CHAPTER 4

Fire Resistant Hydraulic Fluid

Since petroleum base hydraulic fluid is an excellent lubricant, systems which use it as their energy transmission medium can look forward to years of dependable life. But, in some systems or applications, petroleum oil has a major disadvantage; oil under pressure may spray (atomize) at a leak point - it has been the source of many industrial fires.

As we normally deal with petroleum oil in a system, it is not a high degree fire hazard. Petroleum oil is nonvolatile at room temperature and is capable of extinguishing a small flame like that of a match. However, a high pressure line with a pinhole leak spraying an oil mist into the air is a combustible mixture which can be easily ignited by an open flame. A leak of this nature can be considered a fuel nozzle.

In fire-hazardous industrial environments where undisturbed production and operator safety are of primary concern, and the ambient conditions are such that an accidental flame could strike, fire resistant fluids are employed. These fluids are used with the knowledge that operating expenses will increase because the fluid is more expensive than petroleum oil and component life will decrease.

The intent of this lesson is to identify common types of fire resistant fluids for a hydraulic system, to see some problems of a fire resistant fluid in service, and to indicate some maintenance considerations with respect to fire resistant hydraulic fluid.

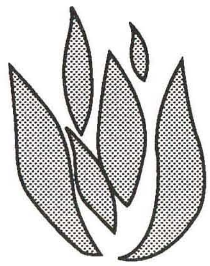
fire resistance determined

Fire resistant fluids are not fireproof. They are just as their name implies - resistant to fire. If fire resistant fluids are heated to a high enough temperature, they will burn.

Fire resistance of a particular fluid is determined by three test specifications: flash point, fire point, and auto ignition temperature. In describing the three tests below, petroleum base hydraulic fluid is used as the test fluid.

flash point

Flash point of a fluid is the temperature to which a fluid must be heated to give off sufficient vapor to ignite when a test flame is applied. As a petroleum oil or any liquid is heated, vapor is given off; liquid evaporates in other words. With a petroleum oil

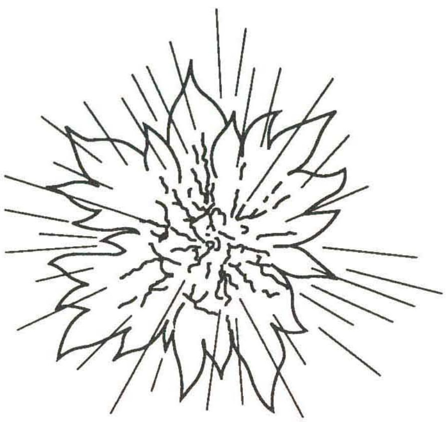


heated to 350-450°F (176.6-232.2°C), enough vapor is given off from the oil's surface to ignite when a flame is applied.

However, once the flame is removed, oil vapor ceases to burn.

fire point

Fire point of a fluid is the temperature to which it must be heated to burn continuously after a test flame has been removed. When a petroleum base hydraulic oil is heated above that temperature, enough vapor is given off from the oil's surface to ignite when a flame is applied and to remain lit after the flame is removed.



auto ignition temperature

Auto ignition temperature of a fluid is the temperature at which it ignites without an external flame or spark.

Heating a petroleum base hydraulic oil between 500-700°F (260-371°C) will result in the fluid bursting into flame. This occurs without a flame present.

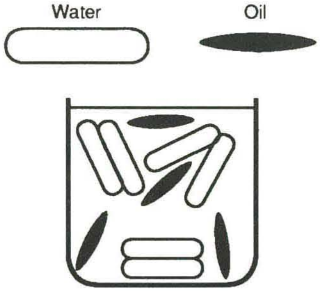
types of fire resistant fluid

Hydraulic fluids which are classified as fire resistant have higher flash, fire, and auto ignition temperatures than petroleum base oil. These fluids can be divided into two types - water base and synthetic.

water base fluid

Water was the fluid used in the first hydraulic systems. Water had several disadvantages as far as lubrication was concerned, but it did not burn. When the need arose for a fire resistant hydraulic fluid, the initial action was to turn once again to water. However, since a certain amount of lubrication was demanded, oil was emulsified with the water.

water-oil emulsion

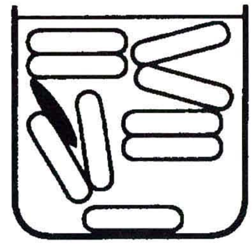


Water-Oil Emulsion

A water base fire resistant fluid consisting of water and oil is not a mixture - oil and water do not mix. Since this is the case, oil is broken down into extremely small droplets, usually by a chemical emulsifier. Oil droplets are carried around by the water, increasing its lubricating qualities. If the fluid is exposed to fire, the water turns to steam extinguishing the flame.

