

Safety Standards

of the

Nuclear Safety Standards Commission (KTA)

KTA 2502 (2011-11)

**Mechanical Design of Fuel Assembly Storage Pools in
Nuclear Power Plants with Light Water Reactors**

(Mechanische Auslegung von Brennelementlagerbecken in
Kernkraftwerken mit Leichtwasserreaktoren)

The previous version of this safety
standard was issued in 1990-06

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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Mechanical Design of Fuel Assembly Storage Pools in Nuclear Power Plants with Light Water Reactors

KTA 2502

Previous versions of this safety standard: 1990-06 (BAnz. No. 20a of January 30, 1991)

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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. 11 of January 19, 2012. 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 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 the Atomic Energy Act and the Radiological Protection Ordinance (StrlSchV) and further detailed in the "Safety Criteria" and in the "Design Basis Accident Guidelines".

(2) Safety standard KTA 3602 specifies the requirements for the layout and design of fuel pools. These design requirements deal with, e.g., capacity, shielding, water quality, criticality safety, leak tightness, possible loadings, and precautionary measures for preventing load crashes. On the basis of these prerequisites, the present safety standard specifies the requirements for the mechanical design of the fuel pool and its internals, i.e., for the mechanical engineering, the structural steel and the reinforced concrete of the fuel pool.

(3) Safety standard KTA 3303 specifies the required fuel pool water temperatures and their respective dependence on the various operating conditions.

(4) The present safety standard specifies the action types and combinations of actions as well as the partial and combination coefficients for the action types and combinations of actions. In addition, it also specifies the requirements regarding verification of the ultimate limit state and of the serviceability limit state, and, supplementing general engineering standards, this safety standard also specifies partial safety factors for the characteristic material property values. Furthermore, requirements regarding permissible materials and the associated materials tests are specified.

(5) General requirements with regard to quality assurance are specified in safety standard KTA 1401.

(6) All plant components classified as structural components are subject to the approved building regulations. This applies to, e.g., reinforced concrete, reinforcing steel, headed studs, anchor plates.

1 Scope

This safety standard applies to the mechanical design of fuel pools and their internals in nuclear power plants with light water reactors.

Note:

This standard can be applied analogously to other pools with comparable safety requirements.

2 Definitions

Note:

The terms permanent, variable and accidental action, action types, combinations of actions, design situations, partial safety factor, ultimate limit state and serviceability limit state are used herein as defined in DIN EN 1990.

(1) Fuel pool water temperature

The fuel pool water temperature as specified in safety standard KTA 3303 is the mixture temperature existing at a sufficient depth down in the fuel pool close to wall.

Note:

Experience shows that only minor differences exist between the temperatures measured in the fuel pool and in the extraction line of the fuel pool cooling system; therefore, the design and controls can be based on the measurement of the fuel pool water temperature.

(2) Requirement category

Requirements specified for safety relevant parts will be different depending on the action types taking the following aspects into consideration:

- probability of occurrence during the service life,
- repair possibilities, and
- limiting the extent of the damage such that, e.g., the serviceability of the respective parts or the stability and functionality of the plant components are maintained.

Depending on these aspects, the parts will be assigned to the different requirement categories A1, A2 or A3 (cf. Section 4.1).

3 Types of Actions

3.1 Permanent Actions (G)

The permanent actions (G) to be considered for the parts or components of the fuel pool are listed in **Table 3-1**.

Nomenclature	Type of Action
a	Dead loads
b	Load from weight of water (static pressure of the coolant)
c	Loads from fuel pool internals (e.g. racks, refueling slot gates, inspection equipment)
d	Temperature actions: cf. Table 3-4
e	Loads from the connecting pipes
f	Loads from bordering and supported components
g	Restricted or restrained imposed deformations or movements (e.g., creepage and shrinkage of concrete)

Table 3-1 Permanent actions

3.2 Variable actions (Q)

The variable actions (Q) to be considered for the parts or components of the fuel pool are listed in **Table 3-2**.

3.3 Accidental actions (A)

(1) The accidental actions (A) to be considered for the parts or components of the fuel pool are caused by those plant internal design basis accidents and by the external events that must be considered for the overall plant at the site of the power plant.

(2) Examples for the accidental actions are listed in **Table 3-3**.

Note:

The load drop of heavy objects into the fuel pool or onto components of the fuel pool does not have to be assumed in view of the safety standards KTA 3602, KTA 3902 and KTA 3905.

