Water works

Less expensive than oil and environmentally friendly, water-based hydraulics deserve a closer look.

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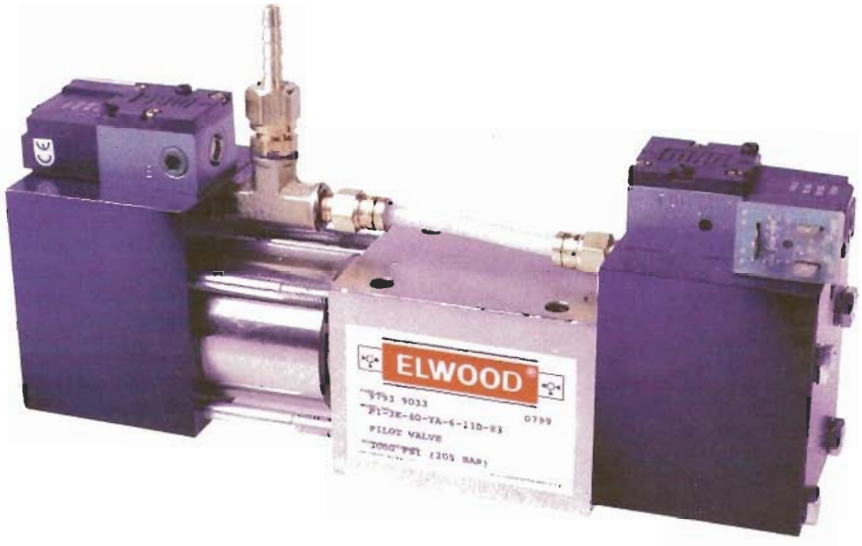


Valves and other components for water-based hydraulic systems often require special designs that handle poor lubricity and resist corrosion. These include stainless-steel components, hardened surfaces, and Viton seals.

Although water was the original hydraulic fluid, today, oil dominates. Oil's high lubricity and viscosity make for efficient hydraulic systems and long-lasting components, and its performance sets the standard against which other fluids are measured. But high prices and growing environmental concerns may mean the pendulum is swinging back toward water, at least a bit.

Water has several attributes that are advantageous in hydraulic systems, including:

Fireproof. Water will not burn, regardless of temperature.

Environmentally friendly. Spills are easy to clean or require no clean up at all. They typically don't result in EPA intervention.

Good heat transfer. Water transfers heat more efficiently than oil, making it useful in systems where high temperatures and overheating are issues.

Low cost. By far, water is less expensive than petroleum oils, synthetics, and other hydraulic fluids.

Fast response. Water has a higher bulk modulus than oil, which basically means it is less compressible. So water may be the better choice in applications requiring extremely fast response.

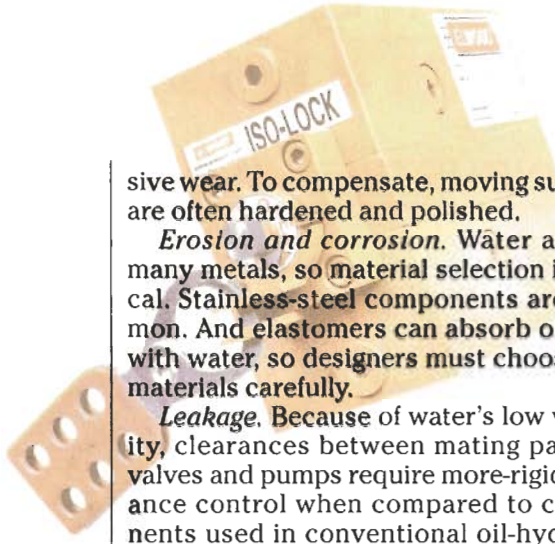
Energy savings. Water's low viscosity lets it moves readily and efficiently through valves and pipes with lower flow resistance than oil.

Film strength. Water has a lower film strength than oil, so it's less likely to retain bubbles and cause foaming problems.

On the other hand, water is by no means the perfect hydraulic fluid. Here's the downside:

Poor lubricity. Water's low viscosity hinders the formation of full-film lubrication common in oil-based systems, so parts may wear out quickly. Water's low film strength exacerbates the problem because it is much less likely to form a protective coating on moving parts and prevent abra-

Edited by Kenneth Korane



sive wear. To compensate, moving surfaces are often hardened and polished.

Erosion and corrosion. Water attacks many metals, so material selection is critical. Stainless-steel components are common. And elastomers can absorb or react with water, so designers must choose seal materials carefully.

Leakage. Because of water's low viscosity, clearances between mating parts on valves and pumps require more-rigid tolerance control when compared to components used in conventional oil-hydraulic systems. Otherwise, internal leaks and energy losses become significant.

