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:

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

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[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**

1.4 *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, health, and 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

D1744 Test Method for Determination of Water in Liquid Petroleum Products by Karl Fischer Reagent (Withdrawn 2016)[3]

D2709 Test Method for Water and Sediment in Middle Distillate Fuels by Centrifuge

D4006 Test Method for Water in Crude Oil by Distillation

D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants

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]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this practice, refer to Terminology D4175.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *nominal filtration rating, n*—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,

[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.

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:*

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.

7.1.3 Most of these VSI oils are fully compatible with regular hydraulic fluids and flushing oils, and draining or removal may not be necessary. However, follow the oil manufacturer's recommendation. In addition, it has been shown that these oils will provide some residual protection to the system and lessen corrosion after the oils have been drained or displaced.

7.1.4 These VSI oils are available in a range of viscosities. However, when an oil of significantly higher viscosity than the flushing oil is used, draining of the assembled system to limit the amount of the higher viscosity VSI oil to 10 % is recommended to prevent significantly increasing the viscosity of the flushing oil.

8. Inspection

8.1 *General:*

8.1.1 All components of the hydraulic system that are fabricated and assembled at a manufacturer's facility and received as unit for installation in the system are defined as preassembled components.

8.1.2 Inspect the preassembled components upon receipt to determine condition and degree of protection. All seals and caps intended to exclude moisture and dirt are checked for integrity and replaced as required. When the initial or subsequent inspection discloses dirt or rusting, the item is immediately cleaned, represerved, and sealed as required. Due to the variety of equipment and materials, details to cover each case cannot be specified. For painted (coated) components, the coating is inspected for integrity and renewed as necessary.

8.2 *Systems Components:*

8.2.1 *Valves, Strainers, and Coolers*—Inspect valves, strainers and coolers, when received from the manufacturer, for contamination. When there is evidence of hard film protective coating or contamination, the unit should be dismantled and all the parts thoroughly cleaned with a petroleum solvent or oil soluble cleaner. In all cases, use clean rags (not waste cloths).

8.2.1.1 Internal surfaces that cannot be reached are flushed with a petroleum solvent or oil soluble cleaner. (**Warning—** Combustible. Skin irritant on repeated contact. Aspiration hazard.)

8.2.1.2 After internal surfaces have been cleaned, they must be thoroughly dried with moisture-free air. All cleaned surfaces are coated immediately by spraying them with an oil supplier approved rust-preventive oil, vapor space inhibitor, or suitable lube oil. After all surfaces have been coated, reassemble the equipment and cap all openings.

8.2.2 *Sumps and Tanks*—Thoroughly inspect sumps, reservoirs, or tanks. Manually remove rust, mill scale, weld spatter, loose paint, etc. Apply a coating of rust-preventive oil, or a vapor space inhibited oil, and seal all openings. Repainting is not recommended.

8.2.3 *Control Devices*—It is important that control devices be installed by qualified personnel. Extreme care is taken to prevent accidental contamination to these devices. Prevent accidental contamination of the associated piping during installation.

8.2.4 *Pumps*—Prior to assembly and installation, inspect pumps for the presence of hard film coatings or contamination. When such coatings or contaminants are present, thoroughly clean and coat the pumps with rust preventive or vapor space inhibited oil.

9. Flushing Program

9.1 *General*—For a unit that is field assembled, keeping the hydraulic system piping or tubing clean enough so that flushing is not necessary is economically and practically impossible. Thus, it is generally recognized that an oil flush must take place after the piping or tubing has been installed but before the system goes into operation. However, the success of this oil flush depends on: (*1*) the success of the efforts to keep dirt out initially, and (*2*) the proper conduct of the flush (the subject of this procedure). A successful flush means that clean pipe and system components are obtained with minimum time and effort. The cleaning and flushing of both new and used systems are accomplished by essentially the same procedure. New systems will often benefit from high velocity flushing. 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 by failures that occur during operation, or introduced during operation or overhaul. Do not flush through valves, bearings, or other critical components. Use inspected clean bypasses. Tight clearances in the system and any flow orifice should always be removed to promote turbulent flow conditions, allowing faster flushing time.

9.1.1 A successful flush should keep the dirt out is achieved by the cooperation and diligence of many parties. Examples of these efforts are listed as follows:

9.1.1.1 Design system to allow successful cleaning.

9.1.1.2 Properly clean and preserve the piping or tubing and other equipment.

9.1.1.3 Durably cover and secure for storage prior to shipment and loading all possible locations for the entrance of dirt (pipe or tubing ends). Shipment and unloading must take place without damage to these covers.

9.1.1.4 Inspect pipe or tubing at the installation site thoroughly to discover any damaged or open covers and have them repaired.

9.1.1.5 Store prior to installation in a sheltered location especially when the storage is to be for long duration.

9.1.1.6 Inspect thoroughly immediately prior to installation, and clean the pipe or tubing when excessive rust or dirt is discovered.

9.1.1.7 Continuously monitor conditions during the complete hydraulic system installation to assure that cleanliness-related tasks are being accomplished. Take measures not to introduce dirt into the pipes or tubing and equipment.

