INTERNATIONAL STANDARD

IEC 60296

Third edition
2003-11

Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear

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CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

FLUIDS FOR ELECTROTECHNICAL APPLICATIONS –

UNUSED MINERAL INSULATING OILS FOR TRANSFORMERS AND SWITCHGEAR

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60296 has been prepared by IEC technical committee 10: Fluids for electrotechnical applications.

This third edition cancels and replaces the second edition, published in 1982 and its amendment 1 (1986), and constitutes a technical revision.

Main changes with regard to previous edition include: the three classes of previous edition have been replaced by only two: transformer oil and low temperature switchgear oil, but a new concept, the lowest cold start energizing temperature, has been included; new properties have been added (i.e. charging tendency); values for properties have been revised.

The text of this standard is based on the following documents:

FDIS	Report on voting
10/566/FDIS	10/569/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until 2008. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

INTRODUCTION

General caution – Health, safety and environmental protection

This International Standard does not purport to address all the safety problems associated with its use. It is the responsibility of the user of the standard to establish appropriate health and safety practices and determine the applicability of regulatory limitations prior to use.

The mineral insulating oils which are the subject of this standard should be handled with due regard to personal hygiene. Direct contact with the eyes may cause irritation. In the case of eye contact, irrigation with copious quantities of clean running water should be carried out and medical advice sought. Some of the tests specified in this standard involve the use of processes that could lead to a hazardous situation. Attention is drawn to the relevant standard for guidance.

This standard gives rise to mineral insulating oils, chemicals and used sample containers. The disposal of these items shall be carried out according to the local regulations with regard to the impact on the environment. Every precaution should be taken to prevent release of mineral insulating oil into the environment.

FLUIDS FOR ELECTROTECHNICAL APPLICATIONS –

UNUSED MINERAL INSULATING OILS FOR TRANSFORMERS AND SWITCHGEAR

1 Scope

This International Standard covers specifications and test methods for unused mineral insulating oils. It applies to oil delivered to the agreed point and time of delivery, intended for use in transformers, switchgear and similar electrical equipment in which oil is required as an insulant and for heat transfer. These oils are obtained by distillation and refining of crude petroleum.

Oils with and without additives are both within the scope of this standard.

This standard is applicable only to unused mineral insulating oils.

Reclaimed oils are beyond the scope of this standard.

This standard does not apply to mineral oils used as impregnants in cables or capacitors.

NOTE Mineral insulating oils complying with the requirements of this standard, of the same class and containing no additives (see 3.4), are considered to be compatible with one another and can be mixed in any proportion. This does not apply to oils containing additives. Where the user wishes to mix such oils, a check is recommended to be made to ensure that the mixture meets the requirements of this standard.

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.

IEC 60076-2, *Power transformers – Part 2: Temperature rise*

IEC 60156, *Insulating liquids – Determination of the breakdown voltage at power frequency – Test method*

IEC 60247, *Measurement of relative permittivity, dielectric dissipation factor and d.c. resistivity of insulating liquids*

IEC 60422, *Supervision and maintenance guide for mineral insulating oils in electrical equipment*

IEC 60475, *Method of sampling liquid dielectrics*

IEC 60628, *Gassing of insulating liquids under electrical stress and ionization*

IEC 60666, *Detection and determination of specified anti-oxidant additives in insulating oils*

IEC 60814, *Insulating liquids – Oil-impregnated paper and pressboard – Determination of water by automatic coulometric Karl Fischer titration*

IEC 61125, *Unused hydrocarbon based insulating liquids – Test methods for evaluating the oxidation stability*

IEC 61198, *Mineral insulating oils – Methods for the determination of 2-furfural and related compounds*

IEC 61619, *Insulating liquids – Contamination by polychlorinated biphenyls (PCBs) – Method of determination by capillary column gas chromatography*

IEC 61620, *Insulating liquids – Determination of the dielectric dissipation factor by measurement of the conductance and capacitance – Test method*

IEC 61868, *Mineral insulating oils – Determination of kinematic viscosity at very low temperatures*

IEC 62021-1, *Insulating liquids – Determination of acidity – Part 1: Automatic potentiometric titration*

ISO 2719, *Determination of flash point – Pensky-Martens closed cup method*

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 3675, *Crude petroleum and liquid petroleum products – Laboratory determination of density – Hydrometer method*

