

Safety Standards

of the
Nuclear Safety Standards Commission (KTA)

KTA 3303 (06/90)

Heat Removal Systems for Fuel Assembly Storage Pools in
Nuclear Power Plants with Light Water Reactors

(Wärmeabfuhrsysteme für Brennelementlagerbecken von
Kernkraftwerken mit Leichtwasserreaktoren)

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

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Heat Removal Systems for Fuel Assembly Storage Pools in Nuclear Power
Plants with Light Water Reactors

KTA 3303

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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. 41a on Feb. 28, 1991. Copies may be ordered through the Carl Heymanns Verlag KG, Luxemburger Str. 449, D- 50939 Koeln (Telefax 0221-4601092).

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Comments by the editor:

In the 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 requirement ¹⁾ to which exceptions are allowed. However, the exception used 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., „... and it is recommended that ...“.

The word combinations **basically shall** or **shall basically** are 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 **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.

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 the hazards arising from the construction and operation of the facility (Sec. 7 para. 2 no. 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 "Safety Criteria for Nuclear Power Plants" and in "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) This safety standard is based on the following:

- a) "Safety Criteria for Nuclear Power Plants" issued by the Federal Minister of the Interior, in particular, Criterion 11.1 which requires that "In a nuclear power plant, equipment shall be provided that allows the safe handling, encasing and storage of nuclear fuel and other radioactive substances. This equipment shall be in such a condition, so arranged and shielded as to exclude inadmissible radiation exposure of staff and the environment, the release of radioactive substances to the environment, or criticality incidents. The equipment used to store irradiated nuclear fuels shall have adequate storage capacity and an appropriate and sufficiently reliable system for the removal of residual heat during specified normal operation and during incidents".
- b) "RSK Guidelines for Light Water Reactors", in particular, Chapter 15 concerning the handling and storage of nuclear fuels and other radioactive materials, as well as Chapter 22.1.2 with respect to the system-related requirements to be met by fuel pool cooling systems contained therein.

(3) An essential constituent of the equipment used for the storage and handling of irradiated fuel assemblies are the systems for the removal of the decay heat released in the fuel pool. As such, these systems are not part of the safety systems of the reactor plant and do not contribute to the control of incidents occurring in the plant. Thus, they are also not part of the scope of the single failure criterion. Nevertheless, heat removal from the fuel pool is an important contribution to the retention of radioactivity and thus important in terms of safety. However, it shall be remembered in this context that although fuel pool cooling is an essential continuous operation, in the case of its failure, a much larger time of interrupted operation is available before occurrence of undesirable conditions than is available for safety systems with respect to incidents.

(4) The requirements to be met by the systems for heat removal from the fuel pool are dealt with in this safety standard KTA 3303; it specifies generically for the following KTA safety standards, in particular, the temperatures to be maintained in the fuel pool. The "Storage and Handling of Fuel Assemblies, Control Rods and Neutron Sources in Nuclear Power Plants with Light Water Reactors" is dealt with in KTA 3602. Supplementary to this, KTA 2502 specifies the requirements to be met by the "Mechanical Design of Fuel Assembly Storage Pools in Nuclear Power Reactors with Light Water Reactors", i.e. requirements with respect to machine and structural design as well as to the concrete structure of the fuel pool. With respect to the system-related connections between systems for heat removal from fuel pools and the residual heat removal systems removing the residual heat from the reactor coolant system to a heat sink, reference is made to safety standard KTA 3301 "Residual Heat Removal Systems of Light Water Reactors".

1 Scope

(1) This safety standard applies to systems for heat removal from water-cooled fuel pools in reactor buildings of nuclear power plants with light water reactors (fuel pool heat removal systems). It specifies requirements which shall be taken into consideration for the design, construction and operation of these systems as well as of the fuel pool in order to ensure adequate fuel pool cooling in all cases of required operation to be assumed.

Note: The fuel pool heat removal systems do not only comprise fuel pool cooling systems but all systems required for the removal of heat from the fuel pool to a heat sink. Furthermore, they also include those parts of other systems, e.g. of the residual heat removal systems, which are also involved in the mentioned function.

