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COMMENTED VERSION

INTERNATIONAL STANDARD

colour inside

Fluids for electrotechnical applications – Unused natural esters for transformers and similar electrical equipment

IEC 62770:2024-10 CMV(en)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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CONTENTS

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FLUIDS FOR ELECTROTECHNICAL APPLICATIONS – UNUSED NATURAL ESTERS FOR TRANSFORMERS AND SIMILAR ELECTRICAL EQUIPMENT

FOREWORD

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This commented version (CMV) of the official standard IEC 62770:2024 edition 2.0 allows the user to identify the changes made to the previous IEC 62770:2013 edition 1.0. Furthermore, comments from IEC TC 10 experts are provided to explain the reasons of the most relevant changes, or to clarify any part of the content.

A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text. Experts' comments are identified by a blue-background number. Mouse over a number to display a pop-up note with the comment.

This publication contains the CMV and the official standard. The full list of comments is available at the end of the CMV.

IEC 62770 has been prepared by IEC technical committee 10: Fluids for electrotechnical applications. It is an International Standard.

This second edition cancels and replaces the first edition published in 2013. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition: 1

a) Introduction of IEC 63012 which details other liquids not covered by this document. IEC 63012 was published in 2019 after the first edition of IEC 62770 (2013).
b) New Table 1 inserted which clarifies definitions.
c) Appearance and colour requirements now merged.
d) Pour point: Introduction of the importance of LCSET with advice on cold temperature behaviour of natural esters.
e) Additives: new agreed wording inserted on the declaration of additives
f) Flash and fire points: now only determined by Cleveland Open Cup method, since the Pensky-Martens closed cup method was identified as problematic with natural esters.
g) Toxicity: Aquatic toxicity now emphasized.
h) Annex B removed as it is no longer needed since the publication of IEC 63012.

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

Draft	Report on voting
10/1215/FDIS	10/1243/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Because of their higher fire points and ~~better~~ lower environmental ~~compatibility~~ impact relative to hydrocarbon petroleum derived insulating mineral oil, the use of vegetable oils and other natural esters is on the rise as insulating and heat transfer fluids in electrical devices such as transformers.

This document sets performance criteria for unused natural esters earmarked for electrical applications. However, the use of natural esters is recommended only for equipment that is not open to the atmosphere, for example sealed transformers and reactors because these ~~fluids~~ liquids are ~~prone~~ susceptible to ~~rapid~~ oxidation.

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

Unused natural esters which are the subject of this document should be handled with due regard to personal hygiene. Direct contact with eyes should be avoided. In case of eye contact, irrigation with copious amounts of clean running water should be carried out and medical advice sought.

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

~~The disposal of natural esters, chemicals and sample containers mentioned in this standard should be carried out in accordance with current national legislation with regard to the impact on the environment. Every precaution should be taken to prevent the release of natural esters into the environment.~~ **2**

FLUIDS FOR ELECTROTECHNICAL APPLICATIONS – UNUSED NATURAL ESTERS FOR TRANSFORMERS AND SIMILAR ELECTRICAL EQUIPMENT

1 Scope

This document describes specifications and test methods for unused natural esters in transformers and similar ~~oil-impregnated~~ liquid-immersed electrical equipment in which a liquid is required as an insulating and heat transfer medium. The exposure of natural ester to air leads to deterioration of the insulating liquid. Use of natural esters is ~~not recommended for electrical equipment that is open to the atmosphere~~ therefore restricted to sealed units, or with the conservator tank protected from the contact with atmosphere by a membrane or other suitable system. **3**

In this document the term "natural esters" applies to insulating ~~fluids~~ liquids for transformers and similar electrical equipment with suitable biodegradability and lower environmental ~~compatibility~~ impact. Such natural esters are vegetable oils obtained from seeds, and oils obtained from other suitable biological materials ~~and delivered to an agreed point, at a set time period~~. These oils are comprised of triglycerides.

Natural esters with additives are within the scope of this document. Because of their different chemical composition, natural esters differ from insulating mineral oils and other insulating ~~fluids~~ liquids that have high fire points, such as synthetic esters or silicone fluids.

Natural ester-derived insulating ~~fluids~~ liquids with low viscosity have been introduced but are not covered by this document. ~~Pertinent properties of such fluids are given in Annex B.~~ IEC 63012 covers these liquids. **4**

This document is applicable only to unused natural esters. Reclaimed natural esters and natural esters blended with ~~non-natural esters fluids~~ other insulating liquids are beyond the scope of this document.

NOTE The chemical nomenclature and scientific notations used in the document are in accordance with the IUPAC handbook (Quantities, Units and Symbols in Physical Chemistry).

