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Petroleum and related products — Guidance for in-servicing of lubricating oils for steam, gas and combined-cycle turbines

Pétrole et produits connexes — Lignes directrices pour le suivi en service des huiles lubrifiantes pour turbines à vapeur, à gaz et à cycle combiné

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Contents

Page

Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative document:

— an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

— an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/PAS or ISO/TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TS 11366 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, Subcommittee SC 4, *Classifications and specifications*.

This first edition of ISO/TS 11366 is derived from the IEC 60962. ISO/TC 28 was asked by IEC/TC 10, *Fluids for electrotechnical applications*, to adopt a technically revised version of IEC 60962, to which a consideration of gas and combined-cycle turbines has been added.

Introduction

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

There are three main types of stationary turbines used in power generation plants:

a) steam turbines,

b) gas turbines, and

c) combined cycle turbines.

The combined cycle turbines are of two types:

— the first type, in which a gas turbine is associated with a steam turbine, with separated lubricating circuits;

— the second type, called single shaft combined cycle turbines, in which the steam and the gas turbines are on the same shaft and are lubricated with the same oil.

The lubrication requirements of gasturbines and steam turbines are quite similar, but there are some major differences. Gas-turbine oils are submitted to localized hot spots, and water contamination is less likely.

Gas-turbine oils have a shorter service life than steam-turbine oils. Steam-turbine oils have a much longer lifetime and experience is available with lifetimes from 10 to 20 years depending on the top-up level. The lifetime of gas-turbine oils generally does not exceed two years.

The values of the various characteristics mentioned in this Technical Specification are purely indicative. For proper interpretation of the results, account is taken of many factors, e.g. the type of equipment, the design of the lubricating oil circuit and the top-up level.

In all cases, the manufacturer's instructions are followed.

Petroleum and related products — Guidance for in-servicing of lubricating oils for steam, gas and combined-cycle turbines

1 Scope

This Technical Specification applies to mineral oils used as lubricating oils and to control fluids used to lubricate steam, gas and combined cycle turbines in service. The lubricants considered in this Technical Specification are those classified in ISO 6743-5 and specified in ISO 8068.

This Technical Specification is intended to

— help power equipment operators evaluate the conditions of the oil in their equipment and maintain the oils in serviceable conditions;

— help users understand how the oils deteriorate and carry out a meaningful programme of sampling and testing of oils in use.

This Technical Specification also gives instructions with respect to the corrective actions that are taken to maximize service life.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3170:2004, *Petroleum liquids — Manual sampling*

ISO 3722:1976, *Hydraulic fluid power — Fluid sample containers — Qualifying and controlling cleaning methods*

ISO 4021:1992, *Hydraulic fluid power — Particulate contamination analysis — Extraction of fluid samples from lines of an operating system*

ISO 8068:2006, *Lubricants, industrial oils and related products (class L) — Family T (Turbines) — Specification for lubricating oils for turbines*

3 Description of turbine oils

Steam- and gas-turbines oils consist of highly refined petroleum base stocks in which additives are added to provide or to improve oxidation stability, as well as rust-protection properties, corrosion-protection properties (mainly for copper and copper containing materials). Additional foam suppressants may be added to limit the foaming tendency. However, care should be taken to avoid adding too much foam suppressant, which may have detrimental effects on air-release properties. Demulsifiers may also be used to improve the water-shedding properties, but this should not be a common practice. Turbine oils should be formulated to have naturally good water-shedding properties, without the help of demulsifiers.

To formulate turbine oils, base stocks of API groups I and II are used with success; for special applications, e.g. high-temperature gas turbines, API groups III and III+ base stocks can also be used. But in most instances, API group I and group II base stocks are largely sufficient for most applications. The refining degree of group I and group II base stocks vary from one producer to another. Hydrogen treatment is essential to get a good response to the antioxidants and to obtain good water-shedding and air-release properties.

Numerous technologies are available to provide the necessary performance in terms of oxidation stability, and rust and corrosion protection. Combinations of phenol- and amine-type antioxidants, associated with proper rust inhibitors and copper corrosion inhibitors, are commonly used.

For some applications, mainly when the turbine is coupled to gears, extreme-pressure additives are required. These extreme-pressure additives shall be chosen so as to not impair the oxidation stability.

All new oils shall comply with ISO 8068, which includes requirements with respect to the most important properties, as follows:

— oxidation stability;

— low tendency to sludge forming;

— rust-protection properties;

— copper corrosion-protection properties;

— foaming tendency;

— air-release ability;

— water-shedding characteristics.

However, all these properties cannot be expected to remain unchanged for the life of the oil.