A two-phase, water-oil fluid is known as an emulsion. At the time this fluid was popular, a normal ratio of water to oil in an emulsion of this type was 60% water to 40% oil. Water was the dominant fluid and carrier of oil droplets.

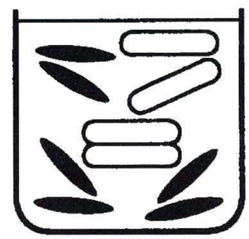
soluble oil fluid (HFA)


Soluble Oil Fluid

Fire resistant hydraulic fluids which are predominantly water, are not normally found in present day hydraulic systems except where large amounts of fluid are lost due to leakage. In these systems, reduced component life is sacrificed for an economical fire resistant fluid. The fluid is relatively inexpensive because the percentage of water is at least 90%.

A water base hydraulic fluid made up of water emulsified with 1-10% oil, is an oil-in-water emulsion commonly referred to as soluble oil fluid. Anyone remarking that he is using 5% soluble oil in his system, is indicating that his fluid is made up of 95% water and 5% oil or chemical concentration.

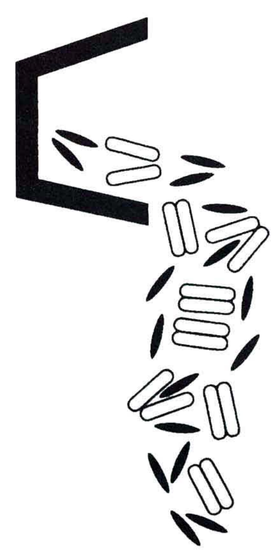
invert emulsion (HFB)


Invert Emulsion

A common water-oil emulsion of a modern hydraulic system is a creamy white liquid made up of 60% oil and 40% water. As compared to a previous emulsion (60% water - 40% oil), the ratio of this emulsion is turned around or inverted.

Since oil is the dominant liquid and carrier of water droplets, invert emulsions have increased lubricating characteristics with a slight decrease in fire resistance.

viscosity of water-oil emulsions



Viscosity of a water-oil emulsion is an important characteristic just as with petroleum hydraulic fluid. Since a soluble oil fluid contains a minimum of 90% water, its viscosity is basically that of water. Consequently, these fluids are rather poor lubricants.

An invert emulsion, on the other hand, normally consists of 60% oil. However, this does not mean that its fluid viscosity will be that of its base oil.

Viscosity of an invert emulsion operating in a typical hydraulic system will have a higher viscosity than a normal petroleum fluid for that system. For example, a system operating with an invert emulsion may have a viscosity of 375 SUS (80.9 cSt) @ 100°F (37.7°C); whereas a petroleum oil would have a viscosity of 150 SUS (32 CST) @ 100°F (37.7°C).

Because of the shearing action between the two fluid phases as it moves through pump and system, invert emulsions exhibit a decrease in viscosity. To ensure that system components are properly lubricated, an invert emulsion with a higher than normal viscosity is used.

(ASTM graph paper does not properly depict the viscosity-temperature relationship of any invert emulsion or of fire resistant fluids in general.)

problems with an invert emulsion

With a water base fire resistant fluid in a machine reservoir, certain problems can arise. Two problems specific to an invert emulsion are phase separation and bacteria formation.

phase separation

Invert emulsion fluids are not designed to be operated at low temperatures. At 32°F (0°C), ice slivers begin to form; at approximately -10°F (-23.3°C), the fluid freezes. Also, freezing and thawing of an invert emulsion cause the two phases to separate.

