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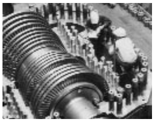

ILK Recommendations

on the Further Development of Periodic Safety Reviews in Germany

Für deutsche Fassung bitte umdrehen!

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Foreword

The International Committee on Nuclear Technology (Internationale Länderkommission Kerntechnik, ILK) was established by the three German states of Baden-Württemberg, Bavaria and Hesse in October 1999. It currently consists of 11 scientists and experts from Finland, France, Germany, Sweden, Switzerland and USA. The ILK acts as an independent and objective advisory body to the three German states on issues related to the safety of nuclear facilities, radioactive waste management and the risk assessment of the use of nuclear power. In this capacity, the Committee's main goal is to contribute to the maintenance and further development of the high, internationally recognised level of safety of nuclear power plants in the southern part of Germany.

The ILK has addressed the experiences gathered to date on performing Periodic Safety Reviews in Germany and in so doing has given special consideration also to international approaches to this topic. The current publication, which was adopted on the 44th ILK meeting held on November 15th, 2006 in Stuttgart, contains the ILK recommendations on the further development of the Periodic Safety Reviews in Germany that are based on the shortcomings identified by the ILK.

The chairman

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Recommendation

1 Periodic Safety Reviews in Germany

1. Since a good number of periodic safety reviews (PSR) has (already) been carried out in Germany, the ILK has asked licensee and technical expert representatives to report on their experiences. These reports have moved the ILK to reflect deeply on the added value associated with a PSR and to make suggestions on further developments of the PSR in Germany which on the one hand avoid known drawbacks while, on the other, also being oriented towards international best practices. Since six plants in Germany are currently on the verge of undergoing or have just begun their last safety review according to the Atomic Energy Act in force, this is a topical recommendation for the ILK to make.

Following the Chernobyl accident, the federal ministry in charge (of reactor safety) initiated a safety review of all German NPPs in 1986. The results are documented together with a suggestion for requirements on future periodic safety reviews (PSR) in the recommendation dating from the 238th meeting of the Reactor Safety Commission (RSK) on November 23, 1988.

Subsequently, PSRs represent a *supplement* to the ongoing oversight of NPP operation performed by the regulatory authority.

PSRs should be performed approximately 3 times during the lifetime of a plant. The RSK evidently assumed a reference operating period for German NPPs of 40 years. A first comprehensive review should be performed after about 10 years following commissioning; the further reviews are then to follow at 10 year intervals

2. In its recommendation approved at the 291th RSK meeting on May 17th, 1995, the RSK reiterated the supplementary nature of the PSR. Its periodic interval already mentioned above was a consequence, in the RSK's view, of the consideration of continuous further developments in safety technology, new findings from research projects and risk studies as well as from the feedback of experience from operation and from special incidents. In order to facilitate performing each successive PSR and to keep expenditures within reasonable limits, the follow-on PSRs can be performed as delta-reviews to the first PSR and the existing PSR documentation can be updated.

According to the RSK, the overall objective of the PSR is to answer to the question of whether the plant continues to have a sufficient standard of safety. This objective is in agreement with the PSR Reference Level 1.5 of the Reactor Harmonization Working Group (RHWG) of the Western European Nuclear Regulator's Association (WENRA) [WE 2006].

For this purpose, representative events must be investigated in detail if this is required by new findings since the last PSR.

Essential reasons for performing a PSR can be summarized as follows:

1. The entire plant documentation is updated at least over larger time intervals, often after many backfits and modifications have been performed, in a way that ensures that documentation is internally consistent and is also updated according to similar criteria across all plants.

2. The preparation and assessment of a PSR require activities that lie outside of routine action. Plant safety benefits from the resulting increase in attention.

3. Influencing factors on plant safety and their interactions are not viewed individually, but rather from a general and holistic perspective.

4. The recommended plant improvements are oriented towards the state-of-the-art in science and technology. They are identified in a systematic way, which puts the further development of the plant on a solid foundation.

