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

Énergie nucléaire — Matières fissiles — Principes de sûreté-criticité lors des opérations d'entreposage, de manutention et de mise en oeuvre du procédé

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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 on 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 the following URL: 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 third edition cancels and replaces the second edition (ISO 1709:1995), which has been technically revised.

A list of all parts in the ISO 1709 series can be found on the ISO website.

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

1 Scope

This document specifies the basic principles and limitations which govern operations with fissile materials. It discusses general nuclear criticality safety criteria for equipment design and for the development of operating controls, while providing guidance for the assessment of procedures, equipment, and operations. It does not cover specific quality assurance requirements or details of equipment or operational procedures.

This document does not deal with the issues associated with administrative criteria relating to nuclear criticality safety. These issues are covered by ISO 14943. It does not cover the effects of radiation on man or materials, unless the material properties affect nuclear criticality safety.

These criteria apply to operations with fissile materials outside nuclear reactors but within the boundaries of nuclear establishments. They are concerned with the limitations which are imposed on operations because of the properties of these materials which permit them to support nuclear chain reactions. These principles apply to quantities of fissile nuclides in which nuclear criticality safety is required to be established.

This document can also be applied to the transport of fissile materials outside the boundaries of nuclear establishments.

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 7753, *Nuclear energy — Performance and testing requirements for criticality detection and alarm systems*

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

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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 http://www.electropedia.org/

3.1
critical
having an effective neutron multiplication factor equal to unity

3.2
double batching
unintended increase in the quantity of a material that is controlled for Nuclear Criticality Safety such that twice the intended quantity is present

Note 1 to entry: This typically applies to processes involving discrete quantities of material.

3.3
fissile material
material, other than natural or depleted uranium, that is capable of sustaining a thermal neutron chain reaction

3.4
fissile nuclide
nuclide capable of undergoing fission by interaction with neutrons of any energy

3.5
credible abnormal conditions
identified faults and/or circumstances outside of the normal envelope of operations that may lead to an unsafe situation

3.6
neutron absorber
material with which neutrons interact significantly by reactions resulting in their disappearance as free particles

3.7
neutron leakage
neutrons leaving a fissile system boundary such that they no longer interact with that system

Note 1 to entry: For an array of fissile units, neutron leakage from one unit may or may not interact with other units.

3.8
nuclear chain reaction
series of nuclear reactions in which one of the agents necessary to the series is itself produced by the same reactions

3.9
nuclear criticality accident
release of energy as a result of inadvertently producing a self-sustaining or divergent nuclear chain reaction

3.10
nuclear criticality safety
protection against the consequences of a nuclear criticality accident, preferably by prevention of the accident and responses to such accidents should they occur

3.11
nuclear criticality risk assessment
technically reviewed analysis that establishes the technical bases, limits, and controls for the nuclear criticality safety of a given operation

3.12
defence-in-depth
hierarchical deployment of different levels of diverse equipment and procedures (known as barriers) to prevent the escalation of faults to a hazardous condition

[SOURCE: IAEA *Safety Glossary* 2007 Edition, modified — The definition has been modified.]

3.13
over batching
unintended increase in the quantity of a material that is controlled for Nuclear Criticality Safety such that one or more extra discrete quantities are present

3.14
criticality safety control
mechanism which provides a high level of assurance that the probability of occurrence of a critical excursion is acceptably low

Note 1 to entry: An engineered feature (active or passive) or administrative requirement that establishes constraints on the range of values that process parameters can assume with a given reliability (i.e. failure frequency), thereby, providing a barrier to a criticality accident.

4 Procedures

4.1 General

The early recognition of the special hazards associated with fissile materials has led to the application of formal control practices based on principles of nuclear criticality safety. Diligent and conscientious application of these principles has produced an accident record which compares favourably with common industrial accidents. Continuation and improvement of this generally favourable record should have the cooperation of all those involved in operations.

4.2 Responsibility

Operational responsibility for nuclear criticality safety shall be clearly defined and shall belong to operations management throughout the normal chain of command.

4.3 Equipment design

Safety shall, to a practicable extent, be taken into account when designing operating equipment, for example, by restrictions on vessel geometry. The early incorporation of nuclear criticality safety considerations into plant and equipment design provides economic benefits. Process and equipment design identified as important for nuclear criticality safety may require approval by the appropriate nuclear criticality safety authority.

4.4 Criticality assessment

4.4.1 A nuclear criticality safety assessment is required for all operations and facilities under the Scope unless it can be shown it is not required through reasons of quantity and/or form of fissile material. Such reasoning shall include consideration of all credible abnormal conditions. The reasoning may be based on comparison with established criteria (for example safely subcritical mass or enrichment of fissile material).

