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Standard Guide for Cleaning, Flushing, and Purification of Steam, Gas, and Hydroelectric Turbine Lubrication Systems[1]

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INTRODUCTION

Optimum turbine system reliability requires a well designed lubricating system and use of a good lubricant that is free of contaminants. Achieving this requires use of proper purification methods to ensure that the oil is free of detrimental contaminants. In addition, it requires an ongoing monitoring program to ensure that the oil quality is within specifications and that corrective action is taken to minimize contaminant generation and ingression. The benefits of purification of an operating lubrication system can be significantly reduced if the lubricating systems are not initially cleaned to a level that will prevent component damage on initial start up after manufacturing or rebuilding.

Care and thorough cleaning are required to minimize and remove contaminants during fabrication, rebuilding, or installation, or combination thereof. Because contaminants will remain from these processes, it is necessary to flush and purify the system to remove them prior to startup. Ongoing purification is required to maintain pure oil during operation. In new systems, the emphasis is on the removal of contaminants introduced during manufacture, storage, field fabrication, and installation. In operational systems, the emphasis is on the removal of contaminants that are generated or carried in during operation, and by malfunctions that occur during operation or contaminants that are introduced during overhaul, or both.

1. Scope*

1.1 This guide covers types of contaminants, oil purification devices, contamination monitoring, contamination control during building or refurbishing of turbine systems, lubrication system flushing, and maintenance of pure lubrication oil.

1.2 To obtain maximum operating life and reliability, or lubricants and system, it is vital that the turbine lubrication system has pure oil. This guide is intended to aid the equipment manufacturer, installer, and turbine operator in coordinating their efforts to obtain and maintain clean lubrication and control systems. These systems may be on land or marine turbine generators and propulsion and mechanical drive equipment. This guide is generalized due to variations in the type of equipment, builder's practices, and operating conditions.

1.3 This guide primarily addresses petroleum based lubricating oil. For systems using nonpetroleum based fluids, this guide may not be appropriate. For nonpetroleum products, consult the equipment and fluid manufacturers.

1.4 This guide is applicable to both large and small lubrication systems. Some equipment specified herein, however, may not be appropriate for all systems. Moreover, in situations where specific guidelines and procedures are provided by the equipment manufacturer, such procedures should take precedence over the recommendations of this guide.

1.5 *This standard does not purport to address 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.*

1.6 *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]

[1] This guide is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.C0.01 on Turbine Oil Monitoring, Problems and Systems.

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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.

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

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
D2272 Test Method for Oxidation Stability of Steam Turbine Oils by Rotating Pressure Vessel
D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants
D4241 Practice for Design of Gas Turbine Generator Lubricating Oil Systems (Withdrawn 2008)[3]
D4248 Practice for Design of Steam Turbine Generator Oil Systems (Withdrawn 2008)[3]
D4378 Practice for In-Service Monitoring of Mineral Turbine Oils for Steam, Gas, and Combined Cycle Turbines
D4898 Test Method for Insoluble Contamination of Hydraulic Fluids by Gravimetric Analysis
D6304 Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration
D6810 Test Method for Measurement of Hindered Phenolic Antioxidant Content in Non-Zinc Turbine Oils by Linear Sweep Voltammetry
D6971 Test Method for Measurement of Hindered Phenolic and Aromatic Amine Antioxidant Content in Non-zinc Turbine Oils by Linear Sweep Voltammetry
D7155 Practice for Evaluating Compatibility of Mixtures of Turbine Lubricating Oils
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
D7843 Test Method for Measurement of Lubricant Generated Insoluble Color Bodies in In-Service Turbine Oils using Membrane Patch Colorimetry
D8112 Guide for Obtaining In-Service Samples of Turbine Operation Related Lubricating Fluid
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

2.2 *ISO Standards:*[4]
ISO 3722 Hydraulic Fluid Power—Fluid Sample Containers—Qualifying and Controlling Cleaning Methods
ISO 4021 Hydraulic Fluid Power—Particulate Contamination Analysis—Extraction of Fluid Samples from Lines of an Operating System.
ISO 4406 Hydraulic Fluid Power—Fluids—Method for Coding Level of Contamination by Solid Particles
ISO 4572 Hydraulic Fluid Power—Filters—Multi-pass Method for Evaluating Filtration Performance

2.3 *API Standard:*[5]
API 614 Lubrication, Shaft-Sealing, and Control-Oil Systems for Special Purpose Applications

3. Terminology

3.1 *Definitions:*

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *adsorption, n*—removal of contaminants from oil by adhesion of the contaminant in an extremely thin layer of molecules to a fixed solid. The solid can be a fiber, a fine powder, or porous particles.

3.2.2 *centrifugation, n*—use of centrifugal force to separate contaminants from oils. Contaminants such as water and particulate are generally more dense than the oil and migrate to the outside of the centrifuge because of centrifugal force.

3.2.3 *cleaning, v*—direct removal of contaminant from any part of the system, generally with the system shut down or offline.

3.2.3.1 *Discussion*—Cleaning can include removal of contaminant by shoveling, sweeping, squeegee, vacuuming, wiping, displacing with clean, high pressure water blasting/jetting, dry compressed air; pressure steam and can be done with the aid of cleaning solutions.

3.2.4 *cleaning solution, n*—fluid used to aid in the removal of sludge and particulate matter in a system.

3.2.4.1 *Discussion*—Cleaning solutions may be classified as surface active oil soluble cleaners, detergent-based, or water based chemical cleaners.

3.2.5 *coalescence, n*—process of passing oil with free water through a fiber sheet, generally in a cartridge form, to cause smaller drops of water to join to form larger ones that can be more easily removed from the oil.

3.2.6 *coalescer, n*—device that uses coalescence (e.g. the aggregation of dispersed water to form sufficiently large droplets so that they fall out of oil-phase suspension) to separate water from oil.

3.2.6.1 *Discussion*—A coalescer generally consists of one or more coalescing cartridge(s) that include a hydrophobic barrier that hinders water from remaining dispersed in passing out with the oil as it passes from the unit. It may also contain a filter located upstream or downstream, or both, of the coalescing cartridge(s).

3.2.7 *displacement flush, n*—system flush using on-board turbine pumps designed to remove unwanted materials from installation or repair.

[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, http://www.ansi.org.

[5] Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, http://www.api.org.

3.2.8 *displacement oil, n*—oil used to remove either a lighter grade flush oil or an oil that is highly contaminated with oil soluble material.

3.2.9 *filter, n*—device containing a screen or fiber depth medium that removes particles from oil by physically trapping them in or on the screen or mesh.

