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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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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn.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again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.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.