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INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Nuclear power plants – Instrumentation and control important to safety – Management of ageing of electrical cabling systems

Centrales nucléaires de puissance – Instrumentation et contrôle-commande importants pour la sûreté – Gestion du vieillissement des systèmes de câbles électriques

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NUCLEAR POWER PLANTS – INSTRUMENTATION AND CONTROL IMPORTANT TO SAFETY – MANAGEMENT OF AGEING OF ELECTRICAL CABLING SYSTEMS

FOREWORD

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International Standard IEC 62465 has been prepared by subcommittee 45A: Instrumentation and control of nuclear facilities, of IEC technical committee 45: Nuclear instrumentation.

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

FDIS	Report on voting
45A/795/FDIS	45A/803/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has 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

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- amended.

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INTRODUCTION

a) Technical background, main issues and organisation of the Standard

With the majority of nuclear power plants over 20 years old, the management of ageing of instrumentation and associated electrical cabling systems is currently a relevant topic, especially for those plants that have extended their operating licenses or are considering this option. This International Standard is intended to be used by operators of nuclear power plants (utilities), systems evaluators, and by licensors.

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

IEC 62465 is the third level IEC SC 45A document tackling the specific issue of management of ageing of electrical cabling systems in nuclear power plants for Instrumentation and Control (I&C) systems important to safety.

IEC 62342 is the second level chapeau standard of SC 45A covering the domain of the management of ageing of nuclear instrumentation systems used in nuclear power plants to perform functions important to safety. IEC 62342 is the introduction to a series of standards to be developed by IEC SC 45A covering the management of ageing of specific I&C systems or components such as electrical cabling systems (IEC 62465), sensors, and transmitters.

IEC 62465 is to be read in association with IEC 62342 and IEC 62096, which is the appropriate IEC SC 45A Technical Report that provides guidance on the decision for modernization when management of ageing techniques are no longer successful.

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 International Standard establishes no additional functional requirements for safety systems. Ageing mechanisms have to be prevented and thus detected by performance measurements. Aspects for which special recommendations have been provided in this International Standard are:

- criteria for evaluation of ageing of electrical cabling systems in nuclear power plants;
- steps to be followed to establish cable testing requirements for an ageing management program for nuclear power plant electrical cabling systems; and
- relationship between on-going qualification analysis and ageing management programs with regards to electrical cabling systems.

It is recognized that testing and monitoring techniques used to evaluate the ageing condition of nuclear power plants' electrical cabling systems are continuing to develop at a rapid pace and that it is not possible for a standard such as IEC 62465 to include references to all modern technologies and techniques. However, a number of techniques have been mentioned within this International Standard and are described in Annexes B, C and D.

To ensure that this International Standard will continue to be relevant in future years, the emphasis has been placed on issues of principle, rather than specific technologies.

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

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

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

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

A fourth level extending the IEC SC 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 – MANAGEMENT OF AGEING OF ELECTRICAL CABLING SYSTEMS

1 Scope

This International Standard provides strategies, technical requirements, and recommended practices for the management of normal ageing of cabling systems that are important to safety in nuclear power plants. The main requirements are presented in the body of this International Standard followed by a number of informative annexes with examples of cable testing techniques, procedures, and equipment that are available for the nuclear industry to use to ensure that ageing degradation will not impact plant safety.

This International Standard covers cables and their accessories (e.g., connectors) installed in nuclear power plants (inside and outside the containment). It provides requirements to perform cable testing for the purposes of predictive maintenance, troubleshooting, ageing management, and assurance of plant safety. It is concerned with Instrumentation and Control (I&C) cables, signal cables, and power cables of voltages less than 1 kV. More specifically, this International Standard focuses on in-situ testing techniques that have been established for determining problems in cable conductors (i.e., copper wire) and, to a lesser extent, on insulation material (i.e., polymer). It follows the IEC 62342 standard on “Management of Ageing” that was prepared to provide general guidelines for management of ageing of I&C components in nuclear power plants, including cables. It should be pointed out that cable testing technologies are evolving and new methods are becoming available that are not covered in this International Standard. More specifically, this International Standard covers typical cable testing methods that have been in use in the nuclear power industry over the last decade. It should also be pointed out that a single cable testing technique is unlikely to provide conclusive results, and a reliable diagnosis normally requires a combination of techniques.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60780, *Nuclear power plants – Electrical equipment of the safety system – Qualification*

IEC/TR 62096, *Nuclear power plants – Instrumentation and control important to safety – Guidance for the decision on modernization*

IEC 62342, *Nuclear power plants – Instrumentation and control systems important to safety – Management of ageing*

IEC 62385, *Nuclear power plants – Instrumentation and control important to safety – Methods for assessing the performance of safety system instrument channels*

IEC/TR 62392, *Suitability of typical electrical insulating material (EIM) for polymer recycling*

3 Terms and definitions

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

3.1
accelerated ageing
accelerated process designed to simulate an advanced life condition in a short period of time. It is the process of subjecting an equipment or a component to stress conditions in accordance with known measurable physical or chemical laws of degradation in order to render its physical and electrical properties similar to those it would have at an advanced age operating under expected operational conditions.

