

Evaluation and qualification of electrical insulation systems

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National foreword

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Summary of pages

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(CEI 60505:1999)

Bewertung und Kennzeichnung
von elektrischen Isoliersystemen
(IEC 60505:1999)

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 98/85/FDIS, future edition 2 of IEC 60505, prepared by IEC TC 98, Electrical insulation systems (EIS), was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60505 on 2000-01-01.

The following dates were fixed:

- latest date by which the EN has to be implemented
at national level by publication of an identical
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- latest date by which the national standards conflicting
with the EN have to be withdrawn (dow) 2003-01-01

Annexes designated "normative" are part of the body of the standard.

Annexes designated "informative" are given for information only.

In this standard, annex ZA is normative and annexes A and B are informative.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60505:1999 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated:

IEC 60085 NOTE: Harmonized as HD 566 S1:1990 (not modified).

CONTENTS

	Page
INTRODUCTION	4
1 Scope	5
2 Normative references	5
3 Terms and definitions	6
3.1 General terms	6
3.2 Terms related to service stresses and ageing	6
3.3 Terms related to testing	8
4 Ageing – General	9
5 Preparation of evaluation methods	12
5.1 Elements for preparing an evaluation method	12
5.2 Validity of existing evaluation methods	13
6 Functional evaluation methods to qualify EIS	13
6.1 General considerations	13
6.2 Types of evaluation procedures	13
6.3 Practical considerations	15
7 Functional ageing tests	17
7.1 Test objects	17
7.2 Test conditions	18
7.3 Determination of EIS service life	18
8 Ageing	19
8.1 General	19
8.2 Assessment of ageing mechanisms	19
8.3 Accelerated ageing	20
8.4 Stress levels	23
8.5 Duration and number of subcycles	23
8.6 Ageing subcycle	23
9 Prediagnostic conditioning	24
10 Diagnostics	24
10.1 Diagnostic tests – End point criteria	24
10.2 Additional specific tests	24
11 Analysing the data	25
11.1 General	25
11.2 Operating experience	25
11.3 Electrical	25
11.4 Thermal	25
11.5 Mechanical	25
11.6 Environmental	25
11.7 Multifactor	25
12 Test report	26
13 EIS coding	26
Annex A (informative) Checklists	27
Annex B (informative) Flow charts	30
Annex ZA (normative) Normative references to international publications with their corresponding European publications	39
Bibliography	

INTRODUCTION

The service life of electrical equipment is frequently determined by the life of its electrical insulation system(s) (EIS). The life of an EIS can be affected by electrical, thermal, mechanical, or environmental stresses acting either individually or in combination.

Intended, estimated or proven service life times are essential parameters for describing the life of electrical insulation systems. In the early days of electrotechnical engineering life figures were rather vague. The limitation of the life of the insulation under thermal stress was one of the first indicators of the effect of ageing in some equipment in service. As experience in using insulation systems increased, it was appreciated that there was a need to select specific materials that were amenable for use in manufacturing processes, to enable the required service life to be achieved and to allow for the calculation of the thermal capability of equipment.

IEC 60085 standardized a number of maximum temperature values and presented a list of insulating materials related to these temperatures (classes) which, when used for insulation systems, would "ensure an economical life for the insulation in a wide range of apparatus".

This was a clearly defined attempt to qualify insulation systems on the basis of (service) experience or tests and a quantification of an insulation system life in terms of time. The limitation of this approach, based entirely on thermal stressing, was recognized and there was a demand for an improved life concept. This requirement and the impossibility of using the material tables in IEC 60085 at a time when many new, synthetic materials were being produced which did not fit neatly into the existing thermal classification, led to a worldwide effort to improve the situation. This led to the elaboration of the present standard, which serves as a guide to IEC technical committees responsible for equipment (ETC) to enable them to develop adequate standards and technical documents.

To determine the intended life is a fundamental task when developing and designing an EIS. Estimated service life of an EIS has to be established for several reasons:

- for type testing when introducing a new EIS into production;
- for quality assurance of production; and
- for estimating the remaining life for maintenance purposes.

EVALUATION AND QUALIFICATION OF ELECTRICAL INSULATION SYSTEMS

1 Scope

This International Standard establishes the basis for estimating the ageing of electrical insulation systems (EIS) under conditions of either electrical, thermal, mechanical, environmental or multifactor stresses.

It specifies the principles and procedures that should be followed, during the development of EIS functional test and evaluation procedures, to establish the service life for a specific insulation system.

This standard is applicable to all IEC technical committees responsible for equipment (ETC) having an EIS.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this international standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However parties to agreements based on this international standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of the IEC and the ISO maintain registers of currently valid International Standards.

