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INTERNATIONAL STANDARD

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**Nuclear power plants – Instrumentation and control important to safety – Electrical equipment condition monitoring methods –
Part 4: Oxidation induction techniques**

**Centrales nucléaires de puissance – Instrumentation et contrôle-commande importants pour la sûreté – Méthodes de surveillance de l'état des matériels électriques –
Partie 4: Techniques d'induction à l'oxydation**

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CONTENTS

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NUCLEAR POWER PLANTS – INSTRUMENTATION AND CONTROL IMPORTANT TO SAFETY – ELECTRICAL EQUIPMENT CONDITION MONITORING METHODS –

Part 4: Oxidation induction techniques

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 document(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.

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IEC/IEEE 62582-4 was prepared by subcommittee 45A: Instrumentation, control and electrical power systems of nuclear facilities, of IEC technical committee 45: Nuclear instrumentation, in cooperation with Nuclear Power Engineering Committee of the IEEE, under the IEC/IEEE Dual Logo Agreement between IEC and IEEE. It is an International Standard.

This document is published as an IEC/IEEE Dual Logo standard.

This second edition cancels and replaces the first 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) Consideration of publication of IEC/IEEE 60780-323;
b) An example added in Annex B and update;
c) Annex C added.

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

Draft	Report on voting
45A/1435/FDIS	45A/1445/RVD

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 the rules given in the ISO/IEC Directives, Part 2, 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 of IEC/IEEE 62582 series, under the general title *Nuclear power plants – Instrumentation and control important to safety – Electrical equipment condition monitoring methods*, can be found on the IEC website.

The IEC Technical Committee and IEEE Technical Committee have 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

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- withdrawn,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

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INTRODUCTION

a) Technical background, main issues and organisation of this standard

This part of IEC/IEEE 62582 specifically focuses on oxidation induction methods for condition monitoring for the management of ageing of electrical equipment installed in nuclear power plants. The methods are primarily suited to samples taken from materials that are polyolefin-based, but they can also be used for some materials based on ethylene-propylene polymers and for some ethylene vinyl acetate materials.

This part 4 of IEC/IEEE 62582 is the fourth part of the IEC/IEEE 62582 series.

IEC/IEEE 62582 series is issued with a joint logo which makes it applicable to the management of ageing of electrical equipment qualified to IEEE as well as IEC Standards.

IEC/IEEE 60780-323 includes the concept and role that condition based qualification could be used in equipment qualification as an adjunct to qualified life. In equipment qualification, the condition of the equipment for which acceptable performance was demonstrated is the qualified condition. The qualified condition is the condition of equipment, prior to the start of a design basis event, for which the equipment was demonstrated to meet the design requirements for the specified service conditions.

Significant research has been performed on condition monitoring techniques and the use of these techniques in equipment qualification as noted in NUREG/CR-6704, Vol. 2 (BNL-NUREG-52610) JNES-SS-0903, 2009 and IAEA-TECDOC-1825:2017.

It is intended that this document be used by test laboratories, operators of nuclear power plants, systems evaluators, and licensors.

b) Situation of the current standard in the structure of the IEC SC 45A standard series

IEC/IEEE 62582-4 is the third level IEC SC 45A document tackling the specific issue of application and performance of oxidation induction measurements in the management of ageing of electrical instrument and control equipment in nuclear power plants.

IEC/IEEE 62582-4 is to be read in association with IEC/IEEE 62582-1, which provides background and guidelines for the application of methods for condition monitoring of electrical equipment important to safety of nuclear power plants.

For more details on the structure of the IEC SC 45A standard series, see item d) of this introduction.

c) Recommendations and limitations regarding the application of this standard

It is important to note that this document establishes no additional functional requirements for safety systems.

d) Description of the structure of the IEC SC45A standard series and relationships with other IEC documents and other bodies documents (IAEA, ISO)

The IEC SC 45A standard series comprises a hierarchy of four levels. The top-level documents of the IEC SC 45A standard series are IEC 61513 and IEC 63046.

IEC 61513 provides general requirements for instrumentation and control (I&C) systems and equipment that are used to perform functions important to safety in nuclear power plants (NPPs). IEC 63046 provides general requirements for electrical power systems of NPPs; it covers power supply systems including the supply systems of the I&C systems.

IEC 61513 and IEC 63046 are to be considered in conjunction and at the same level. IEC 61513 and IEC 63046 structure the IEC SC 45A standard series and shape a complete framework establishing general requirements for instrumentation, control and electrical power systems for nuclear power plants.

