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Electrical insulating materials – A.C. voltage endurance evaluation – Introduction

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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 61251, 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 which was issued in 1993. It constitutes a technical revision.

The main changes with respect to the previous edition are listed below:

- extension of the scope to cover electrical insulating material and insulation systems;
- removal of references to short time dielectric breakdown strength measurements as an indicator of voltage endurance;

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

Enquiry draft	Report on voting
112/88/DTS	112/95/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 maintenance result 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- withdrawn,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.

ELECTRICAL INSULATING MATERIALS – A.C. VOLTAGE ENDURANCE EVALUATION – INTRODUCTION

1 Scope

This technical specification explains many of the factors involved in voltage endurance tests on electrical insulating materials and systems. It describes the voltage endurance graph, lists test methods illustrating their limitations and gives guidance for evaluating the a.c. voltage endurance of insulating materials and systems from the results of the tests.

The terminology to be used in voltage endurance is defined and explained. It should be emphasized that where this technical specification is concerned with materials, the results may not be directly applicable to the performance of insulating systems.

Voltage endurance tests are used to compare and evaluate insulating materials with regard to their various applications in electrical systems. Determining the ability of electrical insulating materials and systems to endure a.c. voltage stress is complex. The results of voltage endurance tests are influenced by many factors so this technical specification should only be considered as an attempt to present a unified view of voltage endurance for simplified planning and analysis. Some documents for the various practical cases exist and others are being developed.

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 60243 (all parts), *Electric strength of insulating materials – Test methods*

IEC 62539, *Guide for the statistical analysis of electrical insulation dielectric breakdown data (IEEE Standard 930:2004)*

3 Terms, definitions and symbols

For the purposes of this document, the following terms, definitions and symbols apply.

3.1 Terms and definitions

3.1.1
voltage endurance
VE
measure of the ability of solid insulating materials to endure voltage

NOTE In this technical specification, only a.c. voltage is considered.

3.1.2
life
time of any technical system until its failure or loss of serviceability

3.1.3
voltage life
time for solid insulating materials to dielectric dielectric breakdown under constant voltage stress

3.1.4
voltage endurance coefficient
VEC
numerical value of the reciprocal of the slope of a straight line log/log VE plot

3.1.5
specimen
representative test object for assessing the value of one or more physical properties

3.1.6
sample
group of nominally identical specimens from the same manufacturing batch

3.2 Symbols

c,c′	constants in the inverse-power model
E	electric stress
E_o	short-time electric strength
E_s	short-time electric strength of prestressed specimens
E_t	electric threshold stress
f	frequency
h, k	constants in the exponential model
L	time to dielectric dielectric breakdown
m	scale parameter in the simple Weibull distribution (one variable)
M	scale parameter in the generalized Weibull distribution (two variables)
n	exponent of stress in the inverse-power model coinciding with the VEC
n_d	differential VEC
n_i	initial VEC
R	dimensional ratio
t	time
t_c	time to dielectric breakdown at constant stress
t_o	time to dielectric breakdown at constant stress E_o
t_p	time to dielectric breakdown with progressive stress
t_{po}	time to dielectric breakdown with progressive stress producing dielectric breakdown at stress E_o
tan δ	dissipation factor
β	shape parameter in the Weibull distribution of times to dielectric breakdown at constant stress
γ	shape parameter of the Weibull distribution of the dielectric breakdown stresses from a progressive stress test
ν	number of dielectric breakdown stress values
ν'	number of dielectric breakdown times

4 Voltage endurance

4.1 Voltage endurance testing

To evaluate the voltage endurance of insulating materials or systems, a number of specimens are subjected to a.c. voltage and their times to dielectric breakdown are measured. In practice, several samples of many specimens are tested at different voltages to reveal the effect of the applied voltage on the time to dielectric breakdown. The mean time to dielectric breakdown of each sample is the average time to dielectric breakdown of all specimens tested at that voltage. The time at which a certain percentage of specimens has broken down is the estimated time to dielectric breakdown with a probability equal to this percentage.

The statistical treatment of the data (either by analytical or graphical methods) allows the extraction of additional data such as other failure percentiles or confidence bounds and, possibly, determination of the distribution (e.g. Gaussian, Weibull, lognormal, etc.).

4.2 Electrical stress

In general, it is advisable to make reference to electrical stress (voltage per unit thickness) instead of voltage. For uniform field, electrical stress is given by the voltage (effective value) divided by the thickness of specimens.

If the electric field is not uniform, the maximum value should be considered.