[IEC 60780]

3.2
ageing assessment
evaluation of appropriate information for determining the effects of ageing on the current and future ability of systems, structures, and components to function within acceptance criteria in all operating conditions (e.g., in normal conditions and after design basis events)

3.3
ageing management
engineering, operations, and maintenance actions to control within acceptable limits ageing degradation of structures, systems, or components

[IAEA Safety Glossary, 2007 edition]

3.4
cable deposit (cable depot)
selection of cable samples placed inside a nuclear power plant for condition monitoring or removal for testing

3.5
cable indenter
means for testing the indenter modulus of a cable's insulation or jacket material

3.6
cabling system
system of cables, including the conductor, shielding, splices, insulation material, and the cable accessories (e.g., connectors)

3.7
Design Basis Accident
DBA
accident conditions against which a facility is designed according to established design criteria, and for which the damage to the fuel and the release of radioactive material are kept within authorized limits

[IAEA Safety Glossary, 2007 edition]

3.8
environmental monitoring
monitoring of severities of ambient environmental parameters (e.g., temperature and radiation dose)

3.9
environmental stress
factor influencing at least one ageing mechanism of the cabling system which is not caused by the change of its physical state

3.10
equipment qualification
generation and maintenance of evidence to ensure that equipment will operate on demand, under specified service conditions, to meet system performance requirements

[IAEA Safety Glossary, 2007 edition]

3.11
high-stress area (hot spot)
limited part of cable subject to more severe environmental stress (irradiation, temperature, mechanical constraints). Areas often localized within a nuclear power plant where temperatures and/or radiation dose rates are higher than expected.

3.12
in-situ cable test
testing that is performed without removing the cabling system from its normal installed position in the plant

3.13
Insulation Resistance (IR) measurement
measurement of resistance between a conductor and ground or between any two electrical conductors

3.14
I-V curve
plot of the relationship between Current (I) and Voltage (V) for a neutron detector

3.15
LCR measurement
measurement of Inductance (L), Capacitance (C), and Resistance (R) of a cabling system

3.16
Loop Current Step Response (LCSR) test
method for measurement of response time of temperature sensors and for separating sensor problems from cable problems

3.17
noise analysis technique
method for in-situ response time testing of sensors, detectors, and transmitters and for on-line detection of blockages, voids, and leaks in pressure sensing lines

[IEC 62385]

NOTE This method is also used to identify ageing degradation in sensors such as neutron detectors and can help separate sensor problems from cable problems.

3.18
Nuclear Instrumentation System
NIS
instrument chain used to measure neutron flux

3.19
qualified life
period for which a structure, system or component has been demonstrated, through testing, analysis or experience, to be capable of functioning within acceptance criteria during specific operating conditions while retaining the ability to perform its safety functions in a design basis accident or earthquake

[IAEA Safety Glossary, 2007 edition]

3.20
Resistance Temperature Detector
RTD
temperature sensor containing a sensing element made of platinum or other metals whose resistance changes with temperature

3.21
test interval
elapsed time between the initiation of identical tests on the same sensor and signal processing device, logic assembly or final actuation device

[IEC 60671]

3.22
Time Domain Reflectometry (TDR) test
method for locating faults along a cable, in the connector, and/or at the end device

4 Technical background

4.1 General

Cabling systems in nuclear power plants can suffer degradation due to ageing and shall require testing to ensure proper plant operation and safety. For example, cables can become dry and embrittled due to ageing and malfunction during plant operation or in accident and post-accident conditions. In a Loss-of-Coolant Accident (LOCA), cables are subjected to hot steam under high pressure and can malfunction if there is any insulation ageing, cracks, or other damage that can allow moisture to enter the cable. The combination of hot steam and high pressure is the dominating reason for possible cable malfunction in a LOCA especially because steam penetrates smaller cracks more easily than water. Ageing of cable insulation materials is covered in IEC 62392.

In addition to problems that can arise from cable insulation damage, there are problems due to cable conductors, connectors, or accessories. These problems can cause measurement errors, erratic signals, spikes, noise, and other anomalies that interfere not only with efficient operation and control of the plant but also with plant safety. This International Standard provides requirements and guidelines to identify these problems.

4.2 Cable types

Cables in nuclear power plants can typically be grouped into the following functional types:

a) instrumentation and control cables (coaxial, triaxial, twisted pair, shielded),

b) low voltage power cables (less than 1 kV),

c) medium voltage power cables (e.g., less than 30 kV),

d) general services cables (ground cables, communication cables, etc.).

The main focus of this International Standard is on I&C cables although many of the aspects considered here are also applicable to low voltage power cables, as they use similar materials and experience similar degradation mechanisms. For example, the methods described here are used for testing the control rod drive mechanism (CRDM) cables and other similar cables in nuclear power plants.

