

Safety Standards

of the

Nuclear Safety Standards Commission (KTA)

KTA 3101.2 (2012-11)

Design of Reactor Cores of Pressurized Water and Boiling Water Reactors; Part 2: Neutron-Physical Requirements for the Design and Operation of the Reactor Core and Adjacent Systems

(Auslegung der Reaktorkerne von Druck- und Siedewasserreaktoren; Teil 2: Neutronenphysikalische Anforderungen an Auslegung und Betrieb des Reaktorkerns und der angrenzenden Systeme)

The previous version of this safety standard was issued in 1987-12

If there is any doubt regarding the information contained in this translation, the German wording shall apply.

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KTA SAFETY STANDARD

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Design of Reactor Cores of Pressurized Water and Boiling Water Reactors; Part 2: Neutron-Physical Requirements for the Design and Operation of the Reactor Core and Adjacent Systems

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Previous versions of this safety standard: 1987-12 (BAnz No. 44a of March 4, 1988)

Contents

Basic Principles	1
1 Scope.....	3
2 Definitions	3
3 Safety-Related Requirements for the Neutron-Physical Design and the Operation of Reactor Cores	4
3.1 Safety Level 1 (normal operation)	4
3.2 Safety Level 2 (abnormal operation)	4
3.3 Safety Level 3 (design basis accidents)	4
3.4 Safety Level 4a (very seldom postulated events)	4
4 Safety-Related Parameters, Requirements and Measures	5
4.1 Safety-Related Parameters	5
4.2 Safety-Related Requirements and Measures	5
5 Limiting and Monitoring the Power Density	7
5.1 Limiting the Power Density	7
5.2 Instrumentation of the Reactor Core	7
5.3 Identification of the Thermo-Hydraulic Operating States	8
5.4 Devices and Measures for Limiting the Power Density	8
6 Systems for Reactivity Control and Shutdown	8
6.1 General Requirements	8
6.2 Control Rod System	9
6.3 Boron Injection Systems	9
7.1 General Requirements	10
7.2 System Description and Boundary Conditions	11
7.3 Checking the Validity and Accuracy	11
7.4 Requirements Regarding Documentation	12
Appendix A Regulations Referred to in this Safety Standard	14

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 BAnz of January 23, 2013. Copies may be ordered through the Carl Heymanns Verlag KG, Luxemburger Str. 449, 50939 Koeln, Germany (Telefax + 49(0)2631-8012223).

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Comments by the Editor:

Taking into account the meaning and usage of auxiliary verbs in the German language, in this translation the following agreements are effective:

shall	indicates a mandatory requirement,
shall basically	is used in the case of mandatory requirements to which specific exceptions (and only those!) are permitted. It is a requirement of the KTA that these exceptions - other than those in the case of shall normally - are specified in the text of the safety standard,
shall normally	indicates a requirement to which exceptions are allowed. However, exceptions used shall be substantiated during the licensing procedure,
should	indicates a recommendation or an example of good practice,
may	indicates an acceptable or permissible method within the scope of this safety standard.

Basic Principles

(1) The safety standards of the Nuclear Safety Standards Commission (KTA) have the task of specifying those safety-related requirements which shall be met with regard to precautions to be taken in accordance with the state of science and technology against damage arising from the construction and operation of the plant (Sec. 7, para. 2, subpara. 3 Atomic Energy Act - AtG) in order to attain the protective goals specified in AtG and the Radiological Protection Ordinance (StrlSchV) and further detailed in the "Safety Criteria" and in the "Design Basis Accident Guidelines".

(2) In order to achieve these protective goals, a reactor plant is designed and operated in such a way that any superordinate safety-related requirements specified for the reactor core can be fulfilled. These requirements include the capabilities for shutdown, residual heat removal and retention of activity.

(3) The fulfillment of these superordinate requirements, among other things, is verified by safety-related analyses. These analyses are carried out for stationary conditions during normal operation, on postulated event sequences during specified normal operation (i.e., normal operation and abnormal operation) and for design basis accidents; these analyses are generally assigned to various analysis areas such as nuclear reactor core design, thermo-hydraulic reactor core design and thermo-mechanical reactor core design.

