



Designation: ~~D6224-02~~ Designation: D6224 - 09

Standard Practice for In-Service Monitoring of Lubricating Oil for Auxiliary Power Plant Equipment¹

This standard is issued under the fixed designation D6224; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

A more systematic approach to monitoring auxiliary power plant equipment can help to minimize the high cost of oil changes and unplanned shutdowns. These avoided costs must be balanced against the cost of sampling and laboratory testing.

~~This practice is designed to assist the user in planning and implementing a meaningful, cost-effective program of sampling and testing of oils in use. Also covered are some important aspects of interpretation of results and suggested action steps so as to maximize service life of the oil and equipment.~~

This practice is designed to help the user plan and implement a meaningful, cost-effective program of sampling and testing of oils in use. Also covered are some important aspects of interpretation of results and suggested action steps so as to maximize service life of the oil and equipment.

This practice is designed to help the user evaluate the condition of the lubricant through its life cycle by carrying out a meaningful program of sampling and testing of oils in use. This practice is performed in order to collect data and monitor trends which suggest any signs of lubricant deterioration and to ensure a safe, reliable and cost-effective operation of the monitored plant equipment.

1. Scope

1.1 This practice covers the requirements for the effective monitoring of mineral oil and phosphate ester fluid lubricating oils in service auxiliary (non-turbine) equipment used for power generation. Auxiliary equipment covered includes gears, hydraulic systems, diesel engines, pumps, compressors, and electrohydraulic control (EHC) systems. It includes sampling and testing schedules and recommended action steps, as well as information on how oils degrade.

NOTE 1—Other types of synthetic lubricants are sometimes used but are not addressed in this practice because they represent only a small fraction of the fluids in use. Users of these fluids should consult the manufacturer to determine recommended monitoring practices.

1.2 This practice does not cover the monitoring of lubricating oil for steam and gas turbines. Rather, it is intended to complement Practice D4378.

~~1.3 The values stated in SI units are to be regarded as the standard.~~

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in 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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*²

D92 Test Method for Flash and Fire Points by Cleveland Open Cup Tester

D95 Test Method for Water in Petroleum Products and Bituminous Materials by Distillation

¹ This practice is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.C0 on Turbine Oils.

Current edition approved Nov. 10, 2002. Published February 2003. Originally approved in 1998. Last previous edition approved in 1998 as D6224-98. DOI: 10.1520/D6224-02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.C0.01 on Turbine Oil Monitoring, Problems and Systems.

Current edition approved July 1, 2009. Published November 2009. Originally approved in 1998. Last previous edition approved in 2002 as D6224-02. DOI: 10.1520/D6224-09.

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.

- D96 Test Methods for Water and Sediment in Crude Oil by Centrifuge Method (Field Procedure)³
- D257 Test Methods for DC Resistance or Conductance of Insulating Materials
- 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
- D665 Test Method for Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water
- D892 Test Method for Foaming Characteristics of Lubricating Oils
- D893 Test Method for Insolubles in Used Lubricating Oils
- D943 Test Method for Oxidation Characteristics of Inhibited Mineral Oils
- D974 Test Method for Acid and Base Number by Color-Indicator Titration
- D1169 Test Method for Specific Resistance (Resistivity) of Electrical Insulating Liquids²
- D1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
- D1401 Test Method for Water Separability of Petroleum Oils and Synthetic Fluids
- D1500 Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)
- D1533 Test Method for Water in Insulating Liquids by Coulometric Karl Fischer Titration
- D1744 Test Method for Water in Liquid Petroleum Products by Karl Fischer Reagent^{3,2}
- D2272 Test Method for Oxidation Stability of Steam Turbine Oils by Rotating Pressure Vessel
- D2273 Test Method for Trace Sediment in Lubricating Oils
- D2422 Classification of Industrial Fluid Lubricants by Viscosity System
- D2668 Test Method for 2,6-*di-tert*-Butyl- *p*-Cresol and 2,6-*di-tert*-Butyl Phenol in Electrical Insulating Oil by Infrared Absorption
- D2896 Test Method for Base Number of Petroleum Products by Potentiometric Perchloric Acid Titration
- D2982 Test Methods for Detecting Glycol-Base Antifreeze in Used Lubricating Oils
- D3427 Test Method for Air Release Properties of Petroleum Oils
- D3524 Test Method for Diesel Fuel Diluent in Used Diesel Engine Oils by Gas Chromatography
- D4052 Test Method for Density and Relative Density of Liquids by Digital Density Meter
- D4057 Practice for Manual Sampling of Petroleum and Petroleum Products
- D4378 Practice for In-Service Monitoring of Mineral Turbine Oils for Steam and Gas Turbines
- D4739 Test Method for Base Number Determination by Potentiometric Hydrochloric Acid Titration
- D5185 Test Method for Determination of Additive Elements, Wear Metals, and Contaminants in Used Lubricating Oils and Determination of Selected Elements in Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
- 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
- E1064 Test Method for Water in Organic Liquids by Coulometric Karl Fischer Titration [76025a403/astm-d6224-09](https://www.astm.org/standards/E1064.html)
- 2.2 *ISO Standard*.⁴
- ISO FDIS 4406.2 Hydraulic Fluid Power Fluids—Code for Defining the Level of Contamination of Solid Particles, 1999

