



Property Risk Consulting Guidelines

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FIRE HAZARDS OF HYDRAULIC SYSTEMS

INTRODUCTION

Hydraulic systems use pressurized liquid to transmit mechanical force, power or motion. All hydraulic fluids in common use today are combustible. The fire hazard is as severe for a small freestanding system containing 10 gal (38 L) of fluid as it is for a large central system containing 1000 gal (3800 L) of fluid. Any amount of pressurized fluid escaping through a ruptured hose, gasket or pipe joint may atomize. If the fluid ignites, a serious torch fire will develop.

Industry frequently fails to apply known ways to prevent and control hydraulic system hazards. As a result, fires involving hydraulic equipment and combustible hydraulic fluids occur often.

This loss prevention guide identifies fire hazards associated with hydraulic fluids. It also explains how to reduce the hazards and how to protect the facility if an incident occurs. It does not cover machine tool cooling and lubricating fluid systems or systems that require kerosene or other low flash point fluids. Such systems may require additional protection.

The major considerations in hydraulic fluid system fire prevention and control are:

- Hydraulic fluid type.
- Piping system design, operation and maintenance.
- Systems interlock design.
- Housekeeping.
- Automatic fire protection system design.

DISCUSSION

Fluid power may use air or an inert gas (pneumatic systems), a liquid (hydraulic systems), or a combination of liquid and gas (hydropneumatic systems). This section will focus on hydraulic systems.

Early hydraulic equipment used water as a power and motion conductor, but water is a poor lubricant and corrodes machinery. Mineral oils soon replaced water. Oils perform well as hydraulic fluids; they lubricate well and actually help preserve machinery. Oils can be custom-blended for different uses, are inexpensive and readily available.

The wide range of fluid power system applications necessitates a variety of fluids to meet the requirements of any given system. Many different formulations of hydraulic fluids are available, and all of them represent some compromise from what might be considered an ideal fluid. Some qualities of hydraulic oils include volatility, foaming resistance, corrosion prevention, and compatibility. For

example, natural rubber cannot be used for seals in systems using petroleum oils and synthetic rubbers differ widely in their resistance to various fluids.

Most industries use hydraulic systems and hydraulically operated equipment. Nearly all metal and plastics forming equipment use hydraulic systems. Less obvious applications include aircraft flight simulators, controlled-crown press and calendar rolls in paper mills, elevators, fork lift trucks, glass working machinery, hydraulic couplings, mining equipment and valve actuators. The metal working industry may be the largest user of hydraulics.

Among the properties of importance in a hydraulic fluid are viscosity (i.e., resistance to flow), viscosity index (viscosity change relative to temperature change); pour point, compressibility, stability, lubricity, volatility, and compatibility.

Hydraulic fluids systems can range in pressure from 200 psi to 10,000 psi (14 to 690 bar).

Lack of adequate supports or anchorage to prevent vibration or movement of piping has been a factor in these failures. Repeated flexing and abrasion of rubber hose against other hose or parts of machines have created weak spots, which eventually resulted in rupture.

POSITION

Whenever possible, locate hydraulic systems and equipment in cutoff areas. Drain the areas to a safe location or provide curbs around the equipment to contain the fluid.

Convert existing hydraulic systems to less flammable hydraulic fluid systems whenever possible. Before converting, consult with the equipment manufacturer concerning needed changes to seals, gaskets, packings, filters, electrical wiring, painted surfaces, and other system components. Also determine how the new fluid will affect system pump, valve and actuator performance.

One year after retrofitting a system with a less flammable fluid likely to be more corrosive than the existing fluid, inspect all vessels internally to determine the corrosion rate, if any, and the time interval to the next inspection. In general, fluids containing water are likely to be more corrosive than those that do not. Ultrasonically survey vessels, which cannot be internally inspected. An ultrasonic survey will not be effective unless baseline readings are taken before the retrofit is completed.

Use less flammable hydraulic fluids in all new hydraulic systems where feasible and only use those fluids evaluated and listed by a nationally recognized testing laboratory.

Provide at least one manual emergency shutdown device for each system that can be actuated from a marked, accessible location that is remote from all hydraulic systems.

