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An American National Standard

Standard Practice for
In-Service Monitoring of Mineral Turbine Oils for Steam and Gas Turbines[1]

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INTRODUCTION

The in-service monitoring of turbine oils has long been recognized by the power-generation industry as being necessary to ensure long trouble-free operation of turbines.

The two main types of stationary turbines used for power generation are steam and gas turbines. The lubrication requirements are quite similar but there are important differences in that gas turbine oils are subjected to significantly higher localized "hot spot" temperatures and water contamination is less likely. Steam turbine oils are normally expected to last for many years. In some turbines up to 20 years of service life has been obtained. Gas turbine oils by comparison have a shorter service life. Many of the monitoring tests used for steam turbine oils are applicable to gas turbine oils.

This practice is designed to assist the user to understand how oils deteriorate and to carry out a meaningful 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.

1. Scope

1.1 This practice covers the requirements for the effective monitoring of mineral turbine oils in service in steam and gas turbines used for power generation. It includes sampling and testing schedules and recommended action steps, as well as information on how oils degrade.

1.2 *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:*

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 130 Test Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test[2]

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 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 1401 Test Method for Water Separability of Petroleum Oils and Synthetic Fluids[2]

D 1500 Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)[2]

D 1533 Test Methods for Water in Insulating Liquids (Karl Fischer Reaction Method)[3]

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 Bomb[2]

D 2422 Classification of Industrial Fluid Lubricants by Viscosity System[2]

D 4057 Practice for Manual Sampling of Petroleum and Petroleum Products[4]

D 4241 Practice for Design of Gas Turbine Generator Lubricating Oil Systems[4]

D 4248 Practice for Design of Steam Turbine Generator Oil Systems[4]

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[1] This practice is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricantsand is the direct responsibility of Subcommittee D02.Con Turbine Oils.

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[2] *Annual Book of ASTM Standards*, Vol 05.01.

[3] *Annual Book of ASTM Standards*, Vol 10.03.

[4] *Annual Book of ASTM Standards*, Vol 05.02.

F 311 Practice for Processing Aerospace Liquid Samples for Particulate Contamination Analysis Using Membrane Filters[5]

F 312 Methods for Microscopical Sizing and Counting Particles from Aerospace Fluids on Membrane Filters[5][6]

2.2 *International Organization for Standardization:*

ISO 4406 Hydraulic Fluid Power-Fluids—Method for coding level of contamination by solid particles

2.3 *Other Standard:*

National Aerospace Standard 1638[7]

3. Significance and Use

3.1 This practice is intended to assist the user, in particular the power-plant operator, to maintain effective lubrication of all parts of the turbine and guard against the onset of problems associated with oil degradation and contamination.

4. Properties of Turbine Oils

4.1 Most turbine oils consist of a highly refined paraffinic mineral oil compounded with oxidation and rust inhibitors. Depending upon the performance level desired, small amounts of other additives such as metal deactivators, pour depressants, extreme pressure additives, and foam suppressants can also be present.

4.2 New turbine oils should exhibit good resistance to oxidation, inhibit sludge formation, and provide adequate antirust, water separability, and nonfoaming properties. However, these properties cannot be expected to remain unchanged during the life of the oil. Some deterioration can be tolerated without prejudice to the safety or efficiency of the system. Reinhibition may improve some properties of the oil. Good monitoring procedures are necessary to determine when the properties have changed sufficiently to warrant corrective action.

5. Operational Factors Affecting Service Life

5.1 The factors that affect the service life of turbine lubricating oils are as follows: (*1*) type and design of system, (*2*) condition of system on startup, (*3*) original oil quality, (*4*) system operating conditions, (*5*) contamination, and (*6*) oil makeup rate.

5.1.1 *Type and Design of System*—Most modern turbine lubricating systems are similar in design, especially for the larger units. For lubrication, the usual practice is to pressure-feed oil directly from the main oil pump. The rest of the system consists of a reservoir, oil cooler, strainer, piping and additional purification or filtration equipment, or a combination thereof. Miscellaneous control and indicating equipment completes the system. If there is an opportunity to participate in system design, it is recommended that appropriate practices be consulted (see Practice D 4241 and Practice D 4248).

