Note:
This is a translation of the RSK statement entitled
"Planung und Prüfung von Arbeiten im Restbetrieb"
In case of discrepancies between the English translation and the German original, the original shall prevail.

RSK Recommendation

(539th meeting of the Reactor Safety Commission (RSK) on 13 December 2023)

Planning and inspection of work during residual operation

RECOMMENDATION

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1 Cause of the discussion

In November 2022, in connection with work towards the decommissioning of the residual-heat removal train JNA20 at the Philippsburg 2 nuclear power plant (KKP 2), boron-containing medium escaped from the refuelling water storage tanks (RWST) JNK20 BB001/002 (hereinafter referred to as RWST) into the previously drained train JNA20 of the residual-heat removal system and from there into several room areas in the reactor building annulus. In addition, some of the liquid flowed into the containment sump via the three-way valve JNA20 AA003, which was in intermediate position.

The planning and implementation steps related to the event as well as the significance of the position of the three-way valve have been discussed by the RSK's subcommittee on REACTOR OPERATION (REAKTORBETRIEB, RB) with regard to potential generic recommendations for plants in residual operation.

2 Course of discussions

At the 284th RB meeting on 17 May 2023, the licensee of KKP 2 reported on the course of the event "Leakage from the JNK20 RWST", the safety assessment carried out, results of the investigation of the event as well as the measures and effectiveness checks derived therefrom /1/.

Following the 284th RB meeting, Physikerbüro Bremen (PhB) was asked by the BMUV for an assessment of issues relating to potentially safety-related consequences of the position of the three-way valve at the time of the event /2/.

At the 286th RB meeting on 16 November 2023, assessments by the expert organisation TÜV NORD EnSys regarding the analysis of the event "Leakage from the JNK20 RWST" /3/ were presented. Representatives of the ESK's DECOMMISSIONING (STILLLEGUNG, ST) committee also took part in the discussions at the 284th and 286th RB meetings.

On the basis of the hearings at the 284th and 286th meetings and the explanations in /1/ to /4/, the REACTOR OPERATION committee discussed the draft of this statement at its 286th and 287th meetings and adopted it at its 287th meeting on 23 November 2023.

The RSK discussed and adopted the recommendation at its 539th meeting on 13 December 2023.

3 Background

At the time of the event, the KKP 2 plant was in residual operation in plant state A with 266 fuel assemblies (FA) still in the spent fuel pool. The residual power production was approx. 552 kW.

In the course of the decommissioning of the residual-heat removal systems JNA20/30, the three-way valve JNA20/30 AA003, hereinafter referred to as the three-way valve, of the drained systems was moved to intermediate position in November 2022 /2/. Depending on the position, the three-way valve connects the

suction side of the low-head safety injection pump either with the sump of the containment or with the borated water storage tank. If the valve is in intermediate position, all three sides are connected with each other. According to the specifications of KKP 2, the intermediate position is the standard position of three-way valves intended to be taken permanently out of service. Like the respective positions of other valves in the residual-heat removal trains 20 and 30, it corresponds to the new basic positions defined in the operating manual in the course of the decommissioning process.

As part of the decommissioning process, all other valves of the trains JNA20/30 of the residual-heat removal system - including vent and drain valves - were set to "OPEN" position, with the exception of valves separating different systems from each other /2/. As a result, there were open connections between the containment and the reactor building annulus at least via several DN25 pipes.[1]

A few days after the valves had been moved into their new positions, work was carried out on safety valve JNA20 AA902 as part of further activities for the decommissioning of JNA20 /1/. Originally, the safety valve was designed to protect the suction line of the low -safety injection pump from the RWST against a pressure increase due to the heating during sump operation. In order to separate the JNA (residual-heat removal system) and JNK (RWST) subsystems and thus to introduce a process engineering interface (system boundary) as part of the decommissioning process, the valve spring was first to be dismantled and then a blanking plate was to be fitted on the piping side towards the borated water storage tank. During the dismantling of the valve spring, boron-containing medium spilled out.

As explained in /1/, with the decommissioning and dismantling licence for KKP 2 in 2020 both the JNA20/30 residual-heat removal trains and the JNK20/30 RWST had already been classified as systems "without significance (*ohne Bedeutung*, oB)" and subsequently been drained. The Planning for the activities in question began in March 2022, at a time when the JNK20 borated water storage tank was empty.

