IEC/IEEE 62582-2

Edition 1.0 2011-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

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

IEC/IEEE 62582-2:2011

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue
New York, NY 10016-5597
United States of America
Email: stds.ipr@ieee.org
Web: www.ieee.org

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About the IEEE

IEEE is the world's largest professional association dedicated to advancing technological innovation and excellence for the benefit of humanity. IEEE and its members inspire a global community through its highly cited publications, conferences, technology standards, and professional and educational activities.

About IEC/IEEE publications

The technical content of IEC/IEEE publications is kept under constant review by the IEC and IEEE. Please make sure that you have the latest edition; corrigenda or amendments might have been published.

- IEC catalogue of publications: www.iec.ch/searchpub

The IEC online catalogue enables you to search by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, withdrawn and replaced publications.

- IEEE products and services : www.ieee.org/go/shop

IEEE publishes nearly a third of the world's technical literature in electrical engineering, computer science, and electronics. Browse the latest publications including standards, draft standards, standards collections, and much more.

- IEC Just Published: www.iec.ch/online_news/justpub

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also by monthly email.

- Electropedia: www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.

- Customer Service Centre: www.iec.ch/webstore/custserv

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:
Email: csc@iec.ch
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00

.

IEC/IEEE 62582-2

Edition 1.0 2011-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX R

ICS 27.120.20

ISBN 978-2-88912-667-5

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 2: Indenter modulus

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 Publication(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.

   IEEE Standards documents are developed within IEEE Societies and Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of IEEE and serve without compensation. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information contained in its standards. Use of IEEE Standards documents is wholly voluntary. IEEE documents are made available for use subject to important notices and legal disclaimers (see http://standards.ieee.org/IPR/disclaimers.html for more information).

   IEC collaborates closely with IEEE in accordance with conditions determined by agreement between the two organizations. This Dual Logo International Standard was jointly developed by the IEC and IEEE under the terms of that agreement.

2) The formal decisions of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees. The formal decisions of IEEE on technical matters, once consensus within IEEE Societies and Standards Coordinating Committees has been reached, is determined by a balanced ballot of materially interested parties who indicate interest in reviewing the proposed standard. Final approval of the IEEE standards document is given by the IEEE Standards Association (IEEE-SA) Standards Board.

3) IEC/IEEE Publications have the form of recommendations for international use and are accepted by IEC National Committees/IEEE Societies in that sense. While all reasonable efforts are made to ensure that the technical content of IEC/IEEE Publications is accurate, IEC or IEEE cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.

4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications (including IEC/IEEE Publications) transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC/IEEE Publication and the corresponding national or regional publication shall be clearly indicated in the latter.

5) IEC and IEEE do not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC and IEEE are not responsible for any services carried out by independent certification bodies.

6) All users should ensure that they have the latest edition of this publication.

7) No liability shall attach to IEC or IEEE or their directors, employees, servants or agents including individual experts and members of technical committees and IEC National Committees, or volunteers of IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board, for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC/IEEE Publication or any other IEC or IEEE Publications.

8) Attention is drawn to the normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) Attention is drawn to the possibility that implementation of this IEC/IEEE Publication may require use of material covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. IEC or IEEE shall not be held responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patent Claims or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

International Standard IEC/IEEE 62582-2 has been prepared by subcommittee 45A: Instrumentation and control of nuclear facilities, of IEC technical committee 45: Nuclear instrumentation, in cooperation with the Nuclear Power Engineering Committee of the Power & Energy Society of the IEEE[1], under the IEC/IEEE Dual Logo Agreement between IEC and IEEE.

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

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

FDIS	Report on voting
45A/841/FDIS	45A/850/RVD

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

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

A list of all parts of IEC/IEEE 62582 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 publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

---

[1] A list of IEEE participants can be found at the following URL:http://standards.ieee.org/downloads/62582-2/62582-2-2011/62582-2-2011_wg-participants.pdf.

INTRODUCTION

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

This part of this IEC/IEEE standard 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 of IEC/IEEE 62582 is the second part of the IEC/IEEE 62582. It 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.

Historically, IEEE Std 323-2003 introduced the concept and role that condition based qualification could be used in equipment qualification as an adjunct to qualified life. In equipment qualification, the condition of the equipment for which acceptable performance was demonstrated is the qualified condition. The qualified condition is the condition of equipment, prior to the start of a design basis event, for which the equipment was demonstrated to meet the design requirements for the specified service conditions.

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

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

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

Part 2 of IEC/IEEE 62582 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.

Part 2 of IEC/IEEE 62582 is to be read in association with part 1 of IEC/IEEE 62582, 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 Standard establishes no additional functional requirements for safety systems.

d) Description of the structure of the IEC SC 45A standard series and relationships with other IEC documents and other bodies documents (IAEA, ISO)

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

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

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

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

IEC 61513 has adopted a presentation format similar to the basic safety publication IEC 61508 with an overall safety life-cycle framework and a system life-cycle framework and provides an interpretation of the general requirements of IEC 61508-1, IEC 61508-2 and IEC 61508-4, for the nuclear application sector. Compliance with IEC 61513 will facilitate consistency with the requirements of IEC 61508 as they have been interpreted for the nuclear industry. In this framework IEC 60880 and IEC 62138 correspond to IEC 61508-3 for the nuclear application sector.

