[Document reference]

NEW WORK ITEM PROPOSAL

Proposer Sweden	Date of proposal
TC/SC	Secretariat
Date of circulation	Closing date for voting

A proposal for a new work item within the scope of an existing technical committee or subcommittee shall be submitted to the Central Office. The proposal will be distributed to the P-members of the technical committee or subcommittee for voting, and to the O-members for information. The proposer may be a National Committee of the IEC, the secretariat itself, another technical committee or subcommittee, an organization in liaison, the Standardization Management Board or one of the advisory committees, or the General Secretary. Guidelines for proposing and justifying a new work item are given in ISO/IEC Directives, Part 1, Annex C (see extract overleaf). **This form is not to be used for amendments or revisions to existing publications.**

The proposal (to be completed by the proposer)

Title of proposal
Methods for condition monitoring of electrical equipment of safety system for nuclear power plants.

☒ Standard	☐ Technical Specification	☐ Publicly Available Specification

Scope (as defined in ISO/IEC Directives, Part 2, 6.2.1)
Standardization of methods used for monitoring the conditions of electrical equipment ~~Content of measurement report~~ in nuclear power plants. The Standard should include description of the methods, control of parameters of importance for the measurement results and format for reporting of measurement results.

Purpose and justification, including the market relevance and relationship to Safety (Guide 104), EMC (Guide 107), Environmental aspects (Guide 109) and Quality assurance (Guide 102) . (attach a separate page as annex, if necessary)
The importance of management of ageing of electrical components important to safety is recognized. Condition measurements are essential in determination of parameters used for estimation of qualified life from artificial ageing as well as in management of ageing after installation. There is an urgent need for an international Standard for ascertaining quality, reproducibility and comparability of results of condition measurements. See further Annex A

Target date	for first CD	for IS ....
Estimated number of meetings	Frequency of meetings: per year	Date and place of first meeting: Stockholm, Sweden
Proposed working methods	☐ E-mail	☐ ftp

Relevant documents to be considered
IEC 60780 (1998), IEC 60544-5, IEC 60216-1, IEC 1244-1, IEC 167, IEC TS 61244-3,
IEEE 323 (2003)

Relationship of project to activities of other international bodies

Liaison organizations IEEE SC-2.1	**Need for coordination within ISO or IEC** IEC TC112

Preparatory work
Ensure that all copyright issues are identified. Check one of the two following boxes

☐ A draft is attached for comment ☒ An outline is attached

We nominate a project leader as follows in accordance with ISO/IEC Directives, Part 1, 2.3.4 (name, address, fax and e-mail): Kjell Spång,Strandskärsvägen 9,SE-42658 V.Frölunda,Sweden,e-mail kjell.spang@swipnet.se

Concerns known patented items (see ISO/IEC Directives, Part 2) ☐ yes If yes, provide full information as an annex ☒ no	Name and/or signature of the proposer

Comments and recommendations from the TC/SC officers		
1) Work allocation		
☐ Project team	☐ New working group	☐ Existing working group no:
2) Draft suitable for direct submission as		
☐ CD	☐ CDV	☐ Publication as a PAS
3) General quality of the draft (conformity to ISO/IEC Directives, Part 2)		
☐ Little redrafting needed	☐ Substantial redrafting needed	☐ no draft (outline only)
4) Relationship with other activities In IEC In other organizations		
Remarks from the TC/SC officers		

Elements to be clarified when proposing a new work item

Title

Indicate the subject matter of the proposed new standard.

Indicate whether it is intended to prepare a standard, a technical report or an amendment to an existing standard.

Scope

Give a clear indication of the coverage of the proposed new work item and, if necessary for clarity, exclusions.

Indicate whether the subject proposed relates to one or more of the fields of safety, EMC, the environment or quality assurance.

