IEC/IEEE 62582-2

Edition 2.0 2022-11

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Nuclear power plants – Instrumentation and control important to safety – Electrical equipment condition monitoring methods – Part 2: Indenter measurements

Centrales nucléaires de puissance – Instrumentation et contrôle-commande importants pour la sûreté – Méthodes de surveillance de l'état des matériels électriques – Partie 2: Mesurages indenter

IEC/IEEE 62582-2:2022-11(en-fr)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 27.120.20

ISBN 978-2-8322-5840-8

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IEC/IEEE 62582-2 was prepared by subcommittee 45A: Instrumentation, control and electrical power systems of nuclear facilities, of IEC technical committee 45: Nuclear instrumentation, in cooperation with Nuclear Power Engineering Committee of the IEEE, under the IEC/IEEE Dual Logo Agreement between IEC and IEEE. It is an International Standard.

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

This second edition cancels and replaces the first edition published in 2011, and its Amendment 1:2016. This edition constitutes a technical revision.

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

a) Modification of the title;
b) Consideration of publication of IEC/IEEE 60780-323.

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

FDIS	Report on voting
45A/1434/FDIS	45A/1444/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with the rules given in the ISO/IEC Directives, Part 2, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts of IEC/IEEE 62582 series, under the general title *Nuclear power plants – Instrumentation and control important to safety – Electrical equipment condition monitoring methods*, can be found on the IEC website.

The IEC Technical Committee and IEEE Technical Committee have decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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

INTRODUCTION

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

This part of IEC/IEEE 62582 specifically focuses on indenter modulus methods for condition monitoring for the management of ageing of electrical equipment installed in nuclear power plants. The indenter method is commonly used to carry out measurements on cables (jackets, insulation) and O-rings.

This part 2 of IEC/IEEE 62582 contains detailed descriptions of condition monitoring based on indenter modulus measurements.

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

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

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

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

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

IEC/IEEE 62582-2 is the third level IEC SC 45A document tackling the specific issue of application and performance of indenter modulus measurements in management of ageing of electrical instrument and control equipment in nuclear power plants.

IEC/IEEE 62582-2 is to be read in association with IEC/IEEE 62582-1, which provides background and guidelines for the application of methods for condition monitoring of electrical equipment important to safety of nuclear power plants.

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

c) Recommendations and limitations regarding the application of this standard

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

d) Description of the structure of the IEC 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 NSS17 for computer security at nuclear facilities. The safety and security terminology and definitions used by the SC 45A standards are consistent with those used by the IAEA.

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

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

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

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

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

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

Part 2: Indenter measurements

1 Scope

This part of IEC/IEEE 62582 contains methods for condition monitoring of organic and polymeric materials in instrumentation and control systems using the indenter measurement technique in the detail necessary to produce accurate and reproducible measurements. It includes the requirements for the selection of samples, the measurement system and measurement conditions, and the reporting of the measurement results.

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

This document is intended for application 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
indenter modulus
ratio between the changes in applied force and corresponding displacement of a probe of a standardised shape, driven into a material

Note 1 to entry: It is expressed in $N \cdot mm^{-1}$.

Note 2 to entry: The term “modulus” typically refers to the modulus of elasticity of a material which is defined as the ratio of the applied stress and the corresponding strain and is expressed in $N \cdot m^{-2}$ (Pa). However, in the use of the indenter, it has become common practice to use the term indenter modulus to describe the ratio of the change in applied force to material deformation and express it in $N \cdot mm^{-1}$.

4 Abbreviated terms and acronyms

DBE	design basis event
IM	indenter modulus
SiR	silicone rubber
CSPE	chlorosulphonated polyethylene
EPDM	ethylene propylene diene monomer
XLPE	crosslinked polyethylene

5 General description

A typical indenter uses an instrumented probe, which is driven at a fixed velocity into the material and includes a load cell or similar force-measuring device, connected to the probe, which measures the force necessary to maintain the constant velocity. The probe's displacement is measured by an appropriate transducer. The travel and force are purposely limited to protect the material from permanent damage. The indenter modulus is calculated by dividing the change in force by the corresponding displacement during inward travel.