(2) The requirements specified in this safety standard shall also be applied to auxiliary, supply and energy systems in as far as their functions are necessary for heat removal from the fuel pool.

(3) This safety standard does not deal with requirements to be met by the design and construction of the fuel pool or of its components other than those related to system technology.

Note: Other requirements relating to the fuel pool are dealt with in KTA 2502 and KTA 3602 and those relating to the components in KTA 3211 (in preparation).

2 Definitions

Note: The terms decay heat power, operating time, decay time and power histogram are used in accordance with the definitions in DIN 25 463 Part 1; the terms refueling and shuffling of fuel assemblies are used in accordance with the definitions in KTA 3602. Furthermore, the terms such as active component, failure, specified normal operation, operational availability, maintenance, passive component, redundant component, redundancy and incident are used as defined in KTA 3301.

(1) Pool water temperature

The pool water temperature is the mixture temperature of the water near the fuel pool wall which is measured at a sufficient depth.

Note: Experience shows that temperatures measured in the fuel pool and in the extraction line leading to the fuel pool cooling system differ only slightly such that it is possible to use the measured pool water temperature as a basis for design and control purposes.

(2) Fuel assembly partial discharge quantity

The fuel assembly partial discharge quantity is the number of those fuel assemblies which, at the end of a core cycle, are not scheduled for use in the next core cycle and which must therefore be transferred from the reactor core into the fuel pool during refueling where they will remain until off-site transportation or re-use.

(3) Core discharge

Core discharge is the discharge of all fuel assemblies from the reactor core into the fuel pool.

3 Specified Applications and Associated Tasks

3.1 General Tasks

When the fuel pool is loaded with irradiated fuel assemblies, the fuel pool heat removal systems have the task of ensuring heat removal from the fuel pool under all plant conditions and doing this adequately with respect to

- a) the working conditions of the plant personnel in terms of ambient conditions and radiation exposure when handling fuel assemblies,
- b) the fuel pool integrity, and
- c) the release of radioactive substances to the environment.

3.2 Specified Normal Operation of the Plant

(1) During specified normal operation of the plant, the fuel pool heat removal systems are required in the following cases:

- Case A: Pool cooling during refueling where the fuel pool is open to the reactor pressure vessel (open partitioning gate valve) during fuel assembly shuffling, and the discharged fuel assemblies constitute the entire reactor core.
- Case B: Pool cooling after core discharge where the fuel pool is isolated from the reactor pressure vessel (closed partitioning gate valve).
- Case C: Cooling of the fuel assembly partial discharge quantities, during start-up starting with closure of the partitioning gate valve, during power operation, during shutdown and plant outage, and ending with the opening of the partitioning gate valve.

(2) In these cases, the fuel pool heat removal systems shall be capable of maintaining the pool temperature as specified with a view to the working conditions of the plant personnel, taking into consideration any failures to be assumed.

(3) A higher temperature is permissible if the fuel pool heat removal systems are in an anomalous system condition, e.g., also in the case of failure of the auxiliary power supply.

3.3 Design Basis Incidents of the Plant

(1) In the case of incidents on which the design of the plant must be based, the fuel pool heat removal systems shall be capable of maintaining the fuel pool temperature which is permissible for such incidents with regard to the integrity of the fuel pool and to the release of radioactivity, taking into consideration any failures to be assumed. This temperature of the fuel pool may be higher than the temperatures stipulated for specified normal operation.

(2) In deviation from the foregoing, in those cases in which an incident cannot result in a reduction of the operational capability or efficacy of the fuel pool heat removal systems, the temperature may reach, but not exceed, the level which is stipulated for specified normal operation of the plant - abnormal system condition (cf. Section 3.2 (3)).

3.4 Events with a Low Frequency of Occurrence

In the case of events which, on account of their low frequency of occurrence are not design basis incidents (e.g., aircraft crash, blast wave from chemical reactions) but for which risk minimization measures shall be provided, the same requirements shall apply with regard to the tasks as those for design basis accidents (cf. Section 3.3 (1)); however, in contrast to the design basis incidents, no failures need to be postulated.

