IEC TS 62332-2

Edition 1.0 2014-04

TECHNICAL SPECIFICATION

SPECIFICATION TECHNIQUE

colour inside

Electrical insulation systems (EIS) – Thermal evaluation of combined liquid and solid components – Part 2: Simplified test

Systèmes d'isolation électrique (SIE) – Évaluation thermique de composants liquides et solides combinés – Partie 2: Essai simplifié

IEC TS 62332-2:2014-04(en-fr)

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ELECTRICAL INSULATION SYSTEMS (EIS) – THERMAL EVALUATION OF COMBINED LIQUID AND SOLID COMPONENTS –

Part 2: Simplified test

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IEC TS 62332-2, which is a technical specification, has been prepared by IEC technical committee 112: Evaluation and qualification of electrical insulating materials and systems.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
112/256/DTS	112/268/RVC

Full information on the voting for the approval of this technical specification 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.

A list of all the parts in the IEC 62332 series, published under the general title *Electrical insulation systems (EIS) – Thermal evaluation of combined liquid and solid components*, can be found on the IEC website.

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

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- reconfirmed,
- withdrawn,
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INTRODUCTION

This technical specification describes a method for the thermal evaluation of electrical insulation systems (EIS) for electrotechnical products with combined liquid and solid components. More specifically, this part addresses liquid immersed power transformers. Part 1 covers general test requirements. This Part 2 covers a simplified test method which can be used as a screening test prior to conducting Part 1 testing or it can be used to determine a thermal classification of an EIS. This method can also be used as a quality control test to evaluate minor product changes.

This specification provides a standardized test method for sealed tube testing. The sealed tube should contain all the primary EIS elements, and in relative component ratios which compare with actual liquid immersed power transformers.

This technical specification has been prepared in conjunction with IEC TC 14, *Power transformers* and IEC TC 10, *Fluids for electrotechnical applications*. Any comments or suggestions from other technical committees to make this technical specification more general are welcome.

ELECTRICAL INSULATION SYSTEMS (EIS) – THERMAL EVALUATION OF COMBINED LIQUID AND SOLID COMPONENTS –

Part 2: Simplified test

1 Scope

This part of IEC 62332, which is a technical specification, is applicable to EIS containing solid and liquid components where the thermal stress is the dominant ageing factor, without restriction to voltage class.

This part specifies a sealed tube test procedure for the thermal evaluation and qualification of electrical insulation systems (EIS). One aspect of this procedure is to also provide a method to assign thermal classifications to materials used in EIS where solid and liquid components are both used. This procedure describes a comparative ageing method whereby a reference system composed of kraft paper and mineral oil is compared to a candidate system of any combination of solid and insulating liquid. The test procedures in this part are specifically applicable to liquid immersed transformer insulation systems.

Similar procedures should also work for other electrotechnical devices with a combination of liquid and solid components, such as bushings, cables or capacitors, but this will be added as additional parts once experience is gained using this technical specification.

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 60085, *Electrical insulation – Thermal evaluation and designation*

IEC 60156, *Insulating liquids – Determination of the breakdown voltage at power frequency – Test method*

IEC 60216-2:2005, *Electrical insulating materials – Thermal endurance properties – Part 2: Determination of thermal endurance properties of electrical insulating materials – Choice of test criteria*

IEC 60216-3, *Electrical insulating materials – Thermal endurance properties – Part 3: Instructions for calculating thermal endurance characteristics*

IEC 60216-4-1, *Electrical insulating materials – Thermal endurance properties – Part 4-1: Ageing ovens – Single-chamber ovens*

IEC 60216-5, *Electrical insulating materials – Thermal endurance properties – Part 5: Determination of relative thermal endurance index (RTE) of an insulating material*

IEC 60243-1, *Electrical strength of insulating materials – Test methods – Part 1: Tests at power frequencies*

IEC 60247, *Insulating liquids – Measurement of relative permittivity, dielectric dissipation factor (tan δ) and d.c. resistivity*

