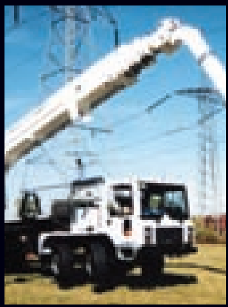
A Penton Publication

May 2002

Hydraulics & pneumatics

The Magazine of Fluid Power and Motion Control Systems

Automate with air



Utility equipment

International fluid power update

Selecting Hydraulic Fluids

By **Michael Zink**

When it comes fluid to performance

Match characteristics to application needs

When designing or operating a hydraulic system, every component must be selected and maintained correctly— with one of the most vital components being the hydraulic fluid itself. There are many different types of fluids available today, and each has certain strengths and weaknesses. This article reviews the major factors involved in selecting and maintaining fluids in modern hydraulic equipment.

With all the different types and formulations of hydraulic fluids available, fluid selection should never be an afterthought.

The word hydraulic comes from the Greek words for water and pipe, so it is no surprise that the first hydraulic fluid was plain water. Water is very good for transferring power from one place to another through a pipe or hydraulic line. In addition to transferring power, however, there are other properties that a good hydraulic fluid must have. Industrial needs have dictated fluid property innovations, which in turn have led to the multitude of fluids that are available for hydraulic applications today. Fluids can be petroleum oil-based, synthetic-based, or water-based (usually containing certain additives), depending on the performance and safety requirements.

Petroleum oil is the most common base for fluids, and most hydraulic components are designed with petroleum oil in mind. Likewise, the performance criteria of other fluids are measured against that of petroleum oil, which is looked at as the standard for fluid performance.

Performance criteria for all hydraulic fluids

Lubrication — Within hydraulic equipment such as pumps and valves, metal components slide against each other on a thin film of hydraulic fluid. The fluid must form a film that helps to reduce friction and heat, which can ultimately lead to component damage. The film strength of a fluid depends largely on its viscosity.

Viscosity — The term *viscosity* refers to the internal friction of a fluid or the resistance to flow exhibited by that fluid. The best viscosity for a fluid depends primarily on the maximum and minimum operating temperatures of the system in which it is installed. At the highest temperatures, the fluid must be thick enough to provide lubrication and minimize internal leakage, but at the lowest temperatures, it must be thin enough to flow readily. Fluid viscosities are typically expressed according to International Standards Organization (ISO) viscosity grades that state the fluid's kinematic viscosity in centistokes (cSt) at 40° C. Common ISO viscosity grades are 10, 22, 32, 46, 68 and 100.

Viscosity index — This index indicates a fluid's viscosity at different temperatures. As with multi-grade motor oil, a hydraulic fluid's viscosity should be as consistent as possible over the entire temperature range it encounters. The viscosity index is an arbitrary scale in which higher values denote greater sensitivity to temperature changes. Typical values range between zero and 300.

Anti-wear — In components such as vane and gear pumps, metal-to-metal contact is part of the component design. In these cases, the fluid must have anti-wear properties in addition to lubrication. Special additives are used to form a protective barrier on the surface of the metal parts. Zinc dithiophosphate (ZDDP) is a commonly used additive. However, its heavy metal content can create problems for waste treatment and disposal, so *ashless* anti-wear hydraulic fluids that do not contain zinc are becoming more common.

Corrosion — Most corrosion in hydraulic systems is due to water getting into the hydraulic fluid. Even humidity in the air can condense and lead to corrosion. Another type of corrosion occurs when the fluid itself, or a product of its

Photo courtesy of ExxonMobil

decomposition, directly attacks materials in the system components. Additives can prevent both types of corrosion, but it is very important to check the compatibility of a fluid with the materials used in system components.

Oxidation — Except for water, all base stocks, whether natural or synthetic, are susceptible to fluid aging or oxidation. The rate of oxidation is directly related to the system temperature, but contamination can increase the oxidation rate even further.

When fluids oxidize, they can form sludge, varnish, and acids. Sludge and varnish can impede the function of components and cause issues such as sticking valves. Acids can attack metals and seal materials creating permanent damage. The best way to prevent fluid oxidation is to keep temperatures low (below 135°F), but fluid manufacturers can add special antioxidants to extend fluid life at higher temperatures.

Elastomer compatibility — Just as many types of fluids exist, there are many types of materials used in seals, hoses, and accumulator bladders. These elastomer materials should be compatible with the fluid at all system temperatures and as the fluid ages. Compatibility between specific fluids and elastomers can be checked with their manufacturers, and general guidelines are available.

Air and water retention — Air or water in a hydraulic circuit can degrade system performance. Air can lead to harmful cavitation, and water can create corrosion and component damage. Special additives — *defoamers* and *demulsifiers* — are sometimes used to improve a fluid's ability to resist air and water retention.

