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Nuclear criticality safety — Analysis of a postulated criticality accident

Sûreté-criticité — Analyse d'un hypothétique accident de criticité

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 27467 was prepared by Technical Committee ISO/TC 85, *Nuclear energy*, Subcommittee SC 5, *Nuclear fuel technology*.

Introduction

In nuclear facilities processing or storing fissile material, provisions are made to avert the risk of criticality. The purpose of a criticality safety analysis is to ensure that the measures taken are adequate to prevent criticality accidents. The risk contributions associated with a criticality accident arise from direct radiation from the fission events, the presence of fission products, as well as from possible airborne radioactive gases and particulates.

Worldwide criticality-accident experience shows that these are very rare events, yet the risk associated with future occurrences cannot be completely eliminated. It is difficult to contemplate all the scenarios whose conditions can lead to a criticality accident, and even more so to avoid them, particularly with solution media where many of the past accidents have occurred. For this reason, an analysis based on postulated accident scenarios, in any facility where a potential risk of criticality can still be extant, can be the vehicle to understand the expected consequences and provide for the appropriate provisions and protective actions.

Nuclear criticality safety — Analysis of a postulated criticality accident

1 Scope

This International Standard specifies areas that are important to study when analysing potential criticality accidents.

NOTE 1 It is important that a criticality accident analysis be performed each time a criticality accident is considered credible, due either to criticality contingencies (double batching, procedural violations, etc.) or to the failure of safety provisions (effectiveness of neutron absorber reduced by fire, etc.).

NOTE 2 It is important that the criticality safety specialist be mindful that the process of evaluation developed in this International Standard does not cater for the unforeseen, since any actually occurring criticality accident will probably result from a scenario not envisioned or from failure to comply with prevailing regulations.

This International Standard does not address detailed administrative measures, for which the responsibility lies with the public authorities, nor does it deal with criteria used to justify the accident criticality analysis of a nuclear facility.

This International Standard does not apply to nuclear power plants.

2 Normative references

The following referenced documents are indispensable for the application 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*

3 Terms and definitions

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

3.1

accident scenario

set of credible, postulated conditions under which a fissile-material-containing facility/process develops one or more fault conditions such that is likely to exceed the critical state, and thus to result in a criticality accident

3.2

radiological consequences

individual and collective radiation doses resulting from the combined effects of external exposure due to direct radiation and internal exposure caused by inhaling or ingesting either volatile radionuclides released to environment or non-volatile and fissile material suspended as particles in the facility

4 Criticality accident analysis objectives

4.1 Criticality accident analysis shall be comprised of the following considerations (see Figure 1):

a) determination of the credible accident scenario(s);

b) estimation of the power history and the energy release;

c) suitable means of detecting the accident and suitable siting of detectors;

d) estimation of potential individual exposure and radiological impact of radionuclide releases on the general public and the environment;

e) suitable provisions for emergency preparedness and response to a criticality accident.

4.2 These requirements may be facilitated in part or whole by the following considerations:

a) criticality accident dynamics, i.e. understanding the mechanisms that govern accident progress in order to estimate energy releases;

b) accident-detection capabilities, including timely triggering of criticality alarms for immediate evacuation of individuals, as a means of limiting radiation exposure risk;

c) analysis of “airborne releases” by measuring potentially releasable fission gases and aerosols, and suspendable nuclear matter, and estimating their impact on people and the environment;

d) accident dosimetry, i.e. determination of the doses due to accident-induced neutron and gamma irradiation, for radiation risk analysis purposes;

e) consideration of the overall risk of harm from measures considered in the emergency plan.

NOTE Items of information in c) and d) are used to estimate radiological consequences.

5 Components of a criticality accident analysis

5.1 Criticality accident analysis topics

The criticality accident analysis should approach the following topics:

a) definition of the accident scenarios that permit the analysis of accident dynamics (total energy release, duration, first power spike characteristics, etc.);

b) study of adequate detector locations based on the analysis of accident phenomena, in particular the first spike characteristics;

c) estimated risk of individual exposure in the vicinity of the criticality accident and assessment of the environmental impact of airborne releases also served by accidents characteristics (fissile media, configurations, energies, etc.);

d) emergency preparedness and response support necessary.

NOTE Annex A illustrates how the components of an analysis of a postulated criticality accident, shown as different steps/stages of a study, can be addressed.

5.2 Definition of a postulated accident and associated neutronics calculations

5.2.1 The criticality safety specialist shall define the accident scenario according to

a) the type of fissile material, type of process (high-temperature, i.e. risk of fire, aqueous, damp, mixtures, etc.) and affected equipment configurations (i.e. geometry, interaction with adjacent materials or moderators, etc.),

b) the events leading to supercriticality, that is, definition and chronology of the accident (insertion of excess fissile material or moderator, loss of moderator, process malfunction, etc.).

5.2.2 Based on the scenario(s) as defined in 5.2.1, the following criticality parameters should be calculated:

a) total reactivity insertion and insertion kinetics, to estimate the power excursion (in particular the first power spike);

b) system neutronics parameters.

NOTE The relevant parameters in b) that can be needed for the analysis are the neutron lifetime, the prompt critical state, the delayed neutron importance (i.e. effective delayed neutron fraction), the material buckling, the infinite multiplication factor, the migration lengths, etc.

5.3 Accident physics calculations

5.3.1 Evaluating criticality accident physics

Given the postulated accident scenario as defined in 5.2, the criticality safety specialist shall evaluate the accident physics by using either or both of the following:

a) calculation codes,

b) simplified models.

WARNING — The long-term effects of an accident can be driven mainly by heat exchanges in the vicinity of the supercritical system (cooling, ventilation). Consideration of the possible long-term accident effects should be given when analysing a criticality accident.

5.3.2 Using calculation codes

5.3.2.1 These calculations require use of a criticality accident computer code that determines power and energy changes in the transient and provides trends for other parameters (temperature, radiolysis gas and steam bubbles, pressure, etc.) as a function of time.

WARNING — Uncertainties determined by validation or justified by the inadequacy of the model to represent the criticality accident scenario can exist. So care should be taken when using computer codes.

5.3.2.2 The calculations shall specifically estimate

a) the accident “envelope”, meaning the total number of fissions that can halt the accident by restoring the system to permanent subcriticality if no suitable means (e.g. neutron poisoning, robotic equipment) were used to quench it,

b) the first power-spike characteristics, which enable the optimal location of the criticality accident alarm system detectors.

5.3.3 Using simplified models

5.3.3.1 For accident physics, simplified options providing “order-of-magnitude” data should be considered.

5.3.3.2 These entail the use of

a) simplified models devised from experimental data,

b) results of experiments or past accidents that were adequately documented.