SLOVENSKI STANDARD
SIST EN 60544-1:1998

01-junij-1998

Electrical insulating materials - Determination of the effects of ionising radiation - Part 1: Radiation interaction and dosimetry (IEC 60544-1:1994)

Electrical insulating materials - Determination of the effects of ionizing radiation -- Part 1: Radiation interaction and dosimetry

Elektroisolierstoffe - Bestimmung der Wirkung ionisierender Strahlung -- Teil 1: Einfluß der Strahlenwirkung und Dosimetrie

Matériaux isolants électriques - Détermination des effets des rayonnements ionisants -- Partie 1: Interaction des rayonnements et dosimétrie

Ta slovenski standard je istoveten z: **EN 60544-1:1994**

ICS:

29.035.01	Izolacijski materiali na splošno	Insulating materials in general

SIST EN 60544-1:1998 **en**

EUROPEAN STANDARD | EN 60544-1

NORME EUROPEENNE

EUROPÄISCHE NORM | October 1994

ICS 29.040.20

Descriptors: Electrical insulating materials, radiation resistance, ionizing radiation, interaction, radioactive dose, dosimetry, X rays, gamma radiation, computation, electromagnetic absorption

ENGLISH VERSION

Electrical insulating materials - Determination of the effects of ionizing radiation
Part 1: Radiation interaction and dosimetry
(IEC 544-1:1994)

Matériaux isolants électriques
Détermination des effets des rayonnements ionisants
Partie 1: Interaction des rayonnements et dosimétrie
(CEI 544-1:1994)

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Bestimmung der Wirkung ionisierender Strahlung
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(IEC 544-1:1994)

This European Standard was approved by CENELEC on 1994-07-05. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CENELEC

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

Central Secretariat: rue de Stassart 35, B-1050 Brussels

Ref. No. EN 60544-1:1994 E

FOREWORD

The text of document 15B(CO)91, as prepared by Sub-Committee 15B: Endurance tests, of IEC Technical Committee 15: Insulating materials, was submitted to the IEC-CENELEC parallel vote in October 1993.

The reference document was approved by CENELEC as EN 60544-1 on 5 July 1994.

The following dates were fixed:

- latest date of publication of an identical national standard	(dop)	1995-07-01
- latest date of withdrawal of conflicting national standards	(dow)	1995-07-01

For products which have complied with the relevant national standard before 1995-07-01, as shown by the manufacturer or by a certification body, this previous standard may continue to apply for production until 2000-07-01.

Annexes designated "normative" are part of the body of the standard. Annexes designated "informative" are given only for information. In this standard, annexes A, B and ZA are normative and annex C is informative.

ENDORSEMENT NOTICE

The text of the International Standard IEC 544-1:1994 was approved by CENELEC as a European Standard without any modification.

ANNEX ZA (normative)

OTHER INTERNATIONAL PUBLICATIONS QUOTED IN THIS STANDARD WITH THE REFERENCES OF THE RELEVANT EUROPEAN PUBLICATIONS

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

NOTE : When the international publication has been modified by CENELEC common modifications, indicated by (mod), the relevant EN/HD applies.

IEC Publication	Date	Title	EN/HD	Date
544-2	1991	Guide for determining the effects of ionizing radiation on insulating materials - Part 2: Procedures for irradiation and test	-	-
544-4	1985	Part 4: Classification system for service in radiation environments	-	-

NORME INTERNATIONALE
INTERNATIONAL STANDARD

CEI
IEC
544-1

Deuxième édition
Second edition
1994-04

Matériaux isolants électriques – Détermination des effets des rayonnements ionisants –

Partie 1:
Interaction des rayonnements et dosimétrie

Electrical insulating materials – Determination of the effects of ionizing radiation –

Part 1:
Radiation interaction and dosimetry

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Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

CODE PRIX
PRICE CODE V

Pour prix, voir catalogue en vigueur
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTRICAL INSULATING MATERIALS – DETERMINATION OF THE EFFECTS OF IONIZING RADIATION –

Part 1: Radiation interaction and dosimetry

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international cooperation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

2) The formal decisions or agreements of the IEC on technical matters, prepared by technical committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

3) They have the form of recommendations for international use published in the form of standards, technical reports or guides and they are accepted by the National Committees in that sense.

