IEC 60296

Edition 5.0 2020-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Fluids for electrotechnical applications – Mineral insulating oils for electrical equipment

Fluides pour applications électrotechniques – Huiles minérales isolantes pour matériel électrique

IEC 60296:2020-06(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

FLUIDS FOR ELECTROTECHNICAL APPLICATIONS – MINERAL INSULATING OILS FOR ELECTRICAL EQUIPMENT

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 fifth edition cancels and replaces the fourth edition published in 2012. This edition constitutes a technical revision.

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

– This International Standard is applicable to specifications and test methods for unused and recycled mineral insulating oils in the delivered state.

– Within the transformer insulating oils, two groups, Type A and Type B, are defined, based on their performance.

– A new method for stray gassing under thermo-oxidative stress of mineral insulating oils, which has been tested in a joint round robin test (RRT) between CIGRE D1 and IEC technical committee 10, has been included.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
10/1117/FDIS	10/1118/RVD

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

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

The committee has decided that the contents of this document 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 document. At this date, the document will be

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- withdrawn,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

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INTRODUCTION

WARNING – This document does not purport to address all the safety problems associated with its use. It is the responsibility of the user of this document 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 document should be handled in compliance with local regulations and suppliers safety data-sheets.

This document 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.

FLUIDS FOR ELECTROTECHNICAL APPLICATIONS – MINERAL INSULATING OILS FOR ELECTRICAL EQUIPMENT

1 Scope

This document provides specifications and test methods for unused and recycled mineral insulating oils (see Clause 3 for definitions). It applies to mineral oil delivered according to the contractual agreement, intended for use in transformers, switchgear and similar electrical equipment in which oil is required for insulation and heat transfer. Both unused oil and recycled oil under the scope of this document have not been used in, nor been in contact with electrical equipment or other equipment not required for manufacture, storage or transport.

Unused oils are obtained by refining, modifying and/or blending of petroleum products and other hydrocarbons from virgin feedstock.

Recycled oils are produced from oils previously used as mineral insulating oils in electrical equipment that have been subjected to re-refining or reclaiming (regeneration) by processes employed offsite. Such oils will have originally been supplied in compliance with a recognized unused mineral insulating oil specification. This document does not differentiate between the methods used to recycle mineral insulating oil. Oils treated on-site (see IEC 60422) are not within the scope of this document.

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

This document does not apply to mineral insulating oils used as impregnating medium in cables or capacitors.

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.

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 60422:2013, *Mineral insulating oils in electrical equipment – Supervision and maintenance guidance*

IEC 60475, *Method of sampling liquid dielectrics*

IEC 60567:2011, *Oil-filled electrical equipment – Sampling of gases and analysis of free and dissolved gases – Guidance*

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

IEC 60666:2010, *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*

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

IEC 61125:2018, *Insulating liquids – Test methods for oxidation stability – Test method for evaluating the oxidation stability of insulating liquids in the delivered state*

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*

IEC 62697-1, *Test methods for quantitative determination of corrosive sulfur compounds in unused and used insulating liquids – Part 1: Test method for quantitative determination of dibenzyldisulfide (DBDS)*

IEC 62961, *Insulating liquids – Test methods for the determination of interfacial tension of insulating liquids – Determination with the ring method*

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

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

ISO 3016, *Petroleum and related products from natural or synthetic sources – 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 3819, *Laboratory glassware –Beakers*

ISO 8754, *Petroleum products – Determination of sulphur content – Energy-dispersive X-ray fluorescence spectrometry*

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

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

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

ASTM D1500, *Standard Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)*

ASTM D6591, *Standard Test Method for Determination of Aromatic Hydrocarbon Types in Middle Distillates – High Performance Liquid Chromatography Method with Refractive Index Detection*

ASTM D7042, *Standard Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)*

ASTM D7896, *Standard Test Method for Thermal Conductivity, Thermal Diffusivity and Volumetric Heat Capacity of Engine Coolants and Related Fluids by Transient Hot Wire Liquid Thermal Conductivity Method*

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

IP 346, *Determination of polycyclic aromatics in unused lubricating base oils and asphaltene free petroleum fractions – Dimethyl sulfoxide extraction refractive index method*

3 Terms and definitions

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

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
mineral insulating oil
insulating liquid for transformers and similar electrical equipment (e.g. switchgear, tap-changers), derived from petroleum products and/or other hydrocarbons

Note 1 to entry: Mineral insulating oils include unused (3.8) and recycled (3.9) mineral insulating oils.

