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Lubricants, industrial oils and related products (class L) — Family T (Turbines) — Specifications for lubricating oils for turbines

Lubrifiants, huiles industrielles et produits connexes (classe L) — Famille T (Turbines) — Spécifications pour les huiles lubrifiantes pour turbines

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 28, *Petroleum and related products, fuels and lubricants from natural or synthetic sources*, Subcommittee SC 4, *Classifications and specifications*.

This third edition cancels and replaces the second edition (ISO 8068:2006), which has been technically revised. It also incorporates the Amendment ISO 8068:2006/Amd 1:2019.

The main changes are as follows:

— updating of the environmental requirements for environmentally acceptable products;

— introduction of steam demulsibility for steam and combined cycle single shaft turbine grades;

— precision with respect to the stage of the filterability tests, wet and dry;

— addition of new viscosity grades for TGCH and THCH categories;

— addition of an EP category for TGCH.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

New requirements for steam and gas turbine lubricants have arisen from technological changes including the increased efficiency of turbines, more severe operating conditions (cycling, peaking duty) and the increased use of alternative fuels. In addition, the simultaneous operation of gas and steam turbines with the same lubrication circuit means that lubricants are expected to satisfy the requirements for both steam and gas turbine lubrication.

The growing concern over environmental protection has led to the use of lubricants that show minimum toxicity towards flora and fauna. Lubricants used in hydraulic power plants, showing risks of leakage either on surface or ground water, are of particular concern. Therefore, minimum aquatic toxicity is required for these lubricants. In addition, biodegradability is desired to respect the ecosystem.

Lubricants, industrial oils and related products (class L) — Family T (Turbines) — Specifications for lubricating oils for turbines

WARNING — The handling and use of products as specified in this document can be hazardous, if suitable precautions are not observed. This document does not purport to address all of the safety problems associated with its use. It is the responsibility of the users of this document to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1 Scope

This document specifies the minimum requirements for lubricants for turbines, as delivered. It is intended to be used in conjunction with ISO 6743-5.

This document specifies the requirements for a wide variety of lubricants for the lubrication of most types of turbines for power generation, including steam turbines, gas turbines, single shaft combined cycle turbines with common lubrication system and hydraulic turbines. This document does not specify the requirements for lubricants for wind turbines, which are covered in ISO 12925-1.

The following lubricants are considered:

— mineral oils, of either API groups I, II, II+, III, including group III from GTL (gas to liquid) process, and III+. Some API groups II and III are suitable for high temperature gas turbines;

— synthetic lubricants, esters (API group V) and polyalphaolefins (API group IV), intended for high temperature gas turbines;

— synthetic lubricants, esters (API group V) and polyalphaolefins (API group IV), environmentally acceptable for use in hydraulic turbines;

— fire resistant phosphate-ester type lubricants.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 760, *Determination of water — Karl Fischer method (General method)*

ISO 1817, *Rubber, vulcanized or thermoplastic — Determination of the effect of liquids*

ISO 2049, *Petroleum products — Determination of colour (ASTM scale)*

ISO 2160, *Petroleum products — Corrosiveness to copper — Copper strip test*

ISO 2592, *Determination of flash and fire points — Cleveland open cup method*

ISO 2909, *Petroleum products — Calculation of viscosity index from kinematic viscosity*

ISO 3016, *Petroleum products — Determination of pour point*

ISO 3104, *Petroleum products — Transparent and opaque liquids — Determination of kinematic viscosity and calculation of dynamic viscosity*

ISO 3170, *Petroleum liquids — Manual sampling*

ISO 3448, *Industrial liquid lubricants — ISO viscosity classification*

ISO 3675, *Crude petroleum and liquid petroleum products — Laboratory determination of density or relative density — Hydrometer method*

ISO 4259-2, *Petroleum and related products — Precision of measurement methods and results — Part 2: Interpretation and application of precision data in relation to methods of test*

ISO 4263-1, *Petroleum and related products — Determination of the ageing behaviour of inhibited oils and fluids — TOST test — Part 1: Procedure for mineral oils*

ISO 4263-3, *Petroleum and related products — Determination of the ageing behaviour of inhibited oils and fluids using the TOST test — Part 3: Anhydrous procedure for synthetic hydraulic fluids*

ISO 4263-4, *Petroleum and related products — Determination of the ageing behaviour of inhibited oils and fluids — TOST test — Part 4: Procedure for industrial gear oils*

ISO 4406, *Hydraulic fluid power — Fluids — Method for coding the level of contamination by solid particles*

ISO 6247, *Petroleum products — Determination of foaming characteristics of lubricating oils*

ISO 6296, *Petroleum products — Determination of water — Potentiometric Karl Fischer titration method*

ISO 6341, *Water quality — Determination of the inhibition of the mobility of Daphnia magna Straus (Cladocera, Crustacea) — Acute toxicity test*

ISO 6614, *Petroleum products — Determination of water separability of petroleum oils and synthetic fluids*

