IEC/IEEE 62582-3

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Nuclear power plants – Instrumentation and control important to safety – Electrical equipment condition monitoring methods – Part 3: Elongation at break

Centrales nucléaires – Instrumentation et contrôle-commande importants pour la sûreté – Méthodes de surveillance de l'état des matériels électriques – Partie 3: Allongement à la rupture

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FOREWORD

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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.

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IEC/IEEE 62582-3 was prepared by subcommittee 45A: Instrumentation and control of nuclear facilities, of IEC technical committee 45: Nuclear instrumentation, in cooperation with the Nuclear Power Engineering Committee of the Power & Energy Society of the IEEE[1], 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 2012. This edition constitutes a technical revision.

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

a) Updated best practices relating to condition monitoring using the tensile elongation method.
b) Updated bibliography, references and context.

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

Draft	Report on voting
45A/1524/FDIS	45A/1538/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/publications/.

A list of all parts of the 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 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

- reconfirmed,
- withdrawn, or
- revised.

[1] A list of IEEE participants can be found at the following URL: http://standards.ieee.org/downloads/62582-3/62582-3-2012/62582-3-2012_wg-participants.pdf.

INTRODUCTION

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

This part of this IEC/IEEE standard specifically focuses on elongation at break methods for condition monitoring for the management of ageing of electrical equipment installed in nuclear power plants. The method is primarily suited to samples taken from equipment that are based on polymeric materials.

This part of IEC/IEEE 62582 is the third part of the IEC/IEEE 62582 series. It contains detailed descriptions of condition monitoring based on elongation at break measurements.

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

IEC/IEEE 60780-323 defined term condition-based qualification which is an adjunct to type testing. The qualified condition is established by condition indicator(s) prior to the start of accident conditions for which the equipment was demonstrated to meet the design requirements for the specified service conditions. IEC/IEEE 60780-323 defined condition indicator.

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 IEC/IEEE standard 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

Part 3 of IEC/IEEE 62582 is the third level IEC SC 45A document tackling the specific issue of application and performance of elongation at break measurements in management of ageing of electrical instrument and control equipment in nuclear power plants.

Part 3 of IEC/IEEE 62582 is to be read in association with Part 1 of IEC/IEEE 62582, which provides requirements for 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 SC 45A 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 NSS42-G 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 3: Elongation at break

1 Scope

This part of IEC/IEEE 62582 contains methods for condition monitoring of organic and polymeric materials in instrumentation and control systems using tensile elongation techniques in the detail necessary to produce accurate and reproducible measurements. This document includes the requirements for selection of samples, 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 IEC/IEEE 62582 and some elements which are common to all methods. Information on the role of condition monitoring in qualification of equipment important to safety is found in IEC/IEEE 60780-323.

This document is applicable to non-energised equipment.

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
elongation
E
tensile strain, expressed as a percentage of the test length, produced in the piece by a tensile stress

[SOURCE: ISO 37:2017, 3.2]

3.2
elongation at break
E_b
tensile strain in the test length at the breaking point

[SOURCE: ISO 37:2017, 3.5]

3.3
nominal elongation at break
tensile strain, expressed as a percentage of the specimen length between the grips, produced in the specimen at the breaking point

3.4
gauge length
L_0
initial distance between the gauge marks on the central part of the test specimen. It is expressed in millimetres (mm)

Note 1 to entry: See figures of the test specimens in the relevant part of ISO 527.

[SOURCE: ISO 527-1:2019, 3.1]

3.5
test speed
rate of separation of the gripping jaws

Note 1 to entry: It is expressed in millimetres per minute (mm/min).

[SOURCE: ISO 527-1:2019, 3.5]

4 General description

This document provides requirements for the condition monitoring of organic and polymeric materials using tensile elongation techniques whereby a test specimen is extended along its longitudinal axis at constant speed until the specimen breaks. During the test, the load sustained on the specimen and its elongation are measured. For this standard, elongation at break is the measured parameter.