4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.

International Standard IEC 544-1 has been prepared by sub-committee 15B: Endurance tests, of IEC technical committee 15: Insulating materials.

This second edition cancels and replaces the first edition published in 1977 and constitutes a technical revision.

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

DIS	Report on Voting
15B(CO)91	15B(CO)93

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

IEC 544 consists of the following parts, under the general title: *Electrical insulating materials – Determination of the effects of ionizing radiation.*

- Part 1: 1994, Radiation interaction and dosimetry
- Part 2: 1991, Procedures for irradiation and test
- Part 4: 1985, Classification system for service in radiation environments

Annexes A and B form an integral part of this standard.

Annex C is for information only.

INTRODUCTION

The establishment of suitable criteria for the evaluation of the radiation resistance of insulating materials is very complex, since such criteria depend upon the conditions under which the materials are used. For instance, if an insulated cable is to be flexed during a refuelling operation in a reactor, the service life will be that time during which the cable receives a radiation dose sufficient to reduce to a specified value one or more of the relevant mechanical properties. Temperature of operation, composition of the surrounding atmosphere, and the time interval during which the total dose is received (dose rate or flux) are important factors which also determine the rate and mechanisms of chemical changes. In some applications, temporary changes may be the limiting factor.

Firstly, it is necessary to define the radiation fields in which materials are exposed and the radiation dose subsequently absorbed by the material. Secondly, it is necessary to establish procedures for testing the mechanical and electrical properties of materials, which will define the radiation degradation, and link those properties with application requirements in order to provide an appropriate classification system.

This part of IEC 544 is the introductory part in a series dealing with the effect of ionizing radiation on insulating materials. Part 2 of IEC 544 describes procedures for maintaining different types of exposure conditions during the irradiation. It also specifies the controls that shall be maintained over these conditions so that desired performances can be obtained. Further, it defines certain important irradiation conditions and specifies the test procedures to be used for property-change determinations and the corresponding end-point criteria. Part 3 (IEC 544-3: 1979) has been incorporated into the second edition of IEC 544-2. Part 4 of IEC 544 defines a classification system to categorize the radiation endurance of insulating materials. It provides a set of parameters characterizing the suitability for radiation service. It is a guide for the selection and indexing of insulating materials and for material specification.

ELECTRICAL INSULATING MATERIALS – DETERMINATION OF THE EFFECTS OF IONIZING RADIATION –

Part 1: Radiation interaction and dosimetry

1 Scope and object

This part of IEC 544 deals broadly with the aspects to be considered in evaluating the effects of ionizing radiation on all types of organic insulating materials. It also provides, for X-rays, γ-rays, and electrons, a guide to dosimetry terminology, methods of determining exposure and absorbed dose, and methods of calculating absorbed dose.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 544. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 544 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 544-2: 1991, *Guide for determining the effects of ionizing radiation on insulating materials – Part 2: Procedures for irradiation and test*

IEC 544-4: 1985, *Guide for determining the effects of ionizing radiation on insulating materials – Part 4: Classification system for service in radiation environments*

3 Definitions [15]*

For the purposes of this part of IEC 544, the following definitions apply.

3.1 **exposure (*X*):** Exposure is the measure of an electromagnetic radiation field (X– or γ-radiation) to which a material is exposed. The exposure is the quotient obtained by dividing d*Q* by d*m*, where d*Q* is the absolute value of the total charge of the ions of one sign produced in the air when all of the electrons (and positrons) liberated by photons in air of mass d*m* are completely stopped in air:

$$X = \frac{dQ}{dm}$$

The SI unit of exposure is the coulomb (C) per kilogram: C/kg. The old unit is the roentgen R: 1 R = 2,58 × 10^{-4} C/kg.

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* The numbers in square brackets refer to the bibliography given in annex C.

The exposure thus describes the effect of an electromagnetic field on matter in terms of the ionization that the radiation produces in a standard reference material, air.