IEC 61513 and IEC 63046 refer directly to other IEC SC 45A standards for general requirements for specific topics, such as categorization of functions and classification of systems, qualification, separation, defence against common cause failure, control room design, electromagnetic compatibility, human factors engineering, cybersecurity, software and hardware aspects for programmable digital systems, coordination of safety and security requirements and management of ageing. The standards referenced directly at this second level should be considered together with IEC 61513 and IEC 63046 as a consistent document set.

At a third level, IEC SC 45A standards not directly referenced by IEC 61513 or by IEC 63046 are standards related to specific requirements for specific equipment, technical methods, or activities. Usually these documents, which make reference to second-level documents for general requirements, can be used on their own.

A fourth level extending the IEC SC 45 standard series, corresponds to the Technical Reports which are not normative.

The IEC SC 45A standards series consistently implements and details the safety and security principles and basic aspects provided in the relevant IAEA safety standards and in the relevant documents of the IAEA nuclear security series (NSS). In particular this includes the IAEA requirements SSR-2/1 , establishing safety requirements related to the design of nuclear power plants (NPPs), the IAEA safety guide SSG-30 dealing with the safety classification of structures, systems and components in NPPs, the IAEA safety guide SSG-39 dealing with the design of instrumentation and control systems for NPPs, the IAEA safety guide SSG-34 dealing with the design of electrical power systems for NPPs, the IAEA safety guide SSG-51 dealing with human factors engineering in the design of NPPs and the implementing guide NSS17 for computer security at nuclear facilities. The safety and security terminology and definitions used by the SC 45A standards are consistent with those used by the IAEA.

IEC 61513 and IEC 63046 have adopted a presentation format similar to the basic safety publication IEC 61508 with an overall life-cycle framework and a system life-cycle framework. Regarding nuclear safety, IEC 61513 and IEC 63046 provide the interpretation of the general requirements of IEC 61508-1, IEC 61508-2 and IEC 61508-4, for the nuclear application sector. In this framework, IEC 60880, IEC 62138 and IEC 62566 correspond to IEC 61508-3 for the nuclear application sector.

IEC 61513 and IEC 63046 refer to ISO 9001 as well as to IAEA GSR part 2 and IAEA GS-G-3.1 and IAEA GS-G-3.5 for topics related to quality assurance (QA).

At level 2, regarding nuclear security, IEC 62645 is the entry document for the IEC/SC 45A security standards. It builds upon the valid high level principles and main concepts of the generic security standards, in particular ISO/IEC 27001 and ISO/IEC 27002; it adapts them and completes them to fit the nuclear context and coordinates with the IEC 62443 series. At level 2, IEC 60964 is the entry document for the IEC/SC 45A control rooms standards, IEC 63351 is the entry document for the human factors engineering standards and IEC 62342 is the entry document for the ageing management standards.

NOTE 1 It is assumed that for the design of I&C systems in NPPs that implement conventional safety functions (e.g. to address worker safety, asset protection, chemical hazards, process energy hazards) international or national standards would be applied.

NOTE 2 IEC TR 64000 provides a more comprehensive description of the overall structure of the IEC SC 45A standards series and of its relationship with other standards bodies and standards.

NUCLEAR POWER PLANTS – INSTRUMENTATION AND CONTROL IMPORTANT TO SAFETY – ELECTRICAL EQUIPMENT CONDITION MONITORING METHODS –

Part 4: Oxidation induction techniques

1 Scope

This part of IEC/IEEE 62582 specifies methods for condition monitoring of organic and polymeric materials in instrumentation and control systems using oxidation induction techniques in the detail necessary to produce accurate and reproducible measurements. It includes the requirements for sample preparation, the measurement system and conditions, and the reporting of the measurement results.

The different parts of IEC/IEEE 62582 are measurement standards, primarily for use in the management of ageing in initial qualification and after installation. IEC/IEEE 62582-1 includes requirements for the application of the other parts of the IEC/IEEE 62582 series and some elements which are common to all methods. Information on the role of condition monitoring in the qualification of equipment important to safety is found in IEC/IEEE 60780-323.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO, IEC and IEEE 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
- IEEE Standards Dictionary Online: available at http://dictionary.ieee.org

3.1
Oxidation induction time
OIT
relative measure of a stabilised material's resistance to oxidative decomposition, determined by the calorimetric measurement of the time interval to the onset of exothermic oxidation of the material at a specified temperature in an oxygen atmosphere, under atmospheric pressure

Note 1 to entry: OIT is expressed in minutes (min).