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

IEC 60317 (all parts), *Specifications for particular types of winding wires*

IEC 60450, *Measurement of the average viscometric degree of polymerization of new and aged cellulosic electrically insulating materials*

IEC 60505:2011, *Evaluation and qualification of electrical insulation systems*

IEC 60554-2, *Cellulosic papers for electrical purposes – Part 2: Methods of test*

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

IEC 60599, *Mineral oil-impregnated electrical equipment in service – Guide to the interpretation of dissolved and free gases analysis*

IEC 60763-2, *Specification for laminated pressboard – Part 2: Methods of test*

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

IEC 60851-5, *Winding wires – Test methods – Part 5: Electrical properties*

IEC 61198, *Mineral insulating oils – Methods for the determination of 2-furfural and related compounds*

IEC 61620, *Insulating liquids – Determination of dielectric dissipation factor by measurement of the conductance and capacitance – Test method*

IEC 62021-1, *Insulating liquids – Determination of acidity – Part 1: Automatic potentiometric titration*

IEC 62021-2, *Insulating liquids – Determination of acidity – Part 2: Colourimetric titration*

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

IEC TS 62332-1:2011, *Electrical insulation systems (EIS) – Thermal evaluation of combined liquid and solid components – Part 1: General requirements*

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

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

ASTM D971, *Standard Test Method for Interfacial Tension Of Oil Against Water By The Ring Method*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply, some of which are taken from IEC 60505.

3.1
electrical insulation system
EIS
insulating structure containing one or more electrical insulating materials (EIM) together with associated conducting parts employed in an electrotechnical device

Note 1 to entry: EIMs with different temperature 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 that of any of the individual components according to IEC 60505.

[SOURCE: IEC 60505:2011, 3.1.1 – modified, the Note 1 to entry has been added]

3.2
candidate EIS
EIS under evaluation to determine its service capability (thermal)

3.3
reference EIS
evaluated and established EIS with either a known service experience record or a known comparative functional evaluation as a basis

3.4
thermal class
designation of an EIS that is equal to the numerical value of the maximum temperature in degrees Celsius for which the EIS is appropriate according to IEC 60085

Note 1 to entry: An EIS may be subjected to operating temperatures exceeding its thermal class, which can result in shorter expected life.

3.5
EIS assessed thermal endurance index
EIS ATE
numerical value of the temperature in degrees Celsius for the reference EIS as derived from known service experience or a known comparative functional evaluation

3.6
EIS relative thermal endurance index
EIS RTE
numerical value of the temperature in degrees Celsius for the candidate EIS which is relative to the known EIS ATE of a reference EIS when both EIS are subjected to the same ageing and diagnostic procedures in a comparative test

3.7
test object
piece of original equipment, a representation (model) of equipment, a component of or part of equipment, including the EIS, intended for use in a functional test

3.8
thermal ageing factor
thermal stress that causes irreversible changes in the EIS

3.9
diagnostic test
periodic application of a specified level of a diagnostic factor to a test object to determine whether the end-point criterion has been reached

3.10
end-point criterion
selected value of either a property or a change of property that defines the end of a component's life

[SOURCE: IEC 61857-1:2008, 3.11, modified – "component's life" replaces "test object in a functional test]

3.11
end-of-life
end of a test object's life, as determined by any selected component meeting its end-point criterion

3.12
sealed tube
sealed container partially filled with the liquid EIM and in which includes the solid EIM in relative component ratios which compare with the actual electrotechnical device

3.13
halving value
HIC
numerical value of the temperature interval in Kelvins which expresses the halving of the time to end-point taken at the temperature equal to TI

[SOURCE: IEC 60050-212:2010, 212-12-13, modified – "equal to TI" replaces the original "corresponding to the temperature index or the relative temperature index"]

4 Thermal ageing test apparatus

4.1 General description

The thermal ageing test apparatus shall be designed to allow the ageing of solid and liquid components. The reference and candidate EIS shall be exposed to test periods at selected elevated temperatures. These test periods consist of a specific time exposure at the selected temperature followed by diagnostic tests. The test system consists of the following elements:

- sealed tubes
- ageing ovens
- test objects.