5. The results of a PSR not only enable a generic assessment at the national level but also facilitate an international comparison of the kind required by the Convention on Nuclear Safety.

2 Performance and Contents of a PSR in Germany

3. The RSK reverts to the well-known defense-in-depth safety concept with its four hierarchic levels in order to determine the contents and scope of a PSR. Given the permanent regulatory oversight of specified normal operation (levels 1 and 2), it is entirely sufficient from the RSK's point of view to present and assess the PSR results for these two levels in a simplified way. By assessing operating experience, including safety-relevant areas of operating management, the aim is to show to what extent the requirements placed on these levels are satisfied and how the technical installations and measures have proven their worth during operation thus far. Investigations concerning level 3 „accidents" constitute the focal point of the PSR. In its 282nd meeting on February 16th, 1994, the RSK takes the view that the PSR requires focusing on enveloping accidents and on the relevant safety systems. At the forefront is the question of whether the enveloping accidents can be controlled by available precautionary measures with sufficient effectiveness and reliability. The review of safety installations is to be based on valid documents and verifications. When assessing deviations from the safety goal oriented requirements, the weighting in particular is to be performed by taking the relevant level of defense in depth into account. The RSK repeated this statement on its 285th meeting on July 12th, 1994. In the course of advances in safety technology, a fourth level of defense was added for very rare beyond design basis events (conditions). The RSK states that the measures in this beyond-design basis area clearly differ from the design basis area (associated with the first three levels) in terms of their technical requirements and the scope of verifications.

The RSK recommends that the licensees take the following steps to prepare the PSR:

1. Brief plant description
2. Safety status analysis (SSA)
3. Probabilistic safety analysis (PSA)
4. Assessment of results.

Later on, an analysis on physical protection was added. It analyzes precautions against criminal attacks and assesses their effectiveness.

4. The *brief plant description* intends to provide a concise overview of the plant's safety concept. At its core is an answer to the question of whether the existing verifications are sufficiently corroborated.

The following aspects are to be taken into account in the description of the plant and all essential safety-related structures, systems and components:

- Configuration
- Arrangement
- Safety-related function
- Design data
- Significant safety-related modifications since commissioning or since the last PSR.

More detailed system descriptions are only necessary in the brief plant description in case there have been any *essential* modifications. Additionally, the plant-internal accident management measures that are assigned according to the safety goals should be described.

Moreover, the brief plant description may include backfit measures that have not yet been implemented or plant-internal accident management measures that have been approved or are undergoing approval and are available for inspection.

5. The *safety status analysis* is a deterministic analysis. It is based on operating experience and proof-of-service and essentially covers levels 1, 2 and 3 of the defense-in-depth safety concept.

The fundamental safety-related requirements that represent a sufficient standard of safety of the operated NPPs are oriented towards the following safety goals:

- Control and limitation of *reactivity*
- Limitation of radiation *exposure*
- *Cooling* of fuel elements
- *Confinement* of radioactive material.

The analysis addresses the question of whether the safety-goal oriented requirements have been satisfied. This is the case whenever the mentioned safety goals are achieved at any time during the representative accidents.

The events associated with safety level 4 address the question of whether incident-specific requirements are sufficiently satisfied, taking into account to their very low frequency of occurrence.

6. Concerning PSA, the RSK initially only wanted to consider the power operating mode. Already at that time, it pointed out the necessity of considering start-up and shutdown conditions insofar as they can be expected to make an essential contribution to the overall plant risk.

After the PSA guideline [BMU 2005] was revised, the scope of operating conditions was extended to include shutdown operation, internal flooding, fire and, to the extent that significant contributions resulted, also external impacts, particularly airplane crash, floods, explosion shockwaves and earthquakes. According to WENRA's PSA Reference Level 1.1 [WE 2006], extreme weather conditions (environmental extremes) should also be considered in a PSA.