IEC 60216: (all parts), *Determination of thermal endurance of solid organic materials*

IEC 60216-3:—, *Determination of thermal endurance of solid organic materials – Part 3: Instructions for calculating thermal endurance characteristics*¹⁾

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 60727-1: *Evaluation of electrical endurance of electrical insulation systems – Part 1: General considerations and evaluation procedures based on normal distributions*

IEC 60727-2: *Evaluation of electrical endurance of electrical insulation systems – Part 2: Evaluation procedures based on extreme-value distributions*

IEC 61356: *Functional evaluation of electrical insulation systems – Principles for test procedures when comparative testing is not feasible*

¹⁾ To be published.

3 Terms and definitions

For the purpose of this International Standard, the following terms and definitions apply:

3.1 General terms

3.1.1

electrical insulation system (EIS)

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

3.1.2

electrical insulating material (EIM)

electrically stressed component in an EIS

3.1.3

reference EIS

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

3.1.4

candidate EIS

EIS under evaluation to determine its service capability (electrical, thermal, mechanical, environmental or multifactor)

3.1.5

intended life

design life of an EIS under service conditions

3.1.6

estimated life

expected service life derived from either service experience or the results of tests performed in accordance with appropriate evaluation procedures, or both, as established by the responsible organisation or technical committee

3.1.7

evaluation

establishment of relationships between service requirements and life data obtained from service experience analysis or from the results of functional tests

3.2 Terms related to service stresses and ageing

3.2.1

"ageing" stress

action of electrical, thermal, mechanical or environmental nature on an EIS which may cause property changes

3.2.2

factor of influence

stress imposed by conditions of operation, environment or test that affects the life of an EIS

3.2.3**service conditions**

combination of factors of influence and duty that are to be expected in a specific application of an electrical device

3.2.4**reference operating conditions**

service conditions of the equipment to which the test conditions of the functional test procedure are related

3.2.5**service requirements**

specified factors of influence, intended performance and duty of an electrical device

3.2.6**service experience**

the quantitative and/or qualitative record during service, with or without failure of an EIS

3.2.7**ageing**

irreversible changes of the properties of an EIS due to action by one or more factors of influence

NOTE Some changes (e.g. hydrolytic changes) can be partly reversible if the ambient conditions change.

3.2.8**ageing factor**

a factor of influence that causes ageing

3.2.9**intrinsic ageing**

irreversible changes of fundamental properties of an EIS caused by the action of ageing factors

3.2.10**extrinsic ageing**

effect of irreversible changes of EIS properties produced by action of ageing factors on unintentionally introduced imperfections in an EIS

3.2.11**interaction**

modifications of the type or degree of ageing produced by the combination of two or more factors of influence relative to their ageing effect if acting individually on separate objects

3.2.12**direct interaction**

interaction between simultaneously applied factors of influence that differs from that occurring with sequentially applied factors of influence

NOTE All factors producing direct interaction are not necessarily ageing factors.

3.2.13**indirect interaction**

interaction which occurs between simultaneously applied factors of influence, which remains unchanged when the factors are applied sequentially

3.3 Terms related to testing

3.3.1

functional test

procedure to obtain information about the suitability of an EIS under specified conditions

3.3.2

test object

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

3.3.3

accelerated ageing

result of an increase in the level and/or frequency of application of the factors of influence beyond normal service conditions

3.3.4

accelerated test

functional test applying accelerated ageing to shorten testing time

3.3.5

prediagnostic conditioning

application of a variable or fixed stress, which is applied to an EIS prior to diagnostic testing

3.3.6

diagnostic factor

variable or fixed stress which is applied to an EIS to establish the degree of ageing

3.3.7

diagnostic test

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

3.3.8

end-point criterion

selected value of either a property or change of property that defines the end-of-EIS life in a functional test

3.3.9

"test" cycle

a time span for periodical, repetitive application of one or more factors of influence, either sequentially or simultaneously, and of diagnostic factors, to an EIS

3.3.10

subcycle

defined segments of the whole cycle for the application of factors of influence and diagnostic factors

3.3.11

monitoring test

continuous application and measurement of a specified level of a diagnostic factor to a test specimen to determine ageing

4 Ageing – General

Ageing is defined as the irreversible changes of the properties of an EIS due to action by one or more factors of influence. Ageing stresses may cause either intrinsic or extrinsic ageing. In most EIS extrinsic ageing predominates because, in practice, they include some imperfections and contaminants. A schematic representation of the basic process is shown in Figure 1.