[SOURCE: IEC 60050-212:2010, 212-17-02, modified – "for transformers and similar electrical equipment, (e.g. switchgear, tap-changers)" added, "crudes" replaced with "petroleum products and/or other hydrocarbons" and note to entry added.]

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

3.3
additive
chemical substance that is added to mineral insulating oil in order to improve certain characteristics

EXAMPLES Antioxidants, metal passivators, metal deactivators, electrostatic charging tendency depressants, gassing tendency modifier, pour point depressants, anti-foam agents and refining process improvers.

[SOURCE: IEC 60050-212:2010, 212-17-13, modified – "specific" replaced with "chemical", "an insulating material or liquid in small proportion" replaced with "mineral insulating oil" and examples added.]

3.4
antioxidant
oxidation inhibitor
additive incorporated in mineral insulating oil that improves oxidation stability

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

Note 2 to entry: For the purposes of this document, the oxidation inhibitor is a synthetic chemical substance of the phenolic type, such as DBPC and DBP described in IEC 60666.

[SOURCE: IEC 60050-212:2010, 212-17-14, modified – "an insulating material to reduce or delay degradation by oxidation" replaced with "mineral insulating oil that improves oxidation stability" and note replaced with notes to entry.]

3.4.1
other antioxidant additive
antioxidant additive of the sulphur-, amine- or phosphorous- type

Note 1 to entry: Sulphur-type additives do not include dibenzyldisulphide (DBDS) or other potentially corrosive sulphur compounds.

3.4.2
passivator
additive used primarily as corrosion deactivator and sometimes as electrostatic charging depressant

Note 1 to entry: It can also improve the oxidation stability, by reducing the catalytic effect of copper on oxidation of the oil

3.5
uninhibited oil (U)
mineral insulating oil containing no oxidation inhibitor or other antioxidant additives

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

[SOURCE: IEC 60050-212:2010, 212-17-19, modified – In the term, deletion of "insulating", in the definition "antioxidant, but which may contain other additives" replaced with "oxidation inhibitor or other antioxidant additives" and note replaced with the note to entry.]

3.6
trace inhibited oil (T)
mineral insulating oil containing minimum 0,01 % and less than 0,08 % of total inhibitor content as measured in IEC 60666

3.7
inhibited oil (I)
mineral insulating oil containing a minimum of 0,08 % and a maximum of 0,40 % of total inhibitor content as measured in IEC 60666

3.8
unused mineral insulating oil (V)
mineral insulating oil, obtained by refining, modifying and/or blending of petroleum products and other hydrocarbons and that has not been used in, nor been in contact with electrical equipment or other equipment not required for manufacture, storage or transport

Note 1 to entry: In some countries unused mineral oil is described as virgin oil.

Note 2 to entry: The manufacturer and supplier of unused mineral insulating oil shall take reasonable precautions to ensure that there is no contamination with polychlorinated biphenyls or terphenyls (PCB, PCT) or other contaminants.

3.9
recycled mineral insulating oil (R)
mineral insulating oil previously used in electrical equipment that has been subjected to re-refining or reclaiming (regeneration) after removal from the electrical equipment

Note 1 to entry: Any blend of unused and recycled oils is to be considered as recycled.

Note 2 to entry: The characteristics of recycled oil are heavily dependent on the oil from which it was recycled, the original refining technique, the service history and the type of recycling process.

Note 3 to entry: Natural or added antioxidants originally present in the oil might have been depleted in service or removed by the recycling process. The oxidation stability therefore needs to be restored/improved and is usually achieved by the addition of an oxidation inhibitor.