Purpose and justification

Give details based on a critical study of the following elements wherever practicable.

a) The specific aims and reason for the standardization activity, with particular emphasis on the aspects of standardization to be covered, the problems it is expected to solve or the difficulties it is intended to overcome.

b) The main interests that might benefit from or be affected by the activity, such as industry, consumers, trade, governments, distributors.

c) Feasibility of the activity: Are there factors that could hinder the successful establishment or general application of the standard?

d) Timeliness of the standard to be produced: Is the technology reasonably stabilized? If not, how much time is likely to be available before advances in technology may render the proposed standard outdated? Is the proposed standard required as a basis for the future development of the technology in question?

e) Urgency of the activity, considering the needs of the market (industry, consumers, trade, governments etc.) as well as other fields or organizations. Indicate target date and, when a series of standards is proposed, suggest priorities.

f) The benefits to be gained by the implementation of the proposed standard; alternatively, the loss or disadvantage(s) if no standard is established within a reasonable time. Data such as product volume of value of trade should be included and quantified.

g) If the standardization activity is, or is likely to be, the subject of regulations or to require the harmonization of existing regulations, this should be indicated.

If a series of new work items is proposed, the purpose and justification of which is common, a common proposal may be drafted including all elements to be clarified and enumerating the titles and scopes of each individual item.

Relevant documents

List any known relevant documents (such as standards and regulations), regardless of their source. When the proposer considers that an existing well-established document may be acceptable as a standard (with or without amendments), indicate this with appropriate justification and attach a copy to the proposal.

Cooperation and liaison

List relevant organizations or bodies with which cooperation and liaison should exist.

Preparatory work

Indicate the name of the project leader nominated by the proposer.

NWIP. Methods for condition monitoring of electrical equipment of safety system for nuclear power plants. Purpose and justification.

1. Purpose

The purpose of this NWIP is to standardize the most commonly used condition monitoring methods – mechanical condition indicators (elongation, indenter modulus,..) dielectric condition indicators (insulation resistance, dielectric loss factor,..), chemical condition indicators (DSC-OIT, OITP, ..). The aims are to identify and define the parameters of primary importance for the results of condition measurements and to standardize the format for reporting of condition measurement results. The requirements on the performance of the condition measurements have to be prescribed in sufficient detail to ensure a degree of accuracy and reproducibility of the results that makes them acceptable for management of ageing of electrical equipment in safety systems of nuclear power plants.

2. Justification for a specific standard on condition monitoring

Existing IEC Standards as well as IEEE Standards and other national Standards on qualification of electrical equipment in safety systems of nuclear power plants refer to condition monitoring as an important tool in management of ageing. Measurement of condition indicators are used in determination of activation energies for calculation of qualified life and in verification after installation that the equipment maintains a status for which it has been demonstrated that it meets the design requirements for the specified service conditions. Methods for condition monitoring are described in various international and national standards. A specific standard satisfying what is needed for application to the management of ageing of electrical equipment in safety systems of nuclear power plants is, however, missing.

There are many benefits of a generally accepted Standard for condition measurement designed for application to the management of ageing of electrical equipment of nuclear power plants: comparability of measurement results from different origins, facilitation of exchange of experiences, usefulness of databases on long term environmental effects on degradation of electrical equipment and components, broad acceptance of qualification results, etc.

3. Relationship to IEEE

It is proposed that the standard is developed within IEC SC45A (WGA10) in close cooperation with members of IEEE SC-2.1– responsible for the preparation and revision of IEEE 323 – with the target that it will ultimately be subjected to a joint logo procedure. The board of IEEE SC-2.1 has expressed that they support this. A joint logo IEC/IEEE standard would widen the use of identical condition measurements to the majority of nuclear power applications, which would very significantly increase the general benefit of the results.

4. Needs for high accuracy and repeatability

In order for the results of the condition measurements to be useful for its purposes the methods must be characterised by a high degree of reproducibility and repeatability.
In 1996-97, an IAEA expert group initiated round robin measurements of conditions of identical unaged and aged cable samples. The measurements were made by a number of laboratories in various countries. The results showed substantial variations between the laboratories. An analysis of the reasons showed that a number of test parameters of importance for the results were not adequately specified and the tradition of use of the methods varied between the laboratories. The following statement was made by the expert group, reported in IEAE TECDOC 1188: "The main conclusion that has come out of this series of round-robin tests has been the need for more detailed specification of the test procedures for condition monitoring methods".

Use of Arrhenius or similar formulas for calculation of acceleration factors in artificial ageing requires knowledge of activation energies of organic materials. The calculation of acceleration factors and qualified life is very sensitive to the values of activation energies as illustrated in the example in Figure 1.

