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

Énergie nucléaire — Matières fissiles — Principes de sécurité en matière de criticité lors du stockage, de la manipulation et du traitement

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 1709 was prepared by Technical Committee ISO/TC 85, *Nuclear energy*, Subcommittee SC 5, *Nuclear fuel technology*.

This second edition cancels and replaces the first edition (ISO 1709:1975), which has been technically revised.

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Nuclear energy — Fissile materials — Principles 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, nor does it 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 reference

The following standard 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 7753:1987, *Performance requirements and testing procedures for criticality detection and alarm systems.*

3 Procedures

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 favorably with the frequency and severity of common industrial accidents. Continuation and improvement of this generally favorable 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 design and provides economic benefits. Process and equipment design may require approval by the appropriate authority.

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

3.4 Criticality assessment

The criticality assessment shall consider all reasonably foreseen 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, in the event of unforeseen circumstances, 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, analised, 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 processing conditions that can be foreseen as reasonable.

4.2 Methods of control

Methods of control of criticality safety in any operation include, but are not limited to, any one or a combination of the following:

a) limitation of the dimensions or shape of operational equipment;

b) control of the mass of fissile material present in an operation;

c) control of the concentration of fissile material in solutions;

d) control of neutron moderation associated with the fissile material;

e) the presence of appropriate neutron absorbers; reliance on neutron absorbers requires assurance of their continued presence;

f) control of the spacing between material and equipment.

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 reliance on administrative control is inherent in any operation.

4.4 Factors affecting criticality

A number of factors shall be considered singly and in combination for a proper assessment of criticality safety. Some of the more important factors are given in 4.4.1 to 4.4.5.

4.4.1 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 reasonably forseeable modes of incorporation shall be considered.

4.4.2 Reflection

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

4.4.3 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.

4.4.4 Neutron absorbers

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.

4.4.5 Geometry

Criticality control can be provided by the use of processing or storage vessels that have a large neutron leakage. 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.

4.5 Possible abnormalities

The effect of the occurrence of reasonably 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.

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 exprimental 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

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 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. Provision shall be made for the receipt of damaged packages.

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.

10 Need for criticality alarms

The need for criticality accident alarms shall be evaluated in accordance with ISO 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 ISO 7753.

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