The oil unavoidably undergoes deterioration; some deterioration can be tolerated without prejudice to the safety and efficiency of the system. Good monitoring procedures are necessary to determine when the oil characteristics have reached the condemning limits, i.e. critical values for the most important characteristics that could be deleterious to the function of the installation.

4 Factors affecting the service life

4.1 General

The following factors can affect the service life of turbine lubricating oils:

— oil system design;

— condition of the oil system at start-up;

— original oil quality;

— system operating temperature;

— contamination rates and oil purification provisions;

— oil make-up rates.

4.2 Oil system design

Most modern turbine-lubricating systems are very similar in design, especially for the larger units. The usual practice is to pressurize feed oil directly from main pump oil. To maintain reliability, after start-up of the turbine, the main pump is directly actuated by the turbine rotor. The oil is pumped from a reservoir of sufficient capacity to ensure a residence time of about 10 min for the turbine oil, so as to allow complete air release by the oil. The rest of the circulating system consists of an oil cooler, a strainer, a purification and filtration system, an oil tank vapour extractor and hydrogen removing units. The purification equipment is of utmost importance for achieving satisfactory oil lives.

For the larger turbines, high-pressure hydraulic pumps (up to 50 MPa outlet pressure) are used to lift the turbine shaft to allow for turning.

4.3 Conditions of the oil system at start-up

The individual components of a turbine lubrication system are usually delivered on-site before the system is installed. These components are generally pre-cleaned and delivered with a protection system to prevent corrosion or contamination ingress. The length of on-site storage and the means taken to preserve the integrity of the protection of the internal surfaces of the lubricating system will affect the amount of contamination introduced prior to use. During the installation of the lubricating-oil system components, attention should be paid to minimizing openings in the system and to maintaining cleanliness. Guidance on contamination control, flushing and purification may be sought from the equipment supplier or other industry experts.

Turbine-oil system contamination before start-up may consist of preservatives, paint, rust particles and various types of solid matter which range from dust, weld and metal chips, to rags, bottles and cans. Minute amounts of remaining preservatives may largely impair the water shedding and air release properties; the remaining particles may induce filter clogging and abrasive wear.

4.4 Original oil quality

Use of a high-quality oil is the best assurance for achieving long service life. The turbine oil shall meet the generally available recognized standards, e.g. ISO 8068 and the requirements of the turbine manufacturer.

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 and tests should be conducted to confirm the typical test data; the analytical data obtained will be used as a base line for future comparison with information on used oil. Recommended tests for new oil are given in 8.4.

When new turbine oil is to be mixed with a charge of a different composition, preliminary tests should be made to ensure that there will be no loss of expected properties due to incompatibility. The preliminary tests should include functional tests, like water-shedding properties, foaming and air-release properties and checks for formation of insoluble matter.

4.5 System operating temperature

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

Many turbine-oil systems are provided with oil coolers to control the temperature. In many cases, oil bulk temperature is maintained below 60 °C, which promotes moisture condensation. However, even with low bulk temperatures, hot spots can be localized in bearings, at gas seals or in throttle-control mechanisms. This can cause significant oil degradation and will eventually cause the oil in the system to show signs of deterioration.

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

4.6 Contamination rates and provisions for purification

Contamination of turbine oils during service occurs both from outside (external contamination) and inside (internal contamination) the system due to the oil degradation, moisture condensation or leaks.

Achieving a clean turbine lubricating-oil system at start-up is of utmost importance. Once attained, the danger of external contamination is less but it still should be guarded against. External contamination may enter the lubrication system through bearing seals and vents; air (oxygen) and moisture are always present in the oil systems. The oil may also be contaminated by the introduction of oils of different types, either of the wrong type or a type incompatible with the system oil. The oil supplier and/or the turbine manufacturer should be consulted before different oils are mixed or additives are used.

External contaminants, on the other hand, are being generated within the system all the time. Such contaminants can include water, metal-wear particles and oil degradation by-products. Metal particles may occur due to wear in journal and thrust bearings, gear, pumps, servo-valves and seals. Metal particles may also occur as a result of rusting, especially if the oil has a relatively high moisture content.

All these contaminants should be removed continuously by properly designed purification devices: filters, centrifuges, coalescers and vacuum dehydrators.

4.7 Oil make-up rates

The frequency and the amount of make-up oil added to the system play a very significant part in determining the life of a system oil charge. Make-up varies from below 5 % per year (8 000 h of service) to as much as 30 % in extreme cases. In turbines where make-up is relatively high compared to the oil degradation rate, the degree of degradation is compensated, and a long life can be expected. In turbines where the make-up is less than 5 %, a real picture of the actual oil degradation is obtained. However, such a system should be carefully watched since the oil life depends almost exclusively on its original quality.