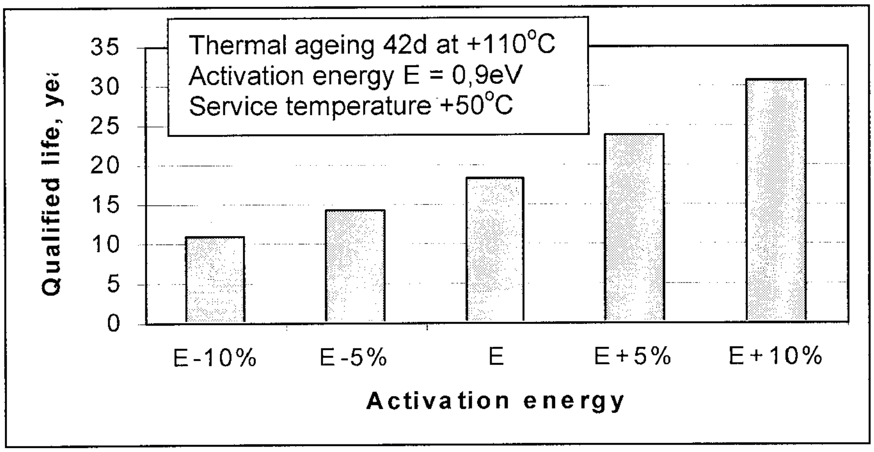


Figure 1. Example of calculated qualified life from artificial thermal ageing

As shown in Figure 1, a small deviation in the activation energy results in a large deviation in the qualified life calculated. Determination of relevant activation energies are normally based on tests which include use of condition monitoring. The relevance of the activation energy determined is related to a number of factors. The quality and repeatability of the condition monitoring technique used is one of the most important factors.

Application of condition monitoring is becoming more common in management of ageing after installation, e.g. as a method for ascertaining operability after installation and for extension of qualified life. IEEE-323 (2003) has also included qualified condition as an alternative or compliment to qualified life. In order to be applicable to management of ageing after installation and use of the concept of qualified condition, the condition indicator values must be determined within tolerances and with a repeatability that makes it possible to compare the condition of the equipment at different measurement occasions with a high degree of accuracy. The problem that arises with non-accurate or non-identical measurements is illustrated by Figure 2, reproducing data from the IAEA round robin measurements. The oxygen induced temperature (OITD) was measured by two different laboratories on identical samples of new and artificially aged cable insulation. Laboratory A presented values on the aged cable samples which were higher than the values of the un-aged cable samples presented by laboratory B. It is obvious that more well defined, accurate and standardised measurements are needed for application to management of ageing and use of the concept of qualified condition.

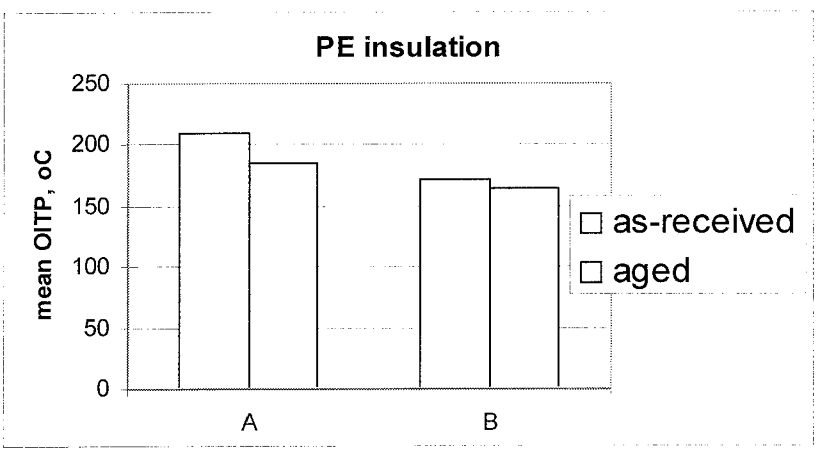


Figure 2. Results of OITP measurements in two different laboratories on identical cable insulation samples

NWIP. Methods for condition monitoring of electrical equipment of safety system for nuclear power plants. Outline.