Vapor pressure. Water's vapor pressure is higher than that of oil. This makes it more susceptible to cavitation when drawn into a pump, so suction lines generally must be pressurized. Also, evaporation can be an issue. And because water freezes, water-hydraulic systems tend to operate within a narrower temperature range.

Component costs. System components tend to be more expensive because they use specialized materials and must be machined to more-rigid tolerance specifications.

WATER-BASED FLUIDS

In some instances, hydraulic systems run on pure water. But more often, due to water's shortcomings, manufacturers turn to additives to give it oil-like properties. Here are the leading water-based fluids.

HFA fluids. These high-water-content fluids, also called 95/5 fluids, typically contain about 95% water and 3 to 5% oil additives. The additives form an emulsion of tiny oil droplets in the water, increasing lubrication and corrosion resistance.

HFA fluids are extremely fire resistant and widely used in steel mills and coal mines. But because it is primarily water, valves and other components must be designed to run on water. HFA fluids cannot be substituted for petroleum oil in typical hydraulic equipment. **Quaker Chemical**'s Quintolubric line is one major brand.

HFB fluids. Primarily oil with about 40% water, this invert emulsion suspends water droplets in the base oil. HFB fluids offer good flame resistance and have better lubricity and corrosion resistance than HFA fluids. However, HFB-based systems must operate at lower temperatures and require more maintenance. One reason is that water evaporation rises with temperature. This throws the mixture out of balance and, with it, fluid performance.

Another reason HFB fluids are maintenance intensive is simply that oil and water don't mix particularly well. If the fluid stops flowing, water can separate from the oil. Due to its sensitive nature and need for constant monitoring and maintenance, HFB fluids are no longer widely used.

HFC fluids. These are water-glycol mixtures. They contain 35 to 45% water in a glycol similar to that used in antifreeze. They also contain corrosion inhibitors and friction modifiers to improve wear resistance. HFC fluids are fire resistant and see fairly wide use, especially in the primary-metals industries.

As with HFB fluids, water content is key to fire resistance, so it must be monitored and kept at appropriate levels. HFC fluids have fair lubrication and antiwear properties, but pump speeds and system tem-

COMPARING HYDRAULIC FLUIDS

	Raw water	Mineral oil	HFA	HFB	HFC (Water glycol)	HFD (Polyol ester)
Fireproof	Yes	No	No	No	No	No
Fire resistant	Yes	No	Yes	Yes	Yes	Yes
Environmentally friendly	Yes	No	Sometimes	No	No	Yes
Fluid costs per gallon	A few ¢	$5 to $6	$0.25 to $0.35	$2 to $4	$6 to $10	$8 to $12

Costs shown here are general ranges for standard industrial products. Note that HFA costs are for the water/additive mixture.

peratures may need to be derated in equipment designed for mineral oils. **Hydro Safe Oil Div.** and Quaker Chemical are two HFC-fluid suppliers.

SELECTION FACTORS

Engineers must consider factors such as temperature, fluid velocity, and pressure regardless of the type of hydraulic fluid. But experts recommend examining some additional factors when weighing the economics of water-based fluids.

Fire resistance. Pure water is the only truly fireproof hydraulic fluid. Because of their high water content, HFA fluids are highly fire resistant. HFB and HFC fluids will ignite if a certain amount of water evaporates. HFD fluids (See "Alternative fluids") will burn but self-extinguish, and do not propagate fire.

Organizations such as **FM Global** (Factory Mutual Research Corp.) and the **U.S. Mining Safety and Health Administration** test and rate fluids for fire resistance. Almost always, users should avoid petroleum-based fluids if fire is an issue. Often, lower insurance rates help offset the higher up-front costs of water-based systems.

Environmentally friendly. Hydraulic oil leaks can contaminate soil and sensitive wetlands and kill marine life in lakes and streams. And this can lead to expensive remediation and hefty EPA fines. To minimize the risk, more and more users are turning to environmentally friendly fluids — particularly in mobile equipment.

Some water-based fluids fit this niche. However, a rigid definition for environmentally safe hydraulic fluids is elusive because rules vary by country and locality. In general, a certain

Where water tops oil

Water-based fluids are used in a wide range of applications, particularly those with potential fire hazards or where product contamination is a concern. Typical examples include:

- Automotive presses, body-component hydroforming machines, and tire manufacturing.
- Ceramics manufacturing, such as grinding wheel presses and cleaning systems.
- Food-processing systems, including fruit presses and vegetable washers.
- Forge presses, where hydraulics controls ram speed, force, and direction.
- Mining equipment such as longwall cutting machines and dust-suppression systems.
- Offshore oil rigs, where water hydraulics is used on oil and gas-line actuators, emergency shut-down systems, and wellhead controls.
- Steel-making equipment such as continuous casters, hot and cold mills, finishing stands, and pickling lines.
- Textile dye-impregnation systems, nonwoven-fabric presses, and cloth-cutting and finishing equipment.
- Tube and pipe manufacturing, including hydrostatic testing and extrusion process lines.
- Wood and paper production equipment like debarkers and chip-board, laminate, and paper presses.

percentage of the fluid (for instance, 60, 90, or 95%, depending on the specific regulation) must break down within a certain time frame, usually 21 or 28 days. Nontoxic, in general, means the fluid won't kill fish if spilled into a waterway.