Most generally, the average make-up lies between 7 % to 10 % per year.

5 Deterioration of turbine oils in service

5.1 General

Irrespective of their initial quality, turbine oils will deteriorate due to the conditions of use. This is quite normal. However, the degradation shall be monitored and reduced, if possible, when it is considered to be excessive.

5.2 Viscosity

Most commercial turbine oils fall into ISO VG 32, ISO VG 46, ISO VG 68 and ISO VG 100 grades. Most gas-turbines are lubricated with ISO VG 32 grade oils; most steam turbines are lubricated with ISO 46 grade oils. The use of ISO VG 68 and ISO VG 100 grade oils is less common.

The main purpose of checking the viscosity of turbine oil in service is to determine whether the correct oil is being used and to detect contamination. Turbine oils rarely show significant viscosity changes due to degradation. Viscosity increase may result from oxidation, volatilization of the lighter fractions of the base stock or emulsion with water. Viscosity decrease is most likely the result of contamination; it may also be the result of cracking by prolonged thermal effect, e.g. malfunctioning of a heater.

Viscosity is determined by ISO 3104.

5.3 Oxidation stability

One of the most important parameters of turbine oil is its oxidation stability. Traditionally, ASTM D 2272 is used as a rapid method to follow changes in the condition of oil in service.

The oxidation stability will gradually decrease in service due to the catalytic effect of the dissolved metals (iron, copper, tin, etc.) and to depletion of the anti-oxidant system. The latter occurs as the result of the normal functioning of the additive (a chemical reaction with the oxidation precursors, giving rise to inactive species). Other causes of the anti-oxidant system depletion are the volatilization (fumes extraction by putting the main oil tank under depression), and the wash-out by water in wet systems.

The rate of removal is, to some extent, dependent on the method and conditions of oil purification, because centrifuges and coalescors tend to remove more of the antioxidant additive with the water than vacuum dehydrators. On the other hand, too high a vacuum in conjunction with a high oil temperature for the vacuum dehydrator type purifiers or seal oil degasifier can pull out some of the volatile antioxidants. This will often be evident as deposits in the top of the vacuum chamber.

As the oxidation-stability reserve decreases, acidic compounds that undergo further reactions are formed, leading to more complex compounds. The cross-linking of the acids formed gives rise to a more-or-less soluble sludge. The solubility of the sludge depends on the type of base stocks used to formulate the products. The sludge generally settles in critical areas of the lubricant circuit and interferes with the lubrication and cooling of bearings and moving parts. The presence of oxidation products leads also to the deposits of lacquer and varnish, possibly provoking sticking of valves.

5.4 Solid particles

The most deleterious contaminants found in turbine oils 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-oil systems is emphasized. In addition to these types of contaminants, there are further opportunities for solids to enter the lubricant oil system, e.g. improperly installed or maintained vents, mainly in dusty and hostile environments, bad shop-floor practices when performing make-ups.

During operation, the equipment can accumulate a significant amount of particulate matter, entering during the topping-up operations through the bearing shaft seals. Other contaminants include the particles created by abrasive wear and those created by rust or corrosion.

Whatever the source, the presence of abrasive solids cannot be tolerated since they promote scoring and damage to the bearing and journals; moreover, they may cause malfunction and sticking of control mechanisms. In addition, solid particles may favour air entrainment, foaming, water emulsification and oxidation.

The particulate matters are to be removed by efficient means, like filtration on a cartridge filter with an appropriate pore size and filtration ratio, which might or might not be combined with centrifuges. In well maintained systems, the abrasive solids are removed before the occurrence of any damage.

5.5 Sludge

The term "sludge" is usually applied to the sediments deposited as the end result of the ageing process. Sludge may be formed in the oil by its oxidation at hot spots, e.g. in bearing housings, seals, gears and control pistons, and its build-up in a normally operated system is dependent upon the oxidation stability of the oil. Other types of sludge may also be formed in wet systems at the oil/water interface by the emulsification of certain additives with water, by the hydrolysis of additives, by bacterial and fungal growth and by corrosion products. In the case of growth of bacteria and fungi, the sludge may have a pungent odour.

The presence of sludge in oil has similar effects to those quoted for solid particles.

5.6 Antirust properties

Antirust protection provided by the lubricant is of significant importance for turbine systems. Protection is required in areas of fluid flow, for surfaces covered by static drops of water, and for areas that are only occasionally splashed by the lubricant.

