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INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Nuclear facilities – Instrumentation important to safety – Spent fuel pool instrumentation

Installations nucléaires – Instrumentation importante pour la sûreté – Instrumentation des piscines de refroidissement et de stockage du combustible

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FOREWORD

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International Standard IEC/IEEE 63113 has been 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.

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

FDIS	Report on voting
45A/1373/FDIS	45A/1382/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 International Organization for Standardization (ISO) / IEC Directives, Part 2.

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- withdrawn,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.

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INTRODUCTION

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

This IEC/IEEE standard sets out the requirements for instrumentation to monitor spent fuel pool water level and temperature in nuclear facilities as well as radiation monitoring in the vicinity of the pool.

Prior to the accident at Fukushima Daiichi, spent fuel pool monitoring in nuclear power plants was provided mainly to enable operators to monitor pool temperature at a location near the top of the pool. It was also used to determine that the water level remained below the point where flooding of operational areas would be a concern and above the level assumed in safety analyses that evaluated the release of fission products from the pool in the event of a fuel handling accident.

In general, robust spent fuel pools protect the fuel from physical damage and use highly reliable coolant systems that ensure continuous decay heat removal. Monitoring of the pool cooling system and drain taps at the bottom of the pool were considered sufficient to confirm pool cooling under operational states and design basis accidents. Because these are straightforward measurements, neither IEC SC 45A nor IEEE NPEC considered that a standard on this topic was necessary.

During the accident at Fukushima Daiichi, explosions occurred in the reactor buildings of units 1, 3, and 4. Hydrogen release from fuel in the spent fuel pool, due to loss of water inventory, had to be considered as a possible cause of the explosions. Instrumentation suitable for checking this hypothesis was not installed and operators could not directly check pool conditions because of radiation dose rates and other hazards in the reactor buildings. Consequently, plant operators had to take action on the assumption that the spent fuel was no longer fully covered by water.

Eventually, it was confirmed that the many extraordinary actions taken by site personnel succeeded in averting a greater release of radioactive material from the spent fuel pools. Nevertheless, the lack of real time information about pool conditions created significant difficulties in responding to the accidents, increased public anxiety, and diverted resources away from activities to restore core cooling.

Subsequent analysis, however, determined that if the water in the reactor well and dryer-separator pits in Unit 4 had not leaked into the spent fuel pool as water in the pool evaporated, the spent fuel in Unit 4 may have become uncovered. [6], [8] [1]

This experience points to a need to provide plant operators with instrumentation to enable them to understand the state of spent fuel cooling under design extension conditions (DEC). To support the design of such instrumentation, the expected pool conditions must be defined and the instruments should be designed considering any special characteristics needed to ensure their high reliability and operability in the presence of hazards that might exist during design extension conditions.

It is also necessary to monitor spent fuel pools during normal operations in order to: detect a potential loss of heat removal from the pool, detect high pool levels that risk pool overflow, confirm the pool contains sufficient water to shield operators from the radiation from fission products contained in the spent fuel, and ensure safety analysis assumptions are met concerning pool water hold-up of fission products in the event of a fuel handling accident.

1 Numbers in square brackets refer to the Bibliography.

To address the specific lessons learned from the Fukushima Daiichi accident and to give an overall view of the requirements for spent fuel pool monitoring, this document establishes criteria for the performance, design, qualification, display, and quality assurance of instruments for monitoring spent fuel pool conditions during both operational states and accident conditions (including design extension conditions) at nuclear facilities.

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

IEC 63113 is at the third level in the hierarchy of SC 45A standards.

IEC 61513 is the first level standard of SC 45A standards, and provides general requirements for I&C systems and equipment that are used to perform functions important to safety in Nuclear Power Plants (NPPs). IEC/IEEE 60780-323 provides the standard for environmental qualification. IEC 62003 provides the requirements for electromagnetic compatibility testing.

IEC 63147/IEEE Std 497™ provides criteria for accident monitoring instrumentation. IEEE Std 497™ was directly adopted as a joint logo standard and a technical report, IEC TR 63123, was prepared to discuss the application of the joint standard within the IEC context.

The structure of this standard is adapted from the structure of IEC 63147/IEEE Std 497™, and the technical requirements of this standard are consistent with the requirements given in IEC 63147/IEEE Std 497™ together with the application guidance given in IEC TR 63123. This standard deals with instrumentation intended to help plant operators avoid severe accidents in spent fuel pools. The introduction to IEEE Std 497™ notes that design extension conditions that are not severe accidents are not covered by that standard. 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 the Standard

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

This standard is directed at facilities in which loss of spent fuel pool inventory makes possible a significant fission product release to the environment. Thus, the standard applies only to spent fuel pools at which the water fill is necessary to prevent a release of fission products that exceeds allowed operational limits.

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

The top-level documents of the IEC SC 45A standard series are IEC 61513 and IEC 63046. IEC 61513 provides general requirements for I&C systems and equipment that are used to perform functions important to safety in NPPs. IEC 63046 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 systems for nuclear power plants.

