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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 ELECTROTECHNICAL COMMISSION

**NUCLEAR POWER PLANTS –
INSTRUMENTATION AND CONTROL IMPORTANT TO SAFETY –
ELECTRICAL EQUIPMENT CONDITION MONITORING METHODS –****Part 3: Elongation at break**

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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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC/IEEE 62582-3:2012. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

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 IEEE¹, 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.

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.

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.

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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~~ 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.

~~Historically, IEEE Std 323-2003 introduced the concept and role that conditionbased 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.~~

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 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.~~

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 ~~specific~~ activities. Usually these documents, which make reference to second-level documents for general ~~topics~~ 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 ~~safety~~ 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, ~~regarding nuclear safety~~. In this framework, IEC 60880, IEC 62138 and IEC 62566 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.~~

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

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.

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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. 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 ~~IEEE Std 323~~ IEC/IEEE 60780-323.

This document is ~~intended for application~~ 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 37:2011/2017, 3.2]

3.2 elongation at break

E_b

tensile strain in the test length at the breaking point

[SOURCE: ISO 37:2011/2017, 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 527-1:20122019, 3.1]

3.5

test speed of testing

rate of separation of the ~~grips of the testing machine during the test~~ gripping jaws

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

[SOURCE: ISO 527-1:20122019, 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 ~~fractures~~ 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 ~~polymers~~ polymeric materials, particularly thermoplastics, the strength ~~may~~ 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 ~~thermoplastic or elastomeric polymers~~ polymeric materials. The method is generally not suitable for fibre reinforced ~~polymers~~ 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 ~~may~~ 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 ~~may~~ 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 ~~may~~ can be sensitive to manufacturing variations, such as porosity. Any changes in formulation ~~need to~~ 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 ~~may~~ can be insufficient material available for this minimum to be satisfied.

The specimens ~~may~~ 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⁻¹ and 100 mm·min⁻¹~~ 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 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.

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.

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.

6.5.3 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.

6.5.4 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 $(\text{mm}\cdot\text{min}^{-1})$
	mm/min
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.

6.5.5 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.

6.5.6 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

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

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 Newtons;

A is the initial cross-sectional area of the specimen, expressed in mm².

The cross-sectional area for tubular specimens is given by:

$$A = \pi \times (D - \delta) \times \delta \quad (4)$$

where

D is the mean value of the outer diameter, and

δ is the mean value of the thickness (see 6.5.2).

6.6 Measurement report

The measurement report shall include the following items.

- a) Identification of the equipment sampled. This shall include:
 - details of the material being sampled, e.g. the generic polymer type, specific formulation numbers,
 - where the sample was taken from,
 - for samples taken in plant, location within the plant.
- b) Pre-history of the equipment sampled. This shall include:
 - time in service, or ageing time for laboratory aged samples,
 - the environmental conditions to which it has been exposed, e.g. temperature, radiation,
 - stabilisation time for unaged samples, 6.1.
- c) Place and date of the measurements.
- d) Number of specimens measured (6.2.2).
- e) Details of specimen preparation (6.3, Annex A and Annex B).
- f) Specimen type – dumb-bell/tube/ring and type of end tab/insert used, dimensions of specimen; indicate whether specimens prepared before or after ageing (6.3 and 6.5.2).
- g) Instrument used and software version used for analysis (6.4.1).
- h) Calibration procedure (6.4.2).
- i) Extensometer type used, if any (6.4.3).
- j) Type of grips used to clamp specimens or pulley diameter for O-ring specimens (6.5.3).
- k) Test speed used (6.5.4).
- l) Whether elongation calculated from gauge length, using an extensometer, or nominal elongation (6.5.6).
- m) Individual elongation values (in %), mean values, and standard deviation; indicate in a comments column any values excluded from calculation of the mean because of failure in the grips or slippage. If strength values (in MPa) have also been calculated, these should be included as subsidiary data.
- n) Examples of typical load versus elongation plots. Any atypical plots shall also be included.

Annex E provides an example of a measurement report from tensile elongation measurements.

Annex A (informative)

Shape and dimensions of test specimens

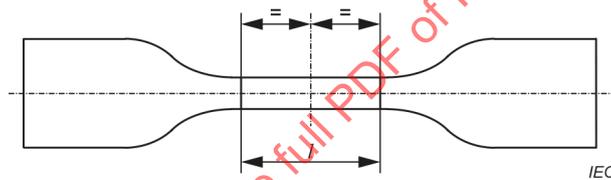
A.1 Preparation of dumb-bell specimens

The recommended shape for dumb-bell test specimens is shown in Figure A.1 with dimensions as specified in Table A.1.

Dumb-bell specimens ~~may~~ can be used with dimensions different from those given in Table A.1, e.g. conforming to National Standards. However, it is important for reproducibility that the same dimensions are used for both baseline measurements and samples taken from aged material.

The test specimens shall be cut from the equipment sample (e.g., a section of cable) using a suitable die, such as described in Annex D.

Specimens should not be prepared from slab samples, since these are not necessarily representative of the material. Slab samples are usually considerably thicker than the material used in equipment such as cables. This ~~may~~ can raise issues of diffusion-limited oxidation and differences in orientation of the molecular structure if slab samples are used.



Key

l is the gauge length

Figure A.1 – Shape of dumb-bell specimens

Table A.1 – Recommended dimensions for dumb-bell specimens

Dimension mm	Type 1	Type 1A	Type 2	Type 3
Overall length – minimum	115	100	75	50
Width of ends	25 ± 1	25 ± 1	$12,5 \pm 1$	$8,5 \pm 0,5$
Length of narrow portion	33 ± 2	22 ± 1	25 ± 1	16 ± 1
Width of narrow portion	$6 \pm 0,2$	$5 \pm 0,1$	$4 \pm 0,1$	$4 \pm 0,1$
Gauge length	25 ± 1	$20 \pm 0,5$	$20 \pm 0,5$	$10 \pm 0,5$
NOTE Type 1 is equivalent to ASTM D-412-C.				

A.2 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. For tubular specimens with outside diameters of < 4 mm, end tabs shall be fitted as in Figure A.2. For larger diameter tubular specimens, soft inserts shall be used as in Figure A.3.

The end tabs and/or inserts ~~need to be~~ shall consist of polymeric material of similar modulus to the material being tested. The combination of end tabs and/or inserts are used to avoid excessive stress in the specimen at the clamping position. This emulates the use of dumb-bell specimens, where stress is concentrated in the gauge length during the test.

To prepare tubular specimens for testing, cut the specimen to a length of 50 mm. For tubular specimens < 4 mm in diameter, cut two end tabs 8 mm in length and slide them over the ends of the specimen, leaving 2 mm of the specimen protruding above the end tab. For larger diameter tubular specimens, cut two inserts 10 mm in length and insert into the ends of the tubular specimen. Place the specimen in the test machine and tighten the grips leaving a central gauge length of 30 mm.

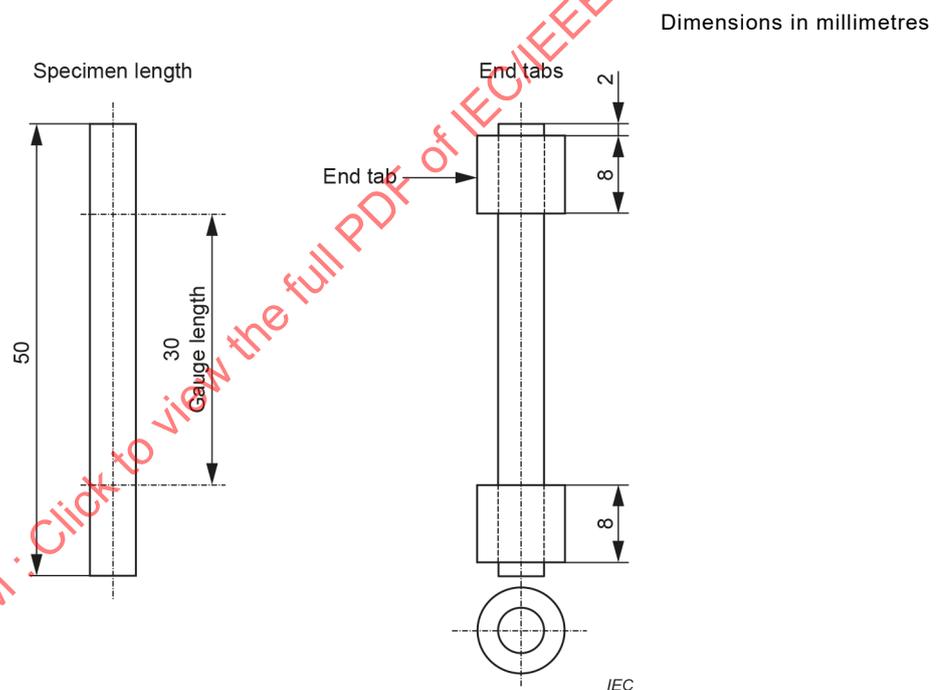


Figure A.2 – Fitting end tabs to tubular specimens

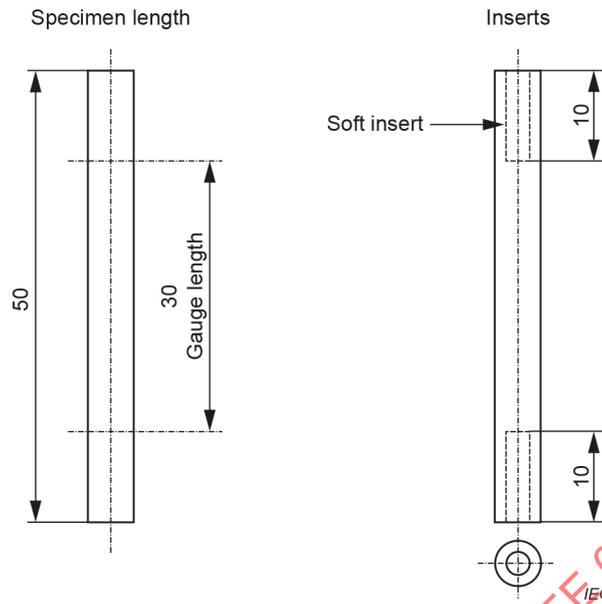


Figure A.3 – Fitting soft inserts to tubular specimens

A.3 O-ring specimens

O-rings shall be tested as complete rings, mounted in the test machine as shown in Figure A.4. If the O-ring internal diameter is too small to use the pulley fittings for mounting, the O-ring ~~may~~ can be cut and the ends gripped using standard grips.