Steam-turbine oils are formulated to provide rust protection; they contain, therefore, rust-protection additives. The rust protection additive may be of various types, depending on the options taken by the formulator: acidic products (e.g. hemi-esters of succinic acid) or metallic soaps (e.g. neutral calcium soaps of benzene sulfonic acids).

In service, the rust-protection additive may be depleted by performing its normal function (plating out on steel surfaces), by removal with water, by removal with wear and corrosion debris, and by chemical reaction with contaminants. In exceptional circumstances where alkaline or polluted water enters the system, acidic rust inhibitors may be depleted much more rapidly.

5.7 Water separability

Water can get into steam-turbine systems as a result of oil-cooler leaks, normal tank breathing and gland seal steam. Water adversely affects turbine oils by reacting with metals to catalyze oxidation. It also depletes water-sensitive oil additives, such as some rust inhibitors, and can cause rusting and corrosion. In gas turbines, minor amounts of water are normally driven off during normal operation. In steam turbines, if the oil is in a good condition, water settles at the bottom of the tank and can be easily drained off as a routine operating procedure. Purification systems will also assist in removing water. If, during aging, the turbine oil has developed poor water-shedding characteristics, significant amounts of water will remain in the system and create problems.

In addition to chemical effects on the oil and additives, the lubricating properties of the oil can also be adversely affected. Adequate lubrication cannot be maintained by oil that contains a significant amount of free or dispersed water. Free water can cause hard, brittle deposits to form on bearings with a Babbitt layer.

It should be noted that the water separability characteristics of oil can be dramatically affected by contamination with small quantities of detergent-type oils. This is often the result of improper oil topping-up operations or by residual quantities of detergent oil in a tank that is subsequently used for a steam turbine.

The water separability characteristics can also be affected by contamination with the residue of cleansing products containing surface-active agents.

5.8 Foaming and air-release characteristics

Foaming problems have generally three possible origins:

— mechanical design: usually the most difficult to overcome but can often be alleviated by preventing suction line air injection and/or by oil tank design changes;

— mechanical assembly and operation: due to air or gas leaks resulting from mis-assembly, excessive seal clearances, operating wear or failure;

— anti-foam agent depletion and contamination: usually can be corrected with an anti-foam agent.

Determination of the cause is necessary to come up with a solution to the problem.

Some foam on the top of the oil reservoir is normal and is a cause of concern only if it becomes excessive. In some cases, foam can block vents or interfere with the tank air extraction fans.

In turbine operation, air-release properties are essential to avoid air entrainment in the circuit with effects of cavitation in the bearings and decrease of the rigidity of the oil film. Care should be taken to use the correct anti-foam agent at the right concentration. Excess anti-foam agent may promote foam and impair the air-release properties. Anti-foam agents, to be efficient, should be correctly dispersed in the oil; the anti-foam agent is not completely soluble and excess anti-foam agent may be removed by the centrifuge. Addition of extra anti-foam agent to the oil in service should be done under the supervision of the oil supplier using the same anti-foam agent as in the original oil.

5.9 Total acid number

When turbine oil deteriorates because of oxidation, acidic by-products are formed. This will increase the acidity of the oil as measured by titration. Consequently, an increasing total acid number is indicative of oil oxidation and can be used as a monitor for this. A high total acid-number value can also be of concern as it can lead to a corrosive attack on bearing materials and other bare metal surfaces. It should be noted that a higher total acid number can also be the result of an improper make-up.

6 Recommended tests and interpretation

6.1 Appearance and odour

The appearance of the oil is examined in transmitted light (for example bottom lighting), using a sample of approximately 10 cm thickness at room temperature.

The appearance of in service oil is significant for detecting cloudiness or sediments that may indicate the presence of free water, insoluble sludge, carbon, fibres, dirt, etc.

An unusual smell, for example pungent, burnt, rotten eggs or solvents, indicates a change in the oil, possibly as a result of degradation, high temperature, bacterial growth or contamination, respectively.

6.2 Colour

The recommended test method is ISO 2049.

The colour of lubricating oil is determined in transmitted light and is expressed by a numerical value based on a comparison with a series of standardized colours. This is not a critical property, but it is quite useful for comparative evaluation. New turbine oils are normally light in colour; a slow darkening is normal over years of service. This darkening is characteristic of the presence of oxidation by product in the oil. A rapid darkening may be an indication of oil degradation or contamination requiring investigation. Colour darkening alone is not itself a cause for alarm, unless supported by other evidence of degradation.

6.3 Total acid number

The recommended test method is ISO 6618.

