Safety Standards

of the
Nuclear Safety Standards Commission (KTA)

KTA 2207 (11/2004)

Flood Protection for Nuclear Power Plants

(Schutz von Kernkraftwerken gegen Hochwasser)

Previous versions of this safety standard
were issued in 06/82 and 06/92

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KTA SAFETY STANDARD

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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 BAnz No. 35a of February 19, 2005. Copies may be ordered through the Carl Heymanns Verlag KG, Luxemburger Str. 449, 50939 Koeln, Germany (Telefax +49-221-94373603).

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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 safety related requirements which shall be met with regard to precautions to be taken in accordance with the state of science and technology against the hazards arising from the construction and operation of the facility (Sec. 7 para. 2 subpra. 3 Atomic Energy Act), in order to attain the protective goals specified in the Atomic Energy Act and the Radiological Protection Ordinance (StrlSchV) and which are further detailed in the "Safety Criteria for Nuclear Power Plants" and in the "Guidelines for the Assessment of the Design of Nuclear Power Plants with Pressurized Water Reactors against Incidents pursuant to Sec. 28 para. 3 of the Radiological Protection Ordinance (StrlSchV) - Incident Guidelines".

(2) In accordance with Criterion 2.6 of the Safety Criteria for Nuclear Power Plants, protective measures are required against the external event flood. According to Table II of the Incident Guidelines, floods belong to that group of design basis accidents where precautionary plant engineering measures are required for damage protection and which, on account of these measures, can be considered as irrelevant with respect to radiological effects on the environment. The basic requirements of these precautionary measures are specified in this safety standard.

(3) This safety standard specifies the general requirements for technical and organizational measures with respect to flood protection. The extent and quality of these measures will depend on the significance assigned to flood protection with respect to meeting the endangered individual safety objectives.

1 Scope

This safety standard applies to nuclear power plants with light-water reactors.

2 Definitions

(1) Design-basis flood

The design-basis flood is that particular flood event on which the flood protection of the plant is based to meet the safety protection goals.

(2) Permanent flood protection

The permanent flood protection is that flood protection which is effective at all times (e.g. protection by flood-safe enclosure, by elevated arrangement, by structural seals).

(3) Temporary flood protection

The temporary flood protection is that flood protection which is only effective at certain times (e.g. protection by mobile flood barriers).

3 Sites

The following sites shall be differentiated between:

a) Sites on rivers and on lakes which are endangered by flood runoffs from the prevailing drainage areas.
b) Coastal sites endangered by flood levels of the ocean.
c) Sites on tidal rivers endangered both by flood runoffs from the prevailing drainage areas and by flood levels of the ocean.

4 Basis for Design

4.1 Design-Basis Flood

(1) With regard to the design-basis flood and specification of the design-basis water level, the relevant flood runoff and flood level shall be determined. All significant parameters and their foreseeable changes shall be taken into account. In particular, it shall be analyzed to what extent the following parameters need to be taken into consideration:

a) Sites on rivers and on lakes:
   - aa) precipitation,
   - ab) snow and glacier melts,
   - ac) condition and characteristics of the drainage area,
   - ad) water retention on the site and in the drainage area,
   - ae) water embankment,
   - af) ice movement,
   - ag) overflow and breach of dikes,
   - ah) dam structures,
   - ai) wind pressure and wave loads,
   - ak) duration and sequence of flood event.
b) Coastal sites
   - ba) tides,
   - bb) overflow and breach of ocean dykes,
   - bc) wind pressure and surf pressure,
   - bd) wave loads,
   - be) secular increase,
   - bf) tidal wave (tsunami),
   - bg) duration and sequence of a storm-tide event.
c) Sites on tidal rivers:
   any relevant parameters under items a) and b).

It shall be analyzed which of the influence factors can occur simultaneously and must, therefore, be superposed.

(2) For the specification of flood protection measures, the dependency of flood runoff and flood level on the probability value (p-value) shall be described.

4.2 Design-Basis Water Level

(1) The design-basis water level, i.e. the highest water level which will occur during the design-basis flood in the proximity of the plant components to be protected and of the protective barriers, shall be determined. The parameters under Section 4.1 (1) shall be taken into consideration.

(2) In the case of sites on inland waters, the decisive variable for determining the design-basis water level shall be based on a flood runoff from a flood with a probability value of 10^{-4}/a.

