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Regulatory requirements with respect to Spent Fuel Pool Cooling

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Important Documents

- "*Safety Requirements for Nuclear Power Plants*" (SiAnf), 22.11.2012, updated 03.03.2015
- "*Interpretations of the 'Safety Requirements for Nuclear Power Plants'*" (SiAnf Interpretations), 29.11.2013, updated 03.03.2015
- "*Heat Removal Systems for Fuel Assembly Storage Pools in Nuclear Power Plants with Light Water Rea*ctors", (KTA 3303, 2015-11), 08.01.2016
- "*Requirements for spent fuel pool cooling*" (RSK 2015), Recommendation of the German Reactor Safety Commission, 09.12.2015

This presentation represents a personal view of the author and does not necessarily represent any official position (BMUB, RSK)

Background

- Introduction of new requirements with respect to spent fuel pool (SFP) cooling by SiAnf in 2012
- During amendment of KTA 3303, questions arose concerning the interpretation of SiAnf requirements
- BMUB asked RSK to clarify SiAnf requirements and their technical implementation:
  - Maintenance of redundancies of spent fuel pool cooling system (FPC) during fuel assembly storage (operational mode F according to SiAnf)?
  - Best operational modes for maintenance of FPC?
  - Further need for clarifications of SiAnf requirements, especially with respect to events of level of defence 3 (LoD 3)?

FPC in German BWRs

- Two operational trains (not part of the safety system)
  - Not designed against earthquakes or rare man-made external hazards
  - 100% capacity in all operational phases (A-F) for events of LoD 3
- Three trains of the residual heat removal system
  - One train for direct SFP cooling
  - All three trains for indirect SFP cooling (via pressure suppression pool)
  - 100% capacity in all operational phases
- Under specific circumstances: cooling with additional cooling system (ZUNA) possible

→ in general more trains available than in PWRs, thus in the following focus only on PWRs

FPC in German PWRs

- Three trains
  - 2 trains as part of residual heat removal / emergency cooling system
    - with two parallel pumps each train
    - emergency power supply by D1 or D2
    - 100% capacity in all operational phases (A-F) for all events of LoD 2 and 3
  - 3rd train for SFP cooling, especially during LOCA
    - Not part of the safety system
    - Not designed against earthquakes or rare man-made external hazards
    - Emergency power supply possible by redundancies 2 or 3 of D1
    - Depending on plant: less than 100% capacity
- RSK accepts crediting operational train for events of LoD 3, if reliable fuction under event specific circumstances is demonstrated

Requirements with respect to SFP cooling

- Before SiAnf:
  - German „single failure concept“ (single failure + unavailability of a safety equipment due to maintenance measures) not fully applied to FPC
- SiAnf:
  - New list of events to be considered, including events on LoD 3
  - Application of the „single failure concept“ to FPC
  - Focus on event B3-01 but
    other events also important to answer questions of BMUB

SiAnf, Annex 2, Table 5.3: Event list fuel storage PWR/BWR

- LoD 3: Reduced heat removal from the spent fuel pool
- B3-01: Loss of two trains of the spent fuel pool cooling system for a longer period (> 30 min.)
  - Fundamental safety functions concerned: Cooling
  - Acceptance targets:
    Limitation of the spent fuel pool water temperatures to values below the design temperature of the pool (T_3) for ensuring its integrity
  - Operational mode: A-F
  - Additional boundary condition:
    For the safety demonstration, grace times and repair possibilities might be taken into account for all operational modes

SiAnf Interpretations, I-5: Requirements for structures, systems and components

- Chapter 5: Event-specific requirements relating to event B3-01
  - The event sets in
    - with the failure of a train currently in operation
    - during the unavailability of a second train due to maintenance measures
- → No ‘common mode’ failure of more than one train

SiAnf, Annex 4: Principles for applying the single failure criterion and the maintenance

- 2.2.3: Redundancy requirements for equipment of LoD 3
  - For the safety equipment required to cope with events on LoD 3, a single failure generally combined with a maintenance case shall be postulated when demanded (degree of redundancy n+2).
- 2.3: Redundancy requirements for safety-relevant equipment during operational modes phases C to F
  - 2.3(2): A degree of redundancy n+0 is permissible in the operational modes E and F if in case of a loss of function of the safety-relevant equipment,
    - relevant acceptance criteria are not exceeded within 10 hours and
    - the active safety-relevant equipment failed or being under maintenance can be made functional within this time frame.

SiAnf Interpretations, I-5: Requirements for structures, systems and components

- Chapter 4: Requirements for the application of the single-failure concept
  - According to 4.1, for the installations for SFP cooling, SiAnf, Annex 4, 2.3 (2) also applies to the operating phases A to D
  - 4.1 further notes:

    “Operating experience has shown that it is possible to make at least one FPC train available
    - within 10 hours
    - if sufficient maintenance resources (sufficient and qualified maintenance personnel, stocks of spare parts, etc.) are provided at the plant.”