In a PSA, probabilistic appraisals of planned and trained-for plant-internal accident management measures can also be taken into account.

In the RSK's view, the PSA is to be performed with proven methods and realistic data giving consideration to the PSA-guidelines that were then still in the process of being drafted. In so doing, plant-internal and external incidents and damages to components and plant parts are to be considered if safety functions are actuated for their control. Older plants may require a determination of the frequency of occurrence of rare external impacts caused by civilization-induced factors.

The operating experience of the individual NPPs is to be acknowledged as far as possible by using plant and component specific data. In order to ensure that the quality of the data is comparable for all plant PSAs, the data should be prepared centrally by experienced experts and should also be coordinated and be made available for plant-specific analyses.

The results of the PSA should supplement the deterministic assessment of the plant safety status and its operating safety as well as being used to establish the necessity and urgency of safety improvements.

7. The following points should be addressed when assessing plant safety:

- Operating experiences and proof-of-service
- Agreement with requirements that are in line with the current state of safety technology
- Balancedness of the safety concept regarding the contributions made by initiating events on the overall frequency of hazard states
- Identification of possible safety deficits and assessment of their significance for plant safety
- Consideration of plant-internal accident management measures
- If required, suggestions for safety-increasing measures.

The individual assessments should be integrated into a coherent overall picture.

The RSK believes that a high and balanced safety standard is given if

- The SSA shows that the requirements needed to satisfy the safety goals have been met and
- The PSA demonstrates the balancedness of the safety concept.

8. The nuclear regulatory authority reviews the described safety status of the plant that is submitted with the PSR documentation with regard to §s 17 and 19 of the German Atomic Energy Act. The third party experts consulted by the

regulatory authorities review the submitted PSR. The procedures described in the PSR guidelines serve as the basis for the review by technical experts.

The regulatory measures to be taken within the context of the overall assessment of the results by the relevant regulatory authority comply with the principles of the Atomic Energy Act.

9. According to the abovementioned remarks, in summary the following objectives of a PSR of nuclear power plants can be identified:

- Response to the question of whether the plant under consideration has a sufficient safety standard, also in its future operation
- Assess the safety of a plant from a comprehensive vantage point, i.e. a holistic safety inventory is made every ten years on the basis of the current plant condition and on the advances in science and technology
- Limit investigations to areas essential to plant safety. This includes operating areas which are expected to have a noticeable impact on the functioning of the safety system in the event of non-availability
- Weighting deviations from requirements according to the relevant level of defense in depth
- Taking into account backfits that are in the process of being implemented; especially for level 4 of the beyond-design basis area
- Assessment of the balancedness of the design through a probabilistic safety analysis with up-to-date methods; especially for assessing older plants that began operations before the current non-legislative regulatory set of guidelines took effect.

The PSR supplements the ongoing nuclear oversight process. Correspondingly, they augment each other. Reviews and assessments of PSR contents should not be undertaken whenever they are redundant to the nuclear oversight process. Furthermore, extensive descriptions that do not represent added value to reports prepared within the framework of ongoing nuclear oversight can be avoided. In general, unnecessary burdens on the licensee in the wake of a PSR must be avoided. For this purpose, the expenditures associated with a PSR should be kept to an appropriate level.

10. The federal ministry in charge has agreed with the RSK recommendations. The Laender committee for nuclear power prepared guidelines for performing PSRs that apply nationwide. The following guidelines are available:

- Basics of the Periodic Safety Review
- Guideline Safety Status Analysis
- Guideline Probabilistic Safety Analysis.

All three guidelines date from December 1996 and were published by the BMU on August 18th, 1997 under the file reference RS I 2-10120/9.0 [BMU 1997]. In the meantime, the PSA guideline has been revised and published in November 2005 in the Bundesanzeiger (federal notification organ) [BMU 2005].