Note:
A procedure for determining flood runoffs for inland waters with the specified probability value is presented in Appendix A.

(3) In the case of coastal site and sites on tidal rivers the determination of the design-basis water level shall be based on a storm-tide water level with a probability value of 10^{-4}/a.

Note:
A procedure for determining storm-tide water levels with the specified probability level is presented in Appendix A.

4.3 Extent of Protection

(1) All plant components, the safety function of which is required to meet the safety protection goals of the Safety Criteria for Nuclear Power Plants, namely,

a) keeping reactivity under control,
b) cooling fuel assemblies,
c) enclosing radioactive materials and
d) limiting radiation exposure,

shall be protected such that they can fulfill their individual function taking the event combinations in accordance with Section 5 into consideration.

(2) All other plant components whose damage or failure due to flood could detrimentally affect the safety function of the above mentioned plant components shall be included in the protection concept.

5 Combination of Influential Loads; Certifications

(1) The influential loads from the design-basis flood, H_B, shall be superposed with the influential loads, L, and with the influential loads from possible consequential events, R_H.

Nomenclature:

L: influential loads (e.g., dead weight, stationary loads, live loads, operating loads, soil pressure, wind loads),

H_B: influential loads from the design-basis flood (e.g., static water pressure from the design-basis water level, flowing water, waves, buoyancy, debris, ice pressure),

R_H: influential loads from possible sequential events brought about by the design-basis flood (e.g. undermining, erosion).

(2) In the case of installations for flood protection not designed against the design-basis earthquake in accordance with KTA 2201.1 it shall be proven whether or not the extent of protection under Section 4.3 is still ensured in case of a combination of influential loads from the flood event with a probability value of 10^{-2}/a and the earthquake event at the inspection level (40% of the loading level of the design-basis earthquake in accordance with KTA 2201.1). No additional event combination with another independent external event or with another independent plant internal design basis accident need to be considered.

Note:
Regarding the event combination of flood with a probability value of 10^{-2}/a and fire, cf. KTA 2101.1.

(3) The determination of the worst-case-loads shall take the load-time-history of the events into account.

(4) The support stability and limits of the water permeability of the structural components required for flood protection shall be proven taking the load combination under para. 1 into consideration. In case the proof of the extent of protection under para. 2 requires proofs regarding the support stability of other structural components serving flood protection, these shall be performed.

(5) Massive concrete structures not subject to requirements regarding leak tightness or that have been provided with structural waterproofing in accordance with KTA 2501 do not have to meet any higher requirements ensuing from event combinations under paras. 1 and 2 than those ensuing from the design of structural components against the design-basis earthquake.

6 Flood Protection Measures

6.1 General Requirements

(1) To achieve flood protection, the following measures shall be considered:

a) structural protection measures,

b) measures for ensuring the accessibility,

c) organizational and administrative measures.

(2) A protection concept shall be developed which shows the plant-specific interaction of the measures under para. 1 items a through c.

6.2 Structural Protection Measures

(1) Basically, permanent flood protection measures shall be provided to cope with the design-basis water level. However, provided a sufficient pre-warning time can be assured, temporary flood protection measures may be provided for individual areas of the plant to protect against the difference between the water levels of the flood with a probability value of 10^{-2}/a and the design-basis water level.

(2) Depending on the site, the following permanent flood protection measures shall, in particular, be employed:

a) elevated site of the nuclear power plant,

b) elevated arrangement of the plant components to be protected,

c) elevated arrangement of the entrances and openings,

d) flood safe enclosures for the plant components to be protected,

e) seals against water loads,

f) water-tight design of penetrations,

g) ensuring drainage of the plant site in the event of a flood.

(3) Temporary flood protection shall, in particular, include the following measures:

a) use of mobile flood barriers (e. g. dam structures with removable beams),

b) use of bilge pumps.

(4) Installations and equipment of the flood protection shall be subject to regular inservice inspection to prove their design conformity.

(5) Installations and equipment of the flood protection that must be resistant to pressurized water and are not subject to regular inservice inspection shall be designed such that the extent of protection under Section 4.3 is maintained for their planned life span.

