IEC/TS 62332-1

Edition 2.0 2011-03

TECHNICAL SPECIFICATION

Electrical insulation systems (EIS) – Thermal evaluation of combined liquid and solid components –
Part 1: General requirements

IEC/TS 62332-1:2011(E)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE **R**

ICS 29.080.30

ISBN 978-2-88912-404-6

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 1: General requirements

FOREWORD

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC/TS 62332-1, which is a technical specification, has been prepared by IEC technical committee 112: Evaluation and qualification of electrical insulating materials and systems.

This second edition cancels and replaces the first edition, published in 2005, and constitutes editorial and technical revisions.

The following significant technical changes with respect to the previous edition have been made:

Modifications have been made to the technical specification based on an extensive test series conducted using this methodology based on the first edition. This included updating expected times and temperatures to use in order to get useful results, as well as making the range of equipment covered more broad. The method can now cover electrotechnical devices using different sealing systems, as well as devices using enamel covered wires

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

Enquiry draft	Report on voting
112/160/DTS	112/168/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.

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

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

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. Part 1 covers general test requirements. Subsequent parts should cover specific product test requirements.

Prior to this technical specification, the procedure for determining the thermal endurance of insulation systems for liquid-immersed products involved one of two processes: firstly, sealed-tube ageing and, secondly, ageing of full-scale models.

The ageing of full-scale models is impractical, especially for larger products, such as power transformers. Similarly, the use of sealed-tube ageing is not practical when testing components having drastically different thermal capabilities. For example, testing of a system with a solid material with an RTI of 200 °C with a liquid having a 130 °C thermal capability cannot be performed efficiently. Accelerated ageing temperatures, which fairly age the liquid, will result in extremely long ageing times for the solid. Accelerated ageing temperatures, which fairly age the solid, will result in extreme, or even hazardous, ageing of the liquid.

This technical specification describes an accelerated thermal ageing procedure and model that allows for the solid materials to be aged at temperatures separate from the liquid ageing temperatures, all in the same apparatus. The model acts more in the true-life ageing mode of insulation systems, where solid insulation near the active parts is exposed to much higher temperatures than the major volume of liquid in the equipment. The model contains all the primary EIS elements, and in relative component ratios which compare with actual electrotechnical products.

The model has a dual temperature capability that allows independent control of the temperatures of the solid and liquid components by the use of separate circuits. A detailed bibliography is provided.

This technical specification has been prepared in conjunction with TC 14, Power transformers. 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 1: General requirements

1 Scope

This part of IEC/TS 62332 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 dual-temperature test procedure for the thermal evaluation and qualification of electrical insulation systems (EIS).

2 Normative references

The following referenced documents are indispensable for the application 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 60085:2007, *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 60216-5, *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 60250, *Recommended methods for the determination of the permittivity and dielectric dissipation factor of electrical insulating materials at power, audio and radio frequencies including metre wavelengths*

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

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

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

IEC 60505:2004, *Evaluation and qualification of electrical insulation systems*[1]

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 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 61857-1:2008, *Electrical insulation systems– Procedures for thermal evaluation – Part 1: General requirements – Low voltage*

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

ISO 287, *Paper and board – Determination of moisture content of a lot – Oven-drying method*

ISO 1924 (all parts), *Paper and board – Determination of tensile properties*

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

ASTM D971-99a, *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

[IEC 60505:2004, definition 3.1.1]

NOTE 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.

1 A fourth edition of IEC 60505 is currently in preparation.

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 Table 1 of IEC 60085:2007

NOTE 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

[IEC 61857-1:2008, definition 3.11, modified]

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
ageing cell
sealed container partially filled with the liquid EIM and in which are mounted the test object, liquid immersion heaters and thermocouples for control and monitoring

4 Thermal ageing test apparatus

4.1 General description

The thermal ageing test apparatus shall be designed to allow the separate 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:

- ageing cells;
- power supply;
- control system;
- safety system;
- sampling system;
- monitoring/data collection system.

