INTERNATIONAL

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Standard Practice for Cleaning, Flushing, and Purification of Petroleum Fluid Hydraulic Systems[1]

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1. Scope*

1.1 This practice covers aid for the equipment manufacturer, the installer, the oil supplier and the operator in coordinating their efforts towards obtaining and maintaining clean petroleum fluid hydraulic systems. Of necessity, this practice is generalized due to variations in the type of equipment, builder's practices, and operating conditions. Constant vigilance is required throughout all phases of design, fabrication, installation, flushing, testing, and operation of hydraulic systems to minimize and reduce the presence of contaminants and to obtain optimum system reliability.

1.2 This practice is presented in the following sequence:

[1] This practice is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of D02.N0 on Hydraulic Fluids.

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***A Summary of Changes section appears at the end of this standard**

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate ~~safety~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
D664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration
D974 Test Method for Acid and Base Number by Color-Indicator Titration
D1774 Test Method for Elastic Properties of Textile Fibers (Withdrawn 2000)[3]
D2709 Test Method for Water and Sediment in Middle Distillate Fuels by Centrifuge
D4006 Test Method for Water in Crude Oil by Distillation
D7042 Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)
D7546 Test Method for Determination of Moisture in New and In-Service Lubricating Oils and Additives by Relative Humidity Sensor
D7647 Test Method for Automatic Particle Counting of Lubricating and Hydraulic Fluids Using Dilution Techniques to Eliminate the Contribution of Water and Interfering Soft Particles by Light Extinction
F311 Practice for Processing Aerospace Liquid Samples for Particulate Contamination Analysis Using Membrane Filters
F312 Test Methods for Microscopical Sizing and Counting Particles from Aerospace Fluids on Membrane Filters
F313 Test Method for Insoluble Contamination of Hydraulic Fluids by Gravimetric Analysis (Withdrawn 1988)[3]

2.2 *ANSI Standards:*

B93.2 Glossary of Terms for Fluid Power[4]
B93.19 Method for Extracting Fluid Samples from the Lines of an Operating Hydraulic Fluid Power System (for Particulate Contamination Analysis)[4]

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

3. Terminology

3.1 *Definitions:*

3.1.1 *nominal filtration rating*—an arbitrary micrometre value indicated by a filter manufacturer. Due to lack of reproducibility this rating is deprecated. (ANSI B93.2)

4. Significance and Use

4.1 Proper fluid condition is essential for the satisfactory performance and long life of the equipment. Prerequisites for proper lubrication and component performance are: (*1*) a well-designed hydraulic system, (*2*) the use of a suitable fluid, and (*3*) a maintenance program including proper filtration methods to ensure that the fluid is free of contaminants. These prerequisites are meaningless unless the hydraulic system is initially cleaned to a level that will prevent component damage on initial start up or when debris may be dislodged by any system upset.

4.2 The cleaning and flushing of both new and used systems are accomplished by essentially the same procedure. In new systems, the emphasis is on the removal of contaminants introduced during the manufacture, storage, field fabrication, and installation. In used systems, the emphasis is on the removal of contaminants that are generated during operations, from failures that occur during operation; or contaminants introduced during overhaul. Both new and used systems may benefit from high velocity flushing to remove materials that can collect in hard to drain pockets or normally non-wetted surfaces.

4.3 While the flushing and cleaning philosophies stated in this practice are applicable to all primary and servo hydraulic systems, the equipment specified herein does not apply to compact systems that use relatively small volumes of fluid unless they are servo systems where it is economically justified.

4.4 It should be emphasized that the established procedures to be followed for flushing and cleaning the hydraulic systems should be accomplished through the cooperative efforts and agreement of the equipment manufacturer, the installer, the flushing service vendor, the operator, and the fluid supplier. No phase of these procedures should be undertaken without a thorough understanding of the possible effects of improper system preparation. The installation and cleaning and flushing of the equipment should not be entrusted to persons lacking in experience.