Safety — One drawback of normal petroleum oil fluids is that they are flammable. Many hydraulic systems operate close to open flames and hot surfaces, which can provide a source of ignition if a hydraulic system leaks. Several types of hydraulic fluids have been developed that provide an increased level of safety for these applications.

Environmental concerns — In many applications, environmental issues such as biodegradability, toxicity, and waste treatment expense impose additional requirements on the selection of hydraulic fluid. Because petroleum oils are not biodegradable, a whole category of environmental fluids has been developed and will be discussed in more detail on subsequent pages.

Selection of petroleum base oils

The crude oil base stock, degree of refining, and additives determine the performance of a particular petroleum oil. Virgin base stocks offer better consistency and quality than reclaimed and re-refined oils. Out of the ground, some crude oil base stocks demonstrate good performance in lubrication and corrosion. Therefore, some basic petroleum hydraulic oils on the market are relatively low in cost. Fully formulated

	Petroleum oil	High water content (HFA)	Invert emulsion (HFB)	Water glycol (HFC)	Phosphate ester (HFD)	Polyol ester (HFD)	Vegetable oil
Typically fire resistant?	No	Yes	Yes	Yes	Yes	Yes	Sometimes
Typically fire environmental?	No	Sometimes	No	No	No	Yes	Yes
Cost	\$3 to \$6 per gallon	\$2 to \$5 per gallon for concentrate	\$2 to \$4 per gallon	\$4 to \$8 per gallon	\$10 to \$15 per gallon	\$8 to \$12 per gallon	\$6 to \$10 per gallon
Design and operation	No concerns. Most equipment is designed to use petroleum oil.	Equipment must be specifically designed to operate with water.	May be used in equipment designed for oil after checking the compatibility of main components. Water content must be closely monitored and controlled. Do not expose to extreme temperatures.	May be used in equipment designed for oil after checking the compatibility of main components. Water content must be monitored. Should not be used at temperatures above 120°F.	Not all common seal and hose materials are compatible with phosphate esters. Regular fluid analysis is required to monitor the presence of acidic byproducts of oxidation.	Can be used in most equipment designed to use petroleum oil. Regular fluid analysis is recommended to monitor the condition of the fluid.	Can be used in most equipment designed to use petroleum oil. Regular fluid analysis is recommended to monitor the condition of the fluid. May not be suitable in low temperatures.
Conversion		Cannot be used in equipment designed for oil.	Because invert emulsions and petroleum oil do not mix, any oil must be completely removed.	Because water glycol and petroleum oil do not mix, any oil must be completely removed.	Because phosphate esters do not mix with petroleum or water, any oil or water must be completely removed	Mixes well with petroleum oil, but residual oil will diminish fire resistance and environmental properties. Any water must be completely removed.	Mixes well with petroleum oil, but residual oil will diminish fire resistance and environmental properties. Any water must be completely removed.

oils typically cost more, and contain additives for anti-wear, corrosion and viscosity index properties necessary in today's hydraulic systems with high pressures and tight tolerances.

Fire-resistant fluid selection

The vast majority of hydraulic systems run on petroleum oil. There are many applications, such as furnaces, forges, steel mills and welding operations, where any leak or spill could ignite with disastrous results. Other common uses of fire-resistant hydraulic fluids are less obvious. For example, many tractors use them because the engine's exhaust manifold can become hot enough to ignite petroleum oil.

Since World War II, several technologies have been developed as safer alternatives to petroleum oil. Some of these, like PCBs, are no longer used because of health and environmental reasons. Today, the International Standards Organization (ISO) recognizes four major groups of fire resistant hydraulic fluids (FRHFs), and has assigned them codes based on their chemistry: HFA for high-water containing fluids; HFB for invert emulsions; HFC for water glycols; and HFD for water-free fluids, including synthetics.

HFA fluids — HFA fluids are also called high-water-content-fluids (HWCF), or 95/5 fluids because they were originally a 5% emulsion of oil in water. The oil adds lubrication and corrosion protection, but the bulk of the fluid is water, so the strengths and weaknesses of water are still largely present with HFA fluids. For example, HFA fluids are extremely fire resistant, but they require equipment that has been specifically designed to run with water. Therefore, they cannot be substituted for petroleum oil in typical hydraulic equipment.

HFA fluids are widely used in steel mills and coal mines, where the equipment is designed with HFA fluids in mind. Traditional oil-based HFA fluids are still in use, but they are being replaced with synthetic products that offer better lubrication, consistency, and resistance to biological growth.