4.2 Construction of the test apparatus

4.2.1 Ageing cells

Each ageing cell is a container constructed of stainless steel, the size to be determined by the size of the test object. The cell volume shall consider the space required for thermal expansion of the liquid at ageing temperatures. The two ends of the cell shall be fitted with removable, sealable bolt-on covers. The test object is mounted within the ageing cell.

Ports shall be provided for

- sampling of the liquid,
- pass-through of electrical circuits for heating of the active parts,
- monitoring and control elements,
- immersion heaters,
- gas blanketing and associated pressure relief system.

The design of the ageing cell shall be configured to maintain the thermocouples controlling the liquid and the solid component of the test objects immersed in the liquid under all ageing temperatures. See also 5.3.3.

For specific details, see Figure 1.

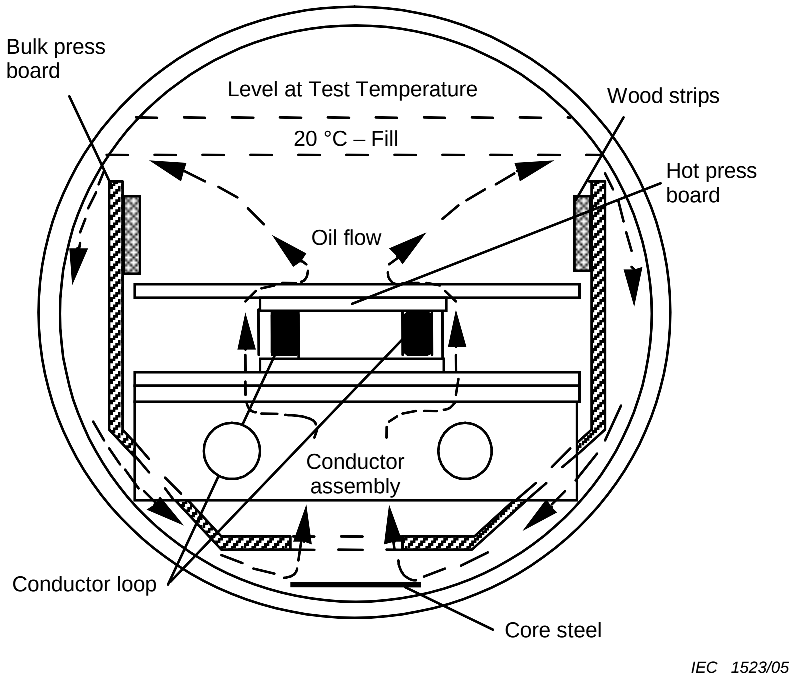

Figure 1 – Ageing cell cross-section

4.2.2 Immersion heaters

Immersion heaters shall have thermal capability to maintain the temperature of the test liquid within the temperature range defined by the test procedure.

4.2.3 Power supply

Separate power supplies shall be provided to independently establish the defined temperatures in the liquid and the test object:

- current through the test object shall establish the required temperature defined by the test procedure;
- the power capacity shall comply with 4.2.2.

For safety reasons, ageing cells shall be connected to earth.

4.2.4 Control circuit system

Automatic monitoring with thermal sensors controls the temperatures of the test object and liquid. A control feedback circuit shall be used to maintain each temperature within ± 2 K.

4.2.5 Gas blanketing system

A gas blanketing system shall be provided which simulates the insulation system used in the electrotechnical product being evaluated. This can be a sealed nitrogen system, which maintains a gas blanket over the liquid in the cell for the purpose of eliminating the possibility of oxidation of the liquid, or it could be a system simulating a desiccated air system. In each case, the gas blanket in each cell shall be regulated to maintain a positive pressure.

4.2.6 Safety system

A pressure relief valve shall be installed on each cell to prevent the internal cell pressure to raise above equipment capability.

NOTE For low thickness walls (e.g.1,2 mm), valves controlling a pressure of 35 kPa would be sufficient and for higher wall thicknesses (e.g. 8 mm) valves controlling a pressure of 85 kPa could be suitable. In any case the pressure should be calculated.

An over-temperature protection device shall be provided, responding to the temperature sensors in both the liquid and the test object in each cell. The sensors for the over-temperature protection shall be independent of the sensors for temperature control.