5. Types of Contamination

5.1 *General*—Hydraulic systems can become contaminated from a variety of sources. Generally, there are five categories of contamination: (*1*) water, (*2*) fluid soluble material, (*3*) fluid insoluble material, (*4*) erroneous fluid additions, and (*5*) hydraulic fluid deterioration. Properly designed systems can normally control water and insoluble contaminants; however, when it is necessary to remove soluble contaminants, a fluid change and flush are required.

5.2 *Water*—Water is almost always present in hydraulic fluids. It may be present in solution or in a free or emulsified form. Water can exist in solution at varying concentrations depending on the nature of the fluid, the temperature, and so forth. For example, hydraulic fluid may hold 50 ppm of water at 21 °C (70 °F) and 250 ppm at 71 °C (160 °F). The water in solution has no adverse effect on lubricating properties of the fluid and causes no corrosion; however, when fluid passes through a cooler some water may come out of solution and become free water in the form of finely dispersed droplets. Many contaminants hinder the separation of this free water from the fluid by settling and may cause an emulsion. In hydraulic fluids, the emulsion impairs circulation, interfere with lubrication and adversely affect contamination control equipment.

5.2.1 Water contamination can be classified as either fresh or sea water, as encountered in land or marine systems. Fresh water enters the hydraulic system from moist air as condensation, through improperly located vents, leaks in coolers, and steam heaters, and because of improper operation. Sea water, in marine hydraulic systems, enters through leaks in coolers, faulty manhole gaskets, faulty sump tank seals and improperly located vents. Sea and brackish water can also present a problem when used as a coolant in land-based units. Water contamination in hydraulic fluids can:

5.2.1.1 Promote fluid oxidation.

5.2.1.2 Reduce fluid stability.

5.2.1.3 Promote sludge.

5.2.1.4 Promote foaming.

5.2.1.5 Form emulsions.

5.2.1.6 Promote rusting and corrosion.

5.2.1.7 Cause additive depletion and drop-out.

5.2.1.8 Adversely affect lubricating properties.

5.2.1.9 Promote bacteria growth.

5.2.1.10 Alter fluid viscosity.

5.2.1.11 Adversely affect fine filtration (that is, excessive back pressure).

5.2.1.12 Promote cavitation.

5.2.2 In the case of severe salt water contamination, it is necessary to remove the operating fluid and clean and flush the hydraulic systems.

5.3 *Soluble Contaminants:*

5.3.1 Soluble contaminants in hydraulic systems include cleaning chemicals, solvents, rust preventives, incompatible lubricants, flushing oils, extraneous oils, oxidation products, gasket sealants, and assembly lubricants. These contaminants cannot be removed by conventional fluid contamination control equipment. Normally, a new charge of fluid accompanied with a displacement flush oil is required to correct the problem. Fluid soluble contaminants can:

5.3.1.1 Change the fluid viscosity.

5.3.1.2 Alter the flash point.

5.3.1.3 Change the color.

5.3.1.4 Result in sludge deposits.

5.3.1.5 Attack elastomeric seals.

5.3.1.6 Initiate additive-water interaction that can cause emulsification, possible additive loss, instability, impaired purification equipment performance, foaming, and air entrainment.

5.3.1.7 Accelerate oxidation.

5.3.2 When a soluble contaminant is present, the fluid supplier and he equipment manufacturer should be consulted regarding the advisability of continued use of the fluid or replacing it with a new charge.

5.4 *Insoluble Contaminants:*

5.4.1 Insoluble contaminants normally encountered are metal particles (including rust) of all types and sizes, fibers, airborne solids, sand, and other nonmetallic particles. These contaminants are often the result of improper manufacturing techniques, improper shipping and storage practices, and careless installation of hydraulic systems. Some of the effects of solid contamination are:

5.4.1.1 Abrasive wear or sticking of components such as: control valve poppets, cylinders, piston rods, and seals.

5.4.1.2 Faulty control functioning, particularly plugged fluid lines/filter plugging.

5.4.1.3 Reduced fluid stability.

5.4.1.4 Sludge formation.

5.4.1.5 Increased foaming tendency.

5.4.1.6 Stabilized water-oil emulsions/accelerated oxidation by catalytic effect of metal particles.

5.4.2 Harmful contamination can exist in the hydraulic system in two forms:

5.4.2.1 *Lodged Contamination*—These contaminants may become dislodged by high fluid flows and temperature differentials or by induced vibration during flushing. Contamination can be lodged in unflushed pockets or settled on the bottom of tanks. Unless this contaminant is removed, it becomes dislodged during startup or during system upsets. Experience, good judgement, and careful inspection by the installation supervisor must be relied upon to determine when such dirt has been satisfactorily removed.