Consider the following when designing hydraulic systems:

- Avoid combustible piping or hoses.
- Use movable pipe connections instead of flexible hose whenever possible. If hose is used, it should be a metallic armored type or it should be enclosed in a second, larger, flexible metallic hose. Metal reinforced flexible rubber hoses are available and vary from a single strand of metal reinforcement to multiple layers of steel reinforcement inside the rubber hoses to fit various pressure applications. Non-armored type hoses should be rated for five times the maximum operating pressure.
- Install hose couplings and fittings in accordance with manufacturer's instructions.
- Design all piping and connections to resist damage from vibration and mechanical injury.
- Provide piping, hose, and connections that are suitable for the pressure involved and the type of hydraulic fluid used.
- Avoid the use of threaded pipe; use welded joints as much as possible to reduce the number of possible leakage points.
- For high-pressure operating systems the use of seamless-steel tubing over piping is preferred. Select tubing with a factor of safety of 6 to 10 or higher over normal operating pressure,

depending on the severity of the application (i.e. vibration, shock, pressure surges, possibility of physical abuse, etc.)

- Arrange system controls to shut down the system when abnormally low or high pressure, low reservoir level or excess flow occurs.
- Keep all hydraulically operated equipment and surrounding areas clean and free of fluid residue and combustible materials.
- Maintain and inspect all hydraulic systems regularly.
- Do not cut or weld in any area where hydraulic fluids are used until the area is free of all oil deposits and the system is shut down and depressurized.
- Locate potential sources of ignition, such as electrical switchgear, electric motors, hot surfaces and open flames away from hydraulic equipment. Shield any equipment that cannot be remotely located.
- For large central systems, and whenever practical, use detachment or shielding to protect electrical equipment from possible fires.

Pre-emergency planning should recognize the hazards of the hydraulically operated equipment and should include provisions for coping with a hydraulic fluid fire.

Less Flammable Hydraulic Fluids

Several hydraulic fluids with less hazardous properties have been developed. The listing agencies refer to these fluids as "less flammable" fluids even though very few listed hydraulic fluids are flammable by NFPA 30 definition. Less flammable hydraulic fluids are not fire resistive. All will burn under certain conditions; however, if less flammable fluids are properly maintained, they are much more difficult to ignite.

Four basic types of less flammable hydraulic fluids are in general use. The fluids, listed with their ISO 6743-4 classifications, are:

- High Water Base Fluids (HFA, HFAE, HFAS)
- Water-in-Oil Emulsions (HFB)
- Water Polymer Solutions (HFC)
- Synthetic Fluids containing no water (HFD, HFDR, HFDS, HFDT, HFDU)

The fluids have properties that require attention if they are expected to successfully replace a petroleum fluid in an existing system. When the fluids are used in new systems, the properties also affect how the systems are to be designed and maintained.

High Water Base Fluids (HFA) are divided into two categories: Oil-in-Water Emulsions (HFAE) and Chemical Solutions in Water (HFAS). They contain 70% or more water with soluble oils and synthetics added. HFA fluids may be corrosive under certain circumstances and may dissolve paints and coatings.

Pumps using HFA fluids generally have a lower life expectancy than pumps used with mineral oils. Fluid properties may affect the pump characteristics and the pumps may need special seals.

Water-in-Oil Emulsions (HFB) are 35% to 40% water dispersed as fine droplets in mineral oil. Emulsifying agents, anti-wear additives, and rust inhibitors are added.

HFB fluids must be carefully maintained, because ingredient proportions affect the hazard. When the fluids lose water, their combustibility increases. Emulsions can separate because of solvent or cleaning fluid contamination or prolonged drum storage. Temperatures above 150°F (66°C) or below 50°F (10°C) or excess pressure can damage emulsions. The manufacturer's instructions must be strictly followed.

Pumps using HFB fluids may have a lower life expectancy than pumps using mineral oils. Fluid properties may affect the pump characteristics.

Water Polymer Solutions (HFC) are glycol, polyglycol or water-glycol solutions containing 35%–50% water. When they are exposed to heat or flame, the water forms a steam blanket and suppresses combustion. When water polymer solutions lose water, their combustibility increases, but their viscosity increases faster and causes the system pumps to overload and shut down before the fluid becomes a high fire hazard.

HFC fluids may attack magnesium, cadmium and zinc. Because they attack aluminum to a lesser degree, aluminum parts should be anodized. Magnesium, cadmium and zinc should not be used. HFC fluids dissolve most paints and varnishes. Their additives reduce corrosion and wear and adjust the viscosity. Ethylene glycol or propylene glycol improves the low temperature properties.

Pumps using HFC fluids have a lower life expectancy than those using mineral oils. HFC fluids have a higher specific gravity, which may affect pump characteristics.

Synthetic Fluids containing no water (HFD) include those fluids based on chlorinated hydrocarbons (HFDS), phosphate-esters (HFDR), a mixture of phosphate-esters and chlorinated hydrocarbons (HFDT), and other compounds (HFDU). HFD fluids are homogeneous compounds with stable characteristics.