According to the updated guideline, "a Level 2 PSA is also conducted in connection with the Level 1 PSA. However, treatment of Level 2 PSA is not associated with a legal classification, especially with regard to the necessary precaution according to § 7 Para. 2 No. 3 of the Atomic Energy Act."

The purpose of the guidelines is to ensure a homogeneous approach in performing and assessing PSRs on a nationwide level. They are meant to provide a clear framework regarding their objectives and their scope.

The Basics of the PSR and the SSA Guideline are ten years old. The current international status in this field is prescribed in particular by the Reference Levels of the WENRA [WE 2006] dating from January 2006. In Germany, the PSR Reference Level 1.3 deserves special attention. According to this, the safety-related significance of deviations of the nuclear regulatory guidelines in force shall be identified and assessed in comparison with best international practices.

11. The PSR supplements the permanent monitoring of NPPs within the framework of state oversight. Within this permanent oversight, where necessary, individual aspects of the PSR are to be continued with in-depth investigations in order to avoid going beyond the scope of the framework given for a PSR.

A PSR is conducted by the licensee in his own responsibility for the safety of his plant and according to existing secondary stipulations in the license provisions of individual plants. The concrete procedures applied are coordinated with the regulatory authority. Implementing the results of a PSR follows the general regulations, i.e. the German Atomic Energy Act. Before the coming to power of the last federal government, there was no direct legal obligation to perform a PSR. In Chapter III/1 of the consensus agreement dating from June 14th, 2000, a safety review is agreed upon for every plant. The due date for every NPP is mentioned in Annex 3 of this agreement. The need for a PSR is waived if the licensee gives a binding declaration that he will cease plant operation within 3 years of the stated date. The amendment to the German Atomic Energy Act

dating from April 27th, 2002 legally sets out the performance of PSRs for all NPPs in § 19a. The dates for the individual NPPs are found in Annex 4 of the German Atomic Energy Act.

3 Results of Periodic Safety Reviews in Germany

12. The measures listed in the reports on the PSR and stated below as examples have largely been identified and initiated within the framework of feedback from experience and regular oversight.

For all plants, no noteworthy deficits were established regarding the state of verification and the fulfillment of legal regulations. The safety status analysis showed that the plants control the hypothetical design basis accidents that can be reckoned with according to the state-of-the-art in science and technology within the permissible threshold values and thus ensuring compliance with the safety goals. For older plants, the analysis revealed that their safety status corresponds to that of the newer plants as a result of the continual backfits. The results concerning operating experience and proof-of-service did not give any indications of weak points nor of any fatigue effects. In all cases, the probabilistic safety analysis resulted in a balanced and sufficiently high safety standard. Additional safety margins were created by implementing suitable and meaningful organizational and technical improvements as well as further investigations and inspections. In this way, safety-technical aspects of the plants were further optimized.

13. For example, loads in the area of diversified safety and relief valves during overfeed procedures in the BWR were reduced or completely eliminated by technical improvement measures. Furthermore, these valves, together with the limitation „shutdown cooling selection" ensure a pressure and water level control that is independent of manual action for low reactor pressures and during shutdown cooling.

The power supply of the safety system was designed to be more reliable by improving voltage stability in the emergency power bar. The electrical decoupling of the independent sabotage and accident management system was improved to avoid the entry of non-system voltages.

Further technical measures concerned improving fire protection between redundant trains, e.g. by applying insulating coating on the main cable route in the space around the containment, an improved protection against internal flooding by installing guard pipes from the building entrances to the first isola-

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ting valve as well as simplifications for performing in-service inspections.

14. The documentation was adapted to the actual state of the plants. Instructions for complex manual actions to be performed under time pressure were included in the operating manual, for example the 100 K/h shutdown for PWR via the main steam safety valve as a back-up measure was described. Furthermore, a through-connection of the safety-feed-in pumps to sump operation by using residual heat removal pumps as forwarding pumps was documented.