ISO 6295, *Petroleum products – Mineral oils – Determination of interfacial tension of oil against water – Ring method*

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

ISO 14596, *Petroleum products – Determination of sulfur content – Wavelength-dispersive X-ray fluorescence spectrometry*

3 Terms and definitions

For the purposes of this document, the following definitions apply:

3.1
transformer oil
mineral insulating oil for transformers and similar electrical equipment where normal oxidation resistance is required

3.2
low temperature switchgear oil
mineral insulating oil for oil-filled switchgear for outdoor application in very cold climatic conditions

3.3
additive
suitable chemical substance which is deliberately added to a mineral insulating oil in order to improve certain characteristics

NOTE Examples include antioxidants, pour point depressants, electrostatic charging tendency depressants such as benzotriazole (BTA), anti-foam agents, refining process improvers, etc.

3.4
antioxidant additive
additive incorporated in an insulating oil to improve oxidation stability

NOTE A large number of antioxidant additives are available. For this standard, these are limited to those identified in IEC 60666.

3.5
uninhibited oil
mineral insulating oil, containing no antioxidant additives, but which may contain other additives

3.6
trace inhibited oil
mineral insulating oil containing up to 0,08 % antioxidant additive together with other additives as mentioned in 3.4

3.7
inhibited oil
mineral insulating oil containing a minimum of 0,08 % and a maximum of 0,40 % antioxidant additive together with other additives as mentioned in 3.3

3.8
unused mineral insulating oil
mineral insulating oil as delivered by the supplier

NOTE Such an oil has not been used in, nor been in contact with electrical equipment or other equipment not required for manufacture, storage or transport. The manufacturer and supplier of unused oil will have taken all reasonable precautions to ensure that there is no contamination with polychlorinated biphenyls or terphenyls (PCB, PCT), used, reclaimed or dechlorinated oil or other contaminants.

3.9
reclaimed oil
mineral insulating oil used in electrical equipment which has been subjected to chemical and/or physical processing to eliminate soluble and insoluble contaminants

NOTE A blend of unused and reclaimed oil in any proportion is regarded as being reclaimed.

4 Properties of oil

Characteristics are listed in Tables 1 and 2 and in Clause 7.

4.1 Functional properties

Properties of oil which have impact on its function as an insulating and cooling liquid.

NOTE Functional properties include viscosity, density, pour point, water content, breakdown voltage and dielectric dissipation factor.

4.2 Refining and stability

Properties of oil that are influenced by quality and type of refining and additives.

NOTE This can include appearance, interfacial tension, sulfur content, acidity, corrosive sulfur, 2-furfural content.

4.3 Performance

Properties that are related to the long-term behaviour of oil in service and/or its reaction to high electric stress and temperature.

NOTE Examples include oxidation stability, gassing tendency and electrostatic charging tendency (ECT).

4.4 Health, safety and environment (HSE) properties

Oil properties related to safe handling and environment protection.

NOTE Examples can include flash point, density, PCA (polycyclic aromatics), PCB/PCT (polychlorinated biphenyls/terphenyls).

5 Classification, identification, general delivery requirements and sampling

5.1 Classification

5.1.1 Classes

For the purpose of this standard, mineral insulating oils are classified into two classes:

– transformer oils;
– low temperature switchgear oil.

5.1.2 Antioxidant additive (inhibitor) content

Transformer oils are classified into three groups, according to their content of antioxidant additive:

– uninhibited transformer oils: marked with U;
– trace inhibited transformer oils: marked with T;
– inhibited transformer oils: marked with I.

5.1.3 Lowest cold start energizing temperature (LCSET)

After the inhibitor marking, the LCSET shall be indicated.

Standard LCSET in this standard is –30 °C; optionally other LCSET can be selected according to Table 1.

Example: Transformer oil I –40 °C, transformer oil T –30 °C, transformer oil U 0 °C.

5.2 Requirements

General requirements of this standard are given in Table 2.

Specific requirements are defined under Clause 7.

5.3 Mixability

Unused insulating oils of the same class, the same group and the same LCSET are considered to be mixable and compatible with each other (see as well IEC 60422).