3.2
Oxidation induction temperature
OITP
calorimetric measurement of the temperature of the onset of exothermic oxidation of the material when subjected to a specified heating rate in an oxygen atmosphere, under atmospheric pressure

Note 1 to entry: OITP is expressed in degrees Celsius (°C).

4 Abbreviated terms and acronyms

CSPE	chlorosulphonated polyethylene
DSC	differential scanning calorimeter
EPDM	ethylene propylene diene monomer
EPR	ethylene propylene rubber
EVA	ethylene vinyl acetate
OIT	oxidation induction time
OITP	oxidation induction temperature
PE	polyethylene
PEEK	poly ether ether ketone
PVC	poly vinyl chloride
STA	simultaneous thermal analyzer
XLPE	cross-linked polyethylene

5 General description

Oxidation induction methods are based on the detection of the oxidation exotherm that occurs when a sample is heated in the presence of oxygen. This exotherm is sensitive to the level of degradation in some organic and polymeric materials and can be used as an indicator of ageing. There are two oxidation induction methods available, based on the time required to reach the onset of oxidation at a constant temperature (oxidation induction time – OIT) or based on the temperature at the onset of oxidation during a constant temperature ramp rate (oxidation induction temperature – OITP). The two methods are complementary, in that OITP is often effective in those materials where OIT is difficult to determine. OIT and OITP decrease with increasing degradation. The methods are generally related to the amount of antioxidants present in the material. As degradation proceeds, these antioxidants are depleted. For material without antioxidants OIT is not suitable, but OITP may give a useful result. In general, OIT and OITP are used to measure the thermal stability of polymers under isothermal (OIT) and dynamic (OITP) heating conditions in oxygen.

6 Applicability and reproducibility

The oxidation induction method is primarily suited to samples taken from materials (such as cable jackets or insulation) that are polyolefin-based (e.g. PE, XLPE). It can also be used for some materials based on ethylene-propylene polymers (e.g. EPR, EPDM) and for some ethylene vinyl acetate (EVA) materials. Oxidation Induction techniques may not be applicable to high temperature polymers in some cases. It is not applicable to high temperature polymers, such as PEEK. The method can be applied to other materials but problems with interpretation of the results may reduce the effectiveness of the test.

The method is generally not suitable for chlorinated polymers (e.g. PVC, CSPE) because of the corrosive degradation products evolved during the measurements, which can damage the instrument. For these materials, smaller sample masses (1 mg to 2 mg) may enable the method to be used with care. In addition, some modern systems are designed with features that protect the equipment from volatile off gases. To determine if the equipment is protected or if additional protective components are needed, consult the equipment manufacturer.

The method is not suitable for field use in the nuclear power plant but uses samples taken from the plant, which are then measured in the laboratory. Each OIT measurement in the laboratory can take up to 90 min to complete for unaged samples, decreasing for heavily aged samples, whereas OITP measurements typically take 30 min to 40 min.

Measurements of OIT typically have a standard deviation of 5 % to 10 % of the mean value whereas measurements of OITP typically have a standard deviation of 1 % to 3 % of the mean value, both within the same laboratory and between different laboratories. Some of this variation arises from inhomogeneity of the sample materials, which becomes significant when making condition measurements on samples whose mass is very low. OITP measurements are usually more reproducible than OIT measurements but require baseline data for interpretation of the changes.

7 Measurement procedure

7.1 Stabilisation of the polymeric materials

An appropriate time period shall be allowed for the polymeric materials in recently manufactured equipment to stabilise before any condition monitoring or accelerated ageing programmes are carried out. The time period over which the polymeric materials stabilise is normally dependent on the processing additives and polymer composition. If manufacturers' stabilisation time data are not available, a period of 6 months shall be allowed.

7.2 Sampling

7.2.1 General

Measurements of OIT or OITP provide information on the status of the equipment only at the specific location which has been sampled. The selection of the sample locations for condition monitoring shall be made based on the environmental conditions in representative areas during plant operation. It is important that these locations represent as wide a range of ageing conditions as possible with special consideration given to locations where ageing conditions could be severe, e.g. hotspots. The location of the sampling and available information about the environmental time history at the sample location selected shall be documented.

