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Nuclear criticality safety — Use of criticality accident alarm systems for operations

Sûreté-criticité — Systèmes de détection et d'alarme de criticité dans le cadre de l'exploitation

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 85 *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 5 *Nuclear installations, processes and technologies*.

This second edition cancels and replaces the first edition (ISO 7753:1987), which has been technically revised.

The main changes are as follows:

— clarification of the scope and title: this standard is intended for CAAS users;

— improved differentiation with IEC 60860, intended for CAAS designers, manufacturers, providers…;

— removal of CAAS need considerations from the normative part;

— more open definition of the MAC to reflect the variety of practices and possibilities;

— more developed clauses regarding management of unavailability, reliability, positioning of CAAS components;

— addition of a “continuum of detection” concept;

— better integration with other existing ISO standards related to criticality-safety (ISO 1709, ISO 11320, ISO 27467, ISO 14943, ISO 16117 and ISO 21391);

— rewriting and expansion of informative Annexes A and B:

  — Elements for the definition of the minimum accident of concern;

  — Principles for CAAS detectors positioning;

— creation of an informative Annex C: Examples of CAAS need considerations.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Nuclear criticality safety programs at facilities that might use or store significant quantities and concentrations of fissile material are primarily directed at avoiding nuclear criticality accidents. However, the possibility of such accidents exists and the consequences can be life-threatening. Nuclear criticality accidents are complex events that can take various forms and without warning signs. For facilities that are judged to have potential for a nuclear criticality accident, the defense-in-depth principle requires limiting their radiological consequences.

Criticality accident alarm systems (CAAS) provide a means to detect nuclear criticality accidents and to trigger an alarm to prompt the evacuation to a radiologically safe location.

This detection is very specific because of the various possible neutron kinetics and radiation fields produced by a nuclear criticality accident comprising neutrons and photons (i.e. gamma radiation) with a broad spectrum of energies. The primary purpose of CAAS is to prompt personnel to evacuate as soon as possible during a nuclear criticality accident, thus limiting individual and collective radiological doses. A CAAS cannot, and is not intended to, protect personnel from radiation from a nuclear criticality accident prior to prompt evacuation or other protective actions.

Considerations about emergency preparedness and response, including the evacuation procedure related to nuclear criticality accidents, are addressed in ISO 11320.

This document is supplemented by three informative annexes:

— Annex A outlines elements for the definition of the minimum accident of concern (MAC);

— Annex B provides examples of application of this document for the positioning of CAAS detectors;

— Annex C looks at the factors which are considered when assessing whether a CAAS is needed or not, through examples.

Nuclear criticality safety — Use of criticality accident alarm systems for operations

1 Scope

This document provides requirements and guidance regarding the use of CAAS for operations of a nuclear facility. Requirements and guidance on CAAS design are provided in the IEC 60860.

This document is applicable to operations with fissile materials outside nuclear reactors but within the boundaries of nuclear establishments.

This document applies when a need for CAAS has been established. Information about the need for CAAS is given in Annex C.

This document does not include details of administrative steps, which are considered to be activities of a robust management system (ISO 14943 provides details of administrative steps).

Details of nuclear accident dosimetry and personnel exposure evaluations are not within the scope of this document.

This document is concerned with gamma and neutron radiation rate-sensing systems. Specific detection criteria can also be met with integrating systems; systems detecting either neutron or gamma radiation can also be used. Equivalent considerations then apply.

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.

ISO 1709, *Nuclear energy — Fissile materials — Principles of criticality safety in storing, handling and processing*

ISO 11320, *Nuclear criticality safety — Emergency preparedness and response*

IEC 60860:2014, *Radiation protection instrumentation — Warning equipment for criticality accidents*

3 Terms and definitions

For the purposes of this document, the terms and definitions of ISO 1709 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
criticality accident alarm system
CAAS
system dedicated to the detection of nuclear criticality accidents and to the warning of the personnel to prompt their immediate evacuation

Note 1 to entry: A criticality accident alarm system is constituted of all components allowing it to ensure its main function and its optional additional functions (see 4.1) if present; these components include, where applicable: detectors, cabinet(s) (e.g. electronic processing/logic cabinet), alarm devices, device for the supervision of the system status, monitoring device in case of alarm triggering, and interconnections, as well as the system power supply(ies).

