IEC 63177

Edition 1.0 2024-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Test methods for compatibility of construction materials with electrical insulating liquids

Méthodes d'essai pour évaluer la compatibilité des matériaux de construction avec les isolants électriques liquides

IEC 63177:2024-05(en-fr)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 29.040.01, 29.080.99

ISBN 978-2-8322-8719-4

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

TEST METHODS FOR COMPATIBILITY OF CONSTRUCTION MATERIALS WITH ELECTRICAL INSULATING LIQUIDS

FOREWORD

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

Draft	Report on voting
112/630/FDIS	112/640/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.

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- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

The objective of the document is to clarify the evaluation methodology for the compatibility between construction materials and electrical insulating liquids. It provides recommendations for manufacturers of liquid-immersed transformers and tap-changers, liquid-impregnated capacitors, and liquid-cooled rotating machines used in electrical vehicles and oil pumps. The recommendations focus on screening appropriate construction materials ensuring compatibility between solid and liquid materials for use with different liquids under varying operating conditions. Additionally, the document contains tests that should be carried out on liquids and construction materials. These tests occur after a conditioning procedure at the desired temperature and for reference samples.

In the past, limited construction materials and liquids based on mineral oil served the industry needs. Since the industry needs have been advanced with new applications and driven by higher flash points and improved reliability of performance for liquid-filled electrical equipment, it is necessary to be able to evaluate high temperature electrical insulation systems, using silicone oils, synthetic esters, natural esters, and other potential suitable insulating liquids.

At the same time, liquid-cooled rotating machines used in electrical vehicles and oil pumps also increase the possibility for construction materials to be exposed to different liquids, driven by better thermal conductive performance. To avoid mechanical, electrical, and sealing failure for construction materials, such as gasket materials, impregnating resins, prefabricates, etc., the test methods described in this document can be applied for different liquid-immersed electrical equipment, including liquid-immersed transformers and tap-changers, liquid-impregnated capacitors and liquid-cooled rotating machines used in electrical vehicles and oil pumps.

The evaluation process specified in this document focuses on the chemical compatibility between construction materials and liquids, but does not provide a long-term thermal or aging evaluation. In addition, threshold values for functional parameters of each material are not specified, as they depend on the requirements of the specific application.

Clause 1 to Clause 5 contain definitions and describe the preparation of suitable solid and liquid test samples.

Clause 6 describes the test procedure (e.g. temperatures, test duration and cycles) and lists the characteristic parameters to be evaluated. This allows an estimate of the basic compatibility of typical construction materials with insulating liquids.

An application example is given in Annex A.

TEST METHODS FOR COMPATIBILITY OF CONSTRUCTION MATERIALS WITH ELECTRICAL INSULATING LIQUIDS

1 Scope

This document specifies the test method for the compatibility of construction materials with electrical insulating liquids for use in electrical equipment, such as liquid-immersed transformers and tap-changers, liquid-impregnated capacitors, and liquid-cooled rotating machines used in electrical vehicles and oil pumps. This document is applicable to mineral insulating liquids, natural esters, silicone insulating liquids, synthetic organic esters, modified esters, capacitor fluids based on synthetic aromatic hydrocarbons and e-transmission fluids used in electrical vehicles and oil pumps. The compatibility tests are not sufficient for a full qualification of construction materials for a given application without additional tests requested by the appropriate IEC Technical Committee or equipment manufacturers.

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 60296:2020, *Fluids for electrotechnical applications – Mineral insulating oils for electrical equipment*

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

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

IEC 60836:2015, *Specifications for unused silicone insulating liquids for electrotechnical purposes*

IEC 60851-4:2016, *Winding wires – Test methods – Part 4: Chemical properties*

IEC 60867, *Insulating liquids – Specifications for unused liquids based on synthetic aromatic hydrocarbons*

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

IEC 62021-3:2014, *Insulating liquids – Determination of acidity – Part 3: Test methods for non-mineral insulating oils*

IEC 62770:2013, *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*

IEC 63012:2019, *Insulating liquids – Unused modified or blended esters for electrotechnical applications*

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

ASTM D1524, *Standard Test Method for Visual Examination of Used Electrical Insulating Liquids in the Field*

3 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:

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

3.1
insulating liquid
insulating material consisting entirely of a liquid

[SOURCE: IEC 60050-212:2010, 212-11-04]

3.2
mineral insulating oil
insulating liquid for transformers and similar electrical equipment (e.g. switchgear, tapchangers), derived from petroleum products and/or other hydrocarbons

[SOURCE: IEC 60296:2020, 3.1]

3.3
natural esters
vegetable oils obtained from seeds and oils obtained from other suitable biological materials and comprised of triglycerides

[SOURCE: IEC 62770:2013, 3.3]

3.4
silicone insulating liquids
liquid organopolysiloxanes whose molecular structure consists mainly of linear chains of alternating silicon and oxygen atoms, with hydrocarbon groups attached to the silicon atoms

[SOURCE: IEC 60836:2015, 3.1]

3.5
synthetic organic ester
insulating liquid produced from acids and alcohols by chemical reaction

[SOURCE: IEC 60050-212:2010, 212-17-08, modified – The Note to entry has been omitted.]

3.6
modified ester insulating liquid
ester insulating liquid which has been made/synthesized or altered by chemical reaction

[SOURCE: IEC 63012:2019, 3.3, modified – The Notes to entry have been omitted.]

3.7
blended ester insulating liquid
homogeneous combination of unused natural, synthetic and/or modified esters that are miscible

[SOURCE: IEC 63012:2019, 3.4, modified – The note to entry has been omitted.]

