

SAFETY STANDARDS
of the
Nuclear Safety Standards Commission (KTA)

KTA 3104
Determination of the Shutdown Reactivity
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Comment:

In these English translations of KTA-Safety Standards the words shall, should and may are used with the following meanings:

- shall** indicates a mandatory requirement,
- should** indicates a requirement¹ to which exceptions are allowed. However, the exceptions shall be substantiated during the licensing procedure,
- may** indicates a permission and is, thus, neither a requirement (with or without exceptions) nor a recommendation: recommendations are worded as such, e.g., "it is recommended that".

The word combinations basically shall/shall basically are used in the case of mandatory requirements to which specific exceptions (and only those!) are permitted. These exceptions - other than in the case of should - are specified in the text of the safety standard.

¹ Please note that in the case of IAEA NUSS standards and ANSI standards, the word "should" indicates a mere recommendation.

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PLEASE NOTE:

Only the original German version of this safety standard represents the joint resolution of the 50-member Nuclear Safety standards Commission (Kerntechnischer Ausschuss, KTA). The German version was made public in Bundesanzeiger No. 44a on March 4, 1988. Copies may be ordered through the Carl Heymanns Verlag KG, Gereonstr. 18-32, D-5000 Köln 1.

Nuclear Safety Standards Commission (KTA)

Federal Republic of Germany

1 Scope

This Safety Standard applies to nuclear power plants with light water reactors. It applies to the determination of the shutdown reactivity of reactor cores for conditions following a shutdown during specified normal operation and for conditions during the course of incidents without loss of coolant. The specification of numerical values for the required shutdown reactivity is not dealt with in this safety standard.

2 Definitions

(1) Shutdown Reactivity

The shutdown reactivity is the reactivity of the reactor which was transferred to the subcritical condition with the equipment provided for this purpose.

Note:

The shutdown reactivity is a function of the reactor condition following shutdown.

(2) Reactivity Equivalent

The reactivity equivalent of a change of condition is the reactivity change caused by that change of condition.

(3) Reactivity Balance

The reactivity balance is the representation of a reactivity difference between two conditions as the sum of reactivity equivalents of simple or composite changes of condition.

(4) Reactivity Coefficient

The reactivity coefficient of a condition parameter is the partial derivative which represents the change in reactivity as a function of this condition parameter.

(5) Reactivity Measuring Method, Inversely Kinetic

The inversely kinetic reactivity measuring method is a method which determines the reactivity on the basis of the time history of a neutron flux signal.

(6) Effectiveness of Reactivity Control Elements, Differential

The differential effectiveness of reactivity control elements is the reactivity coefficient allocated to a control element.

(7) Effectiveness of Reactivity Control Elements, Integral

The integral effectiveness of reactivity control elements is the reactivity equivalent allocated to a control element.

3 Methods for the Determination of the Shutdown Reactivity

(1) The following methods are available for the determination of the shutdown reactivity:

- a) Using a calculation of the effective multiplication factor k_{eff} for the shutdown reactor in accordance with Section 4.
- b) Using a reactivity balance for the transition from a reference condition of known reactivity to the shutdown condition. The following can be used in this reactivity balance:
 - ba) reactivity equivalents calculated in accordance with Section 4, or
 - bb) reactivity equivalents measured in accordance with Section 6.1, or
 - bc) reactivity equivalents determined on the basis of equivalent changes of condition in accordance with Section 6.2, or
 - bd) calculated reactivity equivalents normalized by differential measurements in accordance with Section 6.3, or

be) a combination of calculated and measured reactivity equivalents.

c) As an equivalent change of condition in accordance with Section 7.

(2) The shutdown reactivity shall be determined at least for each operating period. The results of experimental demonstrations shall be extrapolated to cover the entire operating period, either by means of supplementary calculations or on the basis of generally valid physical laws.

Note:

Operating period is the time period during which the reactivity-determining configuration of the reactor core remains unchanged and the nuclear composition of the reactor core is changed only by progressive burnup. For example, an operating period is the time period between two refueling operations (burnup cycle) during which the burnup is, e.g. compensated for by a change in control rod positions or in the boron concentration. In as far as required by the relevant safety criteria to be applied, it shall be assumed that the shutdown equipment is not available in its entirety, e.g. because of a jamming of the most effective control rod.

4 Calculation of the Shutdown Reactivity and of Reactivity Equivalents

(1) For the calculation of the shutdown reactivity and of reactivity equivalents, codes for stationary core calculation shall be used which have been verified for the respective scope of application.

(2) In the analytical methods the physics shall be represented by mathematical models which have been based on the physical laws governing them. For the purpose of describing individual partial physical aspects, it is also allowable, within the scope of an analytical method, to use correlations derived from experiments, provided these experiments are representative of the planned scope of application of the correlation concerned.

(3) An analytical method, including the associated data records, is considered to have been verified as soon as its applicability and accuracy have been demonstrated by means of reference cases. An analytical method is also considered to have been verified if its results show a known systematic deviation from the comparative values so that with a known correction they will be in agreement with the comparative values.

(4) The verification of an analytical method is only required to the extent its results are made part of the demonstration of the shutdown reactivity.

Note:

Example (a)

An analytical method which, with a certain set of input data, is to be used to demonstrate the effectiveness of control rods can be verified by a calculation of

- a) critical control rod configurations or
- b) integral effectiveness of control rods or
- c) differential effectiveness of control rods

which have either been measured or which have been calculated using a method that has already been verified.

Example (b)

If the same analytical method is to be used for the demonstration of temperature coefficients, with a suitably modified set of input data, it shall be verified for this particular application by a calculation of

- a) temperature coefficients or
- b) critical states at different temperatures

which have either been measured or which have been calculated using a method that has already been verified.

(5) As reference cases,

a) measurements made on reactors or critical assemblies, or