6.3 Measures for Ensuring Accessibility

The accessibility of, and the supply with necessary operating materials for, the safety related installations and equipment shall be ensured even during the design-basis flood. This may include the use of auxiliary technical equipment.

6.4 Organizational and Administrative Measures

The permanent and the temporary flood protection shall be supplemented by organizational and administrative measures. These measures include, in particular:

a) ensuring the availability and maintenance of the equipment for the temporary flood protection,

b) linking up with the flood warning system,

c) specifying a situational plant-specific condition or a water level limit value at which the plant shall be shutdown,

d) operating instructions for executing the temporary flood protection measures,

e) rotating the personnel during the duration of the flood event,

f) ensuring the power supply and operability of all equipment and installations required for flood protection.

The individual measures shall be described in the operating manual of the plant.

Appendix A

Determination of Flood Runoffs and Storm Tide Water Levels With a Probability Value of 10^{-4}/a

A 1 Basics

(1) The flood protection for nuclear power plants in accordance with this safety standard presumes a flood event with a probability value (p-value) of 10^{-4}/a, i.e. an extremely seldom flood event. Depending on whether the site is located on inland waters or on coasts tidal estuaries, different procedures are required for determining the design-basis water level in the vicinity of the plant components to be protected and in the vicinity of the protective structures of the nuclear power plant.

(2) In the case of inland water sites, the base assumption is a flood runoff with this probability value for the respective water body. A procedure for determining of such a seldom flood runoff is presented in Section A 2. In individual cases other site-independent procedures may be employed [1]. For inland water sites both the conditions at the site (maximum possible flow) as well as the large-area water retention effects of the water catchment area (water shed) shall be taken into consideration.

Note:
In the case of such a seldom flood event it cannot be assumed that the inland water dyke system in the water catchment area will still be fully effective.

(3) In the case of coastal sites and sites on tidal waters, the base assumption is a storm-tide water level with this probability value. A procedure for determining such a seldom flood level is presented in Section A 3.

(4) On the basis of the flood runoff or of the storm tide water level, the corresponding site specific water level in the vicinity of the plant components to be protected and the protective structures of the nuclear power plant shall be determined, e.g.. by hydraulics calculations.

A 2 Determination of Water Runoffs for a Flood With a Probability Value of 10^{-4}/a for Inland Water Sites

(1) To determine the decisive water runoff of floods for inland water sites, a statistical extrapolation based on the convention introduced in [1] covering the simultaneous occurrence of unfavorable influences shall normally be employed. In this case the following standardized distribution function shall be employed in its expanded form:

$$HQ_{(10^{-4})} = MHQ + s_{HQ} \cdot k_{(10^{-4})} \qquad \text{(A 2-1)}$$

where

$HQ_{(10^{-4})}$: peak-level water runoff of a flood with a probability value of 10^{-4}/a, in m³/sec

MHQ: average peak-level water runoff of a flood over an extended measurement period, in m³/sec

s_{HQ}: standard deviation of peak-level water runoff of a flood over an extended measurement period, in m³/sec

$k_{(10^{-4})}$: frequency factor for an event with the probability value 10^{-4}/a.

Note:
In this procedure the peak-level water runoff of a flood event with a probability value of 10^{-4}/a is extrapolated from the peak-level water runoff of a flood event with a probability value of 10^{-2}/a. Hereby, it is assumed that the peak-level water runoff of a flood event with a probability value of 10^{-2}/a is determined using standard statistical procedures (DVWK-Merkblatt 251). The extended extrapolation is then performed using the Pearson-III probability distribution. This is the basis on which the necessary frequency factors are determined. The convention introduced by [1] calls for a maximization of the skewness coefficient, c, to the value of c = 4.

(2) The statistical parameters MHQ and s_{HQ} and the actual skewness coefficient, c, shall be calculated from the observed data of a representative flood level.

(3) The frequency factor, $k_{(10^{-4})}$, shall be calculated as the product of the frequency factor, k, and a quotient, f, as follows:

$$k_{(10^{-4})} = k \cdot f \qquad \text{(A 2-2)}$$

(4) The frequency factor, $k_{(10^{-2})}$, for a flood with the probability value of 10^{-2}/a shall be interpolated from **Table A-1** based on the actual skewness coefficient, c, of the observed data.

