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Nuclear Energy - Fissile Materials - Principals of criticality safety In storing, handling and processing

Sûreté-criticité – Matières fissiles : Principes de sécurité en matière de criticité lors du stockage, de la manipulation et do traitement

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Foreword

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ISO 1709 was prepared by Technical Committee ISO/TC 85, *Nuclear Energy*, Subcommittee SC 5, *Nuclear Fuel Technology*.

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

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Nuclear criticality safety — Emergency preparedness and responseFissile materials - Principals of criticality safety in storing, handling and processing

1 Scope

This International Standard specifies the basic principles and limitations which govern operations with fissile materials. It discusses general 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 quality assurance requirements or details of equipment or operational procedures. The issues associated with administrative criteria relating to nuclear criticality safety shall be considered in accordance with ISO-14943. It does not cover the effects of radiation on man or materials, or sources of such radiation, either natural or as the result of nuclear chain reactions. Transport of fissile materials outside the boundaries of nuclear establishments is not within the scope of this International Standard and should be governed by appropriate national and international standards and regulations.

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 must be imposed on operations because of the unique properties of these materials which permit them to support nuclear chain reactions. These principles apply to quantities of fissile materials in which nuclear criticality can be established.

2 Normative references

The following standards contains provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards

ISO 11320:2011, *Nuclear Criticality Safety - Emergency Preparedness and Response*

ISO 7753:1987, *Performance and testing requirements for criticality detection and alarm systems*.

ISO 14943:2004, *Administrative criteria relating to nuclear criticality safety.*

3 Procedures

For the purposes of this document, the terms and definitions given in ISO 921 apply.

3.1 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 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 requires the cooperation of all those involved in operations.

3.2 Responsibility

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

3.3 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 criticality safety considerations into plant design facilitates provides economic benefits. Process and equipment design may require approval by the appropriate authority.

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Processing controls may be enhanced by the use of appropriate instrumentation.

3.4 Criticality assessment

A criticality assessment is required for all operations and facilities under the scope defined in Section 1 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 foreseeable abnormal conditions. The reasoning may be based on comparison with established criteria (for example mass or enrichment of fissile material).

The criticality assessment shall consider all foreseeable abnormal conditions. Processing supervision 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 situation.

3.5 Written procedures

Written procedures shall govern all operations involving fissile material in excess of those threshold quantities defined by management. Copies of applicable written procedures should be posted up or available in operating areas.

3.6 Review of procedures

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

3.7 Processing violations

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

3.8 Training

Training of processing operators shall include 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.

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

Assistance in training shall be provided by the criticality safety specialists when requested by management or supervisors.

4 Technical criteria

4.1 General

In the preparation of 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. The achievement of 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.

The assessment should consider all normal and abnormal conditions that can be foreseeable as credible.

4.2 Methods of control

Methods of control of criticality safety in any operation include, any one or a combination of the Factors Affecting Criticality discussed in Section 4.4.

4.3 Achievement of control

The control of criticality safety by such methods as those indicated in 4.2 can be achieved by

a) equipment design;

b) use of process control systems with associated instrumentation;

c) administrative control of operations.

Where practicable, the maintenance of control shall depend on safety features incorporated in the equipment, or instrumentation, rather than on administrative control. It is recognized that some

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reliance on administrative control is inherent in any operation.

4.4 Factors affecting criticality

All relevant factors shall be considered singly and in combination for a proper assessment of criticality safety. A combination of those factors could lead to unexpected critical values. The factors are given in 4.4.1 to 4.4.11.

4.4.1 Mass

The quantity of a fissile substance is a parameter that affects criticality. Criticality control can be provided by control of the mass of fissile material present in an operation.

4.4.2 Geometry

Criticality 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 vessel dimensions caused by over-pressurization or corrosion.

4.4.3 Volume

The volume of a fissile substance is a parameter that affects criticality. By limiting the available space for a fissile material to occupy or by limiting the quantity of material present, criticality 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..

4.4.4 Concentration

The concentration of fissile material in solutions can be a means of criticality safety control. This factor is often closely related to the factor of Moderation since in many cases solutions of fissile material are with effective moderators.

4.4.5 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 forseeable modes of incorporation shall be considered

4.4.6 Neutron absorbers

The presence of appropriate neutron absorbers can be an effective means of criticality control, noting the reliance on neutron absorbers requires assurance of their continued presence. Equipment and processes can conform to the requirements of 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.

Neutron-absorbing materials are most effective for neutrons of thermal energy and care shall be exercised to ensure that their effectiveness is not seriously reduced in operational or accident conditions, which might change the fissile assembly into one characterized by neutrons of intermediate or high energy.