At the freezing point of water (32°F/0°C) some water droplets carried by the oil free themselves from the emulsion, forming ice crystals. As the system operates and temperature increases, ice crystals melt, but do not necessarily emulsify again. In this condition, the fluid has more tendency to rust system components and adversely affect lubrication.

Repeated freezing and thawing of an invert emulsion could cause water and oil phases to separate to a large degree. In this condition, it would be very difficult, if not impossible, to get the two liquids back together. As a result, fire resistance could be a serious problem.

check for phase separation

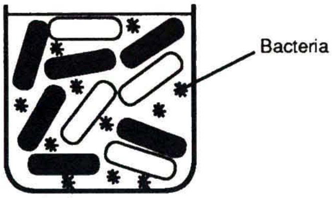
A check for phase separation is performed by inspection. With the fluid in the reservoir mixed, it is difficult to determine whether oil and water phases have separated. Draining off a fluid sample into a jar and allowing the fluid to rest for a period of time, of time, you will note that any free water will settle to the bottom of the jar.

40 micrometres

If you feel phase separation is severe, contact your fluid representative; he may recommend that the fluid be changed.

bacteria formation

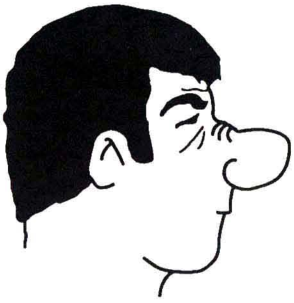
In some situations, under the proper temperature conditions, an invert emulsion can support the growth of bacteria. Bacteria in large quantities can plug pressure sensing orifices of pressure control valves and pressure compensated flow controls. Bacteria can also plug filter elements. All these actions result in an undependable, nonproductive system.



Many invert emulsions are equipped with a bactericide additive to avoid this situation.

check for bacteria formation

A check for bacteria formation is performed by sight and smell. If bacteria is present in an invert emulsion, inlet filters will appear to be coated by mucous or slime. And the bacteria will give off a very offensive odor.

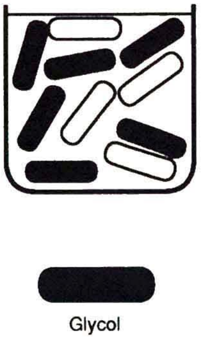


If bacteria is present in an invert emulsion, it will most probably have to be changed.

water glycol (HFC)

Water glycol is another type of water base fire resistant fluid; it consists of water and a glycol which has a chemical structure very similar to automotive antifreeze.

Water glycol is many times dyed red or pink, and normally consists of 60% glycol and 40% water, along with a chemical thickener to increase its viscosity. The glycol actually mixes with the water. The fluid is homogenous and not two-phase like an emulsion; that is, seen through a microscope, the fluid will not appear as separate droplets of water and glycol.

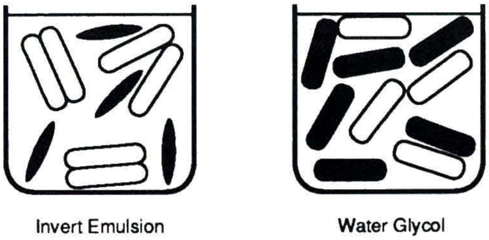


Water glycol fire resistant fluid works well at low temperatures.

comparing invert emulsion with water glycol

When comparing an invert emulsion with a water glycol fluid, we find that:

a. It is more difficult to keep an emulsion stable than to maintain a water glycol solution.



b. Stable invert emulsions have more lubricity.
c. Invert emulsions are less expensive.
d. Water glycol fluids are more fire resistant.
e. Water glycol fluids operate better at low temperatures.