ISO 6618, *Petroleum products and lubricants — Determination of acid or base number — Colour-indicator titration method*

ISO 6743-5, *Lubricants, industrial oils and related products (class L) — Classification — Part 5: Family T (Turbines)*

ISO 7120:1987, *Petroleum products and lubricants — Petroleum oils and other fluids — Determination of rust-preventing characteristics in the presence of water*

ISO 7346-2, *Water quality — Determination of the acute lethal toxicity of substances to a freshwater fish [Brachydanio rerio Hamilton-Buchanan (Teleostei, Cyprinidae)] — Part 2: Semi-static method*

ISO 8192, *Water quality — Test for inhibition of oxygen consumption by activated sludge*

ISO 9120, *Petroleum and related products — Determination of air-release properties of steam turbine and other oils — Impinger method*

ISO 9439, *Water quality — Evaluation of ultimate aerobic biodegradability of organic compounds in aqueous medium — Carbon dioxide evolution test*

ISO 12185, *Crude petroleum and petroleum products — Determination of density — Oscillating U-tube method*

ISO 12937, *Petroleum products — Determination of water — Coulometric Karl Fischer titration method*

ISO 13226, *Rubber — Standard reference elastomers (SREs) for characterizing the effect of liquids on vulcanized rubbers*

ISO 13357-1, *Petroleum products — Determination of the filterability of lubricating oils — Part 1: Procedure for oils in the presence of water*

ISO 13357-2, *Petroleum products — Determination of the filterability of lubricating oils — Part 2: Procedure for dry oils*

ISO 14593, *Water quality — Evaluation of ultimate aerobic biodegradability of organic compounds in aqueous medium — Method by analysis of inorganic carbon in sealed vessels (CO_2 headspace test)*

ISO 14635-1, *Gears — FZG test procedures — Part 1: FZG test method A/8,3/90 for relative scuffing load-carrying capacity of oils*

ISO 14669, *Water quality — Determination of acute lethal toxicity to marine copepods (Copepoda, Crustacea)*

ISO 14935, *Petroleum and related products — Determination of wick flame persistence of fire-resistant fluids*

ISO 20764, *Petroleum and related products — Preparation of a test portion of high-boiling liquids for the determination of water content — Nitrogen purge method*

ISO 20823, *Petroleum and related products — Determination of the flammability characteristics of fluids in contact with hot surfaces — Manifold ignition test*

EN 14832, *Petroleum and related products — Determination of the oxidation stability and corrosivity of fire-resistant phosphate ester fluids*

EN 14833, *Petroleum and related products — Determination of the hydrolytic stability of fire-resistant phosphate ester fluids*

EN 16807, *Liquid petroleum products — Bio-lubricants — Criteria and requirements of bio-lubricants and bio-based lubricants*

EN 17181, *Lubricants — Determination of aerobic biological degradation of fully formulated lubricants in an aqueous solution — Test method based on CO2-production*

ASTM D2272, *Standard Test Method for Oxidation Stability of Steam Turbine Oils by Rotating Pressure Vessel*

ASTM D2711-22, *Standard Test Method for Demulsibility Characteristics of Lubricating Oils*

ASTM D4636-17, *Standard Test Method for Corrosiveness and Oxidation Stability of Hydraulic Oils, Aircraft Turbine Engine Lubricants, and Other Highly Refined Oils*

ASTM D6081, *Standard Practice for Aquatic Toxicity Testing of Lubricants: Sample Preparation and Results Interpretation*

ASTM D6866, *Standard Test Methods for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis*

DIN 51589-1, *Determination of water separation ability of lubricating oils and low-flammability fluids after contact with steam*

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

4 Sampling

Unless otherwise specified in commodity specifications, samples shall be drawn in accordance with ISO 3170.

5 Requirements for turbine oils

Fluids, when tested under the prescribed methods specified in Tables 4 to 12, shall be in accordance with the limits set out in Table 4 to 12, where applicable.

The appearance of the delivered oils shall be clear and bright and free of any visible particulate matter, under visible light at ambient temperature.

These oils shall not contain any viscosity index improver.

Most of the test methods specified in the tables contain a precision statement. In cases of dispute, the procedures described in ISO 4259-2 shall apply. In such cases, it is expected that the conditions specified in ISO 4259-1, ISO 4259-3, ISO 4259-4 and ISO 4259-5 are met. Water content shall be determined in accordance with ISO 760, ISO 6296, ISO 12937 or ISO 20764. In cases of dispute, ISO 20764 shall be used.

The elastomer compatibility index shall be determined in accordance with ISO 1817 and under the conditions listed in Table 1 according to the product category. The standard reference elastomers specified in ISO 13226 shall be used. Table 2 shows acceptable changes of properties. Other elastomers and other limits may be used or specified by the end user depending on the purpose and conditions of actual use. In addition, the turbine oil shall be compatible with all material constituents of the circuit.