In September 2022, as part of the boric acid campaign of KKP 2, it was decided to use the JNK20 RWST for the storage of borated
medium /1/. The contents of the JNK40 RWST were then pumped into the JNK20 tank. Afterwards, the medium remained in this tank. The work order documents for carrying out the decommissioning of JNA20 were finalised after the tank-to-tank transfer of the medium. The fact that in the case of the filled JNK20 tank the work on the JNA20 AA902 valve could not be carried out as planned was not taken into account, as explained below.

The JNA20 AA902 valve is located in a piping section below the fill level of the borated water storage tank. Therefore, due to the geodetic conditions, borated medium spilled out when the safety valve JNA20 AA902 was dismantled. The leakage into the room housing the safety valve was stopped after approx. 40 minutes by reassembling the spring package. However, it was not possible to fit the valve cone tightly onto the valve seat. The leaking valve caused a continuous spill of borated medium into train JNA20 of the residual-heat removal system. From there, it flowed through open vent and drain valves into various rooms in the annulus. In addition, borated medium spilled out into the sump of the reactor building interior via the three-way valve JNA20 AA003, which was in an intermediate position. After a system inspection with the help of valve

[1] According to /2/, there were also open connections (DN25) via other systems between the containment, the annulus and the reactor auxiliary building.

position check lists and the closure of the relevant drain and vent valves, the leaks into the various room areas were stopped approximately four hours after the start of the event /1/.

According to /1/, there were no effects on humans, the plant or the environment, as the leakage medium had been cleaned several times and was therefore free of any activity. Approx. 10 m³ of borated medium entered the affected room areas, but no safety-relevant components were affected. Also, no activity-containing materials were stored in the affected areas.

In the course of an event analysis, three measures and associated effectiveness checks were derived /1/.

4 Assessment criteria

The relevant requirements from the "Guideline Relating to the Procedure for the Preparation and Implementation of Maintenance Work and Modifications at Nuclear Power Plants" /8/, KTA Safety Standard 1402 /9/, the RSK statements /5/ and /6/ and the ESK's Guidelines for the Decommissioning of Nuclear Installations /7/ are used as assessment criteria.

The relevant requirements from /8/ and /9/ are specified in the plant-specific maintenance regulations and relate to the organisation of the work permit procedure. These include requirements for

- the technical clarification of the planned activities
- checks with respect to the need of system isolations,
- independent checks of the work orders for factual accuracy and
- checks during the approvals of the work orders to ensure that they are compatible with the current plant state.

The ESK's Guidelines for the Decommissioning of Nuclear Installations /7/ also require that a suitable work permit procedure be established for the planning, approval, implementation, monitoring and documentation of the work associated with decommissioning.

In its statements /5/ and /6/, the RSK discusses the drop down of a fuel transport cask into the fuel pool and into the transport cask pool as beyond-design-basis scenarios. For residual operation, the RSK demands that a measure for the recirculation of leakages from the containment sump into the fuel pool is to be provided in order to limit the coolant inventory in the containment sump in a PWR in the long run. For this purpose, one of the existing pool cooling trains equipped with the option of sump recirculation can be used. Thereby, any boundary conditions that may deviate from power operation must be taken into account. The feasibility of the make-up and recirculation options must also be demonstrated under these boundary conditions.

The ESK Guidelines for the Decommissioning of Nuclear Installations /7/ recommend that the dismantling concept must include, among other things, dismantling steps and dismantling measures for installations including their interdependencies and the anticipated time schedule while avoiding impermissible retroactive effects on safety-related installations. Furthermore, in the course of safety analyses, the interdependence and influence of various sub-steps during dismantling must be considered and assessed. As dismantling progresses, it must be checked in each case whether adjustments to the existing safety analyses are necessary

to reflect the changed conditions. It must also be taken into account whether events occur under changed boundary conditions that may affect the effectiveness and reliability of installations provided for their control or whether these installations are affected in their effectiveness..

5 Assessment

5.1 Event with borated water storage tank leakage

The event "Leakage from the JNK20 borated water storage tank" was due to a failure of several administrative safety barriers, including an inadequate examination of whether the intended activity was compatible with the existing plant state.