The frequency factor may, alternatively, be calculated with sufficient accuracy from the following equation

$$k = 2.3183 + 0.7725 \times c - 0.0650 \times c^2 \qquad \text{(A 2-3)}$$

(5) The quotient, f, shall be calculated for a maximized skewness coefficient, c = 4, from the frequency factor, $k_{(10^{-4})\max}$, and from the frequency factor, $k_{(10^{-2})\max}$, as follows

$$f = k_{(10^{-4})\max} / k_{(10^{-2})\max} = 12.36/4.37 = 2.8 \qquad \text{(A 2-4)}$$

Note:
Both frequency factors are independent of site-specific data.

(6) Employment of this procedure shall take the general parameters of DVWK-Merkblatt 251 regarding the statistical analysis of flood runoffs into consideration.

A 3 Derivation of Water Levels for a Storm Tide with a Probability Value of 10^{-4}/a for Coastal Sites and Sites on Tidal Waters

(1) The storm tide water levels for nuclear power plants on coastal sites and sites on tidal waters shall normally be derived employing the following statistical extrapolation procedure. The water level for a storm tide with a probability value of 10^{-4}/a, $SFWH_{(10^{-4})}$, shall be determined as the sum of a base value, $BWH_{(10^{-2})}$, and an extrapolation difference, ED, as follows:

$$SFWH_{(10^{-4})} = BWH_{(10^{-2})} + ED \qquad \text{(A 3-1)}$$

where

$BWH_{(10^{-2})}$: base value of the water level for a storm tide with a probability value of 10^{-2}/a at the site

ED: extrapolation difference representing the water level difference between the water level of a storm tide with a probability value of 10^{-4}/a and the base value.

(2) The base value, $BWH_{(10^{-2})}$, shall be determined on the basis of a quantitative statistical extreme-value analysis (in

accordance, e.g., with [2] and [3]) taking relevant parameters (e.g., DVWK-Merkblatt 251) into consideration. The quality of the data shall also be taken into consideration.

Note:
The base value can be determined employing suitable statistical procedures, because

a) the spread of the base values, $BWH_{(10^{-2})}$, is relatively small due to the usually extensive and high quality water-level time series available for coasts and tidal waters,

b) the $BWH_{(10^{-2})}$ water level as a function of the observation duration of the individual time series still is partly in the interpolation region or in the near extrapolation region,

c) the $BWH_{(10^{-2})}$ water level is assured by extensive investigations and is verifiable by physical as well as numerical models.

(3) The water-level data shall be homogenized considering that the storm-tide water levels are dependent on the development of the water level at the coast – especially the secular rise of the sea level – as well as on the anthropogenic changes to the tidal waters.

(4) The extrapolation difference for coasts or for the mouths of tidal rivers shall be determined, e.g., in accordance with [2] and [3].

Note:
The local tide-related excessive wave amplitude is not included in the extrapolation difference.

c	0,0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	
k	2,326	2,399	2,472	2,544	2,615	2,685	2,755	2,823	2,891	2,957	
c	1,0	1,1	1,2	1,3	1,4	1,5	1,6	1,7	1,8	1,9	
k	3,022	3,086	3,149	3,211	3,271	3,330	3,388	3,444	3,499	3,552	
c	2,0	2,1	2,2	2,3	2,4	2,5	2,6	2,7	2,8	2,9	
k	3,605	3,656	3,705	3,753	3,800	3,845	3,889	3,931	3,973	4,012	
c	3,0	3,1	3,2	3,3	3,4	3,5	3,6	3,7	3,8	3,9	4,0
k	4,051	4,088	4,124	4,159	4,192	4,224	4,255	4,285	4,314	4,341	4,367

Table A-1: Frequency factors, k, for an event with a probability factor of 10^{-2}/a and the actual skewness coefficient, c, of the observed data

Appendix B

Regulations Referred to in this Safety Standard

Regulations referred to in this safety standard are valid only in the versions cited below. Regulations which are referred to within these regulations are valid only in the version that was valid when the cited regulations were established or issued.

