Standard Practice for In-Service Monitoring of Lubricating Oil for Auxiliary Power Plant Equipment[1]

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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.

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 D 4378.

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

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with 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:*

D 92 Test Method for Flash and Fire Points by Cleveland Open Cup[2]
D 95 Test Method for Water in Petroleum Products and Bituminous Materials by Distillation[2]
D 96 Test Method for Water and Sediment in Crude Oil by Centrifuge Method Field Procedure[2]
D 257 Test Methods for D-C Resistance or Conductance of Insulating Materials[3]
D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)[2]
D 664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration[2]
D 665 Test Method for Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water[2]
D 892 Test Method for Foaming Characteristics of Lubricating Oils[2]
D 893 Test Method for Insolubles in Used Lubricating Oils[2]
D 943 Test Method for Oxidation Characteristics of Inhibited Mineral Oils[2]
D 974 Test Method for Acid and Base Number by Color-Indicator Titration[2]
D 1169 Test Method for Specific Resistance (Resistivity) of Electrical Insulating Liquids[4]
D 1298 Practice for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method[2]
D 1401 Test Method for Water Separability of Petroleum

[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.

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[2] *Annual Book of ASTM Standards*, Vol 05.01.
[3] *Annual Book of ASTM Standards*, Vol 10.01.
[4] *Annual Book of ASTM Standards*, Vol 10.03.

Oils and Synthetic Fluids[2]
- D 1500 Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)[2]
- D 1533 Test Method for Water in Insulating Liquids by Coulometric Karl Fischer Titration[4]
- D 1744 Test Method for Water in Liquid Petroleum Products by Karl Fischer Reagent[2]
- D 2272 Test Method for Oxidation Stability of Steam Turbine Oils by Rotating Pressure Vessel[2]
- D 2273 Test Method for Particulate Contamination in Aviation Fuel by Line Sampling[2]
- D 2422 Classification of Industrial Fluid Lubricants by Viscosity System[2]
- D 2668 Test Method for 2,6-Ditertiary-Butyl Para-Cresol and 2,6 Ditertiary-Butyl Phenol in Electrical Insulating Oil by Infrared Absorption[4]
- D 2896 Test Method for Base Number of Petroleum Products by Potentiometric Perchloric Acid Titration[2]
- D 2982 Test Method for Detecting Glycol-Base Antifreeze in Used Lubricating Oils[2]
- D 3427 Test Method for Air Release Properties of Petroleum Oils[5]
- D 3524 Test Method for Diesel Fuel Diluent in Used Diesel Engine Oils by Gas Chromatography[5]
- D 4052 Test Method for Density and Relative Density of Liquids by Digital Density Meter[5]
- D 4057 Practice for Manual Sampling of Petroleum and Petroleum Products[5]
- D 4378 Practice for In-Service Monitoring of Mineral Turbine Oils for Steam and Gas Turbines[5]
- D 4739 Test Method for Base Number Determination by Potentiometric Titration[5]
- D 5185 Test Method for the 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)[5]
- E 1064 Test Method for Water in Organic Liquids by Coulometric Karl Fischer Titration[6]

3. Significance and Use

3.1 This practice is intended to assist users, particularly power plant operators, in maintaining effective control over their lubricating oils and lubrication monitoring program. This practice may be used to perform oil changes based on 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 users in monitoring lubricating oils and guarding 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 a 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 (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.

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 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 contact between metal surfaces by the formation of a very thin protective film (that is, elastohydrodynamic lubrication).

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.

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 oil should have good oxidation stability to avoid the formation of insoluble gums or sludges; it 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

[5] *Annual Book of ASTM Standards*, Vol 05.02.
[6] *Annual Book of ASTM Standards*, Vol 15.05.

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*—Turbine oils provide satisfactory lubrication and cooling of bearings and gears (for example, in auxiliary turbines and gearboxes). 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 oils have excellent oxidation resistance and contain rust inhibitors; they are often referred to as R & O oils. Turbine oils 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). 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. 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.

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 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.

5.2 *Deterioration of Oils in Service*—Air (oxygen), elevated temperatures, metals, and water are present to some extent in oil systems. These factors promote oil degradation. 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.

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.

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.

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