9.1.1.8 Prevent contaminant entry during any modifications.

9.1.1.9 Keep work area clean.

9.1.2 The list is not complete but it does illustrate that the manufacturer, the shipper, the installer and the operator all have a hand in ensuring that contaminants generated or entering the piping or tubing is minimal. These efforts to prevent the entrance of contaminants will make the flushing procedure easier, safer, and shorter and thus less costly.

9.1.3 The success of oil flushing also depends on the ability of the hydraulic pump to provide a large flow rate (high velocity flush) thus giving a turbulent flow within the system (see 9.1.5, Note 1). The use of outside pumps is recommended when necessary, to achieve this flow. Oil temperature, oil temperature cycling, vibration, etc., all contribute to the success of an oil flush. However, high oil velocity (two to three times normal system velocity) utilized in a correctly sequenced flush, is by far the most important ingredient to a successful flushing procedure as prescribed in this practice.

9.1.4 Loosening of solids will be promoted by hammering or vibration, at pertinent points in the system. Once the solids are broken loose, they will either settle in the main oil tank, be caught by temporary screens, or filtered out by the user's bypass or full-flow filtration system.

9.1.5 However, it is impractical to flush through certain systems or devices that are assembled, cleaned and sealed in the factory before shipment. Protect such equipment carefully against intrusion of contaminants, and in this flushing procedure, blank off or bypass such equipment until the other systems are clean.

NOTE 1—A turbulent flow in a long tube will be maintained when the Reynolds number is in the 4000 to above 20 000 range, depending on OEM recommendations.

9.1.6 Even for the assemblies that can be flushed thoroughly, the prescribed flushing procedure does not have the ability to flush out any and all conceivable kinds of contaminants. Much adverse experience testifies to this. Therefore, during the entire system installation process, take preventive measures to exclude impurities that cannot be easily removed by the flushing of the fluid systems.

9.1.7 Such contamination when dislodged by system vibration or operational effects will cause problems in subsequent operations.

9.1.8 The knowledge that an oil flush will be performed before startup must not be allowed to lead to the concept that contaminants entering the fluid system are not harmful because "they will all be removed by the flush."

9.1.9 Secondary bypass filtration is recommended to circulate on system reservoir during a high velocity flush and at time of start-up.

9.2 *Preparation of System for Flushing:*

9.2.1 *Inspection*—Prior to the flushing operation, thoroughly inspect all accessible areas of the hydraulic system. When the slightest evidence of contamination is encountered, it should be removed manually. Make final inspection for welding spatter or material that may break loose and contaminate the system with metallic particles. If found they should be completely removed. It must be emphasized that if thorough inspection of all surfaces shows contamination, it must be removed prior to charging the system with flushing oil.

9.2.2 The system should be inspected and any temporary humidity control devices that may have been placed in the system for interim protection before flushing should be removed. The state of cleanliness of a system is always questionable, and therefore, all leads to cylinders and motors must be blanked off as closely as possible to the parts they serve. Jumpers have to be installed to bypass all actuators but install them as to bypass as little of the piping and flow passages as possible. Blank off all other areas in the system that are not to be flushed with the use of numbered blanks. Remove the numbered blanks from the system and account for them according to a check-off list at the end of the flushing period.

9.2.3 Install temporary strainers of 80 to 100 mesh on the suction side of the pump. In addition, install temporary fine mesh strainers (no finer than 100 mesh) on the discharge side of gravity and pressure systems. Use lintless bags temporarily on the inside of the existing hydraulic system strainers, when available, during the flushing period. Install magnetic separating elements in the existing hydraulic system strainers. However, some experience indicates that they are of limited value.

9.2.4 Use auxiliary filters of the nonreactive type to increase the rate of filtration, and to decrease the maximum particle size of contaminants in the hydraulic fluid.

9.2.5 When a hydraulic fluid heater has not been installed, or when it is inadequate, supply heat to the flushing oil with the help of electrical heaters in the tanks. Hot water passed through coolers is recommended; however, when low-pressure steam is used, make sure it complies with manufacturer's recommendation. Ensure that 34.5 kPa (5 psig) is the maximum pressure of the steam admitted to the cooler so that the cooler is not damaged and the flushing oil is not overheated. A preferable method is to pass hot water through the cooler and bubble low-pressure steam through the water somewhere outside the cooler. Vent the cooler to the atmosphere to prevent the buildup of pressure.

9.2.6 Clean all accessible surfaces not previously wiped down with clean rags. Make a final inspection prior to filling the system with flushing oil.

9.3 *Fluid Heating Prior to Flushing* (New and In-Service Units)—Heat the fluid to 60 °C to 82 °C (140 °F to 180 °F) either by means of low-pressure steam 34.5 kPa (5 psig) maximum on the water side of the oil cooler, when it is designed for such service, or by electrical resistance heaters in the purifier or main tank. Circulate the fluid during this period.

9.4 *Selection of Flushing Oils*—The oil selected for flushing of the system can be either the system operating fluid or a special flushing oil. The selection of the type of flushing oil to be used should be based on the judgment of experienced personnel after thorough inspection of the hydraulic system.

9.4.1 *System Operating Fluid*—When the system operating fluid is used for flushing, it is not used for operation unless it has been tested and shown to be of suitable quality for system