Nomenclature	Type of Action
d	Temperature actions: cf. Table 3-4
e	Loads from the connecting pipes
f	Loads from bordering and supported components (e.g., refueling equipment)
h	Loads from setdown events (jolts from operational procedures)
i	Loads from the stored materials (e.g., fuel assemblies, control rods)
k	Loads from transportation or storage containers (e.g., fuel element casks) including lifting accessories, load-bearing equipment and hoisting gear
l	Loads caused by movements of the slot gates (e.g., friction forces)

Table 3-2 Variable actions

Nomenclature	Type of Action
d	Thermal actions: cf. Table 3-4
e	Loads from the connecting pipes
h	Loads from setdown events (jolts from unplanned procedures)
m	Loads from external events (e.g., design basis earthquake in accordance with safety standard KTA 2201.1) including sloshing water
n	Loads from plant internal design basis accidents (e.g., jet impingement forces)

Table 3-3 Accidental actions

Action type ³⁾	Temperature of the Fuel Pool Water ¹⁾	Temperature of the Bordering Rooms ²⁾
Permanent actions (G)	T ₁	T _{R1}
Variable actions (Q)	T ₂	T _{R1}
Accidental actions (A)	T ₃	T _{R1}
	T ₁	T _{R2}
¹⁾ Temperatures T ₁ , T ₂ and T ₃ are specified in safety standard KTA 3303. ²⁾ T _{R1} is the temperature of the operating condition; T _{R2} is the increased temperature due to design basis accidents. ³⁾ For further explanations, cf. Section 6.2.		

Table 3-4: Thermal actions

4 Requirement Categories and Combinations of Actions

4.1 Requirement Categories

(1) Parts and components shall be subject to different requirements in accordance with the respective combinations of actions specified under Section 4.2. For the design,

the different combinations of actions shall be assigned with one of the Requirement categories A1, A2 or A3 specified below. The corresponding load-bearing capacities for the parts and components shall be determined as specified under Section 5.3 for the respective Requirement category.

(2) Requirement Category A1:

Combinations of operational actions that result from the permanent and temporary design situations in accordance with DIN EN 1990 shall be assigned to Requirement Category A1. Complete functionality, the resistance to repeated loading, and a continuous reusability shall remain ensured after occurrence of these combinations.

(3) Requirement Category A2:

Combinations of variable and accidental actions that must be assumed to occur repeatedly in the course of service life shall be assigned to Requirement Category A2. Complete functionality shall remain ensured after occurrence of these combinations.

(4) Requirement Category A3:

Combinations of accidental actions with a low probability of occurrence (smaller than or equal to 10⁻⁴ per year) that must be assumed to occur once in the course of service life shall be assigned to Requirement Category A3. Major plastic deformations (combined with major crack formations in the case of steel-reinforced concrete) are permissible, provided, this is not in contradiction to safety related issues.

4.2 Combinations of Actions

4.2.1 Combinations of actions for parts made of steel or for other components

(1) The design of the parts made of steel or of other components shall be based at least on the combinations of actions specified in **Table 4-1**. Any combinations of actions, parts or components not listed in **Table 4-1** shall be dealt with analogously. A mutual combination of the various accidental actions (A) specified under Section 3.3 is not required.

(2) Loads resulting from deformations of the reinforced concrete structure (e.g., creepage and shrinkage) that act on the fuel pool liner and its anchorings shall be taken into account.

(3) Dependent on the technical design of the substructure for the liner sheet, of the wall frame work, bottom frame work, slot gate frame and transport cask setdown area, the water load shall, additionally, be taken into account for all combinations of actions.

(4) The thermal actions listed in **Table 3-4** shall be taken into account in the case of parts that may be subject to restraint forces from temperature changes.

4.2.2 Combinations of actions for parts made of concrete and reinforced concrete

(1) For the design of the reinforced concrete structure, the actions specified under Section 3 shall be combined in accordance with the rules specified under Section 5.2.

(2) Only technically feasible combinations of actions shall be taken into account. Concerned are loads from reactions of parts made of steel or other components due to the combinations of actions listed in **Table 4-1**. A mutual combination of the various accidental actions (A) specified under Section 3.3 is not required.