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. **5**

~~IEC 60076-14, *Power transformers - Part 14: Liquid-immersed power transformers using high-temperature insulation materials*~~

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 d) and d.c. resistivity ~~of insulating fluids~~*

~~IEC 60296, *Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear*~~

IEC 60475, *Method of sampling ~~liquid dielectrics~~ insulating liquids*

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

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

~~IEC 61100, *Classification of insulating liquids according to fire-point and net calorific value*[1]~~

IEC 61125~~:1992~~, ~~*Unused hydrocarbon-based insulating fluids*~~ *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 62021-3, *Insulating liquids – Determination of acidity – Part 3: Test methods for non-mineral insulating oils*[2]

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

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)*

ISO 2049, *Petroleum products – Determination of colour (ASTM 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 and related products from natural or synthetic sources – Determination of pour point*

ISO 3104, *Petroleum products – Transparent and opaque fluids – 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*

~~[1] Withdrawn in 2009 and partially replaced by IEC 61039.~~

~~[2] To be published.~~

~~ASTM D 1275, *Standard Test Method for Corrosive Sulfur in Electrical Insulating Oils*~~

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

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

~~OECD 201-203, *Test Guidelines for ecotoxicity*~~

~~OECD 301, *Guideline for testing of chemicals adopted by European Council on July 17th 1992*~~

~~US EPA, *Office of Prevention, Pesticides and Toxic Substances (OPPTS)*~~

~~835.311, *Fate, Transport and Transformation Test Guidelines*~~

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses: **6**

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

3.1.1
additives
~~suitable~~ chemical substances which are deliberately added to natural ester insulating ~~fluids~~ liquids in order to improve certain characteristics~~, e.g. pour point, viscosity, foaming, and oxidation stability~~

~~Note 1 to entry: Examples include antioxidants, pour point depressants, electrostatic charging tendency depressant, metal passivator or deactivators, antifoam agent, refining process improver, etc.~~

~~**3.2**~~
~~**corrosive sulfur**~~
~~free sulfur and corrosive sulfur compounds detected by subjecting metals such as copper to contact with an insulating liquid under standardized conditions~~

~~[SOURCE: IEC 60050-212:2010, definition 212-18-20, modified – inclusion of "metals such as"]~~

3.1.2
natural esters
vegetable oils obtained from seeds and oils obtained from other suitable biological materials and comprised of triglycerides

~~**3.4**~~
~~**potentially corrosive sulfur**~~
~~organo-sulfur compounds present in transformer oils that may cause copper sulfide formation~~

~~[SOURCE: IEC 62535:2008, definition 3.1 – modified, the NOTE to entry has been omitted]~~

3.1.3
unused natural esters
~~unused~~ natural esters as delivered by the supplier

Note 1 to entry: Such a liquid has not been used in, nor been in contact with, electrical equipment or other equipment not required for its manufacture, storage or transport.

~~Note 2 to entry: The manufacturer and supplier of unused natural esters will have taken all reasonable precautions to ensure that the natural esters are not contaminated with polychlorinated biphenyls, polychlorinated terphenyls or polycyclic aromatics (PCB,PCT, PCAs,) or corrosive sulfur compounds; used, reclaimed, or dechlorinated oils, or other contaminants.~~

3.2 Abbreviated terms

The abbreviated terms are given in Table 1.

Table 1 – Abbreviated terms 7

Abbreviated term	Full term
DBDS	Dibenzyl disulphide
DDF	Dielectric dissipation factor
HSE	Health, safety and environment
IBC	Intermediate bulk container
LCSET	Lowest cold start energizing temperature
PCBs	Polychlorinated biphenyls
RRT	Round robin test

4 Properties, their significance and test methods

4.1 General

~~Salient~~ Required characteristics of unused natural esters are listed in Table 2.

NOTE 1 Additional information on natural esters for transformers and similar electrical equipment is available in CIGRE brochure 436 and IEEE C57.147-2018™.

NOTE 2 In natural ester at normal operating temperatures, a significant formation of stray gases such as hydrogen and ethane is sometimes witnessed for a specific period (weeks to months) after the transformer is activated. Such unexpected gas formation at low temperature can lead to confusion in the dissolved gas analyses interpretation. Natural esters show a higher tendency towards stray gassing. 8

4.2 Physical properties

4.2.1 Appearance and colour

A visual inspection of unused natural esters (with light transmitted through a glass transparent beaker of approximately 10 cm thickness ~~of natural esters~~ at ambient temperature) will indicate the presence of visible contaminants, free water and suspended matter.

The colour of an insulating liquid is determined in transmitted light, and is expressed by a numerical value based on comparison with a series of colour standards. Colour shall be measured following ISO 2049 (reference method) or ASTM D1500.

4.2.2 Viscosity

Viscosity influences heat transfer and therefore affects ~~the increase of~~ temperature distribution in the transformer and other equipment. The lower the viscosity, the easier the ~~oil~~ liquid circulates, generally leading to better heat transfer. Viscosities at lower temperatures are a

critical factor for the cold start of transformers with ~~ON cooling~~ K class liquid insulation with natural (not forced/pumped) flow (the absence of circulation can lead to possible overheating at hot spots) 9. It can have a negative impact on the speed of moving parts, such as on-load tap changer mechanisms, pumps and regulators. Due consideration should be given to viscosity at the lowest cold start energizing temperature (LCSET). Viscosity at 40 °C and 100 °C shall be measured according to ISO 3104 (referee method) or ASTM D7042.