IEC 61513 and IEC 63046 refer directly to other IEC SC 45A standards for general topics related to categorization of functions and classification of systems, qualification, separation, defence against common cause failure, control room design, electromagnetic compatibility, cybersecurity, software and hardware aspects for programmable digital systems, coordination of safety and security requirements and management of aging. 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 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 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 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 and the implementing guide NSS17 for computer security at nuclear facilities. The safety and security terminology and definitions used by 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 as well as to IAEA GS-R 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 and IEC 62342 is the entry document for the aging management standards.

NOTE 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.

NUCLEAR FACILITIES – INSTRUMENTATION IMPORTANT TO SAFETY – SPENT FUEL POOL INSTRUMENTATION

1 Scope

1.1 General

This document provides criteria for spent fuel pool instrumentation for nuclear power generating stations and other nuclear facilities. The document applies to water filled spent fuel pools where the water volume is necessary to prevent a release of fission products that exceeds allowed operational limits.

1.2 Purpose

The purpose of this document is to establish design, performance, qualification, and display criteria for spent fuel pool instrumentation for normal operation, anticipated operational occurrences, design basis events, and design extension conditions (including severe accident conditions).

1.3 Application

This document applies only to instrumentation for monitoring the condition of the spent fuel pool, i.e., pool level, pool temperature, and area radiation. It does not apply to control systems that are related to the spent fuel pool such as: the pool cooling systems, isolation valve control, crane instrumentation and control, or refuelling machine instrumentation and control.

In some plant designs some of the instruments covered by this document also provide inputs to protection system functions. Such instruments must also comply with requirements for protection systems that are given elsewhere.

The requirements applied to the systems and components performing these functions depend on how they contribute to the safety of the spent fuel pool.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60709:2018, *Nuclear power plants – Instrumentation, control and electrical power systems important to safety – Separation*

IEC/IEEE 60780-323, *Nuclear power plants – Electrical equipment important to safety – Qualification*

IEC/IEEE 60980-344, *Nuclear facilities – Equipment important to safety – Seismic qualification*

IEC 61226, *Nuclear power plants – Instrumentation and control important to safety – Classification of instrumentation and control functions*

NOTE 1 The use of IEC 61226 should take account of the discussion given in IEC TR 63123 [19].

IEC 61513, *Nuclear power plants – Instrumentation and control important to safety – General requirements for systems*

IEC 63046, *Nuclear power plants – Electrical power system – General requirements*

IEEE 384™, 2018, *IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits*

NOTE 2 This document can be used with either IEEE and/or IEC normative references, but one coherent and consistent set of references shall be defined at the beginning of the project and used as a whole as the basis for the design and for all the project.

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
accident conditions
deviations from normal operation that are less frequent and more severe than anticipated operational occurrences

[SOURCE: IAEA Safety Glossary, 2018 Edition]

3.2
anticipated operational occurrence
deviation of an operational process from normal operation that is expected to occur at least once during the operating lifetime of a facility but which, in the view of appropriate design provisions, does not cause any significant damage to items important to safety or lead to accident conditions

[SOURCE: IAEA Safety Glossary, 2018 Edition]

3.3
common cause failure
failures of two or more structures, systems or components due to a single event or cause

Note 1 to entry: Common causes may be internal or external to an instrumentation and control (I&C) system.

Note 2 to entry: The IEC definition differs from the IAEA in that the term "specific" was deleted because this additional word is not necessary to understand the definition.

[SOURCE: IAEA Safety Glossary, 2018 Edition, modified: see Note 2 to entry.]

3.4
design basis accident
postulated accident leading to accident conditions for which a facility is designed in accordance with established design criteria and conservative methodology, and for which releases of radioactive material are kept within acceptable limits

[SOURCE: IAEA Safety Glossary, 2018 Edition]

3.5
design extension conditions
postulated accident conditions that are not considered for design basis accidents, but that are considered in the design process of the facility in accordance with best estimate methodology, and for which releases of radioactive material are kept within acceptable limits

[SOURCE: IAEA Safety Glossary, 2018 Edition]

3.6
monitoring channel
arrangement of components, from sensors to displays, as required to generate a signal from a plant condition and present the signal to the end user

3.7
operational states
states defined under normal operation and anticipated operational occurrences

Note 1 to entry: Some States and organizations use the term operating conditions (in contrast with accident conditions) for this concept.

[SOURCE: IAEA Safety Glossary, 2018 Edition]

3.8
periodic testing
performance of tests at predetermined time points to demonstrate that the functional capabilities of the I&C systems and equipment important to safety are retained and that the characteristics relevant to the claims of safety analysis are satisfied

[SOURCE: IEC 60671:2007, 3.7]

3.9
pond sludge
undesired debris material that originates from the storage of items in the spent fuel pool

3.10
redundancy
provision of alternative (identical or diverse) structures, systems and components, so that any single structure, system or component can perform the required function regardless of the state of operation or failure of any other

[SOURCE: IAEA Safety Glossary, 2018 Edition]

3.11
response time
period of time necessary for a component to achieve a specified output state from the time that it receives a signal requiring it to assume that output state

[SOURCE: IAEA Safety Glossary, 2018 Edition]

3.12
severe accident
subset of design extension conditions during which fuel damage has occurred

[SOURCE: IEC 63147 / IEEE Std 497™, 3]

3.13
supporting features
systems or components that provide services (such as cooling, lubrication and energy supply) required for the systems to accomplish their intended functions

Note 1 to entry: Some countries use the term "auxiliary features".