4.4.7 Physical and Chemical Form

The chemical nature of a fissile material can affect its properties with respect to criticality (e.g. metal verses oxide). The physical form can also affect it criticality properties (e.g. solid or liquid).

4.4.8 Density

The density of a fissile material affects criticality safety. Reduction in density of a single unit will reduce nuclear reactivity due to increased neutron leakage. It is important to distinguish between this factor and Concentration.

4.4.9 Enrichment

The proportion of a fissile isotope to that of a non-fissile, or fissionable isotope has a direct effect on the criticality properties of a nuclear material. Greater enrichments usually result in lower critical parameters, and hence control of enrichment may be used as a means to maintain criticality safety.

4.4.10 Reflection

The most effective neutron reflector commonly encountered in handling and in processing fissile

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material is water of thickness sufficient to yield maximum nuclear reactivity.

However, careful consideration shall be given to systems where significant thicknesses of other common structural materials (for example concrete, steel), which may be more effective neutron reflectors than water, may be present. For some situations, the reflection provided by personnel may be important.

4.4.11 Interaction

Consideration shall be given to neutron interaction between units when at least two units containing fissile material are present. It is possible to reduce neutron interaction to acceptable proportions either by spacing units, by insertion of suitable neutron moderating and absorbing materials between units, or by some combination of these methods.

4.5 Possible abnormalities

The effect of the occurrence of foreseeable abnormal conditions shall be considered in the assessment of safety. These include such factors as

a) loss or introduction of moderating material into or between units of fissile material: for example, evaporation, precipitation, dilution and flooding;

b) introduction of neutron-reflecting material near units of fissile material;

c) change in shape of fissile material due to such occurrences as vessel leakage or breakage;

d) change in operating conditions: for example, loss of flow, precipitation, excessive evaporation, violation of mass or volume limits;

e) change in conditions of neutron interaction: for example, collapse or overturn of equipment;

f) loss of neutron absorber, or reduction in absorber effectiveness as a result of moderator loss;

g) double batching, or over batching to the extent that the equipment does not preclude such an occurrence.

h) Accumulation of material in an undesired location. This could be as a result of mis-routing or leakage of fissile material, or materials that affect criticality safety (e.g. moderators, reflectors)

4.6 Bases of assessment

Wherever possible, the specification for criticality safety shall be established on bases derived directly from experiments. In the absence of directly applicable experimental measurements, which is a common situation, the results of calculations are acceptable, provided they are shown to compare favourably with experimental data. However, calculated results shall be subjected to margins of safety sufficient to guarantee with confidence that the system will be subcritical.

4.7 Margin of safety

In all specifications, the margin of safety shall be commensurate with the uncertainty in the basis of assessment, the probability of its violation, and the seriousness of the consequences of a conceivable criticality accident.

As an example, operations should, in general, incorporate sufficient safety features so that two unlikely, independent, concurrent changes must occur in the conditions originally specified as essential to criticality safety before the system may become critical. The occurrence of one of these changes would indicate that the safety of the process should be re-evaluated.

5 Equipment control

Safety evaluations shall clearly identify those items of equipment that are important in maintaining the safety of operations. For those items identified, they should undergo substantiation to assure they are capable of delivering the credited safety function. Safety equipment should be commissioned and tested to assure they continue to deliver their safety function during operations.

Prior to starting a new or modified process or processing line, it shall be ascertained that all equipment is consistent in dimension and material with the assumptions on which the criticality safety assessment was based.

6 Material control

The movement of fissile material shall be controlled. Appropriate labelling of materials and marking of areas shall be maintained, specifying

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material identification and all limits on parameters that are subjected to criticality control.

7 Dispatch and receipt of material

Appropriate arrangements shall be made between the consignor and consignee before fissile material is dispatched from an establishment or to another facility. Provision shall be made for the receipt of damaged packages.

The movement of fissile material within establishments or facilities is subject , at least, to the same evaluation requirements as that for other processes involving fissile material.

8 Monitoring of procedures

Processing operations shall be reviewed by comparison with the applicable written procedures on a periodic basis. The review shall be conducted by persons not directly involved with operations, and a written report provided for management and supervisors.

9 Need for an emergency plan and criticality alarm

The need for a criticality emergency plan shall be in accordance with ISO-11320. The need for criticality accident alarms shall be evaluated in accordance with IS0 7753. Where alarm systems are considered necessary, emergency procedures shall be prepared. Guidance for the preparation of emergency procedures may be found in annex A of IS0 7753.

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