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Nuclear criticality safety — Estimation of the number of fissions of a postulated criticality accident

Sécurité de criticité nucléaire — Évaluation du nombre de fissions en cas d'un hypothétique accident de criticité

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Foreword

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The committee responsible for this document is ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 5, *Nuclear fuel cycle*.

Introduction

In activities involving fissile materials, the potential for a criticality accident occurrence cannot be totally excluded. Therefore, in order to prepare emergency responses in case of such an occurrence, ISO 27467 specifies areas to be studied (Annex A) to perform the analysis of potential consequences whenever a credible criticality accident may occur. This International Standard deals with one of these areas and is devoted to the estimate of number of fissions (also commonly named “fission yield”) for a postulated criticality accident. This topic is essential because most of the other issues of the criticality accident analysis depend on a suitable estimate of this number of fissions.

Nuclear criticality safety — Estimation of the number of fissions of a postulated criticality accident

1 Scope

This International Standard provides a methodology to estimate a reasonably maximal value of the number of fissions of a postulated criticality accident.

The fission number estimate, associated with its postulated criticality accident, impacts the accident emergency planning and response because it is used for the estimation of radiation doses and of radioactive materials release.

This International Standard does not provide a methodology and guidance to determine bounding accident scenarios.

This International Standard does not cover criticality accident detection which is dealt with by ISO 7753.

This International Standard does apply to nuclear facilities, plants, laboratories, storage, and transportation of fissile material (but not to nuclear power reactor cores) where a credible criticality accident may occur.

2 Terms and definitions

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

2.1
postulated criticality accident
postulated association of one accident scenario and one accident evolution

Note 1 to entry: One postulated criticality accident is associated with one estimated number of fissions.

2.2
accident scenario
set of credible, postulated conditions under which a fissile material-containing facility/process develops one or more fault conditions such that it is likely to exceed the critical state and thus to result in a criticality accident

Note 1 to entry: This definition is drawn from ISO 27467.

2.3
accident evolution
progress of the criticality accident (after the critical state is exceeded), taking into account physical phenomena (for example, temperature and void effects) and possible human interventions to stop it

2.4
area of applicability
set of parameters (for example, environment, geometrical characteristics, fissile material, accident duration) within which a tool/model is intended to be used

Note 1 to entry: In Annex D, the last columns of the tables summarize the area of applicability of some simplified formulae.

3 General principles

PREREQUISITES Once the objectives of the criticality accident analysis (analysis based, for example, on ISO 27467) are defined, one or several criticality accident(s) may be postulated. The assumptions of the postulated criticality accident, and therefore the potential consequences, are to be related with the objectives of the criticality accident analysis (for example, design of evacuation routes, dose mapping, assembly station(s) choice).

EXAMPLE 1 Because bounding assumptions may be different for radiation dose estimates and for radioactive materials release estimates, it is possible to choose a set of assumptions adapted for each estimate.

EXAMPLE 2 The design of evacuation routes may be performed with an arbitrary number of fissions; the goal is to optimize the operators' evacuation routes, whatever the value of the dose is. In this case, the location of the postulated criticality accident is the most important parameter.

3.1 For the estimation of the number of fissions, the following assumptions, as well as their variations, should be considered:

— description of the equipment (geometric configuration, reflector, etc.);

— degree of confinement and environment (vessel open or closed, pressure, cooling, etc.);

— fissile material (quantity, enrichment, media, physical shape, chemical form, etc.);

— total reactivity addition;

— rate of reactivity addition;

— time delay before the first persistent chain reaction (function of the initial neutron source, i.e. spontaneous fissions, (alpha, n)-reactions, etc.);

— duration of the criticality accident (calculated/estimated with and without intervention, where applicable).

3.1.1 The determination of these assumptions should be drawn from the accident scenario and the accident evolution of the postulated criticality accident.

3.1.2 The chosen assumptions shall be within the domain physically possible according to the characteristics of the considered activity (characteristics of the facility, of the transportation, etc.).

