Note:
This is a translation of the RSK statement entitled
"Weiterbetrieb deutscher Kernkraftwerke bis zum 15. April 2023"
In case of discrepancies between the English translation and the German original, the original shall prevail.

RSK statement

(532nd meeting of the Reactor Safety Commission (RSK) on 11 November 2022)

Continued operation of German nuclear power plants until 15 April 2023

STATEMENT

CONTENTS

1 Background

Against the background of the plans to keep the Neckarwestheim II (GKN II) and Isar 2 (KKI 2) nuclear power plants in reserve in 2023, on 20 September 2022, the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) issued a request for advice to the RSK, "on the continuation of power operation of German nuclear power plants in 2023 as a reserve to ensure security of supply" [1] (excerpt):

The continuation of power operation under certain boundary conditions is to be assessed from a safety point of view also against the background of the 13-year-old periodic safety reviews of these nuclear power plants, irrespective of the concrete implementation of reserve operation until the end of April 2023 at the latest, which has to be clarified yet. In a first step, state-of-the-art requirements are to be determined that do not already result directly from the German nuclear rules and regulations or from the plant-specific situation in the two nuclear power plants.

In a second step, these requirements are to be assessed from a safety point of view to determine whether recommendations for organisational or technical measures can be made for the two nuclear power plants that can be implemented in a timely manner. This is to be documented in a corresponding recommendation or statement of the Reactor Safety Commission.

In accordance with the decision of the Federal Chancellor of 17 October 2022, this advisory request had been extended orally at the 530th RSK meeting on 19/20 October 2022 to include the Emsland nuclear power plant (KKE).

The BMUV also commissioned Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH, Physikerbüro Bremen (PhB) and Öko-Institut (ÖI) to prepare an expert opinion on the continued operation of German nuclear power plants until 15 April 2023. The focus of the activities was on

- a comparison of the periodic safety review of the Brokdorf nuclear power plant, which was prepared in 2016 considering the then current Safety Requirements for Nuclear Power Plants (Sicherheitsanforderungen an Kernkraftwerke – SiAnf), with the PSRs of GKN II, KKE and KKI 2 from 2009,
- an evaluation of the results of the so-called extended safety review of GKN II regarding additional findings on safety-relevant aspects concerning applicability to KKE and KKI 2,
- an evaluation of the National Action Plan and the resulting backfitting measures with regard to measures still to be implemented,
- an evaluation of the requirements in the repeatedly revised WENRA safety reference levels and their implementation in the plants, and
- the presentation of the state of the art in science and technology regarding the operating experience to be considered and the implementation of GRS information notices.

The outcome of these investigations was documented in a detailed report [2]. Relevant results from these investigations were taken into account in the preparation of this RSK statement.

2 Operating modes of pressurised water reactors

As an introduction and for a better understanding of the limiting conditions of the operating mode of German pressurised water reactors (PWRs), some of the essential aspects to be considered are presented below.

During **power operation** of a PWR, the excess reactivity in the fuel assemblies (FAs) which is present and required at the beginning of the cycle is compensated for by adding boron to the primary coolant. With increasing burn-up of the FAs in the course of an operating cycle, the boron concentration in the reactor coolant system is steadily reduced. The natural end of an operating cycle is reached when the boron concentration has been reduced to near zero.

Continuation of power operation is also possible beyond the natural end of the cycle, but the reactor power then decreases steadily. The gradient of this power reduction can be influenced to a limited extent by lowering the coolant temperature in the reactor. This mode of operation is referred to as **stretch-out operation**.

Power plant operation

In the German plants, power operation with a natural cycle length of 10 to 12 months is usually practised. In this operating state, the plants are designed for load-following operation. In the past, they were mainly used in base-load operation, but for many years they have also been used in load-following operation.

After reaching the end of the natural operating cycle, stretch-out operation of up to approx. 100 days is possible. This mode of operation is used, for example, to optimise the time of shutdown. As a rule, however, the stretch-out operation mode is not scheduled for longer than 30 days due to the continuous reduction of power and the limited load-following capability during stretch-out operation. In addition, if stretch-out operation is extended to up to 100 days, several adjustments of parameters, for example operational limits and conditions regarding reactor protection, are also necessary during operation.

When shutting down the plant down during stretch-out operation, a restart – especially after transfer into the cold subcritical state – is difficult due to the necessary deboration.

Since, according to current planning, the plants are to be operated under the conditions of “natural end of cycle” and “stretch-out operation”, the associated operational restrictions come into play.

3 Safety reviews

Periodic safety reviews (PSRs) according to §19a of the Atomic Energy Act (AtG) are an essential aspect to be considered regarding the continued operation of the plants beyond 31 December 2022. In accordance with the provisions of the AtG, the last PSRs for the three plants were carried out in 2009. In 2019, the PSRs scheduled in accordance with the AtG did not have to be performed in view of the planned shutdown at the end of 2022. Based on [2], the RSK evaluated the safety reviews performed after 2009 with regard to their results and their applicability.

3.1 Objectives and importance of a periodic safety review (PSR)

The PSR guideline of 1996 [3] defines the objectives of the PSR as follows:

The nuclear power plants in the Federal Republic of Germany are subject to governmental supervision during construction, operation and decommissioning and in case of modifications of the plant and its operation mode if safety-relevant areas are concerned. During supervision, the plant conditions and its mode of operation are examined with regard to compliance with the regulations of the licensing decisions. Further, the necessity of the implementation of new safety-related knowledge resulting from operating experience, safety analyses as well as research and development is examined. In the course of a longer lasting operating period, the range of safety-related knowledge is broadened; the methods and instruments for safety analyses are being further developed. This should lead to a continued development of the plant's safety status and its operational safety. Thus, it is appropriate to perform an overall safety review for each operating nuclear power plant with light-water reactor at appropriate intervals.

The PSR supplements the information on the safety-related plant status for the governmental supervisory authorities.

According to the PSR guideline [3], a PSR (now referred to as SR in accordance with the wording in the Atomic Energy Act) consists of different parts:

- deterministic safety status analysis (SSA),
- probabilistic safety analysis (PSA), and
- deterministic analysis on physical protection.

According to the PSR guideline, the deterministic safety status analysis should include the following parts:

- deterministic protection goal-oriented review for safety systems with system descriptions,
- description of measures for special, very rare events and of the (severe) accident management concept, and
- description of operation management and evaluation of operating experience.

The following deals with the SSA and the PSA. Aspects relevant in terms of security are not dealt with in this statement.

Based on the intentions of a PSR and taking into account the experience with the PSRs carried out in the past, the RSK considers the following aspects to be relevant for the planned continued operation of GKN II, KKE and KKI 2 until 15 April 2023:

Updating the deterministic protection-goal-oriented review for the safety systems with system descriptions and the PSA

With the PSRs, up-to-date plant descriptions and comprehensive safety analyses, including a PSA model for the plants, are developed in each case. Such descriptions and analyses are available for the plants from the last PSRs (2009).

The experience with the PSRs prove that the preparation or updating of the plant descriptions and the safety analyses for the older German nuclear power plants that had gone into operation before 1980 were of high importance, since for these plants there were deviations compared to the nuclear rules and regulations developed later and to the plants that went into operation after 1980, especially the Konvoi plants GKN II, KKE and KKI 2.