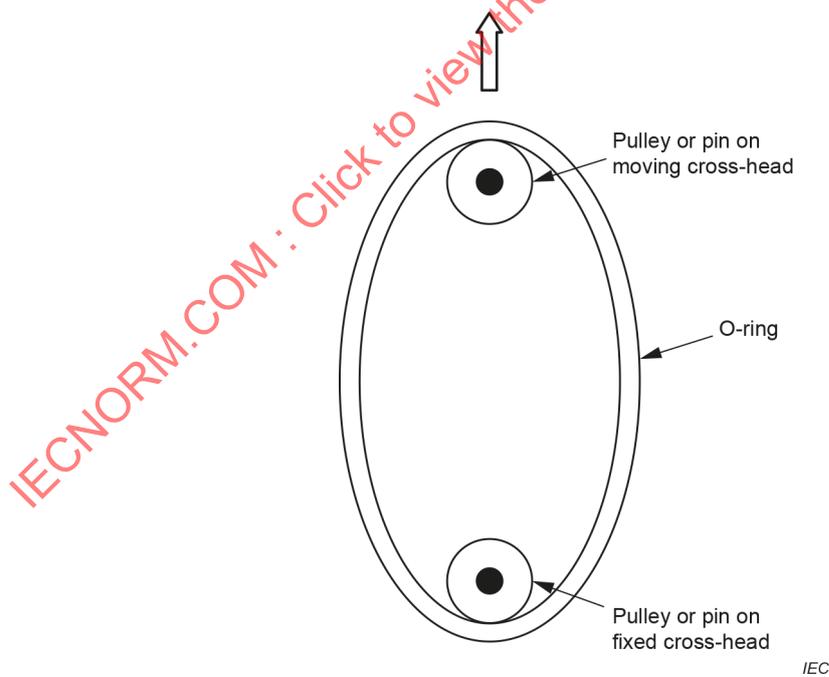


Figure A.4 – Mounting of O-ring specimens in the test machine

Annex B (informative)

Preparation of test specimens from cable samples

B.1 General

The preparation of suitable specimens for elongation at break determination ~~may~~ can be difficult and the level of difficulty is usually dependent on a combination of the cable construction and the level of ageing in the cable. For cables which have been aged in reactor environments (cable sections removed during repairs at outages or where a sacrificial deposit methodology has been adopted), cable lengths are likely to be short and the amounts of material available for testing limited. It is therefore important to be able to produce specimens for testing in an efficient manner.

B.2 Preparation of specimens from large diameter cables

For cable constructions with large diameter conductors, e.g., power cables, it is usually sufficient to strip the cable down by first removing the jacket with a sharp knife and systematically remove any armour or bedding components to reveal the conductors from which the insulation can also be removed using the knife. Dumb-bell tensile test specimens can then be cut from the cable materials using a die as required in ~~5.3.2 Clause A.1~~ Clause A.1. In many cases, specimens will be cut from sections of material which are tubular and require flattening before cutting with the die. For an aged cable material, it ~~may~~ can be appropriate to cut the materials into small sections to avoid excessive stresses that ~~may~~ can occur during flattening of tubular sections.

In many cases, the samples from which the specimens are to be cut are of uneven thickness. The sample can be trimmed to a uniform thickness using a cutting machine such as that shown in ~~IEC 60811-1-1 (see the Bibliography of this standard)~~ IEC 60811-501, which uses a pair of rollers to feed the sample against a highly sharpened blade. Alternatively, a power-driven buffing machine ~~may~~ can be used to remove surface irregularities. Such a machine should have a peripheral speed of ~~15 m·s⁻¹ to 25 m·s⁻¹~~ 15 m:s to 25 m:s and utilise a light pressure and slow feed so that very little material is removed at one cut.

If specimens are prepared from split or buffed material, the specimens should be allowed to relax at standard laboratory temperature for at least 24 h before testing.

B.3 Preparation of specimens from small diameter cables

In cable constructions that use small diameter conductors, e.g., most instrumentation and control cables, it is unlikely that specimens will be able to be cut using a standard die and tubular specimens should be prepared. In this case it is suggested that, when the cable has been stripped down, the conductors are cut to lengths of about 70 mm and approximately 10 mm of the insulation is removed to expose the conductor strands.

To remove the conductor from the insulation material, one of the following methods should be used. It is important to minimise the stresses exerted on the polymeric material during sample preparation. Accordingly, methods a) and b) shown below are the preferred techniques. Methods c), d) and e) should only be used if the other methods are unsuccessful.

- a) One of the centre strands of the conductor is identified and removed by gently pulling with pliers with one hand whilst holding the insulation with another. When one strand has been removed, it ~~may~~ can be possible to remove the remainder in a similar manner. In the case of aged cables, care shall be exercised when removing the final strands as the metal conductor ~~may~~ can have bonded to the insulation and the process ~~needs to~~ should be carried

out slowly to avoid damage to the insulation sample. When the process is complete, the specimen size shall then be trimmed to 50 mm in length, see 6.3.3.

- b) In the case of cores with single conductors, it is considered more appropriate to use spring loaded cable strippers and start at one end of the insulation sample then carefully remove the insulation using repeated slow movements of the cable stripper.
- c) The removal of insulation on wires with solid conductors ~~may~~ can also be facilitated by gently stretching the conductor. The minimum elongation necessary to loosen the insulation from the conductor should be used.
- d) Another practice used to remove cable insulations from conductors is to roll the core by hand on a smooth surface to loosen the conductors and then remove them. Whilst this method will allow the insulation samples to be removed, it is likely that the process of rolling will impart stress onto the insulation which ~~may~~ can affect the results of the tensile test. When cables are aged, the rolling process might even introduce defects which will result in low values of elongation at break.
- e) Where the insulations have bonded to the conductors and removal is difficult, the application of heat to gently warm up the samples before using a cable stripper has been successfully used. This should only be used when all other methods have failed. The application of heat should be for as short a period as possible and the temperature should not exceed 50°C. Under no circumstance shall excessive heat be applied to free the insulation. In addition the use of solvents to soften the insulation ~~must~~ shall not be used because solvent can swell, and plasticise the insulation material. In addition, the presence of solvents can cause premature failure during tensile testing due to environmental stress corrosion.

All tubular specimens should be allowed to relax at standard laboratory temperature for at least 24 h after preparation before testing is carried out.

B.4 Preparation of test specimens from bonded material

Some cable manufacturers use bonded materials in the construction of their cables, e.g., EPR (ethylene propylene rubber) insulation bonded to a CSPE (chlorosulphonated polyethylene) layer. Where this bonded material is large enough for dumb-bell specimens to be prepared, the material can be split or buffed (as in Clause B.2) to remove one of the layers. In this way, the two components of the bonded layer can be tested separately.

For smaller cables, where tubular specimens have to be prepared, it is not generally possible to separate the bonded layers. In this case the elongation measurements are made on both layers. This can introduce additional variability into the test results, since the two materials ~~may~~ can have different elongation values or have degraded at different rates. Where one layer breaks at a lower elongation than the other, this should be noted in the comments section of the report.

Annex C (informative)

Typical load versus elongation curves

Typical load-elongation curves are shown in Figure C.1. The examples shown are for materials that are brittle – curve a); tough, with a yield point – curves b) and c); tough, without a yield point – curve d). For each of these types of curve, the values of elongation E_b and load F_b at break, that are used in calculating elongation at break and tensile strength, are indicated.