Relative Lubricating Effectiveness	
Fluid	**Lubricant Derating Factor**
Petroleum Oil	1.0
Invert Emulsion	2.0
Water Glycol	2.6

problems with water base fluids

With a water base fire resistant fluid in a hydraulic reservoir, certain problems can arise. Some of these problems are reduced component life and water evaporation.

lubricity of water base fluids

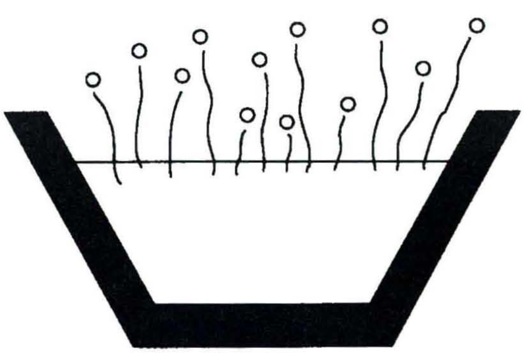
Since water base hydraulic fluids contain a significant percentage of water for fire resistance, they have an inherent disadvantage. With respect to petroleum oil, these fluids have reduced lubricity.

Lubricity and oiliness agents are added to the fluids, but reduced component life is a realistic expectation when these fluids are used. Because of this handicap, water base fire resistant fluids are not normally used in systems which operate above 1800 psi (124 bar).

Of soluble oils, invert emulsions and water glycol fluids, stable invert emulsions have the best lubricity, followed by water glycol and soluble oil fluids, respectively.

water evaporation

Many fluid manufacturers recommend that water base fluids be operated at a maximum temperature of 140°F (60°C) with 120°F (49°C) being more desirable. Above 140°F (60°C), excessive water evaporation may occur.

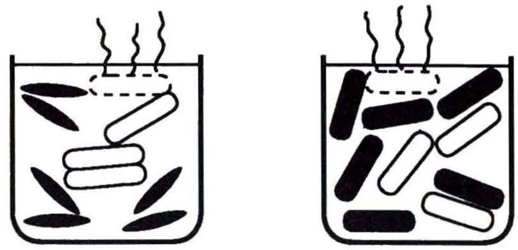


As water evaporates from a water base fluid, some undesirable things can happen. Water vapor escaping from the fluid can condense on unprotected ferrous parts causing rust formation. After a time, rust scale flakes off the unprotected metal surface, becoming a source of dirt for the entire system.

Water base fluids are generally equipped with rust inhibitors, but any unprotected metal surface which is not bathed by the liquid is subject to the attack from escaping water vapor.

Water evaporation affects a fluid's fire resistance. Since the percentage of water determines the fire resistance of a water base fluid, water loss due to evaporation results in the liquid being less resistant to burn.

Loss of water from an invert emulsion or water glycol also affects fluid viscosity. Water loss in a water glycol increases fluid viscosity. In an invert emulsion, water loss causes viscosity to decrease or may even result in the fluid becoming unstable. Top ensure maximum fire resistance and the proper viscosity, water content of water base fire resistant fluid should be monitored by lab analysis at regular intervals.

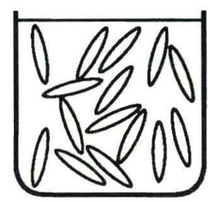


Water Evaporation

synthetic fire resistant fluid (HFDR)

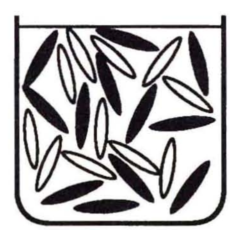
Synthetic fire resistant fluids are man-made liquids which are praised for their resistance to burning while performing close to petroleum oil with respect to lubrication. The most common type of synthetic fire resistant fluid is phosphate ester.

NOTE: Synthetic fire resistant fluids should not be confused with synthetic fluids such as silicones, silicate esters, dibasic acid esters, polyglycol ether compounds and polyol. These fluids have characteristics which are desirable for specific applications, but they are not normally considered fire resistant.



Synthetic

Phosphate ester fluids operate well at high pressure, provide excellent fire resistance, but they are very expensive. In high pressure systems where fire resistance is demanded, but the price of phosphate ester is prohibitive, a blend of phosphate ester and petroleum oil can be used. This fluid has the lubricity the systems demands, but gives a fire resistance less than a phosphate ester fluid.