5.4 Identification and general delivery requirements

a) Oil is normally delivered in bulk, rail tank cars, tank containers or packed in drums or IBC (intermediate bulk containers). These shall be clean and suitable for this purpose to avoid any contamination.

b) Oil drums and sample containers shall carry at least the following markings:
   – supplier's designation;
   – classification;
   – oil quantity.

c) Each oil delivery shall be accompanied by a document from the supplier specifying at least: suppliers designation, oil classification and compliance certificate. At purchaser’s request, the supplier has to indicate the presence (type, concentration) of any additive.

5.5 Sampling

Sampling shall be carried out in accordance with the procedure described in IEC 60475.

6 Properties, their significance and test methods

6.1 Viscosity

Viscosity influences heat transfer and therefore the temperature rise of the equipment. The lower the viscosity, the easier the oil circulates leading to improved heat transfer. At low temperatures the resulting higher viscosity of oil is a critical factor for the cold start of transformers with ON cooling (no circulation and therefore possible overheating at the hot spots) and negatively influences the speed of moving parts, such as in power circuit breakers, switchgear, on-load tap changer mechanisms, pumps and regulators. The viscosity at the lowest cold start energizing temperature (LCSET) shall not exceed 1 800 mm^2/s (resp. 2 500 mm^2/s at –40 °C, see Table 1). This lowest cold start energizing temperature (LCSET) for transformer oils is defined in this standard as being –30 °C (this is 5 K lower than indicated in IEC 60076-2). Other LCSET (see Table 1) can be agreed between supplier and purchaser.

Low temperature switchgear oil should have a lower viscosity at LCSET: max. 400 mm^2/s. Standard LCSET of low temperature switchgear oil is defined with –40 °C but other LCSET may be agreed between supplier and purchaser.

NOTE 1 For more details concerning ON cooling (natural oil circulation without pump), refer to IEC 60076-2.

Table 1 – Maximum viscosity and pour point of transformer oil at lowest cold start energizing temperature (LCSET)

LCSET °C	Maximum viscosity mm^2/s	Maximum pour point °C
0	1 800	–10*
–20	1 800	–30*
–30	**1 800**	**–40**
–40	2 500	–50*
* Optional.		

NOTE 2 There is no lower viscosity limit set in this standard, but under certain conditions oils with a viscosity less than 7 mm^2/s /40 °C can be considered to be a potential aspiration hazard.

Viscosity shall be measured according to ISO 3104, viscosity at very low temperatures according to IEC 61868.

6.2 Pour point

Pour point of mineral insulating oil is the lowest temperature at which the oil will just flow. It is recommended that the pour point should be minimum 10 K below the lowest cold start energizing temperature (LCSET). If a pour point depressant additive is used, this should be mentioned by the supplier to the user. Pour point shall be measured in accordance with ISO 3016.

6.3 Water content

A low water content of mineral insulating oil is necessary to achieve adequate electrical strength and low dissipation losses. To avoid separation of free water, unused insulating oil should have a limited water content. Before filling the electrical equipment, the oil should be treated to meet the requirements of IEC 60422. Where requested by the purchaser, the supplier of oil shall demonstrate that after treatment to remove solid particles, humidity and dissolved air by a vacuum procedure (see note), the oil shall have a high dielectric strength of minimum 70 kV breakdown voltage. Water content shall be measured in accordance with IEC 60814.

NOTE This laboratory treatment referred to consists of filtration of the oil at 60 °C by vacuum (pressure below 2,5 kPa) through a sintered glass filter (porosity 4).

6.4 Breakdown voltage

Breakdown voltage of transformer oil indicates its ability to resist electrical stress in electrical equipment. Breakdown voltage shall be measured in accordance with IEC 60156.

6.5 Dielectric dissipation factor (DDF)

DDF is a measure for dielectric losses caused by the oil. Increased DDF can indicate contamination of the oil by moisture, particles or soluble polar contaminants or poor refining quality. DDF shall be measured in accordance with IEC 60247 or IEC 61620 at 90 °C. In case of dispute, IEC 60247 at 90 °C should be used.

NOTE By agreement between parties, DDF may be measured at temperatures other than 90 °C. In such cases the temperature of measurement should be stated in the report.

6.6 Appearance

A visual inspection of insulating oil (oil sample in transmitted light under a thickness of approximately 10 cm and at ambient temperature) indicates the presence of visible contaminants, free water or suspended matter.