3.2.10 *flushing, v*—circulation of liquid through the lubrication system or a component, when the turbine is not operating, to remove contaminant.

3.2.11 *high-pressure water cleaning, n*—use of high-pressure water to remove heavy rust or fouling from lube system internals and can be defined as hydroblasting, hydrojetting, high pressure water cleaning – high pressure jetting, where water jets/streams penetrate the deposits to flush them out from the pipe and oil system components.

3.2.12 *high-velocity flush, n*—system flush using external pumps that generate three to four times normal operating system velocities and a Reynolds number over 4000.

3.2.13 *operating oil, n*—specific charge or chemistry of oil to be used as the final fill oil after the flush.

3.2.14 *oxidation, n*—chemical reaction of a lubricant at elevated temperatures between dissolved atmospheric oxygen and the base oil.

3.2.14.1 *Discussion*—Oxidation reaction will be accelerated by the presence of oxidation accelerators such as metallic contaminants and water to result in the formation of insoluble soft contaminants, better known as varnish contamination.

3.2.15 *pure oil, n*—homogeneous lubricating oil containing stable additives and free of soluble or insoluble contaminants of concentrations that exceed the lubrication system specifications.

3.2.16 *purification, v*—removal of a contaminant present in the oil through a separation process.

3.2.17 *sacrificial flush oil, n*—charge of oil that is used in the flushing process and not used as the final operating oil.

3.2.18 *surface active flush, n*—system flush with the use of surface active cleaners to remove varnish and sludge.

4. Significance and Use

4.1 This guide is intended to aid the equipment manufacturer, installer, service company, and turbine operator in coordinating their efforts to obtain and maintain clean lubrication and control systems.

4.2 The flushing and cleaning philosophies stated in this guide are applicable to both large and small lubrication systems.

4.3 Clean lubrication systems result from proper system design and good planning, execution, and communication by all involved during commissioning. No phase of these procedures should be undertaken without a thorough understanding of the possible effects of improper system preparation. The installation, cleaning, and flushing of the equipment should not be entrusted to persons lacking in experience.

4.4 Because of the knowledge and specialized equipment that is required, the operator may wish to employ an outside specialist contractor for the system flushing. Review of this guide can provide guidelines for discussion with prospective contractors.

5. Contamination Control Overview

5.1 Lubrication systems can become contaminated from a variety of sources. The main focus of this guide is on the minimization, monitoring, and control of contaminants: water and both soluble and insoluble (stationary and suspended) contaminants. A more detailed discussion of these types of contaminants is given in Appendix X1.

5.2 Contamination control is the complete program of obtaining and maintaining a clean lubricant and lubrication system. This includes proper construction and maintenance practices, appropriate purification equipment, and regular monitoring of contaminants. The contamination control program must be capable of identifying and measuring contaminants and controlling them at, or preferably below, component tolerances. In particular, the sensitivity of bearings, gears, seals, and proportional and servo valves should be reviewed. As described in X2.7.1, cleanliness levels for various system components are generally established by their manufacturers' specifications. These and recommendations of the fluid manufacturer must be considered when employing contamination control systems. In addition, there are insoluble contaminants (oxidation precursors) that are below machine tolerances, but as their volume amasses they create a potential for sludge and varnish creation as a normal consequence of oxidation reactions.

5.3 Contamination control considerations must begin with system design and continue through the manufacture, installation, flushing, cleaning, operation, and maintenance of the system.

5.4 Design of the system must consider component contaminant sensitivity and provide points for sampling oil and methods for controlling contaminants. Contamination monitoring is discussed in Appendix X2 and contamination control methods in Appendix X3. Inclusion of filtration in steam and gas turbine lubrication systems is discussed in Practices D4248 and D4241 respectively.

5.5 The manufacturer must minimize the amount of built-in contaminant by minimizing ingression and by flushing components to achieve target cleanliness levels in the finished component.

5.6 Contamination control during installation and major maintenance of turbine systems is discussed in Section 6.

5.7 Proper heating is critical during flushing and routine operation to minimize oil degradation. Heating is discussed in Appendix X4.

5.8 Removal of contamination by flushing is discussed in Section 7.

5.9 Contamination control in operational systems and during routine maintenance is discussed in Section 8. Properly designed systems can normally control water and insoluble contaminants in operational systems. If, however, it is necessary to remove soluble contaminants other than water, an oil change and also possibly a flush may be required preceeded by an oil system surface cleaning.

6. Contamination Control When Installing and Refurbishing Turbine Systems

6.1 *General:*

6.1.1 Exclusion or removal of contaminant, or both, in manufacturing or refurbishing, or both, are necessary for a subsequent successful flushing and cleaning. This process can be achieved only by the cooperation and diligence of many parties.

6.1.2 *Examples of Essential Precautions to Exclude or Remove Contaminant, or Both:*

6.1.2.1 The system should be designed to allow successful cleaning.

6.1.2.2 The pipe and other equipment must be properly cleaned and preserved.

6.1.2.3 All possible locations for the entrance of dirt (pipe ends) must be durably covered and secured for storage prior to shipment and loading. Shipment and unloading must take place without damage to these covers.

6.1.2.4 Inspection of pipe at the turbine site must be thorough to discover any damage or open covers and to have them repaired.

6.1.2.5 Storage prior to installation must be in a sheltered location, especially if the storage is to be for a long duration.

6.1.2.6 Inspection immediately prior to installation must be thorough, and the pipe must be cleaned if excessive rust or dirt is discovered.

6.1.2.7 Continuous monitoring of conditions during the complete turbine installation must take place to ensure that cleanliness related tasks are being accomplished. Dirt should not be introduced into the pipes and equipment.

6.1.2.8 Great care must be taken to prevent contaminant entry during any modifications.

6.1.2.9 The work area must be kept clean.

6.1.2.10 This list is not complete, but it does illustrate that the manufacturer, the shipper, the operator, and the installation contractor (service company) are all responsible for ensuring that no contaminants enter the lubrication system. These efforts to prevent the entrance of dirt will make the flushing procedure easier, safer, and shorter, and thus less costly.

6.2 *On-Site Contamination Control:*

6.2.1 *General:*

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

6.2.1.2 The preassembled components should be inspected upon receipt to determine condition and degree of protection. All seals and caps intended to exclude moisture and dirt should be checked for integrity and replaced as required. If the initial or a subsequent inspection discloses dirt or rusting, the item should be immediately cleaned, represerved, and sealed, as required. Because of the variety of equipment and materials, details for each case cannot be given here. For painted (coated) components, the coating should be inspected for integrity and renewed as necessary. All components should be checked to ensure that all tape and temporary supports or restraints have been removed. For very compact system it is strongly recommended to check the preassembled system, with inspection for example from the disassembly of flanges, valves etc. As these components are usually under the warranty of the manufacture, it will be critical to communicate this to the manufacture as of part of control at delivery.