For the plants now in operation, a new PSR would require review and update of the plant descriptions and the safety analyses, insofar as this has not already been done within the framework of supervision. In particular, the Safety Requirements for Nuclear Power Plants [4] and their interpretations [5], published since the last safety reviews for these plants, and the technical document on methods and data for the probabilistic safety analysis for nuclear power plants as of 2015 [6] would have to be taken into account.

Findings from safety reviews meanwhile carried out for this subject area are obtained from the results of a so-called extended safety review of GKN II and the 2016 PSR for the Brokdorf nuclear power plant (KBR) initiated within the framework of the supervisory procedure. The conclusions derived from this from the RSK's point of view for the three Konvoi plants are dealt with in chapters 3.3 and 3.4.

Description of measures for special, very rare events and of the (severe) accident management concept

The causes of the reactor accident in Fukushima-Daiichi and the measures to be derived from it were intensively discussed and evaluated in the supervisory procedures and by the RSK. This resulted in plant-engineering improvements for the prevention and management of severe accidents. In parallel, manuals for mitigative accident management measures were introduced to supplement the existing accident management manuals.

Since the last PSRs for GKN II, KKE and KKI 2, progress has been made regarding this topic (additional accident management measures could already be taken into account in the periodic safety review for the KBR plant in 2016 (KBR PSR 2016)), which has led to modifications in the plants (see [7] and [8]). No new requirements have arisen since the reviews in the aftermath of Fukushima. Therefore, the RSK does not see any further need for review or action with regard to the planned continued operation of the plants until 15 April 2023.

Description of operation management and evaluation of operating experience

This aspect is mainly subject to routine supervision by the respective authorities of the Länder. Furthermore, the PSRs also present an overall view, which is essentially a summary of the annual reports to be submitted in accordance with the respective licensing requirements.

Regarding the planned continued operation of the plants until 15 April 2023, the RSK does not see any further need for review or action. Conclusions drawn by the RSK with regard to operation management and management aspects can be found in Chapter 5.

3.2 Experience with periodic safety reviews

A PSR can provide indications to measures that can lead to a further increase in safety. In this respect, the following generic experiences have been gained from the PSRs conducted over the past 30 years:

- The first PSRs were carried out around 1990 for older plants that had been built before the further development of the safety concept for the pre-Konvoi and Konvoi plants. In the PSRs, a comparison was therefore made with the state of the art in the safety-related design that had been further developed in the meantime. This resulted in extensive backfitting recommendations for the “old plants”. Examples are: 49 official requirements for safety-related backfitting measures at the Biblis A nuclear power plant (KWB-A), approx. 200 recommendations for safety improvements at the Unterweser nuclear power plant (KKU).

- A key element of the PSR was the development of PSA models for all plants, including PSAs for internal and external hazards.

- The PSRs for the pre-Konvoi and Konvoi plants did not reveal any corresponding need for backfitting since the basic safety requirements had not changed since their commissioning. With the PSRs, the situation regarding documentation and safety demonstrations was updated and improved, and measures were derived to further increase safety. For example, two measures were derived from KBR PSR 2016 by the operator and nine measures by the authorised experts, which largely concerned adjustments in the operating regulations.

3.3 Applicability of results from periodic safety review KBR 2016

The results of the KBR PSR 2016 are assessed in [2] to determine whether the more recent KBR analysis – compared to the PSRs for GKN II, KKE and KKI 2 – yields additional findings on safety-relevant aspects that could give rise to recommendations for the three plants. Here, recommendations are derived where safety-relevant conclusions result originally from KBR PSR 2016. For issues that are dealt with in KBR PSR 2016 but are based on plant-specific findings from the supervisory procedure or on processes that are also implemented in other plants (e.g. GRS information notices, RSK recommendations, generic activities of the German Association of Large Power Plant Operators (VGB)), no recommendations are derived in [2] since it is assumed that corresponding reviews have also taken place at GKN II, KKE and KKI 2.

3.3.1 KBR safety status analysis (SSA)

KBR SSA 2016 includes the sections “protection goal-oriented analysis”, “safety-relevant individual issues”, “accident calculations” and “operation management and evaluation of operating experience”.

In [2] it is shown that the protection goal-oriented analyses (schutzzielorientierte Analysen – SZA) prepared in the PSR framework follow a presentation designed in the 1990s and 2000s for the PWR-1300 plants. Accordingly, the protection goal-oriented analyses evaluated in [2] for KBR, GKN II, KKE and KKI 2 have a largely identical structure. Likewise, the explanations on individual issues are partly worded identically.

Within the framework of the SZA, the events that are to be analysed under consideration of the plant design of typical PWRs are compiled as a first step. As a change compared to KBR SZA 2006, the event lists of the SiAnf are used in KBR SZA 2016 and the various plant operating states according to the SiAnf operational modes A to F are taken into account.

For the events, a screening is carried out to determine the extent to which a more in-depth consideration is necessary. In accordance with the concept of the SZA, not every single event to be considered is dealt with in depth since some event sequences are classified as representative or covering others in terms of loads and requirements that are significant with regard to operation and safety as well as with regard to plant-internal and also radiological effects.

The event-specific requirements for safety functions and the system functions required to ensure the safety functions are determined for each of the requirement-determining plant transients derived. Here, it is taken into account for the classification of the safety/system functions whether these

- are necessary or only favourable, and
- must be available in the short term, long term, or very long term

to prevent core hazard states or to comply with the accident planning values.

The requirements that must be fulfilled by the active safety functions and the assigned system functions (necessary functions) for accident management are then looked at more closely. Based on this, the requirements

for the safety systems and systems with safety significance are dealt with regarding the system functions they must fulfil and their design (layout, configuration, strength design). The existence of sufficient minimum effectiveness and reliability of the system functions is assessed, also taking into account accident conditions. It is described which features of the systems are essential to ensure the system functions – especially those required for accident management – and which supply functions are required for the safety-relevant system functions. For the safety-relevant structures it is specified which requirements for the function of the structures result from design basis accidents (level of defence 3).

As a consequence of maintaining the design of the SZA and the safety concept of the KBR plant for accident management – no significant modifications were made to safety systems and other essential safety-relevant systems as well as structural components – the presentations within the framework of the KBR SZA of the years 2006 and 2016 are largely similar according to [2].

Regarding significant changes of KBR SZA 2016 (compared to SZA 2006), it is stated in [2] that consideration of the event lists of the SiAnf has led to additionally including the event "loss of residual heat removal due to loss of coolant during 3/4-loop operation" in the list of transients determining requirements. Requirements for additional system functions do not result from this. Since SZA 2006, a Class 1 fault alarm "residual heat removal malfunction" has been added at the KBR as well as new procedures in the operating manual (Betriebshandbuch – BHB) for improved control of a postulated loss of residual heat removal during low-power and shutdown operation. These measures have been designed independently of PSR 2016 as part of a uniform VGB concept and, according to VGB's presentation, they have also been implemented in the other PWR plants (see e.g. [9]). Thus, according to [2], KBR PSR 2016 does not result in a need for further reviews or recommendations for organisational or technical measures.

For the "very rare events", KBR SSA 2016 describes various beyond-design-basis event sequences and the accident management measures available at the KBR. Here, in addition to measures that have been included in the accident management manuals of the PWR plants for many years, processes and measures newly considered and implemented after the Fukushima reactor accident after 2011 are also addressed. The derivation and implementation of the post-Fukushima measures was carried out across all plants within the framework of a process coordinated at VGB and was accompanied by the supervisory authorities, GRS and the RSK. The measures have been realised plant-specifically according to [7]. Thus, according to [2], there is no new safety status that originates from KBR PSR 2016. A resulting need for additional measures in GKN II, KKE and KKI 2 is not seen in [2].