According to the operator's account in /1/, when planning the work order and the relevant work order form (which included work on a large number of individual components), it was not taken into account that the safety valve JNA20 AA902, as the intended interface between the JNA20 train and the JNK20 RWST, requires its own isolation in case of a filled tank due to its integration into the suction line. The fact that the safety valve is integrated into a pipe geodetically below the filling level of the JNK20 borated water storage tank was not known to the person planning the work order at the time and was also not checked separately (e.g. using system plan). No separate work order form providing for a corresponding separate isolation was created for the safety valve JNA20 AA902.[2]

The planning documents contained the information that there was an interface to the filled JNK20 RWST in the area of the JNA20 AA902 safety valve. Nevertheless, during the work permit approval process the so-called “DABN shift" (these are employees of the operational planning team who are specialised in checking work orders for the decommissioning of systems) as well as the shift on duty overlooked the fact that the planned installation of the plug-in-disk onto the safety valve would inevitably result in media being discharged from the filled JNK20 RWST. This indicates an inadequate examination by the two examining shifts. The operator did not identify any further causes for these deficits in planning and examination (e.g. lack of expertise, lack of care and quality assurance) and did not derive any corrective measures.

The RSK points out that also during decommissioning the planning,verifications and approvals of work orders by the responsible departments and shifts must be carried out with great care and with consideration of the relevant technical documents. This applies in particular in view of the continuously changing boundary conditions in the plants to be decommissioned. The licensees must provide the technical departments and shift teams (including the operational planning team, if applicable) with appropriate amount of personnel and expertise and sensitise them through suitable training measures. In addition, the long-term effectiveness of the measures must be evaluated (see Recommendation 1).

The leakage was only stopped approximately four hours after the onset of the event, three hours after the spring was reassembled. This duration does not meet the RSK's expectations about measures to terminate such an event.

[2] One measure derived from the event is that separate work order forms must be created for components that are to be permanently decommissioned and represent a process engineering interface to a system/subsystem that is still in operation. The separate work order form will again trigger the query as to whether an isolation is required (via the computerised operation management system or in work planning).

During the event, there was apparently a lack of understanding with regard to the functionality of the three-way valve. For example, the personnel involved, did not realise that the continuing leakage into various rooms could have been stopped at short notice by resetting the three-way valve JNA20 AA003 from its intermediate position in the direction of sump suction.

The operator has mentioned the formation of a simplified mental model as a contributing factor in this regard /1/. According to the operator, this may lead to the conclusion that, depending on the position of the three-way valve, one or the other flow direction remains open and leakage cannot be completely prevented. Furthermore, the assumption might be that the "sump recirculation mode" position of the three-way valve is only required for the long-term treatment of a loss-of-coolant accident. This type of event will no longer be relevant in residual operation and therefore was not in the focus as it was in power operation modes.

As far as this is concerned, the RSK notes that, according to /5/, /6/, sump recirculation via one of the JNA/FAK10/40 trains must be provided as an emergency measure also during residual operation. Furthermore, as explained in Section 5.2 below, the position of the three-way valve may impair the barrier function of the containment. Prior to the event ,he intermediate position of the three-way valve had been anchored and officially approved in the operating manual . There is no documented analysis regarding the potentially safety-related consequences of the valve's position (see Section 5.2).

Overall, from the RSK´s point of view, the event shows weaknesses with regard to the analysis of actual system and component configurations, which apparently also had an impact on the decision-making process during the event.

According to the RSK's opinion, within the scope of the preservation of technical expertise it has to be ensuredthat therequired knowledge about functionality of structures and equipment that are still relevant during residual operation have to preserved by the responsible personnel (management) to the extent required and shall be taken into account in the technical qualification programmes. This applies in particular to knowledge that is relevant for compliance with fundamental safety functions and the assurance of safety functions (see Recommendation 2).

As described in Section 4, the work on the safety valve was planned at a time when the JNK20 RWST was classified as "oB" and emptied. After the event in November 2022, the classification of the JNK20 RWST was changed from "oB" to "b" (operational).[3]

During the 284th RB meeting, the operator of KKP 2 claimed that, in their view, the classification of the RWST as "oB" was not a factor contributing to the incident. Accordingly, the information as to whether a system is operationally available or not as well as whether the system has been isolated and/or is under maintenance is always documented in the plant operation management system (*Betriebsführungssystem*, BFS). In addition, an "oB" classification does not mean that the affected system may not be operated, but merely that this system can be taken permanently out of service.