6.2.1.3 Undercover storage is recommended. Monthly inspections are recommended, and corrective steps must be taken when necessary. Care must be taken during inspections to minimize disturbance of equipment protection.

6.2.2 *Corrosion Protection:*

6.2.2.1 The application of various types of rust preventives is required to protect uncoated ferrous surfaces from corrosion during the storage and installation phases. Most preservatives today are oil soluble, and special procedures, such as hydraulic lancing, are often used to preserve gear cases, sumps, and tanks. The preservative compounds can normally be removed by flushing the system with regular lubrication oil or oil solvent, although hand cleaning of some components is also employed. If possible, however, the flush oil, operating oil, and preservative should be compatible to preclude foaming, the formation of emulsions, precipitates or the breakdown of lubrication oil additives. A system flush (displacement flush) with a sacrificial flush oil is often recommended to minimize operating oil contamination which could result in reduced performance. Product compatibility of the flush oil should be confirmed in accordance with Practice D7155 testing. Caution should be exercised in this regard. Compatibilities and limitations may generally be obtained from the oil suppliers. Corrosion preventatives have the possibility to be removed by flushing, however care should be taken to assure that all of them have been removed. Consequently it is recommended to check the oil quality after the displacement flush. Achieving oil temperature between 55 °C to 60 °C and higher if possible plays a big role in removing the traces of these corrosion preventatives. The flushing shall be followed by a thorough oil drain of the displacement oil and should be performed carefully. Review with the equipment manufacturer may also be beneficial. All oils added, including preservative oils, should be filtered as discussed in 7.6.

6.2.2.2 Once the rust preventative is removed, the ferrous surfaces are subject to rust unless care is taken to keep all surfaces oil-wetted. Corrosion of unwetted surfaces can be minimized by the use of vapor space inhibited oils to the maximum extent possible. The general procedure for the use of the vapor space inhibited oils is as follows:

(1) Wet all surfaces with vapor space inhibited oils after cleaning.

(2) Do not drain; add sufficient oil to provide a reservoir of the oil in the assembly.

(3) Seal the component to prevent loss of vapor phase protection and intrusion of contaminants.

6.2.2.3 These vapor space inhibited oils may be fully compatible with regular lubricating oils and flushing oils, and draining or removal may not be necessary. Compatibility testing in accordance with Practice D7155 is recommended to confirm compatibility. In addition, it has been shown that these oils may provide some residual protection to the system and minimize corrosion after the oils have been drained or displaced.

6.2.2.4 The vapor space inhibited oils are available in a range of viscosities. However, if 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 to 10 % is recommended to prevent significantly increasing the viscosity of the flushing oil.

6.2.3 *Gear Assemblies:*

6.2.3.1 When shipping gears, additional braces and tapes are frequently used to prevent movement of the elements and damage to the teeth and bearings. Upon receipt of the assembled gears at the installation point, an inspection should be conducted with the gear manufacturer's representative to determine whether any damage has occurred during shipment. At this time the gears should be thoroughly inspected for contamination, and if any is found, the manufacturer's recommendation should be followed for proper represervation. Periodic inspections, careful to minimize vapor space inhibition loss, should be made to ensure that proper preservation is maintained until the gear assembly is placed into regular operation. Upon installation, all temporary restraints, including tape, must be removed.

6.2.3.2 Speed reducers are normally shipped with a thin coating of preservatives applied to all internal machined surfaces that are in contact with lubrication oil, such as gear teeth, bearings, journals, interior housing surfaces, and oil piping. The preservative is oil soluble and is normally removed by the flushing program. Gear cases, protected by vapor space inhibited lubricating oil, should be inspected upon receipt for integrity of seals. Damaged seals should be replaced immediately. If the oil has been lost, the gear case and the gears should be pressure sprayed through the inspection openings with filtered vapor space inhibited oil or rust preventive oil at 55 °C to 57 °C (130 °F to 135 °F). Starting at the top of the case, the gear case and the gears should be thoroughly flushed down. After flushing, the oil level recommended by the gear manufacturer should be reestablished and the unit sealed.

6.2.4 *Valves, Strainer, and Coolers:*

6.2.4.1 Valves and strainers, when received from the manufacturer, should be inspected to determine if there is contamination. If there is evidence of a hard film protective coating or contamination, the unit should be dismantled and all the parts thoroughly cleaned with filtered petroleum solvent. In all cases, use clean, lintless cloths (not waste cloths), a squeegee, or a vacuum cleaner.

6.2.4.2 Coolers should be verified clean from the manufacturer. A Borescope can be used prior to installation for inspection. If any contamination is found within the cooler the system should be cleaned to meet the turbine manufacturer cleanliness specification. Depending on the type of cooler (Fin Fan, Plate, Shell & Tube), metallurgy, and contamination found cleaning can consist of chemical cleaning and or oil flushing to expedite the process. Care should be taken to review cooler pressure and flow restrictions.

6.2.4.3 Internal surfaces that cannot be reached should be flushed with an oil soluble cleaner or filtered petroleum solvent. Alkaline or acid cleaners should not be used.

NOTE 1—Petroleum solvents are flammable; care must be taken to prevent fires. Precautions must also be taken to ensure that workers do not inhale fumes from the solvent or come into contact with liquid solvents for prolonged periods. Filters can generate electric charges. Proper electrical connection of all equipment prior to transferring fluids or starting flushing is required.

6.2.4.4 After internal surfaces have been cleaned, they should be sealed or put into service as soon as possible. If the internal surfaces cannot be effectively sealed or put into service, they must be thoroughly air dried and coated immediately by spraying them with filtered and compatible rust preventive oil. After all surfaces have been coated, the equipment should be reassembled and all openings capped. This rust preventative coating may require removal with flush oil prior to equipment use.

6.2.5 *Sumps and Tanks*—Sumps, reservoirs, or tanks should be completely drained and thoroughly inspected. If present, rust, mill scale, weld spatter, loose paint, and so forth, should be manually removed. A coating of rust-preventive oil, or a vapor space inhibitor oil, should be applied, and all openings should be sealed. This rust preventative coating may require removal with flush oil. Repainting is not recommended.