Table 1 — Test conditions for the determination of the elastomer compatibility index

Fluid	Symbol[a]	Suitable elastomer[b]	Test temperature ± 1 °C	Test duration ± 2 h	
Mineral oils	TSA, TGA, TSE, TGE, TGB, TGSB, TGF, TGSE, THA, THE	SRE-NBR 28/PX	100	168	1 000
		SRE-HNBR/1	130		
		SRE-FKM/2X	150		
Synthetic esters	TGCE THCE	SRE-NBR 28/PX	60	168	1 000
		SRE-HNBR/1	100		
		SRE-FKM/2X	100		
Synthetic hydrocarbons	TGCH THCH	SRE-NBR 28/PX	100	168	1 000
		SRE-HNBR/1	130		
		SRE-FKM/2X	150		
Alkyl phosphate ester Aryl phosphate ester	TSD TGD	SRE-EPM/1	100	168	1 000
		SRE-FKM/2X	100		

[a] See ISO 6743-5 for an explanation of the symbols in this column.

[b] See ISO 13226 for details on the elastomer references.

Table 2 — Acceptable limits for change of properties

Immersion time h	Maximum volume swell %	Maximum volume shrinkage %	Hardness change IRHD[a]	Maximum tensile stress change %	Maximum elongation change %
168	15	−4	±8	−20	−20
1 000	20	−5	±10	−50	−50

[a] IRHD = international rubber hardness degree.

6 Specific environmental requirements for THCH and THCE grades

6.1 General

For the purpose of this document, hydraulic turbine fluids shall be synthetic esters, polyalphaolefins and related hydrocarbon products. The classification of these hydraulic turbine fluids shall be in accordance with ISO 6743-5 for categories THCH and THCE.

The minimum category-defining base oil type content for each category shall be in accordance with Table 3.

Table 3 — Minimum category-defining base fluid content for each category

Category	Unit	Category defining base fluid type [a] content of the total fluid formulation	Total base fluid content of the fluid formulation
THCH	%	> 50	≥ 70
THCE	%	> 50	≥ 70

[a] Category-defining base fluid is identified as the relevant synthetic esters, poly α-olefins and related hydrocarbon products.

Environmentally acceptable hydraulic turbine fluids shall comply with the requirements of EN 16807, as follows: THCH and THCE fluids shall comply with the biodegradability and the toxicity requirements specified in EN 16807. Additionally, THCE fluids shall comply with the carbon of biological origin requirements (see Table 4).

The requirements published in EN 16807 are intended as baseline requirements for all bio-based lubricants, and represent minimum requirements compared to, for example, the European Ecolabel for Lubricants. [11] With the exception of content of carbon of biological origin, these requirements can also be minimum requirements for other types of environmental standard existing in the world.

In a product line of either of the categories of hydraulic turbine fluids, for all grades of a line that uses the same additive package and the same range of base stocks, toxicity requirements may be tested only on the lightest, medium and heaviest grade of the line.

The characteristics of the hydraulic turbine fluids shall comply with the limiting values set out in Table 4 and with the limiting values of the relevant hydraulic turbine fluid category set out in Tables 5 to 14. The test methods and standards listed in Tables 4 to 14 shall apply.

The use of bio-accumulative products in environmentally compatible hydraulic turbine fluids should be minimized, whenever possible. Very persistent and very bio-accumulative (vPvB) substances shall be avoided.

Table 4 — Environmental requirements for categories THCH and THCE

Characteristic of test	Unit	Requirement	Test method
Biodegradability resulting in mineralisation of the organic material, min.	%	60	ISO 14593 [c] or ISO 9439 [c] or EN 17181 [c]
Toxicity [a]			
Acute fish toxicity, 96 h, LC50	mg/l	> 100	ISO 7346-2 [c]
Acute daphnia or copepods toxicity, 48 h, EC50	mg/l	> 100	ISO 6341 [c] or ISO 14669 [c]
Bacterial inhibition, 3 h, EC50	mg/l	> 100	ISO 8192 [c]
Content of carbon of biological origin, min. [b]	%	25	ASTM D6866

[a] Water-soluble fluids shall be tested in accordance with the test method cited. Fluids with low water solubility shall be tested using water-accommodated fractions, and shall be prepared in accordance with ASTM D6081.

[b] Applies only to THCE type products.

[c] In case of dispute or doubt, a referee test should be performed in an independent laboratory with the sample in doubt against a reference substance run in parallel and duplicate to check the operation of procedures.

6.2 Biodegradability

In case of dispute, the referee method for compliance with the biodegradability requirement shall be the method specified in EN 17181. In order to check the procedure during the referee process, a reference compound of known biodegradability shall be tested in parallel. Aniline may be used when testing water-soluble test compounds; for poorly water-soluble test substances, high oleic reference oil (HORO) should be used.