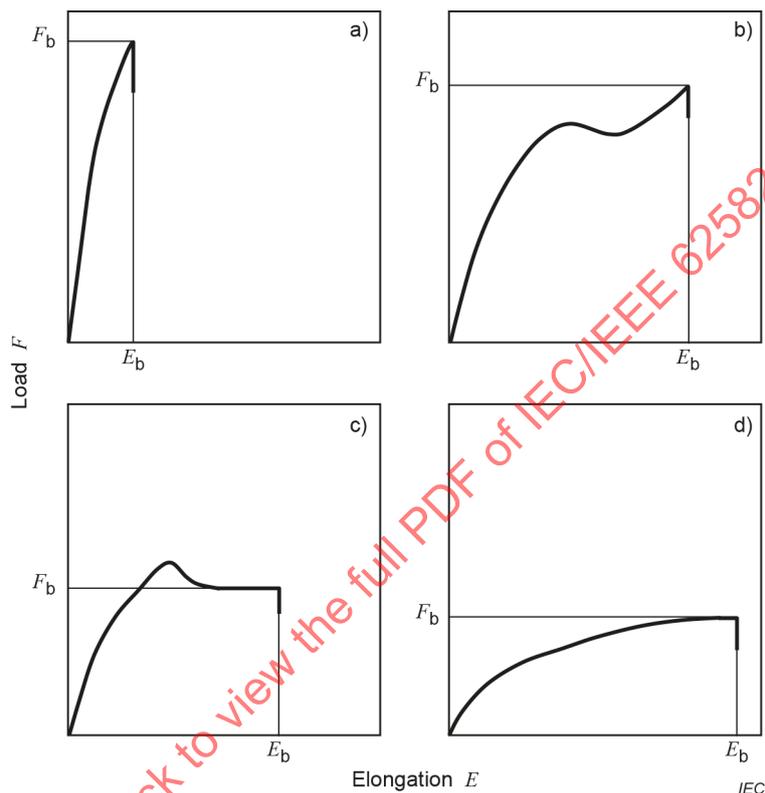


Figure C.1 – Typical load-elongation curves

If the specimen slips in the grips during a tensile test, this will show up clearly in a load versus time plot, as shown in Figure C.2. If this occurs, the elongation value should be reported separately, but not included in the calculation of the mean value.

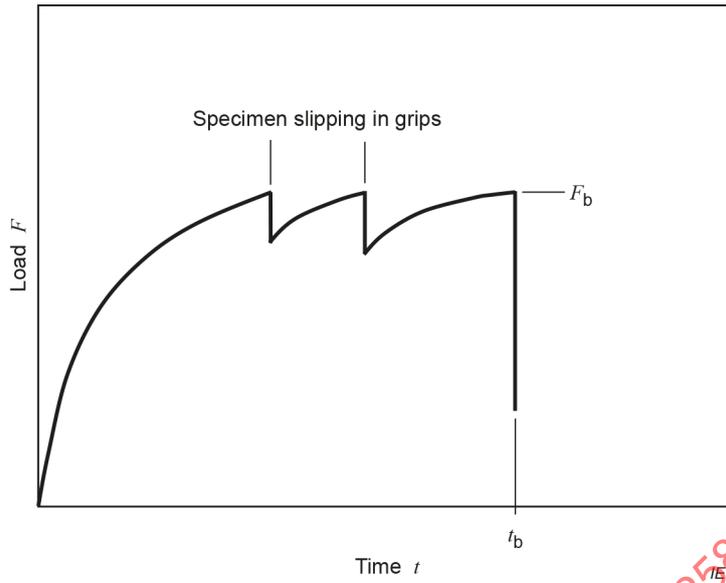


Figure C.2 – Typical load-time curve with a slipping specimen

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Annex D (normative)

Dies for cutting dumb-bell specimens

Cutters used for the preparation of dumb-bell specimens shall have the form shown in Figure D.1, with dimensions corresponding to those given in Table A.1.

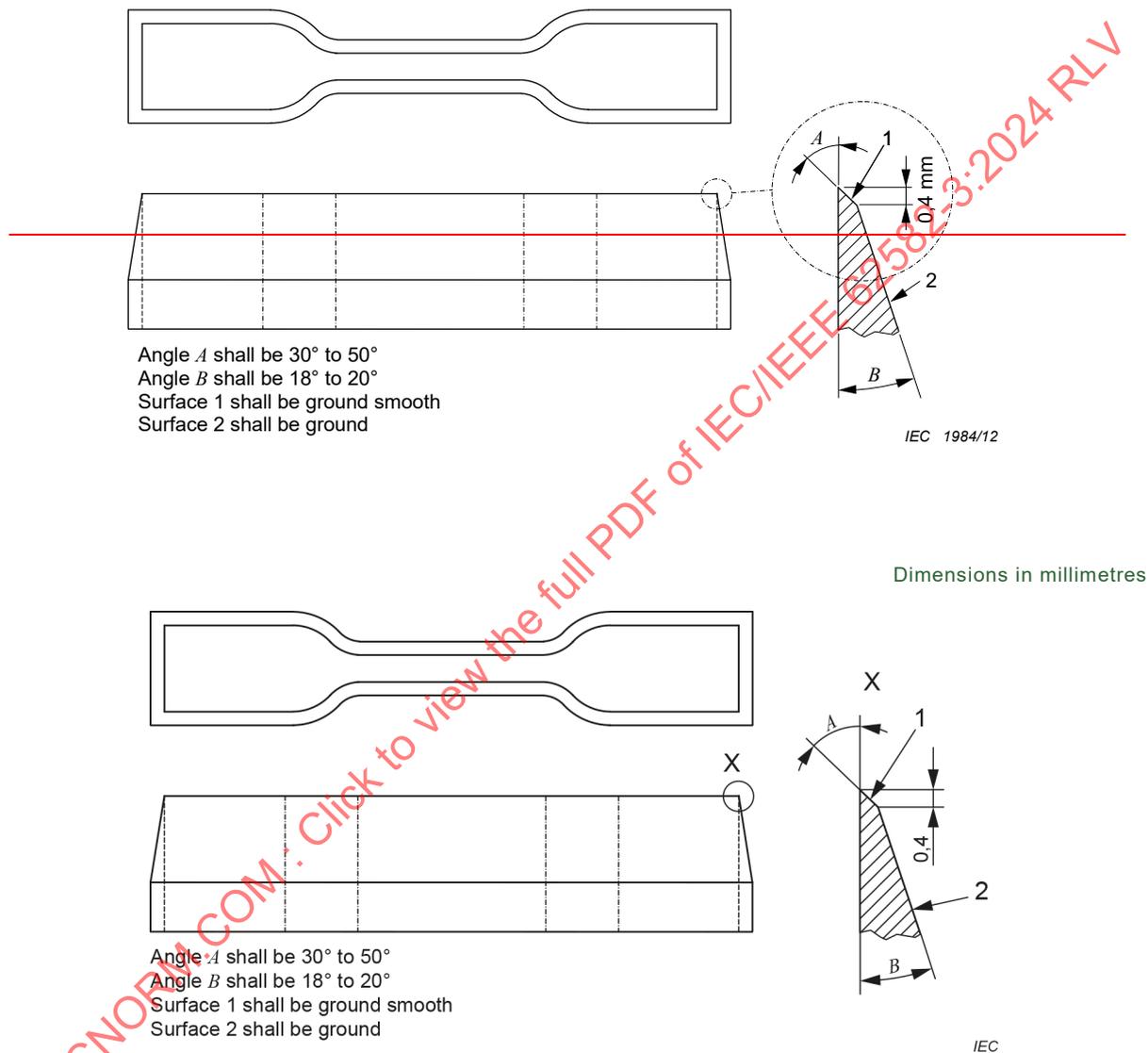


Figure D.1 – Suitable cutters for dumb-bell specimens

Annex E
(informative)

Example of a measurement report from tensile elongation measurements

This example is from the round-robin test programme carried out as part of an IAEA coordinated research programme on cable ageing (see IAEA-TECDOC-1188).

Sample ID	1129 cable insulation, taken from 4-core AIW cable, D14		
Material	Bonded EPR + CSPE insulation, 1 mm thickness – green		
Pre-history	Unaged material Stabilisation time > 6 months Conditioning time prior to testing > 24 h		
Place and date of measurement	13 May 1998 Ontario Hydro		
Specimen type	Tube, with end tab Specimens prepared before ageing		
Gauge or test length	30 mm		
Instrument	Instron		
Calibration method	Dead weight See calibration report No xxxx		
Type of grips	Pneumatic		
Extensometer	None		
Testing speed	50 mm ⁻¹ min ⁻¹		
No. of specimens measured	5		
Elongation and strength values	Elongation at break (%)	Strength (MPa)	
Specimen 1 –	312,2		
Specimen 2 –	326,8		
Specimen 3 –	309,4		
Specimen 4 –	329,6		
Specimen 5 –	351,1		
Mean value	325,8		
Standard deviation	16,6		

Comments:

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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 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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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 3: Elongation at break

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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 $\pm 10\%$.

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 $(25 \pm 5) ^\circ\text{C}$ 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.

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.

6.5.3 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.

6.5.4 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
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.

6.5.5 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.

6.5.6 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 Newtons;

A is the initial cross-sectional area of the specimen, expressed in mm².

The cross-sectional area for tubular specimens is given by:

$$A = \pi \times (D - \delta) \times \delta \quad (4)$$

where

D is the mean value of the outer diameter, and

δ is the mean value of the thickness (see 6.5.2).

6.6 Measurement report

The measurement report shall include the following items.