3.5 System Internal Rare Events

It shall be possible to cope with system internal rare events, cf. Section 4.2.4, by means of prepared measures (e.g. sealing of fuel pool connecting nozzles). These measures shall be designed such that the pool temperature permissible in the case of design basis incidents (cf. Section 3.3 (1)) can be maintained with the help of the fuel pool heat removal systems.

3.6 Other Specified Applications

The fuel pool heat removal systems may also be used for other tasks, e.g. residual heat removal in accordance with KTA 3301 or cleaning of the fuel pool, provided that the requirements of this safety standard for heat removal from the fuel pool are also met during these tasks.

4 Design

4.1 Determining the Thermal Output to be Removed

4.1.1 Heat outputs to be taken into account

(1) The thermal output to be removed in the various specified applications shall, in each case, be on the basis of the condition in which the maximum decay heat power is released within the frame of the scheduled pool allocation. For the refueling phase (Cases A and B), the total thermal output released shall be calculated from the decay heat power of the discharged core plus the decay heat power of the fuel assembly partial discharge quantities which are already in the fuel pool when it is occupied to a maximum.

(2) The thermal input by components of the fuel pool heat removal systems shall be taken into account. The heat emission from the fuel pool as a result of evaporation, convection, heat radiation and heat conduction may be taken into account.

4.1.2 Decay Heat Power

4.1.2.1 Calculation Method

The decay heat power of the fuel assemblies in the fuel pool shall be calculated in accordance with DIN 25 463 Part 1. In this calculation, a margin of error amounting to once the standard deviation (1 x sigma) shall be applied to account for the contribution of the fission products. A separate calculation of the decay heat power is necessary for fuel assemblies from recycled nuclear fuel.

Note: The calculation method for the decay heat power of fuel assemblies made from recycled nuclear fuel is specified in DIN 25 463 Part 2 (in preparation).

4.1.2.2 Operating parameters

(1) The operating time of the fuel assemblies (combined in groups of identical operating histories) shall be the residence time of the fuel assemblies in the reactor until the end of the cycle prior to discharge. The power history and the history of the fuel composition (power histogram) of the reactor core shall be based on the fuel and loading concept which was the basis of the planning of the respective plant.

(2) In the case of a deviation from the basic operating parameters of the design (e.g. cycle length, discharge burn-up), which would lead to an increase in the decay heat power to be removed, it shall be demonstrated that it will be possible, taking into consideration the current boundary conditions, to maintain the pool water temperatures permissible in accordance with Section 4.2.

4.1.2.3 Decay Times

(1) The calculation of the relevant decay times shall be based on the shortest possible time intervals between shutdown and the following design basis points in time in terms of operating technology, while adhering to boundary conditions which are either practice-oriented or to be specified in the operating manual.

(2) The design basis points in time to be used for the calculation of the decay heat power are:

- a) with respect to cooling after core discharge - the completion of the shuffling of fuel assemblies from the reactor core into the fuel pool (t_E) as the time of maximum heat release in the fuel pool.
- b) with respect to cooling of the fuel assembly partial discharge quantities in specified normal operation of the plant - the isolation of the fuel pool by closing the partitioning gate valve (t_T) after completion of refueling.
- c) with respect to cooling of the fuel assembly partial discharge quantities in the case of design basis incidents and events with a low frequency of occurrence which could take place after resumption of power operation, the point in time of the resumption of power operation (t_L) after refueling. In the case of interconnections of the fuel pool heat removal systems with residual heat removal systems, the most unfavorable point in time for heat removal from the fuel pool which may actually occur a few days after the start of power operation shall be considered.

4.2 Fuel Pool Water Temperatures to be Maintained Depending on the Specified Application

Note: A summary of the design of the fuel pool heat removal systems described in the following text of this safety standard is also presented in tabular form in **Appendix A**.

The temperatures referred to as T_1 , T_2 and T_3 are identical with the temperatures T_1 , T_2 and T_3 as specified in KTA 2502 for the mechanical design of the fuel pool.