6.3 Acute daphnia or copepods toxicity

In case of dispute, the referee method for compliance with the toxicity to crustaceans requirement shall be the method specified in ISO 6341. In order to check the procedure during the referee process, a reference compound of known toxicity shall be tested in parallel. Tetrapropylenebenzenesulfonic acid may be used when testing water-soluble test compounds; for poorly water-soluble test substances, potassium 2,4,5-trichlorophenoxyacetate should be used.

The biodegradability and aquatic toxicity tests should be performed in a laboratory operating according to ISO/IEC 17025 or according to good laboratory practice (GLP).

7 Specification tables

7.1 General

See ISO 6743-5 for details on the symbols used for turbine oils.

7.2 Specification for TSA and TGA turbine oils

These lubricants are refined mineral oils with suitable antioxidants and corrosion inhibitors, for the lubrication of steam turbines and gas turbines (normal service). TSA and TGA turbine oils shall be in accordance with the specifications given in Table 5.

7.3 Specification for TSE and TGE turbine oils

These lubricants are TSA and TGA types turbine oils, with additional extreme-pressure performance to lubricate gear systems. TSE and TGE turbine oils shall be in accordance with the specifications given in Table 6.

7.4 Specification for TGB and TGSB turbine oils

These lubricants are refined mineral oils with suitable antioxidants and corrosion inhibitors. These oils shall withstand higher temperatures and exhibit higher thermal stability than TSA and TGA oil types. The TGSB type shall fulfil the requirements of both TSA and TGB oils. TGB and TGSB turbine oils shall be in accordance with the specifications given in Table 7.

7.5 Specification for TGF and TGSE turbine oils

These lubricants are refined mineral oils with suitable antioxidants, corrosion inhibitors and additional extreme-pressure additives to impart the required load carrying performance. These oils shall withstand higher temperatures and exhibit higher thermal stability than TSE and TGE oil types. The TGSE type shall fulfil the requirements of both TGF and TSE oils. TGF and TGSE turbine oils shall be in accordance with the specifications given in Table 8.

7.6 Specification for THA and THE turbine oils

These lubricants are mineral oils with suitable antioxidants, corrosion inhibitors (THA) and additional extreme-pressure additives (THE) when the bearings (normal and thrust) operate in a boundary/mixed lubrication regime upon the start-up of the turbine. THA and THE products are very close to CKB and CKC categories respectively, as defined in ISO 6743-6 and specified in ISO 12925-1. THA and THE turbine oils shall be in accordance with the specifications given in Table 9.

7.7 Specification for TGCH turbine oils

This type of oil is formulated from synthetic base oil, polyalphaolefin type, with suitable antioxidants and corrosion inhibitors. It is intended for high temperature service, with a better oxidation and thermal

stability than TGB type oils, and therefore a longer service life. TGCH turbine oils shall be in accordance with the specifications given in Table 10.

7.8 Specification for TGCH (EP) turbine oils

This type of oil is formulated from synthetic base oil, polyalphaolefin type, with suitable antioxidants and corrosion inhibitors. Comparatively to TGCH category, it contains additional extreme pressure additives to allow a service on geared turbines. TGCH turbine oils shall be in accordance with the specifications given in Table 11.

7.9 Specification for TGCE turbine oils

This type of oil is formulated from a synthetic base oil, synthetic ester type, with suitable antioxidants and corrosion inhibitors. It is intended for high temperature service, in aero-derivative turbines. TGCE turbine oils should be according to either MIL-PRF-7808,[9] MIL-PRF-23699[10] or the manufacturer's specification.

7.10 Specification for THCH turbine oils

This type of oil is formulated from polyalphaolefins and related hydrocarbons, with suitable additives, with the exception of viscosity index improvers. This type of oil is essentially "environmentally acceptable", i.e. biodegradable and with minimum water toxicity, and close to the product type HEPR defined in ISO 6743-4 and specified in ISO 15380. THCH turbine oils shall be in accordance with the specifications given in Table 12.

7.11 Specification for THCE turbine oils

This type of oil is formulated from synthetic esters, with suitable additives, with the exception of viscosity index improvers. This type of oil is essentially "environmentally acceptable", i.e. biodegradable and with minimum water toxicity, and close to the product type HEES defined in ISO 6743-4 and specified in ISO 15380. THCE turbine oils shall be in accordance with the specifications given in Table 13.

7.12 Specification for TSD and TGD turbine oils

7.12.1 This type of oil is based on phosphate esters. In general, phosphate esters are a class of organophosphorus compounds with the following chemical structure:

$$O = P\ (OR)_3$$

where R are alkyl, aryl or aryl substituted groups.

In control systems applications, only triaryl phosphate fluids are used. R, in that case, is a substituted or an unsubstituted phenyl group.

7.12.2 When approved for use as turbine fluids, substituents on the aromatic group are currently either methyl (- CH_3) or tertiary butyl [- $C(CH_3)_3$] groups.

7.12.3 If the substituents are methyl groups, the product is known as trixylyl phosphate (TXP). This material is a substance of very high concern (SVHC) and its use is subject to authorization as it is included in Annex XIV[1)] of the regulation for registration, evaluation, authorization and restriction of chemicals (REACH).[12] Outside of the European Union, the fluid is widely used.