5.4.2.2 ~~*Suspended or Loose Contamination:*~~ *Suspended or Loose Contamination:*

5.4.2.3 Contaminants suspended in the fluid can be generated by particles coming loose from pipe, hose, hydraulic components, tank walls generally caused by high fluid velocity, wear debris, and vibration. Suspended contaminant can be measured, as described in 11.3 and 11.4. To prevent the level of suspended contaminant from getting beyond acceptable limits, hydraulic system filtration can be augmented with a bypass contamination control system (fluid filter or centrifuge). Preferably a full flow filter or a full flow filter plus bypass purification is provided. When a full flow filter is used, a bypass purification system may not be required.

5.4.2.4 The bypass or full flow system, or both, can be in operation during the flush operation as well as on a continuous basis during hydraulic system operation. High-velocity flushes will require appropriately sized full flow filters. The rated flow capacity per hour of a bypass system should be 10 to 20 % of the total system fluid volume.

6. Contamination Control

6.1 *General*—Contamination control in a hydraulic system is the complete program of monitoring and maintaining a clean fluid. Contamination control must begin with the design, manufacture, and installation of the hydraulic system and continue throughout the life of the system. When making inspections or working in or around a unit, care must be taken to prevent contaminants from entering the system. When work that generates contaminants is being performed in the vicinity of the hydraulic system, the system components must be protected even to the extent of suspending operations, and requiring system components to be sealed until the contaminating activity has ceased. The contamination control system must be capable of removing water and particulate matter consistent with contamination tolerance and system cleanliness requirements.

6.1.1 *Initial Filling*—When initially filling the hydraulic system, fluids are to be filtered through filters rated from 3-µm to 10-µm (as needed) with a beta ratio >1000 as they are being transferred into the reservoir. The contamination control system is ready for operation prior to the hydraulic system fill and is operating throughout flushing. See Section 9.5 for new installation flushing details.

6.1.2 *In-Service Units*—The contamination control system is in operation as long as the hydraulic system is in service. Its operation is frequently and regularly monitored to assure that it is performing adequately and to determine the need for its maintenance.

6.1.3 *Connection of Contamination Control System*—The external fluid take-off from the circulating system to the contamination control system is from the lowest point of the fluid sump or reservoir, to facilitate removal of solid contaminants and water.

6.1.3.1 Piping between the reservoir and the contamination control system is designed to minimize the potential for the loss of fluid that results from piping or equipment failure. This means short runs and the fewest possible joints. Piping is sized so as to provide sufficient flow velocity to carry water and dirt to the contamination control system.

6.1.3.2 The fluid return line to the reservoir is located as far removed as possible from the take-off for the contamination control system. The return line must contain suitable means to prevent back flow or siphoning and terminate below the fluid level. To prevent loss of fluid through back flow, auxiliary connections are provided for oil supply from and to station storage tanks. Fluid sampling valves with suitable locking devices are provided before and after the filtration system.

6.1.3.3 Instrumentation such as a differential pressure gage and an alarm is provided with the filters to enable the operator to determine if the contamination control system is functioning properly and also to signal or indicate the necessity for changing or cleaning various filter elements. This is particularly important in automated systems.

6.1.3.4 Filters that never increase differential pressure can be as much as concern as a high differential pressure. This could indicate improper installation or damaged filter allowing bypass.

6.1.3.5 When severe emulsification with water occurs, raise the fluid temperature for a limited time (less than 2 h) to a maximum of 82 °C (180 °F) to facilitate breaking of the emulsion. Prolonged operation above 82 °C (180 °F) may prematurely oxidize the hydraulic fluid.