- a) Identification of the equipment sampled. This shall include:
 - details of the material being sampled, e.g. the generic polymer type, specific formulation numbers,
 - where the sample was taken from,
 - for samples taken in plant, location within the plant.
- b) Pre-history of the equipment sampled. This shall include:
 - time in service, or ageing time for laboratory aged samples,
 - the environmental conditions to which it has been exposed, e.g. temperature, radiation,
 - stabilisation time for unaged samples, 6.1.
- c) Place and date of the measurements.
- d) Number of specimens measured (6.2.2).
- e) Details of specimen preparation (6.3, Annex A and Annex B).
- f) Specimen type – dumb-bell/tube/ring and type of end tab/insert used, dimensions of specimen; indicate whether specimens prepared before or after ageing (6.3 and 6.5.2).
- g) Instrument used and software version used for analysis (6.4.1).
- h) Calibration procedure (6.4.2).
- i) Extensometer type used, if any (6.4.3).
- j) Type of grips used to clamp specimens or pulley diameter for O-ring specimens (6.5.3).
- k) Test speed used (6.5.4).
- l) Whether elongation calculated from gauge length, using an extensometer, or nominal elongation (6.5.6).
- m) Individual elongation values (in %), mean values, and standard deviation; indicate in a comments column any values excluded from calculation of the mean because of failure in the grips or slippage. If strength values (in MPa) have also been calculated, these should be included as subsidiary data.
- n) Examples of typical load versus elongation plots. Any atypical plots shall also be included.

Annex E provides an example of a measurement report from tensile elongation measurements.

Annex A (informative)

Shape and dimensions of test specimens

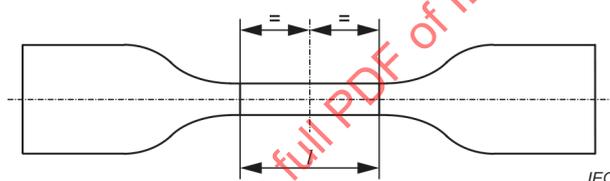
A.1 Preparation of dumb-bell specimens

The recommended shape for dumb-bell test specimens is shown in Figure A.1 with dimensions as specified in Table A.1.

Dumb-bell specimens can be used with dimensions different from those given in Table A.1, e.g. conforming to National Standards. However, it is important for reproducibility that the same dimensions are used for both baseline measurements and samples taken from aged material.

The test specimens shall be cut from the equipment sample (e.g., a section of cable) using a suitable die, such as described in Annex D.

Specimens should not be prepared from slab samples, since these are not necessarily representative of the material. Slab samples are usually considerably thicker than the material used in equipment such as cables. This can raise issues of diffusion-limited oxidation and differences in orientation of the molecular structure if slab samples are used.



Key

l is the gauge length

Figure A.1 – Shape of dumb-bell specimens

Table A.1 – Recommended dimensions for dumb-bell specimens

Dimension mm	Type 1	Type 1A	Type 2	Type 3
Overall length – minimum	115	100	75	50
Width of ends	25 ± 1	25 ± 1	$12,5 \pm 1$	$8,5 \pm 0,5$
Length of narrow portion	33 ± 2	22 ± 1	25 ± 1	16 ± 1
Width of narrow portion	$6 \pm 0,2$	$5 \pm 0,1$	$4 \pm 0,1$	$4 \pm 0,1$
Gauge length	25 ± 1	$20 \pm 0,5$	$20 \pm 0,5$	$10 \pm 0,5$
NOTE Type 1 is equivalent to ASTM D-412-C.				

A.2 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. For tubular specimens with outside diameters of < 4 mm, end tabs shall be fitted as in Figure A.2. For larger diameter tubular specimens, soft inserts shall be used as in Figure A.3.

The end tabs and/or inserts shall consist of polymeric material of similar modulus to the material being tested. The combination of end tabs and/or inserts are used to avoid excessive stress in the specimen at the clamping position. This emulates the use of dumb-bell specimens, where stress is concentrated in the gauge length during the test.

To prepare tubular specimens for testing, cut the specimen to a length of 50 mm. For tubular specimens < 4 mm in diameter, cut two end tabs 8 mm in length and slide them over the ends of the specimen, leaving 2 mm of the specimen protruding above the end tab. For larger diameter tubular specimens, cut two inserts 10 mm in length and insert into the ends of the tubular specimen. Place the specimen in the test machine and tighten the grips leaving a central gauge length of 30 mm.

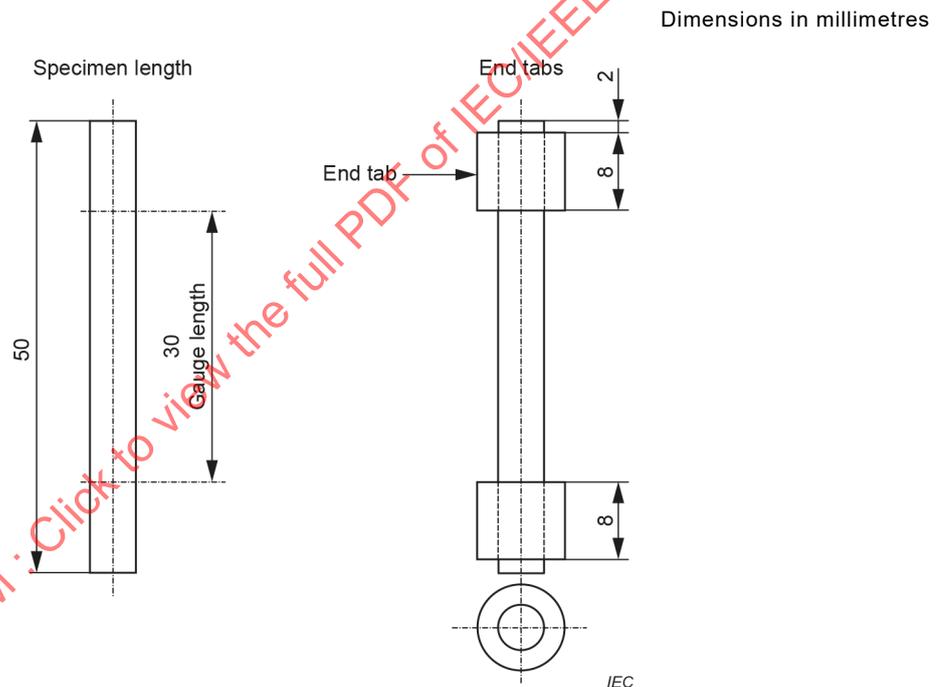


Figure A.2 – Fitting end tabs to tubular specimens

Dimensions in millimetres

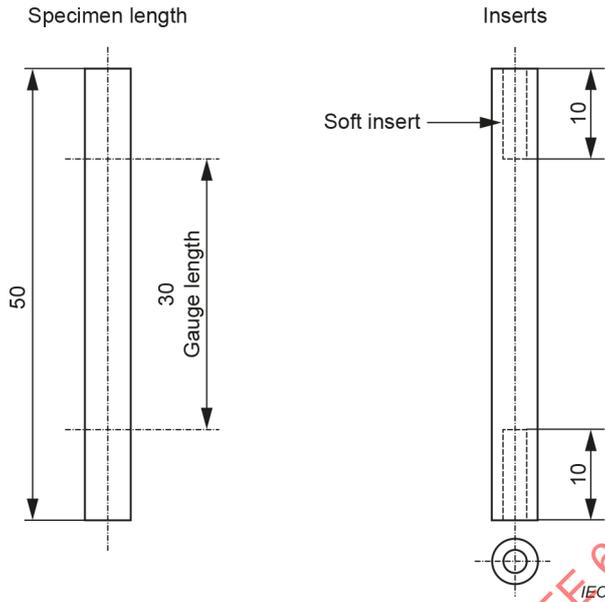


Figure A.3 – Fitting soft inserts to tubular specimens

A.3 O-ring specimens

O-rings shall be tested as complete rings, mounted in the test machine as shown in Figure A.4. If the O-ring internal diameter is too small to use the pulley fittings for mounting, the O-ring can be cut and the ends gripped using standard grips.

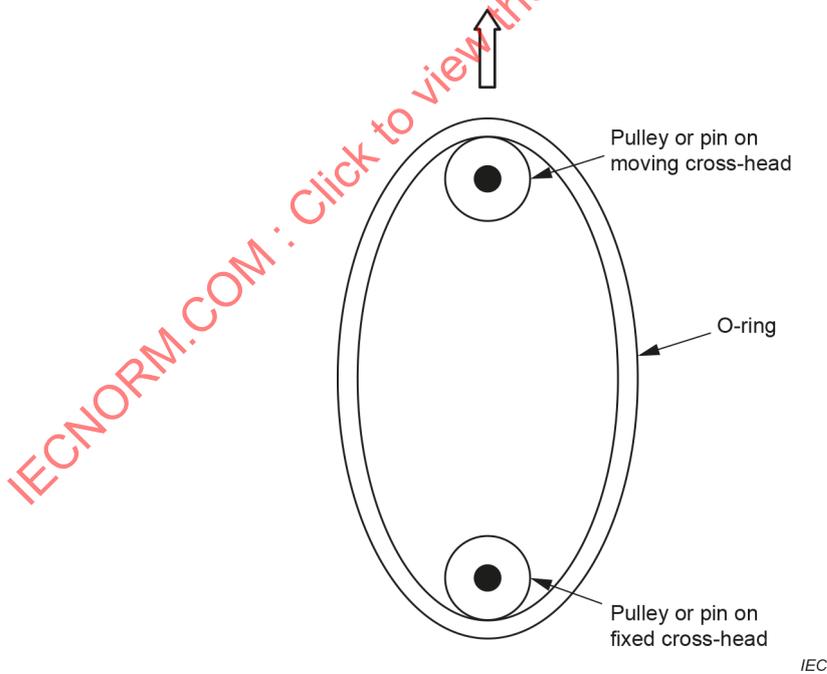


Figure A.4 – Mounting of O-ring specimens in the test machine

Annex B (informative)

Preparation of test specimens from cable samples

B.1 General

The preparation of suitable specimens for elongation at break determination can be difficult and the level of difficulty is usually dependent on a combination of the cable construction and the level of ageing in the cable. For cables which have been aged in reactor environments (cable sections removed during repairs at outages or where a sacrificial deposit methodology has been adopted), cable lengths are likely to be short and the amounts of material available for testing limited. It is therefore important to be able to produce specimens for testing in an efficient manner.

