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colour inside

Electrical insulating materials – Determination of the effects of ionizing radiation –
Part 5: Procedures for assessment of ageing in service

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 5: Procedures for assessment of ageing in service

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). 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. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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IEC 60544-5 has been prepared by IEC technical committee TC 112: Evaluation and qualification of electrical insulating materials and systems. It is an International Standard.

This third edition cancels and replaces the second edition published in 2011. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) added recent references in 7.4 showing that some electrical condition monitoring methods show promising correlations with ageing;
b) updated recommendations for implementation of a sample deposit in 9.2, installation of a sample deposit in 9.3 and testing of samples from the deposit in 9.4;
c) updated list of references.

The text of this International Standard is based on the following documents:

Draft	Report on voting
112/523/CDV	112/553/RVC

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 60544 series, published under the general title *Electrical insulating materials – Determination of the effects of ionizing radiation*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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- withdrawn,
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- amended.

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INTRODUCTION

Organic and polymeric materials provide a significant proportion of the insulation used in electrical systems. These materials are sensitive to the effects of irradiation and the response varies widely between different types. It is therefore important to be able to assess the degree of degradation of these insulating materials during their service lifetimes. This part of IEC 60544 provides recommended procedures for assessing ageing of insulating materials in service.

There are a number of approaches to the assessment of ageing of polymer-based components exposed to radiation environments [1], [2], [3], [4][1]. These are based on the better understanding of the factors affecting ageing degradation which has been developed over several decades. In nuclear power plants, qualification programmes are normally used for the selection of components, including those based on polymeric materials. These initial qualification procedures, such as IEEE Std 323™-1974[2] [5] and IEEE Std 383™-1974**Error! Bookmark not defined.** [6], were originally written before there was sufficient understanding of ageing mechanisms. Most of the methods discussed in this document are therefore used to supplement the initial qualification process.

This document is the fifth in a series dealing with the effect of ionizing radiation on insulating materials.

IEC 60544-1 (Radiation interaction and dosimetry) constitutes an introduction dealing very broadly with the problems involved in evaluating radiation effects. It also provides guidance on dosimetry terminology, several methods of determining exposure and absorbed dose, and methods of calculating absorbed dose in any specific material from the dosimetry method applied.

IEC 60544-2 (Procedures for irradiation and test) describes procedures for maintaining seven different types of exposure conditions during irradiation. It also specifies the controls that should be maintained over these conditions so that when test results are reported, reliable comparisons of material performance can be made. In addition, it defines certain important irradiation conditions and test procedures to be used for property change determinations and corresponding end-point criteria.

IEC 60544-3 has been withdrawn and incorporated into the second edition of IEC 60544-2.

IEC 60544-4 (Classification system for service in radiation environments) provides a recommended classification system for categorizing the radiation endurance of insulation materials.

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1 Numbers in square brackets refer to the Bibliography.

2 IEEE Std 323-1974 and IEEE Std 383-1974 are now withdrawn and have been superseded by more recent revisions.

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

Part 5: Procedures for assessment of ageing in service

1 Scope ~~and object~~

This part of IEC 60544 covers ageing assessment methods which can be applied to components based on polymeric materials (e.g. cable insulation and jackets, elastomeric seals, polymeric coatings, gaiters) which are used in environments where they are exposed to radiation.

The object of this document is aimed at providing methods for the assessment of ageing in service. The approaches discussed in Clause 5 through Clause 9 cover ageing assessment programmes based on condition monitoring (CM), the use of sample deposits in severe environments and sampling of real-time aged components.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60544-1, *Electrical insulating materials – Determination of the effects of ionizing radiation – Part 1: Radiation interaction and dosimetry*~~

IEC 60544-2, *Electrical insulating materials – ~~Guide for determining~~ Determination of the effects of ionizing radiation on insulating materials – Part 2: Procedures for irradiation and test*

IEC TS 61244-1, *Determination of long-term radiation ageing in polymers – Part 1: Techniques for monitoring diffusion-limited oxidation*

IEC TS 61244-2, *Determination of long-term radiation ageing in polymers – Part 2: Procedures for predicting ageing at low dose rates*