3. Significance and Use

3.1 This practice is intended to ~~assist~~help users, particularly power plant operators, ~~in maintaining~~maintain effective control over their mineral lubricating oils and lubrication monitoring program. This practice may be used to perform oil changes based on oil condition and test results rather than on the basis of service time or calendar time. It is intended to save operating and maintenance expenses.

3.2 This practice is also intended to ~~assist~~help users ~~in monitoring~~monitor the condition of mineral lubricating oils and ~~guarding~~guard against excessive component wear, oil degradation, or contamination, thereby minimizing the potential of catastrophic machine problems that are more likely to occur in the absence of such an oil condition monitoring program.

3.3 This practice does not necessarily reference all of the current oil testing technologies and is not meant to preclude the use of alternative instrumentation or test methods which provide meaningful or trendable test data, or both. Some oil testing devices and sensors (typically used for screening oils which will be tested according to standard methods) provide trendable indicators which correlate to water, particulates, and other contaminants but do not directly measure these.

3.4 This practice is intended for mineral type of oil products, and not for synthetic type of products, with the exception of phosphate esters fluids used typically in power plant control systems.

4. General Properties of Lubricating Oils

4.1 In general, lubricating oils are designed to reduce friction and wear, provide cooling, control deposits, and combat the effects

² Annual Book of ASTM Standards, Vol 10.01.

³ Withdrawn.

⁴ Annual Book of ASTM Standards, Vol 10.05.

⁴ Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, <http://www.iso.ch>.

of contamination. A base oil's lubricating properties are enhanced by selected additives. Different machines have different lubricant additive requirements, some of which are described in this section. A lubricating oil prevents Proper lubrication minimizes or precludes contact between metal surfaces by the formation of a very thin protective film (that is, elastohydrodynamic lubrication) and reduces component wear.

~~4.2 *Gear (Circulating) Oils*—The primary requirement of gear oils is that they prevent wear and minimize other forms of damage such as pitting and scuffing by maintaining a lubricant film between the moving surfaces. Although gears are of many types including spur, helical, worm, bevel, and hypoid, they all function with some combination of rolling and sliding motion. The unit loadings of gear-tooth surfaces are relatively high compared with ordinary bearing surfaces. Where the gear loadings are relatively heavy, mineral oils containing extreme pressure (EP) or anti-wear additives may be used as the lubricant. For highly loaded spiral bevel, worm, or hypoid gears where sliding contact predominates over rolling contact between gear teeth, lubricating oils with special wear-reducing additives are used. Sulfur, boron, and phosphorous compounds can be used for this purpose. Anti-foaming additives are also important in gear lubricants.~~ Gear Oils—The primary requirement of gear oils is that they prevent wear and minimize other forms of damage such as pitting and scuffing by maintaining a lubricant film between the moving surfaces.

~~4.3 *Hydraulic Oils*—A hydraulic fluid is required to transmit hydraulic pressure and energy, minimize friction and wear in pumps, valves and cylinders, and protect metal surfaces against corrosion. To obtain optimum efficiency of machine operation and control, the viscosity of the oil should be low enough to minimize frictional and pressure losses in piping. However, it also is necessary to have a sufficiently high viscosity to provide satisfactory wear protection and minimize leakage of the fluid. High-viscosity index fluids help to maintain a satisfactory viscosity over a wide temperature range. The anti-wear properties of high-quality hydraulic oils usually are improved by suitable additives. Since the clearances in pumps and valves tend to be critical, it is important to provide adequate filtration equipment (full flow or bypass, or both) to maintain a minimum particle content and thus minimize wear. The antioxidant additives in the hydraulic oil should have give the oil good oxidation stability to avoid the formation of insoluble gums or sludges; if the oil should have good water separation properties, and, because air may be entrained in the system, the oil should have good air-release properties and resistance to foaming. Similarly, good rust protection properties will assist in keeping system metals in satisfactory condition.~~