4.3 Monitoring and data collection

The output of all temperature sensing devices shall be monitored. Any deviations from the set-point range for more than 1 h shall be recorded hourly until corrected.

5 Construction of the test object

5.1 General

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

- a current-carrying conductor,
- a conductor insulation,
- insulation spacers/barriers,
- a liquid.

Other components may be used as appropriate.

5.2 Determination of component volumes

It is important that the ratios of volumes of components used to construct the test object shall be representative of the electrotechnical product being modelled. Therefore the total volume of the individual components in the products shall be evaluated. Determine the percentage of each individual component as a part of the total volume. The percentages shall be used to determine the volume 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 volume of the individual components to the total volume should be similar.

NOTE 1 The liquid volume is determined at 20 °C.

An example is included in Annex A for calculating the volumes and dimensions of the components.

NOTE 2 Additional components may be inserted into the ageing cell in order to achieve the best balance between temperature and volume requirements.

5.3 Test object

5.3.1 General

The following test object represents a liquid-immersed coil, which includes the liquid and solid components of the EIS.

5.3.2 Conductor assembly

The conductor assembly consists of a length of conductor whose shape and cross-sectional area is representative of that in the electrotechnical product being simulated. Specific conductor dimensions (cross-section and length) shall be based on volume and temperature calculations. An example is provided in Figure 2.

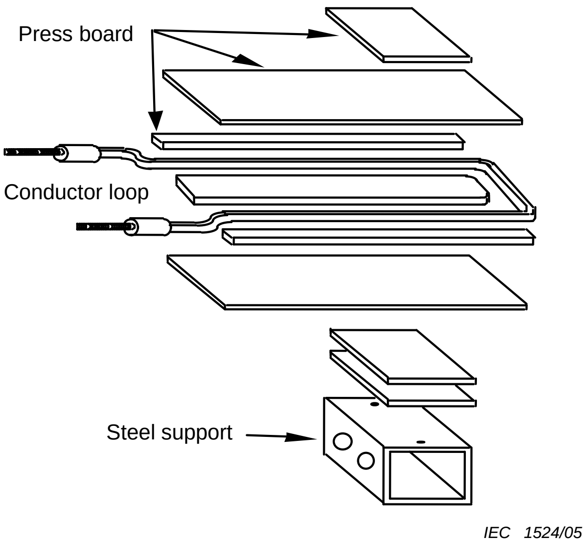

Figure 2 – Example of an insulation package for a transformer winding

The conductor terminals, which pass through the end-plate, shall be brazed to the conductor and fixed in the end-plate.

The conductor shall be insulated as required by the volume ratios determined from 5.2. As an example experience has shown that using pre-cut tensile strips of the width of the bare conductor is the best way to evaluate conductor insulation. The bare conductor should be wrapped with conductor insulation, tensile strips added and then the whole assembly be again wrapped with conductor insulation to keep the test strips as close to the conductor loop as possible.

A suitable device shall be used for temperature measurement and control. The location on the conductor loop where the tensile strips are located should be as close to the thermocouple which is monitoring/controlling the conductor temperature as possible. In this way these test strips are at the correct temperature for the thermal evaluation method.

NOTE 1 Two type K (chromel–alumel) thermocouples or a resistance temperature detector (RTD could be installed securely on the surface of the conductor for temperature measurement and control. Additional thermocouples may be included.

NOTE 2 Thermocouples containing iron present a potential oxidation problem.

The conductor assembly shall have a thermal barrier to establish a temperature gradient between the conductor and the liquid. The material for the thermal barrier shall be one of the EIM used in the test object. Pressboards are usually employed as mechanical electrical support for conductors in the electrotechnical product being simulated. Thermal barriers shall be secured to the conductor assembly by means of an inert tie.

5.3.3 Liquid component

The cell shall be filled with the liquid component used in the electrotechnical product being evaluated. The volume of the liquid shall be determined from requirements in 5.2 based on volume and temperature calculations.

A suitable device for temperature measurement shall be installed within the liquid volume for temperature measurement and another for temperature control. One is located near the liquid surface at room temperature. The second is located near the centre of the liquid volume. For example, for power transformers, the thermocouple located near the surface is used for controlling liquid temperature.

