



BSI Standards Publication

Determination of long-term radiation ageing in polymers

Part 4: Effects of different temperatures and dose rates under radiation condition

National foreword

This Published Document is the UK implementation of IEC TR 61244-4:2019.

The UK participation in its preparation was entrusted to Technical Committee GEL/112, Evaluation and qualification of electrical insulating materials and systems.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2019
Published by BSI Standards Limited 2019

ISBN 978 0 539 00427 4

ICS 17.240; 29.035.01

Compliance with a British Standard cannot confer immunity from legal obligations.

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 31 October 2019.

Amendments/corrigenda issued since publication

| Date | Text affected |
|------|---------------|
|------|---------------|



IEC TR 61244-4

Edition 1.0 2019-09

TECHNICAL REPORT

**Determination of long-term radiation ageing in polymers –
Part 4: Effects of different temperatures and dose rates under radiation
conditions**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 17.240; 29.035.01

ISBN 978-2-8322-7429-3

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

| | |
|--|----|
| FOREWORD..... | 3 |
| INTRODUCTION..... | 5 |
| 1 Scope..... | 6 |
| 2 Normative references | 6 |
| 3 Terms, definitions and abbreviated terms | 6 |
| 3.1 Terms and definitions..... | 6 |
| 3.2 Abbreviated terms..... | 7 |
| 4 Radiation induced degradation mechanisms at standard ambient conditions..... | 8 |
| 4.1 General conventions | 8 |
| 4.2 Effect of presence of oxygen..... | 9 |
| 4.3 Effect of dose-rate effect-1: Physical aspects..... | 9 |
| 4.4 Effect of dose-rate-2: Chemical aspects | 10 |
| 4.5 Research on degradation mechanism | 10 |
| 4.6 Experiences and acceleration factors..... | 11 |
| 4.7 Low dose-rate tests and LOCA survivability | 11 |
| 4.8 Effect of LOCA test environment..... | 11 |
| 4.9 Order effects, synergistic effects, and antagonistic effects | 12 |
| 4.10 Sequential test conditions equivalent to simultaneous methods..... | 12 |
| 4.11 Studies after TMI and later..... | 13 |
| 4.12 Arrhenius law and limitations | 13 |
| 4.13 Slow degradation behaviour observed in service-aged cables | 16 |
| 4.14 Inverse temperature effects | 17 |
| 4.15 Role of antioxidants | 17 |
| 4.16 Other thermal and radiation environment degradation characteristics..... | 18 |
| 5 Accelerated ageing test methods | 18 |
| 5.1 Sequential ageing test | 18 |
| 5.1.1 General | 18 |
| 5.1.2 Sequence of testing and synergistic effects | 19 |
| 5.1.3 Guidance on test sequences..... | 20 |
| 5.1.4 Assessment of accelerated ageing..... | 20 |
| 5.2 Simultaneous ageing test..... | 21 |
| 6 Conclusion | 22 |
| Bibliography..... | 23 |
| Table 1 – Dose rate conditions which do not cause inhomogeneous degradation | 10 |
| Table 2 – E_a value according to materials, manufacturers, and grades | 14 |
| Table 3 – Changes in various properties due to inverse temperature and annealing recovery effects, investigated by several instrumental analyses [111]. | 17 |
| Table 4 – Typical standard acceleration ageing sequence for qualification..... | 19 |
| Table 5 – More recent standard acceleration ageing sequence for qualification | 19 |

INTERNATIONAL ELECTROTECHNICAL COMMISSION

DETERMINATION OF LONG-TERM RADIATION AGEING IN POLYMERS –**Part 4: Effects of different temperatures
and dose rates under radiation conditions**

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.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a Technical Report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC TR 61244-4, which is a Technical Report, has been prepared by IEC technical committee 112: Evaluation and qualification of electrical insulating materials and systems.

The text of this Technical Report is based on the following documents:

| | |
|-------------|------------------|
| Draft TR | Report on voting |
| 112/442/DTR | 112/446/RVDTR |

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

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

A list of all parts in the IEC 61244 series, published under the general title *Determination of long-term radiation ageing in polymers*, 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 "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

IEC 60216 (all parts) and IEC 60544 (all parts) give reference and guidance for managing accelerated thermal and radiological ageing steps for type testing procedures applicable to electrical insulating materials. The actual application of electrical equipment usually requires the consideration of effects which are a consequence of simultaneous occurrence of temperature and radiation at varying intensities.

The CIGRE WG D1.42 study presents degradation data in particular with respect to cable and wire insulation materials gathered from tests where thermal and radiation loads were applied simultaneously. Even if there is a broad range of materials available from the industry, only insulation materials commonly used were selected for this study. These materials are crosslinked polyethylene (XLPE), ethylene-propylene-rubber (EPR), silicon-rubber (SIR) and polyvinylchloride (PVC). Using these test data, power plant operators were in the position to meet requirements defined by regulatory bodies in the frame of 'long term operation application', showing that most insulation materials which have been in operation for 30 to 40 years were in good condition. Furthermore, material samples were collected from real positions and test results were compared with reference samples, unaged as well as artificially aged.

The main objective of the industry is to yield reliable values of the residual lifetime of the insulation materials and linked pieces of equipment made up of these materials. However more research is necessary as the in-service degradation of insulating materials appears to be deviating from estimation based on accelerated ageing tests. For a better determination of the degradation processes of insulation materials it is important to gain a wider knowledge on material degradation and linked synergistic effects at low intensities of thermal and radiological loads. Thus, this document aims to summarize the results, and in some areas update the literature references, from CIGRE WG D1.42, to provide a state-of-the-art document on qualification procedures capable to represent multifactor ageing (hereby thermal and radiological ageing).

DETERMINATION OF LONG-TERM RADIATION AGEING IN POLYMERS –

Part 4: Effects of different temperatures and dose rates under radiation conditions

1 Scope

This part of IEC 61244 provides general guidance for the evaluation/verification of electrical insulation materials (EIM) and electrical insulation systems (EIS) intended to be used in types of equipment exposed to ionizing radiation. Beside sensors, actuators/motors as well as plugs and terminals, cables are a well-known typical application of those EIM and EIS. Their type spectrum covers low voltage power cables, control cables and instrumentation cables. Because of their comparable simple design, cables are the ideal type of equipment to study EIM and EIS degradation processes. But the results of these studies can be easily transferred to the enumerated types of equipment.

Nonetheless, this document provides a state-of-the art report on qualification/verification procedures used to simulate simultaneous effects of temperature and radiation at varying intensities rather than give detailed test programmes valid for specific test methods.

NOTE 1 Use of this document with specific products can require specification of additional product related procedures.

NOTE 2 Some of the procedures described in this document are emerging technologies. Therefore, specified prerequisites, former experiences as well as boundary conditions can be additionally taken into account.

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 (all parts), *Electrical insulating materials – Determination of the effects of ionizing radiation*

IEC TS 61244 (all parts), *Determination of long-term radiation ageing in polymers*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 61244 (all parts) and IEC 60544 (all parts) apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>