6.7 Acidity

Unused mineral insulating oil should be neutral and free from any acidic compound. Acidity should be measured following IEC 62021-1.

6.8 Interfacial tension (IFT)

Low IFT sometimes indicates the presence of undesirable contaminants. IFT shall be measured in accordance with ISO 6295.

6.9 Sulfur content

Different organo-sulfur compounds are present in transformer oils, dependent on the crude oil origin and the degree and type of refining. Refining treats sulfur and aromatic hydrocarbons. As some sulfur compounds have an affinity to metals, they may act as copper passivators or they may promote corrosion.

Sulfur content should be measured following BS 2000 Part 373 or ISO 14596.

6.10 Corrosive sulfur

Some sulfur compounds, e.g. mercaptans, are very corrosive to metal surfaces, i.e. steel, copper and silver (switchgear contacts) and shall not be present in new oil. Corrosive sulfur should be measured following DIN 51353.

6.11 Antioxidant additive content

Antioxidant additive (inhibitor) slows down the oxidation of oil and therefore the formation of oil sludge and acidity. It is important to know whether and in what proportion antioxidant additive has been added in order to monitor additive depletion during service. 2,6-di-tert-butyl-p-cresol (DBPC) is the most commonly used antioxidant, but others are also used. Detection and measurement of defined antioxidant additives shall be determined in accordance with IEC 60666. The type and quantity of each antioxidant additive present in the oil shall be stated in the quality certificate. If co-stabilizers are used during the refining process, their presence shall be agreed between the supplier and the purchaser.

6.12 Oxidation stability

Oxidation of oil gives rise to acidity and sludge formation and can be minimized as a result of high oxidation stability leading to longer service life time by minimizing sludge deposition, electrical losses, metal corrosion, electrical faults and maximizing insulation life. Oxidation stability is measured in accordance with method C of IEC 61125. There is an option for stricter limits for special applications. In some countries more stringent limits and/or additional requirements and tests may be requested.

6.13 Gassing

Gassing tendency of mineral insulating oil, i.e. the gas absorbing property of an oil under electrical stress, is only necessary and important for special transformers like HV (high voltage) transformers and is a measure of the rate of absorption or evolution of hydrogen into oil under prescribed laboratory conditions. Gas absorption properties are related to oil aromaticity which is subject to indirect control by the oil's oxidation requirements. Gassing tendency is measured using method A of IEC 60628. Gassing tendency is a specific requirement.

6.14 Electrostatic charging tendency (ECT)

ECT of oil is an important property for certain designs of HV and EHV transformers which have oil pumping rates that can give rise to the build-up of electrostatic charge. This charge can result in energy discharge causing transformer failure. A method to measure ECT is proposed by CIGRE SC12 (see Bibliography).

ECT is a specific requirement.

6.15 Flash point

The safe operation of electrical equipment requires an adequately high flash point that is measured in accordance with ISO 2719 (Pensky-Martens closed cup procedure).

6.16 Density

Density of oil shall be low enough to avoid, in cold climates, that ice resulting from the freezing of free water is floating on the oil surface and possibly leading to fault conditions developing in flashover of conductors. Density shall be measured in accordance with ISO 3675 (reference method) but ISO 12185 as well is accepted.

6.17 Polycyclic aromatics (PCA)

Some PCAs are classified to be carcinogens and therefore need to be controlled to an acceptable level in mineral insulating oil. PCAs are defined so as to be detectable by extraction with DMSO (Dimethylsulfoxide) under the conditions of BS 2000 Part 346.

6.18 Polychlorinated biphenyls (PCB)

Unused mineral insulating oil shall be free from PCB. The reference method is IEC 61619. The detection limit for a single peak is 0,1 mg/kg.

NOTE The total limits are given by national regulations.

6.19 2-Furfural and related compounds (2-FAL)

2-FAL and related compounds in unused mineral insulating oils can result either from improper redistillation after solvent extraction during refining or from contamination with used oil.

Unused insulating oils should have a low level of 2-FAL and related compounds; measurement should be done according to IEC 61198.

