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

Fluides pour applications électrotechniques – Huiles minérales isolantes neuves pour transformateurs et appareillages de connexion

IEC 60296:2012

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FLUIDS FOR ELECTROTECHNICAL APPLICATIONS – UNUSED MINERAL INSULATING OILS FOR TRANSFORMERS AND SWITCHGEAR

FOREWORD

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International Standard IEC 60296 has been prepared by IEC technical committee 10: Fluids for electrotechnical applications.

This fourth edition cancels and replaces the third edition, published in 2003. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

– specifications for corrosive sulphur compounds that can lead to copper sulphide deposition in transformers (in non-passivated and passivated oils);
– definitions of additives in oil; and
– re-insertion of a missing note on oxidation.

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

FDIS	Report on voting
10/878/FDIS	10/885/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 the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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INTRODUCTION

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

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FLUIDS FOR ELECTROTECHNICAL APPLICATIONS – UNUSED MINERAL INSULATING OILS FOR TRANSFORMERS AND SWITCHGEAR

1 Scope

This International Standard is applicable to specifications and test methods for unused mineral insulating oils (see Clause 3 for definitions). 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 for insulation and heat transfer. These oils are obtained by refining, modifying and/or blending of petroleum products and other hydrocarbons.

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

This standard is applicable only to unused mineral insulating oils.

Recycled oils are beyond the scope of this standard.

NOTE Definitions and specifications for recycled oils will be covered by IEC 62701[1].

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

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 for liquid-immersed transformers*

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

IEC 60247, *Insulating liquids – Measurement of relative permittivity, dielectric dissipation factor (tan δ) and d.c. resistivity*

IEC 60422, *Mineral insulating oils in electrical equipment – Supervision and maintenance guidance*

IEC 60475, *Method of sampling liquid dielectrics*

IEC 60628:1985, *Gassing of insulating liquids under electrical stress and ionization*

IEC 60666, *Detection and determination of specified additives in mineral insulating oils*

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

[1] In preparation.

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IEC 60970, *Insulating liquids – Methods for counting and sizing particles*

IEC 61125:1992, *Unused hydrocarbon-based insulating liquids – Test methods for evaluating the oxidation stability*
Amendment 1 (2004)

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*

IEC 62021-2, *Insulating liquids – Determination of acidity – Part 2: Colourimetric titration*

IEC 62535:2008, *Insulating liquids – Test method for detection of potentially corrosive sulphur in used and unused insulating oils*

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 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*

ASTM D971, *Standard Test Method for Interfacial Tension of Oil Against Water by the Ring Method*

ASTM D7150, *Standard Test Method for the Determination of Gassing Characteristics of Insulating Liquids Under Thermal Stress at Low temperature*

DIN 51353, *Testing of insulating oils; detection of corrosive sulfur; Silver strip test*

EN 14210, *Surface active agents – Determination of interfacial tension of solutions of surface active agents by the stirrup or ring method*

IP 346, *Determination of polycyclic aromatics in lubricant base oils and asphaltene free petroleum fractions – Dimethylsulfoxide refractive method*

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IP 373, *Determination of the sulphur content of light and middle distillates – Oxidative microcoulometry*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
transformer oil
mineral insulating oil for transformers and similar electrical equipment

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

3.3
mineral insulating oil
insulating oil obtained by refining, modifying and/or blending of petroleum products and other hydrocarbons

Note 1 to entry This does not include insulating liquids such as esters, synthetic aromatics or silicone fluids.

3.4
additive
chemical substance that is added to mineral insulating oil in order to improve certain characteristics

Note 1 to entry Examples include antioxidants, metal passivators, metal deactivators, electrostatic charging tendency depressants, gas absorbers, pour point depressants, anti-foam agents and refining process improvers.

3.5
antioxidant additive
additive incorporated in mineral insulating oil that improves oxidation stability

Note 1 to entry A large number of additives which improve oxidation stability, including inhibitors, peroxide decomposers, metal passivators and metal deactivators, are available and may be used in oils if declared (see 6.11.1 and 6.11.2).

3.5.1
inhibitor
antioxidant additives of the phenolic-or amine- type, such as DBPC and DBP described in IEC 60666

Note 1 to entry DBPC = 2,6-di-tert-butyl-para-cresol; DBP = 2,6-di-tert-butyl-phenol.

3.5.2
other antioxidant additive
antioxidant additive of the sulphur- or phosphorous- type

3.5.3
passivator
metal passivator additive used primarily as electrostatic charging depressant, but which may also improve oxidation stability

Note 1 to entry Metal passivators are sometimes described as metal deactivators or corrosion inhibitors.