~~4.4 *Diesel Engine Oils*—In addition to the typical role of lubricating oils which is to lubricate, clean, cool and seal, diesel engine oils are formulated to provide protection from acids and disperse soot particles that are created during the combustion process. Diesel engine oils are compounded with alkaline additives to neutralize the sulfuric acids that are produced when the diesel fuel is combusted. They are also compounded with dispersant/detergents to keep the engine clean and the by-products of combustion (fuel soot) suspended. The combination of wear regimes found in the diesel engine require the lubricants to have high levels of anti-wear additives to protect the engine from wear during the most severe condition. Multi-grade lubricants (high viscosity index) are often employed in diesel engine lubricants that are required to operate over a wide temperature range.~~

~~4.5 *Turbine-type (Pump) Oils or Circulating Oils, or Both*—Turbine—These oils provide satisfactory lubrication and cooling of bearings and gears (for example, in auxiliary turbines, pumps and gearboxes as circulating oils). They also can function as a governor hydraulic fluid. The oil must have a viscosity high enough to maintain a sufficiently thick film of oil on load-bearing surfaces, but low enough to minimize energy losses while providing adequate cooling. These oils are recommended where the degree of loading on bearings and gears is less than in gear oil applications. Turbine or circulating oils, or both, have excellent oxidation resistance and contain rust inhibitors; they are often referred to as R&O oils. Turbine oils They can also contain additives to improve water separability and decrease foaming tendency.~~

~~4.6 *Compressor Oils*—In addition to possessing the correct viscosity for satisfactory bearing and cylinder lubrication, particularly for air compressors, very good oxidation resistance is required to avoid degradation of the lubricant in the presence of heated air. This is particularly important for mineral oils where discharge temperatures are high, since carbon and oxidized oil deposits may autoignite if exposed continuously to temperatures above 148°C (300°F). 148°C. The fire potential that exists under these conditions make low volatility and high auto-ignition values equally or more important than high-flash or fire points. In compressor lubrication, condensed water is present frequently. For this reason, the oil must possess properties that ensure that the oil rather than water wets the metal surfaces. Also, to avoid the accumulation of water-in-oil emulsions in the after coolers, the water should separate out rather than form an emulsion.~~

~~4.7 *Electrohydraulic Control (EHC) Fluids*—Triaryl phosphate ester EHC fluids are inherently fire-resistant and maintain this property throughout their service life. The very low vapor pressure and chemical nature of these fluids result in high flash point, fire point, and autoignition temperature. EHC fluids should be continuously purified using bypass systems to maintain acid number, moisture, and particulates at low levels. Moisture can cause hydrolysis of EHC fluids which results in elevated acid number. Components constructed of copper and lead alloys should be avoided. These fluids are chemically different from mineral oils; consequently, the interpretation of test results will be significantly different. The fluid supplier should be consulted if there is a question about interpretation of analytical results.~~

5. Operational Factors Affecting the Service Life of Oils

~~5.1 *New Oil Quality and Suitability for Intended Use*—Use of high-quality oils that meet recognized standards (such as manufacturer or military specifications) is the best assurance of potentially long service life.~~

~~5.1.1 Viscosity is the most important characteristic of an oil. An oil's load bearing and lubricating properties are related directly to its viscosity. The use of oil with incorrect viscosity can increase wear rates, heat build-up, and lube degradation. In extreme~~

cases, the use of oils with incorrect viscosities can result in rapid catastrophic failures. Use of high-quality oils that meet recognized standards (such as manufacturer military specifications and OEM specifications) is the best assurance of potentially long service life. Careful oil storage is important to prevent the degradation of the lubricant while in storage or being dispensed. Accurate labeling of lubricant containers is vital to ensure proper identification.

5.1.1 Viscosity is the most important characteristic of an oil. Oil's load bearing and lubricating properties are related to its viscosity. The use of oil with incorrect viscosity can increase wear rates, heat build-up, and lube degradation. In extreme cases, the use of oils with incorrect viscosities can result in rapid catastrophic failures.

5.1.2 Oils that meet the equipment manufacturers' requirements should be used. For situations where the manufacturer simply offers a generic viscosity classification without specific performance criteria, the user should consult the equipment manufacturer, lubricant suppliers, and experts in the field of lubrication.