3.2 **electron charge fluence (Q'):** The quotient obtained by dividing dQ by dA, where dQ is the electron charge impinging during the time t on the area dA:

$$Q' = \frac{dQ}{dA}$$

3.3 **electron current density (j):** The quotient obtained by dividing dQ' by dt, where dQ' is the electron charge fluence during the time interval dt:

$$j = \frac{dQ'}{dt} = \frac{d^2Q}{dA\,dt}$$

3.4 **absorbed dose (D):** Measure of the energy imparted to the irradiated material, regardless of the nature of the radiation field. The absorbed dose D is the quotient obtained by dividing d$\bar{\varepsilon}$ by dm where d$\bar{\varepsilon}$ is the mean energy imparted by ionizing radiation to matter of mass dm:

$$D = \frac{d\bar{\varepsilon}}{dm}$$

The SI unit is the gray (Gy). The old unit is the rad:

$$1\ \text{Gy} = 1\ \text{J} \cdot \text{kg}^{-1}\ (= 10^2\ \text{rad})$$

Since this definition does not specify the absorbing material, the gray can be used only with reference to a specific material. The absorbed dose is determined in part by the composition of the irradiated material. When exposed to the same radiation field, therefore, different materials usually receive different absorbed doses.

3.5 **absorbed dose rate ($\dot{D}$):** The quotient obtained by dividing dD by dt, where dD is the increment of absorbed dose in the time interval dt:

$$\dot{D} = \frac{dD}{dt}$$

The SI unit of absorbed dose rate is the gray per second:

$$1\ \text{Gy} \cdot \text{s}^{-1} = 1\ \text{W} \cdot \text{kg}^{-1}\ (= 10^2\ \text{rad} \cdot \text{s}^{-1} = 0{,}36\ \text{Mrad} \cdot \text{h}^{-1})$$

4 Aspects to be considered in evaluating the radiation resistance of insulating materials

4.1 *Evaluation of the radiation field*

For various types of radiation, the radiation field is described in different ways.

4.1.1 An electromagnetic radiation field may be described in terms of photon flux density and energy distribution. However, for X- and γ-rays up to 3 MeV it is customary to characterize the field in terms of its ionizing effect on air. For this purpose, the quantity "exposure" is used.

4.1.2 A particle field is usually characterized in terms of the current density (fluence rate). When the particles have a distribution of energies, as for electron beams, additional information concerning the energy spectrum is required.

4.1.3 In all cases, the objective is to characterize the radiation field in such a way that the absorbed dose and dose rate in any material placed in the field may be calculated. When different materials are exposed to the same fluence of photons or particles, they may absorb different amounts of energy. The first objective is thus to describe standard methods and procedures for measuring the characteristics of the radiation fields to which insulating materials have to be exposed. Clause 5 meets this objective by presenting a list of radiation dosimetry techniques with the relevant references.

4.2 *Evaluation of absorbed dose and absorbed dose rate*

Techniques have been perfected to obtain – from measurements with radiation detectors such as ionization chambers, calorimeters, and chemical dosimeters – the data for calculating the absorbed dose or absorbed dose rate for a material under irradiation. Clause 5 deals with the reliable and conventional techniques of such measurements. Clause 6 contains the material- and energy-dependent factors to be used in the calculation of absorbed dose or absorbed dose rate in other materials of interest from the measured data for X- and γ-radiation, while clause 7 gives dose estimation methods for electron radiation.

4.3 *Radiation-induced changes and their evaluation*

Although the various types of radiation interact with matter in different ways, the primary process is the production of ions and electrically excited states of molecules which, in turn, may lead to the formation of free radicals. Radiation-generated mobile electrons, which become trapped at sites of low potential energy, are also produced. The first phenomenon leads to permanent chemical, mechanical, and electrical changes of the material; the second results in temporary electrical changes in performance [10].

4.3.1 *Permanent changes*

In polymeric materials, the formation of free radicals during irradiation leads to scission and cross-linking processes that modify the chemical structure of the insulation, generally leading to deterioration of the mechanical properties. This mechanical deterioration frequently gives rise to significant electrical property changes. However, important electrical property changes sometimes occur before mechanical degradation is serious. For example, a change in dissipation factor or in permittivity might become serious for the reliable functioning of a resonant circuit. The extent of scission and cross-linking processes depends on the absorbed dose, the absorbed dose rate, the material geometry, and the environmental conditions present during the irradiation. Because the free radicals sometimes decay slowly, there may also be post-irradiation effects.