B.2 Preparation of specimens from large diameter cables

For cable constructions with large diameter conductors, e.g., power cables, it is usually sufficient to strip the cable down by first removing the jacket with a sharp knife and systematically remove any armour or bedding components to reveal the conductors from which the insulation can also be removed using the knife. Dumb-bell tensile test specimens can then be cut from the cable materials using a die as required in Clause A.1. In many cases, specimens will be cut from sections of material which are tubular and require flattening before cutting with the die. For an aged cable material, it can be appropriate to cut the materials into small sections to avoid excessive stresses that can occur during flattening of tubular sections.

In many cases, the samples from which the specimens are to be cut are of uneven thickness. The sample can be trimmed to a uniform thickness using a cutting machine such as that shown in IEC 60811-501, which uses a pair of rollers to feed the sample against a highly sharpened blade. Alternatively, a power-driven buffing machine can be used to remove surface irregularities. Such a machine should have a peripheral speed of 15 m:s to 25 m:s and utilise a light pressure and slow feed so that very little material is removed at one cut.

If specimens are prepared from split or buffed material, the specimens should be allowed to relax at standard laboratory temperature for at least 24 h before testing.

B.3 Preparation of specimens from small diameter cables

In cable constructions that use small diameter conductors, e.g., most instrumentation and control cables, it is unlikely that specimens will be able to be cut using a standard die and tubular specimens should be prepared. In this case it is suggested that, when the cable has been stripped down, the conductors are cut to lengths of about 70 mm and approximately 10 mm of the insulation is removed to expose the conductor strands.

To remove the conductor from the insulation material, one of the following methods should be used. It is important to minimise the stresses exerted on the polymeric material during sample preparation. Accordingly, methods a) and b) shown below are the preferred techniques. Methods c), d) and e) should only be used if the other methods are unsuccessful.

- a) One of the centre strands of the conductor is identified and removed by gently pulling with pliers with one hand whilst holding the insulation with another. When one strand has been removed, it can be possible to remove the remainder in a similar manner. In the case of aged cables, care shall be exercised when removing the final strands as the metal conductor can have bonded to the insulation and the process should be carried out slowly to avoid damage to the insulation sample. When the process is complete, the specimen size shall then be trimmed to 50 mm in length, see 6.3.3.

- b) In the case of cores with single conductors, it is considered more appropriate to use spring loaded cable strippers and start at one end of the insulation sample then carefully remove the insulation using repeated slow movements of the cable stripper.
- c) The removal of insulation on wires with solid conductors can also be facilitated by gently stretching the conductor. The minimum elongation necessary to loosen the insulation from the conductor should be used.
- d) Another practice used to remove cable insulations from conductors is to roll the core by hand on a smooth surface to loosen the conductors and then remove them. Whilst this method will allow the insulation samples to be removed, it is likely that the process of rolling will impart stress onto the insulation which can affect the results of the tensile test. When cables are aged, the rolling process might even introduce defects which will result in low values of elongation at break.
- e) Where the insulations have bonded to the conductors and removal is difficult, the application of heat to gently warm up the samples before using a cable stripper has been successfully used. This should only be used when all other methods have failed. The application of heat should be for as short a period as possible and the temperature should not exceed 50°C. Under no circumstance shall excessive heat be applied to free the insulation. In addition the use of solvents to soften the insulation shall not be used because solvent can swell, and plasticise the insulation material. In addition, the presence of solvents can cause premature failure during tensile testing due to environmental stress corrosion.

All tubular specimens should be allowed to relax at standard laboratory temperature for at least 24 h after preparation before testing is carried out.

B.4 Preparation of test specimens from bonded material

Some cable manufacturers use bonded materials in the construction of their cables, e.g., EPR (ethylene propylene rubber) insulation bonded to a CSPE (chlorosulphonated polyethylene) layer. Where this bonded material is large enough for dumb-bell specimens to be prepared, the material can be split or buffed (as in Clause B.2) to remove one of the layers. In this way, the two components of the bonded layer can be tested separately.

For smaller cables, where tubular specimens have to be prepared, it is not generally possible to separate the bonded layers. In this case the elongation measurements are made on both layers. This can introduce additional variability into the test results, since the two materials can have different elongation values or have degraded at different rates. Where one layer breaks at a lower elongation than the other, this should be noted in the comments section of the report.

Annex C (informative)

Typical load versus elongation curves

Typical load-elongation curves are shown in Figure C.1. The examples shown are for materials that are brittle – curve a); tough, with a yield point – curves b) and c); tough, without a yield point – curve d). For each of these types of curve, the values of elongation E_b and load F_b at break, that are used in calculating elongation at break and tensile strength, are indicated.

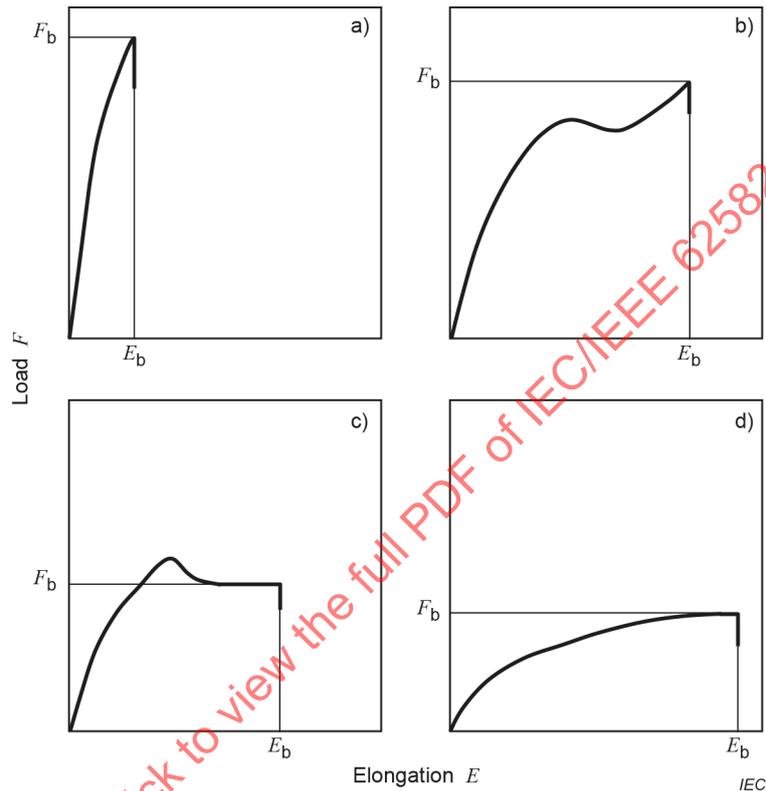


Figure C.1 – Typical load-elongation curves

If the specimen slips in the grips during a tensile test, this will show up clearly in a load versus time plot, as shown in Figure C.2. If this occurs, the elongation value should be reported separately, but not included in the calculation of the mean value.

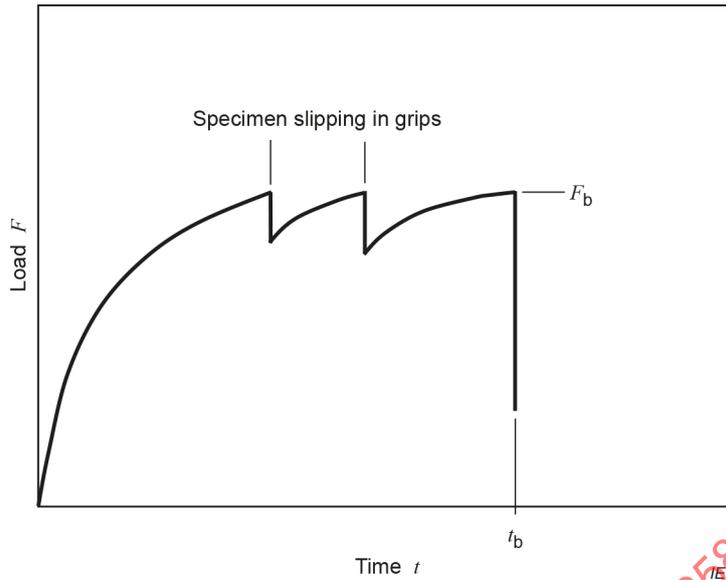


Figure C.2 – Typical load-time curve with a slipping specimen

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Annex D (normative)

Dies for cutting dumb-bell specimens

Cutters used for the preparation of dumb-bell specimens shall have the form shown in Figure D.1, with dimensions corresponding to those given in Table A.1.