The frequency of events for which an increase of the pool temperature up to T_3 is permissible is considered low enough that the occurrence of one of these events is not expected within the lifetime of a single nuclear power plant; however, within the lifetimes of several nuclear power plants, the possibility of such an event occurring at one of these plants cannot be ruled out. The occurrence of T_3 , therefore, constitutes an HS loading condition (see KTA 2502) for the mechanical design of the fuel pool. After occurrence of this temperature, an inspection of the parts and structures of the fuel pool is necessary to ascertain its further functional capability.

4.2.1 Specified Normal Operation of the Plant

4.2.1.1 Normal System Condition

The fuel pool heat removal systems shall be designed such that a pool water temperature of $T_1 = 45^\circ\text{C}$ can be maintained even in the case of a maximum heat input. In this context, the following assumptions shall be made, depending on the case of application:

- a) with regard to core discharge (Cases A and B), all redundant components of the fuel pool heat removal systems intended to cope with this case shall be considered as available.

Note: With regard to the required boundary conditions in the case of maintenance work, cf. Section 8.2.2 (3).

- b) with regard to cooling of fuel assembly partial discharge quantities (Case C), one active component of the fuel pool heat removal systems intended to cope with this case shall have failed or one train which in the course of this operating condition shall undergo maintenance work shall, therefore, be considered as not being available for operation.

4.2.1.2 Abnormal System Condition

It shall be possible to maintain a pool water temperature of $T_2 = 60^\circ\text{C}$. In this context, the following assumptions shall be made, depending on the case of application:

- a) with regard to core discharge (Cases A and B), one active component shall have failed; the remaining redundant components of the fuel pool heat removal systems, intended for this purpose, shall be capable of maintaining the required pool water temperature.
- b) with regard to cooling of the fuel assembly partial discharge quantities (Case C), two active components of differing redundancy shall have failed or one passive component shall not be available for operation (however, there is no loss of integrity, cf. Section 4.2.4 item a)), or one train which is to undergo maintenance work in the course of this operating condition, shall not be available for operation and, additionally, one active component shall have failed. In order to cope with this case, additional cooling capabilities in accordance with Section 5.1 (3) may be used.
- c) The auxiliary power supply shall not be available in Cases A, B and C. In addition one active component shall have failed or one train which is to undergo maintenance work in the cases specified, is not available for operation in the fuel pool heat removal systems intended to cope with this case of application.

4.2.2 Design Basis Incidents of the Plant

(1) It shall be possible to maintain a pool water temperature of $T_2 = 60^\circ\text{C}$. In this context, it shall be assumed that one active component of the fuel pool heat removal systems shall have failed or that one train which is to undergo maintenance work in the course of normal system condition, is not available for operation.

(2) In deviation from the temperature of 60°C as required under para. (1), a pool water temperature of $T_3 = 80^\circ\text{C}$ is permissible in the case of those design basis incidents, during which, in accordance with the incident control concept of the plant,

- a) one or several trains of the fuel pool heat removal systems are not available for fuel pool cooling in order to allow the accomplishment of another higher-level safety function (e.g., emergency core cooling in the case of loss of reactor coolant) or
- b) the boundary conditions for the use of the fuel pool heat removal systems change as a result of the incident whereby their cooling effect is reduced.

In this context, it shall be assumed that one active component of the fuel pool heat removal systems has failed or that one train which in the course of normal system condition shall undergo maintenance work shall, therefore, be considered as not being available for operation.

(3) A temperature of $T_3 = 80^\circ\text{C}$ shall be maintained, also, if more than one train shall be assumed to be unavailable on account of system interconnections; cf. Section 5.2.

4.2.3 Events with a Low Frequency of Occurrence

(1) After any event with a low frequency of occurrence for which planned risk minimization measures have to be taken, it shall be possible to maintain a pool water temperature of $T_3 = 80^\circ\text{C}$.

(2) No failure of system portions intended and designed to be used in the case of these events and no coinciding occurrence of maintenance work on these system portions needs to be assumed. Pre-planned auxiliary measures may be taken into account.