5.1.3 When fresh, unused lubricants are received, a representative sample of oil may be taken and tested (see Table 1) to ensure that general specifications are met. This test data should be compared to a reference baseline from the lubricant supplier and then used for future condition monitoring.

5.1.4 Manufacturer shelf life recommendations should be observed. Oils should be stored to preserve their original quality and

TABLE 1 Guidelines for Sampling and Testing New Oils^A

NOTE 1—Legend—R = Recommended; O = Optional.

NOTE 2—An infrared spectrum may be obtained for new oil to ensure that the oil is not contaminated and to provide a baseline for comparison to spectra of in-service oil.

Test	Common Methods	Gear/Circulating Oils	Hydraulic Oils	Diesel Engine Oils	Turbine-Type Oils	Air Compressor Oils ^B	EHC (PO ₄ Esters)	EHC (Min. Oils)
Appearance ^C	Visual	R	R		R	R	R	R
Viscosity, (40°C)	D445	R	R	O ^D	R	R	R	R
Viscosity (100°C)	D445			R				
Acid number	D664 D974	R	R		R	R	R	R
Water	D1744 ^E D95	O ^F	O ^F	R ^F	O ^F	O ^F	R	O ^F
Oxidation inhibitor	D2668				⊖			
Antioxidants/Oxidation inhibitor	D2668				⊖	⊖		
	Voltammetry	⊖	⊖		⊖	⊖		⊖
	D6971 ^G				O ^G	O ^G		
Oxidation stability (RPVOT)	D2272		⊖		⊖	⊖		
Oxidation stability (RPVOT)	D2272				⊖	⊖		
API gravity or density	D1298 D4052						O	
Flash point (COC)	D92			O				
Water separability	D1401		O		O			
Particle counts	Equipment Manufacturer's Method		R				O	O
Base number	D974 D2896 D4739			R				
Electrical resistivity	D257/D-1169						R	
Electrical resistivity	D257/D1169						R	
Elemental Analysis	D5185 ^G	⊖	⊖	⊖	⊖	⊖	⊖	⊖
Elemental Analysis	D5185 ^H	⊖	⊖	⊖	⊖	⊖	⊖	⊖

^A Tests which are performed on in-service oils for trending purposes should also be performed on new oils for baseline information.

^B Does not include refrigeration (chiller) oils.

^C Appearance includes observations such as color, clarity, odor, and sediment.

^D A diesel engine oil must be tested at 40 and 100°C if it is necessary to determine whether it is the proper multi-grade oil.

^E Test Method D1744 is not recommended for certain lube oils because of additive interferences. Results from Test Method D1744 should be viewed as relative rather than absolute due to additive interferences and other reasons. Test Methods E1064 and D1533 may be used for certain lubricants.

^F Recommended if oil is not clear and bright.

^G Test Method D6971 is not recommended for zinc-based lubricating oils.

^H Another spectrochemical method such as rotating disk electrode (RDE), atomic absorption (AA), or x-ray fluorescence (XRF) may be substituted for the ICP method.

prevent contamination. Stored oils may be tested to ensure and document their quality, cleanliness, and continued suitability for their intended use.

5.1.5 Make-up oils should normally be of the same type, quality, and manufacturer. Available formulations may change over a period of time. Lubricant incompatibility can arise from mixing differing base stocks and additive packages and should be avoided. When oils must be mixed, testing should be performed in an attempt to determine compatibility. Consideration should be given to consulting the lubricant supplier(s) and equipment manufacturer prior to mixing oils.

5.1.3 When fresh, unused lubricants are received it is advisable to obtain typical test data from the oil supplier. Upon receipt of the first oil charge, take a sample of oil to confirm the typical test data and to use as a baseline.

5.1.3.1 In order to avoid possible mixtures with residual flush oil or previous fill oil in equipment, make an oil sample of the new oil charge upon startup the true baseline oil sample.

5.1.3.2 This baseline should be the reference sample for the physical and chemical properties of the fluid, and for future comparisons with used oil information. **This is most important!** Recommended tests for new oil are given in the schedules of this practice. (**Warning**—Physical and chemical properties of lubricants after installation may not match results obtained for new oil as received from the supplier.) (**Warning**—Storage conditions affect the shelf life of lubricants. Manufacturing shelf life recommendations should be followed. If no shelf life guidance information is available and the lubricants is greater than two years old, the lubricant manufacturer should be consulted to confirm suitability for use.)