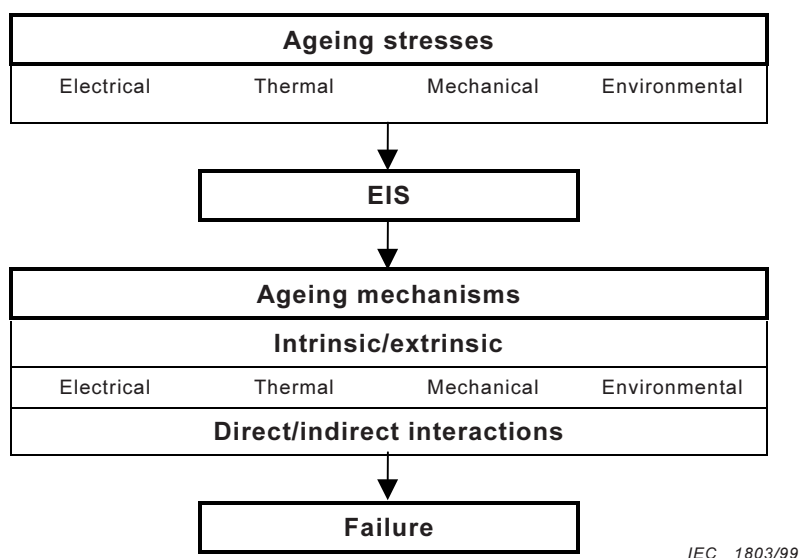


Figure 1 – Ageing of an EIS

The type and level of contamination and/or the extent of imperfections in an EIS will, in many types of electrical apparatus, significantly affect the service performance. In general, the fewer and less severe the contaminant and/or defects in the EIS, the better the performance of the equipment. To avoid obtaining misleading results from functional tests, a candidate EIS should contain, as far as practicable, the full range of contaminants and/or defects expected when the actual system is used in service.

The ageing factors produce electrical, thermal, mechanical or environmental ageing mechanisms that eventually lead to failure. During ageing, applied stresses which initially cannot affect the EIS can become ageing factors and, as a result, modify the rate of degradation.

When ageing is dominated by one ageing factor, this is referred to as single-factor ageing. Multifactor ageing occurs when more than one ageing factor substantially affects the performance of the EIS. Ageing factors can act synergistically, that is, there can be direct interactions between the stresses. Interactions may be either positive or negative.

The ageing of a practical EIS can be complex and failure is usually caused by a combination of ageing mechanisms even though there can be only one dominant ageing factor as, for example, in single-factor ageing.

Where experience or existing knowledge of how a specific EIS will perform in service is limited, the Equipment Technical Committee (ETC) shall decide whether single or multifactor test procedures are appropriate for their specific equipment or apparatus.

In functional evaluation tests, ideally duplication of all the ageing mechanisms that occur in service should be included. In practice, this is often difficult to achieve, as the conditions when a particular ageing mechanism is operative cannot be completely known or understood. Several ageing mechanisms may occur either simultaneously or in sequence.

For example, assume that an EIS is subjected to electrical (E), thermal (T), mechanical (M) and environmental (A) stresses as shown in Figure 2. Initially, during step A, electrical ageing occurs which causes an increase in the dielectric losses and results in one or more localized temperature increases in the insulation. In these higher temperature regions, environmental and thermal stresses become ageing factors and accelerate chemical changes in the insulation (step B). The chemical changes can then act to increase or decrease the total ageing rate; an example is shown in Figure 3. When the mechanical properties of the affected insulation have deteriorated to critical levels that depend on the mechanical stresses, local cracks are initiated (step C). Subsequently, when these cracks reach a critical size, partial discharges will occur and eventually lead to complete failure (step D). Thus the ageing, shown in Figure 3, is not linear with time.