~~IEC 60780, *Nuclear power plants – Electrical equipment of the safety system – Qualification*~~

BWR boiling water reactor
CBQ condition-based qualification
CM condition monitoring
CSPE chlorosulphonated polyethylene
DBE design basis event
DLO diffusion-limited oxidation
DRE dose rate effect
~~DSC Differential scanning calorimeter~~
EPR ethylene propylene rubber
EQ environmental qualification
~~EVA Ethylene vinyl acetate copolymer~~
~~IM Indenter modulus~~
~~LOCA Loss of coolant accident~~
NPP nuclear power plant
OIT oxidation induction time
OITP oxidation induction temperature
~~PE Polyethylene~~
PVC polyvinyl chloride
PWR pressurized water reactor
TGA thermo-gravimetric analysis
VVER water-cooled, water-moderated energy reactor (type of pressurized water reactor developed by Russia)
XLPE cross-linked polyethylene

4 Background

4.1 General

There are a number of factors that need to be considered when assessing ageing of polymeric components in radiation environments. In 4.2 through 4.5, some of these factors are briefly discussed and references made to more detailed information.

To accelerate radiation-ageing environments, the normal approach is to increase the radiation dose rate, often combined with an increase in temperature. The two most important potential complications arising from such increases involve diffusion-limited oxidation (DLO), which is described in 4.2, and chemical dose rate effects (DRE), which are described in 4.3. The implications of these factors on the use and interpretation of condition monitoring (CM) techniques are also discussed. Accelerated ageing programmes are briefly discussed in 4.4 and 4.5.

4.2 Diffusion-limited oxidation (DLO)

When polymers are exposed to an oxygen-containing environment (e.g. air), some oxygen will be dissolved in the material. In the absence of oxygen-consuming reactions (oxidation), the amount of dissolved oxygen will be proportional to the oxygen partial pressure surrounding the polymer (well known from Henry's Law). Ageing will lead to oxidation reactions in the polymer, whose rate will increase significantly as the dose rate and temperature of ageing are increased. If the rate of consumption of dissolved oxygen in the polymer is faster than the rate at which oxygen can be replenished by diffusion from the surrounding atmosphere, the concentration of dissolved oxygen in the interior regions will decrease with time (the oxygen concentration at the sample surface will remain at its equilibrium value). The reduction in internal oxygen

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Electrical insulating materials – Determination of the effects of ionizing radiation –
Part 5: Procedures for assessment of ageing in service

Matériaux isolants électriques – Détermination des effets des rayonnements ionisants –
Partie 5: Procédures pour l'évaluation du vieillissement en service



IEC 60544-5:2022-06(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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Part 5: Procedures for assessment of ageing in service

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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MATÉRIAUX ISOLANTS ÉLECTRIQUES – DÉTERMINATION DES EFFETS DES RAYONNEMENTS IONISANTS –

Partie 5: Procédures pour l'évaluation du vieillissement en service

AVANT-PROPOS

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Cette troisième édition annule et remplace la deuxième édition parue en 2011. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) des références récentes ont été ajoutées en 7.4 afin d'introduire des méthodes de surveillance de l'état qui montrent des corrélations prometteuses vis-à-vis du vieillissement;

b) les recommandations ont été mises à jour pour la mise en œuvre d'un dépôt d'échantillons en 9.2, l'installation d'un dépôt d'échantillons en 9.3 et les essais sur les échantillons du dépôt en 9.4;

c) la liste de références a été mise à jour.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
112/523/CDV	112/553/RVC

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/standardsdev/publications.

Une liste de toutes les parties de la série IEC 60544, publiées sous le titre général *Matériaux isolants électriques – Détermination des effets des rayonnements ionisants*, se trouve sur le site web de l'IEC.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous webstore.iec.ch dans les données relatives au document recherché. A cette date, le document sera

- reconduit,
- supprimé,
- remplacé par une édition révisée, ou
- amendé.

INTRODUCTION

Les matériaux organiques et polymères représentent une proportion significative des isolations utilisées dans des systèmes électriques. Ces matériaux sont sensibles aux effets des irradiations, et leur réponse varie de manière significative selon le type de matériau considéré. Par conséquent, il importe de pouvoir évaluer le degré de dégradation de ces matériaux isolants pendant leur durée de vie en service. La présente partie de l'IEC 60544 fournit des procédures recommandées pour évaluer le vieillissement en service des matériaux isolants.

