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NORME INTERNATIONALE

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

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

IEC/IEEE 62582-3:2012

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

Part 3: Elongation at break

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International Standard IEC/IEEE 62582-3 has been 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.

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

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

FDIS	Report on voting
45A/887/FDIS	45A/891/RVD

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

International standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

A list of all parts of IEC/IEEE 62582, 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 publication will remain unchanged until the stability date indicated 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

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- withdrawn,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

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 thermoplastic or elastomeric polymers.

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.

Historically, IEEE Std 323-2003 introduced 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) and JNES-SS-0903, 2009.

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 Standard 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 top-level document of the IEC SC 45A standard series is IEC 61513. It provides general requirements for I&C systems and equipment that are used to perform functions important to safety in NPPs. IEC 61513 structures the IEC SC 45A standard series.

IEC 61513 refers directly to other IEC SC 45A standards for general topics related to categorization of functions and classification of systems, qualification, separation of systems, defence against common cause failure, software aspects of computer-based systems, hardware aspects of computer-based systems, and control room design. The standards referenced directly at this second level should be considered together with IEC 61513 as a consistent document set.

At a third level, IEC SC 45A standards not directly referenced by IEC 61513 are standards related to specific equipment, technical methods, or specific activities. Usually these documents, which make reference to second-level documents for general topics, 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.

IEC 61513 has adopted a presentation format similar to the basic safety publication IEC 61508 with an overall safety life-cycle framework and a system life-cycle framework. Regarding nuclear safety, it provides the interpretation of the general requirements of IEC 61508-1, IEC 61508-2 and IEC 61508-4, for the nuclear application sector, regarding nuclear safety. In this framework IEC 60880 and IEC 62138 correspond to IEC 61508-3 for the nuclear application sector. IEC 61513 refers to ISO as well as to IAEA GS-R-3 and IAEA GS-G-3.1 for topics related to quality assurance (QA).

The IEC SC 45A standards series consistently implements and details the principles and basic safety aspects provided in the IAEA code on the safety of NPPs and in the IAEA safety series, in particular the Requirements NS-R-1, establishing safety requirements related to the design of Nuclear Power Plants, and the Safety Guide NS-G-1.3 dealing with instrumentation and control systems important to safety in Nuclear Power Plants. The terminology and definitions used by SC 45A standards are consistent with those used by the IAEA.

NOTE 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, that are based on the requirements of a standard such as IEC 61508.

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

Part 3: Elongation at break

1 Scope and object

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. It 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. Part 1 of IEC/IEEE 62582 General 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 IEEE Std 323.

This standard is intended for application to non-energised equipment.

2 Terms and definitions

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

2.1
elongation
tensile strain expressed as a percentage of the test length, produced in the piece by a tensile stress

[SOURCE: ISO 37:2011]

2.2
elongation at break
tensile strain in the test length at the breaking point

[SOURCE: ISO 37:2011]

2.3
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

2.4
gauge length
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 527-1:2012]

2.5
speed of testing
rate of separation of the grips of the testing machine during the test. It is in millimetres per minute (mm/min)

[SOURCE: ISO 527-1:2012]

3 General description

A test specimen is extended along its longitudinal axis at constant speed until the specimen fractures. 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 polymers, particularly thermoplastics, the strength may remain consistently equal to the yield strength after ageing even when the elongation has decreased to < 50 % absolute.

4 Applicability and reproducibility

The method 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.

This method is primarily suited to samples taken from equipment that are based on thermoplastic or elastomeric polymers. The method is generally not suitable for fibre reinforced polymers or resins such as epoxides.

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

5 Measurement procedure

5.1 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.

5.2 Sampling

5.2.1 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 may be sensitive to manufacturing variations, such as porosity. Any changes in formulation need to be evaluated.

5.2.2 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 may be insufficient material available for this minimum to be satisfied.

The specimens may 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 %.