4 Performance of PSRs internationally

15. The ILK has asked representatives from the countries USA, Finland, France, Sweden and Hungary to report on the objectives, content and licensee commitment towards a PSR. The contributions received can be found in the Annex to this recommendation.

16. In the mentioned European countries with a peaceful utilization of nuclear power, PSRs are performed at intervals of 10 years. In terms of content, they are largely based on the IAEA recommendations as stated in the Safety Guide NS-G-2.10 [IAEA 2003]. All countries share the overarching aim of a PSR, namely providing a sufficient basis for assessing whether the plants in question can be operated safely also in the future. Additional goals mentioned include:

- Taking into account the accumulated operating experience and proof-of-service for future plant modifications
- Updating plant documentation
- Knowledge transfer to younger staff
- Comparing the achieved safety standard of the various plants while giving consideration to international best practices
- Taking into account recent safety engineering findings including methods of verification
- Systematically identifying backfit measures whose implementation timeline corresponds to the results of the PSA, and finally
- (Performing) an international review in accordance with the Convention on Nuclear Safety.

The PSA extends to Level 2. This had already been recommended by the ILK in its statement ILK-04 [ILK 2001] also for German plants and had been integrated into the PSA guideline [BMU 2005] in 2005. The internal events to be taken into account for Level 1 include fire, flooding, cooling of the fuel pool, the crash of heavy loads and boron dilution transients.

The holistic perspective on Man, Technology, and Organization (MTO) is rounded off by a description of safety management, measures for ensuring and developing a high safety culture as well as technical and non-technical aging management.

17. The United States plants do not perform a periodic safety review. The Nuclear Regulatory Commission (NRC) takes the view that its Reactor Oversight Process (ROP), which includes periodic reviews of the efficiency of licensee programs for identifying and correcting safety problems, enables a sufficiently continuous assessment of the safety status, thereby eliminating the need for additional periodic reviews. The ROP approach is both risk-informed and performance-based. The safety-related significance of inspection findings is determined using the Significance Determination Process (SDP) in a risk-informed way. A so-called action matrix determines the measures that result from indicator levels and the SDP-results.

The ROP does not serve the purpose of identifying possible improvements to safety measures. The purpose of oversight is to assure that the licensee complies with its Current Licensing Basis (CLB). CLB represents the basis for licensing. The presumption of this approach is that compliance with the CLB results in adequate protection of public health and safety. The ROP can not be used to impose new requirements on the licensees. If the NRC wishes to impose such requirements, they must be evaluated in a cost/benefit context using the so-called backfit rule. The backfit rule is not used when the requirements to be imposed mitigate a threat to the adequate protection of public health and safety.

5 Weaknesses of previous PSRs in Germany

18. (1) The Periodic Safety Review is intended as a supplement to the ongoing monitoring performed in the framework of regulatory oversight of the operation of NPPs. The documentation for the first PSR exceeds the originally intended size.

(2) The large scope of documentation leads to long processing and reviewing times. The supplemental, integral and general nature of a PSR does not justify such long processing periods. In the BMU's letter (reference number 73/97 S)

accompanying the PSR guidelines and addressed to the nuclear regulatory authorities of the Laender dated Sept. 1, 1997, is written "It (the PSR) should not take longer than two years".

(3) The probabilistic analysis of systems gives an in-depth view of their mode of operation, their limits and failure mechanisms. Third party companies and experts make a significant contribution to this analysis. In practice, the propagation of the knowledge gained and the experiences made (in preparing the PSA) to a larger circle of staff at the plant is not sufficient in every case.

(4) Using PSA results to assess deviations, to set up a timescale for (implementing) improvement measures and to propose the removal of unnecessary requirements while preserving the underlying safety concept represents the great exception rather than the rule. A timely risk-informed licensing and regulatory action calls for an appropriate consideration of PSA results. This appears to provide the main reason for the rather reticent to dismissive attitude of German licensees towards more extensive PSAs: They do not identify any benefits deriving from the PSA for themselves and instead tend to view it in terms of an additional burden.

