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Nuclear energy – Fissile materials – Principles of criticality safety in handling and processing

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Nuclear energy – Fissile materials – Principles of criticality safety in handling and processing

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies the factors and technical criteria which form the basis on which the procedures relating to criticality safety in handling and processing fissile materials should be established. It does not cover details of equipment design or of operational procedures, nor does it refer to the effects of radiation on man or materials or to sources of such radiation, either natural or the result of nuclear chain reactions. Transport of fissile materials outside the boundaries of nuclear establishments should be governed by appropriate national and international regulations.

These principles apply to all operations with fissile materials outside the cores of nuclear reactors but within the boundaries of nuclear establishments. They are concerned with the limitations which must be imposed on processes and equipment because of the unique nuclear properties of these materials by which they can support nuclear chain reactions. These principles apply to quantities of fissile materials in which nuclear criticality can be established.

2 PROCEDURES

2.1 General

Common industrial procedures are not sufficent for operations with fissile materials and shall be supplemented by appropriate regulations to enhance criticality safety in the process.

2.2 Responsibility

Ultimate responsibility for criticality safety in all operations shall rest clearly on process management through the normal management chain of command. Individual responsibility shall be clearly defined and recorded in establishment instructions.

2.3 Specialist advice

The advice of specialists in criticality safety shall be obtained when assessing the safety of a process and of operational procedures. It is recommended that these specialists be independent of normal process management and that they should directly advise the manager of the establishment. The safety features of all designs and operational procedures for processes shall be assessed by two separate, and preferably independent, groups. At least one of these groups shall be skilled in the interpretation of experimental criticality data as well as being familiar with process operations.

2.4 Criticality assessment

2.4.1 Criticality assessment shall begin as early as possible in the design stage of new processes or whenever a change is contemplated in an existing process. Consideration shall be given to the basic forms of control to be employed; for example, restriction of vessel geometry, limitations on mass, use of process control instrumentation, or any other feature or combination of features. Wherever possible, controls other than administrative ones shall be used for criticality safety.

2.4.2 As part of the initial assessment, consideration shall be given to the need for a radiation monitoring system to detect the occurrence of a criticality accident.

2.4.3 Criticality assessment shall take account of abnormal conditions and non-routine operations. Consideration shall be given to the most reactive system that could be produced in the course of normal operations or that is a technically possible result of abnormal circumstances.

2.4.4 Unusual occurrences or situations shall be investigated to determine their possible effects on criticality safety.

2.5 Training

Adequate training in criticality safety shall be given to all personnel involved in operations with fissile materials.

2.6 Operational control

2.6.1 Careful operational control shall be exercised over all processes and materials to enforce compliance with the safety assessment.

2.6.2 Clear and comprehensive written operating instructions, including safety instructions, shall be prepared for all normal and non-routine operations with fissile materials.

2.6.3 Regular reviews and inspections of process procedures shall be instituted to guard against the accumulation of a number of minor changes in process conditions causing the initial assessment to be invalidated.

2.6.4 Accountancy procedures shall be established to ensure that the location and movement of fissile material can be adequately controlled and recorded.

2.6.5 Emergency and radiological protection procedures shall be prepared and rehearsed for use in the event of a criticality accident.

2.6.6 Actions to be taken following a criticality accident shall be carefully considered and prescribed in order not to cause any further accident.

2.7 Movement within the establishment

The movement of fissile material within an establishment or between stages of a process shall at all times be fully controlled according to clearly defined procedure.

2.8 Dispatch and receipt of material

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

3 TECHNICAL CRITERIA

3.1 General

In general considerations of criticality safety problems, it is assumed that only those substances commonly encountered in nature and in constructional materials or usually associated with processes will be mixed with or located near fissile materials. The achievement of criticality depends upon.

a) the properties of the fissile material;

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

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

3.2 Methods of control

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

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

b) control of the mass of fissile material present in a process;

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

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

e) the presence of appropriate neutron absorbers.

3.3 Achievement of control

The control of criticality safety by such methods as those indicated in 3.2 can be achieved by

a) equipment design;

b) use of process control instrumentation;

c) administrative control of operations.

Where possible, the maintenance of control shall depend on safety features incorporated in the equipment or on the instrumentation rather than on administrative control.

3.4 Factors affecting criticality

A number of factors shall be considered both singly and in combination for a proper analysis of criticality safety. Some of the more important factors are the following :

a) *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 handling and the processing of fissile material.

b) *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 surround or cover an appreciable fraction of a container surface.

Where the extent of neutron reflection by such partial or potential reflectors as vessel walls, supports, or personnel cannot be assessed accurately, or the possibility of neutron reflecting materials being introduced accidentally by flood or firefighting cannot be discounted, the most effective reflector conditions shall be assumed in the assessment of single units. If limitation of reflecting materials can be guaranteed, appropriate relaxations are permitted.

c) *Interaction.* Consideration shall be given to neutron interaction between units when more than one unit containing fissile material is present. It is possible to reduce neutron interaction to acceptable proportions either by spacing items or by insertion of suitable neutron moderating and absorbing materials between items, or by some combination of these methods.

d) *Neutron absorbers.* Equipment and processes can conform to the requirements of criticality safety by the use of neutron absorbing materials, such as cadmium and boron, provided available data confirm their suitability and their presence can be assured. The use of solid neutron absorbers in the construction and assembly of equipment is preferred; the use of solutions of neutron absorbers is less desirable because of the administrative and chemical controls necessary to ensure their presence. 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.

3.5 Possible abnormalities

The effect of the occurrence of possible 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 of 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 limits;

e) change in conditions of neutron interaction; for example, collapse or overturn of equipment, passage of fissile material in transport.

4 EVALUATION PHILOSOPHY

4.1 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, the results of calculations are acceptable provided they are shown to compare favourably with experimental data.

4.2 Margin of safety

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

Operations shall, in general, incorporate sufficient safety features to ensure that two independent, concurrent changes must occur in the conditions originally specified as essential to criticality safety before the system may become critical. Following the occurrence of one of these changes the safety of the process shall be re-evaluated.