5.3.4 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 and enclosure material. Insulation barriers of bulk pressboard are provided with holes to allow oil flow which simulates the electrotechnical product being evaluated. The oil flow is shown in Figure 1 by the dashed line and arrow pattern. The relative volumes of these components should match those of the evaluated product, with the exception of magnetic core steel and enclosure material. The relative quantity of magnetic core steel and enclosure material shall be determined, based on the surface area exposed to the liquid component. An example is given in Annex A.

6 Test procedures

6.1 General

A three-temperature ageing test shall be completed to establish the thermal rating of the new system. A reference EIS shall be used to validate the testing of the candidate EIS. Unless otherwise stipulated by the equipment TC, the reference system shall be cellulose solid insulation and mineral oil.

6.2 Preparation of the test objects

6.2.1 General

The quantity of samples of solid and liquid insulation should be sufficient to supply all reference and candidate test objects and requirements for diagnostic testing.

All solid samples shall be pre-conditioned by drying. For optimum drying conditions, refer to the relevant material testing standards.

Immediately after drying, the conductor assembly and other materials shall be vacuum-impregnated with the liquid under evaluation. The impregnation process is conducted for 6 h to 24 h, at 70 °C to 90 °C.

Prior to inserting the test objects into the ageing cell, remove the pre-conditioned solid and liquid diagnostic test samples.

A clean, dry ageing cell is then filled with the previously determined volume of liquid and the impregnated test object is inserted. The cell is quickly sealed then purged with dry sealing gas.

Following its assembly, the ageing cell is placed into a test rack. All power, control, monitoring and grounding circuits as well as the sealing gas supply line shall be connected. With power on, the pressure within the cell is monitored while the internal elements are being heated. Excess pressure is bled off until the cell reaches its ageing temperatures.

6.2.2 Reference test object

The reference EIS shall be composed of solid materials and liquid that have an established performance in combination. At the time of issue of this technical specification, the only established reference EIS is composed of cellulose solid materials and mineral oil. The EIS ATE of this reference system is recognized to be 105 °C. However, if the equipment TC has established another EIS with known performance, this may be used as the reference EIS. The equipment TC should provide specific details.

For verification of reference EIS ageing, a single set of three test objects composed of the reference EIS shall be evaluated along with the candidate test objects. For the cellulose and mineral oil system, the ageing temperatures shall be as follows:

- conductor with kraft cellulose insulation: 160 °C;
- mineral oil according to IEC 60296: 115 °C.

NOTE 1 If other solid or liquid insulating (e.g biogenic oils or synthetic oils) materials are used corresponding standards should be used.

Experience has shown that, at these temperatures, 50 % of the original tensile strength of the solid insulation will be reached in 1 000 h.

NOTE 2 In the event that the 50 % value has not been reached within 1000 h, a second set of three test objects should be aged at an increased cycle time based upon evaluation of the test results.

6.2.3 Candidate test object

Three sets of three ageing cells each (nine cells) shall be used for the candidate system for each test temperature, in order to determine the half-life of the system at the pre-selected temperatures (a total of 27 test cells).

The physical shape, size and construction of the reference and candidate test object shall be similar**,** with one or more of the solid materials and/or liquid replaced with the candidate materials to be evaluated.

6.3 Diagnostic tests

6.3.1 General

Samples of both the solid insulation and the liquid insulation shall be tested prior to start-up and after shutdown of each cell. Electrical and physical properties of the solid insulation and the liquid shall be measured. Changes between the initial and final states shall be used to determine the amount of degradation occurring during the testing cycle. Results of the initial moisture content measurements shall be used to determine whether or not the materials are adequately dried prior to start-up.

