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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



112/427/CD

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IEC TC 112 : EVALUATION AND QUALIFICATION OF ELECTRICAL INSULATING MATERIALS AND SYSTEMS

SECRETARIAT:

Germany

SECRETARY:

Mr Bernd Komanschek

OF INTEREST TO THE FOLLOWING COMMITTEES:

TC 2, TC 14, TC 23, TC 42, TC 55, TC 96

PROPOSED HORIZONTAL STANDARD:

☐

Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.

FUNCTIONS CONCERNED:

☐ EMC

☐ ENVIRONMENT

☐ QUALITY ASSURANCE

☐ SAFETY

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TITLE:

Electrical insulation systems - Procedures for thermal evaluation - Part 41: Specific requirements for electrical insulation systems for use in dry-type high-voltage transformers with operating voltages of 1kV and above

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**ELECTRICAL INSULATION SYSTEMS - PROCEDURES FOR THERMAL
EVALUATION****Part 41: Specific requirements for electrical insulation systems for use in
dry-type high-voltage transformers with operating voltages of 1kV and
above**

FOREWORD

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International Standard IEC 61857-41 has been prepared by IEC technical committee TC-112.

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

FDIS	Report on voting
XX/XX/FDIS	XX/XX/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.

142 This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

143 The committee has decided that the contents of this publication will remain unchanged until the
144 stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to
145 the specific publication. At this date, the publication will be

- 146 • reconfirmed,
- 147 • withdrawn,
- 148 • replaced by a revised edition, or
- 149 • amended.

150

151 The National Committees are requested to note that for this publication the stability date is 2021.

152 THIS TEXT IS INCLUDED FOR THE INFORMATION OF THE NATIONAL COMMITTEES AND WILL BE DELETED AT
153 THE PUBLICATION STAGE.

154

155

INTRODUCTION

156 This document is for the evaluation of electrical insulation systems [EIS] to be used in
157 transformers with an operating voltage above 1 kV. The approach is to evaluate the EIS using
158 the concept of voltage stress level values [kV/mm]. The test is designed to establish the
159 thermal classification of the EIS.

160

161 The performance of any transformer designed and constructed using the EIS established in
162 accordance with this document shall be evaluated in accordance with the application
163 requirements set by the appropriate IEC Technical Committee.

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**ELECTRICAL INSULATION SYSTEMS-PROCEDURES FOR THERMAL
EVALUATION –****Part 41: Specific requirements for electrical insulation systems for use in
dry-type high-voltage transformers with operating voltages of 1kV and
above****1 Scope**

This document describes the test procedure for the thermal evaluation of an electrical insulation system [EIS] for use in dry-type, cast-coil and resin encapsulated transformers operating at voltages of 1kV and above.

This Standard is intended to evaluate the EIS to be used for a range of transformers constructed using a single EIS with insulation thickness being adjusted to maintain the Voltage Stress Level [VSL] at or below the tested values of the established EIS.

The performance of any transformer designed and constructed using the EIS established in accordance with this document shall be evaluated in accordance with the application requirements set by the appropriate IEC Technical Committee.

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 60076-11, Power transformers - Part 11: Dry-type transformers

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

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

IEC 60493-1, Guide for the statistical analysis of ageing test data - Part 1: Methods based on mean values of normally distributed test results

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

IEEE C57.12.58-1991 - IEEE Guide for Conducting a Transient Voltage Analysis of a Dry-Type Transformer Coil

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60505 and IEC 61857-1, as well as the following definitions, apply.

203 **3.1 Electrical stress path**

204 Any possible pathway for an electrical failure within any transformer designed and constructed
205 using the EIS.

206 **3.2 Family of coils**

207 All production coils based on the same EIS for the selection of the materials to be used in
208 construction.

209 NOTE: A family can cover a wide range of operating voltages with each possible arcing path constructed to function at
210 or below the Voltage Stress Level [VSL] evaluated.

211 **3.3 Total insulation**

212 Total group of materials in a fully functional transformer represented by the EIS.

213 NOTE: This includes any air-gap that is part of the design. The test coil is to have the same, or smaller, air-gap
214 included during the application of electrical stresses in which the air-gap is part of the total insulation path.

215 **3.4 Voltage stress level [VSL]**

216 Value of the maximum voltage at a measured location divided by the total insulation thickness at
217 that measured location (expressed in kV/mm).