7.12.4 Additives can be incorporated to enhance oxidation stability, corrosion and rust protection, reduce foaming. Use of viscosity modifiers is not allowed.

7.12.5 Phosphate esters fire-resistant fluids are difficult to ignite and show little tendency to propagate flame but are not non-inflammable.

1) Available at https://www.echa.europa.eu/authorisation-list.

7.12.6 The fire safety tests are used to measure and describe the properties of fire-resistant fluids under controlled laboratory conditions and should not be considered as simulating the exact behaviour of the fluids under actual fire conditions.

7.12.7 TSD and TGD turbine oils shall be in accordance with the specifications given in Table 14.

Table 5 — Specifications for turbine oils L-TSA and L-TGA

Characteristic of test	Unit	Requirement			Test method
Viscosity grade		**32**	**46**	**68**	**ISO 3448**
Colour	rating	report			ISO 2049
Appearance	rating	clear and bright			visual
Kinematic viscosity at 40 °C					
min.	mm^2/s	28,8	41,4	61,2	ISO 3104
max.	mm^2/s	35,2	50,6	74,8	
Viscosity index (min.)		90	90	90	ISO 2909
Pour point (max.)	°C	−6	−6	−6	ISO 3016
Density at 15 °C	kg/m^3	report			ISO 12185 or ISO 3675
Flash point open cup (min.)	°C	185	185	185	ISO 2592
Total acid number (max.)	mg KOH/g	0,2	0,2	0,2	ISO 6618
Water content (max.)	mg/kg	200	200	200	ISO 6296 or ISO 12937
Foaming (tendency/stability) (max.)					
— Sequence I at 24 °C	ml/ml	450/0	450/0	450/0	
— Sequence II at 93 °C	ml/ml	50/0	50/0	50/0	ISO 6247
— Sequence III at 24 °C after 93 °C	ml/ml	450/0	450/0	450/0	
Air release time at 50 °C (max.)	min	5	5	6	ISO 9120
Corrosiveness to copper (3 h at 100 °C) (max.)	rating	1	1	1	ISO 2160
Corrosion preventive properties (24 h)	rating	pass	pass	pass	ISO 7120:1987, Clause 9 (Procedure B)
Demulsibility [a] (max. time to reach ≤ 3 ml emulsion at 54 °C)	min	30	30	30	ISO 6614 [c]
Steam demulsibility [a] (max.)	s	300			DIN 51589-1 [c]
Oxidation stability (RPVOT) [b]	min	report	report	report	ASTM D2272
Oxidation stability					
— Total acid number at 1 000 h (max.)	mg KOH/g	0,3	0,3	0,3	
— Time for total acid number 2 mg KOH/g (min.)	h	3 500	3 000	2 500	ISO 4263-1
— Sludge after 1 000 h (max.)	mg	200	200	200	
Filterability (dry) stage 1 (min.)	%	85	85	85	ISO 13357-2
Filterability (wet) stage 1 (min.) [a]	%	50	50	50	ISO 13357-1
Cleanliness at the delivery stage [d]		- / 17 / 14 or better			ISO 4406

[a] Applies to TSA only. Lower limits for emulsion volume or time may be specified.

[b] RPVOT = rotating pressure vessel oxidation test. This value is useful for the follow-up in service. It should not normally be below 250 min.

[c] Either ISO 6614 or DIN 51589-1 can be used.

[d] ISO 11500, using an automatic particle counter calibrated according to ISO 11171, is the preferred test method for counting and sizing particles.

Table 6 — Specifications for turbine oils L-TSE and L-TGE

Characteristic of test	Unit	Requirement			Test method
Viscosity grade		**32**	**46**	**68**	**ISO 3448**
Colour	rating	report			ISO 2049
Appearance	rating	clear and bright			visual
Kinematic viscosity at 40 °C					
min.	mm^2/s	28,8	41,4	61,2	ISO 3104
max.	mm^2/s	35,2	50,6	74,8	
Viscosity index (min.)		90	90	90	ISO 2909
Pour point (max.)	°C	−6	−6	−6	ISO 3016
Density at 15 °C	kg/m^3	report			ISO 12185 or ISO 3675
Flash point open cup (min.)	°C	185	185	185	ISO 2592
Total acid number (max.)	mg KOH/g	0,2	0,2	0,2	ISO 6618
Water content (max.)	mg/kg	200	200	200	ISO 6296 or ISO 12937
Foaming (tendency/stability) (max.)					
— Sequence I at 24 °C	ml/ml	450/0	450/0	450/0	
— Sequence II at 93 °C	ml/ml	50/0	50/0	50/0	ISO 6247
— Sequence III at 24 °C after 93 °C	ml/ml	450/0	450/0	450/0	
Air release time at 50 °C (max.)	min	5	5	6	ISO 9120
Corrosiveness to copper (3 h at 100 °C) (max.)	rating	1	1	1	ISO 2160
Corrosion preventive properties (24 h)	rating	pass	pass	pass	ISO 7120:1987, Clause 9 (Procedure B)
Demulsibility [a] (max. time to reach ≤ 3 ml emulsion at 54 °C)	min	30	30	30	ISO 6614
Oxidation stability (RPVOT) [b]	min	report	report	report	ASTM D2272
Oxidation stability					
— Total acid number at 1 000 h (max.)	mg KOH/g	0,3	0,3	0,3	
— Time for total acid number 2 mg KOH/g (min.)	h	3 500	3 000	2 500	ISO 4263-1
— Sludge after 1 000 h (max.)	mg	200	200	200	
Filterability stage 1 (dry) (min.)	%	85	85	85	ISO 13357-2
Filterability stage 1 (wet) (min.) [a]	%	50	50	50	ISO 13357-1
Load carrying capacity – FZG test (A/8,3/90) Failure load stage (min.)		8	9	10	ISO 14635-1
Cleanliness at delivery stage [c]		- / 17 / 14 or better			ISO 4406