6.2.6 *Bearings*—It is important that bearings be installed by qualified personnel. Extreme care should be taken to prevent accidental contamination of, or damage to, the bearings and journals. Bearing surfaces should be protected by rust-preventive oil that is readily soluble in flushing oil or vapor space inhibitor oil. All openings should be sealed.

6.2.7 *Control Devices*—Installation and contamination protection for oil-wetted control devices should be handled as carefully as that for bearings. Extreme care must also be taken to prevent accidental contamination of the associated piping during installation.

6.2.8 *Pumps*—Prior to assembly and installation, pumps should be inspected for the presence of hard film coatings or contaminants. If any are present, the pumps should be thoroughly cleaned, coated with rust-preventive or vapor-space inhibitor oil, and sealed.

7. Flushing

7.1 If the equipment manufacturer has supplied detailed flushing procedures, they should take precedence over these recommendations.

7.2 *Flushing Methods:*

7.2.1 *Displacement Flush*—For new systems and systems with service hours that do not typically require surface active cleaning or the improved cleaning of a high-velocity flush, but require lubricant ISO Cleanliness lowered to meet OEM specification or replacement of current charge of lubricant.

7.2.1.1 For a unit that is field assembled, keeping the lubrication and hydraulic control system piping 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 has been installed and just before the turbine and its driven equipment go into operation.

The success of this oil flush, however, depends to a large degree on the success of the efforts to keep dirt out initially and the proper preparation and conduct of the flush. A successful flush means that clean pipe and system components are obtained in a minimum of time and with a minimum of effort.

7.2.1.2 The cleaning and flushing of both new and used systems are accomplished by essentially the same procedure. In the new systems, the emphasis is on the removal of contaminants introduced during the manufacture, storage, system temporary rust protection, field fabrication, and installation. In used systems, the emphasis is on removal of contaminants that are generated during operation or are introduced to the system during overhaul.

7.2.1.3 A displacement flush utilizes a displacement flush oil of the same chemistry as the final operating oil. System pumps and flow channels are utilized to circulate the displacement flush oil. Side stream filtration is recommended to improve flush effectiveness.

7.2.2 *High-Velocity Flush*—For new systems and systems with service hours that may not require surface active cleaning and will benefit from enhanced flushing compared to displacement flushing. High velocity oil flush results typically in a higher cleaning efficiency and also in a flushing time that is significantly shortened. Moreover, high flow rates of oil initiate the removal of contaminants in most cases (apart from severe corrosion of oil aging agglomerates and varnish), whereas flushing with system pumps do not assure the contamination displacement from all corners, pipes, dead zones of the oil system.

7.2.2.1 It is important to review the flow path and verify that no restrictions or dead spots are left while flushing activities are taking place before performing a high-velocity flush. Low or no, flow regions (dead spots) or "traps" will allow for contaminates to gather and redistribute throughout the system once the flush has concluded.

7.2.2.2 Lube oil lines that do not see continuous flow during normal operation often collect contaminates at valves and orifices. These locations can be found on the outlet side of the system pumps, that is, pressure relief valves, and on units with fixed drain piping back to the lube oil reservoir. In these cases, the lube oil flushing procedure should include opening and flushing out these lines.

7.2.2.3 Moreover, achieving the high oil velocities in return headers is hardly achievable without additional distribution of additional oil stream headed separately from the flushing skid. The disproportion of supply/discharge header compared to return header is the reason. High-velocity Oil Flushing is critical to removing contaminates left behind when foreign material can be introduced to the lube oil system and in cases when welding activities are conducted in the field, that is, precommissioning, pipe-modifications, major maintenance activities.

7.2.2.4 The primary requirement for a successful oil flush is a high oil velocity at least three to four times normal system velocity, and a Reynolds number over 1000 within the system. Wherever possible, turbulent flow should be achieved in system pipes. Jumpers are installed around critical components such as bearings and control valves to elevate bearing supply and return flow rates and protect critical surfaces from contaminants. System headers may be isolated to increase pipeline velocity. The use of outside pumps is typically required to achieve this flow.

7.2.3 *Surface Active Oil Soluble or Detergent Based Cleaner*—Flushing for in-service systems with varnish or sludge that require a cleaning solution for effective deposit removal.

NOTE 2—Using detergents, as surface tension acting products, in turbine lube oil systems can impact the lube oil characteristics such as air release or demulsibility. When using detergents, it is strongly recommended to perform additional flushing steps to remove the remaining concentration of these detergents, and attach a lot of importance on the maximum drain of the flushing oil.

7.2.3.1 Some turbine and associated hydraulic systems may require a surface active flush to clean inaccessible internal surfaces of varnish. The term varnish is being used to include all internal deposits, including sludge. Flushing with a surface active cleaner is typically reserved for gas turbines with combined hydraulic and turbine oil reservoirs. Minor levels of oil soluble cleaners or solvent cleaners may impact operating oil demulsibility, required in steam turbine operation. A subsequent displacement flush shall be conducted to effectively remove the surface active cleaning agent. Both the surface active flushing fluid and the following displacement flush fluid should not be reused as they may impact the performance of the final system operating oil. Hydraulic system flushing can be improved with the use of flushing blocks that are used to bypass the system servo valves.

7.2.3.2 Some hydraulic fouling deposits require water-based cleaning agents, that is, chemical cleaning – degrease. This method should only be used in extreme fouling and oxidation applications. In the event that the lubricant oxidizes and carbon deposits cause filter plugging and hydraulic valve failure a lubrication engineer and chemical service flushing expert should be consulted to review the metallurgy of the system and chemistry appropriate to clean the system. Water-based chemical cleaning will be followed by lube oil displacement or high-velocity oil flushing and vacuum dehydration to remove residual water and particulate contaminates.

7.2.4 High-pressure water flush for systems with service hours that have developed significant rust or fouling to the extent that less aggressive flushing methods are ineffective. Cleaning the surfaces with high pressure water stream/jets means that the water streams/jets at high pressure level effectively penetrates the soft and hard deposits (especially rust, welding slag and splatter, varnish agglomerates) that high oil velocities removes slowly, less effectively, if at all. Special care must be taken to remove all flush water at the completion of this flush.

7.2.5 *General Flushing Method Guidance:*

7.2.5.1 It may not be practical to flush through certain systems or devices that are assembled, cleaned, and sealed in the factory before shipment. Such equipment should be carefully protected against intrusion of contaminants, and in this flushing procedure, such equipment should be blanked off or bypassed until other systems are clean. This guidance also applies to oil coolers, that are highly recommended to flush separately first and avoid massive dirt ingress in other oil system sections and piping.