NOTE Elongation at break rather than tensile strength is used because for some polymeric materials, particularly thermoplastics, the strength can remain consistently equal to the yield strength after ageing even when the elongation has decreased to < 50 % absolute.

5 Applicability and reproducibility

The tensile elongation method described in this document is related to the long chain molecular structure of the polymer. As degradation proceeds, changes in the molecular structure occur as a result of cross-linking, chain scission, oxidation and other degradation mechanisms. These changes usually decrease the elongation at break.

The tensile elongation method described in this document is primarily suited to samples taken from equipment that are based on polymeric materials. The method is generally not suitable for fibre reinforced polymeric materials or resins such as epoxides.

The tensile elongation method described in this document cannot be used in the field in the nuclear power plant but uses samples taken from the plant, which are then measured in the laboratory. Each tensile elongation measurement in the laboratory can take between 5 min and 10 min to complete.

NOTE Round robin tests using a method close to the current standard have shown a typical laboratory variation in results of measurements of elongation at break on identical specimens of 8 % to 10 %.

The mechanical properties of some polymeric materials can be affected by the moisture content. Most organic and polymeric materials currently used in the containment are not significantly hygroscopic. However, if hygroscopic materials are used, the influence of the moisture content of the material on elongation at break should need to be considered, particularly after artificial thermal ageing as a consequence of long-term exposure to high temperature in an oven.

Degradation of some polymeric materials in radiation environments cannot be correlated to elongation at break.

6 Measurement procedure

6.1 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 should be allowed before commencing ageing to allow initial values from unaged samples to become stable.

6.2 Sampling

6.2.1 General

Measurements of tensile elongation provide information on the status of the equipment only at the specific location which has been sampled. Knowledge of the environmental conditions in representative areas during plant operation is a prerequisite for selecting sample locations for condition monitoring. 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.

Sampling procedures shall comply with local instructions, taking into account safety of personnel and equipment. Handling of equipment during removal of samples from the plant should be minimised, e.g. cables should not be bent more than is necessary to remove the sample.

Measurements of elongation at break are formulation dependent and can be sensitive to manufacturing variations, such as porosity. Any changes in formulation shall be evaluated.

6.2.2 Sample requirements

When preparing samples from whole cables that have been aged in the laboratory or in a deposit, samples shall be taken from sections of the cable at least 100 mm from the ends, unless such ends have been sealed during ageing.

In order to obtain reasonable confidence, a minimum of 5 test specimens is required for elongation measurements to be made on one specific sample. However, it is recognised that in some cases, e.g. in samples taken from hot-spots, there can be insufficient material available for this minimum to be satisfied.

The specimens can be prepared from equipment taken from the sampling location or, alternatively, be prepared in advance and placed in the sample locations.

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 % and 75 %.

6.3 Specimen preparation

6.3.1 General

When elongation tests are being carried out as part of a condition monitoring programme involving comparative and consecutive measurements, identical specimen preparation methods and shapes and dimensions of the specimen shall be used.

The type of specimen used for elongation measurements will depend on the geometry of the equipment being sampled. Where possible, dumb-bell specimens shall be used. For some equipment, e.g. the wire insulation in small diameter cables, dumb-bell specimens cannot be prepared and tubular specimens shall be used as specified in 6.3.3. Moulded O-rings may also be used as test specimens, where appropriate.

Dumb-bell or tubular specimens, or moulded O-rings are the most common form of specimens used for condition monitoring. For some equipment alternative specimen geometries may be necessary.

Specimens prepared from equipment before ageing, for example for use in a sacrificial deposit, may be used. Care shall be taken that diffusion-limited oxidation is not an issue when using pre-prepared specimens compared with those prepared after ageing.

NOTE 1 Preparation of test specimens from aged samples can be difficult, see Annex B for suggested approaches for preparing such material.

NOTE 2 Recent studies have shown little significant difference between the oxidation of samples aged as whole cables and those aged as prepared specimens (see Bibliography JNES-SS-0903), for small diameter cables in a limited number of specific materials.

