handle, knob or cam), electric solenoid-operated, or pilot-operated (air or hydraulic pressure actuates the valve). Some valves use the pressure of the circuit's fluid to actuate themselves, like with relief valves. Valves can also be actuated with cables, levers, plungers, torque motors and so forth.

There are nearly as many types of hydraulic valves as there are ways to actuate them. You have solenoid valves, flow control valves and pressure control valves as the three primary groups of valves, but each of those also have their own sub-species. Solenoid valves can be poppets or spool valves, and either of those can be electro-proportional or servo-controlled. Flow control valves can be hydrostats (also known as pressure-compensators) or simply needle valves, and can be used to meter-in or meter-out fluid.

Pressure control valves are the most varied of the three primary groups. They open and close, just as other valves, but these are more dynamic, with linear rise and fall of performance, based on the pressure acting upon them. Most pressure valves (like relief valves, sequence valves, counterbalance valves, and so forth) are normally closed, meaning that it takes a rise in pressure to open them. However, the pressure-reducing valve is the only one that closes when pressure rises above a set point.

There is a dizzying array of hydraulic valves available, and each one could warrant their own page. It's hard to simplify a vast subject and answer "what is a hydraulic valve," but as long as you understand they're devices that open and close to control the pressure, flow and direction of fluid in a hydraulic system, then you've got the basics down.