5.1.4 Manufacturer shelf life recommendations should be observed. Oils should be stored to preserve their original quality and prevent contamination. Stored oils may be tested to ensure and document their quality, cleanliness, and continued suitability for their intended use. It is suggested that oil manufacturers' recommendations be followed when storing lubricants to ensure maximum product life.

5.1.5 Make-up oils should normally be of the same type, quality, and manufacturer. Available formulations may change over a period of time. Lubricant incompatibility can arise from mixing differing base stocks and additive packages and should be avoided. When oils must be mixed, testing should be performed in an attempt to determine compatibility in accordance with Practice D7155. Consideration should be given to consulting the lubricant supplier(s) and equipment manufacturer prior to mixing oils.

5.2 *Deterioration of Oils in Service*—Air (oxygen), elevated temperatures, metals, and water (moisture) are present to some extent in oil lubricating systems. These factors that promote oil lubricant degradation. Lubricant deterioration occurs by one or more of the following processes:

5.2.1 *Oxidation Degradation*—Chemical changes are brought about by oxygen in the atmosphere forming oxidation by-products which degrade the performance of the oil. These changes can adversely affect the oils viscosity and acidity. This process occurs as the result of chemical changes brought about by oxygen in the atmosphere and proceeds by a chain reaction that is catalyzed with the presence of air, water, heat and certain metals. The results of oxidation can consist of AN increase, viscosity (KV) increase, or sludge and varnish deposits, or a combination thereof as end-products within the lubricating system.

5.2.2 *Thermal/Oxidation Degradation*—At elevated temperatures, hydrocarbons are subject to thermal cracking which forms unstable compounds. Performance additives in the oil may also degrade at high temperatures. The unstable compounds are easily oxidized and also tend to polymerize to form resins, waxes, and sludge. Thermal oxidation can occur at local hot spots within a system and as a result of high bulk oil temperatures. Thermal Degradation—This process occurs in the absence of oxygen and at much higher temperatures. Typically, temperatures of more than 300°C may cause the hydrocarbon molecule to crack and produce various degradation species. Some of these species are low molecular weight by-products that evaporate or burn (producing a noticeable “burnt” smell in the oil) and other degradation species are high molecular weight by-products that form sludge and varnish.

5.2.3 *Loss of Additives*—Additives are used to protect the oil and enhance its performance abilities. When these additives are depleted with service, oil oxidation, foaming, excessive wear, or premature rusting may result. Lubricant Deposits and Sludge (Lacquering)—As lubricants degrade either through thermal and mechanical forces, they may produce submicron, high molecular weight, polar insoluble particles. These particles may agglomerate, become insoluble in the oil, as it is non-polar in nature, and adsorb onto the metal parts of a lubricating system. Some highly refined base oils used in the manufacturing of lubricants (API Group II and above) may be less tolerant to the presence of these degradation by-products due to their high purity and lower solvency. Base oils with proper formulation can result in low deposit tendency oils. Deposits (such as varnish) could be very costly to an equipment operator, as they may deposit on bearing and turning gear surfaces increasing wear, settle in servo-valves causing valves to stick and seize, coat heat exchangers lowering their performance and form in reservoirs acting as a catalyst to further degradation. If deposits are found in the system, analysis can be performed on the deposit to identify possible root causes. The insoluble polar compounds may be removed by the use of some electrostatic separation technologies and through carefully performed high velocity flushes.

5.2.3.1 When these conditions of lubricants deposits and sludge occur, dramatic reductions in the viscosity of the oil are possible and the flash point of the resulting fluid can also change.

5.2.4 *New Oil Make-up*—Addition of new oil is required in nearly every system to make up for losses due to leakage, filter changes, or other maintenance. The amount and frequency of added make-up oil sometimes plays a very significant part in determining the life of a system oil charge. Make-up can vary from less than 5% per year to greater than 30% in extreme cases.

In equipment where the make-up is very low (below 5%), oil oxidation and additive depletion are the primary determinants of service life. In-service oil should be tested at sufficient intervals to detect contamination, oxidation, and additive depletion. In equipment where make-up is relatively high, the degree of degradation is minimal because the additives are being replenished. Hydrolysis—Hydrolysis is a mode of degradation in the presence of moisture. This is very important for phosphates (and other esters) and may also have an effect on additive systems in oil-based products. The major characteristic of hydrolysis is the generation of corrosive acids in the fluids.

5.2.5 Loss of Additives—Additives are used to protect the oil and enhance its performance abilities. When these additives are depleted as a result of service, the performance of the oil will be reduced as a consequence of oil oxidation, foaming, excessive wear, or premature rusting.