Table 2 – General specifications

Property	Test method	Limits	
		Transformer oil	Low temperature switchgear oil
1 – Function			
Viscosity at 40 °C	ISO 3104	Max. 12 mm^2/s	Max. 3,5 mm^2 /s
Viscosity at –30 °C [a]	ISO 3104	Max. 1 800 mm^2/s	--
Viscosity at –40 °C [b]	IEC 61868	--	Max. 400 mm^2/s
Pour point [a]	ISO 3016	Max. –40 °C	Max. –60 °C
Water content	IEC 60814	Max. 30 mg/kg [c]/ 40 mg/kg [d]	
Breakdown voltage	IEC 60156	Min. 30 kV / 70 kV [e]	
Density at 20 °C	ISO 3675 or ISO 12185	Max. 0,895 g/ml	
DDF at 90°C	IEC 60247 or IEC 61620	Max. 0,005	
2 – Refining/stability			
Appearance	--	Clear, free from sediment and suspended matter	
Acidity	IEC 62021-1	Max. 0,01 mg KOH/g	
Interfacial tension	ISO 6295	No general requirement [f]	
Total sulfur content	BS 2000 Part 373 or ISO 14596	No general requirement	
Corrosive sulfur	DIN 51353	Not corrosive	
Antioxidant additive	IEC 60666	(U) uninhibited oil: not detectable (T) trace inhibited oil: max. 0,08 % (I) inhibited oils: 0,08 – 0,40 %	
2-Furfural content	IEC 61198	Max. 0,1 mg/kg	
3 – Performance			
Oxidation stability [1]	IEC 61125 (method C) Test duration: (U) Uninhibited oil: 164 h (T) Trace inhibited oil:332 h (I) Inhibited oil: 500 h		
- Total acidity		Max. 1,2 mg KOH/g[1]	
- Sludge		Max. 0,8 % [1]	
DDF at 90 °C	IEC 60247	Max. 0,500 [1]	
Gassing	IEC 60628, A	No general requirement	
4 – Health, safety and environment (HSE)			
Flash point	ISO 2719	Min. 135 °C	Min. 100 °C
PCA content	BS 2000 Part 346	max. 3 %	
PCB content	IEC 61619	Not detectable	

[a] This is the standard LCSET for an transformer oil (see 5.1) and can be modified depending on the climatic condition of each country. Pour point should be minimum 10 K below LCSET.

[b] Standard LCSET for low temperature switch gear oil.

[c] For bulk supply.

[d] For delivery in drums and IBC.

[e] After laboratory treatment (see 6.4).

[f] Where it is used as a general requirement, a limit of minimum 40 mN/m is recommended.

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[1] In some countries more stringent limits and/or additional requirements may be requested.

7 Specific requirements for special applications

7.1 Higher oxidation stability and low sulfur content

For transformers with higher operating temperatures or designed for extended service life, there may exist restricted limits after oxidation test (see IEC 61125, method C). Mostly, such oil is inhibited (I) [2, 3].

– Total acidity: max. 0,3 mg KOH/g;
– Sludge: max. 0,05 %;
– DDF at 90 °C: max. 0,050;
– Total sulfur content: max. 0,15 %.

7.2 Electrostatic charging tendency (ECT)

For OF- or OD-cooled power transformers (IEC 60076-2) with high oil circulation speed, as e.g. HV/DC transformers, a limit may be agreed between purchaser and manufacturer.

7.3 Gassing

For equipment with high electrical field stress or special design, gas which may be formed under special stress conditions must be absorbed by the oil. Therefore the gassing tendency according to IEC 60628 must be agreed between the oil manufacturer and the user of the oil.[4]

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2 In some countries more stringent limits and/or additional requirements may be requested.

3 In some countries a DDF of max. 0,020 after 2 h of oxidation (see IEC 61125, method C) is considered as acceptable for application in EHV instrument transformers and bushings.

4 In some countries limits are available.

Bibliography

DIN 51353: *Detection of corrosive sulfur – Silver strip*

BS 2000, Part 346: *Determination of polycyclic aromatics in lubricant base oil and asphaltene free petroleum fractions – Dimethylsulfoxide refractive method*

BS 2000, Part 373: *Determination of the sulfur content of light and middle distillates – Oxidative microcoulometry*

CIGRE SC12: *Static electrification in power transformers* (CIGRE SC12 – Technical Brochure, Product Id 170 [2000])

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