7.2.5.2 Even for assemblies that can be flushed through freely, the prescribed flushing procedure may not have the ability to flush out any and all conceivable kinds of contaminants. Much adverse experience testifies to this. Therefore, it is clear that great care should be exercised during the entire system installation to prevent unnecessary impurities from entering the oil systems that cannot be easily removed by flushing. Such contamination, when dislodged by turbine vibration or system operational effects, could cause problems in subsequent operations.

7.2.5.3 The knowledge that a system flush will be performed before startup should not be allowed to lead to the misconception that contaminants entering the oil system are not harmful because "they will all be removed by the flush."

7.2.5.4 A written process and procedure should be developed for each flush regardless of OEM. The procedure should include OEM cleanliness guidelines, site specific standards, owner requirements, deliverables, lubrication handling, and timeline.

7.3 *General Guidelines for Flushing of Operational Systems to Remove Contaminant:*

7.3.1 Guidelines for when to remove used oil or flush an operational system to reduce contaminant, or both, are given in 8.5.

7.3.2 The remainder of Section 7 should be reviewed and the applicable sections decided upon, after consultation of the equipment user with the appropriate suppliers, based on the condition of the system and used oil.

7.3.3 Sea water contamination requires special procedures. After removal of excess salt water, corrosion inhibitors specifically developed for this type of contamination might be used in the system.

7.4 *Preparation of System for Flushing:*

7.4.1 Prior to the flushing operation, all accessible areas of the lubricating oil system should be thoroughly inspected. If significant contaminant is encountered, it should be manually removed. Final inspection for welding splatter or materials that may break loose and contaminate the system with metallic particles should be made. If found they should be completely removed. As always, containment of oil within the powerhouse is important. Ensure that any service companies involved are aware of the responsibility to prevent oil from reaching the environment. For piping systems that are not typically exposed to the pressures and temperatures, (and vibrations, if applicable) being used during flushing, preparations must be made to quickly and effectively respond to any potential oil leaking from the system.

7.4.2 Any temporary humidity control devices (vacuum dehydrators, coalescing filters) placed in the system must be removed. The state of cleanliness of the system at this time is always questionable, and therefore, all lubricating oil manifolds and leads to bearings must be blanked off as closely as possible to the parts they serve. For high-velocity flushing, jumpers may be installed to bypass all bearings, but they should be so installed as to bypass as little of the piping and flow passages as possible. All other areas in the system that are not to be flushed should be blanked off with the use of numbered blanks. Ensure that the flushing loop is contained with positive-closure valves; check valves are insufficient to protect equipment from high-velocity flush. The numbered blanks must be removed from the system and accounted for on a checklist at the end of the flushing period. All items should be identified on flush flow path marked P&ID DWG's and written procedures.

7.4.3 Despite all efforts, some particles large enough to damage pumps may remain. In all systems, installing temporary strainers of 80 to 100 mesh on the suction side of the lubrication oil or flush pumps, or both, is recommended. In addition, install temporary fine mesh strainers on the discharge side of gravity and pressure systems. Customary marine practice is to install these in the duplex strainers on the discharge side.

7.4.4 Whenever possible, use of full flow filters during the flush is recommended. Auxiliary filters may be used to provide higher filtered oil flow rates and finer filtration. All purification systems should be ready for operation as soon as the flushing oil is installed. It is generally desirable to purify the reservoir, pump, and purification systems before beginning to flush the rest of the unit. This has the advantage of providing clean oil to other parts of the system. In addition, when purified oil is used for flushing, the increased contaminant observed in the oil when additional sections are flushed gives some measure of flush effectiveness. If necessary, pipes and valves for recirculation to the reservoir should be installed. If this piping is temporary, valves at the reservoir and purification device should be provided to allow removal of the temporary piping.

7.4.5 Frequently, sampling points installed for monitoring oil cleanliness during routine operation are not adequate to monitor the cleanliness of components and the progress of the flush. Sampling points must be installed as necessary, as described in X2.2.2, and Guide D8112. If the lubricating oil heater has not been installed, or if it is inadequate, heat may be supplied to the flushing oil in several ways. The best method is to pass hot water through the cooler; this can be generated by bubbling low-pressure steam through the water somewhere outside the cooler. The cooler must be vented to the atmosphere to prevent pressure build up. Low pressure steam may also be used; however, the cooler should be checked against the manufacturer's recommendation. Great care must be taken to ensure that not over 34 kPa (5 psig) steam is admitted to the cooler so that the cooler is not damaged and the flushing oil is not overheated. Electrical heaters may also be used. The cautions outlined in Appendix X4 must be observed to avoid overheating the oil.

7.4.6 A lance attached to a clean hose should be used for hot oil spraying of gearing or other hard to reach areas. It can be attached to the cooler (currently being used as a heater) or an oil pump discharge strainer. For safety, the hose, lance, and any other fittings used must be pressure rated for the full flush pump outlet pressure. Precautions must also be taken to protect personnel from the hot oil spray. Extreme fire and spark protection precautions must be taken. Even less hazardous lubricants can ignite if heated and sprayed; conventional mineral oils may form explosive mixtures under such conditions.

7.4.7 A rotating nozzle (patent pending) is attached to a flange and a clean hose for hot oil spraying of gearing or other hard to reach areas. It can be supplied via temporary bypass line from system supply header line. The nozzle is mounted on 1 150# flange and inserted inside of the area to be flushed. A 360º rotating nozzle sprays the flushing oil, and used for seal oil tanks and larger gear box openings that allow for insertion of the mechanism.

7.5 *Selection of Flushing Oil:*

7.5.1 The oil selected for flushing of the system can be either the system operating oil or flushing oil that is compatible with the operating oil . In cases where residual flush oil may be of sufficient quantity as to impact system operating oil performance, similar viscosity flushing oil should be used. In some cases there may be a benefit to using a very low viscosity oil (~15 cSt) for high-velocity flushing, then performing a displacement flushing step with in-service oil which will be discarded, prior to bringing the system back into normal operation. In all cases, 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 lubricating system. To minimize oil contamination, delivery should only be made in clean containers with clean or flushed hoses, pumps and manifolds. For large quantities, use of stainless steel or aluminum tank trucks or tank cars and cleanliness certification are required.

7.5.2 *System Operating Oil*—In applications where an existing unit is being flushed, the previous turbine lubricating oil may be used as flushing oil or subsequently as the operating oil, or both. In this case, the oil has been stored in a storage tank. When the system operating oil is used for flushing, it should not be used for operation unless it has been tested and shown to be suitable for system operation following flushing. This precaution is necessary because oil-soluble contaminants picked up during the flush may be incompatible with system components or cause foaming, emulsification or reduced oxidation resistance, or combination thereof.

