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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Insulating liquids – Unused modified or blended esters for electrotechnical applications

Isolants liquides – Esters neufs modifiés ou mélangés pour applications électrotechniques

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INSULATING LIQUIDS – UNUSED MODIFIED OR BLENDED ESTERS FOR ELECTROTECHNICAL APPLICATIONS

FOREWORD

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International Standard IEC 63012 has been prepared by IEC Technical Committee 10: Fluids for electrotechnical applications.

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

FDIS	Report on voting
10/1078/FDIS	10/1082/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 website 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- withdrawn,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.

INTRODUCTION

Electrical insulation and heat transfer are essential functions of insulating liquids for electrotechnical applications. Until recently, these liquids have been normally homogeneous, selected from different categories, such as most common mineral oils or newer synthetic esters, natural esters or silicone liquids. The continuous research for improvement of performance characteristics of equipment drives an interest in exploring benefits from combinations of liquids. Some known examples of desired improved characteristics include optimized liquid cost, increased cooling performance, improved flash point, extended insulation life or reduced environmental impacts.

Currently, international standards exist for specifically defined liquid categories (mineral oils, synthetic esters, natural esters, silicone liquids). None of them cover chemically modified natural ester liquids or blends of various esters. Moreover, the existing standards do not cover synthetic esters whose characteristics may go beyond the limits defined in IEC 61099.

Some modified esters or their blends are already available as commercial products by liquid suppliers. Examples are:

- Palm fatty acid ester with low viscosity of 5 mm^2/s at 40 °C and with flash point of 176 °C.
- Blend of triglycerides (50 %) and monoesters (50 %) with low viscosity of 17 mm^2/s at 40 °C and with flash point of 200 °C.

The number of sources for ester liquids or their blends is expected to grow over the coming years. Such liquids need to be characterized to confirm suitability for the intended application by the user. Performance characteristics of blends should not be solely assumed from performance characteristics of their individual components. This document is to provide minimum requirements on characterization of new compositions.

WARNING

This document sets performance criteria for unused modified/synthetized or blended esters earmarked for electrical applications. This document does not purport to address all the safety problems associated with their use. It is the responsibility of the user of this document to establish appropriate health and safety practices and determine the applicability of regulatory limitation prior to use.

Performance of some of the tests mentioned in this document could lead to a hazardous situation. Attention is drawn to the relevant standard test method for guidance.

The disposal of liquids, chemicals and sample containers mentioned in this document should be carried out in accordance with current local and national legislation with regards to the impact on the environment. Every precaution should be taken to prevent the release of the liquid into the environment.

INSULATING LIQUIDS – UNUSED MODIFIED OR BLENDED ESTERS FOR ELECTROTECHNICAL APPLICATIONS

1 Scope

This document defines requirements for the characterization of unused modified esters or blends of unused esters used as insulating liquids for electrotechnical applications. It does not cover liquids that contain any proportion of used liquids.

The liquids covered by this document are intended mainly for transformer applications.

Unused modified/synthetized esters are derived from a natural or synthetic base, or are blends of both. This document covers a variety of ester liquids not covered by other standards specific to natural esters (IEC 62770) or synthetic esters (IEC 61099).

As it addresses various categories of liquids, this document also covers a wide range of values for certain performance characteristics. An important property is viscosity, which can affect the design and cooling performance of electrical equipment. A categorization is defined based on the kinematic viscosity of the different liquids. The category of low viscosity ester liquids is established.

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

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

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

IEC 60897, *Methods for the determination of the lightning impulse breakdown voltage of insulating liquids*

IEC 61099:2010, *Insulating liquids – Specifications for unused synthetic organic esters for electrical purposes*

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

IEC TR 61294, *Insulating liquids – Determination of the partial discharge inception voltage (PDIV) – Test procedure*

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 62021-3, *Insulating liquids – Determination of acidity – Part 3: Test methods for non-mineral insulating oils*

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

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

IEC 62770, *Fluids for electrotechnical applications – Unused natural esters for transformers and similar electrical equipment*

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 2211, *Liquid chemical products – Measurement of colour in Hazen units (platinum-cobalt scale)*

ISO 2592, *Petroleum and related products – Determination of flash and fire points – Cleveland open cup method*

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*

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

ASTM D1275, *Standard test method for corrosive sulphur in electrical insulating liquids*

ASTM D1903, *Standard practice for determining the coefficient of thermal expansion of electrical insulating liquids of petroleum origin, and askarels*

ASTM D3300, *Standard test method for dielectric breakdown voltage of insulating oils of petroleum origin under impulse conditions*

ASTM D4172, *Standard test method for wear preventive characteristics of lubricating fluid (four-ball method)*

ASTM D7150, *Standard test method for the determination of gassing characteristics of insulating liquids under thermal stress*

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*

ASTM E1269, *Standard test method for determining specific heat capacity by differential scanning calorimetry*

DIN 51350-1, *Testing of lubricants – Testing in the four-ball tester – Part 1: General working principles*

DIN 51350-2, *Testing of lubricants – Testing in the four-ball tester – Part 2: Determination of welding load of liquid lubricants*

DIN 51350-3, *Testing of lubricants – Testing in the four-ball tester – Part 3: Determination of wearing characteristics of liquid lubricants*

OECD 301-B, *OECD Guidelines for the testing of chemicals – Section 3: Environmental fate and behaviour – 301 Ready biodegradability – 301 B: CO_2 Evolution test*

OECD 301-C, *OECD Guidelines for the testing of chemicals – Section 3: Environmental fate and behaviour – 301 Ready biodegradability – 301 C: Modified MITI test*

OECD 301-F, *OECD Guidelines for the testing of chemicals – Section 3: Environmental fate and behaviour – 301 Ready biodegradability – 301 F: Manometric respirometry test*

U.S. Environmental Protection Agency, EPA 712-C-98-076, *US EPA OPPTS Series 835: Fate, transport and transformation test guidelines – Group C: Laboratory biological transformation test guidelines – 835.3110 Ready biodegradability*

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 https://www.iso.org/obp/ui

3.1
unused insulating liquid
liquid as delivered by the supplier which has not been used in, or been in contact with electrical equipment or other equipment not required for its manufacture, storage or transport

3.2
ester insulating liquid
insulating liquid consisting of fatty acid esters

Note 1 to entry: Fatty acid esters are commonly prepared from the reaction of alcohols and carboxylic acids or found naturally in vegetable oils and fats.