HFB fluids — HFB fluids are also emulsions. In these fluids, water is suspended in petroleum oil, which at 60%, makes up the bulk of the product. These fluids offer much greater lubrication and corrosion resistance than HFA fluids, and in some cases offer performance approaching that of petroleum oil. The water provides the extinguishing mechanism should a fire occur.

HFB fluids require regular maintenance to ensure safe and trouble-free performance. The system temperature should be kept low so that the water does not evaporate. Likewise, the stability of the fluid should be checked regularly to maintain fire resistance. Because of the maintenance requirements and inherent instability of water-in-oil emulsions, HFB fluids are not widely used.

HFC fluids

HFC, or water glycols, are the most commonly used fire resistant hydraulic fluids. They contain 35 to 45 percent water, a glycol similar to those used in antifreeze, and special thickeners that improve viscosity. As in HFB fluids, the water content provides fire resistance, so it needs to be monitored and maintained to appropriate levels. HFC fluids typically have fair lubrication and anti-wear properties. However, the service life of ball and roller bearings exposed to it may be reduced.

HFC fluids can be used in most equipment designed for oil, but pump speeds, temperatures, and pressures may have to be adjusted. All water-based fluids, including HFCs are very incompressible. In an operating hydraulic system, this can allow pressure within the system to peak very quickly. These extreme pressure peaks can damage components, so HFC fluids should be specified with this in mind.

HFD fluids — The HFD group contains several different types of products that are all considered *synthetic* because they contain neither petroleum oil nor water.

Once widely used, phosphate ester fluids were the first HFD fluids and are the most fire resistant within the HFD family. Their use declined due to poor environmental performance, limited compatibility, and high cost. Some phosphate esters have very high auto-ignition

What is fire resistance?

The term *fire resistant* often is mistakenly understood to be the same as fire-*proof*. It is not necessarily the same. Almost all FRHFs will burn under certain conditions. HFB and HFC fluids will ignite if a certain amount of water evaporates. Most HFD fluids will burn but, self-extinguish and do not propagate the fire. Only HFA fluids can really be considered fire-proof.

Fluids can be tested to determine their fire resistance. The most common tests are those used by FM Global (also known as Factory Mutual Research Corp.), the testing and approval arm of a major industrial insurance underwriter. For many years, FM Global has maintained a list of *less hazardous* hydraulic fluids based on tests that simulate a high-pressure leak with an ignition source present.

Early this year, FM Global published a new standard, which is based on new tests of a fluid's inherent capacity to ignite and propagate a flame. Beyond a simple approval designation, the new FM Global standard calculates a value called the *spray flammability parameter* (SFP), with lower SFP values indicating better inherent fire resistance.

Fire-resistant fluids will be grouped into three categories based on their calculated SFPs. Details of the new standard, scheduled to be effective in July 2003, are available from FM Global. For more information on this topic, visit www.fmglobal.com (enter *hydraulic* into the search window).

Beyond FM Global, many other organizations and companies have developed fire resistance tests, usually to simulate a certain type of real-world accident. The U.S. Mining Safety and Health Administration has its own approval standard for FRHFs in underground mines. A person choosing a fire resistant fluid should look for certification and details of the fire resistance tests before selecting a particular product.

temperatures so they are still used in specific applications, such as aircraft and power generation.

Phosphate esters largely have been replaced by polyol esters. Based on organic esters, polyol esters offer good inherent fire resistance, and are the most common HFD fluids used today. Polyol ester fluids offer good compatibility with system materials, easy conversion from petroleum oil, and excellent hydraulic fluid performance. In addition, the organic nature of these fluids gives them good environmental performance in biodegradability and aquatic toxicity. Polyol esters can cost more than twice as much as petroleum oil, so they are still only used when fire resistance or biodegradability are high priorities.

Other types of synthetic, fire resistant fluids have been formulated to fill certain niche markets. Water-free polyalkalene glycols (PAGs) feature extended fluid life and good environmental performance. Silicone oils are also used in some critical applications however, these are extremely expensive.

Environmental fluid selection

When hydraulic fluids leak, they frequently end up on the ground or in the water, killing marine life and contaminating the soil. To minimize these negative effects, environmental fluids are becoming popular, particularly in mobile equipment applications. Fluids are said to be environmental when they are biodegradable and non-toxic — especially to fish.

The exact definitions and requirements for an environmental hydraulic fluid vary by country and sometimes by local laws. In general, environmental fluids must be *readily biodegradable*, which means that 60% of the fluid must break down within 28 days of exposure, and they must pass aquatic toxicity tests that measure their effect in small concentrations on specific species of fish. Typically, environmental hydraulic fluids are also ashless, because they do not contain the anti-wear additive zinc dithiophosphate, the presence of which would cause environmental concerns.