HFD fluids are strong solvents and require special seals. Paints, other coatings and insulation used in and around HFD systems must be able to resist HFD fluid damage. HFD fluids should not affect pump life expectancy.

Hazards

All commonly used hydraulic fluids except water are combustible or can become combustible. Petroleum-based fluids present the most serious hazard. Their flash points range from 300°F to 600°F (149°C to 316°C) and auto ignition temperatures range from 500°F to 750°F (260°C to 399°C). When these fluids discharge under pressure in a fine mist, they ignite easily, burn rapidly, and emit large quantities of heat. In fact, their heats of combustion, which are over 18,000 Btu/lb (2327 kJ/kg), are comparable to fuel oil.

Table 1 gives a sample of various FM approved hydraulic fluids and their respective flash points and auto ignition temperatures versus those of petroleum based oils. ISO 7745-12 (E) provides additional guidance.

TABLE 1
Comparison Of Petroleum Based Vs. Less Hazardous Hydraulic Oils

Test Method	Petroleum Based Hydraulic Oils	Approved Less Hazardous Hydraulic Oils
Flash Point Range	300 – 600°F	None. Not applicable
Auto Ignition Temperatures	500 – 750°F	752 – 1030°F

SI Units: 1 °F= (°C x 9/5) + 32

Fire Protection

Provide automatic sprinklers in all areas containing hydraulically operated equipment, hydraulic systems, or hydraulic piping. Sprinkler systems should extend to all areas, including pits that would be damaged by hydraulic fluid release or hydraulic fluid fire. The “torch effect” should be considered. In general, automatic sprinkler protection should extend not less than 50 ft (15 m) in all directions from the hydraulic equipment and hydraulic fluid piping.

Design sprinkler protection for areas containing combustible hydraulic fluids not listed as less flammable for Extra Hazard (Group 1). Use at least 5000 ft² (465 m²) when 165°F (74°C) rated sprinklers are used. The area of application can be reduced to 3000 ft² (279 m²) when 286°F (141°C) rated sprinkler heads are used. In either case, increase the area of application by 30% when using dry pipe systems.

Areas containing 'limited' amounts of combustible hydraulic fluids may be protected as Ordinary Hazard (Group 2) if they meet the following criteria:

- The fluids are confined to freestanding systems on individual machines.
- No system contains more than 50 gal (189 L) of fluid.
- The ceiling height, machine spacing and lack of surrounding combustible materials make it unlikely that flame will spread from one machine to another.
- Good housekeeping and sound maintenance are provided.

Design sprinkler protection for areas containing 'less flammable hydraulic fluids' for Ordinary Hazard (Group 2).

Provide proper type fire extinguishers and hose stations for the hydraulically operated equipment and surrounding building areas. Hose stations should have 1 in. (25.4 mm) connections and 100 ft (30.5 m) of 1½ in. (38 mm) fire hose. Locate hose stations at 100 ft (30.5 m) intervals in all areas the system occupies, including large pits or basements, and at all entrances to pits and basements.

Provide at least 500 gpm (1890 L/min) for hose stream use. Design the water supply to meet the sprinkler and hose demand for at least three hours.

Ensure pits drain to a safe location, and drained fluids will not cause environmental problems. Using foam-water systems in pits may reduce or eliminate drainage problems by reducing the volume of agent necessary to control a fire.

Special Extinguishing Systems

Waterspray and/or carbon dioxide protection may be warranted for high hazard, high value machinery. Design these systems in accordance with applicable NFPA and AXA XL Risk Consulting Guidelines. Extra fire protection may also be needed where hydraulic system components are shielded from the ceiling sprinklers and when equipment surfaces are near or above the hydraulic fluid flash point.

Turbine, compressor and generator hydraulic systems may require waterspray protection. Design fire protection for these systems in accordance with NFPA 850, NFPA 851 and NFPA 15.

System Design, Operation and Maintenance

Design hydraulic system vessels and piping to contain the system pressure under all possible operating conditions.

Protect systems against overpressure with at least two independent methods. One method should be a relief valve or rupture disk located where each pump or other pressure source discharges.

Avoid threaded connections by using welded or bolted-flange connections when possible. If using threaded connections, prepare and assemble them according to a written procedure that will assure sound and leak-free joints. Consider seal-welding threaded joints.

Brace piping and other components to avoid stressing joints, especially if tubing or threaded pipe is involved.

Design piping systems to prevent fatigue failures. Machine operation or startup/shutdown causes low cycle fatigue. Vibration causes high cycle fatigue. Flexible piping joints or resilient bracing may be needed.