B3-01: First Results

- For B3-01,
  - failure of a train currently in operation together with
  - unavailability of a second train due to maintenance measures and
  - a single failure

  may result in a complete loss of active SFP cooling
- Making at least one train available can be credited if
  - relevant acceptance criteria (here: T_3) are not exceeded within 10 hours and
  - sufficient maintenance resources (sufficient and qualified maintenance personnel, stocks of spare parts, etc.) are provided at the plant.

RSK Recommendation 1a/b

- Preventive maintenance leading to the unavailability of one train of the FPC should only be performed, if the time until T_3 is reached (after an event takes place, taking into account a single failure) is longer than 10 hours
- During preventive maintenance, sufficient maintenance resources (sufficient and qualified maintenance personnel, stocks of spare parts, etc.) have to be ensured
- Only in individual cases and for substantial reasons preventive maintenance may be performed even if T_3 may be reached in less than 10 hours. In these cases, specific conditions have to be met (compare RSK 2015)

RSK Recommendation 1a/b

- Further Remarks:
  - If temperature remains below T_3 due to remaining active SFP cooling even after an event (loss of one train, preventive maintenance in a second train, single failure in a third train), preventive maintenance is not restricted
  - Servicing (according to SiAnf Annex 4, 3.3.2) is permitted, if available time until T_3 may be reached is considerably longer than the time needed to bring equipment back to functionality
- Operational modes adequate for preventive maintenance of FPC must be chosen under consideration of other events (LOCAs, hazards …)

B3-01: Additional Results

- Apart from preventive maintenance, also unplanned maintenance (repair) has to be considered
- B3-01 may result in a complete loss of active SFP cooling during planned as well as unplanned maintenance of FPC
- According to SiAnf, Annex 4, 2.2.3, for comparable situations
  - maintenance shall be sufficiently restricted in time and
  - the permissible unavailability shall be specified in the operational documentation
- To be able to credit repair of at least one train within 10 hours
  - sufficient maintenance resources (sufficient and qualified maintenance personnel, stocks of spare parts, etc.) have to be provided

RSK Recommendation 2

- Requirements with respect to FPC availability and measures in case of unplanned maintenance have to be covered by the operational documentation
- In case of unplanned maintenance, sufficient maintenance resources (sufficient and qualified maintenance personnel, stocks of spare parts, etc.) have to be ensured in due time

B3-01: Further Results

- Formally, B3-01 is defined as taking place during times of maintenance (according to SiAnf Interpretations)
- Nevertheless, also for times without maintenance,
  - failure of a train currently in operation together with
  - a single failure

  should be considered
- Without maintenace (planned or unplanned), at least one train will remain available
- In some plants, not all trains have 100% capacity
  → even with one train available, T_3 may be reached

RSK Recommendation 3

- Operating conditions without maintenance, in which T_3 may be reached within 10 hours (even with a remaining train), have to be excluded

Further Remarks

- If with a remaining train, T_3 will not be reached within 10 hours, but may be reached afterwards, sufficient maintenance resources (sufficient and qualified maintenance personnel, stocks of spare parts, etc.) have to be provided

Further events of LoD 3 – Loss of coolant from SFP: B3-02 to B3-04

- For B3-02 to B3-04,
  - Loss of a train due to leaks together with the
  - unavailability of a second train due to maintenance measures and
  - a single failure

  may result in a complete loss of active SFP cooling
  → see Recommendations 1-3
- Furthermore, loss of coolant from SFP may result in short term loss of active cooling functions, until
  - leak is isolated and
  - coolant is added

RSK Recommendation 4 and 5

- For events with loss of coolant from SFP
  - measures and equipment for sufficiently fast isolation of leak have to be provided and
  - during fuel unloading it has to be ensured, that for events with total loss of active SFP cooling, time to reach T_3 is longer than time needed to
    - isolate the leak and
    - add coolant to restart active SFP cooling

    taking into account the reduced SFP inventory
- During maintenance work on FPC, piping from SFP should be sealed by two isolation valves (or equivalent measures and equipment)

External events: Design basis earthquake

- Only two trains of FPC designed to be operational after design basis earthquake (DBE)
- Due to single failure concept, DBE may result in a complete loss of active SFP cooling
- → see Recommendations 1-3
- To be able to credit repair of at least one train within 10 hours
  - sufficient maintenance resources (sufficient and qualified maintenance personnel, stocks of spare parts, etc.) have to be provided

RSK Recommendation 6

- If just one train designed against earthquake is available due to maintenance (planned or unplanned)
  - sufficient maintenance resources (sufficient and qualified maintenance personnel, stocks of spare parts, etc.) have to be provided
  - that remain available under the specific circumstances of DBEs.

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Vielen Dank für Ihre Aufmerksamkeit!
Thank you for your attention!

Haben Sie noch Fragen?
Do you have any questions?