7.2.2 Sample requirements

To enable up to 5 measurements to be made on one specific sample, a minimum of 50 mg of material is needed. The material to be sampled shall be cleaned of surface debris. No solvents shall be used to clean the surface. Samples typically may take the form of slivers or scrapings of material taken from the surface of a cable jacket or a thin slice through insulation at a termination. The location of the sampling position shall be noted, including its radial distribution (i.e. whether it is a surface sample or a through thickness slice).

When sampling dual layer materials, e.g. cables, it shall be clear in the report how the samples have been obtained. The measured value will be dependent on the proportion of each layer included in the sample tested. For this reason, it is recommended that the layers are not mixed when technically possible.

Sampling and measurement procedures shall comply with local instructions, taking into account the safety of personnel and equipment

Care shall be taken to avoid unsuitable conditions in storage during the time period between sampling and measurements. It is recommended that samples be stored in the dark at temperatures not exceeding 25 °C and at humidity conditions within 45 % to 75 %.

7.2.3 Precautions

When taking samples for OIT/OITP in the field, the equipment shall be visually inspected before and after the sampling in order to document that the equipment is not damaged.

If samples are to be taken from operational equipment in plant, the impact of such sampling on future operational use and qualification of such equipment shall be evaluated prior to sampling.

Where removal of material from operational equipment is considered detrimental to qualification or future use, the equipment should be removed from service or repaired according to the utility's local procedures to ensure that qualification is maintained.

7.3 Sample preparation

Samples for each OIT or OITP measurement shall be 5 mg ± 1 mg in mass. Some older, less sensitive equipment may require the use of larger samples. In this case, 10 mg ± 1 mg of material should be used for the measurements. Regardless of which value is used, the mass of the sample in each measurement should be consistent. Each sample shall be chopped or ground into pieces with max dimensions of 1 mm. It is recommended that the chopped sample should be screened with a mesh to provide a particle size not greater than 0,85 mm as consistent sample preparation is important to enable reproducible oxidation of the sample during measurement. The chopped or granular sample shall be placed into a sample pan appropriate to the instrument being used and packed to achieve a good contact to the sample pan.

The sample pans shall be of aluminium, ceramic, or platinum and be open or have lids with holes or mesh to allow free access for oxygen during the measurement. A minimum of three samples shall be measured. If the results of measurements on three samples have a standard deviation > 10 % of the mean value for OIT or > 3 % of the mean value for OITP, an additional two samples should be measured if sufficient material is available. Out of these five measurements the highest and lowest will be removed and use the mean value of the remaining three samples.

If smaller sample mass needs to be used, e.g. for chlorinated materials, this should be noted in the measurement report.

7.4 Instrumentation

The instrument used for oxidation induction measurements shall be capable of determining exotherms in the sub-milliwatt range, e.g. a differential scanning calorimeter (DSC), simultaneous thermal analyzer (STA), or differential thermal analyzer (DTA). It shall be capable of maintaining an isothermal stability of ± 0,3 °C over the duration of the measurement, typically up to 90 min. The temperature ramp rate shall be programmable.

The instrument shall allow purging of the sample chamber with specific gases at a controllable rate. The distance between the gas-switching point and the instrument cell needs to be kept as short as possible, with a dead time of less than 1 min, to minimise the switching volume. Accordingly, for a flow rate of 75 ml·min^{-1}, the dead volume shall be less than 75 ml.

For analysis purposes, the difference in heat flow between a reference pan and the sample pan as a function of time (for OIT measurements) or temperature (for OITP measurements) shall be measured.

7.5 Calibration

The instrument shall be calibrated according to the manufacturer's recommendations and the relevant QA (quality assurance) procedure, using a suitable calibration standard for the temperature ranges being used (e.g. lead/indium/tin). Measurement of a reference sample shall be carried out prior to each batch of OIT or OITP measurements to verify this calibration.

7.6 OIT measurement method

7.6.1 Measurement procedure

The measurement procedure is illustrated in Figure 1. It includes the following steps.

- The sample is heated in nitrogen at a rate of temperature rise of 50 °C ·min^{-1} until 10 °C below the set temperature T_{set}. The ramp rate is then reduced to 5 °C·min^{-1} to reach the set temperature.
- The sample is then held for 2 min at the set temperature in nitrogen after which the atmosphere in the instrument is switched to oxygen.
- The oxidation exotherm is detected by a rapid increase in heat flow.
- The time from switching the atmosphere to oxygen until the sample starts oxidising is determined. This time is the oxidation induction time.