Regarding the two open items identified by KBR in the context of SSA 2016, it is stated in [2] that it should be examined whether a safety-related improvement can be realised by corresponding additions in the written operating rules of GKN II, KKE and KKI 2. The open items relate to two additions to the BHB (insertion of a sealing plug in the sump suction line when opening the residual heat removal system in the annulus, cross-references in BHB chapters on the admissibility of lifting the concrete slabs above the reactor cavity, see Appendix 1 of this statement).

According to [2], the presentation of the so-called safety-relevant individual issues within the framework of KBR SSA 2016 does not give any indications of additional safety-relevant aspects to be considered that originate from PSR 2016. The recommendations made by the independent expert in this respect relate to the

amendments to individual passages in the BHB and in the accident management manual in connection with optimised control of loss-of-coolant accidents with release of insulating material. In this regard, it is argued in [2] that modifications were also made to GKN II, KKE and KKI 2 and their written operating rules within the respective supervisory procedures. Therefore, no recommendations are derived in [2].

Regarding the accident analyses relevant for KBR, it was checked in accordance with [2] within the framework of KBR SSA 2016 whether new findings have been obtained since the analyses were prepared within the framework of the licensing procedures for construction and operation or within the framework of licence and modification applications that call the validity of the existing safety demonstrations into question. With the exception of three newly prepared analyses, the review and assessment of the safety demonstrations did not reveal any indications of new findings that call into question the validity of the existing calculation results. Recommendations are not derived in [2] from the newly prepared analyses.

The presentations on operation management and evaluation of operating experience in KBR SSA 2016 have a plant-specific character to a large degree so that no recommendations for organisational or technical measures can be derived according to [2].

Regarding reportable events that occurred at KBR and that could suggest the performance of further reviews and/or recommendations for organisational or technical measures at other plants, it is argued in [2] that these are recorded in the course of the safety-related assessment of reportable events continuously performed by the Incident Registration Centre at BASE, GRS, BMUV and RSK. Against the background of the established processes for event assessment, no recommendations are derived in [2] for organisational or technical measures.

In summary, the evaluation of KBR SSA 2016 for GKN II, KKE and KKI 2 carried out in [2] only shows a need for review with regard to the additions to the KBR, which are due to two open items (insertion of a sealing plug in the sump suction line when opening the residual heat removal system in the annulus, cross-references in the KBR chapters on the admissibility of lifting the concrete slabs above the reactor cavity). A need for technical retrofitting that can be derived from KBR SSA 2016 is not recognisable on the basis of the explanations in [2]. The RSK agrees with these conclusions from [2], see Chapter 8 and Appendix 1.

3.3.2 KBR probabilistic safety analysis (PSA)

It is shown in [2] that KBR PSA 2016 was carried out in accordance with the requirements being state of the art in science and technology in 2014. The basis for KBR PSA 2016 was provided by the guidelines of the PSA working group [10], [11] and [12] (PSA methods volume and associated technical volumes). The 2009 PSAs of GKN II, KKE, and KKI 2 were conducted in accordance with the requirements of [10] and [11]. The full version of the supplementary volume on methods and data for the probabilistic safety analysis for nuclear power plants was published in 2016 [6]. According to [2], it has not been comprehensively considered to what extent KBR PSA 2016 covers the current state of the art in science and technology.

The Level 1 PSA of the KBR PSR for internal events (power operation) is evaluated in [2] with regard to the scope required by the rules and regulations applicable at that time, the essential methodological differences and generic data (reliability parameters) compared to the PSAs of GKN II, KKE and KKI 2 from 2009. Here, the

aspects relating to initiating events, determination of effectiveness conditions, system analysis, reliability parameters and presentation of results are compared. The evaluation shows a broad methodological consistency between the different PSAs. Differences can be seen, among other things, with regard to the number of accident management measures assessed. In KBR PSA 2016, significantly more accident management measures were assessed than in the PSAs for GKN II, KKE and KKI 2.[1]

With regard to the reliability parameters used, it is stated in [2] that there have been further developments between 2009 and 2016 with regard to the determination of data for common-cause failures (CCFs) and in the area of the assessment of manual measures, which could already be taken into account in the KBR PSA to some extent.

Regarding the Level 1 PSA for low-power and shutdown (LPSD) operation, the comparative evaluation performed in [2] shows that there is no relevant difference between these PSAs. Only fire events during LPSD operation were not included in the 2009 PSAs of GKN II and KKE, while a small number of fire events during LPSD operation were qualitatively considered in the PSAs of KKI 2 and KBR. It was concluded that fires during LPSD operation do not contribute significantly to the overall damage frequency.

According to [2], the evaluation of the PSA regarding internal and external hazards shows that in all PSAs "internal fire" and "internal flooding" during power operation were subjected to an in-depth probabilistic analysis.

With regard to PSAs for external hazards (Einwirkungen von außen – EVA), it is stated in [2] that in all three plants a site-specific, stepwise approach procedure according to [10] was applied in the PSAs, as far as necessary. Thus, either only rough, qualitative or quantitative analyses were performed site-specifically or, for impacts with a site-specific risk relevance that cannot be neglected, probabilistic in-depth analyses (EVA-PSA) were performed for power operation. Due to the site-specific differences, a direct comparability of the individual EVA-PSAs is not given here according to [2].

Overall, in [2], no reason for further reviews or for recommendations on organisational or technical measures is seen in the context of the planned continued operation until 15 April 2023. The RSK agrees with these conclusions from [2].

3.4 Applicability of results from the GKN II extended safety review

For the GKN II plant, a periodic safety review was no longer required due to the lifetime limitation of 2011 in accordance with § 19a AtG. As explained in [2], the supervisory authority considers the extended safety review to be an appropriate way to review plant safety within the framework of supervision applying the current regulatory standards.

The main focus of the extended safety review is on the demonstration that the events belonging to a spectrum of accidents specified conservatively for each plant are controlled in an effective and reliable manner. The assessment criteria of the extended safety review are based on the Safety Requirements for Nuclear Power

[1] A more comprehensive consideration of accident management measures tends to lead to more favourable PSA results.

Plants [4] and their interpretations [5], supplemented by further requirements from rules and regulations (mainly KTA safety standards) and various RSK statements and recommendations.

The extended safety review follows a slightly different methodology than the protection goal-oriented analysis discussed in Section 3.3.1 in the context of the PSR. While in the protection goal-oriented analysis, for example, all safety-relevant equipment, systems and procedures installed in the plant (with the exception of accident management measures) can be credited for the control of events, this is only the case with the approach adopted in the extended safety review if they satisfy specific supplementary requirements (see e.g. [15]).

According to [2], as of September 2022, accident analyses have been submitted for GKN II within the scope of the extended safety review for 21 events from the "Event list for power and low-power and shutdown operation at PWRs" of the SiAnf [4]. Furthermore, analyses for safety demonstration have been submitted for all eleven events from the "Event list fuel storage PWR and BWR" of the SiAnf [4].

For the events considered within the framework of the extended safety review, control of events was demonstrated based on the requirements in the SiAnf (subject to the fulfilment of any still existing requirements of the independent experts). In some cases, additions to the BHB or the status of safety demonstrations for safety-related parameters have been made as derived measures in order to ensure the conformity of the corresponding safety analyses with the requirements of the SiAnf and to anchor the boundary conditions of the accident analyses in the status of safety demonstrations.