6.1.3.6 Overheating of the hydraulic fluid can cause cracking that can result in severe viscosity reduction. This can be prevented by maintaining heater skin temperatures below 121 °C (250 °F), and ensuring that fluid hydraulic pumps are operated during heating. Ensure that the steam heating pressure is less than 34.5 kPa (5 psig). Experience has shown that a safe watt density for electrical heaters is 0.77 W/cm^2 (5 $W/in.^2$). Higher densities up to 3.1 W/cm^2 (20 $W/in.^2$) have been used with adequate circulation to avoid exceeding the allowable heater skin temperatures indicated above. Temperature controls are installed to maintain these maximum levels. At all times, heating elements must be totally immersed, a fluid level control will provide adequate protection. Control heating of the oil so as not to go below the minimum in fluid viscosity recommended for the pumps.

6.1.4 *Piping or Tubing Contamination Control System*—The interconnecting piping or tubing and contamination control system must be as clean as the initial hydraulic system. The bypass contamination control system, when present, is piped separately with no connection to the hydraulic fluid piping or tubing. It should be designed so that the contamination control system can take suction from and discharge to any of the following: (Safeguards are provided to prevent fluid being drained below minimum fluid level in the sump).

6.1.4.1 Main hydraulic reservoir.

6.1.4.2 Storage tank.

6.1.4.3 Auxiliaries, see details in following section.

6.1.5 Bypass contamination control system suction and discharge piping or tubing size is sized for turbulent flow at all times and based on the capability of the filtration device. Piping includes: bypass around fluid heater, pressure relief valves on inlet and outlet pumps, sample cocks on fluid inlet and outlet, and check valves and stop valves as required. A drain line is installed from the water removal equipment to a sludge tank or dirty fluid tank.

6.1.6 The suction lines from any reservoir or tank are situated at the lowest point to facilitate removal of solid contaminants and water. Piping between systems should be designed to minimize fluid loss by sloping the lines in the direction of flow for proper drainage.

6.1.7 Fluid return lines to reservoirs should be as far as possible from the take off line and discharge below the normal fluid operating level. The lines contain a sight flow glass near the reservoir.

6.2 *Contamination Control Procedures*—Contamination control systems normally employ one or more of the following procedures to assure the most efficient removal of water and solid contaminants.

6.2.1 *Full-Flow Contamination Control*—The most effective means of maintaining clean fluid is by full flow treatment while the fluid is being circulated during flushing and during normal operation of the unit. This method is capable of removing solids rather than water since the equipment is a full flow (filter/strainer). When water contamination is present, it can normally be controlled by a bypass type system.

6.2.2 *Bypass Contamination Control:*

6.2.2.1 In a bypass mode, a portion of the fluid is continuously withdrawn, the contaminants are removed and the fluid then returned to the reservoir. Continuous bypass although less efficient than full flow, is preferred over batch filtration because the system can continue in operation even though the hydraulic system has been shut down. When a centrifuge, dehydrator, or coalescer is used, both water and solid contaminants are removed although the presence of particulate matter will reduce the water removal effectiveness of the coalescer. Thus, the bypass system is the primary system considered over batch purification.

6.2.2.2 The capacity of a bypass system is at least 10 % to 20 % of the total fluid circulation flow rate.

6.2.2.3 The contamination control system should be capable of maintaining particulate matter and free water contamination below limits established for the system by the equipment manufacturer.

6.2.3 *Batch Contamination Control:*

6.2.3.1 Batch methods are generally employed for filtering fluid in the storage system. However, when severe fluid contamination is observed in a storage tank, appropriate valving for the use of a continuous bypass device (perhaps portable) is recommended. The source of contamination in the system is located and corrected.

6.2.3.2 When the fluid storage tank is likely to encounter low temperatures, a prescribed heater will be required. This is to heat the fluid to obtain a suitable viscosity for the filtration system and for operation of the hydraulic pumps. (**Warning—**Proper controls must be provided to avoid overheating of noncirculated fluid.).

6.3 *Contamination Control Processes—*The basic methods for removal of contaminants are gravity, centrifugation, and mechanical filtration.

