

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

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

**Fluides pour applications électrotechniques – Esters naturels neufs pour transformateurs et matériels électriques analogues**





**THIS PUBLICATION IS COPYRIGHT PROTECTED**  
**Copyright © 2013 IEC, Geneva, Switzerland**

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester.  
If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de la CEI ou du Comité national de la CEI du pays du demandeur.

Si vous avez des questions sur le copyright de la CEI ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de la CEI de votre pays de résidence.

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

Tel.: +41 22 919 02 11  
Fax: +41 22 919 03 00  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://www.iec.ch)

### About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

### About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

#### Useful links:

IEC publications search - [www.iec.ch/searchpub](http://www.iec.ch/searchpub)

The advanced search enables you to find IEC publications by a variety of criteria (reference number, text, technical committee,...).

It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Stay up to date on all new IEC publications. Just Published details all new publications released. Available on-line and also once a month by email.

Electropedia - [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary (IEV) on-line.

Customer Service Centre - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: [csc@iec.ch](mailto:csc@iec.ch).

---

### A propos de la CEI

La Commission Electrotechnique Internationale (CEI) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

### A propos des publications CEI

Le contenu technique des publications de la CEI est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

#### Liens utiles:

Recherche de publications CEI - [www.iec.ch/searchpub](http://www.iec.ch/searchpub)

La recherche avancée vous permet de trouver des publications CEI en utilisant différents critères (numéro de référence, texte, comité d'études,...).

Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

Just Published CEI - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Restez informé sur les nouvelles publications de la CEI. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - [www.electropedia.org](http://www.electropedia.org)

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 30 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (VEI) en ligne.

Service Clients - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: [csc@iec.ch](mailto:csc@iec.ch).



IEC 62770

Edition 1.0 2013-11

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

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

**Fluides pour applications électrotechniques – Esters naturels neufs pour transformateurs et matériels électriques analogues**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

COMMISSION  
ELECTROTECHNIQUE  
INTERNATIONALE

PRICE CODE  
CODE PRIX



ICS 29.040

ISBN 978-2-8322-1191-5

**Warning! Make sure that you obtained this publication from an authorized distributor.  
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

## CONTENTS

FOREWORD.....	4
INTRODUCTION.....	6
1 Scope.....	7
2 Normative references .....	7
3 Terms and definitions .....	9
4 Properties, their significance and test methods.....	9
4.1 General.....	9
4.2 Physical properties .....	9
4.2.1 Appearance .....	9
4.2.2 Viscosity.....	10
4.2.3 Pour point.....	10
4.2.4 Water content .....	10
4.2.5 Density .....	10
4.3 Electrical properties .....	10
4.3.1 Breakdown voltage .....	10
4.3.2 Dielectric dissipation factor (DDF) .....	10
4.3.3 Relative permittivity (dielectric constant).....	11
4.4 Chemical properties .....	11
4.4.1 Acidity .....	11
4.4.2 Corrosive sulfur .....	11
4.4.3 Additive content.....	11
4.4.4 Furfural content .....	11
4.5 Performance .....	11
4.5.1 Oxidation stability .....	11
4.5.2 Total acidity.....	12
4.5.3 Viscosity.....	12
4.5.4 Dielectric dissipation factor (DDF) .....	12
4.6 Health, safety and environmental (HSE) properties .....	12
4.6.1 Fire point and flash point .....	12
4.6.2 Polychlorinated biphenyls (PCBs) .....	12
4.6.3 Biodegradation .....	12
4.6.4 Toxicity.....	12
5 Classification, identification, general delivery requirements and sampling.....	12
5.1 Classification .....	12
5.2 Identification and general delivery requirements .....	13
5.3 Sampling.....	13
Annex A (normative) Summary of the test method for evaluating oxidation stability of unused natural esters .....	15
A.1 Introductory remark.....	15
A.2 Test conditions .....	15
A.3 Precision.....	15
A.4 Relative repeatability ( <i>r</i> ).....	15
A.5 Relative reproducibility ( <i>R</i> ).....	15
Annex B (informative) Specifications of low-viscosity insulating fluids derived from natural esters .....	16
Bibliography.....	17



Table 1 – General specifications .....	14
Table A.1 – Relative repeatability and relative reproducibility obtained for different parameters during RRT .....	15
Table B.1 – Specifications for low-viscosity of monoesters derived from natural esters .....	16

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**FLUIDS FOR ELECTROTECHNICAL APPLICATIONS –  
UNUSED NATURAL ESTERS FOR TRANSFORMERS  
AND SIMILAR 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.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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

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

FDIS	Report on voting
10/909/FDIS	10/933/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

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

## INTRODUCTION

Because of their higher fire points and better environmental compatibility relative to 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 standard 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, e.g. sealed transformers and reactors because these fluids are prone to rapid oxidation.