3.3
modified ester insulating liquid
ester insulating liquid which has been made/synthesized or altered by chemical reaction

Note 1 to entry: The chemical reaction could come about by means of organic chemistry processes, or biochemical processes including enzymatic reactions.

Note 2 to entry: Modified ester insulating liquids can, for example, be composed of triglycerides, polyol esters, fatty acid monoesters, fatty acid diesters or combinations thereof.

3.4
blended ester insulating liquid
homogeneous combination of unused natural, synthetic and/or modified esters that are miscible

Note 1 to entry: The natural esters in this definition are those defined in IEC 62770, synthetic esters in this definition are those defined in IEC 61099.

3.5
additive
chemical substance which is deliberately added to an insulating liquid in small proportion in order to improve certain characteristics

4 Classification

4.1 General

As it addresses various compositions of insulating liquids, this document also covers a range of values for certain performance characteristics when these are compared to other recognized liquids with precisely defined performance characteristics. Therefore, the following categorizations are established.

4.2 Fire performance classification

The insulating liquids are classified for fire performance according to IEC 61039.

4.3 Viscosity classification

Viscosity influences heat transfer and therefore the temperature rise of the equipment. The lower the viscosity, the easier the liquid circulates leading to improved heat transfer.

Viscosity of natural esters and some synthetic esters is usually higher than that of mineral oil. This requires special considerations at the equipment design stage and may affect performance of equipment at low temperatures, too. Adjustment of modified or blended ester composition allows for tailoring the viscosity and other properties to fit the equipment design requirements.

Based on the viscosity, the liquids are classified as in Table 1. The category V1 refers to esters of low viscosity, similar to mineral oils. The category V2 refers to esters of higher viscosity than V1, but still lower than typical synthetic or natural esters. The category V3 refers to modified or blended esters that do not show low viscosity characteristics.

NOTE At the stage of development of this document, there are no commercial modified or blended esters with viscosity category V3. This category makes provision for future technical developments.

5 Properties, significance and test methods

5.1 Physical properties

5.1.1 Appearance

A visual inspection of unused modified or blended esters (with light transmitted through approximately 10 cm thickness of the liquid at ambient temperature) shall not indicate the presence of visible contaminants, free water or suspended matter.

5.1.2 Colour

If required, colour shall be measured according to ISO 2211 (Hazen scale) or ISO 2049 (ASTM scale).

5.1.3 Viscosity

Kinematic viscosity shall be measured according to ISO 3104 and reported at 40 °C. The user can request viscosity values in the range of temperatures 0 °C to 100 °C (with at least three points: 0 °C, 40 °C and 100 °C).

NOTE Another suitable method for viscosity measurement is given in ASTM D7042.

It is beneficial to have the value of viscosity at temperatures below 0 °C to understand the behaviour of the liquid in temperatures near the pour point, for example at −20 °C.

NOTE Viscosity at very low temperatures can be measured according to IEC 61868.

At low temperatures, the resulting higher viscosity of liquid is a critical factor for the cold start of transformers with natural liquid circulation (no forced 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. Lowest cold start energizing temperature (LCSET) requirements should be agreed upon between supplier and purchaser.

5.1.4 Lubricity

If liquid is to be used in equipment with moving parts, for example switching equipment, tap changers, the lubricity shall be measured. The test method shall be that given in ASTM D4172 or DIN 51350 (parts 1 through 3). In the case of ASTM D4172, the test parameters shall be: load 392 N, rotation speed 1 200 r/min temperature 75 °C, duration 60 min.

5.1.5 Thermal conductivity

Thermal conductivity shall be measured in accordance with ASTM D7896 and the value shall be given by the manufacturer.

NOTE Users can request that the thermal conductivity be measured at a range of temperatures, e.g. 0 °C to 100 °C (at least three points), for calculating the thermal performance of the equipment in different conditions.

5.1.6 Thermal expansion coefficient

Thermal expansion coefficient shall be measured in accordance with ASTM D1903 and the value shall be reported by the manufacturer.

NOTE Users can request that the thermal expansion coefficient be measured at a range of temperatures, e.g. 0 °C to 100 °C (at least three points), for calculating the thermal performance of the equipment in different conditions.

5.1.7 Specific heat capacity

Specific heat shall be measured in accordance with ASTM E1269 and the value shall be given by the manufacturer.

NOTE Users can request that the specific heat capacity be measured at a range of temperatures, e.g. 0 °C to 100 °C (at least three points), for calculating the thermal performance of the equipment in different conditions.

5.1.8 Pour point

Pour point of insulating liquid is the lowest temperature at which the liquid is just sufficiently fluid to flow at test conditions. Pour point shall be measured in accordance with ISO 3016. Table 1 gives the requirement for a maximum pour point of −25 °C acceptable for modified or blended esters. A lower value may be required by end users based on regional ambient