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Second edition
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Long-term radiation ageing in polymers –

Part 3: Procedures for in-service monitoring of low-voltage cable materials

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

LONG-TERM RADIATION AGEING IN POLYMERS –

Part 3: Procedures for in-service monitoring of low-voltage cable materials

FOREWORD

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- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC 61244-3, which is a technical specification, was prepared by subcommittee 15E: Methods of test, of IEC technical committee 15: Insulating materials, which has now been merged with IEC technical committee 98: Electrical insulation systems into IEC technical committee 112: Evaluation and qualification of electrical insulating materials and systems (provisional title).

This second edition cancels and replaces the first edition, published in 1998, and constitutes a technical revision. The main technical changes with regard to the previous edition are as follows:

a) as there have been technical advances in established test methods and newer methods have become available, several additions have been made to the techniques available in Clause 5;

b) some of the techniques listed in the previous edition were found to be either unsuitable for use as cable monitoring methods in plants, or less sensitive to radiation ageing than other methods; these techniques have now been removed;

c) a list of abbreviations and their meanings has been added.

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

Enquiry draft	Report on voting
15E/252/DTS	15E/258/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.

IEC 61244 consists of the following parts, under the general title *Long-term radiation ageing in polymers*:

Part 1 Techniques for monitoring diffusion-limited oxidation

Part 2: Procedures for predicting ageing at low dose rates

Part 3: Procedures for in-service monitoring of low-voltage cable materials

The committee has decided that the contents of this publication will remain unchanged until the maintenance result dateindicated 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.

INTRODUCTION

Polymers are widely used as electric insulating materials (e.g. in cables for control, instrumentation and power) in environments in which they are exposed to radiation. In such applications, these materials may well be required to survive the full working life of the plant, which may be more than 40 years, and possibly accident conditions up to and at the end of their working life. Although considerable data are available on the behaviour of polymeric insulating materials under irradiation, there is still some uncertainty on the effects of long-term, low-dose rate irradiation such as would be experienced by cables. There is, therefore, a requirement for techniques for monitoring the state of degradation of cable materials *in situ* throughout the lifetime of the plant. Suitable cable monitoring techniques would also be important to surveillance programmes in support of plant life extension and licence renewal. Although this technical specification is primarily aimed at cable condition monitoring in radiation environments, it can also be applied to other polymeric components. Many of the techniques are equally applicable to thermal-only ageing of polymeric components.

LONG-TERM RADIATION AGEING IN POLYMERS –

Part 3: Procedures for in-service monitoring of low-voltage cable materials

1 Scope

This part of IEC 61244, which is a technical specification, summarizes the main cable monitoring techniques which are currently being assessed worldwide. These techniques are primarily aimed at monitoring degradation of low-voltage cables. Most of the methods are at the development stage and require more in-plant evaluation before they could be recommended as standard techniques. The advantages and disadvantages of each method, and its current state of development, are outlined in the following clauses.

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 60544-5:2003, *Electrical insulating materials – Determination of the effect of ionizing radiation – Part 5: Procedures for assessment of ageing in service*

3 Abbreviations

BR	Butyl rubber
CM	Condition monitoring
CSPE	Chlorosulphonated polyethylene
CP	Chloroprene
DLO	Diffusion limited oxidation
DSC	Differential scanning calorimetry
EPR	Ethylene propylene rubber
EVA	Ethylene vinyl acetate
IR	Infrared
OIT	Oxidation induction time
OITP	Oxidation induction temperature
NIR	Near infra-red reflectance
NMR	Nuclear magnetic resonance
PE	Polyethylene
PVC	Polyvinyl chloride
PEEK	Polyetheretherketone
SBR	Styrene butadiene rubber
TGA	Thermo-gravimetric analysis
XLPE	Cross-linked polyethylene
XLPO	Cross-linked polyolefin

4 Requirements of a monitoring technique

There is a range of requirements which the ideal cable monitoring technique would need to satisfy. In practice, no one technique can currently satisfy all of the requirements and a range of techniques is likely to be needed. In each case, baseline data (i.e. data on unaged material of the same formulation and manufacturer) are needed to make full use of the techniques.