Il existe un certain nombre d'approches pour l'évaluation du vieillissement de composants à base de matériaux polymères exposés aux environnements sous rayonnement [1], [2], [3], [4][1]. Celles-ci sont fondées sur une meilleure compréhension des facteurs qui ont une incidence sur la dégradation due au vieillissement, qui s'est accentuée depuis plusieurs décennies. Dans une centrale nucléaire de puissance, des programmes de qualification sont utilisés pour le choix des composants, y compris ceux à base de matériaux polymères. Ces procédures de qualification initiales, telles que l'IEEE 323™-1974[2] [5] et l'IEEE 383™-1974[2] [6], ont été initialement rédigées avant d'avoir acquis une connaissance suffisante des mécanismes de vieillissement. La plupart des méthodes examinées dans le présent document sont, de ce fait, utilisées pour compléter le processus de qualification initial.

Le présent document constitue la cinquième partie d'une série qui traite de l'effet des rayonnements ionisants sur les matériaux isolants.

L'IEC 60544-1 (Interaction des rayonnements et dosimétrie) constitue une introduction qui traite très largement des problèmes liés à l'évaluation des effets des rayonnements. Elle fournit également des recommandations concernant la terminologie de la dosimétrie, plusieurs méthodes de détermination de l'exposition et de dose absorbée, ainsi que des méthodes de calcul de dose absorbée dans tout matériau spécifique selon la méthode de dosimétrie appliquée.

L'IEC 60544-2 (Méthodes d'irradiation et d'essai) décrit les procédures pour maintenir les sept types de conditions d'exposition pendant l'irradiation. Elle spécifie également les contrôles qu'il convient d'effectuer dans ces conditions afin de pouvoir établir des comparaisons fiables des performances de matériaux à partir des résultats d'essai consignés. En outre, elle définit certaines conditions d'irradiation importantes, ainsi que les procédures d'essai à utiliser pour déterminer les modifications de propriétés et les critères de point limite correspondants.

L'IEC 60544-3 a été annulée et incorporée dans la deuxième édition de l'IEC 60544-2.

L'IEC 60544-4 (Système de classification pour l'utilisation dans un environnement sous rayonnement) fournit un système de classification recommandé pour classer par catégorie les matériaux isolants selon leur comportement sous rayonnement.

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1 Les chiffres entre crochets renvoient à la Bibliographie.

2 L'IEEE 323-1974 et l'IEEE 383-1974 ont été supprimées et remplacées par des révisions plus récentes.

MATÉRIAUX ISOLANTS ÉLECTRIQUES – DÉTERMINATION DES EFFETS DES RAYONNEMENTS IONISANTS –

Partie 5: Procédures pour l'évaluation du vieillissement en service

1 Domaine d'application

La présente partie de l'IEC 60544 traite des méthodes d'évaluation du vieillissement qui peuvent être appliquées aux composants à base de matériaux polymères (gaines et isolations de câble, joints en élastomère, revêtements polymères, garnitures) qui sont utilisés dans des environnements où ils sont exposés aux rayonnements.

L'objet du présent document est de fournir des méthodes pour évaluer le vieillissement en service des matériaux. Les approches examinées dans les Articles 5 à 9 concernent les programmes d'évaluation de vieillissement fondés sur une surveillance de l'état (CM, *Condition Monitoring*), l'utilisation de dépôts d'échantillons dans des environnements sévères et l'échantillonnage de composants vieillis en temps réel.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60544-2, *Matériaux isolants électriques – Détermination des effets des rayonnements ionisants sur les matériaux isolants – Partie 2: Méthodes d'irradiation et d'essai*

IEC TS 61244-1, *Détermination du vieillissement à long terme sous rayonnement dans les polymères – Partie 1: Techniques pour contrôler l'oxydation limitée par diffusion*

IEC TS 61244-2, *Détermination du vieillissement à long terme sous rayonnement dans les polymères – Partie 2: Méthodes pour prédire le vieillissement à faible débit de dose*