Total acid-number changes give an indication of the lubricant condition. The total acid number slightly decreases during the first hours of service and then increases. The increase of total acid number indicates the presence of acidic oxidation products or, less likely, contamination with acidic substances. The values are often very low and accurate determination is important. It should be kept in mind that the total acid number does not strictly measure oxidation stability reserve.

6.4 Sludge and deposits

As the oxidation stability decreases, oil will eventually reach a stage when small volumes of oil are oxidized to the sludging stage in areas of the system where conditions are severe. This sludging may occur without any increase in acid value.

The accumulation of sludge or deposits in any part of the turbine system is a cause of concern. During outages, inspection should be made of all accessible parts of the system, in particular the reservoir, the turning gear, etc. Varnishing is usually an indication that the oil has been in service too long. If significant amounts of sludge, arising from oil oxidation, are found in the circuit, action should be taken to clean out the system and replace the oil charge. If the deposits consist essentially of contaminant material, such as fly ash or other debris, appropriate action is necessary to remedy the cause.

Measurement of the amount of sludge in turbine oils can be performed using methods like membrane filtration (ISO 4405) or centrifuging (ASTM D2273). Ultracentrifugation has been also suggested to detect very fine pollution.

6.5 Particle counting

The methods for particle counting are:

— ISO 4407 for microscope counting;

— ISO 11500 for automatic counting.

The calibration of the automatic particle counters is performed using ISO 11171 (UFTD).

To report the contamination, the ISO 4406 contamination code or the NAS 1638 code can be used.

It is essential to take samples out of the circuit in specially decontaminated bottles, using standardized procedures and special sampling points in the circuit, so as to ensure that no foreign material is introduced that would interfere and distort the result. See ISO 3722 for the cleaning of the samples and ISO 4021 for the sampling procedure.

It should be emphasized that there is a need for the proper cleaning and flushing of new oil systems and operating systems after maintenance on the oil system. In certain cases, the use of extra oil filtration equipment on a temporary basis could be an advantage. If the concentration of particles increases suddenly, investigate immediately to determine the source and check the functioning of the purification equipment. In the case of corrosion products, check the rust-corrosion properties of the oil.

The presence of moisture as very finely dispersed particles, the presence of air bubbles or the antifoam additive, can be at the origin of high counts in the ISO 11500 automatic method; in case of doubt, the microscope counting as described in ISO 4407 is recommended.

The analysis of the particles by any suitable mean (e.g. ICP, ferrography, etc.) can be very useful to determine the origin of the contamination.

6.6 Kinematic viscosity

The recommended method is ISO 3104.

Viscosity values that are well outside the specifications can cause operational problems.

However, the main purpose for checking the viscosity of in-service turbine oils is to determine if the correct oil is being used and is being added as make-up and for detecting other liquid contamination.

6.7 Remaining oxidation stability

The recommended method is ASTM D2272, the rotary pressure vessel oxidation test (RPVOT).

One of the most important properties of turbine oil is its oxidation stability. Traditionally, oxidation stability is evaluated using the test in ISO 4263-1, with the method in ASTM D 2272 being used as an ancillary method for following changes of oil condition in service. The remaining oxidation stability is expressed as a percentage of the oil’s initial RPVOT value.

Other laboratory tests have been found suitable to measure the remaining oxidation stability. This should be done in consultation with the oil supplier.

6.8 Water content

The recommended test method is ISO 6296. However, some additives present in turbine oils may interfere with the Karl Fischer reagent, giving rise to erroneous results. In case of doubt or dispute, ISO 20764 should be used.

Water content is an important parameter. The presence of high quantities of water in turbine oil promotes deterioration by reacting with the additives and impairs the foaming and the air-release properties. Also, the presence of excessive water could indicate a malfunction of the purification equipment or of the turbine system. The cause of the presence of excessive water should be determined and corrected as soon as possible.

6.9 Rust prevention characteristics

The recommended test method is ISO 7120:1987, procedure A.

If the rust on the test probe is indicated as being "heavy" or "moderate" when tested with distilled water (ISO 7120:1987, procedure A) and if the oil sample is taken early in the life of the charge, the conditions in the system are very severe, i.e. the system is very wet and/or dirty or is being incorrectly maintained (water flushing from the bottom of the tank, neglected or bad operation of the purifier or of the centrifuge). The cause should be investigated immediately and corrected and then the oil rechecked. The oil supplier should be consulted regarding possible re-inhibition.

After some years of service, a rating "moderate" in the rust test may indicate normal inhibitor depletion. The oil supplier should then be consulted regarding possible re-inhibition.

6.10 Water separability

The recommended method is ISO 6614.

Water separability (or demulsibility) is certainly, with oxidation stability, among the most important properties of steam turbine oil.