The ideal monitoring technique would have the following attributes:

– non-intrusive, causing minimal cable disturbance;
– capable of use during normal operation;
– not require disconnection of equipment;
– related to an identifiable degradation criterion;
– applicable to a wide range of cable materials and configuration;
– applicable at accessible locations;
– capable of measuring degradation at hot-spots;
– reproducible and capable of compensating for environmental conditions (temperature, humidity);
– less expensive to implement than periodic cable replacement;
– readily available reference data.

5 Techniques available

5.1 General

There is a wide range of possible techniques which are being considered for cable monitoring. A few are already in use in-plant, whilst others are only at the laboratory evaluation stage. Those methods for which there is most experience have been published in IEC 60544-5. Such methods consist of:

– indenter;
– oxidation induction time and oxidation induction temperature;
– thermo-gravimetric analysis;
– density measurements;
– equipment deposit.

The monitoring methods which have been evaluated can be grouped together under generic types, as follows:

a) Local tests without sampling

  – indenter;
  – sonic velocity;
  – near infrared reflectance;
  – torque testing;

b) Local tests with micro-sampling

  – modulus profiling;
  – NMR relaxation;
  – infrared spectroscopy;
  – oxidation induction time (OIT) and temperature (OITP);

– thermogravimetric analysis (TGA);
– density measurements;
– gel fraction and solvent uptake.

Each of these types of test is described in more detail in the following subclauses.

5.2 Local tests without sampling

5.2.1 General

The term "local" refers to techniques which give information on the state of the cable at the measuring point only and are thus likely to miss localized degraded areas. These methods can only be applied in man-accessible areas and are generally limited to tests of the cable jacket material except at terminations where the insulation is exposed. Where the techniques have been cross-correlated with changes in elongation at break, which is a consistent indicator of degradation, these methods have a predictive capability. This type of test will provide immediate data in-plant on the state of the cable. Where the cable jacket is more likely to degrade than the insulation (which is often true), the methods provide early warning of cable failure. Local bend tests by manipulation of the cable by hand can give qualitative information when carried out by experienced personnel.

5.2.2 Indenter

The indenter is an instrument that determines a parameter related to the compressive modulus of a polymer. By driving an instrumented probe of known shape into the surface of the polymer, the load exerted is measured. Details of the method are given in IEC 60544-5.

5.2.3 Sonic velocity

This technique is under development and at present (2005), has only been tested on PVC based cables [1-3][1]. Sonic velocity testing is based on the fact that the velocity of sound in a solid medium is dependent on both the density and the elastic modulus and is given by:

$$C^2 = \frac{E}{\rho}$$

where

C is the sonic velocity;

E is the elastic modulus;

ρ is the polymer density.

Since both modulus and density can change during ageing of cable materials, changes in sonic velocity would be expected to occur on ageing.

The tester uses piezoelectric transducers to transmit and receive a series of pulses as shown schematically in Figure 1. The signal transit times can be plotted as a function of transducer separation distance (up to a few centimetres) to obtain the slope which represents velocity. Sonic velocity measurements have been made at 20 kHz on a series of PVC jacketed cables and on strips of jacket material cut from the cables. Comparison between the data obtained on the test strips and the complete cables has shown that the technique is dependent on the cable geometry and adjacent shielding and insulation components. The magnitude of the sonic velocity at this frequency also varies considerably with different formulations of PVC, therefore baseline data would be required for each type of cable used in a plant if the technique was to be of practical use [1]. Other work, using 1MHz pulses [2][3], found the sonic velocity to be strongly dependent on the degradation of PVC jacket materials but independent of cable geometry and PVC formulation (Figure 2).

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[1] Figures in square brackets refer to the bibliography.