3.6
uninhibited oil
mineral insulating oil containing no inhibitor

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Note 1 to entry No inhibitor means that the total inhibitor content is below the detection limit of 0,01 % indicated in IEC 60666.

3.7
trace inhibited oil
mineral insulating oil containing less than 0,08 % of total inhibitor content as measured by IEC 60666

3.8
inhibited oil
mineral insulating oil containing a minimum of 0,08 % and a maximum of 0,40 % of total inhibitor content as measured by IEC 60666

3.9
unused mineral insulating oil
mineral insulating oil not recycled as delivered by the supplier

Note 1 to entry 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.

Note 2 to entry The definition of recycled oils will be given in IEC 62701 (in preparation).

Note 3 to entry A blend of unused and recycled oil in any proportion is regarded as being recycled.

4 Properties of oil

NOTE Oil characteristics are listed in Tables 1 and 2 and in Clause 6.

4.1 Functional properties

Properties of oil that have an 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 These can include appearance, interfacial tension, sulphur content, acidity, corrosive sulphur, 2-furfural and related compounds content and stray gassing.

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) and PCB/PCT (polychlorinated biphenyls/ terphenyls).

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5 Classification, identification, general delivery requirements and sampling

5.1 Classification

5.1.1 Classes

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

– transformer oils;
– low temperature switchgear oils.

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.

5.2 Requirements

General requirements of this standard are given in Table 2.

Specific requirements are defined under Clause 7.

5.3 Miscibility

Unused mineral insulating oils of the same class (5.1.1), the same group (5.1.2), same LCSET (5.1.3) and containing the same types of additives are considered to be miscible and compatible with each other (see IEC 60422).

5.4 Identification and general delivery requirements

Identification and general delivery requirements are as follows:

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 (see 5.1);
   – oil quantity.
c) As agreed between the supplier and purchaser each oil delivery may be accompanied by a document specifying the supplier's designation, oil classification and compliance certificate.

NOTE This standard may be traceable to a specific batch of oil processed.

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d) The supplier shall declare the generic type of all additives, and their concentrations in the cases of inhibitors and passivators.

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 poor or no circulation of oil 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 (respectively 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 at –40 °C but other LCSET may be agreed between supplier and purchaser.

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

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

6.2 Pour point

The 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 at least 10 K below the lowest cold start energizing temperature (LCSET). If a pour point depressant additive is used, this shall be declared 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 breakdown voltage and low dissipation losses. To avoid separation of free water, unused insulating oil should have limited water content. Before filling the electrical equipment, the oil should be treated to meet the requirements of IEC 60422. Water content shall be measured in accordance with IEC 60814.

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6.4 Breakdown voltage

The 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. The supplier shall demonstrate that after treatment to reduce particles, water and dissolved air by a vacuum procedure (see note), the oil shall have a high dielectric strength (breakdown voltage >70 kV).

NOTE This treatment referred to consists of filtration of the oil at 60 °C by vacuum (pressure below 2,5 kPa) through a sintered glass filter (with a maximum pore size of 2,5 μm).

6.5 Dielectric dissipation factor (DDF)

DDF is a measure for dielectric losses within the oil. DDF values above requirements of Table 2 can indicate contamination of the oil by 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 can be measured at temperatures other than 90 °C. In such cases the temperature of measurement can 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) will indicate the presence of visible contaminants, free water or suspended matter.

6.7 Acidity

Unused mineral insulating oil should be free from any acidic compound. Acidity shall be measured according to IEC 62021-1 or IEC 62021-2.

6.8 Interfacial tension (IFT)

Low IFT sometimes indicates the presence of polar compounds. IFT shall be measured in accordance with EN 14210 or ASTM D971.

6.9 Sulphur content

Different organo-sulphur compounds are present in mineral oils, dependent on the crude oil origin and the degree and type of refining. Refining reduces the content of sulphur and aromatic hydrocarbons. As some naturally present sulphur compounds have an affinity to metals, they may act as natural oxidation inhibitors or they may promote corrosion.

Sulphur content is a specific requirement of 7.1.

Sulphur content should be measured following IP 373 or ISO 14596.

6.10 Corrosive and potentially corrosive sulphur

Some sulphur 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. This type of corrosive sulphur should be detected following DIN 51353.

Some other sulphur compounds, e.g. dibenzyldisulphide (DBDS), may result in the deposition of copper sulphide (Cu_2S) in paper insulation, reducing its electrical insulation properties (see Annex A). This has resulted in several equipment failures in service.

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