4.2.4 System Internal Rare Events

It shall be possible to maintain a pool water temperature of $T_3 = 80^\circ\text{C}$. In this context, the following cases shall be considered:

- a) Failure (loss of integrity) of one passive component (cf. Section 5.3).

No additional failures of components of the fuel pool heat removal systems and no coinciding maintenance work on these subsystems need to be assumed. Planned auxiliary measures may be taken into account (cf. Section 5.1 (3) and Section 6.2 (6)).

- b) Failure of an additional active component during maintenance work while refueling.

In the case of systems which are to undergo maintenance work in the course of plant outage for refueling purposes, in particular after core discharge, the failure of one additional active component shall be assumed to coincide with the maintenance work on one train. In this case, the use of additional cooling capabilities in accordance with Section 5.1 (3) may be taken into account.

Note: With regard to the required boundary conditions in the case of maintenance work, cf. Section 8.2.2(3).

4.3 Boundary Conditions of the Heat Sink

4.3.1 Thermal Discharge into Bodies of Water

In the case of thermal discharge into bodies of water (direct cooling), the highest monthly average temperature determined over several years of observation shall be used as the design basis cooling water intake temperature.

4.3.2 Thermal Discharge into the Atmosphere

In the case of thermal discharge into the atmosphere through wet cooling towers, the system design shall be based on the peak wet bulb temperature reached on twenty days per year on a long-term average. In the case of thermal discharge through dry cooling towers, a corresponding reference temperature shall be selected.

5 System Concept

5.1 Basic Concept

(1) In accordance with the requirements specified in Section 4.2, the fuel pool heat removal systems shall be designed at least as dual-train systems. With regard to the passive components, exceptions are permissible, provided, measures to ensure operational availability, in particular, those measures in accordance with Section 5.1 (3), are scheduled.

(2) The required instrumentation and control equipment as well as auxiliary, supply and energy systems should also have a train-wise layout that corresponds to the train-wise layout of the fuel pool heat removal systems.

(3) In order to cope with the failure of two redundant trains or of one common passive component, a third train or another additional cooling capability shall be available; auxiliary measures are also permissible in this context. To this end, equipment and cooling media existing in the plant should be given preference (e.g., by using operational interconnections with other systems).

(4) In planning the system concept, in particular with regard to interconnections with other systems and to the control equipment and instrumentation of the systems, a time limited interruption of pool cooling may be taken into consideration. The allowable interruption time results from the heat-up process starting at the maximum operating temperatures - indicated, e.g., by a "temperature high" alarm - to the maximum permissible pool water temperature T_1 , T_2 or T_3 in each case.

5.2 System Interconnections

(1) A system interconnection of the fuel pool heat removal systems for other functions, in particular for other heat removal functions and for fuel pool cleaning, is permissible, provided, the requirements of this safety standard specified for the fuel pool heat removal system are fulfilled in all cases of application under consideration. E.g., the following interconnections for a simultaneous or non-simultaneous operation are permissible:

- Interconnection between the fuel pool cooling systems and other heat removal systems during power operation.
- Interconnection between the fuel pool cooling systems and the residual heat removal system and use of the cooling capacity of the latter during the refueling phase.
- Application of components of the fuel pool heat removal systems to residual heat removal functions, e.g., for the residual heat removal from the reactor core after an external event.
- Interconnection of the power supply systems for the residual heat removal and fuel pool heat removal systems in the case of a failure of the auxiliary power supply.

(2) In as far as the fuel pool heat removal systems including the associated auxiliary, supply and energy systems are interconnected with other systems, for which failure assumptions for certain specified applications are made (e.g., in accordance with the single failure concept or with KTA 3301), the subsystems assumed to be unavailable for operation are regarded as also having failed for the heat removal from the fuel pool as defined under Section 4.2.1.2, item c) and under Section 4.2.2; no additional failure need to be assumed for the fuel pool heat removal systems. In such a case, an additional cooling capability in accordance with Section 5.1 (3) may be employed or the allowable interruption time in accordance with Section 5.1 (4) may be taken advantage of. The alternating use of an active component for several functions in the course of one and the same case of application should be avoided.