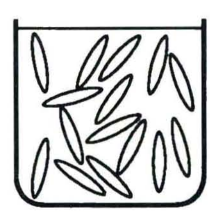


Phosphate Ester — Petroleum Blend

comparing water base with synthetic fire resistant fluid

When comparing a water base fluid with a synthetic fire resistant fluid, we find that:

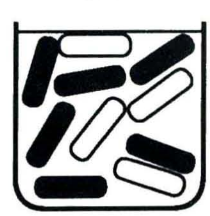
a. Synthetic fluids exhibit more lubricity and can operate at higher pressures.
b. Synthetic fluids are more expensive.
c. Synthetic fluids are more fire resistant.
d. Flash point, fire point and auto ignition temperature for a phosphate ester fire resistant fluid are approximately 455°F (235°C), 665°F (352°C), and 1150°F (621°C) respectively.



Synthetic

Blend

Invert Emulsion



Water Glycol

Fire resistance for water base fluid is not indicated by flash and fire temperature points as long as water is present in the fluid. Auto ignition temperature for water glycol is approximately 1100°F (593°C); for an invert emulsion, it is approximately 825°F (440.6°C).

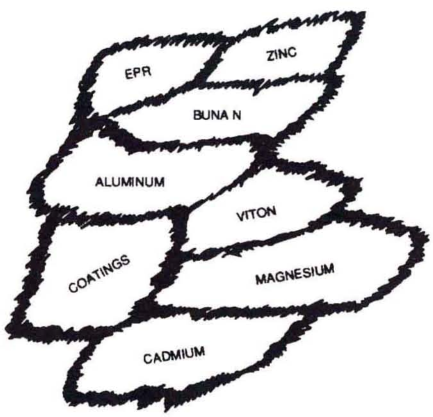
problems with fire resistant fluids

Using a fire resistant fluid in a hydraulic system can result in certain problems. Some of these problems are compatibility with seals and protective coatings, foaming and air retention, and dirt retention.

compatibility with fire resistant fluids

A common material for sealing petroleum oil is Buna N. This material is also compatible with an invert emulsion as well as a water glycol. When switching a system from petroleum oil to an invert emulsion or water glycol, system seals will not require changing if they are Buna N. These types of seals would require change if certain synthetic fluids, such as phosphate ester, were used.

When switching from petroleum oil to a water base fire resistant fluid, some problems could occur with protective coatings. If a reservoir interior is protected with petroleum compatible paints and varnishes, a water base fluid may dissolve the coating.

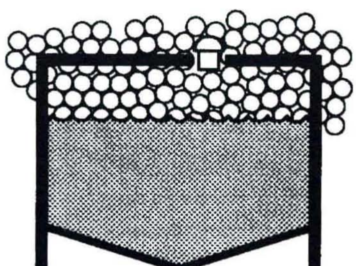


Water glycol fluids and some chemical concentrates are not compatible with some metals. They may attack zinc, cadmium, magnesium, and certain alloys of aluminum, generating gummy residues which plug orifices and filters and cause valve spools to stick. It is recommended that parts which are alloyed or plated with these metals not be used with water glycol. Examples of such parts might be galvanized pipe, and zinc or cadmium plated strainers, fittings and reservoir accessories.

The common Buna N seal material used for dynamic sealing of a petroleum base fluid is not acceptable for a phosphate ester or phosphate ester blend fluid. These fluids require Viton, EPR, or any other suitable material.

Synthetic fire resistant fluids tend to dissolve petroleum compatible paints and varnishes; however, these fluids do not attack common metals found in a hydraulic system.

foaming and air retention with fire resistant fluids



Foaming

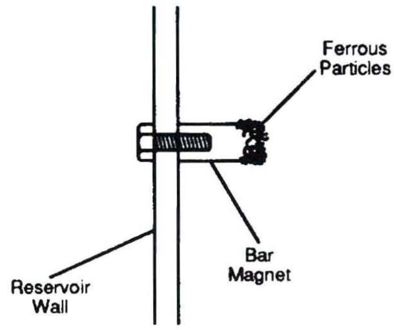
Water base and synthetic fire resistant fluids have more of a tendency to retain air and to foam compared to petroleum oil. After returning to the reservoir, fire resistant fluids require more time in a reservoir to give up any accumulated air bubbles.

Consequently, systems using fire resistant fluids should have larger reservoirs than comparable systems using petroleum oil.

dirt retention with fire resistant fluids

As it returns to a reservoir, fire resistant fluids have more of a tendency to retain dirt in suspension compared to petroleum oil. A fluid is supposed to allow any reasonably sized dirt to settle to reservoir bottom, but a fire resistant fluid tends to hold the dirt.