[a] Applies to TSE only.

[b] RPVOT = rotating pressure vessel oxidation test. This value is useful for the follow-up in service. It should not normally be below 250 min.

[c] ISO 11500, using an automatic particle counter calibrated according to ISO 11171, is the preferred test method for counting and sizing particles.

Table 7 — Specifications for turbine oils L-TGB and L-TGSB

Characteristic of test	Unit	Requirement			Test method
Viscosity grade		**32**	**46**	**68**	**ISO 3448**
Colour	rating	report			ISO 2049
Appearance	rating	clear and bright			visual
Kinematic viscosity at 40 °C					
min.	mm^2/s	28,8	41,4	61,2	ISO 3104
max.	mm^2/s	35,2	50,6	74,8	
Viscosity index (min.)		90	90	90	ISO 2909
Pour point (max.)	°C	−6	−6	−6	ISO 3016
Density at 15 °C	kg/m^3	report			ISO 12185 or ISO 3675
Flash point open cup (min.)	°C	200	200	200	ISO 2592
Total acid number (max.)	mg KOH/g	0,2	0,2	0,2	ISO 6618
Water content (max.)	mg/kg	200	200	200	ISO 6296 or ISO 12937
Foaming (tendency/stability) (max.)					
— Sequence I at 24 °C	ml/ml	50/0	50/0	50/0	
— Sequence II at 93 °C	ml/ml	50/0	50/0	50/0	ISO 6247
— Sequence III at 24 °C after 93 °C	ml/ml	50/0	50/0	50/0	
Air release time at 50 °C (max.)	min	5	5	6	ISO 9120
Corrosiveness to copper (3 h at 100 °C) (max.)	rating	1	1	1	ISO 2160
Corrosion preventive properties (24 h)	rating	pass	pass	pass	ISO 7120:1987, Clause 9 (Procedure B)
Demulsibility [a] (max. time to reach ≤ 3 ml emulsion at 54 °C)	min	30	30	30	ISO 6614
Oxidation stability (RPVOT) (min.)	min	750	750	750	ASTM D2272
Oxidation stability (RPVOT modified) (min.) [b]	%	85	85	85	ASTM D2272
Oxidation stability at high temperature (72 h at 150 °C)					
— viscosity change	%	report	report	report	ASTM D4636-17, subclause 10.3 (Alternative Procedure 2)
— acid number change	mg KOH/g	report	report	report	
— metal specimen mass change (steel, aluminium, cadmium, copper, magnesium) (max.)	mg/cm^2	±0,250	±0,250	±0,250	
Oxidation stability					
— Time to reach an acid number of 2 mg KOH/g (min.)	h	5 000	5 000	5 000	ISO 4263-1
Filterability stage 1 (dry) (min.)	%	85	85	85	ISO 13357-2
Filterability stage 1 (wet) (min.) [a]	%	50	50	50	ISO 13357-1
Cleanliness at delivery stage [c]		- / 17 / 14 or better			ISO 4406

[a] Applies to TGSB only.

[b] RPVOT = rotating pressure vessel oxidation test. ASTM D2272 is performed after the treatment of 300 ml of oil at 121 °C, by bubbling clean and dry nitrogen for 48 h at the rate of 3 l/h. The result is expressed as the percent of life versus the sample without treatment.

[c] ISO 11500, using an automatic particle counter calibrated in accordance with ISO 11171, is the preferred test method for counting and sizing particles.