6 Applicability, reproducibility and complexity

6.1 General

When organic and polymeric materials age, they often harden which will result in an increase of indenter modulus. Some materials, such as some formulations of butyl rubber, soften during thermal and/or radiation ageing. The purpose of monitoring changes in indenter modulus is to estimate degradation rates and levels induced by ageing.

6.2 Applicability

The indenter method is commonly used to carry out measurements on cables (jackets, insulation) and O-rings. Its use requires special fixtures depending on the geometry of the samples.

This method should only be applied to materials whose hardness changes monotonically with ageing.

The indenter method can be carried out on equipment with high integrity in a non-invasive manner. However, the process of performing indenter measurements on equipment in field should include controls to ensure that damage – from the probe or from handling in order to access suitable measurement points – has not been imparted to the equipment. The process should include correction of any equipment that has been damaged or suspected of incurring damage.

Measurements in the field require access to the exterior wall of the equipment. For field measurements on cables, this often limits the measurements to jacket materials. It can be possible to assess the condition of cable insulation from indenter measurements on its jacket if there is a known relationship between the ageing degradation of the jacket material and the degradation of the insulation. This relationship shall be justified to be valid and sufficiently sensitive to provide the valid monitoring through the life of the test object.

6.3 Reproducibility

Indenter modulus values can be influenced by variability in specimen dimensions and construction, temperature and moisture content of the specimen, stabilisation of the specimen, and contamination of the specimen. If measurements are made under excessive vibration, this can influence the measured value. The influence by variability in the specimen dimensions and construction is typically the case for measurements on cables, where the measurement point may be situated above a cavity beneath the jacket surface. The cross-section of typical cable core insulation can differ substantially from that of an ideal tube and can result in variability in the measured values of indenter modulus depending on where the measurement is made. These variations tend to be localised. Measurements shall be taken at several points on the equipment to compensate for these local variations (see 7.6).

An illustration of variations due to variability in specimen dimensions and construction is given in Annex A.

A good knowledge of the construction of the equipment is important before the selection of measurement positions is made. In the case of loosely constructed cables, the variability is expected to be high and it is important that the measurements on the jacket are made over a conductor rather than free space.

6.4 Complexity

The degree of complexity experienced during indenter modulus measurements in the field will often depend on cable accessibility. Existing instruments can be used in the field on cables that are accessible. In this case, data generation is rapid and measurements at a large number of points can be carried out over short time periods. Instruments can be configured such that data are generated and stored directly. Measurements on equipment with more complex geometries and limited accessibility can require the development of special fixtures. The same fixture shall be used for repeated indenter modulus measurements.

7 Measurement procedure

7.1 Stabilisation of the polymeric materials

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

7.2 Sampling and measurement locations

Laboratory measurements of indenter modulus on samples selected from the field and indenter modulus measurements in the field only provide information on the status of the equipment at a specific location. Knowledge of the environmental conditions in representative areas during plant operation is a prerequisite for selecting locations. Since heating and radiation effects on equipment under test could be most apparent closest to the sources of heat and radiation, the choice of locations should consider capturing the potential for significant ageing effects near sources of heating and radiation. The position of the test locations and available information about the environmental time history of the locations selected shall be documented.

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

7.3 Conditions for measurement

The surface on which the measurements are made shall be cleaned of surface debris. In the field, it can be necessary to apply a dry wipe to remove accumulated dirt from the surface and prevent contamination of the indenter instrument. Under no circumstances shall solvents be used for surface cleaning.

The indenter modulus varies with the temperature and moisture content of the sample as shown in Annex A.

When measurements are carried out in the laboratory, e.g. after accelerated thermal ageing, they shall be made in a surrounding air temperature of (20 ± 5) °C and a relative humidity of 45 % to 75 %. Samples shall be allowed time to reach equilibrium with their surroundings before measurements are started.

NOTE Where the materials are hygroscopic, it is noted that the sample can be extremely dry after artificial accelerated ageing as a consequence of long-term exposure to high temperatures in an oven. For these materials, the values of indenter modulus measured can be significantly higher than for a sample in equilibrium with the laboratory atmosphere. This is particularly important for condition monitoring of hygroscopic insulation material when the final value of indenter modulus, on which qualified condition is based, is measured on completion of accelerated thermal ageing before the sample is subjected to a DBE test. Clause A.3 provides guidance on dealing with this specific concern.