6.3.2 Dumb-bell specimens

Recommendations for the shape and dimensions of dumb-bell specimens are given in Annex A. The test specimens shall be cut from the specimen using a suitable die (see Annex D).

In samples used for condition monitoring, there is usually only a limited amount of material available. For this reason, smaller specimens than are usually used for tensile measurements may be necessary.

6.3.3 Tubular specimens

Tubular specimens are used for equipment such as cable insulation where the core diameter is too small to enable dumb-bell specimens to be cut. Tubular specimens are prepared by removing the conductor from lengths of the insulation material. The overall length of the stripped insulation shall be a minimum of 50 mm.

Care shall be taken to avoid damage to the polymeric insulation when stripping out the conductor. See Annex B for suggested methods of preparing specimens.

With this type of specimen, end tabs or soft inserts are needed to prevent breakage in the grips of the tensile testing machine, as detailed in Annex A.

6.3.4 O-ring specimens

Moulded O-rings may be used as the test specimens. It is essential that the same specimen dimensions are used for both unaged and aged samples for condition monitoring. O-ring samples may be taken from aged equipment.

6.4 Instrumentation

6.4.1 Tensile test machine

The instrument used for tensile elongation measurements shall be capable of measuring the load exerted on the specimen and the separation between the specimen grips during continuous stretching of the specimen at a constant rate. The test machine shall be capable of testing speeds between 10 mm/min and 100 mm/min with a tolerance of ± 10 %.

Specimen grips shall be attached to the test machine so that the axis of the specimen coincides with the direction of pull through the centre line of the grip assembly. The test specimen shall be held such that slip relative to the grips is prevented. Pneumatic grips are preferred to mechanical grips. The clamping system shall not cause undue stress on the specimen resulting in potential premature fracture at the grips.

For the testing of O-ring specimens, the test machine shall have two pulleys or rounded pins attached, one to the fixed part and one to the moving cross-head. These pulleys or pins shall be aligned along the direction of pull and shall have a diameter no greater than one third of the O-ring's initial internal diameter and not less than 3 times the cord diameter.

The load indicator shall be capable of showing the tensile load carried by the specimen and indicate the load value with an accuracy of at least 1 % of the actual value.

6.4.2 Calibration

The instrument shall be calibrated according to the manufacturer's recommendations as well as traceable to a national measurement standard with a certificate of calibration of measuring and testing equipment, for the load and elongation range appropriate for the specimens being tested.

6.4.3 Use of extensometers

Measurement of the grip separation or crosshead travel from a tensile test machine calibrated to manufacturers' specifications shall provide the specimen elongation during the tensile test.

An extensometer may be used as an alternative method of measuring elongation. If used, it shall be of the non-contacting type. Non-contacting video extensometers are available which can be used to measure specimen elongations to high levels of accuracy. If such extensometers are used, a pair of marks shall be made on the surface of the specimen within the straight section of the specimen. The distance between these marks shall be equal to the gauge length for dumb-bell specimens and be 20 mm for tubular specimens.

The same method for measuring elongation of the specimen shall be used for both aged and unaged samples.

6.5 Tensile elongation measurement method

6.5.1 Conditioning

Specimens shall be conditioned at a laboratory temperature of (25 ± 5) °C and a relative humidity of 45 % to 75 % for at least 3 h prior to testing.

6.5.2 Dimensions of test specimens

If tensile strength is to be measured as subsidiary information from the tensile test, then the dimensions of the test specimen shall be determined as follows.

For dumb-bell specimens the width and thickness shall be measured in the gauge length section of the specimen. Dimensions shall be measured to the nearest 0,1 mm using a suitable instrument such as a vernier calliper or dial gauge.

For tubular specimens, the diameter and thickness shall be measured. Optical measurement of the thickness at a number of radial locations around the specimen shall be made. If practical, 6 locations are recommended. Where the thickness is variable, e.g. where insulation overlays a stranded conductor, a best estimate shall be made of the cross-sectional area.