Table 8 — Specifications for turbine oils L-TGF and L-TGSE

Characteristic of test	Unit	Requirement			Test method
Viscosity grade		**32**	**46**	**68**	**ISO 3448**
Colour	rating	report			ISO 2049
Appearance	rating	clear and bright			visual
Kinematic viscosity at 40 °C					
min.	mm^2/s	28,8	41,4	61,2	ISO 3104
max.	mm^2/s	35,2	50,6	74,8	
Viscosity index (min.)		90	90	90	ISO 2909
Pour point (max.)	°C	−6	−6	−6	ISO 3016
Density at 15 °C	kg/m^3	report			ISO 12185 or ISO 3675
Flash point open cup (min.)	°C	200	200	200	ISO 2592
Total acid number (max.)	mg KOH/g	0,2	0,2	0,2	ISO 6618
Water content (max.)	mg/kg	200	200	200	ISO 6296 or ISO 12937
Foaming (tendency/stability) (max.)					
— Sequence I at 24 °C	ml/ml	50/0	50/0	50/0	
— Sequence II at 93 °C	ml/ml	50/0	50/0	50/0	ISO 6247
— Sequence III at 24 °C after 93 °C	ml/ml	50/0	50/0	50/0	
Air release time at 50 °C (max.)	min	5	5	6	ISO 9120
Corrosiveness to copper (3 h at 100 °C) (max.)	rating	1	1	1	ISO 2160
Corrosion preventive properties (24 h)	rating	pass	pass	pass	ISO 7120:1987, Clause 9 (Procedure B)
Demulsibility [a] (max. time to reach ≤ 3 ml emulsion at 54 °C)	min	30	30	30	ISO 6614
Oxidation stability (RPVOT) (min.)	min	750	750	750	ASTM D2272
Oxidation stability (RPVOT modified) (min.) [b]	%	85	85	85	ASTM D2272
Oxidation stability at high temperature (72 h at 150 °C)					
— viscosity change	%	report	report	report	ASTM D4636-17, subclause 10.3 (Alternative Procedure 2)
— acid number change	mg KOH/g	report	report	report	
— metal specimen mass change (steel, aluminium, cadmium, copper, magnesium) (max.)	mg/cm^2	±0,250	±0,250	±0,250	
Oxidation stability					
— Time to reach an acid number of 2 mg KOH/g (min.)	h	5 000	5 000	5 000	ISO 4263-1
Filterability stage 1 (dry) (min.)	%	85	85	85	ISO 13357-2
Filterability stage 1 (wet) (min.) [a]	%	50	50	50	ISO 13357-1
Load carrying capacity – FZG test (A/8,3/90) Failure load stage (min.)		8	9	10	ISO 14635-1
Cleanliness at delivery stage [c]		- / 17 / 14 or better			ISO 4406

[a] Applies to TGSE only.

[b] RPVOT = rotating pressure vessel oxidation test. ASTM D2272 is performed after the treatment of 300 ml of oil at 121 °C, by bubbling clean and dry nitrogen for 48 h at the rate of 3 l/h. The result is expressed as the percent of life versus the sample without treatment.

[c] ISO 11500, using an automatic particle counter calibrated according to ISO 11171, is the preferred test method for counting and sizing particles.

Table 9 — Specifications for turbine oils L-THA and L-THE

Characteristic of test	Unit	Requirement			Test method
Viscosity grade		**68**	**100**	**150**	**ISO 3448**
Colour	rating	report			ISO 2049
Appearance	rating	clear and bright			visual
Kinematic viscosity at 40 °C					
min.	mm^2/s	61,2	90,0	135	ISO 3104
max.	mm^2/s	74,8	110,0	165	
Viscosity index (min.)		90	90	90	ISO 2909
Pour point (max.)	°C	–12	–12	–9	ISO 3016
Density at 15 °C	kg/m^3	report			ISO 12185 or ISO 3675
Flash point open cup (min.)	°C	180	200	200	ISO 2592
Total acid number	mg KOH/g	report			ISO 6618
Water content (max.)	mg/kg	200	200	200	ISO 6296 or ISO 12937
Foaming (tendency/stability) (max.)					
— Sequence I at 24 °C	ml/ml	100/0	100/0	100/0	
— Sequence II at 93 °C	ml/ml	100/0	100/0	100/0	ISO 6247
— Sequence III at 24 °C after 93 °C	ml/ml	100/0	100/0	100/0	
Air release time at 50 °C (max.)	min	12	-	-	ISO 9120
Air release time at 75 °C (max.)		-	18	30	
Corrosiveness to copper (3 h at 100 °C) (max.)	rating	1	1	1	ISO 2160
Corrosion preventive properties (24 h)	rating	pass	pass	pass	ISO 7120:1987, Clause 9 (Procedure B)
Demulsibility (max. time to reach ≤ 3 ml emulsion at 54 °C)	min	30	-	-	ISO 6614
Demulsibility for THA					
Free water (min.)	ml	-	30	30	ASTM D2711-22, Clause 9 (Procedure A)
Emulsion (max.)	ml	-	2	2	
Water in oil (max.)	%	-	0,5	0,5	
Demulsibility for THE					
Free water (min.)	ml	-	80	80	ASTM D2711-22, Clause 10 (Procedure B)
Emulsion (max.)	ml	-	1	1	
Water in oil (max.)	%	-	2	2	
Oxidation stability for THA Time to reach an acid number of 2 mg KOH/g (min.)	h	1 000	1 000	1 000	ISO 4263-1
Oxidation stability at 95 °C for THE					
Viscosity at 100 °C increase (max.)	%	6	6	6	ISO 4263-4
Precipitation number (max.)		0,1	0,1	0,1	

NOTE 1 In most cases, CKB type products (see ISO 6743-6 and ISO 12925-1) can be applied for THA type products.