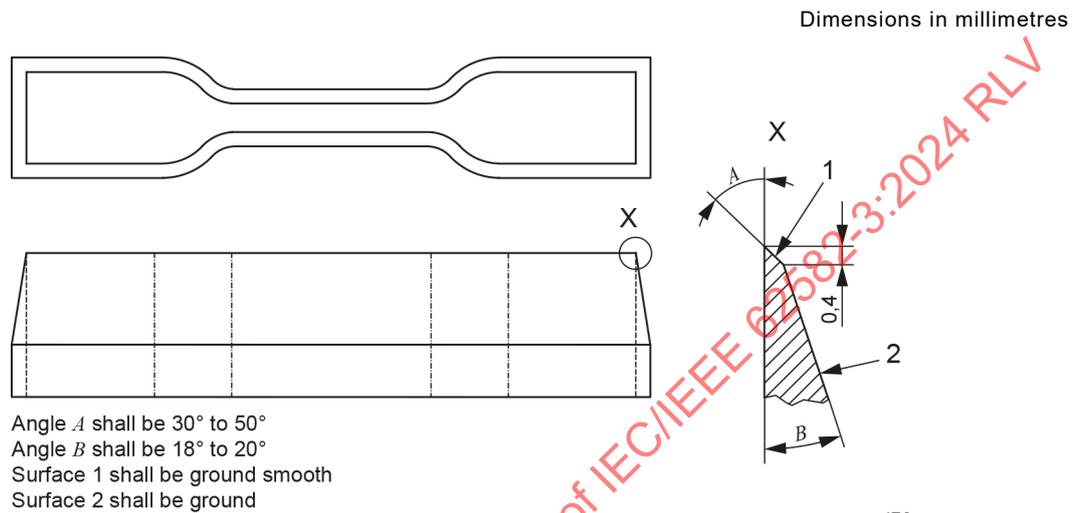


Figure D.1 – Suitable cutters for dumb-bell specimens

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Annex E (informative)

Example of a measurement report from tensile elongation measurements

This example is from the round-robin test programme carried out as part of an IAEA coordinated research programme on cable ageing (see IAEA-TECDOC-1188).

Sample ID	1129 cable insulation, taken from 4-core AIW cable, D14		
Material	Bonded EPR + CSPE insulation, 1 mm thickness – green		
Pre-history	Unaged material Stabilisation time > 6 months Conditioning time prior to testing > 24 h		
Place and date of measurement	13 May 1998 Ontario Hydro		
Specimen type	Tube, with end tab Specimens prepared before ageing		
Gauge or test length	30 mm		
Instrument	Instron		
Calibration method	Dead weight See calibration report No xxxx		
Type of grips	Pneumatic		
Extensometer	None		
Testing speed	50 mm/min		
No. of specimens measured	5		
Elongation and strength values		Elongation at break (%)	Strength (MPa)
	Specimen 1 –	312,2	
	Specimen 2 –	326,8	
	Specimen 3 –	309,4	
	Specimen 4 –	329,6	
	Specimen 5 –	351,1	
	Mean value	325,8	
	Standard deviation	16,6	

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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

AVANT-PROPOS

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L'IEC/IEEE 62582-3 a été établie par le sous-comité 45A: Systèmes d'instrumentation, de contrôle-commande et d'alimentation électrique des installations nucléaires, du comité d'études 45 de l'IEC: Instrumentation nucléaire, en coopération avec le "Nuclear Power Engineering Committee" de l'IEEE¹ Power and Energy Society, selon l'accord double logo IEC/IEEE passé entre l'IEC et l'IEEE. Il s'agit d'une Norme internationale.

Le présent document est une norme double logo IEC/IEEE.

Cette deuxième édition annule et remplace la première édition parue en 2012. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques suivantes par rapport à l'édition précédente:

- a) mise à jour des meilleures pratiques relatives à la surveillance de l'état par la méthode d'allongement en traction;
- b) mise à jour de la bibliographie, des références et du contexte.

Le texte de cette Norme internationale est issu des documents suivants de l'IEC:

Projet	Rapport de vote
45A/1524/FDIS	45A/1538/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/publications.

Une liste de toutes les parties de la série IEC/IEEE 62582, publiées sous le titre général *Centrales nucléaires – Instrumentation et contrôle-commande importants pour la sûreté – Méthodes de surveillance de l'état des matériels électriques*, se trouve sur le site web de l'IEC.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous webstore.iec.ch dans les données relatives au document recherché. À cette date, le document sera

- reconduit,
- supprimé, ou
- révisé.

¹ Une liste des participants IEEE est disponible à l'adresse: http://standards.ieee.org/downloads/62582-3/62582-3-2012/62582-3-2012_wg-participants.pdf.

INTRODUCTION

a) Contexte technique, questions principales et structure de la norme

La présente partie de la norme IEC/IEEE traite en particulier des méthodes de mesurage de l'allongement à la rupture, utilisées pour la surveillance de l'état dans le cadre de la gestion du vieillissement des matériels électriques installés dans les centrales nucléaires. La méthode convient plus particulièrement aux échantillons prélevés sur des matériels réalisés à partir de matériaux polymères.

La présente partie de l'IEC/IEEE 62582 est la troisième partie de la série IEC/IEEE 62582. Elle contient des descriptions complètes de la surveillance de l'état, qui repose sur des mesurages de l'allongement à la rupture.

La série IEC/IEEE 62582 est publiée en double logo, ce qui la rend applicable pour la gestion du vieillissement des matériels électriques qualifiés tant dans le cadre des normes IEEE que dans celui des normes IEC.

L'IEC/IEEE 60780-323 définit le terme "qualification par surveillance d'état" qui est un complément aux essais de type. L'état qualifié est établi par un ou plusieurs indicateurs d'état avant le début des conditions accidentelles pour lesquelles le matériel a été évalué en satisfaisant aux exigences de conception dans le cadre des conditions de service spécifiées. L'IEC/IEEE 60780-323 définit le terme "indicateur d'état".

Des recherches importantes ont été réalisées sur les techniques de surveillance d'état et sur l'utilisation de ces techniques dans le cadre de la qualification des matériels, comme cela est indiqué dans les documents NUREG/CR-6704, Vol. 2 (BNL-NUREG-52610), JNES-SS-0903:2009 et IAEA-TECDOC-1825:2017.

La présente norme IEC/IEEE est destinée à être utilisée par les laboratoires d'essai, les exploitants de centrales nucléaires, les évaluateurs de systèmes et les concédants de licence.

b) Positionnement de la présente norme dans la structure de la collection de normes du SC 45A de l'IEC

La Partie 3 de l'IEC/IEEE 62582 est le document de troisième niveau du SC 45A de l'IEC qui traite de la question particulière de l'application et des performances des mesurages de l'allongement à la rupture dans le cadre de la gestion du vieillissement des matériels électriques de mesure et des équipements de contrôle-commande dans les centrales nucléaires.

La Partie 3 de l'IEC/IEEE 62582 doit être lue conjointement avec la Partie 1 de l'IEC/IEEE 62582 qui fournit les exigences pour l'application des méthodes de surveillance de l'état des matériels électriques importants pour la sûreté utilisés dans les centrales nucléaires.

Pour plus d'informations sur la structure de la collection de normes du SC 45A de l'IEC, voir le point d) de la présente introduction.

c) Recommandations et limites relatives à l'application de la présente norme

Il est important de noter que le présent document n'établit pas d'exigences fonctionnelles supplémentaires pour les systèmes de sûreté.

d) Description de la structure de la collection des normes du SC 45A de l'IEC et relations avec d'autres documents de l'IEC, et avec les documents d'autres organisations (AIEA, ISO)

La collection de normes établies par le SC 45A de l'IEC est structurée en quatre niveaux. Les documents de niveau supérieur dans la collection des normes établies par le SC 45A de l'IEC sont l'IEC 61513 et l'IEC 63046.

L'IEC 61513 établit les exigences générales relatives aux systèmes et équipements d'instrumentation et de contrôle-commande (systèmes d'I&C) utilisés pour réaliser des fonctions importantes pour la sûreté des centrales nucléaires. L'IEC 63046 établit les exigences générales relatives aux systèmes d'alimentation électrique des centrales nucléaires; elle couvre les systèmes d'alimentation électrique y compris les alimentations des systèmes d'I&C.

L'IEC 61513 et l'IEC 63046 doivent être prises en compte ensemble et au même niveau. L'IEC 61513 et l'IEC 63046 structurent la collection de normes du SC 45A de l'IEC et constituent un cadre complet qui établit les exigences générales relatives aux systèmes d'instrumentation, de contrôle-commande et d'alimentation électrique des centrales nucléaires.

L'IEC 61513 et l'IEC 63046 font directement référence à d'autres normes du SC 45A de l'IEC quant aux exigences générales relatives à des sujets spécifiques, tels que la catégorisation des fonctions et le classement des systèmes, la qualification, la séparation des systèmes, la défense contre les défaillances de cause commune, la conception des salles de commande, la compatibilité électromagnétique, l'ingénierie des facteurs humains, la cybersécurité, les aspects logiciels et matériels relatifs aux systèmes numériques programmables, la coordination des exigences de sûreté et de sécurité, et la gestion du vieillissement. Il convient de considérer que ces normes, auxquelles il est fait directement référence à ce deuxième niveau, forment, avec l'IEC 61513 et l'IEC 63046, un ensemble documentaire cohérent.