Product-fluid compatibility. In many processes, fluid leaks contaminate products and render them worthless. For this reason, food processors and textile manufactures often avoid petroleum oil.

Reservoir size. At a forge-press installation we recently visited, a single, 100,000-gallon reservoir supplied all the presses with hydraulic fluid. In this instance, cost saving from water-based fluids versus petroleum oil are substantial, to say the least. For any large system, consider if similar savings offset higher component and maintenance costs.

System costs. In general, the higher a fluid's water content, the more pumps, valves, filters, conductors, and connectors will cost. As mentioned previously, water's poor lubricity mandates tighter tolerances and specialized materials for many components. For example, many of **Elwood Corp.**'s valves for HFA fluids have stainless-steel internal parts, rely on proprietary processes to increase the corrosion resistance and hardness of the materials, and feature special Viton seals to improve the performance of the valves with water. These design considerations all help prevent internal leaks and high fluid velocities from damaging equipment, and have proven successful in harsh, heavy-duty environments.

FLUID MAINTENANCE

All hydraulic systems need good filters and regular monitoring for fluid cleanliness. In oil-based systems, this helps prevent problems such as oxidation, contamination, water ingression, and excessive component wear. Water-based systems have some special considerations in terms of monitoring and maintenance.

Dilution. With fluids being a mix of two or more components, such as a 95/5 HFA, users must maintain the proper ratio for the fluid and entire system to consistently work as intended.

pH. Users must monitor and control fluid pH or it can lead to bacterial growth and contamination. Water's natural pH is 7.0, and experts recommend maintaining pH levels in the 8.0 to 9.5 range. Below 7.0, in the acidic region, the fluid may attack system components.

Bacteria and fungus. Users must prevent microbial growth in water-based systems or it quickly leads to clogged filters and fouled components. Bactericides added to water are the

most prevalent method, but sterilization and filtration are other options. In large reservoirs, UV radiation (used in municipal water systems) may be a viable alternative.

Water hardness. To prevent mineral deposits, keep water hardness levels in the 50 to 200-ppm range.

Filtration. Water-based systems need filters, just like oil hydraulics. But they must be compatible with water. Fiberglass and stainless-steel mesh are common media, while housings typically use special coatings or stainless steel.

General filtration guidelines for water-based systems include 40 μm for servo and proportional valves, 75 μm for directional and pressure-control valves, and 150 μm for descale and on-off valves. Note that filtration media that's too fine — below 40 μm — can remove beneficial additives from water-based fluids. **MD**

Alternative fluids

In addition to petroleum oils and water-based fluids, here are some other options for hydraulic-system designers.

HFD fluids. These synthetic fluids are neither petroleum nor water based. Most HFD fluids today are polyol esters, which offer good material compatibility and hydraulic-system performance, along with easy conversion from petroleum oil. Among their advantages, polyol esters are biodegradable, nontoxic, and fire resistant. However, they are expensive, costing more than twice as much as petroleum oils. They are mainly used in mobile equipment. Quaker Chemical is one manufacturer of HFD fluids.

Norpar/kerosene. This paraffin-based hydrocarbon fluid has better oxidation properties than mineral oils. Oxidation primarily takes place at high temperatures. It breaks down the fluid and forms contaminants such as sludge, varnish, and acids that cause valves to stick and attack metals and elastomers. A major advantage of Norpar, made by **ExxonMobil**, is that it doesn't interact or react with aluminum. Thus, it is primarily used in applications such as aluminum cold rolling.

Vegetable oil. Generally based on Canola (rapeseed) oil, these fluids have lubrication and antiwear properties equivalent to mineral oil. And they are biodegradable and nontoxic, making them a good choice for mobile, agricultural, and forest machines as well as boats and marine equipment. Limitations include oxidation at higher temperatures and poor low-temperature performance, as well as costs ranging from $6 to $10/gallon.

PAGs. Polyalkylene glycols are designed for industrial applications requiring fire resistance and biodegradability. They feature good antiwear properties, high oxidation resistance, and excellent low-temperature performance. **Dow Chemical** is one supplier of PAG fluids.

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