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 limitation prior to use.

Unused natural esters which are the subject of this standard 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 standard could lead to a hazardous situation. Attention is drawn to the relevant standard 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.



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

### 1 Scope

This International Standard describes specifications and test methods for unused natural esters in transformers and similar oil-impregnated electrical equipment in which a liquid is required as an insulating and heat transfer medium.

Use of natural esters is not recommended for electrical equipment that is open to the atmosphere.

In this standard the term “natural esters” applies to insulating fluids for transformers and similar electrical equipment with suitable biodegradability and environmental compatibility. 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 standard. Because of their different chemical composition, natural esters differ from insulating mineral oils and other insulating fluids that have high fire points, such as synthetic esters or silicone fluids.

Natural, ester-derived insulating fluids with low viscosity have been introduced but are not covered by this standard. Pertinent properties of such fluids are given in Annex B.

This standard is applicable only to unused natural esters. Reclaimed natural esters and natural esters blended with non-natural esters fluids are beyond the scope of this standard.

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

### 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 60076-14, *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 and DC 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*

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<sup>1</sup>*

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

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

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 dibenzyl disulfide (DBDS)*

ISO 2592, *Determination of flash and fire point – 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 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*

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

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*

---

<sup>1</sup> Withdrawn in 2009 and partially replaced by IEC 61039.

<sup>2</sup> To be published.

### 3 Terms and definitions

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

#### 3.1

##### **additives**

suitable chemical substances which are deliberately added to natural ester insulating fluids 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"]

#### 3.3

##### **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]

#### 3.5

##### **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.

### 4 Properties, their significance and test methods

#### 4.1 General

Salient characteristics of unused natural esters are listed in Table 1.

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

#### 4.2 Physical properties

##### 4.2.1 Appearance

A visual inspection of unused natural esters (with light transmitted through approximately 10 cm thickness of natural esters at ambient temperature) indicates the presence of visible contaminants, free water and suspended matter.



#### **4.2.2 Viscosity**

Viscosity influences heat transfer and therefore affects the increase of temperature in the transformer and other equipment. The lower the viscosity, the easier the oil circulates leading to better heat transfer. Viscosities at lower temperatures is a critical factor for cold start of transformers with ON cooling (absence of circulation can lead to possible overheating at hot spots). It can have negative impact on the speed of moving parts such as on-load tap changer mechanism, 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.

#### **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.

#### **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 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.

#### **4.2.5 Density**

Density of natural esters shall be measured in accordance with ISO 3675 (reference method), but ISO 12185 is 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.

#### **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 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.

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



### 4.3.3 Relative permittivity (dielectric constant)

It 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 at 90 °C should be used.

NOTE Typical value 2,8 – 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 contain very low concentrations of free fatty acids; presence of free fatty acids can affect acidity of natural esters.

### 4.4.2 Corrosive sulfur

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

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

### 4.4.3 Additive content

Additives include antioxidants, metal deactivators, pour point depressants, etc. 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 accordance with IEC 60666 or other suitable methods. Total concentration of additives shall be less than a weight fraction of 5 %.

The supplier with mutual consent should declare the generic types of all additives, and their concentrations in the case of antioxidants and passivators. Information on initial type and concentration of additives is useful for supervision and maintenance guidance during the life of natural esters in transformers and similar electrical equipment.

### 4.4.4 Furfural content

Furanic compounds, including 2-Furfural, are degradation products of Kraft insulating paper; such compounds are not typically present in unused natural esters. 2-Furfural and related compounds shall be determined in accordance with IEC 61198.

NOTE Certain furanic compounds may be present at trace levels in unused natural esters.

## 4.5 Performance

NOTE This concerns the properties that are related to the long-term behaviour of natural ester insulating fluids in service and/or their reaction to high electric stress and temperature. Acceptable operating temperatures for esters are provided in IEC 60076-14.

### 4.5.1 Oxidation stability

Unused natural esters are recommended for application only in equipment that is not open to atmosphere because these fluids are prone to rapid oxidation. Oxidation stability of these fluids can be assessed with modifications to the procedure as described in Method C of IEC 61125:1992.

NOTE The modifications in IEC 61125 for natural esters are given in Annex A.

#### 4.5.2 Total acidity

Acidity of natural esters subjected to oxidation stability test. Acidity should be measured in accordance with 1.9.4 of IEC 61125:1992.

#### 4.5.3 Viscosity

Viscosity of natural esters subjected to oxidation stability test shall be measured at 40 °C according to ISO 3104.

#### 4.5.4 Dielectric dissipation factor (DDF)

DDF measurements after oxidation stability test provides a measure for dielectric losses resulting from the water and soluble polar compounds formed in a dielectric liquid as a result of oxidation. DDF shall be measured in accordance with IEC 60247 or IEC 61620.