KTA 2201.1	(06/90)	Design of nuclear power plants against seismic events; Part 1: Basic principles
KTA 2501	(06/02)	Structural waterproofing in nuclear power plants
DVWK-Merkblatt 251	(1999)	Guideline on the statistical analysis of flood water runoffs DVWK (DVWK - German association for water management, water building and landscape ecology)

Literature:

[1] KLEEBERG, H.-B.; SCHUMANN, A. H. (2001): Ableitung von Bemessungsabflüssen kleiner Überschreitungswahrscheinlichkeiten (Determination of design-basis water runoffs with a small probability value)
Wasserwirtschaft, Vol. 91, No. 2, February 2001, pages 90-95

[2] JENSEN, J.; FRANK.T: Zur Abschätzung von Sturmflutwasserständen mit sehr kleinen Überschreitungswahrscheinlichkeiten (On the determination of water levels from storm-floods with a very small probability value)
Die Küste, special edition, No. 67, 2003

[3] JENSEN, J.: Eintrittswahrscheinlichkeiten von Sturmfluten – Statistisch gesehen (Probability of occurrence of storm floods – Statistical View)
HANSA (12), Vol. 137, 2000 b

Appendix C (informative)

Changes with Respect to Previous Version 06/92

The adjustment of this safety standard with respect to the state of science and technology required changes especially of the sections “Design Basis” and “Load Combinations”. The essential changes with respect to the previous version 06/92 are commented on in the following.

Section 4 “Design Basis”

(1) In the previous version 06/92 of safety standard KTA 2207 it was indicated that the design-basis flood was an extremely seldom flood with a probability of occurrence in the order of 10^{-4} per year.

(2) In accordance with guide lines and risk assessments related to large dams, the present safety standard KTA 2207 specifies the design-basis flood as being a flood event with a probability value of 10^{-4}/a.

Because of the different physical flood event sequences on inland waters, coastal sites and sites on tidal waters, the requirements with regard to determining the design-basis flood in Section 4 were revised. Accordingly, in case of inland water sites, the parameters for determining the design-basis water level shall be based on a flood runoff in the inland water and, in the case of coastal sites and sites on tidal rivers, on a storm flood water level.

Appendix A was introduced to specify the determination of flood runoffs and storm flood water levels with a probability value of 10^{-4}/a, individually for inland waters as well as for coastal sites and sites on tidal waters. This is based on the scientific investigations published in [1], [2] and [3]. Accordingly, the corresponding water level shall be determined in the proximity of the plant components to be protected and of the protective barriers, e.g., by means of a hydraulic calculation or of other water-level/water-runoff relationships. Further changes in Section 4 relate to adaptations of the standard’s text to the newly detailed specifications. The terminology “annual rate of occurrence” was, generally, replaced by “probability value”.

(3) Within the framework of probabilistic safety analyses for nuclear power plants (PSA) the flood event was also probabilistically evaluated. The analyses have shown that, based on an occurrence probability of about 10^{-4}/a for an external flood, the “probabilities of hazard conditions (risk contributions)” are valued at less than about 10^{-6}/a and, the individual risk path “Flood” with respect to the “probabilities of hazard conditions” is a magnitude below the total probability of all failure types. The balanced safety concept with regard to flood is assured for a probability of occurrence of about 10^{-4}/a since these floods make no dominant risk contribution.

Section 5 “Load Combinations and Certifications”

(1) The load combination LH1 (load combination “100-yearly flood” – required only for embankments) as specified in the previous version 06/92 of the safety standard KTA 2207 could be dropped because it is covered by the load combination “design-basis flood” (LH2). The load combination LH2 was then reworded to comply with the new text (see also Section 4).

(2) The load combination (LH3) of a flood event with a probability value of 10^{-2}/a and an earthquake event at the inspection level (40% of the loading level of the design-basis earthquake in accordance with KTA 2201.1) was reworded to comply with the new text, and the examination of the Extent of Protection in accordance with Section 4.3 was added.

(3) The requirements regarding loads and load combinations under Section 5 were adapted to conform to the newer DIN standard regarding civil engineering (e.g. DIN 1045-1, DIN 1055-100). Furthermore, the terms “loads” and “load combinations” were generally replaced by “events” and “event combinations”.

Other Sections and Appendices

(1) The entire safety standard was reviewed with regard to the referred standards and regulations. Any references to corresponding DIN standards regarding civil engineering were dropped to enable application of the actual civil engineering standards in the future.

(2) The definitions already contained in other standards and regulations were dropped.

(3) General editing also pertained to precising several previous formulations taking experience feedback into account.