The most common applications for environmental fluids are agricultural, forestry, mining, and construction machinery, boats and marine equipment, and offshore drilling operations. Some of these applications must use environmental fluids, but others use them to reduce cleanup costs.

The most common base for environmental hydraulic fluids is vegetable oil — usually rapeseed oil. Vegetable oil products are available today with lubrication and anti-wear properties equal to that of petroleum oil. Vegetable oil's most common limitations are oxidation and cold weather performance.

Because vegetable oils are naturally occurring esters, they are susceptible to hydrolysis and oxidation, especially in the presence of heat. At sub-zero temperatures, they can congeal, making cold starting very difficult.

Synthetic base fluids are also popular as environmental fluids. Polyol esters and water-free PAGs are used in both environmental and fire resistant fluids. These synthetic base fluids can have high oxidation resistance and excellent low-temperature performance, yet still be biodegradable and non-toxic.

Companies also are developing new additive chemistries to improve hydraulic performance while maintaining environmental compatibility. Vegetable oil suppliers are using genetic engineering to produce oils with improved stability. Ester manufacturers are designing molecules that provide ever-increasing performance in both hydraulic and environmental properties. Although the environmental segment receives a lot of investment and attention, significant growth of these fluids in the U.S. will require clear governmental definitions and regulations regarding their use.

Environmental and fire resistant

As mentioned above, some of the synthetic bases used in fire resistant fluids are also biodegradable and non-toxic. Therefore, products are available that fit both fire resistant and environmentally sensitive applications. The most common fluids of this type are synthetic polyol esters. These fluids are effectively used in mobile equipment where environmental concerns are obvious and where hot exhaust manifolds can ignite a fluid leak. HFA fluids can also be both fire resistant and environmental, but as in any water-hydraulic application, systems and components must be designed specifically for use with high-water-content-fluids.

Summary

Based on petroleum oil's high performance and low cost, any hydraulic system designer or user would prefer to use it. In many applications, however, safety and environmental concerns dictate the use of another fluid. In these cases, end users must strike a compromise between system needs and fluid performance characteristics to arrive at a solution that both minimizes cost and maximizes the desired health and safety benefits. ■

Michael D. Zink is global marketing manager, Quaker Chemical Corp., Conshohocken, Pa. For more information, e-mail fluidpower@quakerchem.com or visit www.quintolubric.com.

General information

on Quaker's Fluid Power Products

We are moving, growing and using new technologies to solve ever-changing customer problems. On the way, we strive to use our tremendous global reach, strength of process knowledge and breadth of personnel to position ourselves to deliver everywhere in the world the best from anywhere within Quaker.

Quintolubric® is Quaker Chemical's family of specialty, fire-resistant hydraulic fluids. For more than 30 years, Quaker Chemical has been a leading supplier of specialty hydraulic fluids, and the Quintolubric® brand is recognized around the world as the name for high-quality, high-performance, fire-resistant and environmentally compatible fluids.

HFA

- Hydraulic fluids for use in equipment designed to operate with low-viscosity fluids. The HFA-concentrates are diluted with water: in most cases the water content in the emulsions or solutions is 95–99%.
- HFA fluids are used in some steel mill applications and in underground mining.
- Quaker Chemical markets several HFA products for various applications including the brand names Quintolubric® 807, Quintolubric® 814 and Quintolubric® 818.
- Quaker's products outperform competitive products in stability, bioresistance and corrosion prevention with low applied costs.

HFC

- Also called "water glycols," these fluids are solutions, not emulsions, since glycols are truly soluble in water. A typical fluid contains 40–45 % water and the remainder is a blend of glycols, thickeners and additives.
- These fluids are widely used in steel mill applications as well as underground mining and offshore drilling.
- Quaker Chemical markets HFC products for specialty applications under the brand name Quintolubric® 702.

HFD

- These synthetic fluids can be used in equipment designed for traditional mineral oil fluids and provide better performance than fluids containing water.
- In addition to fire resistance, these fluids provide excellent biodegradability and low aquatic toxicity, making them ideal for use where better environment protection is required.
- Quaker's HFD fluids are used in numerous industries wherever fire resistance and biodegradability are required.
- Quaker's flagship HFD product is Quintolubric® 888. Other products of this type include Quintolubric® 822 and 850.
- Quintolubric® 888 is unique in the industry because the exact same product is available worldwide. Quintolubric® 888 outperforms competitive products in fluid life and consistent performance.
- Quaker is recognized as the leader in HFD-U fluids by major equipment builders and end users around the world.

Quaker Chemical
Delivering everywhere, the best from anywhere.

Web: http://www.quintolubric.com ***Email: fluidpower@quakerchem.com***