The text provided below is intended as a suggestion of the structure of the Standard and of what kind of information that should be worked out and included. A suggestion of a standard procedure for indenter measurements is given as an illustration of the details needed for achievement of the repeatability and accuracy required in management of ageing.

Foreword

In case this standard is developed as a joint effort between IEC and IEEE this should be indicated in the foreword.

Introduction

1 Scope

This International Standard specifies methods for condition monitoring of electrical equipment of safety system for nuclear power plants. The methods specified are applicable as tools for determination of values (e.g. activation energies) used in determination of qualified life in initial qualification. They are furthermore applicable to follow-up and management of ageing after installation, including application of the concept of qualified condition.

2 Normative references

3 Definitions and abbreviations

3.1 Condition monitoring

Measurement of a physical property of equipment, its part or materials, that changes with time.

3.2 Qualified condition (from IEEE 323-2003)

The condition of equipment, prior to start of a design basis event, for which the equipment was demonstrated to meet the design requirements for the specified service conditions.

Further definitions to be given

4 Examples of application of condition monitoring as part of equipment qualification and management of ageing

4.1 General

Condition monitoring as part of management of ageing of electrical components in nuclear power plants can have one or a combination of the following aims

- Determination of activation energies for use in Arrhenius and similar formulas for establishment of qualified life from artificial laboratory thermal ageing, followed by demonstration that the equipment meets the design requirements for the specified service conditions.

- Establishment of qualified condition as an alternative or complement to qualified life. The qualified condition is the condition - status of degradation due to ageing – for which the equipment has been demonstrated to meet the design requirements for the specified service conditions.
- Management of ageing after installation based on following the change of the value of a condition indicator and observing when it approaches the qualified condition.

Condition monitoring can also be used for determination if the degradation of the age sensitive materials included in the equipment is within values at which it is well established that the ageing effects on operability in specified service conditions are negligible.

4.2 Use of condition monitoring in determination of activation energies

The most common way to determine activation energies for use in establishment of qualified life from accelerated thermal ageing includes use of condition monitoring. Basically, the activation energy is calculated from results of measurement of the change of a certain condition (degradation) indicator as function of time at different temperatures. The pairs of values of temperature and time to reach a certain level of degradation are plotted in an Arrhenius diagram, where the inverse of absolute temperatures (*1/T*) are indicated in a linear scale on the abscissa and the time *t* is indicated in a logarithmic scale on the ordinate. An example is shown in Figure 1.

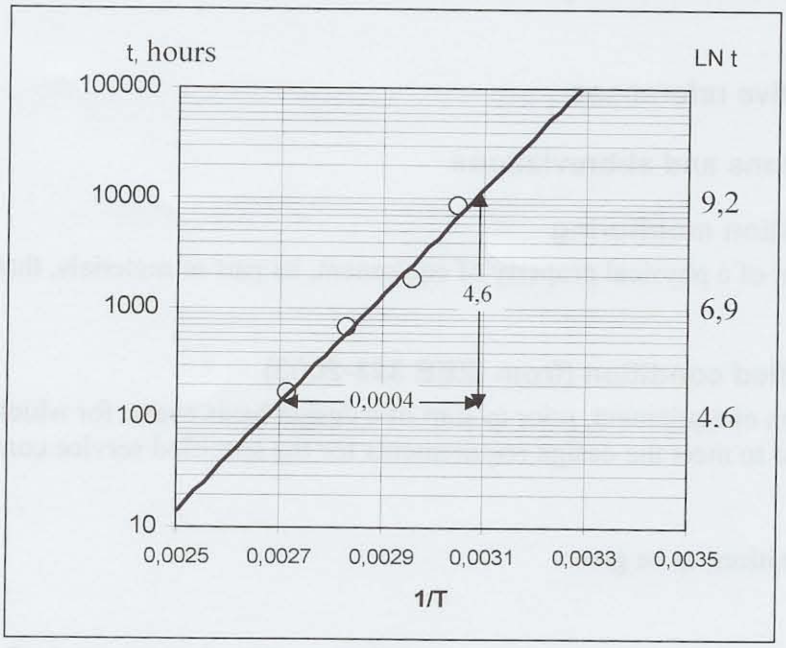


Figure 1. Example of an Arrhenius diagram

A straight line between the points indicates that there is an Arrhenius behaviour of the dependency between rate of degradation and temperature. The activation energy E in eV is calculated from the slope of the line

$E = S*k$, where S is the slope of the line ($\Delta t/\Delta(1/T)$) and k is the Bolzman constant ($0{,}8617*10^{-4}$ eV/K).