6.3.2 Solid insulation

At start-up, the solid insulation samples pre-conditioned according to 6.2 shall be tested using one or more diagnostic tests to be chosen by the equipment TC to determine end of life. Additional tests may be used for monitoring purposes. Examples of typical diagnostic tests for cellulosic materials are as follows:

Characteristics	*Test specification*
Moisture content:	IEC 60554-2 (ISO 287)
Dielectric strength in oil:	IEC 60243-1
Tan δ and permittivity ε in oil:	IEC 60250
Tensile strength:	IEC 60554-2 (ISO 1924)
Compression strength:	IEC 60763-2
Degree of polymerization (cellulose):	IEC 60450

NOTE For solid insulation which includes enamel coated wires, most of the above test methods are not appropriate. In such cases, the key characteristic to monitor for the enamel coated wires is the dielectric strength retention. There has only been limited experience using such coated wires with this test method.

6.3.3 Liquid insulation

At start-up, the liquid insulation pre-conditioned according to 6.2 shall be tested using one or more diagnostic tests to be chosen by the equipment technical committee to determine end of life. Additional tests may be used for monitoring purposes. Examples of typical diagnostic test for liquids are as follows:

Characteristic	*Test specification*
Colour and appearance:	ISO 2049
Breakdown voltage:	IEC 60156
Interfacial tension:	ASTM D971
Acidity:	IEC 62021-1
Dielectric dissipation factor (DDF) at 90 °C	IEC 60247 or IEC 61620
Water content :	IEC 60814
Dissolved gas :	IEC 60567 and IEC 60599
2-furfural content :	IEC 61198

6.4 Thermal ageing

6.4.1 Recommended solid-component ageing temperatures

Select the ageing temperatures for conductor temperature control, based on the expected thermal class in Table 1 below. The four ageing period durations are defined for each ageing temperature.

Table 1 – Recommended ageing temperatures and periods for expected thermal class

Duration of ageing period h	**Expected thermal class**							
	90 °C	**105** °C	**120** °C	**130** °C	**155** °C	**180** °C	**200** °C	**220** °C
6 000/12 000/18 000/24 000	110	125	140	150	175	200	220	240
2 000/4 000/6 000/8 000	125	140	155	165	190	215	235	255
500/10 00/1 500/2 000	140	160	170	180	205	230	250	270

6.4.2 Recommended liquid ageing temperatures

Liquid ageing temperature should be at least 10 K above the highest acceptable operating temperature for the equipment being modelled. However, it shall not exceed a temperature at least 10 K below the flash-point of the liquid. If, for reasons of risk, the former temperature cannot be attained, then the best safe temperature should be used. For mineral oil, a liquid ageing temperature of 115 °C has been successfully demonstrated.

6.4.3 Reference EIS ageing temperatures

For the purposes of this technical specification, the selected reference EIS is stated as Kraft cellulose paper and mineral oil, for use in power transformers, and shall be aged according to 6.2.2, i.e:

– conductor with Kraft cellulose insulation: 160 °C

– mineral oil per IEC 60296: 115 °C

Additional equipment reference test objects shall be determined as a result of the complete test.

Age the three reference test cells under the above-established times and temperatures. Remove and evaluate samples of the liquid and solid materials for diagnostic testing.

6.4.4 Ageing procedures of the candidate EIS

Age the nine candidate test cells according to Table 1 of 6.4.1.

Ageing times of the candidate test cells shall be selected in a way that provides a larger statistical sampling at the end-points, i.e. one cell tested at the first ageing period, two cells tested at the second ageing period, and three cells each tested at the third and fourth ageing periods. The third and fourth ageing periods may be adjusted based on the data obtained from the first two points.

At the end of each period, remove and evaluate samples of the liquid and solid materials for diagnostic testing. A judgement shall be made relative to the condition and volume of liquid remaining in each cell. The test data shall be recorded.

6.5 End-point testing

The diagnostic test of the solid and liquid samples shall be selected according to 6.3, for example, from among the following:

- tensile strength;
- compression strength;
- degree of polymerization;
- solid dielectric strength;
- dielectric strength of enamel coated wires;
- oil acidity:
- interfacial tension

The end-point criteria may be established for each diagnostic test, with suitable justification as reported in Clause 7.

7 Analysis of data

7.1 End-point criteria

7.1.1 General

The criteria by which a test object is considered to have failed shall be fully defined prior to the start of the test. An adequate test shall be included in the test period to detect when a failure occurs, denoting end-of life for each test object. The use of more than one end-point criterion will tend to make interpretation of the test results more difficult. It is recommended that only one end-point criterion be used for each component in the test object (solid/liquid). The equipment TC for the EIS being modelled shall define the specific end-point criterion.