IEC 61513 refers to ISO as well as to IAEA 50-C-QA (now replaced by IAEA GS-R-3) 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.

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

Part 2: Indenter modulus

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 the indenter modulus 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. Part 1 of IEC/IEEE 62582 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 the qualification of equipment important to safety is found in IEEE Std 323.

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

2 Terms and definitions

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

2.1
indenter modulus

ratio between the changes in applied force and corresponding displacement of a probe of a standardised shape, driven into a material. It is expressed in $N \cdot mm^{-1}$.

NOTE 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 $N \cdot mm^{-1}$.

3 Abbreviations and acronyms

DBE	Design Basis Event
IM	Indenter Modulus
SiR	silicone rubber
CSPE	chlorosulphonated polyethylene
EPDM	ethylene propylene diene monomer
XLPE	crosslinked polyethylene

4 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.

5 Applicability, reproducibility, and complexity

5.1 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.

5.2 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 may 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 may 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 life.

5.3 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 may 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 6.6).

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

NOTE 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.

5.4 Complexity

The degree of complexity experienced during indenter modulus measurements in the field will often depend on cable accessibility. Existing instruments may 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 may require the development of special fixtures. The same fixture shall be used for repeated indenter modulus measurements.

6 Measurement procedure

6.1 Stabilisation of the polymeric materials

An appropriate time period shall be allowed for the polymeric materials in recently manufactured equipments 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.

6.2 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 equipment heating and radiation effects 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 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.

6.3 Conditions for measurement

The surface on which the measurements are made shall be cleaned of surface debris. In the field, it may 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 1 Where the materials are hygroscopic, it should be 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.

NOTE 2 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.

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

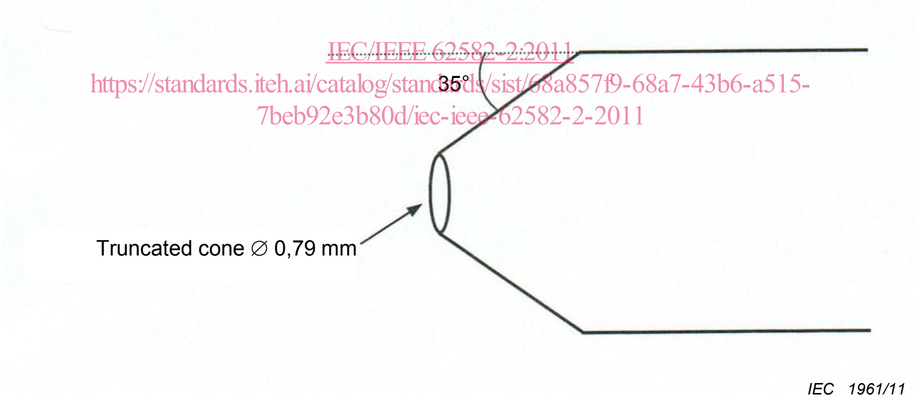

Figure 1 – A schematic representation of the geometry and dimensions of the probe tip used in the indenter

A typical indenter is a hand held cylindrical 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 is 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 may be directly connected to a computer or capable of data storage in-situ which may 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.

6.5 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 %.

6.6 Selection of measurement points

In each of the selected locations for field measurements, measurements shall be carried out at several points and the mean value and standard deviation shall be reported. If the number of points is more than 7, the highest and lowest value shall be deleted before calculation of the mean value and the standard deviation. For measurements on cables, a minimum of three points around the circumference at each of three longitudinal positions shall be used. Where space is limited, it may not be possible to rotate around the cable circumference. In this case, a minimum of nine points shall be selected with a separation of 60 mm to 100 mm along the cable length.

In the case of laboratory measurements on samples of cables, a minimum of three points around the circumference at each of three longitudinal positions shall be used. None of the measurement points shall be less than 100 mm from the ends of the sample.

For measurements on o-rings, a similar number of points shall be measured if the size of the o-ring allows.

6.7 Selection of probe velocity and maximum force

Before the start of the measurement, the test parameters shall be loaded into the measurement system. In particular, the required maximum load and maximum displacement should be set as limits to prevent damage to the equipment measured.

The probe velocity can have a significant influence on the measured value of indenter modulus. The probe velocity shall be 5 mm·min^{-1} to 5,2 mm·min^{-1}. The probe velocity that is selected shall be reported.

The maximum force that is selected needs to be a compromise between a value which is high enough to achieve reasonable resolution in the displacement axis and a value that is low enough to ensure that the probe does not damage the cable. For many polymeric insulation materials, a maximum force of 10 N is recommended. This will normally result in a probe penetration depth which is significantly less than 1 mm. For certain insulation materials, such as SiR, a maximum value lower than 10 N may be required to avoid excessive penetration.

6.8 Clamping

When carrying out measurements on cables, the measured value of indenter modulus may be strongly affected by variations in the force used to keep the cables securely in position within the clamp. In order to minimise these effects, the cable shall be clamped using the minimum force required to keep it in place. Problems in clamping shall be included in the measurement report.

6.9 Determination of the value of the indenter modulus

The indenter modulus is determined by the slope of the force-displacement curve and is expressed in N·mm^{-1}.

$$IM = (F_2 - F_1)/(d_2 - d_1) \tag{1}$$