[3] Plant components are assigned to class "b" if they are to remain available for operation during the period of residual operation without fuel assemblies.

From the point of view of the RSK, systems should be classified according to their utilisation (operable or potentially available). If systems - as in this case JNK20 - are used for the provision of potentially activity-containing media and thus have a retention function, this contradicts a classification as "oB" (*ohne Bedeutung*, without significance) in the understanding of the RSK. In addition, it increases the certainty of planning and action if the user can be sure that systems classified as "no longer operationally required" are actually no longer used for operational purposes. Therefore, in the case of classification systems that differentiate between systems that are still in operational use (*betrieblich*, b - operational) and systems that are no longer operationally required (which can be assigned to decommissioning, e.g. "oB" – without significance), the operational use of systems classified as "no longer required" should not be an option anymore. Clear criteria and procedures should be defined for the classifications (see Recommendation 3).

5.2 Position of the three-way valve

If it is assumed for plant states in residual operation that a residual-heat removal train has been opened and the three-way valve is in intermediate position or aligned into the direction of suction from the containment sump and the sump suction line has not been sealed, there are potentially negative consequences on

a containment ventilation isolation since even if the containment isolation valves in the ventilation system are closed, there remains a flow path from the containment to the annulus;

b the measure "Return of coolant from the containment sump" required by the RSK in /5/ and /6/ on the 4th level of defence since a loss of coolant from the sump into the annulus will occur and the return of coolant will be impaired or prevented.

In these cases, a change of the position of the three-way valve may be necessary in case of a respective event.

The concrete consequences depend on the time that has passed since the nuclear shutdown of the plant and the flow area exposed by the opening of the train. The immediate safety significance is low in the case of reduced residual power, e.g. six months after the plant has been shut down, and with small flow cross-sections, especially if the valve can be switched remotely from the control room.

In the present case of KKP 2, the immediate safety significance was low as the above-mentioned constellation on the residual-heat removal trains JNA20/30 occurred approximately three years after the plant was shut down. Furthermore, the available flow cross-sections were small according to the information given in /2/.[4]

Irrespective of this, however, the RSK believes that decommissioning activities have to be prevented from impairing the functions of measures and equipment still to be kept available and functioning according to the licence.

When a residual-heat removal train is opened, the associated three-way valve effectively becomes a containment isolation valve with regard to the barrier function of the containment. In this specific event at

[4] For KKP 2, it was required at the time of the event that a smoke-tight isolation of the containment must be possible. The operator does not consider this to be jeopardised by open small-diameter piping /2/.

KKP 2, the three-way valves of the JNA20/30 trains were classified as "oB", while the ventilation isolation of the containment was still classified as safety-related. Thus, the functionality of a function classified as safety-related was impaired by a plant component that was classified as being of no significance for operation ("oB"), which in the view of the RSK does not meet the requirements for consistent classification (see Recommendation 4).

As shown in /2/, only the AK1 interfaces were considered as part of the safety assessment for the decommissioning of JN20/30. Based on the explanations in /2/, it can therefore be concluded that the opening of penetrations between the containment and the annulus / reactor auxiliary building was not the subject of a safety assessment in the process regarding the decommissioning of JNA20/30.

In the present case, the consideration of interfaces to systems that continue to have a safety-related significance in residual operation was not sufficient to assess in advance any potential influences of the decommissioning of the JNA20/30 systems on the barrier function of the containment.

From the point of view of the RSK, it must be identified in advance for all planned activities whether these measures impair safety-relevant functions and equipment. If impairments are possible, they must be assessed in advance from a safety perspective and the results must be submitted to the supervisory authority. Written operating procedures may need to be supplemented with defined steps (such as the closing of valves). It should be noted here, that in some cases, restricting the focus of the safety-related assessment on potential adverse effects on interfaces with systems that continue to have a safety-related significance in residual operation may not be sufficient to cover all influences (see Recommendation 5).

As long as there are still fuel assemblies in the spent fuel pool, the RSK is of the opinion that activities for the decommissioning of residual-heat removal trains should be planned in such a way that no open penetrations between the containment and the annulus is established via the sump suction line of the residual-heat removal system. If the three-way valve is positioned in the direction of the sump or in intermediate position, the suction nozzles should be reliably sealed with suitable sealing elements (see Recommendation 6).