### 4.6 Health, safety and environmental (HSE) properties

NOTE These are the properties that are related to safe handling of natural esters and minimization of their adverse impact. Examples can include flash and fire points, polycyclic aromatics (PCAs), and polychlorinated biphenyls/polychlorinated terphenyls (PCBs/PCTs).

#### 4.6.1 Fire point and flash point

The safe operation of electrical equipment requires an adequately high fire point that is measured in accordance with ISO 2592. Flash point is measured according to ISO 2719.

#### 4.6.2 Polychlorinated biphenyls (PCBs)

Unused natural esters shall be free from PCBs.

Concentrations of these chemicals can be measured according to IEC 61619; total concentration shall be less than 2 mg kg<sup>-1</sup>.

NOTE PCBs and related compounds can be present in unused natural esters only because of cross-contamination.

#### 4.6.3 Biodegradation

Natural esters exhibit better environmental compatibility relative to petroleum-derived insulating mineral oils. Specific tests need to be undertaken to demonstrate ready biodegradability of these fluids. Tests include OECD 301B, C or F; or US EPA – OPPTS 835.311.

NOTE Natural esters can be classified in accordance with IEC 61039, based on biodegradability observed with OECD 301:1992.

#### 4.6.4 Toxicity

Unused natural esters are considered non-toxic and suppliers shall supply assays that define the product as non-toxic.

NOTE Toxicity of natural esters can be assessed with test methods such as a modified Ames test or other suitable internationally recognized assays such as OECD 201-203; US EPA 600/4.82.068:1983.

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

### 5.1 Classification

For the purpose of this standard, natural esters are classified in a single class.

- less flammable natural esters.

NOTE There are other natural ester derived liquids, which may have a different classification. However, these liquids are not covered by this standard, an example of such liquids is described in Annex B.

## 5.2 Identification and general delivery requirements

- a) Natural esters are normally delivered in bulk, rail tank cars, tank containers, or packed in drums or (intermediate bulk containers). These shall be clean and suitable for this purpose in order to avoid any contamination.
- b) Liquid drums and sample containers shall carry at least the following markings:
  - supplier's designation;
  - classification;
  - liquid net weight.
- c) Each natural esters delivery shall be accompanied by a document from the supplier specifying at least: supplier's designation, liquid classification and quality certificate. At the request of the purchaser and by mutual consent, the supplier should declare all generic types of additives and their concentrations in a datasheet in accordance with the international and local regulations.

## 5.3 Sampling

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

**Table 1 – General specifications**

Property	Test method	Limits
<b>Physical</b>		
Appearance		Clear, free from sediment and suspended matter
Viscosity at 100 °C	ISO 3104	Max. 15 mm <sup>2</sup> ·s <sup>-1</sup>
Viscosity at 40 °C	ISO 3104	Max. 50 mm <sup>2</sup> ·s <sup>-1</sup>
Pour point	ISO 3016	Max. –10 °C
Water content	IEC 60814	Max. 200 mg·kg <sup>-1</sup>
Density at 20 °C	ISO 3675 or ISO 12185	Max. 1 000 kg·m <sup>-3</sup>
<b>Electrical</b>		
Breakdown voltage	IEC 60156 (2,5 mm gap)	Min. 35 kV <sup>a</sup>
Dissipation factor (tan δ) 90 °C	IEC 60247	Max. 0,05
<b>Chemical</b>		
Soluble acidity	IEC 62021-3	Max. 0,06 mg KOH g <sub>oil</sub> <sup>-1</sup>
Corrosive sulfur DBDS	IEC 62535 or ASTM D1275B IEC 62697-1	Non corrosive Below detection limit
Total additives	IEC 60666 or other suitable methods	Max. weight fraction 5 %
Performance – Salient properties after oxidation stability test in accordance with Method C of IEC 61125:1992 <sup>b</sup>		
Total acidity	1.9.4 of IEC 61125:1992	Max. 0,6 mg KOH g <sub>oil</sub> <sup>-1</sup>
Viscosity at 40 °C	ISO 3104	Max. 30 % increase over the initial value
DDF (tan δ) at 90 °C	IEC 60247	Max. 0,5
<b>Health, safety and environment (HSE)</b>		
Fire point	ISO 2592	Min. 300 °C
Flash point	ISO 2719	Min. 250 °C
Biodegradation	US EPA OECD 301 B, C or F US EPA OPPTS 835.311	Readily biodegradable
<sup>a</sup> At delivery. <sup>b</sup> See Annex A for details of oxidation stability parameters.		



## Annex A (normative)

### Summary of the test method for evaluating oxidation stability of unused natural esters

#### A.1 Introductory remark

Oxidation stability of natural esters is evaluated under accelerated aging conditions similar to those described in Method C of IEC 61125:1992.