Many factors can cause a steam turbine oil to lose this property:

— pollution with a detergent, e.g. cross contamination by an engine oil, insufficient rinsing after use of alkaline agents for cleaning the oil system;

— high oxidation, resulting in the formation of polar compounds that have surface-active properties;

— demulsifying agent wash-out losses: the water-separation properties of new turbine oil should be normally obtained without the help of a demulsifying agent, however, in some instances, the oil supplier has a valid reason to use a minute amount of demulsifier to meet a demulsibility target; the depletion of the demulsifier after repeated water contamination gives rise to a loss of the demulsibility.

In case of loss of water separability, a demulsifying agent can always added, but under the supervision of the oil supplier. However, in most instances, it is preferable to change the oil.

6.11 Foaming characteristics

The recommended method is ISO 6247.

This test indicates the tendency of turbine oil to generate stable foam.

The presence of a small quantity of evanescent foam at the surface of the oil in the oil tank is generally not a problem. The foam becomes a problem when it is stable and when it is generated at a sufficiently high level to provoke an overflow. If foam reaches the inlet of the pump, air will be introduced in the system, resulting in lubrication problems.

The foaming properties of oil are affected by the degree of oxidation and by the presence of water.

In case of foaming, the addition of extra anti-foam agent in the circuit can always be envisaged, but this operation should not be performed except under the supervision of the oil supplier. In this case, it shall be verified that the treatment does not affect the air-release properties.

6.12 Air-release value

The recommended test method is ISO 9120.

This test indicates the ability of oil to block the entry of air into the oil circuit. This is a very sensitive property of a turbine oil, mainly affected by the quality of the base stock used, by the pollution or contamination and by the oxidation level. In contrast to the foaming or the water-separation properties, there is no additive to combat bad air-release properties.

High air-release values may induce cavitation in the bearings and in the pumps, leading to a “spongy” response of the hydraulic circuits.

When an air-release value becomes high, the oil shall be changed.

6.13 Flash point

The recommended test methods are ISO 2592 and/or ISO 2719.

A decrease of the flash point could indicate cracking of the oil or contamination by very light products (solvents or fuel).

When refortifying an oil with an antioxidant, a rust inhibitor, an anti-foam agent, or a demulsifier is envisaged, this shall be done under the control of the oil supplier. Preliminary laboratory tests are required to check that the treatment envisaged is efficient and does not impact the other properties. If the characteristics of the oil are globally very near to the condemning limits, refortification should not be done.

7 Sampling

7.1 General

When taking lubricant samples from equipment in service, it is important that proper sampling techniques be followed. Some guidelines are suggested in 7.2 to 7.5 for proper sampling techniques. For particle counting, some specific rules shall be followed: see ISO 3722 and ISO 4021.

7.2 Sampling point

For a sample to be representative, it shall be obtained from a suitable point.

The preferred sampling method for in-service oil from an operating unit is sampling from a line. The line should contain oil that is free-flowing and that is not deadheaded. For instance, the line in the bearing header, the active filter and active heat exchanger are free-flowing; the lines to the gauge cabinet are deadheaded. The oil standing in the sample line and sample line valve shall be drawn off and discarded. The sample should be taken without further adjustment of the valve.

An alternative sampling method is dipping from the tank. If the system is not operating, the oil should be thoroughly circulated before a sample is taken. If this is not possible, then samples from different depths may be required.

For trouble-shooting purposes, it may be desirable to obtain samples at different locations on the system so as to trace sources of contamination or to determine the effectiveness of the purifiers, etc.

7.3 Sampling line

When using a sampling line, ensure that the line has been thoroughly flushed before taking a sample. The amount of flushing oil required will depend on the sampling line dimensions, length and diameter.

NOTE Test results can differ, depending on the location of the sampling point in the lubricating oil circuit. For the follow-up of an oil charge, always compare results of samples taken at the same sampling point.

7.4 Containers

Samples should be taken in a suitable container, i.e. the container should be:

a) clean: if in doubt about its cleanliness, use another container; if it is not possible, flush it out with the fluid being sampled;

b) resistant to the material being sampled: the container's resistance can be verified, if time permits, by allowing the sample to stand in the container and observe the effects; aluminium foil makes a good, resistant cap liner;

c) appropriate for whatever handling is required: containers with leaking tops and glass containers improperly protected are not suitable for shipment;

d) appropriate for the analysis required: an extensive analysis of the sample, if it is required, cannot be done on the contents of a container that is too small.

For visual inspection, use a clean glass container.

Where possible, the container opening should be covered with foil prior to screwing on the cap. This is to prevent the ingress of contaminants from the cap.