5.1.2 *Condition of System on Start-up*:

5.1.2.1 The individual components of a lubrication system are usually delivered on-site before the system is installed. The length of on-site storage and means taken to preserve the integrity of the intended oil wetted surfaces will determine the total amount of contamination introduced during this period, the magnitude of the task of cleaning and flushing prior to use, and the detrimental effects of the contaminants. Guidance on contamination control, flushing, and purification may be sought from the equipment supplier or other industry experts.

5.1.2.2 Turbine oil system contamination prior to startup usually consists of preservatives, paint, rust particles, and the various solids encountered during construction which can range from dust and dirt to rags, bottles, and cans. Their effect on turbine oil systems is obvious.

5.1.3 *Original Oil Quality*:

5.1.3.1 Use of a high-quality oil is the best assurance of potentially long service life. Oils meeting recognized standards are generally available, and one that at least meets the requirements of the turbine manufacturer shall be used.

5.1.3.2 It is advisable to obtain typical test data from the oil supplier. Upon receipt of the first oil charge, a sample of oil should be taken to confirm the typical test data and to use as a baseline for future comparisons with used oil information. This is most important! Recommended tests for new oil are given in the schedules of this practice (see Table 1 and Table 2).

5.1.3.3 When new turbine oil is to be mixed with a charge of a different composition prior checks should be made to ensure no loss of expected properties due to incompatibility. These should include functional tests and checks for formation of insolubles.

5.1.4 *System Operating Conditions*:

5.1.4.1 The most important factors affecting the anticipated service life of a given lubricating oil in a given turbine system are the operating conditions within the system. Air (oxygen), elevated temperatures, metals, and water are always present to some extent in these oil systems. These elements promote oil degradation.

5.1.4.2 Most turbine oil systems are provided with oil coolers to control temperature. In many cases, bulk oil temperatures are maintained so low [below 60°C (140°F)] that moisture condensation can occur. Even with low bulk oil temperatures, however, there can be localized hot spots such as in bearings, at gas seals, and in throttle control mechanisms that can cause oil degradation and eventually cause system oil to show signs of deterioration.

5.1.4.3 Under the higher temperature conditions which are present in gas and steam turbines, oxidation of the oil can be accelerated by thermal-oxidative cracking leading to the production of viscous resins and deposits particularly at the point of initiation.

5.1.5 *Contamination*:

5.1.5.1 Contamination of turbine oils occurs both from outside the system and from within due to oil degradation and moisture condensation or leaks. Development of a clean turbine oil system on start-up or following maintenance is essential. Once attained, the danger of external contamination is less but should be guarded against. The oil can be contaminated by the introduction of different type oils which are of the

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[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[7] Available from Aerospace Industries Association of America, Inc., 1725 De Sales St., N.W., Washington, DC.

TABLE 1 Steam Turbines—Sampling and Testing Schedules [Mineral Oils]

Schedule 1 New Oil

Samples:	
(a) From transport or drums	
(b) From storage tank	
Tests:	
Viscosity	[A]
Acid No.	[B]
Appearance	clear and bright
Water content	no free water
Color	[B]
Rust test	Pass[C]
Cleanliness	[D]
RBOT	[B]

[A] Should meet Classification D 2422.
[B] Should be consistent with user purchase specifications, new oil reference, or manufacturer's requirement, or combination thereof.
[C] Should pass D 665A for land-based turbines. Should pass D 665B for marine turbines.
[D] Definition of suitable cleanliness levels depends on turbine builder and user requirements. Filtration or centrifugation, or both, of oil into turbine and during service is strongly recommended.

Schedule 2 Installation of a New Oil Charge[A]

Sample:	
After 24-h circulation. Retain approximately 4 L (1 gal).	
Tests:	
Viscosity	[B]
Acid No.	[B]
Appearance	clear and bright
Water content	no free water
Color	[B]
Cleanliness	[B,C]
RBOT	[B,D]

[A] Follow recommended flushing procedures prior to installing a new oil charge whether it is an initial fill or an oil replacement.
[B] Should be consistent with user purchase specifications and new oil reference.
[C] Definition of suitable cleanliness levels depends on turbine builder and user requirements. Filtration or centrifugation, or both, of oil into turbine and during service is strongly recommended.
[D] Important as a baseline to determine turbine system severity.