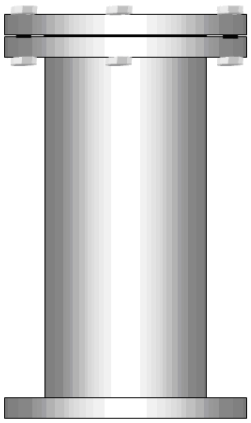
4.2 Sealed tubes

Each sealed tube is a container constructed of stainless steel or other suitable materials such as glass, the size to be determined by the size of the test objects. Additionally, the material for the tube shall either not affect the ageing (such as glass or stainless steel) or identically constructed tubes shall be used for all sets of experiments. The cell volume shall consider the space required for thermal expansion of the liquid at ageing temperatures, as well as space for the EIM to be evaluated. The EIM to be evaluated should be fully immersed in the liquid during the entire test period. Either one or both ends of the cell shall be fitted with removable, sealable bolt-on covers.

Ports shall be provided for

- sampling of the liquid,
- gas blanketing and associated pressure relief system.

For example, see Figure 1.



IEC 1019/14

Figure 1 – Sealed tube example

4.3 Gas blanketing system

A gas blanketing system shall be provided which simulates the insulation system used in the transformer being evaluated. This can be a sealed gas system, which maintains a gas blanket over the liquid in the cell for the purpose of reducing oxidation of the liquid. In each case, the gas blanket in each cell shall be regulated to maintain a positive pressure as is described in below in 4.4.

Free breathing liquid preservation systems are not included due to safety hazard of testing liquids at temperatures above their flashpoints where additional oxygen is available. In the case of a sealed test, the amount of available oxygen is limited.

NOTE Oxygen is known to increase ageing of insulation systems, so a test with air would be expected to be more severe than one sealed with nitrogen.

4.4 Pressure relief system

A pressure relief valve shall be installed on each cell to prevent the internal cell pressure from rising above the capability of the sealed tube. Additionally, the test should simulate the end application which is under evaluation. As an example, for liquid-immersed transformer applications, the transformer tanks are designed to operate at a pressure of up to 150 kPa. The technical evaluation for this design should use a method (such as a pressure relief valve) to control the pressure in the cells at a level consistent with the end use application being evaluated. If not otherwise specified, choose a level of 150 kPa for this test pressure.

Pressure control has two functions. The first is for safety and the second is to control the pressure at a low consistent level to better model the actual transformer application. This pressure control can be accomplished by using a pressure relief value equal to that used on the transformer for which the evaluation is being conducted, or by the means of an expanding bellows which allows increasing gas space of the test cell without an increase of pressure.

4.5 Ageing ovens

The ageing ovens used shall meet the requirements of IEC 60216-4-1.

5 Construction of the test object

5.1 General

The test object is designed to model the EIS portion of the transformer under evaluation and usually consists of

- a conductor insulation,
- other solid insulation components,
- structural components,
- metallic materials (typically copper or aluminium and steel),
- an insulating liquid,
- other components in the candidate if they differ from the reference system and if they reasonably affect the outcome of the test.

5.2 Determination of component weights

It is important that the ratios of weights of components used to construct the test object shall be representative of the candidate transformer being modelled. Determine the percentage of each individual component as a part of the total weight. The percentages shall be used to determine the weight of those individual components to be used in the construction of the test object. In a family of products with the same specific EIS, the ratio of weight of the individual components to the total weight should be similar. Other components which affect aging based on surface area are included on this basis.

Table 1 provides the weights and dimensions of the components to be used in the reference test. This table is based on the ratio of materials assuming 100 g of solid for each type of EIS. Each of the items in this table is described in more detail in the clauses following the table. The reference should be selected that is most appropriate for the candidate under test.