7.5.3 *Flushing Oil Selection:*

7.5.3.1 Any operator who uses a flushing oil assumes responsibility to ensure its mechanical and chemical compatibility with the entire lubricating oil system and all turbine equipment exposed to this oil, including, but not limited to:

(1) All components of the lubrication and flushing systems.

(2) Final charge of lubricating oil.

(3) Permanent or temporary flushing hose lining at temperatures up to 88 °C (190 °F), including those to boiler water feed pump turbine systems.

(4) Rust preventive paints used in pedestal and guard piping.

(5) Preservatives used to protect pipes during shipping, storage, and installation that normally may not be removed prior to flushing.

(6) Residual oil impact on performance of system operating oil.

7.5.4 *Varnish Cleaner Selection*—Removing varnish from lube oil system surfaces can be accomplished through the use of cleaners. This varnish is not removed from the system. Once dispersed from surfaces, it remains suspended within the lubricant. Cleaners are, therefore, to be used in accordance with the recommendations by the cleaner's supplier or manufacturer.

7.5.4.1 *Surface Active Oil Soluble Cleaners*—is added to the operating turbine at the supplier's recommended percentage, mixed and circulated with in-service oil, and then drained with in-service oil during a maintenance outage. Selection of surface-active oil soluble cleaner should take into account compatibility with in-service oil, cleaning time available prior to outage and by the supplier's recommendation, and cleaning efficiency.

7.5.4.2 *Detergent-Based Cleaners*—used for cleaning turbine reservoirs during maintenance outages, often performed by third party flushing companies using auxiliary filtration. Sacrificial rinses are required to remove any residual cleaner as this will interfere with performance of the new turbine oil.

7.5.4.3 *Water-Based Chemical Cleaners*—used for cleaning turbine reservoirs during maintenance outages, often performed by third party flushing companies. Water and a chemical cleaner are added to a drained lube oil reservoir, circulated at high velocity throughout the system and then drained. The system is then dried prior to filling with new turbine oil.

7.6 *Supplying Flushing Oil to Reservoir*—When filling the turbine lubricating system, oil should be filtered with as fine or finer filters as the system operating or flushing filters. In addition, in the flushing process, it is generally advisable to filter the oil between transfers. This allows single pass filtration that prevents the purified oil from mixing with the contaminated oil. Filtration of oils (to OEM specifications) while warm will improve element life. Filter ratings on transfers to holding tanks can vary with oil temperature and oil contaminant levels. The reservoir should be filled to the minimum operating level to ensure that the system lubricating oil pump(s) are always submerged and operate properly.

7.7 *Flushing Procedure:*

7.7.1 Elevated oil temperature, oil temperature cycling and vibration contribute to the success of an oil flush. Hammering or vibration at pertinent points will promote loosening of solids in the system. Once solids are loosened, a high-velocity flush should carry the solids to the filters. Otherwise, they will settle by gravity in the main oil tank, eventually be caught by temporary screens, or removed by filtration.

7.7.2 *Monitoring of Contaminant During Flushing:*

7.7.2.1 Monitoring of contaminant, especially particulate, is commonly performed during the flush and is strongly recommended. These analyses ensure that clean oil is being used for the flush and provide the best measure of the flush's progress.

7.7.2.2 The analyses for particulate may be performed on site using a particle count method or field analysis of contaminant from a sample drawn through an analysis membrane as discussed in X2.5.2 or performed in a laboratory as discussed in X2.6. If the analysis is performed on site, the person performing the analysis should be completely familiar with the operation and limitations of the apparatus. If the analyses are to be performed by a laboratory, the schedule must be established before the flush commences to provide timely results.

7.7.2.3 Flushing decisions based on sample cleanliness should only be made by personnel familiar with both the flush dynamics and the significance of the sample cleanliness. For system components, some manufacturers will require full flow analysis for large particles, typically larger than 125 µm. This generally entails filtering all return oil through strainers of the appropriate mesh. For flushes with full-flow filtration bags, the bags themselves can be examined for visible particles, and additional criteria such as having no visible hard particles (e.g. solder) and only a small amount of visible soft particles can be used to determine when a flush is complete. If required, these analyses should be performed with the appropriate throughput and by personnel familiar with the procedure.

7.7.3 *Maintenance of Purification Apparatus During Flushing*—Experience in flushing lubricating oil systems has shown that almost all of the foreign matter is collected in the filters or temporary strainers during the first few hours of flushing. During this time, whenever a noticeable increase in the pressure drop across the strainers is observed, the strainers should be cleaned and bags renewed. This may occur as frequently as 15 min intervals. The lubrication oil contamination control devices must be inspected and cleaned frequently. Auxiliary filters, when used, should be operated within the pressure drop limits as specified by the manufacturer.

7.7.4 *Startup*—If appropriate, the lubricating oil pump(s) should be started. Oil circulation in the reservoir should be begun and purification started. The oil should be gradually heated to 65 °C to 71 °C (150 °F to 170 °F) by use of the purifier oil heater and, if necessary, by methods described in 7.4.5. Circulation and purification should be continued as long as it is necessary to flush the system. When heating the oil, the guidelines given in Appendix X4 should be followed to avoid overheating the oil. Purification of the reservoir should continue until the oil reaches the desired cleanliness level as determined by taking a reservoir sample or sample immediately upstream of a purification device as discussed in Appendix X2. For high-velocity flushes with an outside pump skid providing larger than normal flowrates and higher temperatures than normal for the lubrication piping system, instruct the service company to ramp up pressure and temperature slowly. Ensure that startup is scheduled when Plant personnel are available to walk the pipes, watch for any leaks, and make any necessary repairs. This is especially important if vibration/hammering of the piping will be performed.

7.7.5 Flushing times of 12 h to as much as several days may be necessary to reach the desired level of cleanliness. Periodic sampling and analysis, as discussed in 7.7.2, is recommended to monitor the progress of the flush. Throughout the flushing period, the oil in the system should be maintained at 65 °C to 71 °C (150 °F to 170 °F), except when rotating the equipment. This temperature is necessary to maintain fluidity of the flushing oil in the system and to dissolve oil soluble materials and to aid in loosening adherent particles. General practice is to allow the oil temperature to drop 28 °C to 32 °C (50 °F to 60 °F) for 2 h to 3 h during flushing to allow for pipe contraction. This procedure aids in removing any scale that may be on the pipe.