5.3 Specimen preparation

5.3.1 General

When elongation tests are being carried out as part of a condition monitoring programme involving comparative and consecutive measurements, identical specimen preparation method and shape 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 5.3.2. 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.

5.3.2 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.

5.3.3 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.

5.3.4 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.

5.4 Instrumentation

5.4.1 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^{-1} and 100 mm·min^{-1} 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.

5.4.2 Calibration

The instrument shall be calibrated according to the manufacturer's recommendations for the load and elongation range appropriate for the specimens being tested.

5.4.3 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 required. 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.

5.5 Tensile elongation measurement method

5.5.1 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.

5.5.2 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.

For O-ring specimens, the internal diameter and radial thickness shall be measured. The internal diameter shall be measured using a calibrated cone gauge or other suitable measuring equipment.

5.5.3 Clamping

For dumb-bell and tubular test specimens, the specimen shall be placed in the test grips, ensuring that the longitudinal axis of the specimen is aligned with the axis of the testing machine. The grips shall be tightened evenly and firmly to avoid slippage of the test specimen. Grip separation shall be such that only the wide sections of dumb-bell specimens are in contact with the grips. For tubular specimens, the grip separation shall be 30 mm.

For O-ring samples, the specimen shall be placed over the pulleys or pins attached to the fixed and moving cross-head of the test machine, ensuring that the specimen is not twisted.

5.5.4 Testing speed

The recommended testing speeds are shown in Table 1. The same test speed shall be used for all tests on the same material.

Table 1 – Testing speeds for elongation measurements

Specimen type	**Testing speed** (mm·min^{-1})
Dumb-bell specimens – types 1, 1A and 2	20
Dumb-bell specimens – type 3	10
Tubular specimens	50
O-ring specimens	50

The types refer to Annex A, Table A.1.

These testing speeds are much slower than normally used for tensile testing of polymeric specimens for QA purposes but are recommended because slower test speeds tend to give more reproducible results. Also, the measurements may not necessarily be directly comparable with tests made at higher speeds. For this reason elongation at break values derived from tests performed with higher speeds may not be appropriate as reference values for ageing monitoring. In condition monitoring tests, the amount of material available for testing is very limited and there is often no scope for the preparation of additional specimens.

5.5.5 Recording data

The load exerted on the specimen and the corresponding distance between the grips shall be recorded during the test, preferably using an automated recording system which can display the load-elongation curve during the test. The test shall be continued until the specimen breaks.

Examples of typical load-elongation curves are shown in Annex C.

5.5.6 Calculation of results

For dumb-bell and tubular specimens, the elongation at break is calculated from

$$\varepsilon(\%) = 100 \times \frac{E_b - E_0}{E_0} \quad (1)$$

Where ε is the elongation at break (expressed as a percentage), E_0 is the initial distance between the specimen grips and E_b is the distance between grips at break.

If a non-contacting extensometer has been used during the test, the parameters E_0 and E_b represent the initial distance between the marks on the specimen and the distance between the marks at break, respectively.

For O-ring specimens, the elongation at break is given by

$$\varepsilon(\%) = 100 \times \frac{\pi d + 2L_b - C}{C} \quad (2)$$

where L_b is the distance between the pulley centres at break, C is the initial internal circumference of the ring and d is the diameter of the pulleys.

NOTE 1 The calculation of elongation assumes negligible friction between the test rig pulleys or pins and the O-ring material.

The arithmetic mean and standard deviation of the test results shall be calculated. Data from any specimens which broke in the grips or slipped from the grips shall not be included in the calculation of the mean. Any such data shall be reported separately.

NOTE 2 The tensile strength of the test specimens can also be extracted from the test as subsidiary data. The tensile strength is calculated on the basis of the cross-sectional area of the specimen in the gauge length:

$$\sigma = \frac{F}{A} \quad (3)$$

where σ is the tensile strength, expressed in MPa; F is the measured load at break, measured in Newton; A is the initial cross-sectional area of the specimen, expressed in mm^2. The cross-sectional area for tubular specimens is given by