Protect piping from impact damage caused by vehicles, machine parts or other external loads.

Strictly control quality when assembling a hydraulic system to minimize hazards. Use approved assembly techniques. Document the steps necessary to produce sound joints and, if possible, provide gauges to allow inspection of the following operations:

- Cutting pipe threads.
- Making up threaded connections.
- Flaring tubing.
- Fitting up patented fittings (Swagelok™, etc.)
- Applying connectors to hose ends.
- Assembling flanged connections.

Thoroughly train operators in normal procedures; emphasize procedures needed to control machine pressure, stress and vibration. Regularly drill operators in emergency operating procedures, particularly rapid shutdown and depressurizing, spill control and fire control. Reinforce rules for housekeeping and leak detection and control.

Make periodic inspections to prevent leaks. The operators may perform the following daily and shift inspections:

- Inspect all joints daily before startup and at least once during each shift. Look for cracks in tubing or in threaded pipe connections and splits next to flared connections. Inspect hoses for cracks, abrasions or other signs of distress. Also, look for hoses moving from their end couplings.
- Inspect and test relief valves and other overpressure protection devices.
- Inspect and maintain pumps, valves and seals in accordance with the manufacturer's recommendations. Look for leakage daily and repair leaks promptly.

Maintenance staff should also perform routine inspections for leaks every week and more frequently inspect adverse conditions such as chaffed hoses or leaking joints.

Additional recommendations to prevent leaks include:

- Maintain a leakage log. Summary information about leaks can help the purchasing department, equipment designers and manufacturers to avoid poorly performing seals or joints.
- Ensure worn or damaged hose and piping are replaced with material suitable for the service. Pressure and temperature ratings and fluid compatibility are important.
- Standardize fittings used at a facility. Many different "standard" connectors, O-rings and other fittings are available. Some cannot be identified visually, even when placed next to fittings made to a different standard. Mixed fittings can often be assembled, but most "hybrid" connections will leak.
- Do not reuse O-rings or other seals.

Inspect pressure vessels internally every five years, unless the corrosion rate or jurisdictional requirements require more frequent inspections. If internal inspection is impossible, use ultrasonic thickness testing. Cast, forged, layered, wire-wrapped and other special vessels and vessels operating at more than 500 psi (34.5 bar) may require more frequent inspection or advanced inspection techniques. Refer to the manufacturer's recommendations.

System Interlocks

Hydraulic systems have a variety of controls, transducers and interlocks to provide alarms or relief paths to sumps, to bypass pumps or to otherwise keep system pressure within design limits. For most systems, interlocks can also be designed to minimize the volume of fluid pumped to a large leak.

To use interlocks to prevent excess pressure, make sure the maximum rate of system pressure rise is slow enough for an interlock to detect the condition and shut down the pressure source before a

serious condition develops. If an interlock cannot reliably protect any part of a system from overpressure, install an additional relief valve, a rupture disk or other device in that part of the system.

Two types of interlocks can be provided to minimize fluid supply to a rupture, and they may be applied to most systems. One shuts down the fluid supply in case of abnormally low system pressure. The other shuts down the fluid system in case of excess flow.

Both interlocks may require time delays to prevent nuisance trips when the system starts or during initial system fill or during loading cycles when there is little resistance to machine movement. Such interlocks may be designed to respond to different flows and pressures at various points in a large system.

Two other system shutdown interlocks may be useful to limit fluid supply to a fire. Devices may be needed to detect:

- Sprinkler system waterflow.
- Excess temperature or rate-of-temperature-rise above the equipment.

Note: Concern has been expressed that rapid shutdown of equipment in the midst of an operating cycle could cause further damage and/or business interruption. A programmed/delayed shutdown of equipment should be considered, provided additional oil release can be minimized where such circumstances can be shown to exist.

Housekeeping

Even with excellent maintenance, hydraulic fluid leaks are difficult to avoid. The following recommendations apply:

- Provide drip pans under seals and joints where leakage cannot be eliminated. Use curbs or dikes to contain spills in areas where spills are likely.
- Fully depressurize, isolate, lock out and, if possible, drain any portion of the system that is to be opened.
- Promptly remove and replace any thermal or electrical insulation that becomes soaked with fluid.
- Clean up all spills promptly and ensure all resulting fluid residue is removed. Leakage from high pressure lines may atomize and spread far from the leak.
- Minimize storage or use of combustibles, such as cardboard boxes and wooden forms and pallets, near hydraulic systems. Never allow rags or other combustible waste materials to accumulate.