6.3.1 *Gravity:*

6.3.1.1 Gravity purification can only separate out contaminants that are heavier than the fluid. The rate of separation is dependent on viscosity of the fluid, particle size and specific gravity of the contaminants, and quiesence of the fluid. Gravity separation is often accomplished during quiescent fluid storage and must be supplemented by one or more of the other contamination control methods.

6.3.1.2 A method for reducing the contaminant load on filters is to heat the fluid in a tank and allow the solids and the water to settle. This settling tank should be equipped with low-pressure steam heating coils or low-watt density electrical resistance heaters of designated size and a drain that terminates in a waste fluid tank. The settling tank is connected to the contamination control system suction and discharge lines. This settling tank is equipped with a drop line to the hydraulic sump, or reservoir and the valve on this line is locked closed. The capacity of the settling tank should be sufficient to hold the entire operating charge. Settled material can be more readily removed from gravity tanks, when the tanks are provided with sloped, conical, or vee bottoms.

6.3.2 *Mechanical:*

6.3.2.1 *Centrifuge—*Centrifugation is a means of separating fluids of different density and removing solid contaminants from fluids by utilizing centrifugal force developed by rotating the fluids at a high speed. For hydraulic fluid, the degree of separation is dependent upon the flow rate, viscosity of the fluid and the density of the solids and specific gravity of the fluid contaminants. Commercial units are sized to attain a specific level of separation. Clean fluid and separated water are continuously discharged automatically by the centrifuge; sludge and solid contaminants remain in the centrifuge bowl and are periodically removed manually, or automatically, as in the self-cleaning type centrifuge. These units are commonly called purifiers or clarifiers. With centrifugal purifiers, the solids and water are removed so they are no longer in contact with the fluid that reduces the self catalyzing effects on oxidation.

6.3.2.2 *Filters—*Mechanical filters remove solid contaminants by passing fluid through restrictions that trap the solid particles. Depending upon the choice of filter media, particles as small as or less than one micrometre can be removed. As contaminants are removed and collected on the filter element, the pressure drop across the filter increases, ultimately requiring replacement or cleaning of the elements.

6.3.3 *Supplementary Methods—*Supplementary methods for contamination control are coalescers, vacuum dehydration, and adsorption (for descriptions of these methods see 12.3, 12.4, and 12.5). Contamination control by the preceding methods can, under certain conditions, deplete the hydraulic fluid additives.

6.3.4 *Limitations of Contamination Control Devices—*Centrifuges are gravity related and effectiveness is dependent upon particle size and density and gravitational force developed. Most mechanical-type filters are ineffective for water removal. Coalescers are designed primarily for water removal and are limited by the solid contamination, viscosity, and surfactants in the fluid. Vacuum dehydrators and air stripping have low single-pass water removal efficiency. Certain types of adsorbents can affect the fluid's chemical composition and should only be used after verification.

7. Storage

7.1 *General:*

7.1.1 During storage, protect all components from rust, contaminants, and damage as much as possible. Undercover storage with proper vent breather filers is recommended. Monthly inspections are recommended, and corrective steps must be taken when found necessary. Take care during inspections to minimize disturbance of equipment protection.

7.1.2 The protection of all uncoated components requires that an application of some type of rust preventive be used to protect ferrous surfaces from corrosion during the storage and installation phases. Remove the preservative compounds by flushing the system with regular hydraulic fluid or oil solvent, although hand cleaning of some components is also used. However, the flush oil and preservative must be compatible to preclude foaming, the formation of emulsions, or the breakdown of hydraulic fluid additives. Once the rust preventive is removed, the ferrous surfaces are subject to rust unless care is taken to keep all surfaces oil-wetted. To lessen these undesirable effects vapor space inhibited (VSI) oils can be used. The general requirements for the use of the vapor space inhibited oils are:

7.1.2.1 Wet all surfaces with vapor space inhibited oils after cleaning.

7.1.2.2 Do not drain but add sufficient oil to provide a reservoir of the oil in the assembly.

7.1.2.3 Seal the component to prevent loss of vapor phase protection and intrusion of contaminants.