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

The user should always draw off a sample of sufficient size to be able to keep a reference sample than can be used in case of analytical problems or for further investigations in case of problems.

7.5 Sample marking

A sample should always be properly marked. Marking should include at least the following information:

a) customer name, if appropriate;

b) site;

c) location;

d) turbine serial number;

e) turbine service hours;

f) oil references;

g) oil service hours;

h) oil volume in service;

i) oil make-up quantity since the last analysis;

j) sampling point;

k) date of sample;

l) type of purification system;

m) oil appearance at sampling and after standing for 1 h;

n) health and safety labels, where appropriate.

8 Examination of new oil

8.1 General

Experience has shown the need for standardizing procedures for the sampling, examination and acceptance of incoming supplies of turbine oils.

It is essential that personnel responsible for sampling and testing have the necessary experience and skills, and that scrupulous attention be paid to details at all times to avoid erroneous results, repeated samplings and unwarranted delivery rejections.

It is equally essential that all incoming supplies of oil be adequately monitored to guard against incorrect or contaminated material being delivered.

Contamination of lubricating oils with particulates or detergent oils has been noted, especially when suppliers make deliveries in tanker vehicles not adequately cleaned for steam- or gas-turbine oils. The tanker contents can become contaminated by residual material left in the bottom valve manifold or by inadequate sealing of hose and pipe ends. The former is most likely to 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. Different products should not be transported in the same tanker.

8.2 Sampling of new oil deliveries

Sampling of incoming supplies shall be in accordance with the sampling techniques previously described.

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

Sampling consignments of oil in drums shall be done in accordance with ISO 3170. Bottom samples shall be collected by either a tube or thief sampler. These samplers permit the collection of settlings on the bottom of the container without introducing false contamination by scraping the container liner wall. In cases where the product is suspected of being non-uniform, sample a larger number of drums. Where contamination is suspected, there is no alternative to sampling every drum.

For bulk consignments, the samples should be taken from the bottom of the tanker compartment as above and/or when the oil is first being discharged. Each tanker compartment should be sampled. If these samples are clear of debris or water, then the samples can be combined for subsequent laboratory analysis of the consignment. In addition to sampling individual tanker compartments, further sample(s) should be taken 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.

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.

8.3 Examination of new oil deliveries

All samples should be immediately examined for appearance.

With drums, tests should be completed on the combined sample before the oil is used in service. Individual drum samples should be retained until the combined sample is passed as being satisfactory.

With tanker deliveries, the decision regarding additional tests should not be made before the tanker is discharged or the oil put in service, based on an assessment of the risk involved by the acceptance of an off-specifications product, i.e. whether or not the charge can be readily recovered and corrected before passing into service if the subsequent tests indicate that this is necessary. This may be possible if there is a separate make-up tank or a new oil tank, the size of which should be sufficient to hold at least one tanker delivery.

8.4 Testing schedules

8.4.1 Minimum requirements

The minimum requirements for an acceptance test at the time of delivery are given in Table 1 for steam turbines and in Table 2 for gas turbines. For single-shaft, combined-cycle turbines, apply the data given for steam turbines.

Table 1 — Minimum sampling inspections — Steam turbine — New oil

New oil — Steam turbine (Sampling: from transport or drums, or from a storage tank)	
Test	**Test result**
Viscosity	a
Acid number	b
Appearance	Bright and clear
Water content	No free water
Colour	b
Rust test	Pass[c]
Cleanliness	d
RPVOT	b

a Compliance with ISO 3448.

b Should be consistent with user purchase specifications, new oil reference, or manufacturer's requirement or combination thereof.

c Should pass ISO 7120:1987, procedure A, for land-based turbines and ISO 7120:1987, procedure B, for marine turbines.

d Definition of suitable cleanliness levels depends on turbine builder and user requirements. Filtration or centrifugation, or both, of oil into the turbine and during service is strongly recommended.

Table 2 — Minimum sampling inspections — Gas turbine — New oil

New oil — Gas turbine (Sampling: from transport or drums, or from a storage tank)	
Test	**Test result**
Viscosity	[a]
Acid number	[b]
Appearance	Bright and clear
Water content	No free water
Colour	[b]
Rust test	Pass[c]
Cleanliness	[d]
RPVOT	[b]

[a] Compliance with ISO 3448.

[b] Should be consistent with user purchase specifications, new oil reference, or manufacturer's requirement or combination thereof.

[c] Should pass ISO 7120:1987, procedure A, for land-based turbines and ISO 7120:1987, procedure B, for marine turbines.