According to [2], no need for retrofitting of GKN II has resulted from the updated analyses for safety demonstration. On the component side, only new "light" plugs are provided for the fuel pool cooling lines to be able to seal postulated leaks in the fuel pool cooling lines within the available grace times also under the conditions of loss of offsite power.

In [2] it is further stated that in individual cases the safety demonstrations do not fully satisfy all the requirements of the SiAnf. However, the corresponding constellations had been assessed in detail for the events concerned. According to [2], the overall view of the failure assumptions to be made that impermissible states or states not covered by the existing safety demonstrations can occur did not reveal any safety-relevant potential for improvement through any hardware-related plant modifications.

According to [16] and [2], overall, the results of the extended safety review confirm that the design of GKN II meets the requirements under the currently valid rules and regulations.

Regarding the applicability to KKE and KKI 2, it is to be noted that the assessments made within the framework of the extended safety review for the control of the considered individual events of level of defence 3 are based on the concrete availability regulations in BHB chapters 2-1.3 and 2-1.4 of GKN II. If there are relevant differences between the regulations at the individual plants, this may have an effect on the confirmation of event control under the boundary conditions of the SiAnf, primarily with regard to the application of the single failure concept. An examination in this respect was not provided for within the framework of the statement [2]. Therefore, only general statements on the level of detail of BHB chapters 2-1.3 and 2-1.4 of KKE, KKI 2 and GKN II were made in [2]. Application of extended safety review assessments beyond the recommendations presented in Appendix 2 such that the requirements of the SiAnf and further assessment criteria are met in the

individual demonstrations of event control is not possible without a detailed plant-specific examination and thus not in the remaining time frame.

For the majority of the BHB additions or changes that have been made in the context of the extended safety review, applicability to KKE and KKI 2 is considered to be given in [2]. In addition, a recommendation is derived in [2] that resulted from a comparison of BHB parts of GKN II, KKE and KKI 2 (see No. 4 in Appendix 2). For the planned continued operation until 15 April 2023, the RSK agrees with these assessments and recommendations, whereby only those recommendations from [2] were included in Appendix 2 whose implementation seems feasible in time within the remaining time frame. Irrespective of the continued operation until 15 April 2023, the RSK has also included recommendations from [2] that are relevant regarding low-power and shutdown states and the storage of the FAs in the spent fuel pool.

4 Plant-specific features and their applicability

4.1 Steam generator tube corrosion at GKN II

Regular non-destructive examinations at GKN II showed wall thinning with different degradation characteristics on steam generator tubes from 2017 onwards. On the one hand, this concerned volumetric wall thinning originating from the secondary side, which was first detected in 2017. In 2018, all steam generator tubes were subjected to examinations again, which also showed degradation originating from the secondary side in the form of linear, circumferentially oriented crack-like wall thinning and other volumetric indications. There were further corresponding findings in 2019 as well as in smaller numbers and to a lesser extent in the years 2020 to 2022. In no case did through-wall material degradation occur. Tubes with volumetric indications larger than a defined indication depth were sealed with rolled-in plugs, tubes with crack-like findings were always sealed with fill-in and rolled-in plugs.

The cause of the degradation was determined to be unfavourable secondary-side water-chemical conditions, which had led to the ingress of corrosive ionic impurities into the tube sheet area of the steam generators.

On these findings, the RSK issued a statement [18] at its 512th meeting on 22/23 October 2019, which contains a total of nine recommendations to ensure the integrity of steam generator tubes.

In recent years, the RSK Committee on PRESSURE-RETAINING COMPONENTS AND MATERIALS (DKW) has continuously dealt with the findings on the steam generator tubes, the water chemistry conditions and the proofs on the admissibility of the approaches established at the GKN II plant, most recently at its 191st meeting on 5 October 2022, where the plant operator presented the analyses on the water chemistry and the findings from the refuelling and maintenance outage in 2022 and their safety-related assessment. It became clear that crack-like findings continue to be detected in the steam generator tubes. However, due to the small area affected in each case, there is a large distance up to the fracture-mechanically determined limits above which steam generator tube failure must be assumed. The analyses of the water chemistry on the secondary side show that there is no further ingress of corrosive impurities into the steam generator secondary side. Against this background, the Committee came to the conclusion in its discussion that the findings to date do not preclude operation of GKN II until 15 April 2023. This presupposes that within the framework of supervision, the water-chemical conditions and the safety demonstrations, which have so far only been assessed

for operation until the end of 2022, are also positively assessed for operation in the coming year, including a shutdown with refuelling. The RSK agrees with the statements of the RSK Committee DKW.

Applicability to other plants:

The degradation symptoms observed at GKN II occurred in the other plants still in operation only at KKE, but there to a very small extent.

In accordance with the recommendations of GRS information notice WLN 2018/06, which had been initiated by the findings in GKN II, KKE had brought forward tests on the steam generators to 2019. Three steam generators were free of findings, while two tubes of one steam generator were sealed as a precautionary measure due to findings. The last eddy current tests were carried out in 2020, which revealed only one crack-like indication. The assessment of the overall situation at KKE, i.e. the test results for the steam generator tubes with assessment of the gap depth changes and the assessment of the water chemistry showed that there were no indications of a still active corrosion mechanism. Therefore, special tests in 2021 and 2022 were considered no longer necessary.

Against this background, the RSK does not see any further need for action regarding this issue for the planned continued operation of the plants KKE and KKI 2 until 15 April 2023.

4.2 Corrosion indications in French nuclear power plants

Within the framework of the international exchange of experience, GRS and the RSK were informed about the findings on primary circuit connecting pipes of the French PWR plants. The RSK Committee DKW repeatedly dealt with the current findings and their applicability to German plants, most recently at its 191st meeting on 5 October 2022.

It can be concluded that

- the systems engineering conditions differ significantly; in particular the potentially affected pipe sections in German plants are considerably shorter than in the French plants and they have only two weld seams in the unisolable section, whereas in French plants there are 13 weld seams in this section,

- there are significant differences in the execution and testability of these weld seams; in contrast to the French plants, the weld seams in German plants are ground on the inside and can be subjected to tests without restrictions,

- so far, no indications due to stress corrosion cracking have been detected in the connecting pipes of the emergency core cooling and residual heat removal system in German plants, and

- the pipes are appropriately instrumented in connection with fatigue monitoring and it can be deduced from this that there are no conditions, e.g. temperature stratification or alternating thermal loads, that lead to active failure mechanisms.

Therefore, from the RSK's point of view, there is no reason to assume comparable indications in these pipe sections in German plants, and measures beyond the recurrent test programme are not deemed necessary.

4.3 Effects of a grid failure on plant operation

In view of the results of the special analysis winter 2022/2023 carried out by the transmission system operators for electricity, the issue of auxiliary power supply of nuclear power plants after grid failure is raised.

In principle, it can be stated that the German NPPs are designed for a failure of the transmission grid. In the event of a grid failure, the plant is disconnected from the transmission grid as per design and the plant switches to so-called island operation by load rejection to auxiliary station supply. If load rejection fails, loss of offsite power occurs, i.e. the plant is automatically shut down and voltage supply is subsequently ensured by the emergency diesel generators. Within the framework of the RSK's post-Fukushima robustness analyses, it was shown that the German plants can also cope with a long-term grid failure. In addition, it has been agreed between the power plant operators and the grid operators that nuclear power plants will be supplied with priority regarding the restoration of grid supply to enable the restoration of auxiliary power supply via the grid. This topic was last discussed with the grid operators during the consultations of the RSK Committee on ELECTRIC INSTALLATIONS (EE) at the 264th meeting on 24 April 2018 [19].