Au troisième niveau, les normes du SC 45A de l'IEC, qui ne sont pas citées en référence directement par l'IEC 61513 ou l'IEC 63046, traitent d'exigences particulières relatives à des matériels particuliers, des méthodes techniques ou des activités spécifiques. Généralement, ces documents, qui font référence aux documents de deuxième niveau pour les exigences générales, peuvent être utilisés de façon isolée.

Un quatrième niveau qui est une extension de la collection de normes du SC 45 de l'IEC correspond aux rapports techniques qui ne sont pas des documents normatifs.

Les normes de la collection du SC 45A de l'IEC mettent en œuvre de manière systématique et décrivent les principes de sûreté et de sécurité et les aspects fondamentaux donnés dans les normes de sûreté de l'AIEA pertinentes pour les centrales nucléaires, ainsi que dans les documents pertinents de la collection de l'AIEA pour la sécurité nucléaire (NSS). Cela concerne en particulier le document d'exigences SSR-2/1 qui établit les exigences de sûreté relatives à la conception des centrales nucléaires, le guide de sûreté SSG-30 qui traite du classement de sûreté des structures, systèmes et composants des centrales nucléaires, le guide de sûreté SSG-39 qui traite de la conception des systèmes d'instrumentation et de contrôle-commande des centrales nucléaires, le guide de sûreté SSG-34 qui traite de la conception des systèmes d'alimentation électrique des centrales nucléaires, le guide de sûreté SSG-51 qui traite de l'ingénierie des facteurs humains lors de la conception des centrales nucléaires et le guide de mise en œuvre NSS42-G qui traite de la sécurité informatique pour les installations nucléaires. La terminologie et les définitions utilisées pour la sûreté et la sécurité dans les normes établies par le SC 45A sont conformes à celles utilisées par l'AIEA.

L'IEC 61513 et l'IEC 63046 ont adopté une présentation similaire à celle de la publication fondamentale de sécurité IEC 61508, avec un cycle de vie d'ensemble et un cycle de vie des systèmes. En ce qui concerne la sûreté nucléaire, l'IEC 61513 et l'IEC 63046 donnent l'interprétation des exigences générales des parties 1, 2 et 4 de l'IEC 61508 pour le secteur nucléaire. Dans ce cadre, l'IEC 60880, l'IEC 62138 et l'IEC 62566 correspondent à l'IEC 61508-3 pour le secteur nucléaire.

L'IEC 61513 et l'IEC 63046 font référence à l'ISO 9001, ainsi qu'aux documents AIEA GSR partie 2, AIEA GS-G-3.1 et AIEA GS-G-3.5 pour les aspects qui concernent l'assurance qualité (QA).

Au deuxième niveau, en ce qui concerne la sûreté nucléaire, l'IEC 62645 est le document chapeau des normes de sécurité du SC 45A de l'IEC. Elle se fonde sur les principes pertinents de haut niveau et sur les concepts principaux des normes génériques de sécurité, en particulier l'ISO/IEC 27001 et l'ISO/IEC 27002; elle les adapte et les complète pour les rendre pertinents pour le secteur nucléaire; elle est en coordination étroite avec la série de normes IEC 62443. Au deuxième niveau, l'IEC 60964 est le document chapeau des normes du SC 45A de l'IEC applicables aux salles de commande, l'IEC 63351 est le document chapeau des normes applicables à l'ingénierie des facteurs humains et l'IEC 62342 est le document chapeau des normes applicables à la gestion du vieillissement.

NOTE 1 On considère que pour la conception des systèmes d'I&C qui mettent en œuvre des fonctions de sûreté conventionnelle dans les centrales nucléaires (par exemple, pour assurer la sécurité des travailleurs, la protection des biens, la prévention contre les risques chimiques, la prévention contre les risques liés au procédé énergétique), des normes nationales ou internationales sont appliquées.

NOTE 2 Le Rapport technique IEC TR 64000 donne une description plus complète de la structure globale de la collection de normes du SC 45A de l'IEC, ainsi que ses relations avec les autres organismes de normalisation et les autres normes.

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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

1 Domaine d'application

La présente partie de l'IEC/IEEE 62582 fournit des méthodes de surveillance d'état pour les matériaux organiques et polymères des systèmes d'instrumentation et de contrôle-commande. Ces méthodes reposent sur des techniques d'allongement en traction et sont suffisamment détaillées pour obtenir des mesures exactes et reproductibles. Le présent document comprend des exigences concernant le choix des échantillons, le système et les conditions de mesurage, ainsi que l'établissement du rapport des résultats des mesures.

Les différentes parties de l'IEC/IEEE 62582 sont des normes de mesurage, qui sont principalement destinées à être utilisées pour la gestion du vieillissement dans le cadre de la qualification initiale et après installation. L'IEC/IEEE 62582-1 fournit des exigences concernant l'application des autres parties de l'IEC/IEEE 62582 et certains éléments communs à l'ensemble des méthodes. L'IEC/IEEE 60780-323 fournit des informations concernant le rôle de la surveillance de l'état dans la qualification des matériels importants pour la sûreté.

Le présent document s'applique aux matériels qui ne sont pas sous tension.

2 Références normatives

Le présent document ne contient aucune référence normative.

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions s'appliquent.

L'ISO, l'IEC et l'IEEE tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse <http://www.electropedia.org/>
- ISO Online browsing platform: disponible à l'adresse <http://www.iso.org/obp>
- IEEE Standards Dictionary Online: disponible à l'adresse <http://dictionary.ieee.org>

3.1 allongement

E

déformation en traction, exprimée en pourcentage de la longueur d'essai, résultant d'une contrainte de traction exercée sur l'éprouvette

[SOURCE: ISO 37:2017, 3.2]

3.2 allongement à la rupture

E_b

allongement de la longueur de la base de mesure au moment de la rupture

[SOURCE: ISO 37:2017, 3.5]

3.3 allongement nominal à la rupture

allongement, exprimé en pourcentage de la longueur de l'éprouvette entre les mors de serrage, obtenu au moment de la rupture

3.4 longueur de référence

L_0

distance initiale entre les repères sur la partie centrale de l'éprouvette. Elle est exprimée en millimètres (mm)

Note 1 à l'article: Voir les figures des éprouvettes dans la partie applicable de l'ISO 527.

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

3.5 vitesse d'essai

vitesse de séparation des mâchoires de serrage

Note 1 à l'article: Elle est exprimée en millimètres par minute (mm/min).

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

4 Description générale

Le présent document fournit des exigences pour la surveillance de l'état des matériaux organiques et polymères à l'aide de techniques d'allongement en traction par lesquelles une éprouvette est étirée suivant son axe longitudinal à une vitesse constante jusqu'à la rupture de l'éprouvette. Durant l'essai, la force appliquée sur l'éprouvette et son allongement sont mesurés. Dans la présente norme, l'allongement à la rupture est le paramètre mesuré.

NOTE L'allongement à la rupture est utilisé en lieu et place de la résistance à la traction, car pour certains matériaux polymères, en particulier les thermoplastiques, la résistance peut rester constamment égale à la résistance observée au seuil viscoélastique après vieillissement même lorsque la réduction de l'allongement est < 50 % en valeur absolue.

5 Applicabilité et reproductibilité

La méthode d'allongement en traction décrite dans le document repose sur la présence de longues chaînes dans les structures moléculaires des polymères. Lors du processus de dégradation, les structures moléculaires subissent des variations sous l'effet des procédés de réticulation, des mécanismes de rupture des chaînes, d'oxydation ou d'autres phénomènes de dégradation. Ces variations se traduisent généralement par une diminution de la valeur d'allongement à la rupture.

La méthode d'allongement en traction décrite dans le présent document convient plus particulièrement aux échantillons prélevés sur des matériels réalisés à partir de matériaux polymères, mais n'est généralement pas adaptée aux matériaux polymères renforcés par des fibres ou aux résines, comme les résines époxy.

La méthode d'allongement en traction décrite dans le présent document ne peut pas être mise en œuvre sur le terrain dans les centrales nucléaires, mais elle utilise des échantillons provenant des centrales, qui font ensuite l'objet de mesurages en laboratoire. La réalisation de chaque mesurage d'allongement en traction peut prendre entre 5 min et 10 min en laboratoire.

NOTE Des essais interlaboratoires effectués selon des méthodes proches de celle décrite dans la présente norme ont permis d'observer au niveau des valeurs d'allongement à la rupture mesurées sur des éprouvettes identiques, un écart de 8 % à 10 % par rapport aux essais en laboratoire classiques.

Les propriétés mécaniques de certains matériaux polymères peuvent être sensibles à la teneur en humidité. La plupart des matériaux organiques ou polymères actuellement utilisés dans le confinement ne sont pas significativement hygroscopiques. Néanmoins, si des matériaux hygroscopiques sont utilisés, il convient de prendre en compte l'influence de la teneur en humidité de ces matériaux sur l'allongement à la rupture, en particulier après un vieillissement thermique artificiel obtenu par une exposition prolongée à une température élevée dans une étuve.

La dégradation de certains matériaux polymères dans les environnements exposés à des rayonnements ne peut pas être corrélée à l'allongement à la rupture.