When a fire resistant fluid is used in a system, good fluid filtration should be a prime consideration. And, the use of magnets should not be overlooked.

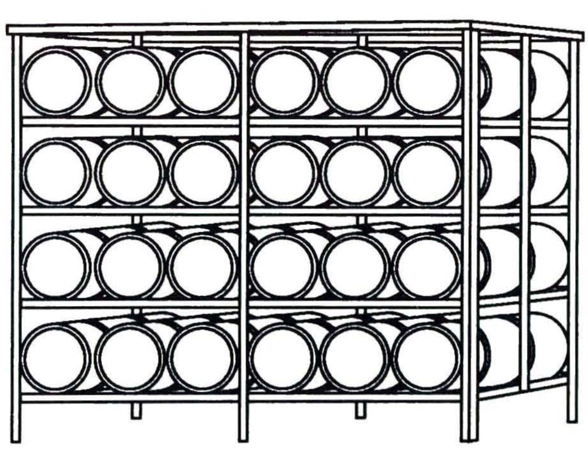


maintenance considerations

Maintenance considerations of fire resistant fluids with regard to storage are basically the same as for petroleum oil; that is, store barrels on their sides so that water does not collect on barrel tops and leak into the fluid.

Invert emulsion fluids have additional storage requirements. These fluids can have their stability affected by repeated freezing and thawing. Care should be taken then to ensure that the fluid does not freeze.

Transferring oil from barrel to reservoir is another important consideration. Before the drum plugs are removed, the drum cover should be cleaned. This procedure should also be followed for any apparatus or tools which will be used in the process such as hoses, pumps, funnels, reservoir filler holes, and the operator's hands. A check should be made to see that the barrel contains the correct fluid by brand name and viscosity. And, if a pump is used to transfer fire resistant fluid, care should be taken that the pump is not filled with a different fluid and that pump materials and connector assemblies are compatible with the fluid.



With the fire resistant fluid in the reservoir, it should be maintained and monitored at regular intervals. Maintenance of the fluid includes filling a reservoir when its minimum oil level has been reached, fixing leaks and servicing filters.

Water base hydraulic fluid should be regularly checked for its water content since its concentration must be kept in a narrow range as it affects viscosity and fire resistance.

Adding water to an invert emulsion is not normally recommended because of the critical mixing process which is demanded. Adding water to a water glycol solution is common but it is not a simple matter of running a hose to the reservoir from the nearest water tap. Makeup water should be free of mineral deposits which could contaminate a system. Distilled steam condensate or deionized water are suitable for use in a water glycol solution. The amount of water to be added is determined after analysis of the fluid sample by a lab.

problem 1

Because of the danger of fire, a system operating at 2200 psi (151.7 bar) with petroleum base fluid is required to change to a fire resistant fluid.

Describe what type of fire resistant fluid might be recommended in this case and indicate its affect on existing system seals and protective coatings.

problem 2

A maintenance man, seeing that fluid level in a hydraulic reservoir is low, fills a pail with water from a shop faucet and dumps it into the reservoir. The reservoir is filled with a creamy white, water base fire resistant fluid. The water doesn't appear to mix with the existing fluid.

Point out two things the maintenance man has done wrong.

problem 3

A certain individual cannot see why fire resistant fluid is needed in a system. "Oil doesn't burn," he says. "Anyone who has worked in a plant has seen someone extinguish a cigarette in a pool of oil."

Explain how hydraulic oil can be a fire hazard.

problem 4

A system which has recently been changed from petroleum oil to an invert emulsion, has a problem with excessive rusting on the inside reservoir surface.

Explain the cause of the rust formation.

problem 5

On the night shift, a machine's hydraulic system was changed from petroleum oil to an invert emulsion. The day shift maintenance man knows that the viscosity of the petroleum oil was 150 SUS (32 CST) @ 100°F (37.7°C). He notices that the invert emulsion has a viscosity of 375 SUS (80.9 CST) @ 100°F (37.7°C). He feels someone has made a mistake.

Has a mistake been made? Explain.