Parts or Components		Requirement Category		
		A1 ⁵⁾	A2 ⁵⁾	A3 ⁵⁾
1	Liner sheet	d	d ⁶⁾	d ⁶⁾
2	Bottom frame work	c + i + h at T ₁	c + i at T ₂ c + i + h at T ₁	c + i at T ₃ c + i + m at T ₁
3	Anchor plates, mountings on anchor plates (weld attachments and consoles), wall frame work	c + f + h at T ₁	c + f at T ₂ c + f + h at T ₁	c + f at T ₃ c + f + m at T ₁
4	Slot gate	a + b + h at T ₁	a + b at T ₂ a + b + h at T ₁ a + b + l at T ₁	a + b at T ₃ a + b + m at T ₁
5	Slot gate frame	Actions from reactions to the combinations of actions of row 4		
6	Steel pipe penetration	e ¹⁾	e ¹⁾	e ¹⁾
7	Fuel assembly rack	a + i + h at T ₁	a + i at T ₂ a + i + h at T ₁	a + i at T ₃ a + i + m at T ₁
8	Fuel assembly rack fixation	Actions from reactions to the combinations of actions of row 7		
9	Other racks and internals ²⁾ that are not safety related	a + i + h at T ₁	a + i at T ₂ a + i + h at T ₁	a + i at T ₃ a + i + m at T ₁
10	Mobile shielding	a	-	a + m at T ₁ ³⁾
11	Observation window ⁴⁾	a + b at T ₁	a + b at T ₂	a + b at T ₃ a + b + m at T ₁
12	Hydraulic compensator	a + b + relative displacements at T ₁	a + b + relative displacements at T ₂	a + b + relative displacements at T ₃ a + b + m ³⁾ + relative displacements at T ₁
¹⁾ Actions result from the analysis of the connecting pipe systems. ²⁾ Verification for A1 is sufficient, provided, sequential damages have no safety related significance. ³⁾ Provided, this is required on account of risk assessments. ⁴⁾ Glass window pane in accordance with the special agreement with, and specification of, the manufacturer. ⁵⁾ Cf. Section 3 regarding nomenclatures a through m, as well as T₁, T₂ and T₃. ⁶⁾ To be verified for the number of load cycles, cf. Section 6.1.2 para. 4.				

Table 4-1: Combinations of actions for selected parts made of steel or for components

5 Verifications

5.1 General Requirements

(1) Verifications may be performed either analytically or experimentally or by combining analysis and experiment. In this context, the methods developed for analyzing bending and the static equilibrium of bars and rods as well as the analytical methods described in Appendix B of safety standard KTA 3201.2 (e.g., finite element methods) may be used or other to be specified methods.

(2) The mechanical design of the parts and components shall basically follow the safety concept specified in accordance with DIN EN 1990. Any deviations from this safety concept shall be substantiated. It shall be verified that the design value of the load does not exceed the design-basis value, cf. **Figure 5-1**. The verification shall be performed taking the correlation of combinations of actions and requirement categories as specified in Section 4.1 for the parts and components into account.

(3) The partial safety factors, γ_F , and the combination coefficients, ψ , to be applied in determining the combinations of actions for the ultimate limit state and the serviceability limit state, as well as the partial safety factors, γ_M , to be applied in determining the load bearing capacities are specified in Sections 5.2 and 5.3.

(4) The verifications required with respect to the limit states of parts made of steel or other steel components shall be performed in accordance with Parts 1-1, 1-3 through 1-10 and 1-12 of DIN EN 1993. In addition to DIN EN 1993-1-4, the requirements specified in DIBt General Construction Approval Z-30.3-6 shall be taken into account. The parts made of reinforced concrete shall be dimensioned in accordance with DIN EN 1992-1-1 under special consideration of the dimensioning specifics presented in DIN 25449. All deviations specified in the present safety standard with regard to the technical standards cited above shall be taken into account.

(5) In individual cases and under certain prerequisites, it is permissible to also perform the stress analyses in accordance with other, then to be specified verification procedures (e.g., concept of stress limitation).

5.2 Limit States

5.2.1 Ultimate limit state (ULS)

The appropriate combination rules for actions of the design situations concerning the ultimate limit state (ULS) are specified in DIN EN 1990. Accordingly, it is required to distinguish

between permanent, variable and accidental design situations and those design situations on account of earthquakes.

5.2.2 Serviceability limit state (SLS)

The appropriate combination rules for actions of the design situations concerning the serviceability limit state (SLS) are specified in DIN EN 1990. Accordingly, it is required to distinguish between seldom (characteristic), frequent and quasi permanent design situations.

5.2.3 Partial and combination coefficients

Unless otherwise specified in **Table 5-1**, the partial safety factors for permanent actions, γ_G , for variable actions, γ_Q , and for accidental actions, γ_A , shall be chosen in accordance with Appendix A.1 of DIN EN 1990. A partial safety factor of 1.00 shall be applied to the combination rules for the serviceability limit state.

5.3 Load-bearing Capacities

5.3.1 Design-basis values

The design-basis values of the load-bearing capacities shall be calculated as the quotient of the characteristic values of the load-bearing capacities of the parts or other components and the material dependent partial safety factors specified under Section 5.3.2.