(5) The new PSA guideline [BMU 2005] also does not contain quantitative assessment criteria, e.g. in the style of the IAEA.

(6) Technical experts rely on the current KTA rules or detailed technical case studies instead of general requirements to assess PSR results. This runs counter to the basic philosophy of a PSR, namely, to verify the attainment of safety goals with the existing technical installations and measures for potential event courses. In the Basics of the PSR one can read in section 4.2: "The safety goals are deemed to be fulfilled if the safety goal oriented requirements, particularly the necessary safety functions, are met. In this respect, technical design specification not complying literally nuclear regulations is permissible, too." The safety goal oriented requirements, in turn, "are based on the sublegal regulations with reference to recent, corroborated findings".

(7) Sometimes the results of the individual assessments prepared by technical experts called in by the authority are all regarded as being of equal importance.

(8) Some formulations in the guidelines can be variously interpreted. One example is given by the adjective "safety-goal oriented". It arises in connection with the safety-goal oriented requirements, see (6).

(9) The following topics are currently insufficiently covered or not addressed at all by a PSR:

- Aspects relating to MTO {Man, Technology, Organization}
- Safety Management and Safety Culture, see ILK-19 [ILK 2005]
- A comprehensive and systematic aging management.

6 Advantages of a PSR

19. The widespread application of periodic safety reviews on an international level speaks for its preservation and thus for its continued development. In the ILK's opinion, especially the following benefits are associated with a PSR:

- Frequently, a large number of plant improvements, backfits, repairs and measures in the framework of aging management have been conducted since the last PSR. Each of these modifications was assessed individually by the ongoing nuclear oversight. The new PSR intends to give a more holistic viewpoint. This may possibly amount to more than the mere sum of all modifications.
- Continuous further developments in safety technology, new findings from research projects and risk studies as well as the feedback of experience from operation of NPPs worldwide result in a holistic orientation to plant improvements.
- In everyday operation of plants and nuclear oversight, routine activities may preoccupy the staff thus preventing it from looking at the big picture. A PSR can counteract this tendency and be an eye-opener for interrelationships that might otherwise go unnoticed.
- Personnel, technical and organizational interrelationships can be uncovered by a PSR. In this way, it can broaden the knowledge base of staff with regard to peculiarities of their plant, provided that the PSR investigations are performed with significant participation of plant staff.
- A PSR provides a welcome opportunity for the plants to compare and update their documentation in terms of consistency using comparable methods.
- An important tool of the PSR is the probabilistic safety assessment (PSA). Every PSR offers the opportunity to reduce the uncertainties of the PSA by increasingly using plant-specific reliability data instead of more generic data as a result of growing operating experience. Additionally, increasingly advanced methodology can be applied in performing a PSA.

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7 Recommendations on the Further Development of PSR in Germany

20. The concrete recommendations on the further development of the periodic safety reviews in Germany arise from its weaknesses as identified by the ILK (cf. chap. 5).

(1) In order to strengthen the supplementary nature of a PSR, the possibility of delta-investigations should be used more often for follow-up PSRs. Therefore, particularly in follow-up PSAs, the documentation of the first PSA should be used as far as possible. The documentation for follow-up PSRs should be self explaining to the extent possible. Furthermore, the possibility exists of performing the investigations for a PSR by using predefined key topics. The PSR Reference Level 1.3 [WE 2006] should be taken into account (see above, no. **10**)

(2) Whenever a further development of verification methods or the adaptation of requirements to new findings enable an improved verification method, new verifications should only be demanded if significantly different results are to be expected.

(3) The findings gained from a PSA about the mode of operation and the failure mechanisms of the various systems should be utilized much more than before to provide further training and education to new plant staff, regulatory authority and to technical experts. The investigations on the SSA (safety status analysis) and PSA should be performed with significant participation of plant staff. Also junior coworkers should be integrated in the PSR team in the process. The same applies to the assessment of analyses. Moreover, the experiences gained should be used to refine the simulator training programs (cf. PSA Reference Level 3.5 of WENRA [WE 2006)].