4.2.3 Pour point

~~Pour point of unused natural esters is the lowest temperature at which the natural esters will just flow. Pour point shall be measured in accordance with ISO 3016.~~

~~Crystallization behaviour of natural esters depends on time and temperature. Crystals should not be present in liquid at application temperature; precautions shall be taken if oil temperature inside the electrical device is lower than 0 °C. Below this temperature thermal and dielectric behavior of the device with natural esters can be adversely affected. A well-defined method to measure crystallization behavior is not available at present.~~

The pour point of liquids is the lowest temperature at which the liquid will flow. The pour point shall be measured in accordance with ISO 3016.

Longer dwell times (weeks or months) below 0 °C can lead to an increase of the pour point, or, alternatively, to an increase of viscosity of the liquid in comparison to the original state (the so-called "cold-and-hold behaviour"). It depends on the individual molecular structure and formulation and the time the liquid is exposed to the low temperature. While natural ester liquids show pour points in the region of -15 °C to -31 °C, it has been noticed that they can show a tendency to precipitate ester crystals if held for extended periods at temperatures slightly above the pour point. These crystals will re-melt back into the bulk ester liquid with no side effects once the mixture has been warmed up, but this can take time. For references see the bibliography.

Precautions shall be taken if the electrical equipment is to be left or stored at continuously low temperatures below 0 °C. The possible partial crystallization can result in an unforeseeable and undetermined increase in viscosity, which can adversely affect the mechanical, thermal, and dielectric behaviour of the device immersed in natural ester liquid.

An acknowledged method to measure the effect of crystallization behaviour is not available at present. As a substitute, additional viscosity measurement at low temperatures according to IEC 61868 is recommended, using standing times of 24 h, 72 h and 168 h. The lowest cold start energizing temperature (LCSET) is the temperature which, after a defined holding time, leads to a viscosity equal to or lower than the maximum admissible viscosity needed for the proper function of the equipment. During the normal operation of the equipment, no crystals shall be present in the liquid.

Tap-changers: It is common practice that, before energizing, the on-load tap-changer (if present) is operated to reach a position where the transformer can be energized without carrying an abnormally large load. It can happen that the spring-operated diverter switch cannot complete its operation if the natural ester liquid is partially crystalized. Such situation shall be avoided in any case. 10

4.2.4 Water content

Water content of natural esters affects their dielectric properties. Water content shall be measured in accordance with IEC 60814.

NOTE 1 Due to the moderately polar nature of natural esters, water content at which free water will appear and cause deterioration of electric strength is significantly higher in natural esters than that in mineral insulating oils.

NOTE 2 The terms “water” and “moisture” are the same in this document.

4.2.5 Density

Density of natural esters shall be measured in accordance with ~~ISO 3675~~ ISO 12185 (reference method), but ~~ISO 12185~~ ISO 3675 or ASTM D7042 are also acceptable.

4.3 Electrical properties

4.3.1 Breakdown voltage

Breakdown voltage of unused natural esters shall be measured in accordance with IEC 60156.

~~Because of the difference in properties of natural esters, an initial set-up time is required; it may range between 15 min and 30 min, when there are no visible bubbles in the liquid before measurements are made.~~ **11**

4.3.2 Dielectric dissipation factor (DDF)

DDF is a measure for dielectric losses caused by the liquid. High DDF can indicate contamination of the liquid with moisture, particles, 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.~~

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

4.3.3 Relative permittivity (dielectric constant)

Relative permittivity is the ratio of the amount of electrical energy stored in the liquid at an applied voltage, relative to that stored in a vacuum. It shall be measured in accordance with IEC 60247 or IEC 61620 at 90 °C. In case of dispute, IEC 60247 (reference method) at 90 °C ~~should~~ shall be used.

NOTE A typical value is between 2,8 and 3,3.

4.4 Chemical properties

4.4.1 Acidity

Unused natural esters should be near neutral; acidity shall be measured in accordance with IEC 62021-3.

NOTE Natural esters ~~may~~ can contain very low concentrations of free fatty acids; presence of free fatty acids can affect the acidity of natural esters. This is reflected in the values given in Table 2.

4.4.2 Corrosive sulfur

~~Free~~ Corrosive sulfur and potentially corrosive compounds ~~are~~ shall be detected by contacting copper with insulating liquid under the standardized conditions specified in IEC 62535 ~~or ASTM D1275B~~. Known corrosive sulfur compounds such as dibenzyl disulphide (DBDS) shall not be present above the detection limit given in IEC 62697-1.

NOTE Corrosive sulfur compounds are not naturally present in vegetable oils or other natural esters. The tests given in IEC 62535 can verify that any additives used are non-corrosive and that cross-contamination with a potentially corrosive ~~oils~~ liquid has not occurred.

4.4.3 Additive content

Additives include antioxidants, metal deactivators, pour point depressants, dyes, etc. An antioxidant additive slows down the oxidation of esters and, in turn, the formation of gels and acidity. ~~One such antioxidant is 2, 6-di-tert-butyl-p-cresol (DBPC), also known as BHT, but others are also used.~~ Detection and measurement of defined anti-oxidant additives shall be in