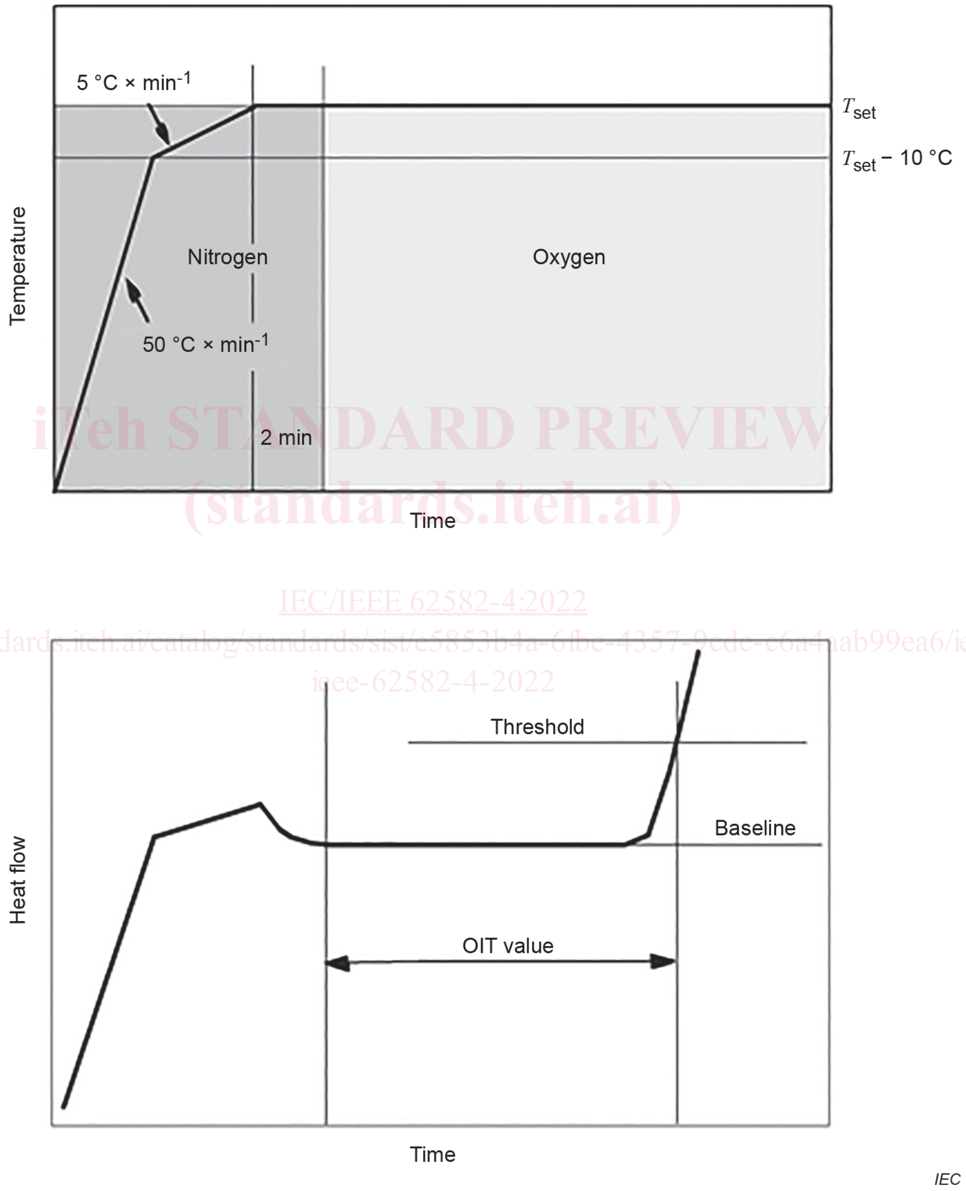

Figure 1 – OIT measurement – Schematic of temperature and gas profile and corresponding heat flow

7.6.2 Temperature profile

The reproducibility of OIT measurements is dependent on using a standardised thermal history. T_{set} for OIT measurements shall be 210 °C, provided that the oxidation induction time for unaged material is at least 30 min. The OIT value is highly dependent on T_{set} selected, see example in Annex C. If the OIT is less than 30 min for unaged material, then T_{set} shall be