4.3 Voltage endurance (VE) graph

This is the graph of the time to dielectric breakdown versus the corresponding value of electrical stress. In the VE graph, the electrical stress is plotted as the ordinate with either a linear or logarithmic scale. The times to dielectric breakdown are plotted on the abscissa, usually with a logarithmic scale. The voltage endurance line on this graph gives the final result of the VE tests as it allows clear and complete evaluation of voltage endurance of the specimens under the specified test conditions. For maximum significance, materials or systems should be compared at equal thickness.

An accurate plotting of the line requires many tests at different voltages and some tests are required at voltages which result in long times to dielectric breakdown.

The voltage endurance line may be straight or curved. In the latter case, its trend can often be approximated by a few straight regions, sometimes a first part for short times with a low slope, a middle region (which may extend to long times) with a steeper slope and finally a further trend of the line showing a tendency to become horizontal (see Figure 1, where a general VE line is shown). The shape of the VE graph may change greatly from one material or system to another.

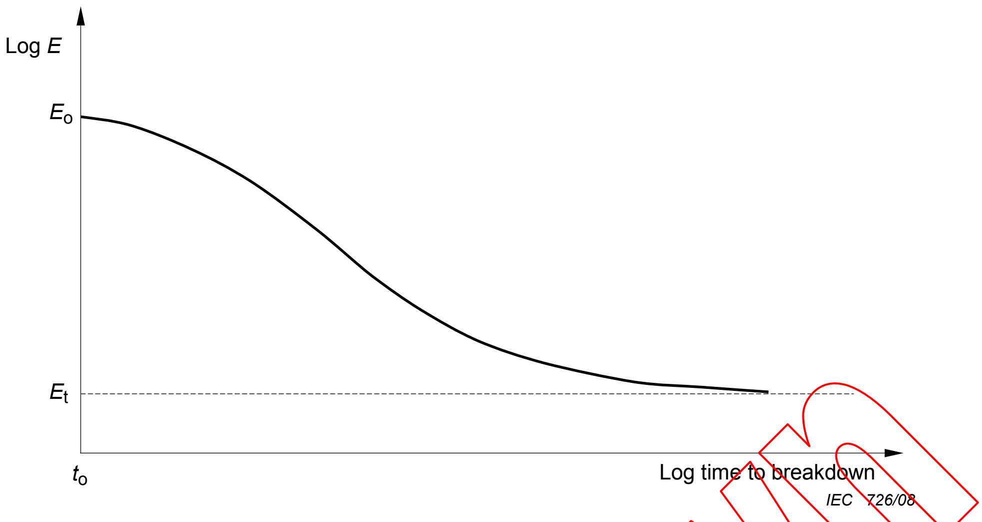

Figure 1 – General voltage endurance line

4.4 Short-time electric strength

The short-time electric strength is generally measured using a linearly increasing voltage. The duration of such a test, as used in this specification, is of the order of some tens of seconds up to some tens of minutes. These short-time electric strength measurements can be used to indicate the degree of ageing of specimens subjected to voltage by comparing the values after voltage exposure with the initial ones.

The results of electric strength tests (or, in general, of tests with increasing voltage) are not reported directly in the VE graph. Instead, a constant voltage test at the same stress as the mean electric strength, E_o (or very close to it, say 0,8 or 0,9E_o), is made to determine the time to dielectric breakdown, t_o, with constant stress. The point (E_o, t_o) is the origin of the VE line. More details on this procedure are given in 5.5. However, when this procedure is used, the following precautions should be taken:

i) The test should be carried out under the same conditions (humidity, temperature, etc.), in the same test cell and with the same procedures as for the voltage endurance tests.

ii) The test specimens and the conditions of the specimen dielectric breakdown should be examined and recorded for future use in the analysis of the results. The latter is to ensure that the mode of failure at high stress is the same as that of the other specimens tested later at lower stress.

4.5 Voltage endurance coefficient (VEC) – *n*

The slope of the VE line is an indicator of the response of a material or system to electrical stress. The parameter n is dimensionless. With a low slope of the VE line, even a small reduction of stress produces a great increase in life. The reciprocal of the slope is taken to be consistent with the numerical value of the exponent n in Equation (1). A large value of the VEC does not necessarily accompany a high electric strength. It may happen that the material with lower VEC has a longer time to dielectric breakdown at the same stress if its short-time electric strength is so high that its poorer endurance is compensated for. The value of n should be associated with a high mean electric strength before attributing a high endurance to the material. What is most significant is the retention of usable electric strength for long periods of time.

4.6 Differential VEC (n_d)

If the VE line is curved in log-log coordinates, its slope may be measured by means of the tangent at any point. For any electrical stress, and thus for any point on the line, the differential voltage endurance coefficient, n_d, can be defined as the numerical value of the