Schedule 3A (First 12 Months Operation—New Turbine)

Test[A]	Viscosity	Acid No.	Appearance	Water Content	Color	Rust Test	Cleanliness	RBOT
Frequency[B]	Every 1–3 months	Monthly	Daily[C]	Monthly[C]	Weekly	Every 6 months	Every 1–3 months	Every 2–3 months

Schedule 3B Normal Operation

Note 1—This schedule should be used as a guide. Increased frequency is required for a severe turbine or for oils approaching the end of their service life. Most turbines should be covered by this schedule.

Test[A]	Viscosity	Acid No.	Appearance	Water Content	Color	Rust Test	Cleanliness	RBOT
Frequency[B]	Every 3–6 months	Every 1–3 months	Daily[C]	Every 1–3 months[C]	Weekly	1 Year	Every 1–3 months	Every 6–12 months

[A] If contamination is suspected, additional tests such as Flash Point, Foam, and Water Separability, may be useful to determine degree and effect of contaminants present. An outside laboratory or oil supplier can also assist in a more in-depth analysis.
[B] Frequency is based on continuous operation or total accumulated service time.
[C] If product is hazy or contains water in suspension, check water content.

wrong type or are incompatible with the system oil. The oil supplier or the turbine manufacturer, or both, should be consulted before additions are made.

5.1.5.2 External contamination can enter the system through bearing seals and vents. Internal contaminants are always being generated. These include water, dirt, fly ash, wear particles, and oil degradation products. From whatever source, contamination must be dealt with by monitoring oil condition and the use of purification devices such as filters and centrifuges on a regular basis. These can be removed by purification devices such as filters, centrifuges, coalescers, and vacuum dehydrators.

5.1.6 *Oil Makeup Rate*—The amount and frequency of makeup oil added to the system plays a very significant part in determining the life of a system oil charge. Makeup varies from below 5 % per year to as much as 30 % in extreme cases. In turbines where makeup is relatively high compared to the oil degradation rate, the degree of degradation is compensated for and long oil life can be expected. In turbines where the makeup is very low (below 5 %), a truer picture of oil degradation is obtained. However, such a system should be carefully watched since the oil life is dependent almost exclusively on its original quality. In the United States, the average makeup is typically around 7 to 10 % per year.

5.2 The combination of all of the preceding operational factors for a given turbine determine its *severity level*. Each unit is different and the equilibrium operating conditions for each system must be determined in order to fix its severity level. The more severe a turbine system, the shorter the service

TABLE 2 Gas Turbines—Sampling and Testing Schedules [Mineral Oils]

Schedule 4 New Oil

Samples:	
From transport or drums	
From storage tank	
Tests:	
Viscosity	[A]
Acid No.	[B]
Appearance	clear and bright
Color	[B]
Cleanliness	[C]
RBOT	[B]

[A] Should meet Classification D 2422.
[B] Should be consistent with user purchase specifications, new oil reference, or manufacturer's requirement, or combination thereof.
[C] Definition of suitable cleanliness levels depends on turbine builder and user requirements. Filtration or centrifugation, or both, of oil into turbine and during service is strongly recommended.

Schedule 5 Installation of a New Oil Charge[A]

Sample:	
After 24-h (h) circulation. Retain approximately 4 L (1 gal).	
Tests:	
Viscosity	[B]
Acid No.	[B]
Appearance	clear and bright
Color	[B]
Cleanliness	[BC]
RBOT	[BD]

[A] Follow recommended flushing procedures prior to installing a new oil charge whether it is an initial fill or an oil replacement.
[B] Should be consistent with user purchase specifications, new oil reference, or manufacturer's requirements, or combination thereof.
[C] Should agree with turbine builder and user requirements. Filtration of oil into turbine and during service is strongly recommended.
[D] Important as a baseline to determine turbine system severity.