7.7.6 *Flushing/cleaning of Coolers*—Each lubricating oil cooler should be cleaned separately to provide maximum oil velocity in the cooler to optimize contaminant removal. This cleaning process may have to be achieved by dismantling the cooler as it will require carefully selected chemicals to clean efficiently the oil side of the cooler.

7.7.7 *Flushing of Gravity Tanks*—If there is more than one gravity tank in a gravity system, circulation of the flushing oil should be alternated through each of the gravity tanks for a minimum of 12 h or more for each tank (see 7.4.7 on page above).

7.7.8 *Flushing of Lubricating and Auxiliary Pumps*—Each lubricating oil pump and auxiliary pump should be used during the flushing period. When incorporating off-board pumps to facilitate the flush the Lubricating and Auxiliary Pumps can be run:

(1) for final screening after the unit is reinstated, or

(2) with temporary bypass hoses run back to the lube oil reservoir for testing purposes.

The intent is to capture the pumps, spools and items that may not be incorporated in the flushing activities. When running during final screening the unit is reinstated to normal operating conditions and 100/60 mesh or OEM recommended screensare inserted at the closest upstream flanges or screening location to the bearings. Screens should be deemed clean to manufacturer and owner specification then removed and replaced with turbines final reinstatement items, that is, gaskets, orifices, screens, basket strainers. Leaving inspection screens in during operation can lead to plugging and eventually cut off flow to the bearings. It is vital to use identifying markers with your inspection screens and not screen between two common gaskets, that is, handles, color differentiator, tagging process, logging process in and out.

7.7.9 *Flushing of Piping*—During the early phases of the flushing period, the piping, particularly at joints and flanges, may be vibrated, sparged, or hammered to dislodge any scale or weld splatter that may have adhered to the surface. The absence of contaminants, such as lint, welding beads, or other extraneous matter, on strainers or bags and accessible parts of the system indicates that the system is clean. The final decision to flush additional parts of the system, however, should be based on cleanliness criteria specified by the equipment manufacturer or established prior to the flush. After these criteria have been met, other parts of the lubricating oil system should then be flushed by removing blanks and jumpers.

7.7.10 *Flushing of Gears:*

7.7.10.1 At this point in the flush, if the unit being flushed is a geared unit, the gear case should be opened and sprayed with oil cooled to 55 °C to 60 °C (130 °F to 140 °F). All accessible points, including the upper surfaces of the casing, should be included. This flushing should be done through the inspection openings on the gear housing. The gears should be jacked progressively to new positions to permit thorough cleaning. Jacking should not be continuous and should not be done if the oil temperature is in excess of 60 °C (140 °F). Upon completion of the flushing by hose, the inspection covers should be secured and oil circulation continued, while gradually heating the oil to 65 °C to 71 °C (150 °F to 170 °F). The flushing procedure should be continued until the entire system is thoroughly cleaned. At this point, a representative sample should be taken for verification of cleanliness.

7.7.10.2 All oil strainers adjacent to gear oil spray nozzles should be examined and cleaned as necessary. When no evidence of contaminants appears in the strainers, bags, or auxiliary filters or from oil analysis, oil circulation to these gears should be stopped. If practical, representative bearings should be inspected and their condition should be used as a guide to whether further flushing is necessary. Bearing inspection may not, however, be practical or recommended, especially in packaged gas turbine systems.

7.7.11 *Flushing of Turbine Main Bearings and Sumps:*

7.7.11.1 The turbine main bearings will be one of the most sensitive components to particulate that moves through the system as a result of a flush. The turbine manufacturer's guidelines for flushing turbine bearings areas (bearings or bearing sumps, or both) should be used whenever available. When not available, the following should be considered.

7.7.11.2 Bearing areas should be flushed with clean fluid only. This may be accomplished either by isolating the bearing areas and flushing all upstream components, including valves and piping, to a specified cleanliness level and then redirecting the flow of clean fluid through the bearing area or by placing a screen or bag filter immediately upstream of the bearing area to ensure that particulate freed within the system does not flow through the bearing. Same as above in section 7.7.8 - Final screening the unit is reinstated to normal operating conditions and 100/60 mesh or OEM recommended screens are inserted at the closest upstream flanges or screening location to the bearings. Screens should be deemed clean to manufacturer and owner specification then removed and replaced with turbines final reinstatement items. that is, gaskets, orifices, screens, basket strainers. Leaving inspection screens in during operation can lead to plugging and eventually cut off flow to the bearings. It is vital to use identifying markers with your inspection screens and not screen between two common gaskets, that is, handles, color differentiator, tagging process, logging process in and out.

7.7.11.3 Monitoring fluid cleanliness at the first accessible location downstream of the bearing area being flushed gives the most reliable indication of bearing cleanliness. Some manufacturers may require full flow monitoring of the fluid coming from these areas for relatively large particles using screens. Experience indicates that if these are used, screens and analysis procedures should be designed to eliminate the influence of environmental contaminant that could unnecessarily prolong the flush.

7.7.12 *Flushing Procedures Specific to Surface Active Flushing:*

7.7.12.1 Confirm in-service oils suitability for use as to support surface active cleaner and insoluble system contaminants. In-service oil solubility and contaminant testing, like ultra-centrifuge or membrane patch colorimetry, may be suitable. The surface active cleaner shall be added in concentrations and circulated based oil suppler recommendations. Side stream filtration is recommended, during the flush. Flushing may be considered complete based on time and or system before and after test coupon cleanliness. A test coupon is an area or part of the lubrication system that has deposit formation (varnish/sludge) that can be used for validation during the surface active flush using photo or boroscope documentation.

7.7.12.2 At the flush completion the flush oil, containing surface active cleaners, should be completely drained. Particular attention should be paid to low point draining. A subsequent flush oil should be used to remove cleaner residue that may impact the performance of the final fill operating oil. At the completion of this flush the oil should be drained and the system prepared for confined space entry cleaning.

7.7.13 *Flushing Procedures Specific to High-Velocity Flushing:*

7.7.13.1 Bearing and hydraulic section jumpers are required to provide for increased flow rate to obtain a minimum Reynolds number of 10 000. External pumping done through isolated turbine sections offers elevated flush velocities. Turbine sections are isolated and flushed in sequences that provide for optimum system cleaning. (**Warning—**Fluid temperature may increase due to internal friction. It is recommended to monitor and appropriately control the temperature within safe operating levels.)

7.7.13.2 Reynolds number, that is, turbulent flow can be impacted by (3) different factors and should be reflected when planning the oil flush. Lube oil viscosity, pipe diameter, and flushing pump flow rate all contribute to the Reynolds number calculation. If looking to use off-board pumps when calculating your target Reynolds number, you should calculate Re. against the main lube oil supply header line and target > Re10 000 as a minimum flow.