Black-start-capable power plants are allocated to all three plants which can supply them with the necessary auxiliary power in the event of a grid failure.

5 Operation management and management aspects

5.1 Staffing situation including external support

The current legal situation provides for the GKN II, KKE and KKI 2 plants to be permanently taken off the grid on 31 December 2022. The operators have completed their planning in the power plants accordingly and also prepared for decommissioning accordingly. After termination of power operation, the plants will be shut down to residual heat removal mode, the reactor pressure vessel (RPV) will be opened, and the FAs will be transferred from the RPV to the spent fuel pool. This process corresponds to refuelling, but in contrast to a maintenance and refuelling outage, no extensive maintenance activities with high personnel expenditure would be carried out in the reactor area in parallel to this last core unloading.

The operators have been planning for some time the initiation of decommissioning, among other things by drawing up work plans, taking systems out of service, adapting plant operating procedures and reducing personnel.

The short-term plan to continue operation until 15 April 2023 results in special challenges for the operating staff since additional refuelling and, in the case of KKI 2, a short shutdown to repair the pressuriser pilot valves is to be and had to be planned, respectively, and then implemented within a few weeks. These previously unplanned activities require that, in contrast to a regular maintenance and refuelling outage, these measures

must be planned and carried out in a very short time (work planning, procurement of external staff, procurement of spare parts, etc.).

In case of a continuation of power operation until 15 April 2023, it is therefore necessary to ensure that the qualified personnel required for this purpose are available for the additional activities and the safe operation of the plants. In particular, the availability of the responsible persons and the staffing of the control rooms are to be ensured.

Since responsible and other qualified personnel will be required for a longer period of time also after the shutdown of the plants to monitor fuel cooling, the RSK assumes that the necessary provision of personnel can be fulfilled for a foreseeable period until 15 April 2023, if necessary by means of postponing early retirement agreements. The requirements of the safety specifications and the technical qualification guidelines etc. are to be complied with.

However, in addition to maintaining operation management, the current situation leads to an additional burden on the operating personnel (own and external staff). This requires appropriate attention from management staff in terms of supervision, motivation and quality of work. Special measures may be required to ensure motivation and quality of work.

According to the RSK's assessment, this situation was further aggravated at the plants by the lengthy decision-making process on the manner in which operation is to be continued. Against this background, the RSK recommends that the supervisory authorities pay special attention to the aspects of personnel capacity and safety culture.

Furthermore, the RSK points out to all relevant decision makers that short-term or partly diametrically divergent decisions on lifetime extension (e.g. continued operation of KKE yes/no) may have a negative influence on the safety-related boundary conditions for the operation of the German nuclear power plants. In this respect, this influence is to be taken into account with reliable, plannable and consistent decisions. The communication on the corresponding decision-making processes should take into account the expectations formulated in the RSK memorandum on the potential threat to nuclear safety by loss of know-how and motivation [30].

Furthermore, the RSK recommends adapting the agreements for the control of events (e.g. crisis management team support by the plant manufacturer, support services by Kerntechnischer Hilfsdienst GmbH (KHG)) accordingly with regard to the planned continued operation until 15 April 2023.

5.2 Organisation and processes

In the past, some events occurred at German nuclear power plants that were due to coordination and organisational deficiencies, particularly with regard to the coordination of interdisciplinary and interdepartmental activities as well as in necessary decision-making during refuelling and maintenance outages. In connection with another event, it is to be stated that certain activities on isolated safety-relevant systems were exempted from the requirements of the work permit procedure regulated in the maintenance rules. The RSK Committee on REACTOR OPERATION (RB) dealt with these events and, in addition to the measures

derived by the plant operators, made further suggestions to the plant operators and supervisory authorities concerned regarding clear regulations on responsibilities, improvement of the coordination between departments as well as planning and work preparation for the refuelling and maintenance outages. The RSK expects that these suggestions will be taken into account in the activities to be performed by 15 April 2023.

5.3 Recurrent tests

The scope and periodicity of the recurrent tests are specified in the respective testing manuals. The fulfilment of the test requirements is checked and documented within the framework of nuclear supervision with the involvement of authorised experts. This ensures that the recurrent tests are performed in accordance with the specifications of the testing manuals and that any modifications applied for by the plant operator will be dealt with in the supervisory procedure, taking into account the shutdown date.

In the case of adaptations (e.g. postponements or omissions) that may have been made taking into account the shutdown date of 31 December 2022, it is to be assessed for extended power operation until 15 April 2023 within the framework of the supervisory procedure whether these modifications are permissible and give no reason for concern from a safety point of view also for this later shutdown date.

6 Update of the state of the art in science and technology through recent RSK consultations

6.1 Protection concept of German nuclear power plants against aircraft crash

On 17 March 2011, the Federal Environment Ministry requested the Reactor Safety Commission in connection with the events at the Japanese plant Fukushima to prepare a catalogue of requirements for a safety review of the German nuclear power plants and to assess the results of such a review on the basis of criteria. The subject of this safety review was the assessment of the robustness of the German nuclear power plants against beyond-design-basis events.

For the nuclear power plants GKN II, KKE, KKI 2, KWG, KBR and KRB II C still in operation in 2021, the RSK review showed that the requirements from the load assumptions according to the RSK guideline (crash of a fast-flying military aircraft of the Phantom type) are fulfilled for all plants. Due to the high basic protection of the plants still in operation, the RSK considered load transfer from the crash of medium-sized and large commercial aircrafts to be possible. However, further safety demonstrations were considered necessary to confirm these assumptions.

Within the framework of the extensive investigations and analyses based on this and carried out with the accompaniment by the RSK, it could be shown [20] that even in the event of a deliberate crash of a large commercial aircraft onto the nuclear power plants still in operation in 2021, cooling of the fuel elements in the reactor and in the spent fuel pool would be maintained so that releases of radioactive substances from fuel damage are not to be expected.

With its final statement [20], the RSK concluded its consultations on aircraft crash in 2021 and sees no need for further safety demonstrations with regard to the planned continued operation until 15 April 2023.

6.2 Update of the state of the art in science and technology in connection with natural external hazards

Within the framework of the implementation of the EU stress test for nuclear installations (see Section 7 below) by the European Nuclear Safety Regulators Group (ENSREG), the Peer Review Board recommended that the site-specific hazard due to natural external hazards be reviewed every ten years [7]. The PSR was considered a suitable framework for these reviews. For the three plants GKN II, KKE and KKI 2, no PSR has been carried out since 2009. Irrespective of this, the RSK and some committees have in the meantime carried out the following site hazard reviews with regard to natural external hazards. Based on this, the RSK does not see any relevant deficits that could arise with regard to natural external events due to PSRs not having been submitted.

6.2.1 Floods and heavy rain

In view of the flooding events in July 2021 in Rhineland-Palatinate, North Rhine-Westphalia and neighbouring regions in France, Luxembourg and Belgium, the RSK Committee on PLANT AND SYSTEMS ENGINEERING (AST) dealt with the question to what extent consequences result from these events with regard to the sites of German nuclear power plants and research reactors [21].