If open connections via trains of the residual-heat removal system cannot be temporarily avoided in the course of the steps towards decommissioning, as may be the case during draining and venting activities, measures must be defined as part of a preceding safety assessment to ensure that the three-way valve can be switched over immediately if required. It should be noted that in this case, the function of the respective valve must fulfil the classification requirements that apply to the containment isolation and/or to the residual-heat removal/pool cooling trains that have to be kept available.

6 Recommendations

The RSK derives the following recommendations from the assessment of the event "Leakage from the JNK20 Refueling Water Storage Tank" in combination with the status of the residual-heat removal trains JNA20/30 at that time:

1 It must be ensured that also during decommissioning the planning, verifications and approvals of work orders by the responsible departments and shifts must be carried out with great care and with

consideration of the relevant technical documents. This applies in particular in view of the continuously changing boundary conditions in the plants to be decommissioned. The licensees must provide the technical departments and shift teams (including the operational planning team, if applicable) with appropriate amount of personnel and expertise and sensitise them through suitable training measures. In addition, the long-term effectiveness of the measures must be evaluated.

2 Within the scope of the preservation of technical expertise it has to be ensured that the required knowledge about functionality of structures and equipment that are still relevant during residual operation have to preserved by the responsible personnel (management) to the extent required and shall be taken into account in the technical qualification programmes. This applies in particular to knowledge that is relevant for compliance with fundamental safety functions and the assurance of safety functions.

3 In the case of classification systems that differentiate between systems that are still in operational use (*betrieblich*, b - operational) and systems that are no longer operationally required (which can be assigned to decommissioning, e.g. "oB" – without significance), the operational use of systems classified as "no longer required" should not be an option anymore. Clear criteria and procedures should be defined for the classifications.

4 When a residual-heat removal train is opened, the associated three-way valve effectively becomes a containment isolation valve with regard to the barrier function of the containment. This has to be taken into account in the planning of the corresponding work. The classification of these valves must be in line with their safety significance. This also applies to other valves and equipment relevant in connection with the barrier function of the containment.

5 For all planned activities for the decommissioning of systems, it must be identified in advance whether these measures impair safety-relevant functions and equipment. If impairments are possible, they must be assessed in advance from a safety perspective and the results must be submitted to the supervisory authority. Written operating procedures may need to be supplemented with defined steps (such as the closing of valves). It should be noted here that in some cases, restricting the focus of the safety-related assessment on potential adverse effects on interfaces with systems that continue to have a safety-related significance in residual operation may not be sufficient to cover all influences.

6 With regard to the effectiveness of the recirculation of coolant from the containment sump into the spent fuel pool to be provided as an emergency measure according to the recommendation of the RSK, an opening of flow paths leading to coolant losses from the containment must be prevented. The three-way valves of drained residual-heat removal systems must therefore either be secured in closed position in the direction of the containment sump or, alternatively, the associated containment sump suction nozzles must be sealed with suitable sealing elements.

7 Referenced documents

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/2/ Physikerbüro Bremen; Stellungnahme - Austritt von borhaltigem Medium aus dem Flutbehälter JNK20 in mehrere Raumbereiche im KKP 2: Sicherheitstechnische Bewertung der zum Ereigniszeitpunkt im Restbetrieb bestehenden offenen Verbindung zwischen dem Reaktorsicherheitsbehälter und dem Reaktorgebäuderingraum über in Zwischenstellung befindliche Sumpfarmatur; 12.10.2023

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/6/ RSK; Anforderungen an die Kühlung der Brennelemente im Lagerbecken im Restbetrieb; Stellungnahme (518. Sitzung am 21.10.2020)
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/8/ Richtlinie für das Verfahren zur Vorbereitung und Durchführung von Instandhaltungs- und Änderungsarbeiten in Kernkraftwerken; RS-Handbuch 3-41; vom 1. Juni 1978

(GMBl. 1978, Nr. 22, S. 342)
“Guideline Relating to the Procedure for the Preparation and Implementation of Maintenance Work and Modifications at Nuclear Power Plants”
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/9/ Sicherheitstechnische Regel des KTA; KTA 1402: Integriertes Managementsystem zum sicheren Betrieb von Kernkraftwerken; Fassung 2017-11
„KTA 1402 (2017-11) - Integrated Management System for the Safe Operation of Nuclear Power Plants“
https://www.kta-gs.de/e/standards/1400/1402_engl_2017_11.pdf