3.8
compatibility (of materials)
ability of materials to be used together without deleterious changes in any of the materials

[SOURCE: IEC 60050-212:2010, 212-14-19]

3.9
breakdown voltage
voltage at which electric breakdown occurs under prescribed test conditions, or in use

[SOURCE: IEC 60050-212:2010, 212-11-34]

3.10
dielectric dissipation factor
absolute value of the ratio of the imaginary to the real part of the complex relative permittivity

Note 1 to entry: The dielectric dissipation factor is equal to the tangent of the dielectric loss angle.

Note 2 to entry: In English the abbreviation DDF is sometimes used to characterize the dielectric loss in insulating materials.

[SOURCE: IEC 60050-212:2010, 212-11-29, modified – The admitted terms have been deleted and, in the definition, $\tan \delta = \varepsilon_r'' / \varepsilon_r'$ has been deleted.]

3.11
acidity
quantity of base, expressed in milligrams of potassium hydroxide per gram of sample, required to titrate potentiometrically or colourimetrically a test portion in a specified solvent to the end point

[SOURCE: IEC 62021-3:2014, 3.1]

3.12
thermal class
designation that is equal to the numerical value of the recommended maximum continuous use temperature in degrees Celsius

Note 1 to entry: EIS subjected to operating temperatures exceeding its assigned thermal class can result in shorter expected life.

Note 2 to entry: Electrical insulation materials with different thermal endurance indices (ATE/RTE according to IEC 60216-5) may be combined to form an EIS which has a thermal class that may be higher or lower than the recommended maximum continuous use temperature of any of the individual components according to IEC 60505.

[SOURCE: IEC 60085:2007, 3.11]

3.13
electric insulation system
EIS
insulating structure containing one or more electrical insulating material together with associated conducting parts employed in an electrotechnical device

[SOURCE: IEC 60085:2007, 3.2]

3.14
transformer
electric energy converter without moving parts that changes voltages and currents associated with electric energy without change of frequency

[SOURCE: IEC 60050-151:2001, 151-13-42]

3.15
capacitor
two-terminal device characterized essentially by its capacitance

Note 1 to entry: The term "capacitor" is used when it is not necessary to specify whether a capacitor unit or capacitor bank is meant.

[SOURCE: IEC 60050-151:2001, 151-13-28, modified – Note 1 to entry has been added.]

3.16
e-transmission fluid
fluid which is used in transmission with integrated e-motor design and plays dual roles of cooling e-motor and lubricating transmissions

3.17
liquid-cooled rotating machine
type of rotating machine whose cooling system relies on fluids instead of air or water

Note 1 to entry: During operation period, heat exchange happens between fluids and rotating machine.

3.18
impregnating resin
solventless compound of low viscosity which is applied by casting or dipping techniques, and which solidifies after application

Note 1 to entry: The resin normally has a viscosity low enough to permit complete penetration into fine windings, etc.

Note 2 to entry: See also 212-15-36, varnish.

[SOURCE: IEC 60050-212:2010, 212-15-31]

3.19
coating
insulating material such as varnish or dry film laid on the surface of the assembly

Note 1 to entry: The coating and base material of a printed board form an insulating system that may have properties similar to solid insulation.

[SOURCE: IEC 60664-2-1:2011]

4 General information

It is possible that individual tests will not be sufficient for the full evaluation of the construction material compatibility. Other detection methods such as dissolved gas analysis (DGA) can be informative to detect compatibility problems at the beginning stage if additional requirements are agreed upon between supplier and user.

NOTE 1 Based on the test experiences, sampling directly after opening the test vessel is the common practice and there is negligible effect on the determination of the compatibility.

Selection of the tests depends on the stress of application and shall be agreed between the involved parties.

Some equipment manufacturers have their own testing protocols for construction material, which are adapted to their design, and shall be aligned between supplier and user.

Beyond construction materials discussed in 5.1, other remaining construction materials shall be tested according to each specific application request.

NOTE 2 The requirements for the oven can be referred to the series standards of IEC 60216-4.

5 Sampling and preparation

5.1 Test specimens – Solid materials

Test specimen size shall be such that the ratio of surface area to electrical insulating liquid volume is balanced between 100 % to 400 % of normal use in electrical equipment and the test sample specified in 6.5.

Some suggested ratios and preparations are as follows:

If the surface area of test specimen can be measured, surface areas no less than 52 cm^2 shall be used with each 800 ml of liquid. If the surface area of the specimen is less than 50 cm^2, the amount of insulating liquid shall be reduced accordingly.

If the surface area of test specimen cannot be measured, the test specimen shall be used in the amount of 1 % by the weight of the liquid.

Multi-component materials (e.g. unsaturated polyester resin, epoxy resin, vinyl ester resin or phenolic resin in combination with cellulose, glass fibres or polyester fabrics and fillers) shall be cured or treated in compliance with the different requirements of each application known to be compatible with the insulating liquid.

Solid polymer-based materials such as those made of polyamides, polypthalamides, polytetrafluoroethylene (PTFE) or other high-performance materials shall be tested on suitable sample parts (or sections thereof) as used in the real application. If tensile strength of multi-component materials and solid materials shall be determined, standardized tensile specimen (tensile rods) shall be prepared and immersed in 800 ml of liquid.

Adhesives can be tested by creating bonded joint samples, using the same materials and combinations as in the industrial application. For thread lock materials, threaded connection samples shall be created, which are fastened with a defined torque, as in the industrial application.

Gasket materials shall be tested not less than 65 cm^2 surface area per 800 ml of liquid. Samples as used in the application (or sections thereof) can be used.