Aliquots of the natural esters samples are maintained at 120 °C in the presence of a solid copper catalyst, while a constant volume of air is bubbled through the samples for 48 h. The resistance to oxidation is estimated by measuring volatile acidity, soluble acidity, sludge formation, viscosity and DDF. The values obtained for these parameters after accelerated oxidation are compared against the values obtained prior to accelerated oxidation.

#### A.2 Test conditions

All test conditions i.e. the amount of natural esters, length and diameter of copper catalyst, oxidation temperature and oxidant (air) flow rate are the same as described in Method C of IEC 61125:1992. The only modification is in the duration for accelerated aging, which is set at 48 h.

#### A.3 Precision

Precision values obtained during the Round Robin test on commercially available natural esters after 48 h oxidation are given in Table A.1. Relative reproducibility for each parameter is based on results obtained from 11 participating laboratories. The values reported in Table A.1 are in general agreement with values reported for mineral insulating oils in IEC 61125.

#### A.4 Relative repeatability (*r*)

Duplicate determinations carried out by one laboratory at the 95 % confidence level.

#### A.5 Relative reproducibility (*R*)

Duplicate determinations carried out by different laboratories at the 95 % confidence level.

**Table A.1 – Relative repeatability and relative reproducibility obtained  
for different parameters during RRT**

Parameter	<i>r</i> %	<i>R</i> %
Viscosity at 40 °C	5	7,5
Total acidity	13	38
Sludge	22	57
DDF (tan δ) at 90 °C	–	47

## Annex B (informative)

### Specifications of low-viscosity insulating fluids derived from natural esters

From a chemical and biochemical point of view, the natural esters (i.e. esters that can be found in biological materials) comprise many other molecules besides the triglycerides to which the definition of natural esters in this standard refers.

The triglycerides are the main constituents of vegetable oils (and animal fats) and these fluids are usually characterized by high fire point and flash point, which categorize them in class K according to IEC 61100. Compared to mineral oils, they are less flammable but they have also a higher viscosity and a higher pour point.

NOTE According to IEC 61100, class K fluids have a fire point > 300 °C (according to ISO 2592 – open cup) and a flash point > 250 °C (according to ISO 2719 – closed cup)

Other insulating fluids, derived from various natural esters, have been developed for use in some electrotechnical applications (e.g. low/medium voltage power transformers with ONAN cooling). Such fluids mainly consist of fatty acid mono-esters that allow lowering the viscosity or mixtures of triglycerides and fatty acid mono-esters.

The properties of the low-viscosity insulating fluids derived from natural esters are close to those of mineral oils, as shown in Table B.1.

**Table B.1 – Specifications for low-viscosity of monoesters derived  
from natural esters**

Property	Test method	Limits
<b>Physical</b>		
Viscosity at 100 °C	ISO 3104	Max. 6 mm <sup>2</sup> ·s <sup>-1</sup>
Viscosity at 40 °C	ISO 3104	Max. 18 mm <sup>2</sup> ·s <sup>-1</sup>
Viscosity at 0 °C	ISO 3104	Max. 90 mm <sup>2</sup> ·s <sup>-1</sup>
Pour point	ISO 3016	Max. –25 °C <sup>a</sup>
<b>Electrical</b>		
Breakdown voltage	IEC 60156 (2,5 mm gap)	Min. 35 kV <sup>b</sup>
Dissipation factor (tan δ) at 90 °C	IEC 60247	Max. 0,05
<b>Health, safety and environment (HSE)</b>		
Fire point	ISO 2592 (open cup)	Min. 175 °C
Flash point	ISO 2719 (closed cup)	Min. 135 °C
Biodegradation	US EPA OECD 301 B,C,F US EPA OPPTS 835.311	Readily biodegradable
<sup>a</sup> LCSET Lowest cold start energizing temperature –10 K.		
<sup>b</sup> At delivery and ≥70 kV after treatment (see IEC 60296 for a description of the laboratory treatment).		

## Bibliography

IEC 60050-212:2010, *International Electrotechnical Vocabulary – Part 212: Electrical insulating solids, liquids and gases*

IEC 60050-421, *International Electrotechnical Vocabulary – Chapter 421: Power transformers and reactors*

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

IEC 61039, *Classification of insulating fluids*

IEC 61099, *Specification for unused synthetic organic esters for electrical purposes*

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

ASTM D6871: Standard specification for natural (vegetable oil) ester fluids used in electrical apparatus

*International Union of Pure and Applied Chemistry (IUPAC) Handbook of terms and definitions*

CIGRE Brochure 436, *Experiences in Service with New Insulating Liquids. Working Group A2. 35, October, 2010*

IEEE C57.147<sup>th</sup>, *Guide for Acceptance and Maintenance of Natural Ester Fluids in Transformers*

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

US EPA 600/4.82.068:1983, *Interim Procedure for Conducting the Salmonella/Microsomal Mutagenicity Assay (Ames Test)*

---