(4) The safety standards series KTA 3101 is comprised of the following three parts:

Part 1: Principles of the thermo-hydraulic design,

Part 2: Neutron-physical requirements for the design and operation of the reactor core and adjacent systems (*the present safety standard*),

Part 3: Mechanical and thermal design (*in preparation*).

The present Part 2 of safety standards series KTA 3101 deals with those precautionary measures referred to under para. (1) for nuclear power plants that are particular to the neutron-physical design of the reactor core.

(5) Some of the analysis areas are interconnected in a sense that the results of a prior analysis is needed as input data for a subsequent analysis; **Figure G-1** presents several examples of the safety-related parameters and shows their typical interconnections. Specific requirements are specified for each individual analysis; in order to meet these requirements, the results of the analyses must meet specified criteria.

(6) Part of the results of the nuclear reactor core analysis are used as input data for subsequent event sequence analyses. The transferred data describe physical situations, however, are dependent on the details of the mathematical models and numerical program codes used in the analyses. Nevertheless, a certain number of safety-related parameters of the reactor core can be used, independently of the models, to describe the basic physical situation. These represent the safety-related properties of the reactor core.

(7) The type of the safety-related parameters depends on the reactor type, on the event sequences on which the design of the overall plant is based, and on the applied analysis method. **Table G-1** lists typical safety-related parameters from the analysis areas of neutron physics and thermo-hydraulics which are representative for light water reactors of the current design.

Reactor power
Power density distribution, Power density
Margin to critical boiling states
Effectiveness of the control rods
Shutdown rate of emergency shutdown system
Reactivity rate during control rod motion
Effectiveness of the boron injection systems
Reactivity rate during boron injection
Shutdown reactivity
Average reactor core burnup, Fuel rod burnup, Local burnup
Reactivity coefficients of - coolant temperature, - coolant density (void coefficient), - fuel temperature (Doppler coefficient), - boron concentration
Decay-ratio (BWR)
Kinetic parameters

Table G-1: Typical safety-related parameters

(8) The nuclear safety-related parameters are calculated with the help of nuclear analysis systems. These analysis systems are suited to determine the following parameters:

- a) Multiplication factor, reactivity,
- b) Neutron flux density,
- c) Neutron current density,
- d) Gamma flux density,
- e) Reaction rates for neutron capture, neutron scattering and for fission,
- f) Thermal energy release rate of (power density),
- g) Burnup distribution, and
- h) Change of nuclide densities.

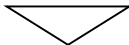
KTA 3101.1 Thermo-hydraulic Core Design 	KTA 3101.2 Nuclear Core Design 	KTA 3101.3 Thermo-mechanical Core Design 	Evaluated Data as input to other analysis areas
Departure from nucleate boiling Decay ratio (stability – BWR)	Power density	Fuel rod and fuel temperatures Casing deformations	 Thermo-hydraulic reactor core design
Pressure losses Coolant flow distribution Density and coolant temperature distribution inside reactor pressure vessel	Reactivity / Reactivity balance Power density	Permissible fuel assembly / fuel rod / peak pellet burnup Fuel rod and fuel temperatures Permissible power density gradients (PCI – pellet cladding interaction)	 Nuclear reactor reactor core design
Flow forces	Neutron flux Fuel assembly / fuel rod / peak pellet burnup Power density Power histories	Fission gas plenum pressure Oxide layer thickness Expansion / reference stress values Casing deformations	 Thermo-mechanical reactor core design
Departure from nucleate boiling Pressure losses Density and coolant temperature distribution inside reactor pressure vessel	Reactivity coefficients Effectiveness / speed of shut-down systems Max. absolute / differential reactivity insertion Kinetic parameters Power density Power histories Fuel assembly / fuel rod / peak pellet burnup Decay energy	Oxide layer thickness Fuel rod and fuel temperatures Permissible fuel rod enthalpy values Permissible hydrogen content of cladding tube	 Analyses of transients and design basis accidents
Decay ratio (stability – BWR)	Neutron flux Power density	Permissible power density gradients (PCI – pellet cladding interaction)	 Instrumentation and control equipment
Flow distribution			 Thermo-hydraulics of plant
	Boron-10 content Decay power Neutron flux Nuclide inventory		 System engineering
	Nuclide inventory		 Radiological protection

Figure G-1: Examples of results from the three analysis areas of reactor core design and their typical interconnections as well as connections to other analysis areas