Within the framework of the post-Fukushima robustness analyses, flooding of the plant site was considered (see [8]). However, the flash floods and log jams at bridges in smaller water bodies that occurred as a result of heavy rainfall in July 2021 were not taken into account.

The AST Committee therefore held further consultations on these issues. It was reported that, especially in the case of the Ahr flood, heavy runoff occurred due to the steep local topography. In much flatter topographies, flash floods with comparable erosion are not to be expected. Against this background, the need for an in-depth study was derived for only two plant sites (GKN II and KWG) on the basis of a preliminary examination of the available topographical information.

The Committee held further consultations on the two sites and submitted additional analyses. These analyses did not reveal any risk to plant safety from local heavy rainfall events. Against this background, no further need for consultation with regard to the flooding events in July 2021 was derived by the RSK Committee AST [21].

6.2.2 Earthquake

In 2013, the so-called “PEGASOS Refinement Project” (PRP), a probabilistic seismic hazard analysis for the NPP sites in Switzerland, was completed. Based on this, the seismic hazard assumptions for Swiss NPPs were redetermined by the Swiss Federal Nuclear Safety Inspectorate (ENSI) [23] in 2016. This resulted in seismic hazards to be assumed that are significantly stronger than those determined for the original design basis of the Swiss NPPs.

Furthermore, new hazard assumptions for Germany were published in the same period in the field of conventional rules and regulations. The investigations of the GeoForschungsZentrum Potsdam (GFZ) “D-

EQHAZ16" [24] resulted in updated findings on the seismic hazard in the area of German NPP sites for return periods of up to approx. 2,500 years.

Against the background of the state of the art in science and technology as further developed by the above-mentioned investigations, in 2018 and 2019, the RSK Committee AST dealt with the question whether consequences are to be drawn from the current results regarding the determination of the seismic design spectra for the German NPP sites [25]. Against the background of the Swiss PRP results, special attention was paid to amplification effects that may result from the local ground conditions.

For the consultations, it was also possible to draw on new seismic hazard analyses prepared after 2011 for the three German NPP sites with the highest site-specific seismic hazard relative terms (in descending order: Philippsburg, Neckarwestheim and Gundremmingen). Within the framework of the updated hazard analyses, methods such as those used in the PRP were used for each of the three sites.

Within the framework of its consultations, the RSK Committee AST came to the conclusion that the current seismic hazard analyses for the Philippsburg, Neckarwestheim and Gundremmingen sites confirm the seismic engineering parameters of the design basis earthquakes. For the other sites, it is shown in [25] that, in view of the (very) low basic seismic hazard there, any amplifications by the local subsurface conditions would lead to significantly lower loads than these were assumed for the design. An overall view of all available results and findings did not reveal any further need for consultations.

6.2.3 Lightning protection

According to the RSK statement "Assessment of the coverage of extreme weather conditions by the existing design" [26], analyses should be conducted to demonstrate robustness against design basis weather conditions with a return frequency of 10^{-4}/a in line with international developments (ENSREG, RHWG/WENRA). As far as hazards from weather conditions in this frequency range cannot be determined with sufficient reliability, effective management of hazards from these weather conditions should be demonstrated deterministically using engineering judgement. In addition, it was suggested with a view to robustness that events beyond these hazards should be taken into account by engineering estimates for the determination of safety margins.

In this respect, in-depth investigations on the issue of lightning effects have been performed (see RSK statement "Lightning with parameters exceeding the standardised lightning current parameters" from the 488th meeting of the Reactor Safety Commission (RSK) on 3 November 2016 [27]). Furthermore, safety standard KTA 2206 "Design of Nuclear Power Plants against Damaging Effects from Lightning Strikes" was updated. The requirements were implemented in the supervisory procedure.

7 International requirements and current developments

7.1 Implementation of the measures of the National Action Plan of the EU post-Fukushima stress test

In Germany, a National Action Plan for measures at the nuclear power plants was first published on 31 December 2012 in response to the reactor accident in Fukushima and continued until its completion in 2017. The National Action Plan summarised the work of the operators of the German nuclear power plants, the nuclear supervisory authorities of the Länder, GRS, the RSK, the European stress test and the Second Extraordinary Meeting of the Contracting Parties at the IAEA within the framework of the Convention on Nuclear Safety (CNS).

At all plants in power operation, various preventive and mitigative accident management measures were implemented in addition to the already existing ones. Regarding the significance of the recommendations in the National Action Plan and their implementation at the plants, the nuclear regulatory authorities of the Länder have stated and confirmed that there are no design deficits and that the necessary precaution against damage as required by the Atomic Energy Act has been taken in all German nuclear power plants.

For the GKN II, KKE and KKI 2 plants, the supervisory authority confirmed the implementation of all activities and measures within the scope of the National Action Plan. In summary, from the RSK's point of view, no further requirements result for continued operation until 15 April 2023.

7.2 WENRA reference levels

The Safety Reference Levels for Existing Reactors of the Western European Regulators Association (WENRA) were published for the first time in 2006 and serve to harmonise the safety requirements in the WENRA member states. The focus of the safety reference levels (SRLs) is on nuclear safety and, in particular, on aspects that are particularly relevant for harmonisation. The member states have undertaken to implement the SRLs in their national rules and regulations.

WENRA regularly revises the SRLs when new findings and experience become available. In doing so, the further development of the state of the art in science and technology, including the further development of the IAEA safety standards, is also taken into account. Since 2009, updated SRLs have been developed in 2014 following the Fukushima-Daiichi reactor accidents and published in 2020.

Within the framework of the update of the SRLs, various aspects resulting from the further development of the state of the art in science and technology were introduced. These include, in particular,

- requirements for the area of design extension conditions (Issue F),
- introduction of SAMG and measures related to on-site emergency preparedness (Issue LM, Issue R),
- consideration of natural and man-made external hazards (Issue T, Issue TU, Issue O),
- internal hazards (Issue SV), and
- integrated management system and safety culture (Issue C).

Updates to the WENRA safety reference levels are reviewed in an existing process and, if necessary, transposed into the German rules and regulations and considered in the supervisory activities. Extensive updates were also included in the scope of consideration of other processes that led to the implementation of measures. These include the RSK robustness analysis (442nd /450th meeting), the EU stress test and the EU Topical Peer Review.

In summary, from the RSK's point of view, the update of the WENRA reference levels does not give rise to further examinations or recommendations on organisational or technical measures in the context of the planned continued operation until 15 April 2023.

7.3 Research and development and operating experience

7.3.1 Evaluation of research results

As described in [28], the operators have their own self-imposed and officially defined requirements with regard to the monitoring and evaluation of operationally relevant findings and research results. New insights and research results are also evaluated and assessed on a higher level with the involvement of the plant manufacturer and coordinated by VGB. The process “evaluation of research projects/results” is monitored and accompanied by the VGB committee work. The feedback from the individual houses (operator organisations) is collected centrally by the VGB, evaluated by the VGB committees and, where appropriate, measures for follow-up/implementation are derived.

Research results continue to be evaluated by GRS and the plant manufacturer.

In addition, there are established procedures in the nuclear supervisory procedures for monitoring the state of the art in science and technology. This also includes the evaluation of relevant research results. Therefore, there are no further requirements in this respect for the planned continued operation of German nuclear power plants until 15 April 2023.

7.3.2 Reporting procedure according to AtSMV and GRS information notices

The evaluation of the operating experience of nuclear power plants is an internationally required and established approach with the aim of making a significant contribution to improving nuclear safety by tracking and evaluating events.