218 **3.5 Dry type transformers**

219 Transformers of which the magnetic circuit and windings are not immersed in an insulating liquid.
220

221 **3.6 Cast coil transformers**

222 Transformers with vacuum casted coils. Coils fully impregnated with an epoxy resin.

223 **3.7 Resin encapsulated transformers**

224 Coils are covered (encapsulated) by a resin, e.g., Epoxy resin.

225 **3.8 Transformer coil family**

226 Entire range of production models constructed with the same EIS (same group of materials).

227 **3.9 Condensation chamber**

228 A device designed to provide an atmosphere of high relative humidity (above 95%) at 5 K to 10 K
229 above room temperature, with the test cells placed on a rack which is cooled at 5 K to 10 K
230 below room temperature, to produce surface moisture (visible condensation).

231

4 General information

4.1 Thermal classification

4.1.1 Evaluation performed as a Thermal Index [TI]

This part of the 61857 series can be performed without the inclusion of a reference EIS. When performed without a reference EIS, the value assigned is a thermal index [TI] value.

The thermal index value assigned is determined by establishing the decomposition pattern of the test data developed at the elevated ageing temperatures and projecting that pattern out to a pre-selected correlation time coordinate of 40 000 hours. The use of a pre-selected correlation time is not by itself an indication of any possible expected operating life of any transformer designed and constructed using the EIS. The correlation time is used for the purpose of uniform assignment of the thermal classification of the candidate EIS.

4.1.2 Evaluation performed as a Relative Thermal Index [RTI]

This part of the 61857 series can be performed with the inclusion of a reference EIS. When performed with a reference EIS, the value assigned is a relative thermal index [RTI] value.

Whenever using a reference EIS testing will be conducted using the same methods for both reference and candidate EIS.

The relative thermal index value assigned is determined by establishing the decomposition pattern of the test data developed at the elevated ageing temperatures and comparing the results to the decomposition pattern of the reference EIS. When used to establish a RTI value, the reference EIS shall be the present EIS used by the individual manufacturing company.

4.2 Methodology

This test is designed to evaluate the performance of the EIS using voltage stress levels [VSL] that may occur with any winding method or technique. The evaluation and the established VSL values are then usable for any winding technique where the voltage stress levels are at or below the values evaluated in the specific EIS.

The evaluation follows the structure in IEC 61857-1 with test coils being transformer coils or representative coils; refer to clause 5.1. Representative coils shall be constructed with the same materials and using the same processes as used in the construction of transformer coils. The decision to use representative coils is based on the expectation that the coils will be smaller in size and lighter in weight.

This test procedure follows similar protocols of other test methods within the IEC 61857 series where the test coils are subjected to initial screening tests followed by repeated thermal endurance cycles consisting of sub-cycles in the following order:

- a) a thermal ageing sub-cycle (Clause 4.3);
- b) a sub-cycle of pre-diagnostic cold shock (Clause 4.4) and humidification (Clause 4.5), in that order;
- c) dielectric diagnostic testing (Clause 4.6).

4.3 Thermal ageing

The information and table in IEC 61857-1 clause 6 relate to the selection of ageing temperatures which are based on a correlation time in the range of 20 000 hours. This part of the 61857 series uses 40 000 hours as the correlation time. The selection of ageing temperatures shall consider the adjustment to the higher correlation time, usually implying an increase of the ageing temperatures of 6 K -10 K. As with IEC 61857-1, this part requires that the ageing program must

use at least three ageing temperatures, with each temperature separated by at least 10 K from each of the other ageing temperatures. Additionally, as stated in 61857-1, the highest ageing temperature shall result in a minimum log mean test life of 100 hours. Clause 11 discusses the minimum log mean test life requirements for the lowest ageing temperature.

Note: Annex B provides examples of ageing programs where more than three ageing temperatures would be required.

This typical adjustment based on common ageing patterns illustrated in 61857-1 shall be combined with the results of the thermal exposure portion of the screening test in clause 9 of this part. When the range of possible ageing temperatures indicate the general pattern from 61857-1 can be adjusted within the possible range of ageing temperatures the length of time needed for completion of the full thermal ageing is expected to fit within the expectation for completion within approximately 5 000 hours. If the range of possible ageing temperatures restricts the upward shift of ageing temperatures the length of time needed for completion must be expected to increase.