In the example above $E = \frac{4,6}{0,0004} \cdot 0,8617 \cdot 10^{-4} = 0,99eV$

The acceleration factor determined by the Arrhenius formula is very sensitive to the value of the activation energy. The dependency is shown in Figure 2.

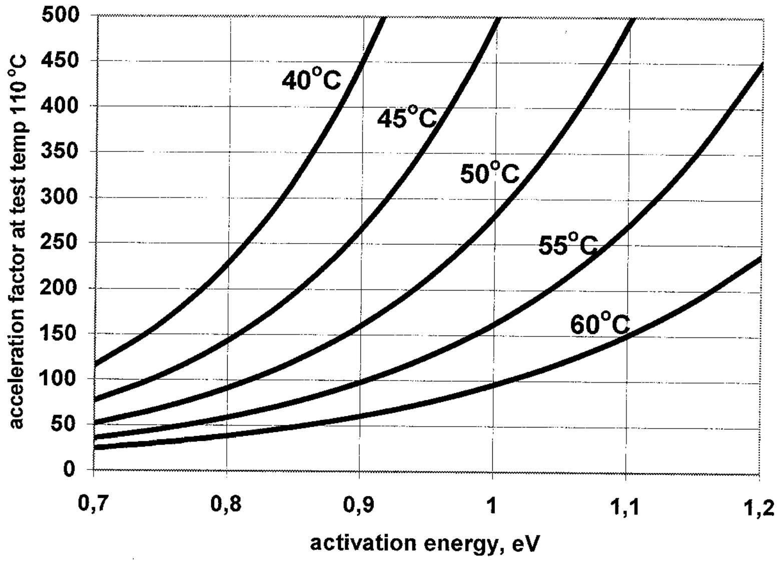
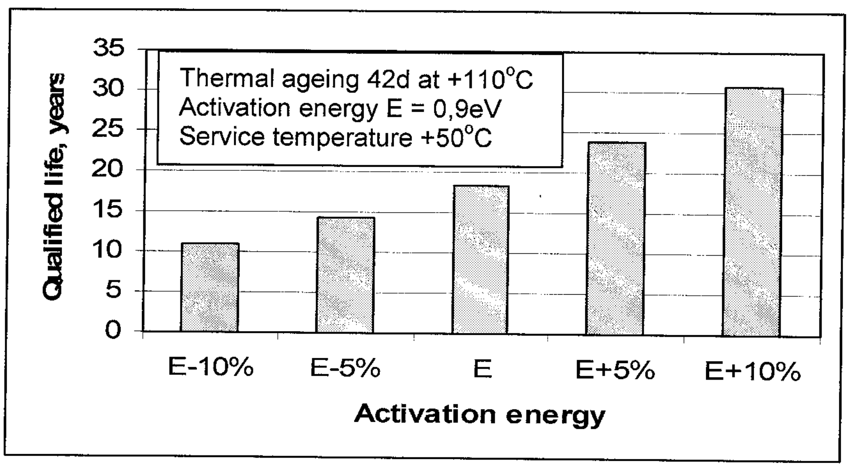


Figure 2. Thermal ageing at temperature 110°C. Acceleration factor as function of service temperature and activation energy.



If the actual service temperature is +50°C and the accelerated thermal ageing is made at 110°C, the acceleration factor is just above 150 at an activation energy of 0,9 eV. A 10% overestimation of the activation energy results in an assumption of an acceleration factor above 250 and an overestimation of qualified life by 67%. The diagram shows that inaccuracy in determination of the activation energy has a large influence on the acceleration factor and consequently on the qualified life determined from thermal ageing followed by demonstration that the equipment meets the design requirements for the specified service conditions. High accuracy and repeatability of the condition monitoring method used in measurements for determination of activation energies is required.

4.3 Use of condition monitoring in application of qualified condition

4.3.1 General

Condition based qualification is included in IEEE 323*) as a complement or alternative to qualified life.