Events occurring at German nuclear power plants that have a certain safety significance are reported to the nuclear supervisory authorities as “reportable events” in accordance with established reporting criteria under the Nuclear Safety Officer and Reporting Ordinance (AtSMV). Reportable events are subject to a multi-stage procedure for consideration within the framework of nuclear regulatory supervision, as described in the Handbook on Cooperation between the Federation and the Länder in Nuclear Law [13].

In addition to the processes described in [13], there is an exchange of experience on reportable and other events across the plant operators within the framework of the VGB working group on event analysis and evaluation of experience (tasks also include the assessment of national/international experience evaluations and reports as well as ensuring the exchange of experience). Furthermore, there is an evaluation contract with the plant

manufacturer which refers to the recording, evaluation and assessment of special events at German and foreign nuclear power plants.

Furthermore, the RSK and its committees are informed about all reportable events. They select individual reportable events for in-depth consultations if, in the opinion of the members, these could have an increased safety significance (e.g. indications of deficiencies in plant operating procedures or systematic failures).

GRS examines whether an event provide grounds for the preparation of a so-called information notice (Weiterleitungsnachricht – WLN). In this case, GRS derives recommendations for measures to be taken to improve plant safety.

In [2] it is stated that GRS – in addition to the above-mentioned reportable events in German nuclear installations – evaluates international events on behalf of the BMUV, in particular on the basis of the "International Reporting System (IRS)" of the IAEA, with regard to applicability to German nuclear power plants, safety-relevant findings and improvement possibilities that can be derived from the events. The results of the investigations, including the derived recommendations, can be introduced into the supervisory procedure in the form of GRS information notices, should it appear that safety relevance is given.

According to [2], information notices present the results of the investigations on the event, its causes, its safety significance and the corrective measures taken, and they make recommendations for increasing safety, the implementation of which is to be checked for each individual plant. The information notices are sent to the nuclear supervisory authorities, authorised experts, operators and manufacturers.

The information notices are to be assessed by the operators of the nuclear installations concerned with regard to applicability to their own plants and, if applicable, corresponding corrective measures are to be provided for the implementation of the recommendations issued by GRS. The authorities of the Länder evaluate the operator reports with the involvement of authorised nuclear experts and verify the implementation of the recommendations. Whether and how the recommendations given in the information notices have been implemented in the nuclear power plants on a plant-specific basis is communicated to GRS by the authorities of the Länder on behalf of the BMUV by sending experience feedback on the individual information notices.

This experience feedback is further evaluated by GRS. According to [2], a summary report containing an overview of the feedback received and an assessment of the plant-specific measures of all information notices of a year is usually distributed by GRS two years after the information notices have been sent out towards the end of the year. This report describes how recommendations are implemented in the plants.

With regard to possible recommendations with regard to the planned further operation of the plants GKN II, KKE and KKI 2, [2] comes to the conclusion that it should be checked whether recommendations that were assessed as not or not fully implemented in past feedback reports have been implemented in the meantime. The RSK recommends that the status of implementation of recommendations from information notices be reviewed by the operators and the competent supervisory authorities and that the recommendations that have not been completed be assessed with regard to their relevance for the planned continued operation until 15 April 2023.

8 Summary safety assessment of the planned continued operation of GKN II, KKE and KKI 2

For the processing of the tasks of the BMUV's advisory request, the RSK has examined, under appreciation of the above assessments, to what extent safety-related aspects result from not available current PSRs or from current developments that are, for example, not yet addressed in the nuclear rules and regulations, as well as from current findings in the plants that would have to be considered for the planned continued operation of the plants until 15 April 2023.

Two current safety reviews for PWR plants, the PSR of the KBR pre-Konvoi plant of 2016 and the GKN II extended safety review have basically taken into account the rules and regulations valid at the time of preparation and, in addition, also further developed requirements from rules and regulations, including relevant RSK recommendations. The results of these current safety reviews are largely applicable to the plants concerned since the pre-Konvoi and Konvoi plants largely meet identical design requirements and the design and the associated plant technologies are very similar. Backfitting measures performed in the meantime in response to more recent findings or events such as those in Fukushima have also been implemented in a harmonised manner, supported by intensive operator and regulatory experience sharing. However, there are differences in the respective plant operating procedures, which must be taken into account with regard to the applicability of the results.

The RSK recommends that the aspects identified from KBR SSA 2016 with regard to the additions to the operating manual – on the one hand, insertion of a sealing plug in the sump suction line when opening the residual heat removal system in the annulus and, on the other hand, cross-references in BHB chapters on the admissibility of lifting the concrete slabs above the reactor cavity (see Appendix 1) – be also examined for GKN II, KKE and KKI 2 and implemented where appropriate **(Recommendation 1)**. A need for technical retrofitting that can be derived from KBR SSA 2016 is not recognisable for the RSK. KBR PSA 2016 does not give any reason for further examinations or for recommendations on organisational or technical measures within the scope of the planned continued operation of GKN II, KKE and KKI 2 until 15 April 2023.

The RSK further recommends that recommendations made in connection with the GKN II extended safety review (see Appendix 2) be examined for KKE and KKI 2 and, where appropriate, implemented in agreement with the competent supervisory authority **(Recommendation 2)**.

The results of the consideration of plant-specific features (see Chapter 4) do not indicate the necessity of any additional measures for the planned continued operation until 15 April 2023.

In accordance with the current legal situation, the operators of the plants have prepared for the shutdown of the plants on 31 December 2022 and the necessary measures. This also includes the adaptation in the number of plant personnel to the post-operational and decommissioning phase. These plans now have to be changed or adapted at very short notice. In case of continued operation until 15 April 2023, it will be necessary to ensure that the qualified personnel required for this purpose are available for the additional activities and the safe operation of the plants. Special attention is to be paid to the availability of the responsible persons and to the staffing of the control rooms. In addition to the importance of adequate personnel availability, the RSK points out the compliance with qualified processes for the planning and implementation of additional refuelling and/or repairs under the given exceptional conditions. According to the RSK's assessment, the situation was aggravated by the lengthy decision-making process on the manner in which operation is to be continued. Against this background, the RSK recommends that the supervisory authorities pay special attention to the aspects of personnel capacity and safety culture **(Recommendation 3)**.

The RSK further recommends adapting the agreements for the control of events (e.g. crisis management team support by the plant manufacturer, support services by KHG) accordingly with regard to the planned continued operation until 15 April 2023 **(Recommendation 4)**.

The assessment regarding the update of the state of the art in science and technology, international requirements and national supplements as well as research and development did not reveal any indications of necessary improvements for operation until 15 April 2023.

With regard to the evaluation of operating experience, the RSK recommends that the status of implementation of recommendations from information notices be reviewed by the operators and the competent supervisory authorities and that the recommendations that have not been completed be assessed with regard to their relevance for the planned continued operation until 15 April 2023 **(Recommendation 5)**.

In summary, the RSK does not see any safety-related reasons opposing the planned continued operation of GKN II, KKE and KKI 2 until 15 April 2023 if taking into account the recommendations made.

9 Further considerations

In view of the fragile boundary conditions of the European energy supply, the public and political debate continues as to whether the German nuclear power plants that are still operational can or must continue to be operated beyond April 2023, possibly also over several fuel cycles. Thus, it cannot be ruled out that the continued operation of German nuclear power plants for a longer period will be considered necessary as a result of political decision-making processes.