5.3.2 Partial safety factors

The partial safety factors, γ_M , for determining the load-bearing capacity at the ultimate limit state are dependent on the design situation (permanent and variable, and accidental including earthquake), on the structural materials as well as on the applicable requirement categories specified under Section 4.1. Regarding parts made of concrete and reinforced concrete, the required partial safety factors are listed in **Table 5-2**. Regarding parts made of steel and other steel components, the partial safety factors are independent of the requirement category and shall be chosen depending on the respective material in accordance with DIN EN 1993-1 or DIN EN 1993-1-4, respectively. Partial safety factors for other materials shall be chosen in accordance with the approved engineering standards.

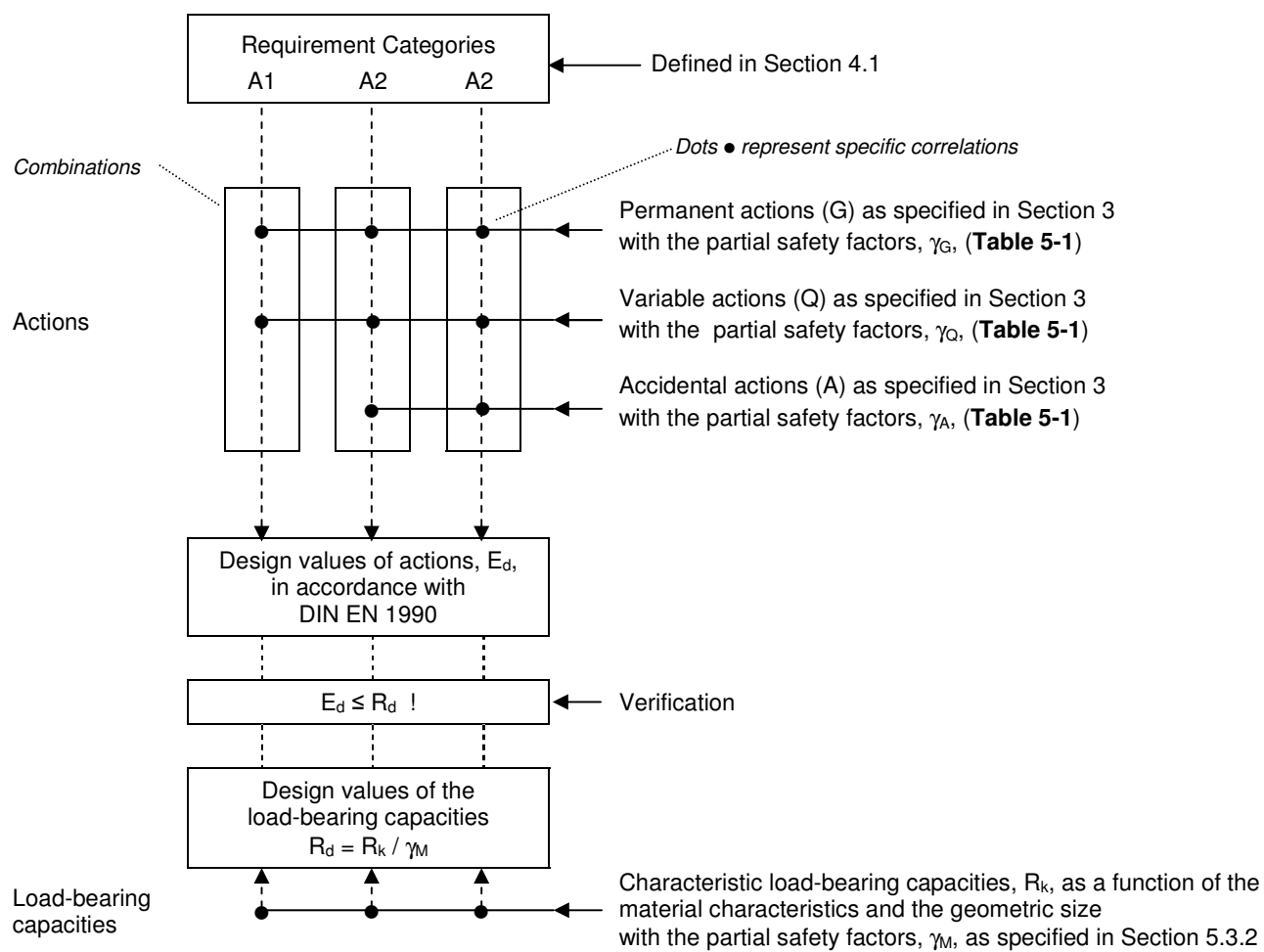


Figure 5-1: Procedural diagram for verifying the ultimate limit state (ULS)