*) If qualified condition is included in the revision of IEC 60780 we can refer to this. The reasons/benefits of including condition based qualification should be left to the generic standard 60780.

4.3.2 Establishment of qualified condition

The use of condition based qualification requires as a minimum establishment of the values of appropriate condition indicators at the end of an age conditioning prior to the test (e.g. DBE testing) for demonstration that the equipment meets the design requirements for the specified service conditions. These values represent the qualified condition. The benefit of using condition based qualification as complement or alternative to qualified life is considerably enhanced if the trends (variation with time) of the values of the condition indicators are established during the age conditioning, e.g. by performing the age conditioning incrementally and measuring the values of the condition indicators at each increment.

In case the initial qualification has been performed with the target to establish a qualified life and no condition measurements have been included it may be possible to establish the qualified condition afterwards without repeating the demonstration (e.g. DBE test) that the equipment meets the design requirements for the specified service condition. If identical samples of equipment are available which are new or have been stored in environmentally controlled conditions, the qualified condition can be established by repeating the age conditioning used in the establishment of the qualified life and determination of the values of appropriate condition indicators (during and) at the end of the conditioning.

It is crucial for the application of qualified condition that the monitoring of the condition is repeatable. The use of the qualified condition for management of ageing after installation requires that the methods used are very well defined and documented and that the measurement errors are small. The measurements after several years of installation may be made by other personnel, instrumentation and in other laboratories than used when the qualified condition was established.

It is also important that the condition indicators are sensitive to effects of ageing and well correlated to exposure time.

4.3.3 Management and follow-up of ageing of installed equipment

The degradation due to ageing of installed equipment can be followed by condition monitoring at certain time intervals. If the equipment qualification is condition based and the end condition to which it is qualified for operation under specified service conditions, the condition measured is compared with the qualified condition.

Depending on the condition indicators used and the acceptable influence of the measurement on the equipment, the condition measurement can be non-destructive or destructive. If the equipment is accessible and does not have to be removed for condition measurement and the method used is non-destructive, the condition measurement can be made on-site. If the equipment is not accessible for condition measurement or the method used is destructive, the condition measurements have to be made on equipments which are either removed and substituted by identical equipments or on spare samples which have been stored in representative positions (equally or more severe than the conditions of installed equipments).

4.4 Baseline data from condition monitoring

Knowledge of limits of degradation due to ageing below which the operability of equipments in specified service conditions is not significantly affected can be very useful in application of condition based qualification or in complimentary control of life based qualification. An example used extensively for elastomeric materials is elongation-at-break, defined either as the minimum limit of elongation-at-break or as the ratio between elongation-at-break for the aged material and for the unaged material. The general usefulness of data on values of condition indicators after ageing for which operability in DBE has been demonstrated depends largely on the use of identically performed, standardised and well reported condition measurements.

5 Summary of requirements on methods for condition monitoring

A general requirement on methods for condition monitoring used as an element in qualification and management of ageing of electrical equipment of the safety system of NPP's is that

- It is sensitivity to degradation due to ageing of importance to the performance under design service conditions;
- It has a consistent trend with ageing of the material monitored;

It is critical that the methods used for condition monitoring are very well defined and have a high degree of repeatability.

6 Indicators used in condition monitoring of electrical equipment for nuclear power plants

6.1 General

Condition indicators are used for assessing the effect of degradation from ageing. There are a large number of methods and indicators that have been and are used. This international Standard is limited to the most commonly used indicators. From the point of view of usefulness they can be subdivided in

– Non-destructive

– Destructive

Non-destructive methods are often preferable since the degradation of the equipment can be followed without demounting and substitution of installed equipment or use of equipment deposits.

6.2 Mechanical indicators

The most commonly used indicators of degradation of mechanical properties are

- Tensile, often indicated by elongation-at-break
- Indenter modulus

Tensile measurements are generally destructive.

Indenter modulus measurements are generally regarded as non-destructive. Normally, the intrusion of the anvil into the material does not affect the operability or further ageing of the equipment.

6.3 Chemical indicators

The most commonly used indicators of degradation of chemical properties are

- Thermo-gravimetric analysis (TGA)
- Oxidation induction time (OIT)
- Oxidation induction temperature (OITP)
- …

The samples needed for these measurements are normally of the order of a few mg. Samples can normally be collected from the material without affecting the operability or further ageing of the equipment.