Instrumentation cables (including thermocouple extension wires) are normally low voltage (typically <1 kV). Typically, they are used for digital or analog transmission of sensor or instrument signals. Resistance temperature detectors, pressure transducers, and some thermocouple extension leads usually are of a shielded and twisted pair configuration (most thermocouple extension wires are made of mineral insulated cables). Radiation detection and neutron monitoring circuits often use coaxial or triaxial shielded configurations. Control cables for auxiliary components such as control switches, valve operators, relays, and contactors are usually of a low voltage, low current type. They are often made of multi-conductor cables, with shielding for application near high voltage systems. Low voltage power cables (<1 kV) are used to supply power to low voltage auxiliary devices such as motors, motor control centres, heaters, and small transformers. These cables may be single conductor or multi-conductor and are usually unshielded.

Typically, a cable consists of four to eight components. For example, the main components for an I&C or a low voltage power cable are:

- conductor(s),
- electrical insulation or dielectric,
- shielding,
- outer jacket.

In some cables, particularly control and low voltage power cables, there may be a jacketing layer over the insulation on the individual conductors, providing fire retardance. This is usually referred to as a conductor jacket or inner jacket if it is present. In general, the term jacket would normally refer to the outer layer of the cable construction. Other components which may be present in a cable include:

- filler or bedding materials, which occupy the gaps between insulated conductors in multi-conductor (also known as multi-core) cables, to improve mechanical stability of the cable;
- tape wraps, which may provide additional electrical, mechanical or fire protection, or identify conductor groupings;
- armouring layers, which are sometimes used for mechanical protection under the outer jacket layer.

Annex A provides a description of a typical cable and the components that are normally involved in the testing activity covered in this International Standard.

4.3 Reasons for cable ageing management

Cable testing is performed in nuclear power plants for a number of reasons such as troubleshooting, to identify problems such as signal anomalies, to establish baseline measurements as a reference for predictive maintenance, and to evaluate cable ageing.

In recent years, cable ageing management has become more important for two main reasons. Firstly, some plants have obtained licence renewal to operate cables for an extended qualified life. Secondly, the nuclear power industry has recognized that there are limitations in cable qualification testing in the areas of pre-ageing and the use of models such as the Arrhenius law for assessing qualified life.

A challenge in management of ageing of cables and determination of problems is in detection of hot spots along a cable and how to locate the hot spot. Hot spots can occur due to radiation effects, electrical heating effects, ambient heat, and mechanical stress and there is no reliable in-situ technique to locate hot spots along a cable. In particular, cables are often in conduits and means such as visual inspections do not provide effective diagnostics of cable conditions.

4.4 Cable stressors

Ageing and degradation of cables results from long-term exposure to radiation, heat, humidity, vibration, and other environmental stressors that exist in nuclear power plants. These also include lubricants, chemicals, or contaminants that a cable may come into contact with in a plant. Also, there are internal stressors such as ohmic heating from the passage of electric currents in the cable. Both the cable insulation material and the conductor are affected by ageing. Table 1 shows examples of ageing stressors with potential to damage cables. Furthermore, mechanical stressors such as bending, squeezing, vibration, or a combination of these effects with other environmental stressors (synergism), can alter the ageing characteristics of cables.

4.5 Cable testing techniques

To guard against the adverse consequences of cable ageing and degradation, periodic testing and condition monitoring of cables should be performed in nuclear power plants especially for those cables that are important to safety. For this purpose, numerous techniques have been developed to measure ageing effects in cables and to identify effective cable maintenance techniques. In Annexes B, C, and D of this International Standard, examples of basic testing techniques for cables are described. These and other techniques which can meet the requirements of this International Standard may be used to ensure reliable cable service and protect the safety of nuclear plants against consequences of cable degradation and ageing.

NOTE This International Standard provides methods for assessing cable systems, including connectors and end devices. Methods for assessing ageing degradation of cable insulation are covered in IEC 62392.

Table 1 – Examples of stressors with potential to damage cables

Ageing stressor	Affected component	Consequence
Corrosion/oxidation	Conductor	Increased resistance and self-heating
	Connector	Increased resistance and self-heating
Vibration	Conductor	Increased resistance, reduced strength
	Connector	Reduced strength, reduced connection quality
	Insulation	Formation of cracks, reduced insulation resistance (IR) when subjected to humidity, loss of material
Heat and ionising radiation	Insulation	Changes in mechanical properties, changes in flammability characteristics, loss of additives (plasticisers, anti-oxidants, etc.)
Moisture/water	Insulation and conductor	Acceleration of the effects of radiation and thermal ageing, deterioration of cable material, shorting and shunting effects if moisture enters the cable, reduction of IR, swelling
Lubricants, contaminants	Insulation material and connector	Deterioration of insulation material

5 Cable testing requirements

5.1 General

The control and safety systems of nuclear power plants depend on reliability of cables in operational conditions. Therefore, the performance of cables especially those having safety relevance, shall be verified periodically during the plant life time. This is of particular concern for cables supporting safety functions and cables whose failure could impact qualified equipment and have consequences on plant safety.

This clause gives requirements for in-situ testing to verify that electrical cabling systems provide reliable service and to ensure safety.