5.2.6 New Oil Make-up Rate—Addition of new oil is required in nearly every system to make up for losses due to leakage, filter changes, or other maintenance. Monitor the amount and frequency of added make-up oil, since they play a very significant part in determining the life of a system oil charge.

5.3 *Contamination*—Contamination of lubricating oils occurs both from outside and from within the system. Common types of contamination are: debris introduced at initial startup or after an overhaul, lubricant degradation byproducts, component wear debris, airborne particulates, and water (moisture). Contamination is often the most significant factor affecting oil service life. Contamination of oil is a valid reason to change oil and flush to restore system cleanliness.

5.3.1 *Condition of Equipment on Start-up*—Oil system contamination prior to start-up usually consists of preservatives, paint, moisture, rust particles, and construction debris such as dust, dirt, or welding spatter. Extreme care must be taken to avoid the introduction of any contamination into a machine during manufacture, assembly, installation, servicing, or repair. Whenever practical, flushing the system before starting operation is recommended. Fluid cleanliness should be brought to a level of one to two ISO FDIS 4406.2 classes below warning levels before beginning operation. If flushing is not performed, oils should be tested soon after startup or repair to verify their cleanliness.

5.3.2 External Contamination-Solids—Solid contamination consists of any material small enough to pass through bearing seals and vents or which can be introduced with make-up oil. Consideration may be given to *prefiltering* make-up oil to prevent introducing contaminants into an otherwise clean system.—Solid contamination consists of any material small enough to pass through bearing seals and vents or which can be introduced with make-up oil. From whatever source, contamination must be dealt with by monitoring oil condition and using purification devices such as filters and centrifuges on a regular basis.

5.3.3 *External Contamination-Liquid*—Coolant leaks, moisture or steam condensation, or introduction of improper lubricating oils can compromise the oil. Accumulated water promotes oil degradation as well as interfering with lubrication. Contamination with an improper lubricant is not easily corrected without a complete oil change. An oil monitoring program may be used to monitor and identify contaminants likely to be encountered in service.

5.3.4 *Internal Contamination*—Contaminants include wear debris and oil degradation products. The types of internal contaminants will vary by equipment type and oil type; the rate of generation will be highly dependent on the equipment operating conditions. The analysis methods employed must be able to identify expected wear debris and degradation products. Testing frequencies should be sufficient to account for operating conditions. [b36e-4cfe-a2f8-fl676025a403/astm-d6224-09](https://www.astm.org/standards/d6224)

6. Sampling

6.1 *General*—When taking lubricant samples from storage tanks or equipment in service, it is important that proper sampling techniques are followed. The following are some suggested guidelines for proper sampling technique and sample handling techniques. (See also Practice D4057—When taking lubricant samples from storage tanks or equipment in service, it is important that the extracted sample is representative and is taken from a specified location(s) to monitor the properties of the lubricant. The following are some suggested guidelines for proper sampling technique and sample handling techniques. (See also Practice D4057.) The user should have written procedures to insure that samples are taken consistently according to good maintenance practices.

6.2 *Representative Sampling*—To be representative, a sample must be obtained either from an agitated tank or a free flowing line. A sample line should always be flushed before a sample is taken. The system should be in steady state operation. An agitated tank is one which is currently in use or is within 25 minutes of shutdown. A fluid sample is probably not representative if: (1) the system fluid is hot while the sample is cold, (2) the fluid in the system is one color or clarity in an in-line sight glass while the sample is a different color or clarity, and (3) the fluid viscosity of the reservoir fluid is different from that of the sample when both are at the same temperature. Samples should be taken in the same manner each time to allow reliable trending of oil properties.—A representative sampling location is a sampling location that supports repeatable and representative lubricant sampling to monitor the health of the equipment and the properties of the lubricant. To be representative, collect oil samples when machines or equipment are running at normal operating temperatures, loads, pressures and speeds. To ensure that insoluble material is suspended evenly throughout the system. A fluid sample is probably not representative if: (1) the system fluid is hot while the sample is cold, (2) the fluid in the system is one color or clarity in an in-line sight glass while the sample is a different color or clarity, and (3) the fluid viscosity of the reservoir fluid is different from that of the sample when both are at the same temperature. Samples should be taken in the same manner each time to allow reliable trending of oil properties.

6.2.1 It should be noted that on occasion a sample may be requested which will not be representative. At that time, sampling instructions, as specified by the requestor, must be followed. For example, a sample might be taken off the top or the bottom of