6.4 Dielectric indicators

The most commonly used indicators of dielectric properties are

- Insulation resistance
- Dielectric loss factor
- …

6.5 Electrical indicators

The most commonly used electrical indicators of defects in cables are

- TDR
- …

7 Measurement procedures

7.1 General

In this clause the most common methods for the condition monitoring are described in detail. For each method, the items of importance for the measurement results are identified and specified.

One example – indenter measurements – is outlined below illustrating the extent of details and items that needs to be given for each condition indicator included in this standard in order to reach the goal of sufficiently accurate and repeatable measurements. It should be considered to what extent some of the material, e.g. background information, can be moved to informative annexes.

For other indicators only examples of items which need to be covered in addition to a description of the measurement method are given below. The examples are not exhaustive – experts in the preparation group will find further items that need to be covered in order to define accurate and repeatable measurements.

7.2 Indenter measurements

Included as an illustration, not as a final proposal.

The maximum force is a compromise between the need for a rise time which is long enough to achieve reasonable resolution in the time scale axis and a total travel distance short enough to result in an anvil intrusion that can be accepted for a non-destructive measurement. For most insulation materials, a maximum force of 10 N is recommended. This will normally result in a probe penetration depth below 1 mm (for unaged material, smaller for aged material). For some rather soft insulation materials, e.g. Sir, a lower value has to be used in order to avoid deep penetration.

7.2.6 Clamping of object

The indenter modulus can be significantly dependent on the force by which the specimen is clamped in the mounting fixture. In order to minimize the effect of the clamping, the specimen shall be mounted in the fixture using the minimum clamping force needed for the specimen to be fixed.

7.2.7 Determination of the value of the indenter modulus

The indenter modulus *M* is determined by the slope of the force-penetration depth curve and expressed in N/mm.

$$M = \frac{F_2 - F_1}{d_2 - d_1}$$

where F_i is the corresponding force values at penetration depth *di*

d_i is the penetration depth $= \frac{5}{60} \cdot t_i$ if the travel speed is 5 mm/s; t_i is the travel time

In cases where the force-penetration depth curve is not linear, the indenter modulus shall be determined by using the values $F_1 = 1$N och $F_2 = 4$N.

7.2.8 Reporting

The measurement report shall as a minimum include the following information:
Measurements made in laboratory:

a) Identification and description of the specimen
b) Pre-history (unaged, artificially aged, naturally aged)
c) Locality of the measurement (laboratory, on-site)
d) For laboratory measurement of thermally artificially aged specimen: time allowed for attaining laboratory temperature before performing the measurements (time interval between removing of the specimen from the heat chamber until start of measurement)
e) Measurement temperature; if outside 18-23°C normalisation to 20°C.
f) Measurement instrumentation and calibration
g) Mounting of the specimen for measurements (clamping)
h) Measurement points
i) Probe speed
j) Maximum force (or diagram showing the whole force versus penetration depth curve)
k) Indenter modulus value, mean value and standard deviation, in N/mm together with an information on the force interval for which it has been determined (normally 1N-4N)
l) Any other information of importance in interpretation of the measurement results in relation to the purposes of the measurements.

7.3 Tensile tests

Requirements on the test machine used
Calibration procedure
Method of gripping samples and type of grip face
Test temperature
Cross-head speed
Method of measuring elongation
Content of measurement report

7.4 OIT and OITP tests

Requirements on instrument used
Method of calibration
Sample weight and preparation method
Type of sample pan (open or closed)
Oxygen flow rate used
Temperature profile used to reach oxidation temperature (OIT tests) or temperature ramp rate and starting temperature (OITP tests)
Method of establishing baseline (data plot)
Method of establishing oxidation onset

7.5 TGA tests

Requirements on instrument used
Method of calibration
Sample weight and preparation method
Type of sample pan (open or closed)
Oxygen flow rate used
Temperature ramp rate and starting temperature
Method of establishing oxidation onset
Content of measurement report

7.6 Insulation resistance

To be stated

7.7 Dielectric loss factor

To be stated

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8 Measurement procedures

8.1 Tensile measurements

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