NOTE 2 In some cases, where high extreme-pressure performance is requested, CKC type products (see ISO 6743-6 and ISO 12925-1) can be applied for THE type products.

[a] Applies to THE only.

[b] ISO 11500, using an automatic particle counter calibrated according to ISO 11171, is the preferred test method for counting and sizing particles.

Table 9 *(continued)*

Characteristic of test	Unit	Requirement			Test method
Viscosity grade		**68**	**100**	**150**	**ISO 3448**
Filterability stage 1 (dry) (min.)	%	80	80	not required	ISO 13357-2
Load carrying ability – FZG test (A/8,3/90) [a] Failure load stage (min.)		10	10	10	ISO 14635-1
Cleanliness at delivery stage [b]		- / 17 / 14 or better			ISO 4406

NOTE 1 In most cases, CKB type products (see ISO 6743-6 and ISO 12925-1) can be applied for THA type products.

NOTE 2 In some cases, where high extreme-pressure performance is requested, CKC type products (see ISO 6743-6 and ISO 12925-1) can be applied for THE type products.

[a] Applies to THE only.

[b] ISO 11500, using an automatic particle counter calibrated according to ISO 11171, is the preferred test method for counting and sizing particles.

Table 10 — Specifications for turbine oils L-TGCH

Characteristic of test	Unit	Requirement				Test method
Viscosity grade		**32**	**46**	**68**	**100**	**ISO 3448**
Colour	rating	report				ISO 2049
Appearance	rating	clear and bright				visual
Kinematic viscosity at 40 °C min. max.	 mm^2/s mm^2/s	 28,8 35,2	 41,4 50,6	 61,2 74,8	 90 110	ISO 3104
Viscosity index		report				ISO 2909
Pour point	°C	−21	−21	−18	−15	ISO 3016
Density at 15 °C	kg/m^3	report				ISO 12185 or ISO 3675
Flash point open cup (min.)	°C	200	200	200	200	ISO 2592
Total acid number	mg KOH/g	[a]	[a]	[a]	[a]	ISO 6618
Water content (max.)	mg/kg	200	200	200	200	ISO 6296 or ISO 12937
Foaming (tendency/stability) (max.) — Sequence I at 24 °C — Sequence II at 93 °C — Sequence III at 24 °C after 93 °C	 ml/ml ml/ml ml/ml	 50/0 50/0 50/0	 50/0 50/0 50/0	 50/0 50/0 50/0	 50/0 50/0 50/0	ISO 6247
Air release time at 50 °C (min.)	min	5	5	7	10	ISO 9120
Corrosiveness to copper (3 h at 100 °C) (max.)	rating	1	1	1	1	ISO 2160
Corrosion preventive properties (24 h)	rating	pass	pass	pass	pass	ISO 7120:1987, Clause 9 (Procedure B)
Demulsibility - time to reach ≤ 3 ml emulsion at 54 °C	min	[a]	[a]	[a]	-	ISO 6614
Demulsibility - time to reach ≤ 3 ml emulsion at 82 °C	min	-	-	-	[a]	ISO 6614
Oxidation stability (RPVOT) (min.) [b]	min	1 000	1 000	1 000	1 000	ASTM D2272
Oxidation stability (RPVOT modified) (min.) [c]	%	85	85	85	85	ASTM D2272
Oxidation stability at high temperature (72 h at 175 °C) — viscosity change (max.) — acid number change (max.)	 % mg KOH/g	 [-3, +5] 2	 [-3, +5] 2	 [-3, +5] 2	 [-3, +5] 2	ASTM D4636-17, subclause 10.3 (Alternative Procedure 2)
Oxidation stability — Time to reach an acid number of 2 mg KOH/g (min.)	h	4 000	3 500	3 000	2 500	ISO 4263-1
Filterability stage 1 (dry) (min.)	%	80	80	80	80	ISO 13357-2
Cleanliness at delivery stage [d]		- / 17/ 14 or better				ISO 4406

[a] To be negotiated between the end user and the supplier.

[b] Oils with results greater than 1 000 min exhibit poor precision. It would be expected that oils of this type exhibit values significantly higher than 1 000 min and probably above 1 500 min.

[c] RPVOT = rotating pressure vessel oxidation test. ASTM D2272 is performed after the treatment of 300 ml of oil at 121 °C, by bubbling clean and dry nitrogen for 48 h at the rate of 3 l/h. The result is expressed as the per cent of life versus the sample without treatment.

[d] ISO 11500, using an automatic particle counter calibrated according to ISO 11171, is the preferred test method for counting and sizing particles.