It may not be possible to make field measurements in standard atmospheric conditions. In such cases the surrounding air temperature and the temperature at the surface at which the measurements are made shall be recorded.

Annex A shows a method for transformation of a measured indenter modulus to a corresponding modulus at a different temperature. In addition to reporting the temperature at which the value has been measured, it is recommended that the corresponding value at 20 °C be calculated and reported.

7.4 Instrumentation

The indenter functions by driving an instrumented probe at a fixed velocity into the material whilst a load cell or similar force-measuring device, connected to the probe, measures the applied force. The probe shall have the shape of a truncated steel cone with the geometry and dimensions shown in Figure 1. The probe's displacement is measured by an appropriate transducer. The point at which the tip of the probe is brought into contact with the material is sensed by a change in force. The probe's total displacement is normally limited to a fraction of a mm to prevent permanent deformation and to keep within the range of approximate linear proportionality between force and displacement. The indenter modulus (IM) is then calculated by dividing the change in force by the corresponding displacement during inward travel. The small displacements and loads that occur during this process prevent permanent effects on the material.

NOTE 1 Although the total displacement is limited, for some materials the relationship between force and displacement is still significantly non-linear.

Dimensions in millimetres

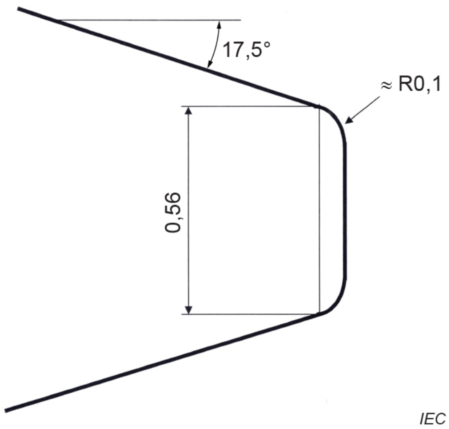

Figure 1 – Geometry and dimensions of the profile of the probe tip (truncated cone) used in the indenter

A typical indenter is a hand held instrument. At the head of the instrument, an appropriate clamping device holds a cable or wire securely in position so that the probe can be driven uniformly into the jacket or insulation of the cable or wire respectively. The probe is situated within the instrument and is attached to a sensitive load cell. A servo-controlled electric motor with appropriate gearing provides the capability to drive the probe towards the sample and the probe's position is measured by a transducer. A temperature sensor can be located close to the clamping device. The power and servo-control to the electric motor, and outputs from the load cell, transducer and temperature sensor are fed by cable into a separate controller which can be directly connected to a computer or capable of data storage in-situ which can be downloaded into a remote computer. Parameters such as probe velocity, and maximum load, and displacement are preloaded into the controller before the start of measurement. The instrument is also designed such that the cable clamp can be modified to allow calibration of the load cell using an appropriate weight and the probe travel using a dial gauge.

NOTE 2 When measuring on a wire with small diameters the result could be more non-linear in the beginning of the curve due to that only a part of the tip of the anvil have contact with the sample. This could influence the reproducibility with only small changes in the way to perform the measurement. See Figure 2.

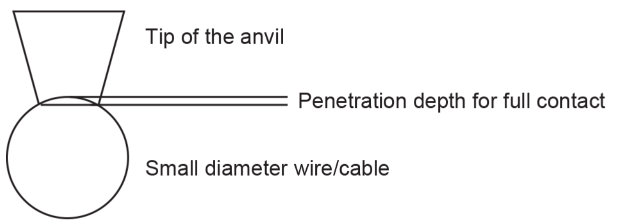

Figure 2 – Penetration depth for full contact on the tip of the anvil

7.5 Calibration and tolerances

The indenter and the measurement system shall be calibrated before each series of measurements in accordance with the manufacturer's instructions. The calibration shall be carried out on both the force sensor and probe velocity. The total error of force measurement shall be less than 3 % of the upper limit of the force range, including instrumentation tolerances as well as reading precision. The probe velocity shall be constant. The total measurement error of the required velocity shall be less than 2 %.

The user of the instrument shall have a defined process for visual inspection and measuring of the tip of the anvil. If wear or other damage to the tip of the anvil occurs to the extent that the dimensions are no longer according to Figure 1, then the anvil shall be replaced.