7.7.13.3 *On-Board vs. Off-Board*—Turbulent flow. All bearing bypass "jumper" lines should include isolation valves for two purposes.

(1) If utilizing on board pumps it will be necessary to isolate and flush the unit in sections to increase flow and reach the recommended Reynolds number. Utilization of off-board pumps to achieve three to four times normal or targeted Reynolds 10 000 turbulent flow (or greater) across main supply header will allow for flushing of entire turbine and generator and reduce flushing time.

(2) As section of unit is deemed clean, closing isolation valve allows greater flush flow to be directed to the areas that need additional cleaning time.

7.7.14 *Terminating the Flush*—When all steps of the procedure are completed, the contaminated sections of the system have been flushed and sample evaluations indicate that operating cleanliness requirements for all components have been met, including any manufacturer or user cleanliness requirements, terminate the flush.

7.8 *Draining of Oil Used for Flushing*—If the oil is to be drained when the flushing procedure is complete, it should be drained as soon as practical and safe. Allowing the oil to cool will leave more contamination in the system than if drained while it is still hot. Oil lines should be opened at the lowest points and the oil allowed to drain. Breaking of flanges and the use of a vacuum will improved drain effectiveness. The oil should then be removed from sumps, tanks, and coolers. The sump and all tanks and accessible surfaces should be manually cleaned with lint-free rags to remove all traces of residual contamination and as much oil as possible. The flushing oil, after purification, may be used for flushing another installation, after it has been determined that the product is free of contaminants and still contains solvency and rust inhibiting properties. After the flushing oil has been drained and surfaces cleaned, the lubricating oil system should be again thoroughly inspected for evidences of contamination. The system should then be completely rechecked to determine if it is secure for operation. Clean dry air or Nitrogen can be used to help push the oil back to the lube oil reservoir for removal. This will allow for greater amount of efficiency in removal percentage. Care should be taken to not over pressure lines, filter housings, or control devices.

7.9 *Displacement Oil*—If very light oil is used for flushing, or if there are quantities of special flushing oil left in the system, displacement oil must be used. Another reason for the use of displacement oil is to remove flushing oil or cleaners, or both, that are highly contaminated with oil soluble materials. A displacement flush is also recommended when changing the type of oil in a system. Displacement oil should be compatible with and approximately the same viscosity as the operating charge to be installed. To minimize the impact of the displacement flush oil on the operating oil it is recommended that these oils be of the same chemistry. Strainers and filter housings and other large vessels should be drained, strainers cleaned, and all filter elements replaced. Pump the displacement oil into the system as soon as possible. The circulating pumps and turning or jacking gear, if present, should be started, the oil heated to 60 °C to 70 °C (140 °F to 160 °F), and circulated for a minimum of 2 h with purification. Circulation of the oil should be continued for 12 h or until inspection of the strainers and filter bags shows no evidence of contaminants. The displacement oil should be drained while warm to improve flow. Low points and isolated areas should be drained or vacuumed clean.

7.10 *Interim Corrosion Protection*—With respect to corrosion, one of the most critical times for a lubricating oil system is the long idle period that may exist between flushing and regular operation. Proper scheduling of the flushing operation will minimize this idle period. The use of oil with a vapor space inhibitor will protect the system from corrosion by condensation. If a corrosion inhibitor is used, consult with the oil supplier on compatibility with the system oil. Confirm compatibility with Practice D7155. During this period, the system should be inspected frequently for signs of corrosion, particularly the upper portions of the gear case where the newly charged oil has not come into contact with the case and gear surfaces. It is in this region that moisture will condense into droplets of water and start the corrosion process and contaminate the new oil. If corrosion is taking place, it can be minimized by hand lancing these portions of the housing. Corrosion on the gear teeth can be prevented by rotating the bull gear a turn and a quarter every week with the lubrication oil system operating, thereby coating all of the teeth with a new protective film of oil. Cold oil, approximately 38 °C (100 °F), should be used for this purpose and when hand lancing to obtain best adhesion.

7.11 *New Oil Charge*—After the lube oil reservoir is inspected and certified clean and ready for receipt of new oil, a full charge of new turbine oil should be installed in the system as soon as possible. This charge should be introduced through filters, purified to one ISO Code level below OEM recommended ISO Cleanliness level and certified as clean before circulating, for example, OEM recommends ISO Cleanliness at 18/17/14 so the target should be 17/16/13. ISO Cleanliness levels tend to rise once system pumps are placed in operation.

8. Contamination Control In Operational Units

8.1 *Contamination Control During Operation*—Contamination control systems should be in operation as long as the lubricating oil system is in service. These systems should maintain oil purity at levels discussed in X2.7. Additional guidelines for contamination monitoring in operating systems are given in Practice D4378. The oil contamination levels and the operation of all purification devices should be constantly monitored to ensure that they are performing adequately and to determine the need for maintenance. In addition, all openings from the system to the atmosphere, such as breather vents, should be regarded as sources of contaminant. Whenever practical, these should be provided with particle and moisture control devices. When making inspections or working on or around a turbine, care must be taken to prevent contaminants from entering the lubrication system. When extraneous work that may generate contaminants is being performed in the vicinity of the lubrication system, precautions should be taken to ensure that system components are not exposed and all access points closed or protected, prior to beginning the work.

8.2 *Contamination Control During Oil Transfer:*

8.2.1 There are several reasons why oil may be transferred out of all or part of the lubrication system. These include preparation for repair of a system component, system overhaul, or replacement because the oil no longer meets specifications. In the first two cases, the oil will probably be returned to the system, while in the third case, it will probably be discarded.

8.2.2 If the oil is to be retained, it should be transferred to a certified clean container. Before transferring the lubricant, inspect the storage tank for particulate and water and clean if necessary. Residues from previous fills are contaminants and should be removed if practical.

8.2.3 When the oil is being transferred from the system, it should pass through a filter equal to or greater rating than currently installed in the system and care should be taken to remove all the oil. Heaters, coolers, and purification devices can contain large amounts of oil that contain contaminants. In addition, this prevents inadvertent spillage later.

8.2.4 Purification of the oil during transfer or temporary storage is also recommended if analyses indicate it is required. If the entire system is drained, contractors with large portable purification units may be employed to purify the oil. These contractors should be able to provide a process for handling the lubricants and certificate of analysis indicating the fluid meets the established cleanliness criteria. On completion of system