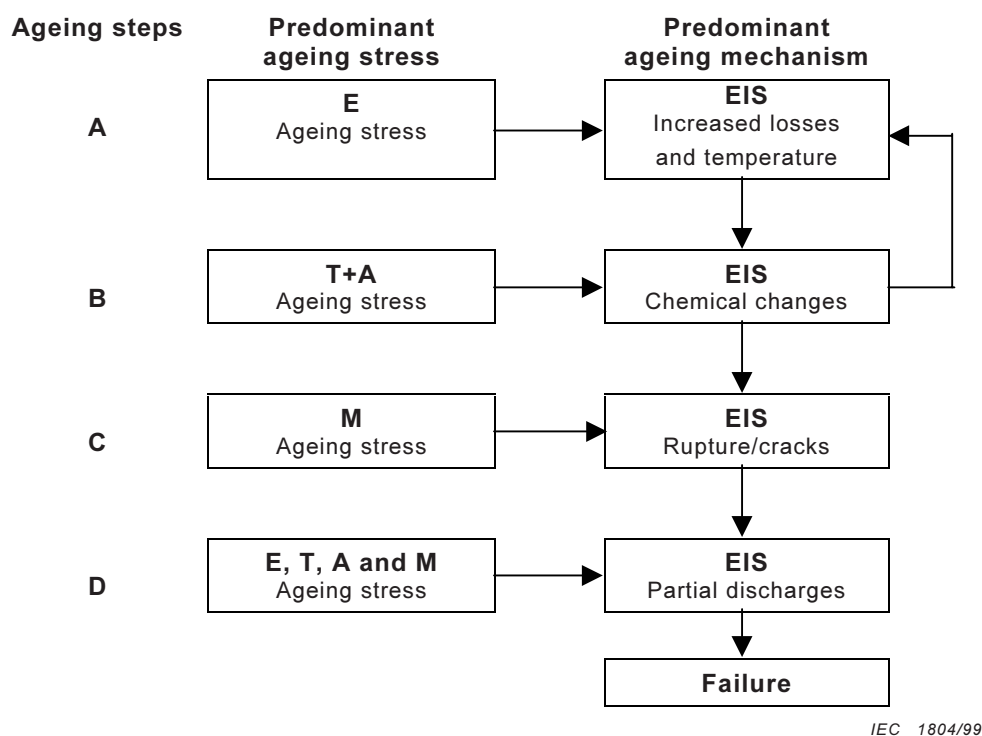


Figure 2 – Example of possible ageing mechanisms as a function of time

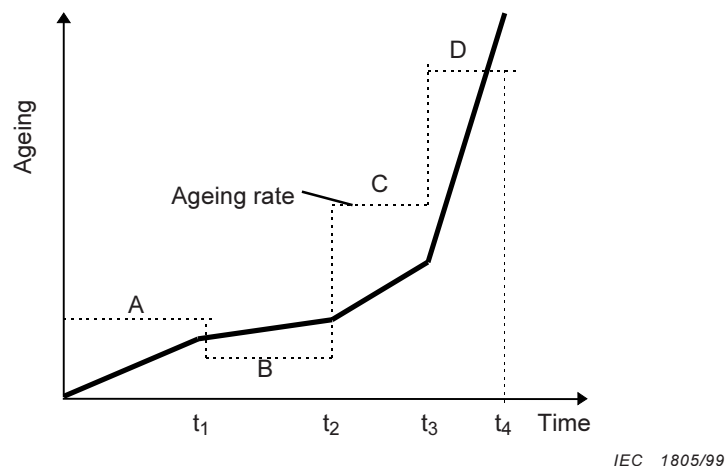


Figure 3 – Ageing as a function of time for Figure 2

Alternatively, as shown in Figure 4, the chemical changes in step B can further increase the dielectric losses and result in a rapid increase in temperature, leading to localized melting. As a consequence, during step C, the loss of mechanical strength is sufficient to cause failure. The ageing/time characteristic is shown in Figure 5.

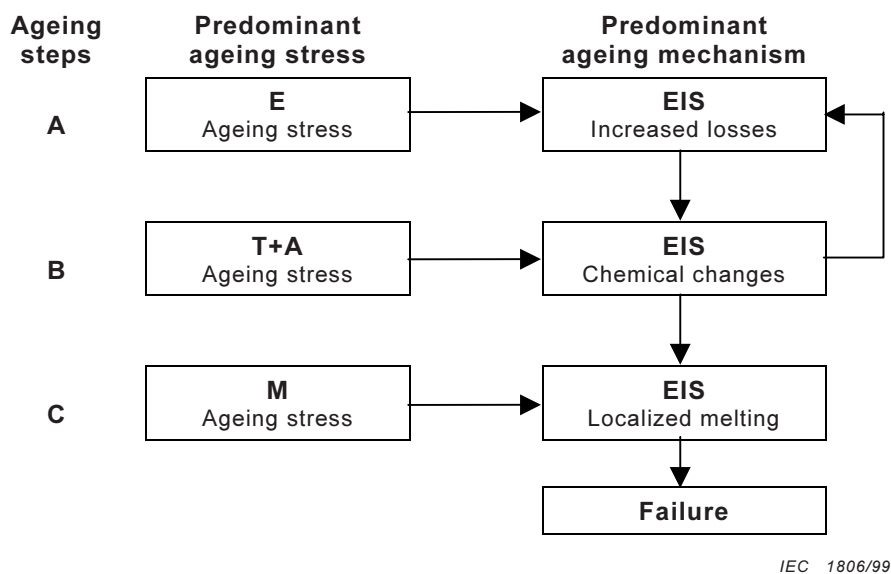


Figure 4 – Example of possible ageing mechanisms as a function of time