5.3 Coolant Makeup

(1) In order to replenish of water losses due to evaporation and leakages (stuffing boxes, pool lining) and for replenishing losses after operating processes and leakage cases, a makeup capability shall be provided. The capacity of this makeup capability shall be designed such that the sum of the times required for failure detection, leakage isolation and coolant replenishment up the minimum water level does not exceed the allowable interruption time for reaching the pool water temperature $T_3 = 80^\circ\text{C}$ in accordance with Section 4.2.4. In this context, a leak cross section corresponding to the cross section of a pipe of DN 50 shall be used as a basis.

Note: The minimum water level results from the requirements specified for normal operation of the fuel pool cooling system in accordance with Section 6.2 (3) and (4).

(2) Protection against unintentional overfilling shall be provided, e.g., by means of sufficient overflow cross sections or surveillance by instrumentation and control equipment (cf. Section 7.2).

5.4 Penetration of the Containment

(1) Each pipe of the fuel pool heat removal systems which penetrates the containment and serves the purpose of heat removal from the fuel pool after loss-of-coolant accidents shall be provided with one directly or indirectly acting isolating equipment outside the containment in accordance with KTA 3404. They do not need to be included in the automatic penetration isolation if the pressure design of the system region outside the containment equals at least the pressure design of the containment.

(2) Pipes having no fuel pool heat removal function after loss-of-coolant accidents and connected to pipes of the fuel pool heat removal systems, as specified in Section 5.4 (1), outside of the containment, shall be included in the penetration isolation in accordance with KTA 3404. On the condition that the design of the subsequent system was based on at least the design pressure of the containment, each of the respective pipes shall be provided with an isolation valve located close to the branch point. Otherwise, two valves shall be provided.

5.5 Activity Barriers to the Heat Sink

(1) Any uncontrolled radioactivity discharge via the fuel pool heat removal systems to the heat sink shall be prevented.

Note: Basically, two activity barriers are provided. The first barrier may be a passive component (heat exchanger), the second another passive component or an arrangement providing an appropriate pressure differential.

(2) Leakages and activities shall be monitored in accordance with KTA 1504.

6 Requirements for the Fuel Pool and for Components of the Fuel Pool Heat Removal Systems

6.1 Design

(1) The design of the fuel pool and the components of the fuel pool heat removal systems shall be based on the requirements specified under Section 4. The boundary and ambient conditions applied shall be those to be anticipated for the various specified applications. An incident-related increase in operating pressures and changes in ambient conditions shall be taken into account. In those cases in which $T_2 = 60^\circ\text{C}$ is assumed to be exceeded, the most unfavorable temperature history for the fuel pool (both for heat-up and cooling down) resulting from the event sequence to be assumed shall be applied to the design of the fuel pool. The drives shall be designed in accordance with KTA 3504. The maximum permissible operating temperature for the components of the fuel pool cooling system should not be lower than 100°C .

(2) The requirements resulting from the properties of the cooling media (e.g. radioactivity, boric acid and oxygen content) and their interactions with the materials shall be taken into account.

(3) Components whose function is required for the control of external events shall be designed to cope with the resulting stresses. It shall be possible to isolate branching pipes which are not designed to withstand these external events. A physical separation of the redundant components may provide sufficient protection if the stresses remain restricted to partial regions of the plant.

6.2 Physical Arrangement

(1) If possible, the components of the fuel pool heat removal systems shall be arranged outside of the containment so that, if necessary, they are accessible for actuation and maintenance and repair.

Note: With regard to maintenance and repair after a loss-of-coolant accident, the planning procedures in accordance with Sec. 9.2.3 KTA 1301.1 shall be observed.

(2) Suction and feed nozzles of the fuel pool cooling system shall be arranged and designed such that the circulation in the fuel pool is supported and a short-circuit flow is avoided.

(3) Any formation of eddy currents involving an intake of air shall be prevented under all operating conditions.