Schedule 6A In-Service (First 6 Months Operation—New Turbine)

Test	Viscosity	Acid No.	Appearance	Color	Cleanliness	RBOT
Frequency[A]	500 h	500 h	100 h	200 h	500 h	500–1000 h

Schedule 6B In-Service Normal Operations

Note 1—This schedule should be used as a guide. Frequency should be varied depending on the turbine severity and oil condition

Test	Viscosity	Acid No.	Appearance	Color	Cleanliness	RBOT
Frequency[A]	500 h	500–1000 h	100 h	200 h	1000 h	1500–2000 h

[A] Frequency is based on hours of actual service.

life for a given oil. A useful approach to determine the severity of a turbine is given in Appendix X1.

6. Sampling

6.1 *General*—When taking oil 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 sampling handling techniques (see Practice D 4057).

6.2 *Representative Sampling*—To be representative, a sample must be obtained either from an agitated tank or a free-flowing line.

6.2.1 The preferred sampling method is as follows:

6.2.1.1 *Dipping from the Tank*—Oil samples should be taken by dipping from the tank. Lubricant should be thoroughly circulated before the sample is taken.

6.2.2 The secondary sampling methods are:

6.2.2.1 *Sampling from a Line*—The line should contain lubricating oil which is free flowing and not deadheaded. For instance, the lines in a bearing header, an active filter, and active heat exchanger are free flowing; the lines to a gage cabinet are deadheaded. In equipment with dual filters or heat exchangers, the inactive filters or heat exchangers do not have flowing fluid and are not suitable sampling points. When using a sampling line, it is necessary that the line has been thoroughly flushed before taking a sample. Adequate amount of flushing will depend on sampling line dimensions, length, and diameter.

Note 1—Test values obtained will differ depending on the sample locations. Use caution when comparing sample results from different sample points.

6.2.2.2 *Tapping from a Reservoir*—As previously described, the lubricating oil must be thoroughly agitated in the reservoir and the tap line flushed before a sample can be taken.

6.2.3 An oil sample is probably not representative if: (*1*) the system oil is hot while the sample is cold, (*2*) the oil in the system is one color or clarity in a sight glass while the sample is a different color or clarity, and (*3*) the viscosity of the reservoir oil is different from that of the sample when both are at the same temperature.

6.2.4 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 a tank to check for contamination. In all cases the sample point should be marked on the sample container.

6.3 *Sample Container*—Samples should be taken in a suitable container. To be suitable the container should be:

6.3.1 *Clean*—If in doubt about its cleanliness, use another container; if this is not possible, flush it out with the oil to be sampled.

6.3.2 *Resistant to the Material Being Sampled*—To verify the container's resistance, if time permits, allow the sample to stand in the container and observe its effects. Aluminum foil makes a good, resistant cap liner.

6.3.3 *Appropriate for Whatever Handling Is Required*—Containers with leaking tops and glass containers improperly protected are not suitable for shipment. Appropriate regulations for handling and shipment of samples must be observed.

6.3.4 *Appropriate for the Analyses Required*—An extensive chemical analysis, if that is why a sample is required, cannot be done on the contents of a container which is too small.

NOTE 2—Some lubricant suppliers and commercial laboratories provide sample containers which meet all these requirements. These should be used whenever possible. If frequent samples are taken, an adequate supply of containers should be kept.

6.4 *Sample Markings*—A sample should be properly marked. Markings should include at least the following information:

6.4.1 Customer name (if appropriate),
6.4.2 Site,
6.4.3 Location,
6.4.4 Turbine serial number,
6.4.5 Turbine service hours,
6.4.6 Oil service hours,
6.4.7 Date sample taken,
6.4.8 Type of oil sampled,
6.4.9 Sampling point,
6.4.10 Type of purification system (filters/centrifuge, and so forth), and
6.4.11 Makeup (gallons) since last sample was taken.

6.5 *Sampling of New Oil Deliveries*:

6.5.1 Samples taken should be representative of the oil being examined but obtained from the point(s) most indicative of gross contamination by debris and water, that is, just above the bottom of the drum or tanker compartment bottom.

6.5.2 When consignments of oil are in drums, sample them in accordance with Practice D 4057.

6.5.3 For bulk consignments, sample each tanker compartment. If these are clear of debris and water, then the samples can be combined for subsequent laboratory analysis of the consignment.