6 Procédure de mesure

6.1 Stabilisation des matériaux polymères

Une durée suffisante doit être prévue pour permettre aux matériaux polymères des matériels de fabrication récente de se stabiliser avant d'engager tout programme de surveillance d'état ou de vieillissement accéléré sur ces matériels. La période nécessaire à la stabilisation des matériaux polymères dépend normalement des produits additifs liés au procédé et de la composition des polymères. Si les données du fabricant concernant le temps de stabilisation des polymères ne sont pas disponibles, il convient alors d'attendre 6 mois avant d'engager les programmes de vieillissement pour permettre aux valeurs initiales des échantillons non vieillis de se stabiliser.

6.2 Échantillonnage

6.2.1 Généralités

Les mesurages d'allongement en traction fournissent des informations sur l'état du matériel uniquement à l'endroit spécifique, où a été réalisé le prélèvement. La connaissance des conditions d'environnement dans des zones représentatives durant l'exploitation de la centrale est une condition préalable au choix des lieux de prélèvement pour réaliser la surveillance d'état. Il est important que ces lieux correspondent à une gamme aussi large que possible de conditions de vieillissement, en prenant en compte tout particulièrement les lieux où les conditions de vieillissement pourraient être plus sévères, par exemple les points chauds. Le lieu d'échantillonnage et les informations disponibles concernant l'historique des conditions d'environnement sur le lieu de prélèvement choisi doivent être documentés.

Les procédures d'échantillonnage doivent satisfaire aux instructions locales, en prenant en compte la sécurité du personnel et des matériels. Il convient de réduire le plus possible la manipulation des matériels durant le prélèvement des échantillons dans la centrale. Par exemple, il convient de ne pas plier les câbles plus que cela est nécessaire pour prélever l'échantillon.

Les mesurages d'allongement à la rupture dépendent de la formule des matériaux et peuvent être sensibles aux variations observées en fabrication, comme la porosité. Toute modification de la formule doit être évaluée.

6.2.2 Exigences relatives aux échantillons

Lors de la préparation d'échantillons prélevés sur des câbles entiers préalablement vieillis en laboratoire ou en dépôt sur site, les échantillons doivent être prélevés dans des sections de câbles situées à au moins 100 mm des extrémités des câbles, sauf dans le cas où ces extrémités auraient été hermétiquement fermées durant la phase de vieillissement.

Pour obtenir une confiance raisonnable, un nombre minimal de 5 éprouvettes est exigé pour les mesurages d'allongement à effectuer sur un échantillon particulier. Néanmoins, il est admis que dans certains cas, par exemple pour les échantillons prélevés sur les points chauds, le volume de matériaux disponibles peut ne pas être suffisant pour obtenir ce nombre minimal d'éprouvettes.

Les éprouvettes peuvent être préparées à partir des matériels prélevés sur le lieu d'échantillonnage ou peuvent, à défaut, être préparées à l'avance et placées sur les lieux de prélèvement.

Toute condition de stockage non appropriée doit être évitée pendant l'intervalle compris entre l'échantillonnage et les mesurages. Il est recommandé de stocker les échantillons dans l'obscurité à des températures inférieures ou égales à 25 °C et dans des conditions d'humidité comprises entre 45 % et 75 %.

6.3 Préparation des éprouvettes

6.3.1 Généralités

Lorsque les essais d'allongement sont réalisés dans le cadre d'un programme de surveillance d'état comprenant des mesurages comparatifs et consécutifs, les méthodes de préparation, les formes et les dimensions des éprouvettes utilisées doivent être identiques.

Le type d'éprouvette utilisé pour les mesurages d'allongement dépend de la forme géométrique du matériel sur lequel est prélevé l'échantillon. Lorsque cela est possible, des éprouvettes haltères doivent être utilisées. Pour certains matériels, par exemple l'isolant des fils de câbles de faible diamètre, des éprouvettes haltères ne peuvent pas être préparées et des éprouvettes tubulaires doivent alors être utilisées, comme cela est spécifié au 6.3.3. Des joints toriques moulés peuvent également être utilisés comme éprouvettes, le cas échéant.

Les éprouvettes haltères ou tubulaires, ou les joints toriques moulés, sont les formes d'éprouvettes les plus couramment utilisées pour la surveillance d'état. Pour certains matériels, il peut être nécessaire d'utiliser d'autres formes géométriques d'éprouvettes.

Les éprouvettes préparées à partir de matériels avant vieillissement, par exemple pour être placées dans un dépôt sur site sacrificiel, peuvent être utilisées. L'oxydation à diffusion limitée doit faire l'objet d'une attention particulière en s'assurant qu'elle ne pose pas problème lorsque des éprouvettes préparées à l'avance sont utilisées par comparaison avec des éprouvettes préparées après vieillissement.

NOTE 1 La préparation des éprouvettes à partir d'échantillons vieillis peut être difficile, voir l'Annexe B qui suggère des approches pour préparer de tels matériaux.

NOTE 2 Des études récentes ont montré peu de différence entre l'oxydation d'échantillons vieillis de câbles entiers et celle d'éprouvettes vieilles préparées (voir le document JNES-SS-0903 dans la Bibliographie), pour les câbles de faible diamètre dans un nombre limité de matériaux particuliers.

6.3.2 Éprouvettes haltères

L'Annexe A. fournit des recommandations pour la forme et les dimensions des éprouvettes haltères. Les éprouvettes doivent être découpées dans l'échantillon au moyen d'un emporte-pièce adapté (voir l'Annexe D).

Dans les échantillons utilisés pour la surveillance d'état, le volume de matériaux disponibles est généralement limité. Pour cette raison, il peut être nécessaire d'utiliser des éprouvettes de dimensions inférieures à celles utilisées pour les mesurages de traction.

6.3.3 Éprouvettes tubulaires

Les éprouvettes tubulaires sont utilisées pour certains matériels, comme l'isolant des câbles dont le diamètre du conducteur est trop faible pour permettre le découpage d'éprouvettes

haltères. Les éprouvettes tubulaires sont préparées en retirant l'âme sur la longueur du matériau isolant. La longueur hors tout de l'isolant dénudé doit être de 50 mm au minimum.

L'âme doit être dénudée avec précaution afin de ne pas endommager l'isolant polymère. L'Annexe B suggère des méthodes de préparation des éprouvettes.

Avec ce type d'éprouvette, l'emploi de manchettes ou d'inserts souples est nécessaire pour éviter que les extrémités ne se déchirent au niveau des mors de serrage de la machine d'essai de traction, comme cela est indiqué à l'Annexe A.

6.3.4 Éprouvettes toriques

Des joints toriques moulés peuvent être utilisés comme éprouvettes. Il est essentiel d'utiliser des dimensions identiques d'éprouvettes pour les échantillons vieillis et non vieillis dans le cadre de la surveillance de l'état. Les échantillons toriques peuvent être prélevés sur des matériels vieillis.

6.4 Instrumentation

6.4.1 Machine d'essai de traction

L'instrument utilisé pour les mesurages d'allongement en traction doit être capable de mesurer la force appliquée sur l'éprouvette et la distance entre les mors de serrage de l'éprouvette durant l'étirage en continu de celle-ci à une vitesse constante. La machine d'essai doit pouvoir réaliser l'essai à des vitesses d'essai entre 10 mm/min et 100 mm/min avec une tolérance de $\pm 10\%$.

Les mors de serrage de l'éprouvette doivent être solidarisés à la machine d'essai de sorte que l'axe de l'éprouvette coïncide avec la direction de la force de traction passant par l'axe central de l'assemblage de serrage. L'éprouvette doit être maintenue de manière à éviter qu'elle ne glisse des mors de serrage. Les mors pneumatiques sont privilégiés aux mors mécaniques. Le système de serrage ne doit pas produire de contrainte exagérée sur l'éprouvette, susceptible d'entraîner une rupture prématurée de celle-ci au niveau des mors.

Pour les essais d'éprouvettes toriques, la machine d'essai doit comporter deux poulies ou deux axes arrondis solidarisés à la machine, l'un situé sur la partie fixe et l'autre sur la traverse mobile. Ces poulies ou goupilles doivent être alignées suivant la direction de la force de traction et doivent avoir un diamètre inférieur ou égal au tiers du diamètre interne initial de l'éprouvette torique et supérieur ou égal à trois fois le diamètre du brin.

L'indicateur de force doit être capable d'afficher la force de traction à laquelle est soumise l'éprouvette et indiquer la valeur de cette force avec une exactitude d'au moins 1 % par rapport à la valeur réelle.

6.4.2 Etalonnage

L'instrument doit être étalonné conformément aux recommandations du fabricant, par référence à une norme de mesurage nationale et être accompagné d'un certificat d'étalonnage des appareils de mesurage et d'essai, pour la plage de valeurs de force et d'allongement appropriées des éprouvettes en essai.

6.4.3 Utilisation d'extensomètres

Le mesurage de la distance entre les mors de serrage ou le déplacement de la partie mobile de la machine d'essai de traction étalonnée conformément aux spécifications du fabricant doit permettre de réaliser l'allongement de l'éprouvette pendant l'essai de traction.

Un extensomètre permet une autre méthode possible pour mesurer l'allongement. Dans ce cas, un extensomètre sans contact doit être utilisé. Des extensomètres vidéo sans contact sont disponibles et peuvent être utilisés pour mesurer l'allongement des éprouvettes avec des