(4) The suction lines of the fuel pool cooling system shall be arranged in such a way that there are perfect intake conditions for the pumps even at elevated water temperatures.

(5) Suction and feed nozzles shall be designed such that, with regard to the formation of waves, the flow velocity is sufficiently low not to impair the transparency of the water and not to promote the formation of aerosols.

(6) An isolation capability of the suction and feed nozzles from the fuel pool or an equivalent auxiliary measure shall be provided in order to maintain the cooling capacity in the case of leakage and for repairs conducted on the first isolation valves.

(7) Pipes not serving the cooling of the fuel pool shall be connected to the pool in such a way that their failure does not in any way affect cooling.

(8) Pipes inside the fuel pool shall be provided with features or arranged in such a way that any impermissible level decrease resulting from siphoning effects is impossible.

(9) The components of the fuel pool heat removal systems shall be arranged such that their integrity is not impaired by mechanical impacts (e.g., by the failure of adjacent high-energy pipes or transportation processes) and that any flooding diminishing the operability of the components is prevented.

7 Instrumentation and Control

7.1 Control

(1) Manual control of the fuel pool heat removal systems is permissible. The controls may be designed component-wise (individual actuation) or group-wise for functionally related groups of components (group actuation).

(2) The actuation elements for the fuel pool heat removal systems shall be located in the control room. If required by the protection concept of the plant, e.g., for operation after external events, additional controls shall be located in the remote shutdown station or in a local control station.

7.2 Surveillance

(1) The "pool water temperature" measuring point in the fuel pool shall be designed as one of the measuring points of the incident surveillance indication, and the "pool level" measuring point as a measuring point of the incident wide-range indication in accordance with KTA 3502. A Class 1 hazard alarm in accordance with KTA 3501 shall be generated before the temperature limit T_2 is exceeded and also before the pool level decreases to the minimum water level.

(2) Other appropriate variables of state shall be measured for operational surveillance and regarding the efficacy of fuel pool cooling. Before the temperature limit T_1 is exceeded and when the operational coolant level limits are reached, Class 2 hazard alarms in accordance with KTA 3501 shall be generated.

8 Operation

8.1 Mode of Operation

(1) The fuel pool heat removal systems shall be operated in such a way that it is ensured that the fuel pool water temperatures specified under Section 4.2 are not exceeded; in this context, there is a free choice between the continuous and an intermittent mode of operation.

(2) All components of the fuel pool heat removal systems should be available for operation at the start of refueling.

(3) For all cases of application in which the fuel pool heat removal systems must be temporarily shutdown on account of their interconnection with another heat removal system, it shall be ensured that it is possible to resume fuel pool cooling in good time before the individually permissible pool water temperature is exceeded.

(4) In the cases of design basis incidents, of events having a low frequency of occurrence and of system internal rare events, claim should be taken of the fuel pool water temperature T_3 in accordance with Section 4.2, only, and only as long, as this is necessary on account of the event sequence and the condition of the system. The temperature T_2 should best be aimed for.

(5) In the case of external events, heat removal from the fuel pool shall be ensured in accordance with the protection concept of the plant.

8.2 Maintenance

8.2.1 Repairs

(1) If one of the components of the fuel pool heat removal systems fails, repairs should be conducted immediately after detection of the failure.

(2) The actually available redundancy of the fuel pool heat removal trains (including additional cooling capabilities in accordance with Section 5.1 (3)) shall be used as the basis for the specification of the repair times; in Case C (cooling of the fuel assembly partial discharge quantities) this is related to the maintenance of a pool water temperature $T_2 = 60^\circ\text{C}$, in Cases A and B (core discharge), to the maintenance of a pool water temperature $T_3 = 80^\circ\text{C}$.

(3) Precautionary measures shall be taken in order to ensure adherence to the repair times specified in each individual case.

8.2.2 Servicing and Inspection

(1) The pool water temperature $T_1 = 45^\circ\text{C}$ as specified in Section 4.2.1.1, shall be maintained in the course of servicing and inspection tasks.

(2) Servicing and inspection tasks leading to an interruption of the operational availability of a component should preferably be conducted at a time when the thermal output to be removed from the fuel pool is as low as possible, e.g., towards the end of the operating cycle of the plant.