4 Symbols and abbreviated terms

AOO	Anticipated Operating Occurrence
CANDU	Canada Deuterium Uranium (Reactor)
CCF	Common Cause Failure
DBA	Design Basis Accident
DEC	Design Extension Conditions
SFP	Spent Fuel Pool

5 Functional requirements

Spent fuel pools within the scope of this document shall be provided with monitoring instrumentation that enables the plant staff to recognize the following conditions.

a) Thermodynamic conditions in the pool. Pool thermodynamic conditions may be determined by measurement of pool temperature. Higher than normal temperatures may indicate an abnormally high rate of pool water evaporation. Normal temperatures in combination with unexpected loss of inventory may indicate that the pool is leaking.

b) Maximum water level. Pool inventory has approached the point where there is a risk of water overflowing the top of the pool.

c) Minimum water level for moving fuel. Pool inventory less than this level would be insufficient to comply with accident analysis assumptions of iodine decontamination factors following a fuel handling accident.

d) Minimum active cooling water level. Pool inventory has approached the point where there is a risk that operation of the normal fuel pool cooling system cannot be supported.

e) Minimum shielding water level. Pool inventory has approached the point where the coolant cannot provide substantial shielding for a person standing on the spent fuel pool operating deck.

f) Top of fuel water level. Pool inventory has reached the point where the fuel remains covered but actions to implement make-up water addition should no longer be deferred.

g) Air dose rate above the pool. Gamma radiation dose rates in the pool building are at a level that indicates that significant loss of shielding has occurred.

Functional requirements for conditions a), d), e), f) and g) are intended to monitor design extension conditions that do not involve fuel damage. There is reason to believe that information about those conditions will enable the operators to restore pool cooling before fuel in the pool is damaged. Nevertheless, provisions should[2] also be made to enable the plant staff to recognize the following severe accident conditions:

h) Fuel damage water level. Pool inventory has approached the point where fuel damage is expected.

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2 Extending the range of fuel pool water level measurement is necessary only if specific injection modes are needed under the fuel rack level to ensure fuel integrity or to maintain fuel pool tightness in at least one accident scenario (DEC included). Detection of these conditions becomes more important if robust means to provide makeup water to the spent fuel pool have not been separately implemented. For example: portable pumps that are not dependent upon plant power sources for makeup to the SFP and primary and alternative delivery points for makeup water.

i) Bottom of fuel water level. Pool inventory has reached the point where air cooling is the dominant cooling mechanism for the fuel.

When functions to detect conditions h) or i) are implemented they shall comply with the requirements given in this document.

In this document the term "spent fuel pool monitoring instrumentation" refers to any monitoring instrumentation that is specifically intended to detect one or more of the conditions listed above.

Annex A provides further discussion of conditions a) through i) above and the spent fuel pool monitoring instrumentation functions intended to detect these conditions. It also gives a diagram showing an example of how the measurements might physically relate to each other and the spent fuel pool itself.

The specific values corresponding to the above conditions shall be determined based upon plant-specific design information. Instruments that are intended to detect conditions a), d), e) and f) shall accurately indicate the water level when the water is both below and above its saturation temperature.

Instruments that are intended to detect conditions a), b), and c) are meant for use in plant operational states.

Instruments that are intended to detect conditions a), d), e), f), and g) are meant for use during accident conditions to alert operators to situations that may jeopardize the cooling of spent fuel under DEC.

Instruments that are intended to detect conditions g), h), and i) are meant for use during severe accident conditions to alert the operators to situations that may immediately result in or have already resulted in fuel damage.

A spent fuel pool that contains two or more sections that are connected by normally open gates may be treated as a single spent fuel pool. If the isolable sections of the pool are not used for long-term storage of significant quantities of fuel (as defined by local regulations), sensors for level and temperature monitoring channels shall be located in the main pool. Administrative provisions shall be put into place to ensure that these instruments are operable before pools are isolated from each other.

If, however, the multiple pool sections are normally isolated and used for long-term storage of significant fuel quantities, each section shall be treated as an individual spent fuel pool.

Criteria for spent fuel pool monitoring instrumentation apply to all instruments that are intended to detect conditions a) through i). Additional criteria are given for DEC spent fuel pool monitoring instrumentation, and these apply only to instruments that are intended to detect conditions a) and d) through i).

The terms used for the different functions and functional groups intended to detect the conditions identified above and their relationship to plant states are shown in Table 1.