(4) The involved groups {licensees, regulatory authority, and technical experts} should agree in advance on criteria regarding the assessment of PSR results (guidelines currently in force), of deviations and of the timeline for improvement measures that have taken the findings of the PSA into account. This corresponds to the WENRA PSA Reference Levels 3.2 and 3.4 [WE 2006]. In harmonizing the basis of PSR a structured approach for the assessment of deviations should be described.
After the PSA results have become available, they should be used to identify superfluous measures or those not contributing significantly to safety and to make proposals for their removal. Before conclusions and measures are taken based on PSA results, peer reviews of PSAs should be performed that are requested by the authority or the licensee and are undertaken by independent third parties such as staff from other plants or international organizations. To round things off, licensees and regulatory authorities should hold a concluding discussion where planned improvement measures are discussed.

(5) With the PSA guideline [BMU 2005], the requirements on a PSA in Germany were brought up to the international level. What is missing, however, is the quantification of major parameters, such as, for example, the core damage frequency (CDF) or the frequency of large early releases (LERF). The CDF value suggested by the IAEA for new plants could be adopted for plants currently in operation in Germany. The possibility of determining a goal for LERF should be investigated.

(6) For all plants in operation, the basic idea of the PSR, namely the proof of achieving the safety goals within permissible threshold values using existing technical installations during a potential event course, should be the focus of attention. The current KTA guidelines are partly formulated in a plant-specific way and therefore they are not directly applicable to older plants. To this purpose, the safety goal oriented approach should be clearly defined as in KTA 2000 [KTA 2000].

(7) If the regulatory authority appoints technical experts to review the PSR documentation, then these technical experts should classify their review findings according to the safety-related significance. For this purpose, the relevant levels of defense in depth should be used.

(8) The PSR guidelines should be reviewed for clarity. Text passages that are open to interpretation should be worded more precisely without necessarily going into more detail in order to avoid strengthening the prescriptive tone. For this purpose, sufficient flexibility in performing the assessment should be maintained. Experiences gained in using the PSR guidelines should be taken into account when updating the texts.

(9) The PSR investigations should include the following topics:

- The interrelationships between MTO {Man, Technology, Organization}
- The Safety Management in force along with the indicators used as well as measures for maintaining and strengthening Safety Culture, ILK-19 [ILK 2005]
- A comprehensive and systematic aging management.

In a PSR, not only the plant engineering itself but also the MTO-interdependencies and the safety culture should be analyzed in a holistic way. In particular, all safety relevant events and anomalies that have appeared since the last PSR are important for this analysis, especially if they indicate a poor safety culture (compare the safety factors of IAEA [IAEA 2003]). Here, too, the holistic picture of all inconsistencies in operating experience is possibly more revealing than the sum of individual analyses. Special methods may be applied when carrying out such analyses to ensure that the results achieved in this way do justice to their supplementary nature with regard to the reviews performed within the framework of ongoing nuclear oversight.

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8 Appendix: International approaches to performing PSRs

8.1 USA

Nuclear power reactors in the USA are licensed for 40 years with possible extension usually by 20 years. The oversight by the Nuclear Regulatory Commission (NRC) is achieved via the Reactor Oversight Process (ROP) and periodic reviews of the effectiveness of the licensee programs to identify and correct safety problems.

The ROP is risk-informed and performance-based. The overall framework is shown in the following figure (Figure 1, http://www.nrc.gov/reactors/operating/oversight/).