3.2
minimum accident of concern
MAC
"smallest" nuclear criticality accident that a *criticality accident alarm system* (3.1) is required to be able to detect

Note 1 to entry: The minimum accident of concern is used to determine and verify the adequate positioning of the CAAS detectors.

Note 2 to entry: The minimum accident of concern is usually expressed in terms of

— doses within a given time, or dose-rates at a given distance, or,

— fission yield within a given time, or fission yield rate, or,

— reactivity insertion, or,

— fission yield resulting in a given dose.

Note 3 to entry: Further information about the MAC is given in 4.3 and Annex A.

3.3
detection zone
area inside of which a nuclear criticality accident meeting the definition of the MAC would trigger the CAAS alarm

3.4
false alarm
unintentional activation of the alarm signal in the absence of a nuclear criticality accident

Note 1 to entry: The cause of a false alarm could be a malfunction of a part or the whole of the system, as well as the triggering due to an external cause (heat, high ambient dose, etc.) or a maintenance error.

4 General design, detection principle

4.1 CAAS functions

4.1.1 Main function

The main function of a CAAS is to provide prompt warning to personnel, in order to limit the radiological consequences due to a nuclear criticality accident. The goal of the alarm is to prompt nearby personnel to evacuate as soon as possible and to deter access to the zones that are to remain evacuated. Estimation of consequences of a potential nuclear criticality accident shall be prepared before implementing the CAAS. Guidance for such estimation is provided in ISO 27467.

This main CAAS function should be maintained as long as a presence of a CAAS provides a net benefit. Unavailability of the main CAAS function shall be identified and managed (see Clause 5).

The alarm shall be designed to provide a prompt evacuation order to all personnel inside the boundaries of the zones to be evacuated and to warn against access to those zones; these boundaries shall meet the requirements of ISO 11320. The emergency arrangements for preparedness and response should be fulfilled in accordance with ISO 11320 as appropriate.

4.1.2 Additional functions (optional)

A CAAS may provide additional functions, given its main function is not affected. These services might be, for example,

— to provide remote monitoring of an ongoing or apparently stopped nuclear criticality accident in order to plan the emergency response, or

— to record detectors' signal for analysis during or after a nuclear criticality accident.

This remote monitoring and signal recording capability should be implemented outside of zones to be evacuated.

Personnel required to operate this remote monitoring and signal recording capability shall be trained in these tasks.

4.2 Resilience

The ability to perform the CAAS main function shall be able to withstand the high radiation emission due to a nuclear criticality accident. The requirements of IEC 60860:2014, 6.6 shall apply for detectors radiation resilience.

NOTE 1 Whenever possible, electronic cabinets and power supplies (Note 1 to entry 3.1) are placed outside of areas where they might receive high radiation doses.

NOTE 2 IEC 60860 contains requirements and specifications regarding resilience of CAAS to environmental, mechanical, and electromagnetic conditions.

If additional functions (4.1.2) are implemented, it should be ensured that repeated excursions would not impair these features.

The CAAS shall be powered by an uninterruptible power supply, allowing continuous operation of the system in the case of failure of external power.

The period during which the CAAS power supply is sustained should be such that, in the event of failure of external power, the system stays in an alarm state long enough for all evacuations to be initiated and for an access control to affected areas to be implemented. This period should also be sufficient to ensure that a CAAS function is maintained during the instigation of alternate arrangements regarding CAAS unavailability.

The sustaining of power supply is not required in situations of managed unavailability of the CAAS (see Clause 5).