WARNING — The estimation of the number of fissions is only the first part of the determination of the consequences of the postulated criticality accident (see, for example, the flow diagram from ISO 27467 in Annex A). The overall estimation of the consequences shall take into account all the aspects of the criticality accident and iterations between estimation of the number of fissions and subsequent actions (for example, doses estimation) should be performed. For example, in case of different possible locations for a criticality accident, the postulated criticality accident leading to the highest number of fissions may not necessarily lead to the maximum doses for workers and the public because of its location. Other assumptions affecting the consequences of the postulated criticality accident should then be considered, such as:

— location of the equipment, place of the criticality accident;

— building description;

— location of people;

— criticality accident alarm system presence/absence.

3.2 Each fissions number estimate shall be associated with an approximated duration. Account should be made of any anticipated human interventions in the accident evolution.

3.3 Number of fissions shall be determined by using simplified models (4.3 and notably 4.3.2) or calculation tools (4.4) or both.

4 Fissions number estimate

4.1 General

4.1.1 For the estimate of the number of fissions, the use of the simplified models route (4.3) should be firstly considered.

4.1.2 The use of the calculation tools route (4.4) may then be considered, according to the objectives of the criticality accident analysis (for example, design of evacuation routes, dose mapping, and assembly station(s) choice). This route requires:

— the availability of a calculation tool able to simulate the criticality accident, and

— the determination of all input data needed for the calculation tool.

4.1.3 In the case where the two routes of estimate are used, the origin of a different order of magnitude between the two results should be understood and documented.

4.2 Input data

4.2.1 The input data needed for the simplified models or the calculation tools (geometry, external environment, media characteristics, etc.) shall be taken from assumptions considered for the accident scenario and the accident evolution. When the accident scenario and the accident evolution do not set necessary input data, these should be measured or calculated or estimated from the international literature.

NOTE Depending on the way estimates are made, the type and the number of input data needed may vary.

4.2.2 The selected input data sensitivities (linked to uncertainties and possible variations pointed out in 3.1) should be studied for the chosen route(s) of estimate (4.3 and/or 4.4). This study will provide a better understanding of the uncertainties associated with the estimated number of fissions. This study may be one possible basis for the nuclear criticality safety specialist to appropriately select a maximal estimate. Otherwise, further justifications should be made as to the applicability of the result.

4.2.3 Account shall be made for parameters that could vary significantly for the criticality accident duration.

4.3 Use of simplified models

4.3.1 The estimate of number of fissions should be based on simplified options providing “order-of-magnitude” values.

4.3.2 This estimate should rely on the collective experiences from past criticality accidents (Annex B) and criticality experiment results (Annex C) and the possible use of simplified formulae (Annex D).

4.3.3 When a simplified model is used, the consistency of its area of applicability with the chosen assumptions of the postulated criticality accident shall be justified and documented.

NOTE The duration of the criticality accident has a significant impact on the evaluation. Actually, simplified models are mainly based on criticality experiments and past criticality accidents stopped after human intervention.

4.3.4 To estimate the number of fissions, the simplified models results should be associated with the sensitivity study performed (4.2.2).

4.4 Use of calculation tools

WARNING — Care should be taken when using the criticality accident calculation tool results for the estimation of the number of fissions. In particular, a complete validation of a criticality accident calculation tool is presently difficult, mainly due to the complexity of models and paucity of criticality experiment and precise information from past criticality accidents.

4.4.1 The calculation tool used shall be documented, including the verification of the adequate implementation of the different models (for example, neutron physics, thermal transfer, bubbles behaviour).

4.4.2 When it is possible, comparison between the calculation tool results and experiments/accidents close to the chosen assumptions of the postulated criticality accident should be documented.

4.4.3 When a calculation tool is used, the consistency of its area of applicability with the chosen assumptions of the postulated criticality accident shall be justified and documented. In case of inconsistency, the calculation tools may still be used; however, justification for its use shall be documented.

4.4.4 Free evolution of the system during the accident duration shall be accounted for. Resulting assumptions used in the calculation should lead to a maximal evaluation of the number of fissions.

4.4.5 To estimate the number of fissions, the calculation tool results should be associated with the sensitivity study performed (4.2.2) and with other available elements (for example, results obtained from comparison with experiments, complexity of models, possible penalizing hypothesis in the models).

Annex A
(informative)

Flow diagram of a criticality accident analysis(from ISO 27467:2009)