6.5.4 In cases where the product is suspected of being nonuniform, sample a larger number of drums. Where contamination is suspected there is no alternative to sampling every drum.

6.5.5 From tanker deliveries, in addition to sampling individual tanker compartments, further sample(s) should be taken preferably from the outlet of the flexible pipework or at least from the tanker bottom valve manifold. This further sampling is necessary because the tanker contents can become contaminated by residual material left in the bottom valve manifold. This can occur particularly when different products are being carried in separate compartments or previous deliveries of a different product have been made to other locations without subsequent adequate cleaning and flushing.

6.5.6 Bottom samples must be collected by either a tube or thief sampler (for example, Bacon bomb). These samplers permit collection of settlings on the bottom of the container without introducing false contamination by scraping the container lining or wall.

6.5.7 Take the sample(s) from the outlet of the flexible pipework or the tanker bottom valve manifold while maintaining a good flow after flushing the line.

6.6 *Preservation of Sample*—If tests are not run immediately, store the sample(s) away from strong light or excessive heat.

7. Examination of New Oil on Delivery

7.1 Experience has shown the need for standardizing procedures to be undertaken for the sampling, examination, and acceptance of incoming supplies of turbine oil. It is essential that personnel responsible for sampling and testing shall have the necessary experience and skills, and that scrupulous attention to detail be applied at all times to avoid erroneous results.

7.2 It is equally essential that all incoming supplies of oil be adequately monitored to guard against incorrect or contaminated material being delivered. Cleanliness of the delivery container should be noted; if the container is dirty on the outside, there may be particulate contamination on the inside. Particulate contamination can also be a problem when the lubricant comes in contact with dirty or poorly maintained equipment.

7.3 Sampling of incoming supplies should be in accordance with proper sampling procedures (see Section 6).

7.4 All samples should be immediately examined for appearance.

7.5 A testing schedule for new oil is included in this practice (see Table 1 and Table 2). With drums, tests should be completed on the bulk sample before the oil is used in service. Individual samples should be retained until the bulk sample is passed as satisfactory.

7.6 With tanker deliveries the additional tests to be completed before the tanker is discharged can only be judged from the risk involved by the acceptance of nonspecification product, that is, can the charge be readily recovered and corrected before passing into service if the subsequent tests indicate this to be necessary.

8. Deterioration of Turbine Oils in Service

8.1 *How Turbine Oils Degrade*—Irrespective of initial quality, turbine oils will deteriorate in service. In the case of oils in some large steam turbines, this is a slow process so that for many years the oil may look like new. Deterioration occurs by one or more of the following processes:

8.1.1 *Oxidative Degradation*—This occurs as the result of chemical changes brought about by oxygen in the atmosphere.

Initially, hydroperoxides are formed and the process proceeds by a chain reaction.

8.1.2 *Thermal/Oxidative Degradation*—This can occur at hot spots in turbines. At elevated temperatures, hydrocarbons are subject to thermal cracking to form unstable compounds. These unstable compounds are easily oxidized and also tend to polymerize to form resins and sludge.

8.1.3 *Water Accumulation in the System*—Accumulated water promotes oil degradation as well as interfering with lubrication.

8.1.4 *Loss of Additives*—This can result in more rapid oxidation and premature rusting.

8.1.5 *Influx of Contaminants*—Contaminants arising within the system (corrosion and wear products) or from without (fly ash, dirt, and fluids) cause lubrication and wear problems.

8.2 *Properties of Oils Which Must Be Retained*—In determining the condition of the system oil for continued service, the most important properties of the used oil are: (*a*) viscosity, (*b*) oxidation stability reserve, (*c*) freedom from sludge, (*d*) freedom from abrasive contaminants, (*e*) anticorrosion protection, and (*f*) freedom from water contamination.

8.2.1 *Viscosity*—Most commercial turbine oils are sold under ISO (International Standards Organization) viscosity classification system. Oils fall into ISO-VG-32, VG-46, VG-68, and VG-100 viscosity grades corresponding to 32, 46, 68, and 100 cSt at 40°C and to approximately 165, 240, 350, and 515 SUS at 100°F (Classification D 2422). The main purpose for checking the viscosity of used turbine oil is to determine if the correct oil is being used and to detect contamination. Used turbine oils rarely show significant viscosity changes due to degradation. Occasionally, viscosity increases due to an emulsion with water contamination. The method normally used for viscosity determinations is Test Method D 445.