[d] Definition of suitable cleanliness levels depends on turbine builder and user requirements. Filtration or centrifugation, or both, of oil into the turbine and during service is strongly recommended.

8.4.2 Installation of a new oil charge

The minimum requirements for an acceptance test at installing a new oil charge are given in Table 3 for steam turbines and in Table 4 for gas turbines. For single shaft combined cycle turbines, apply the data given for steam turbines.

Table 3 — Minimum sampling inspections for a new oil charge — Steam turbine

Installation of a new oil charge[a] — Steam turbine (Sampling: after 24 h circulation; retain 4 l for further reference)	
Test	**Test result**
Viscosity	[b]
Acid number	[b]
Appearance	Bright and clear
Water content	No free water
Colour	[b]
Cleanliness	[b,c]
RPVOT	[b,d]
Air release	[e]

[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 the turbine and during service is strongly recommended.

[d] Important as a base line to determine turbine system severity.

[e] Comparison with new oil air release characteristics on delivery may indicate the presence of contaminants.

Table 4 — Minimum sampling inspections for a new oil charge — Gas turbine

Installation of a new oil charge[a] — Gas turbine (Sampling: after 24 h circulation; retain 4 l for further reference)	
Test	**Test result**
Viscosity	[b]
Acid number	[b]
Appearance	Bright and clear
Water content	No free water
Colour	[b]
Cleanliness	[b,c]
RPVOT	[b,d]
Air release	[e]

[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 the turbine and during service is strongly recommended.

[d] Important as a base line to determine turbine system severity.

[e] Comparison with new oil air release characteristics on delivery may indicate the presence of contaminants.

9 Examination of oils in service

9.1 Testing procedures

9.1.1 General

Two types of test can be distinguished:

— field screening tests, which are done by the unit operator or his/her equivalent and are performed at the location of the equipment;

— laboratory tests, which are those normally performed in a qualified laboratory, for example by the oil supplier or at the central facility of the user.

9.1.2 Field screening tests

The field screening tests consist mainly of a visual inspection of the sample collected in a clean glass bottle. Careful visual inspection can be advantageously used to extend the period between the more detailed routine laboratory tests. Table 5 gives the parameters to check visually and the significance of the observations carried out. It is good practice to carry out this visual inspection, preferably on a daily basis but at least on a weekly basis.

The principle of these visual inspections is to check the appearance of the sample immediately after sampling and after standing for 1 h.

Table 5 — Visual inspection of the samples

Appearance of the oil: immediately after sampling	Appearance of the oil: after standing 1 h	Probable cause	Action to be taken
Clear	Clear	—	—
Foam at the surface	Foam collapsed	Air entry in the circuit	Seek origin.
	Persistent foam	High foaming tendency	Control foaming.
Sample cloudy and becoming clear from the bottom	Clear	Aeration	Seek origin.
	Persistent cloudiness	High air entrainment	Seek origin and laboratory control.
Sample cloudy, becoming clear from the top	Clear, or slightly opaque, decanted water	Unstable water emulsion	Seek origin of water ingress.
	Milky	Stable emulsion with water	Seek origin and laboratory control.
Dirty	Presence of decanted solid particles	Contamination, filtration problem	Seek origin and control of the circuit.
Strong colour, rapid and unusual darkening		Contamination or excessive degradation	Seek origin and control of the oxidation.
Unusual odour	Acre	Oil cracking	Seek origin, control total acid number, flash or fire points.
	Rotten egg	Bacteria growing in an anaerobic medium	Check for the presence of water. Withdraw the decanted water and consider a biocide treat.

9.1.3 Laboratory tests

The laboratory tests should include a determination of the characteristics given in Table 6. Some of these tests can be performed in the user's laboratory; other tests, requiring sophisticated equipment, are carried out either in the laboratory of the turbine oil supplier or in any other qualified laboratory.

The list of the laboratory tests is not exhaustive; it includes the minimum tests to perform on a regular basis in order to have a good picture of the status of the oil in service.

Turbine manufacturers or users may have additional requirements or may propose other warning limits for the characteristics.

Additional requirements concern, for example, a determination of the sediments by filtration in accordance with ISO 4405, with warning limits ranging from 20 mg/l to 50 mg/l, the determination of the wear metals by ICP (ASTM D5185) without warning limits, the record of an infra-red spectrum to follow the eventual depletion of the antioxidant system and the oxidation of the oil.

The most tricky and delicate determination among all the tests mentioned is the air-release value: the precision of the test is not very good. Users and turbine manufacturers indicate much lower air-release values than those given in the table. Values of 6 min maximum for an ISO VG 32 grade and 8 min maximum for an ISO VG 46 grade are very often mentioned.

