IEC/IEEE 63113

Edition 1.0 2021-04

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

IEC/IEEE 63113:2021-04(en-fr)

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

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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.

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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.

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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.

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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.

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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].

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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 Std 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]

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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]

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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.

[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.

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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.

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Table 1 – Relationship of functional groups used in this document

<table>
<tr><th></th><th colspan="2">Operational states</th><th colspan="3">Accident conditions</th></tr>
<tr><td rowspan="2">Plant state</td><td rowspan="2">Normal operation</td><td rowspan="2">Anticipated operational occurrence (AOO)</td><td rowspan="2">Design basis accidents (DBA)</td><td colspan="2">Design extension conditions (DEC)</td></tr>
<tr><td>DEC without significant fuel degradation</td><td>Severe accidents</td></tr>
<tr><td>Conditions</td><td colspan="2">a), b) and c)</td><td>see Note 1</td><td>a), d), e), f) and g)</td><td>g), h) and i)</td></tr>
<tr><td rowspan="2">Terms used for functional groups (see Note 2)</td><td colspan="3">Spent fuel pool monitoring instrumentation</td><td colspan="2"></td></tr>
<tr><td colspan="3"></td><td colspan="2">DEC spent fuel pool monitoring instrumentation</td></tr>
<tr><td></td><td colspan="3">NOTE 1 Typically, there are no DBAs associated with pool water level, temperature and radiation dose rates; therefore, this document does not specify spent fuel pool monitoring instrumentation for DBAs.

NOTE 2 One or more monitoring channels make up a functional group of monitoring instrumentation.</td><td colspan="2"></td></tr>
</table>

Some facilities also use spent fuel pool monitoring instrumentation to actuate safety systems; actuation of fuel building ventilation systems for example. This document does not provide criteria for the actuation of safety systems. If, however, instruments provided for actuation of safety systems are also used to detect one or more of the conditions above, the instrumentation shall satisfy the requirements of this document as well as all requirements applicable to the safety actuation functions.

6 Performance criteria

6.1 Range

Spent fuel pool level monitoring instrumentation shall cover the full range of levels for the pool from condition b) to condition f) in Clause 5.

If DEC spent fuel pool monitoring instrumentation is provided for conditions h) and i), the range shall be extended to cover the full range of level to condition i).

Spent fuel pool temperature monitoring instrumentation shall cover, with margin, the temperature range from the minimum expected pool temperature up to the spent fuel pool boiling point (e.g., 10 °C to 125 °C), when pool building pressure is at the structure's maximum design pressure. The temperature measurement locations shall include two points. One point shall be at the minimum active cooling water level (condition d) and another point shall be between the minimum shielding water level (condition e) and the top of the fuel water level (condition f) to provide information for an extended period of time before a significant loss of inventory causes all of the temperature sensors to become uncovered.

Spent fuel pool radiation monitoring instrumentation (condition g) shall cover the range from background levels to 110 % of the calculated maximum dose rate above the pool given the maximum radiological release condition from the pool.

Each spent fuel pool monitoring parameter may be provided by a single instrument, multiple instruments, or multiple technologies. If multiple monitoring channels or technologies are provided to cover the full measurement range, overlap between ranges shall be provided to enable the operator to follow trends throughout the entire range and check consistency of indication in the overlap range.

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6.2 Accuracy

6.2.1 General

The accuracy of all spent fuel pool monitoring instrumentation shall be sufficient to enable operators to identify each of the conditions given in Clause 5.

Determination of the accuracy of monitoring channels shall include instrument channel uncertainties and measurement errors caused by the operating environment. The measurement errors might be caused, for example, by changes to the physical characteristics of the coolant, environmental effects or radiological effects.

6.2.2 Additional criteria for DEC spent fuel pool monitoring instrumentation

DEC spent fuel pool monitoring instrumentation shall, without recalibration, maintain the required accuracy following a power interruption or change of power supplies.

6.3 Response time

Spent fuel pool monitoring instrumentation shall have a response time sufficient to provide timely information to support appropriate actions.

6.4 Required accident operating time

DEC spent fuel pool monitoring instrumentation shall, after the initiation of accident conditions, be capable of operating for a time period that exceeds the duration of the event or a time period that exceeds the time needed to deploy an alternative means for monitoring and placing these means into stable operation.

6.5 Reliability

Where reliability goals have been established for spent fuel pool monitoring instrumentation, appropriate analysis of the design shall be performed to confirm that such goals have been achieved. For additional information on guidance to perform reliability analysis, see IEEE Std 352™, IEC 60812 or IEEE Std 577™.

6.6 Documentation of performance criteria

6.6.1 General

A documented assessment shall be performed for all spent fuel pool monitoring instrumentation to confirm that the as-designed performance meets or exceeds the performance criteria.

6.6.2 Additional criteria for DEC spent fuel pool monitoring instrumentation

The assessments for DEC spent fuel pool monitoring instrumentation shall document the magnitude and direction of errors imposed by accident conditions.

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7 Design criteria

7.1 Redundancy

At least two channels shall be provided for DEC spent fuel pool monitoring instrumentation. These monitoring channels may be based upon the same or diverse technology.[3]

7.2 Common cause failure

DEC spent fuel pool monitoring instrumentation shall be protected against common cause failures resulting from the following:

- The effects of the maximum seismic ground motion considered in the design of the spent fuel pool structure. Qualification requirements are given in 8.1 and 8.2.
- The effects of temperature, humidity, radiation and electromagnetic conditions that are postulated to occur in the vicinity of monitoring channel components under operational states and accident conditions. Qualification requirements are given in 8.1 and 8.3.
- The effect of shock and vibration at the levels postulated in the area of monitoring channel components under accident conditions. Qualification requirements are given in 8.1 and 8.4.
- The effect of pond sludges.[4]

7.3 Physical independence and separation

Redundant spent fuel pool accident monitoring channels shall be physically separated from each other and protected as necessary to ensure that none of the items below will cause the operators to lose information that is intended to alert them to situations that may jeopardize the cooling of spent fuel or that may result in unacceptable fission product release.

- Internal hazards,
- Missiles that may result from natural phenomena identified in the plant's design basis, and
- Missiles that may result from the progression of DEC.

Possible sources of missiles include, for example, debris from damage to structures or components around, above, or within the spent fuel pool.

Examples of arrangements for protecting the spent fuel pool monitoring instrumentation include locating sensors and other equipment:

- On opposite sides of the pool,
- In recesses within the pool,
- In cask decontamination pits,
- Next to or connected to structures that may provide protection against falling debris, such as structural elements or components that become disconnected from their supports due to mechanical shock or fire.

3 In this case, the requirement for redundancy is not related to the potential for random failure of monitoring channels. Instead, the requirement for redundancy is intended to ensure that the operators have necessary information even if mechanical hazards associated with accident conditions disable a single monitoring channel.

4 Pond sludges may be a particular issue for certain pools that have been in operation for many decades.

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