(3) However, if servicing and inspection work has to be conducted during plant outage after core discharge, the following shall be observed with regard to the planning of these tasks:

The start of maintenance work t_w shall be chosen such that, in the actual case,

- a) the remaining redundant components maintain the fuel pool water temperature at $T_1 = 45^\circ\text{C}$ and
- b) in the case of a postulated additional failure of an active component in accordance with Section 4.2.4 item b), the specified pool water temperature of $T_3 = 80^\circ\text{C}$ can be maintained.

8.2.3 Functional Tests

Functional tests shall be conducted on all active components. These should be performed every four to eight weeks. These tests can also be performed by means of operational switch-overs between trains.

Appendix A

Overview of the Design Requirements of the Fuel Pool Heat Removal Systems

Case (corresponding section of this safety standard)	Required fuel pool water temperature	Loading of the fuel pool	Design points in time ¹⁾	Non-functioning components ²⁾
Specified normal plant operation, normal condition of the system (Section 4.2.1.1)	45°C	entire core fuel assembly partial quantity	t_w t_T	1 train in maintenance 1 active component failed or 1 train in maintenance
Specified normal plant operation, abnormal condition of the system (Section 4.2.1.2 a), b))	60°C	entire core fuel assembly partial quantity	t_E t_T	1 active component failed 2 active components failed or 1 passive component failed or 1 train in maintenance and 1 active component failed ⁴⁾
Loss of auxiliary power supply (Section 4.2.1.2 c))	60°C	entire core fuel assembly partial quantity	t_E t_T	1 active component failed or 1 train in maintenance ⁴⁾
Design basis incidents of the plant (Section 4.2.2)	60°C 80°C ^{5) 6)}	entire core fuel assembly partial quantity	t_E t_L	1 active component failed or 1 train in maintenance ⁴⁾
Events with a low frequency of occurrence (Section 4.2.3)	80°C ⁵⁾	entire core fuel assembly partial quantity	t_E t_L / t_T ³⁾	- -
System internal rare events (Section 4.2.4)	80°C ⁵⁾	entire core fuel assembly partial quantity	t_E t_W t_T	1 passive component failed (loss of integrity) 1 active component failed and 1 train in maintenance ⁴⁾ 1 passive component failed (loss of integrity)
<p>1) Nomenclature: t_E empty core t_T partitioning gate valve closed after fuel assembly change t_L start of power operation after fuel assembly change t_w start of maintenance (see Section 8.2.2 para. (3)).</p> <p>2) in as far as so designed and intended; interconnections of systems not considered.</p> <p>3) In the case of plant-internal incidents t_L; in the case of external events t_T.</p> <p>4) In the case that maintenance tasks should be performed.</p> <p>5) Load case HS in accordance with KTA 2502.</p> <p>6) 80 °C in the case of design basis incident with effects on the fuel pool heat removal systems in accordance with Section 4.2.2 para. (2).</p>				

Appendix B

Regulations Referred to in this Safety Standard

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

Single Failure Concept (03/84)		Interpretation of the Safety Criteria for Nuclear Power Plants, Single failure concept - Basic principles for applying the single failure criterion (GMBI 1984, pages 208 to 210)
KTA 1504	(06/78)	Measuring liquid radioactive materials for monitoring the radioactive discharge
KTA 2502	(06/90)	Mechanical design of fuel assembly storage pools in nuclear power plants with light water reactors
KTA 3301	(11/84)	Residual heat removal systems of light water reactors
KTA 3404	(09/88)	Isolation of operating system pipes penetrating the containment vessel in the case of a release of radioactive substances into the containment vessel
KTA 3501	(06/85)	Reactor protection system and monitoring equipment of the safety system
KTA 3502	(11/84)	Incident instrumentation
KTA 3504	(09/88)	Electrical drives of the safety system in nuclear power plants
DIN 25 463 Part 1	(05/90)	Decay heat power in nuclear fuels of light water reactors; Non-recycled nuclear fuels