From the point of view of the RSK, the issues at stake to ensure the safe operation of the nuclear power plants concerned, which might arise in case of extended operation, should not be discussed only shortly before a decision is taken. These issues should rather be dealt with at an early stage against the background of the time needed for decision-making and implementation of safety-related measures.

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[30] RSK-Memorandum “Drohende Gefährdung der kerntechnischen Sicherheit durch Know-How- und Motivationsverlust”, verabschiedet in der 449. Sitzung der Reaktor-Sicherheitskommission am 12.07.2012

Appendix 1: Recommendations derived from the KBR 2016 safety review

1. To prevent or limit loss of coolant into the annulus due to maintenance work, KBR states in the protection goal-oriented analysis that it will be specified in the corresponding part of the BHG to place a sealing plug in the affected sump suction line.

   In this context, it is stated in [2] that regarding this issue, VGB had explained to the RSK Committee AST in 2012 that, within the scope of work on sump suction lines and connected systems, precautionary measures are taken at the German plants to ensure that postulated leakages in the containment do not lead to flooding of the reactor building annulus or to spread of activity. It is also stated that for this purpose, precautionary measures would be taken within the scope of the work order and work permit procedure as well as within the scope of conducting the isolation procedure to prevent a loss of coolant into the reactor building annulus. This includes, in particular, the insertion of a sealing plug in the sump suction line.

   The addition to the BHB announced in the context of PSR 2016 thus serves to additionally increase the reliability of existing administrative precautions. If not already in place, additions in this regard should be implemented in the written operating rules (e.g. operating and engineering procedures) of GKN II, KKE and KKI 2.

2. Regarding event 17.3 “Failure of high-energy tanks inside the containment” it is described within the framework of the protection goal-oriented analysis that a possible projectile effect of the control assembly drive rod in case of a rupture of a control assembly nozzle will be counteracted by the concrete slabs above the reactor cavity. According to existing BHB regulations, these concrete slabs are only removed when the coolant pressure has been lowered to the required extent. To further improve the incorporation of this precautionary measure in the BHB, KBR announces corresponding cross-references for further BHB chapters.

   It should be examined whether an improvement in safety can be realised by corresponding additions to the written operating rules of GKN II, KKE and KKI 2.

Appendix 2: Recommendations derived from the GKN II extended safety review

Events B3-01 (Loss of two trains of the spent fuel pool cooling system for a longer period (> 30 min.) and B3-02 (Loss of coolant from the spent fuel pool due to leaks with a cross section > DN 25 up to the largest connecting pipe)

1. "Light" plugs for sealing leaks in the connecting pipes of the spent fuel pool were purchased for GKN II, which can also be handled under the conditions of loss of offsite power.[2] If not already available, equipment for sealing leaks in connecting pipes of the spent fuel pool (plugs or similar), which can also be handled under the conditions of loss of offsite power, should be purchased for KKE and KKI 2.

2. Individual additions to the GKN II BHB made within the scope of the extended safety review describe additional modes of operation (essentially overflow cooling) and specify the conditions required for this (e.g. with regard to phase-specific flooding water supplies required to enable sump operation). It should be examined whether an improvement in safety can be realised by corresponding additions to the written operating rules of KKE and KKI 2.

Event B3-11 (Fuel assembly damage during handling)

3. With regard to possible FA damage during handling, BHB Chapter 2-1.4 of GKN II has been supplemented to the effect that during work on penetrations and in case of unavailability of ventilation penetrations, containment isolation is ensured if at least one of the two containment isolation valves is isolated in CLOSED position. If this cannot be ensured, isolation must be provided by suitable substitute measures (e.g. blind flanges). It should be examined whether an improvement in safety can be realised by corresponding additions to the written operating rules of KKE and KKI 2.

Events D3-12 (Inadvertent level drop during mid-loop operation with consequential loss of residual heat removal pumps), D3-13 (Loss of one train, in operation, of the residual heat removal system) and D3-14 (Loss of all residual heat removal trains due to faulty signals)

4. As stated by VGB in [29], the RSK recommendations in [9] were dealt with and implemented via the Land-specific supervisory procedures. In this respect, it is to be noted that the restriction presented by VGB in [29], according to which no work may be carried out during 3/4-loop operation on isolated safety or safety-relevant equipment if work and tests can have an impact on residual heat removal, is contained in BHB Chapter 2-1.4 of GKN II. The corresponding recommendation should be implemented, if not already done, in the written operating rules of KKE and KKI 2.

5. One of the additions to BHB Chapter 2-1.4 of GKN II serves to prevent prolonged boiling conditions in operational mode E when only two trains (JNA (residual heat removal system)/FAK (fuel pool cooling system)) or JNA) are available, which can be used for removal of residual heat from fuel assemblies in the

[2] A comparable requirement was also derived in the context of the KBR PSR 2016 review.

RPV. It should be examined whether an improvement in safety can be realised by corresponding additions to the written operating rules of KKE and KKI 2.[3]

6. One of the additions to BHB Chapter 2-1.4 of GKN II requires the availability of the secondary-side heat removal via two steam generators beyond operational mode C (according to the SiAnf) until the RPV closure head has been lifted off in operational mode D. It should be examined whether an improvement in safety can be realised by corresponding additions to the written operating rules of KKE and KKI 2.

7. One of the additions to BHB Chapter 2-3.2.4 of GKN II (closure of the drain line from the reactor well into the containment sump) serves to prevent loss of coolant via the reactor well and setdown area as a result of a boiling-induced discharge of liquid coolant from the RPV in the event of failure of residual heat removal prior to flooding (3/4-loop operation, RPV closure head detensioned or lifted off). It should be examined whether an improvement in safety can be realised by corresponding additions to the written operating rules of KKE und KKI 2.

Event D3-11 (Inadvertent injection by operational systems or by safety equipment in case of ineffectiveness of limitation measures provided)

8. BHB Chapter 2-1.4 of GKN II has been supplemented with regard to the inadmissibility of planned maintenance measures leading to the unavailability of the pressuriser safety valves in operational mode C. According to [2], there are no specifications in the BHB chapters 2-1.4 of KKE and KKI 2 regarding the availability of the primary-side pressure limitation in operational mode C. It should be examined whether an improvement in safety can be realised by corresponding additions to the written operating rules of KKE und KKI 2.

Event D3-34 (Loss of coolant from the containment via systems connected to the reactor coolant pressure boundary)

9. BHB Chapter 2-1.3 of GKN II has been supplemented by availability requirements for gate valves in the chemical and volume control system, which are controlled by an interlock that is fail safe under emergency conditions. Furthermore, during the 2022 maintenance and refuelling outage, a one-time performance of special tests of measuring circuits took place regarding the protective interlocks in the chemical and volume control system. The background to the special tests was that the measuring circuits had not been tested within the framework of the annual recurrent tests. It should be examined whether an improvement in safety can be realised by corresponding additions to the written operating rules of KKE und KKI 2 and additional tests on protective interlocks.

[3] In this regard, it should also be noted that KKE and KKE 2 BHB 2-1.4 have lower availability requirements for residual heat removal and spent fuel pool cooling systems than GKN II BHB 2-1.4. While at least three trains (JNA, FAK) and four redundants must be available in GKN II, variants with three available redundants are also admissible in KKE and KKE 2. In GKN II and KKE BHB 2-1.4, the availability of at least two JNA redundants is required, while according to KKI 2 BHB 2-1.4, variants with only one available JNA redundant are also admissible.