Table 1 – Reference component weight ratio calculations

	Transformer type		
Test material descriptions	**Distribution**	**Power – Core type**	**Power – Shell type**
Insulating liquid	1 330 g	760 g	330 g
Conductor insulation		10 g	10 g
Layer insulation	50 g		
Low density pressboard	50 g	10 g	80 g
High density pressboard		80 g	10 g
Ratio – Liquid to solid	13,3 to 1	7,6 to 1	3,3 to 1
Surface area of core steel	9,6 cm^2	9,6 cm^2	9,6 cm^2
Enamel wire samples	5 samples	5 samples	5 samples
Surface area of copper	9,6 cm^2	9,6 cm^2	9,6 cm^2

In addition to the ratios of the solid and liquid insulation components shown in Table 1, other materials as described in 5.3.4 and 5.3.5 should be included as well, but are not included here for simplicity. Enamel wire samples are described in Annex A.

5.3 Test object

5.3.1 Conductor insulation

Depending on the type of transformer, the conductors can range from small round wires, to larger rectangular wires or metal foils. The insulation for each of these may differ. The

insulation may be either enamel coating, conductors wrapped with thin insulating materials or, in the case of the metal foils, thicker papers/films, sometimes with adhesive coatings.

The conductor insulation should be tested in a way that can allow estimation of the expected thermal capability of the material when combined with a fluid. For thin wire wrap materials, the test specimens can be pre-cut tensile strips. A minimum of 20 test specimens per ageing cell should be included in each cell. For enamel coated round wires, twisted wire pairs of can be aged, again with a minimum of 20 test specimens per ageing cell. For applications such as distribution transformers, the thicker layer papers or films used with metal foils, can be evaluated similar to the thin wire wrap materials.

For papers/films with adhesive coatings, a separate test to evaluate the technical characteristic of the adhesive should be conducted. The failure mode for this test may be bond strength retention of the adhesive rather than a tensile retention test of the base paper/film insulation.

Include the same ratio of exposed surface area of the conductor metal (copper or aluminium) as in the transformer being evaluated for paper/film wrapped conductors.

5.3.2 Other solid insulation components

Other solid materials are typically used in the transformers. These components include pressboard products that are adjacent to the conductors (spacer materials), and as such experience the same temperature extremes as the conductor insulation or other materials which are used in the cooler part of the transformer (such as cylinders or oil-flow barriers). In other type of designs, the insulated conductors may be separated by insulating papers which again experience the same extreme temperatures as the conductor insulation. Each of these materials should be included in the correct ratio as described in 5.2.

5.3.3 Liquid component

The cell shall be filled with the liquid component used in the transformer being evaluated. The weight of the liquid shall be determined from requirements in 5.2 based on weight and temperature calculations. Care shall be taken to allow space for expansion of the liquid in the cell at elevated temperatures.

5.3.4 Structural components

Other materials are used in the transformer that are for “mechanical purposes” only, and have no direct impact on electrical performance of the insulation system, but if they fail in the application, could cause a degradation of the insulation system. Examples of such components include, but are not limited to, tie cords, netting tapes, adhesive tapes, etc. Many of these components are manufacturing aids, so a failure in operation is not a design problem, as long as the components degrade in a way that does not affect the other materials (chemical compatibility) or affect design parameters, e.g. block cooling.

These materials could be included in the test consistent with 5.2.

NOTE At present, no method has been developed as to how to evaluate the addition of these materials into the test object. Once experience with this test specification has been obtained, a method to evaluate these materials will be added.

5.3.5 Other components

For products being simulated, representative components that are not included in the EIS but are expected to affect it, shall be included. Examples include pieces of core steel, material supporting the leads, coatings, solder and enclosure materials. The relative weights of these components should match those of the evaluated product, with the exception of magnetic core steel and tank material. The relative quantity of magnetic core steel and tank shall be determined, based on the surface area exposed to the liquid component. An example is given