4.3 Detection criterion

A CAAS shall trigger its alarm for any nuclear criticality accident whose characteristic meets or exceeds those of the MAC.

The MAC shall be justified and documented. Annex A provides elements for the definition of the MAC and guidance that can be applied to determine it. Several MACs may be defined in a facility.

NOTE The minimum accident of concern assumed in the 1987 version of this International Standard delivers "*an absorbed neutron and gamma dose in free air of 0,2 Gy at a distance of 2 m from the reacting material within 60 s*".

Predicting the location of a nuclear criticality accident and its neutron kinetics is a difficult topic. Considering Annex A, this difficulty can result in a residual risk of nuclear criticality accident with characteristics not meeting the MAC. If the response to such an accident would provide a net benefit to personnel, its detection should be considered in order to constitute a continuum of detection below the MAC. This detection may be performed with means complementary to the CAAS, such as non-dedicated radiation sensing equipment, which are then not CAAS. In this case, adequate accident response procedures shall be provisioned, in accordance with ISO 11320.

5 Management of unavailability

Provision shall be made to manage conditions where an unavailability of the CAAS is identified, unless it can be justified that there is no need for the CAAS given the particular condition.

NOTE 1 Situations where a CAAS might be unavailable include malfunction or failure (unintentional events) as well as maintenance and testing (intentional events).

Unavailability may be managed by

— ordering an evacuation of personnel from the zones which are no longer covered, or

— applying anticipated actions that would negate the need for a CAAS for the duration of this unavailability (shutdown of operations, cessation of transfers, emptying of the process equipment or facility from any fissile material, etc.), or

— maintaining the main CAAS function by other means.

The main CAAS function may temporarily be obtained by the use of portable devices or ambient radiation monitoring equipment not dedicated to nuclear criticality accidents. Any temporary substitution shall be evaluated to be able to perform as an adequate alternative to the existing permanent CAAS. In this case, any performance shortfalls of the temporary system against the existing permanent CAAS should be justified with regards of the unavailability duration.

NOTE 2 IEC 60860:2014 4.5 requires the failure of important CAAS components, including detectors, to be revealed by visual and/or audible indication.

6 System design

6.1 General

This clause presents system design requirements as derived from the scope of this document, aimed at CAAS users.

A CAAS is usually constituted of several components forming a whole. These components shall be protected from failure by design, to ensure the system responds as intended.

Any unavailability or failure should be managed according to Clause 5.

IEC 60860 details additional requirements and specifications aimed at CAAS manufacturers, including electronics, detectors and alarm.

A redundancy of components may be implemented in order to ensure continued operation of the CAAS.

The CAAS design should be reviewed as changes to the facility or operating conditions warrant.

6.2 Alarm

The CAAS shall trigger a prompt evacuation alarm inside the zones to be evacuated; this alarm shall also warn against re-entry to these zones.

The CAAS alarm shall primarily be an audible warning. Visual signals or other alarm means shall be considered to supplement the sound signal to ensure a prompt response of personnel in circumstances where a sound signal would be ineffective (high background noise level, hearing protections, outside building, etc.).

The CAAS' alarm signal shall be specific, so as to be distinct from other signals or alarms, which requires a response different from that necessary in the event of a nuclear criticality accident.

The alarm shall be automatically and promptly actuated upon detection of a nuclear criticality accident with characteristics meeting the MAC (IEC 60860:2014, 6.3). After actuation, the alarm shall be maintained even if radiation level falls below the triggering threshold. The minimum alarm duration shall be assessed to ensure that personnel, in the whole area to be evacuated, perceives the alarm and initiates evacuation. This duration should be documented in the emergency procedures. Manual resets should be provided outside the zones to be evacuated. Manual resets shall have limited access.

6.3 Connections

If several components of a CAAS are connected through a link, it should be ensured that this link is protected from disruption, failure, or interference, for the system to maintain its function in situations where the CAAS function is needed.