8.2.2 *Oxidation Stability Reserve*:

8.2.2.1 One of the most important properties of new turbine oil is its oxidation stability. Traditionally, this has been measured by Test Method D 943 with Test Method D 2272 being used as an ancillary (rapid) method for following changes of oil condition in service. Oxidation stability will gradually decrease in service, deterioration being promoted by the catalytic effects of metals in the system (iron and copper) as well as by the depletion of the antioxidant. The latter occurs as a result of the normal function of the additive (chemically it acts as a chain-stopper in controlling oxidation), or by volatilization. As the oxidation stability reserve decreases, acidic compounds are produced which in turn undergo further reactions to form more complex compounds. The end product of these processes is an insoluble sludge. Although only a minute fraction of the oil is converted in this way, sufficient sludge can form to settle in critical areas of the system and interfere with proper lubrication and cooling of bearings and moving parts.

8.2.2.2 The test method most used to determine the present state of oxidative degradation (and indirectly the oxidation stability reserve) is the acid number (Test Methods D 664 and D 974). Most rust inhibitors used in turbine oils are acidic and contribute to the acid number of the new oil. An increase in acid number above the value for new oil indicates the presence of acidic oxidation products or, less likely, contamination with acidic substances. An accurate determination of the acid number is very important. However, this test does not measure oxidation stability reserve which is better determined by Test Method D 2272, the Rotating Bomb Oxidation Test (RBOT). This latter test is included in the recommended testing schedules (see Table 1 and Table 2).

8.2.3 *Freedom from Sludge*:

8.2.3.1 Due to the nature of the highly refined lubricant base stocks used in the manufacture of turbine oils, they are very poor solvents for sludge. This is the main reason why the oxidation stability reserve of the oil must be carefully monitored. Only a relatively small degree of oxidation can be permitted, otherwise there is considerable risk of sludge deposition in bearing housings, seals, gears, and pistons.

8.2.3.2 Measurement of the amounts of sludge in turbine oils (for example, by porous membrane filtration) is possible. Sludge already laid down within the system would not be included in such a determination. Other tests, however, can signal deteriorating quality in the oil even before any significant formation of sludge occurs.

8.2.3.3 Filtration and centrifugation assist in removing sludge from the oil as it is formed but cannot protect the system if the oil is allowed to deteriorate too far before an oil change.

8.2.4 *Freedom from Abrasive Contaminants*:

8.2.4.1 The most deleterious solid contaminants found in turbine oil systems are those left behind when the system is constructed and installed or when it is opened for maintenance and repair. The need for proper cleaning and flushing of new or repaired turbine systems is emphasized. Beyond these types of contaminants, there are few opportunities for solids to enter the lube oil system, although in very dusty areas where units may be out-of-doors, some solids can enter through improperly installed or operating vents.

8.2.4.2 During operation, the equipment begins to accumulate significant amounts of particulates. Some may enter the system through the makeup oil when it is added. Fly ash may be drawn in with the air at bearing shaft seals. Other contaminants may be abrasive degradation and corrosion products developed in the system. Whatever the source, the presence of abrasive solids in the oil cannot be tolerated since they will promote scoring and damage to bearings and journals as well as causing malfunction and sticking of control mechanisms. These must be removed by the use of filters or centrifuge, or both. When the amount of makeup is low and the various filters and purifiers are operating satisfactorily, abrasive solids are generally removed before any damage is done. In a properly maintained system the particulate level presents no problem. Cleanliness of the system oil can be determined by gravimetric means (Practice F 311 or Methods F 312) or by particle counting, the latter normally by means of electronic particle counters. Desired cleanliness levels are sometimes designated by the equipment manufacturer or user. If a cleanliness level is not specified by the manufacturer, cleanliness in the range from ISO −/14/11 to −/16/13 (ISO-4406) is usually considered satisfactory (the dash indicates no requirement to count the 2 micron particles).

8.2.5 *Anticorrosion Protection*:

8.2.5.1 Antirust protection provided by the lubricant is of