4.4.2 The nuclear criticality safety assessment shall consider all normal and credible abnormal conditions. Process management shall assist in determining such abnormal conditions. The process shall be required to remain subcritical with an appropriate margin under such conditions, but it should be recognized that additional assessment may be required before attempting to recover from the abnormal condition.

4.5 Written procedures

Written procedures shall govern all operations involving fissile material in excess of those threshold quantities requiring nuclear criticality safety assessment. Copies of applicable written procedures should be posted up or available in operating areas.

4.6 Review of procedures

The assessment of criticality safety aspects of written procedures shall be performed by persons skilled and familiar with nuclear criticality safety practices and processing operations. These persons should, to a practicable extent, be administratively independent of operations.

4.7 Processing violations

Processing violations and unusual occurrences shall be reported, analysed, and considered for possible improvements in nuclear criticality safety practices.

4.8 Training

4.8.1 Training of processing operators shall include nuclear criticality safety. The extent of training shall provide confidence that the operator can conduct activities without undue risk to himself, his co-workers or the facility.

4.8.2 Supervisors shall be sufficiently knowledgeable to provide guidance to operators concerning the safety of operations.

5 Technical criteria

5.1 General

5.1.1 The potential for criticality depends upon:

a) the nuclear properties of the fissile material;

b) the mass of fissile material present and its distribution within the system being assessed;

c) the mass and distribution of all other materials associated with the fissile material.

In the preparation of nuclear criticality safety assessments, it is generally assumed that only those substances commonly encountered in nature and in construction materials, or usually associated with operations, will be mixed with or located near fissile materials.

5.2 Methods of control

Criticality safety control(s) in any operation are based upon any one or a combination of the factors affecting criticality discussed in 5.4.

5.3 Achievement of control

5.3.1 The control of nuclear criticality safety by such methods as those indicated in 5.4 can be achieved by:

a) equipment design;

b) use of process control systems with associated instrumentation;

c) administrative control of operations.

5.3.2 Where practicable, the maintenance of control shall depend on safety provided by the equipment, or instrumentation, rather than on administrative control. It is recognized that some reliance on administrative control is inherent in any operation. Where controls are based on equipment, passive safety design should be considered in preference to active safety systems (for example a favourable geometry vessel is preferable to a non-favourable geometry vessel that is instead controlled by monitoring and control of fissile concentration).

5.4 Factors affecting criticality

5.4.1 General

All relevant factors shall be considered singly and in appropriate combination for both normal operations and abnormal conditions assessed for a comprehensive assessment of nuclear criticality safety. A combination of those factors could lead to necessary complex optimization of critical values. The factors are given in 5.4.2 to 5.4.13.

5.4.2 Mass

Criticality safety control can be provided by control of the mass of fissile material present in an operation.

5.4.3 Geometry

Criticality safety control can be provided by the use of processing or storage vessels that have a large neutron leakage (e.g. by limitation of the dimensions or shape of operational equipment). Cylinders or slabs of a suitable shape can be very reliable safety designs. Consideration shall be given to possible changes in geometry by faults such as leaks/ruptures of vessels and pipework, or unintentional transfers of fissile solutions to unfavourable geometry vessels. Consideration shall also be given to potential vessel dimension changes such as (but not limited by) over-pressurization, bulging/distortion or corrosion.

5.4.4 Volume

By limiting the available space for a fissile material to occupy or by limiting the quantity of material present, criticality safety control may be achieved. Examples such as a limited size vessel or tank, or a limit to the volume of a solution present in a process are a means of defining a volume control.

5.4.5 Concentration

The quantity of fissile material per unit volume can be a means of nuclear criticality safety control. Concentration is a factor most commonly associated with fissile solutions. This factor is often closely related to the factor of moderation since in many cases solutions of fissile material are with effective moderators.

5.4.6 Moderation

The presence of neutron-moderating material mixed with fissile material can substantially reduce the mass of fissile material necessary to achieve criticality. Water, oil and similar hydrogenous substances are the most common moderators present in the storage, handling and processing of fissile material, and all credible combinations shall be considered.

5.4.7 Neutron absorbers

5.4.7.1 The presence of appropriate neutron absorbers can be an effective means of criticality safety control, noting the reliance on neutron absorbers requires assurance of their continued presence. Equipment and processes can conform to the requirements of nuclear criticality safety by using neutron absorbing materials, such as cadmium and boron, provided available data confirm that their suitability and their presence can be assured. Where practicable, the incorporation of solid neutron absorbers as permanent, integral parts of equipment is more desirable than the use of neutron absorbers in solution, because of the processing controls required to demonstrate the continued presence of dissolved absorbers.