CAAS detectors and their connections should be implemented and maintained ensuring the minimization of common-mode failure causes.

6.4 Failure of detectors, false alarms, detection logic

Occurrence of false alarms shall be minimized, as hazards associated with prompt evacuation can be significant (injuries during evacuation, non-securing of processes, loss of containment, physical security breaches, etc.) and the frequency of false criticality alarms can eventually lead personnel to become complacent to prompt evacuation, and thus to an ineffective or incomplete evacuation.

Reduction of false alarms may be achieved by requiring several detectors to coincidentally detect the nuclear criticality accident in order to trigger the alarm (e.g. a 2/*n* logic, where *n* is the number of detectors assigned to the surveillance of a given zone), or by adjusting the trigger threshold or position of the detectors according to the radiological level in the facility without prejudice to the detection of the MAC.

6.5 Obsolescence, replacement parts

The availability for replacement of any CAAS components should be considered to define the life cycle of installed systems. Components different from the original ones may be used, but the modified system shall meet the requirements of this document.

6.6 Supervising

The system status shall be supervised to ensure its ability to detect a nuclear criticality accident.

Personnel who are required to interrogate the status of the system shall be trained for this task.

The provision of a remote system status supervisory station, outside of the zones needing to be evacuated, should be considered.

NOTE 1 This system status supervision capability is distinct from the optional monitoring capability cited in 4.1.

NOTE 2 During an emergency response, information gathered by remote supervision can also help to safely assess the situation, such as confirming the occurrence or termination of a nuclear criticality accident.

7 Criteria for positioning

7.1 General

The positioning of the different components of a CAAS is an important step of the implementation of a CAAS. There exist different requirements for each component, detailed thereafter.

7.2 Positioning of detectors and detection zone

Annex B provides principles for the positioning of CAAS detectors. The detection zone is mainly determined by the positioning of CAAS detectors. Attenuation brought by building elements and shielding shall be taken into account. Attenuation brought by equipment should be considered.

It shall be justified and documented that all locations where CAAS surveillance is needed are included in a detection zone.

The potential failure of detectors should be considered when determining the detection zone.

In placing the minimum required detectors to cover the zone where CAAS surveillance is needed, their placement may be optimized to extend the detection zone.

NOTE 1 Such an extension of the detection zone is supported by the feedback from past accidents which shows that a nuclear criticality accident can occur in an unexpected location.

NOTE 2 Such an extension of the detection zone also allows covering zones where future activities of the facility might stand.

NOTE 3 Adequate positioning of detectors relative to each other helps ensure that during in situ radioactive source tests, only one detector is triggered at a time.

7.3 Alarm signal

The CAAS alarm devices shall be positioned so that they can be clearly perceived at all points of the evacuation zone, and in order to deter access to these zones once an evacuation has been initiated.

NOTE IEC 60860 and EN 50849 give additional information regarding sound levels required for sound systems for emergency purposes.

7.4 Positioning of other CAAS components

CAAS components should be positioned to be able to maintain the main CAAS function in the event of a nuclear criticality accident, taking into account limitations due to their design characteristics. The radiation levels can be determined using the principles in Annex B.

If the design of any CAAS component cannot guarantee the main CAAS function would be ensured in case of a nuclear criticality accident, this component shall be protected against high radiation emissions.

8 Testing

The main CAAS function (whole system) shall be tested at commissioning and periodically; adequate frequencies of these periodic tests shall be justified and documented, in accordance with the stipulations of the manufacturer.

Instrument response to radiation shall be checked at commissioning and periodically to confirm continuing instrument performance. In a system having redundant channels, the performance of each channel shall be monitored. The test interval may be determined on the basis of experience; adequate frequencies of these tests shall be justified and documented; for facilities having a large number of detectors, a rolling programme of testing of detectors may be implemented. Records of the tests shall be maintained.