7.1.2 End-of-life of the liquid component

The relevant equipment TC shall select the accepted end-point criteria. In the case of mineral oil, the values to be considered are those pointed out in IEC 60422, according to the category of equipment considered.

NOTE 1 There has been limited experience in using liquid testing as an end-point criteria using this technical specification.

NOTE 2 This is not valid with an electrical breakdown or a dissipation factor because a new non-degraded oil can have a low electrical breakdown and a high dissipation factor.

7.1.3 End-of-life of the solid component

The preferred end-point criterion for the solid insulation shall be degradation to 50 % of the original value of the selected mechanical property 6.5 or the corresponding DP value in case of paper. Other choices for end-point criterion are described in Table 1 of IEC 60216-2:2005.

NOTE 1 This is not valid for other materials e.g enamel coated wires, where the end of life criteria is 80% retention of dielectric strength. As there is limited experience with this method and enamel coated wires, this number may be conservative, and with experience may be changed to a different number.

The total number of hours to end-of-life shall be recorded for the solid component in the test object at each ageing temperature. The life (in hours) at each ageing temperature shall be calculated according to IEC 60216-3.

NOTE 2 There is no estimate required for the average life of the liquid.

7.1.4 Extrapolation of data

Linear regression analysis on the solid component data shall be carried out in accordance with IEC 60216-5. (Interpretation of the analysis will be included according to IEC 60505.)

7.2 Report

The report shall include all records, relevant details of the test, and analysis, including

- reference to this technical specification,
- description of the EIS tested (reference and candidate EIS),
- ageing temperatures and ageing periods of each EIS,
- sealing method used for evaluation,
- diagnostic tests and end-point criterion used for each EIS,
- detailed description of the test objects (including volumetric ratios),
- number of test objects at each temperature for each EIS,
- individual times to end-of-life for each component,
- mean log times to end-of-life for each ageing temperature, for each EIS.

Multiple point ageing tests shall also include

- regression line with log mean points, for the solid component,
- regression equation and coefficient of correlation for the solid component,
- EIS ATE and/or thermal class of the reference EIS solid component,
- EIS RTE and assigned thermal class of the candidate EIS solid component.

Annex A
(informative)

Component volume ratio spreadsheet example

A spreadsheet can be used for the calculation of component amounts (volume, area) on the basis of the ageing cell dimensions and the type and design of the EIS to be tested. The calculations allow the determination of the volume ratios of the materials in the model which would simulate the active (for example conductor and magnetic core) and non-active (structural boards and the EIM as part of the EIS) parts of the equipment being modelled. The following is an example of spreadsheet output information available for the ageing of an EIS for a power transformer.

- Volume of hot insulation
  - Insulation on the conductor
  - Hot pressboard (spacers)
  - Hot insulation other than on the conductor wrap
- Volume of low temperature insulation (in cool liquid areas)
  - Low temperature (bulk) pressboard
  - Additional samples for material balance
- Area of magnetic core steel

Table A.1 shows examples of component volume ratio calculations

Table A.1 – Examples of component volume ratio calculations

Component (ratio)	Materials (units)	Reference transformer	Reference model (cellulose)	Candidate model (hybrid)
A	Hot insulation volume (cm^3)	269 000	155	165
B	Low temperature insulation volume (cm^3)	683 000	373	373
C	Mineral oil volume (cm^3)	8 325 000	3270	3270
D	Core surface area (cm^2)	128 000	69,7	69,7
(B/A)	Low temperature insulation/hot insulation	2,54	2,41	2,26
(B/C)	Low temperature insulation/liquid	0,082	0,114	0,114
(A/C)	Hot insulation/liquid	0,032	0,048	0,050
(B/D)	Low temperature insulation/core area	5,34	5,36	5,36

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

3, rue de Varembé
PO Box 131
CH-1211 Geneva 20
Switzerland

Tel: + 41 22 919 02 11
Fax: + 41 22 919 03 00
info@iec.ch
www.iec.ch