Because of the longer correlation time, and the need to provide more options depending on the output of the thermal screening test, Table 1 provides options for selecting the appropriate times and temperatures for conducting this ageing. It should also be noted that 61857-1 suggests that the ageing temperatures and ageing periods selected should be chosen to reach the anticipated average test life in 5 to 10 test cycles for each set of test objects. For this part, a valid test result requires at least one successful test cycle with subsequent test cycles being of approximately equivalent lengths. If no failures have occurred after 4 test cycles, the ageing cycle time may be doubled. If any failures occur prior to the completion of the third test cycle, the ageing cycle time shall be reduced in half.

Table 1 – Suggested ageing temperatures and ageing periods

Ageing period per cycle	Ageing temperature for EIS with anticipated thermal class of °C (assuming 40 000 hours correlation time)								
	90	105	120	130	155	180	200	220	250
504 to 840 hours	120	135	150	160	185	210	230	250	280
336 to 504 hours	130	145	160	170	195	220	240	260	290
168 to 336 hours	140	155	170	180	205	230	250	270	300
72 to 168 hours	150	165	180	190	215	240	260	280	310
24 to 72 hours	160	175	190	200	225	250	270	290	320

4.4 Cold exposure

The cold exposure is to help initiate condensation on the surface of the coils. The condensation is part of the conditioning to help with the diagnostics of the insulation.

As part of the conditioning, after each thermal ageing cycle, the test coil is allowed to cool to standard laboratory conditions. Once the surface of the test coil has reached $-25\text{ °C} \pm 5\text{ K}$ the test coil is held at this temperature for 1 hour ± 10 minutes. The surface temperature of the test coil is measured by thermocouples placed in direct contact with the surface of the coil.

Within 10 minutes of removal from the cold exposure, each test coil is placed into a condensation chamber.

4.5 Humidification

Each test coil is placed into the condensation chamber for a minimum of 40 hours, after which visible condensation should still be present

4.6 Dielectric Tests

4.6.1 General

Dielectric testing of the test coils is the method which is used as the diagnostic tool for establishing failure. This clause describes how to conduct the dielectric tests of the test coils. Clause 6 describes how the voltage used in initial diagnostic tests are calculated and Clause 9 describes the pretesting suitability test as well as the dielectric screening test to determine the voltage range to be considering during the ageing phase of the test program. Clause 10 describes the use of dielectric tests during the ageing program.

In this standard there are two dielectric tests that are used for the testing of the test coils. These two methods are operating voltage test (4.6.2) and impulse dielectric test (4.6.3). The operating voltage test is required for all EIS intended for coils operating at 1 kV and above. Both diagnostic tests are required for EIS intended for coils operating at 2,5 kV and above. The latter implies a BIL of 10kV and above. When both diagnostic tests are to be used, the operating voltage test should be conducted first.

There are six potential electrical stress paths in test coils. The test coils will not likely contain all six of these paths. The order of dielectric testing should be as follows eliminating the paths not present in the test coil:

- 1) Turn-to-turn
- 2) Layer-to-layer
- 3) Disk-to-disk
- 4) Section-to-section
- 5) Coil-to-coil
- 6) Coil-to-ground

4.6.2 Operating Voltage Test

In most cases (with the exception of the initial stage of the dielectric screening test in Clause 9.4), the test coils will be subjected to the conditioning cycles described in Clauses 4.4 and 4.5 prior to this test.

Following the conditioning cycle, the test coils are individually removed from the condensation chamber and subjected to a dielectric diagnostic test within 45 minutes of removal. The test voltage for each electrical stress path is held for 60 sec $\pm$ 5 sec.

Industry experience has shown that a current flow in excess of 50 mA is useful in detecting failure. Failure can also be determined by visible arcing. The life of each test coil is based on the first failure in any electrical stress path within that test coil. The test is successful if no collapse of the test voltage occurs.

4.6.3 Impulse Dielectric Test

In the case of the impulse dielectric test, if the test coil is not a working transformer, as with the testing described in 4.6.2, the impulse voltage is applied along each electrical stress path in the sequence outlined in 4.6.1. Apply the appropriate voltage following the agreed upon method such as IEC 60076-11 clause 21 (1.2 μ s $\pm$ 30% / 50 μ s $\pm$ 20% negative impulse wave) or IEEE C57.12.91. Since we are only using this test as a diagnostic tool, only a single test would be required, with the voltage level determined in Clause 6.3 and Clause 9.