Note 4 to entry: Such recycled oils are often produced from mixtures of mineral insulating oils of different origins. The manufacturer and supplier of recycled mineral insulating oil shall take reasonable precautions to ensure that there is no contamination with polychlorinated biphenyls or terphenyls (PCB, PCT) or other contaminants.

3.10
reclaimed mineral insulating oil
regenerated mineral insulating oil
recycled mineral insulating oil used in electrical equipment, which has been subjected after removal from the electrical equipment to chemical and physical processing to reduce soluble and insoluble contaminants

3.11
re-refined mineral insulating oil
recycled mineral insulating oil used in electrical equipment that has been removed from service and subjected to a process similar to that used for the production of unused mineral insulating oil from virgin feedstock, in order to reduce the level of undesired compounds

Note 1 to entry: Such re-refined oils are often produced from mixtures of mineral insulating oils of different origins including processes such as distillation and hydrogenation.

4 Properties of oil

4.1 General

Oil characteristics are listed in Table 2, Table 3 and Table 4 and in Clause 6 and Clause 7.

4.2 Functional properties

These are properties of oil that have an impact on its function as a liquid for insulation and heat transfer.

NOTE Functional properties include viscosity, density, pour point, water content, breakdown voltage, dielectric dissipation factor, as well as specific heat capacity, thermal conductivity and expansion coefficient.

4.3 Production and stability

These are properties of oil that are influenced by the quality and type of refining and additives.

NOTE 1 These can include appearance, interfacial tension, sulphur content, acidity, corrosive sulphur, potentially corrosive sulphur, 2-furfural and related compounds content and stray gassing.

NOTE 2 Properties like aromatic content, refractive index or/and distribution of aromatic type of compounds can provide valuable information on consistency of a certain oil product.

4.4 Performance

These are properties that are related to the long-term behaviour of oil in service and/or its reaction to high electrical or thermal stresses. In terms of performance, transformer insulating oils are divided into Type A (Table 3) and Type B (Table 4).

4.5 Health, safety and environment (HSE) properties

These are oil properties related to safe handling and environmental protection.

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

5 Classification, labelling, identification, general delivery requirements and sampling

5.1 Classification and labelling

5.1.1 Classes

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

– transformer oils;

– low temperature switchgear oils.

Within the transformer oils two groups of oils are defined: Type A (Table 3) and Type B (Table 4).

Type A insulating oils are fully inhibited ("I" according to 5.1.2) and deliver higher oxidation stability than Type B.

Type B insulating oils can be uninhibited ("U"), trace inhibited ("T") or fully inhibited ("I") and deliver good resistance to oil degradation and provide good oxidation stability.

Inhibitor concentration for inhibited oil in service needs to be monitored and eventually maintained. This is described in IEC 60422.

NOTE During base oil refining some components such as aromatic and polycyclic aromatic compounds are removed depending on the severity and type of refining process.

Uninhibited oils are typically made from base oil(s) with the aim to retain a balance of removable components, some of which are easily oxidized, while others provide some protection against the normal oxidation process. The refining process is optimized to retain certain sulphur and aromatic compounds which act as natural antioxidants. However, since the natural antioxidants are not as effective as synthetic antioxidants, the uninhibited oils will exhibit less oxidative stability compared to inhibited oils.

Uninhibited oil contains a certain amount of so called natural antioxidants, some of them present from the beginning (mostly sulphur-containing acting as secondary antioxidants), others being formed as intermediates by oxidative processes (mostly oxidation of aromatic compounds then acting as radical scavengers). Inhibited oil is a blend of base oil(s) with a synthetic antioxidant. The additive response and the resulting oxidation stability of the inhibited oil depends very much on the refining severity. The antioxidant is added to control the oxidation processes. The inhibitor acts as radical scavenger and protects the base oil hydrocarbons – depending on the degree of refining – from oxidation. Oils with very high oxidative stability are inhibited oils and can be achieved by blending very severely treated base oil and antioxidant.

5.1.2 Antioxidant (oxidation inhibitor) content

Mineral insulating oils are classified into three groups, according to the content of antioxidant additive:

– uninhibited mineral insulating oils: marked with U;

– trace inhibited mineral insulating oils: marked with T;