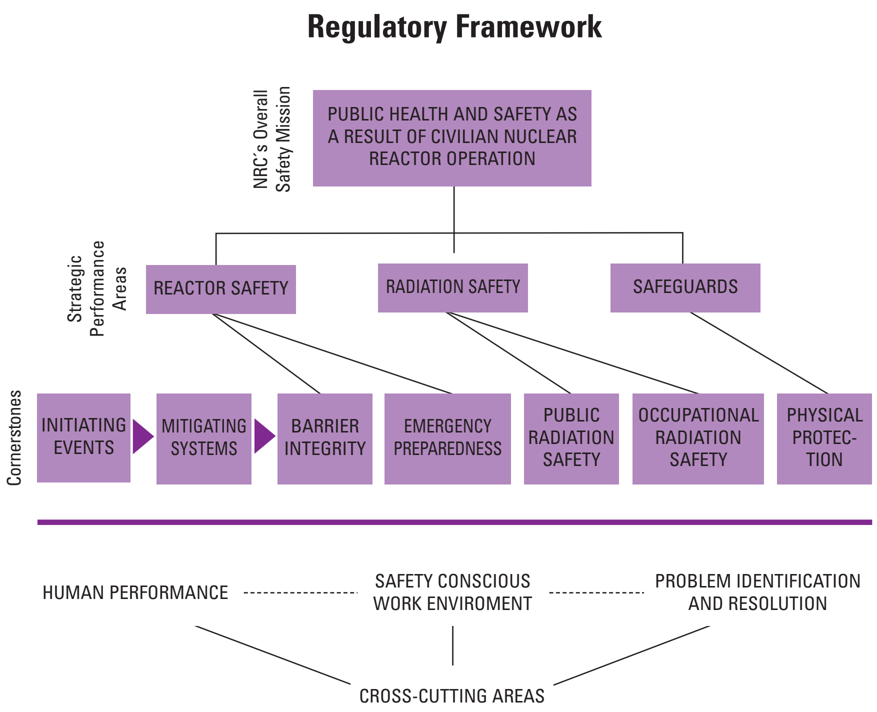

Figure 1: General framework of nuclear oversight in the USA

The strategic performance areas show the broad areas of interest to the NRC where it evaluates the safety standard of plants. Beneath each strategic area there is a set of cornerstones that are used to measure the achieved plant safety performance. In addition to the cornerstones, there are three cross-cutting areas so named because they affect more than one cornerstone. Satisfactory performance in each cornerstone, the cross-cutting areas, and the programs to identify and correct problems leads to the conclusion that the plant is safe.

For each cornerstone, there are two kinds of information collected: 1. the licensee reports information on performance indicators, e.g., unplanned reactor shutdowns (automatic and manual) and safety-system unavailability; and 2. the NRC inspectors report findings from inspections. The safety significance of the indicator values is determined by comparing them with thresholds listed in the ROP. The safety significance of the inspection findings is determined via a risk-informed process called Significance Determination Process (SDP). The licensee and regulatory actions resulting from the indicator levels and the SDP results are determined by an "action matrix" which is also risk-informed.

Although there may be minor differences, it appears that the information collected regarding licensee performance is the same in both the PSR and the ROP, supplemented by periodic reviews of the effectiveness of the licensee programs. The difference appears to be in the actions taken. The purpose of the NRC oversight is to assure that the licensee complies with its Current Licensing Basis (CLB), i.e., the totality of licensee commitments that allow it to operate the facility. The presumption is that compliance with the CLB results in "adequate protection of public health and safety".

If there are advances in the state-of-the-art in science and technology, the NRC has two options. If the NRC concludes that the new information affects "adequate protection," it will demand that the licensees take appropriate action. If the new knowledge does not affect adequate protection, the NRC must perform a cost-benefit analysis according to the backfit rule before it imposes new requirements on the licensees. The cost-benefit analysis is also risk-informed.

8.2 Finland

Regulatory requirements for PSR are given in the Finnish Regulatory Guide YVL-1.1, Regulatory Control of Safety at Nuclear Facilities. PSR is mainly based on the continuously updated documents listed in the Nuclear Energy Decree. These documents are FSAR (Final Safety Analysis Report), PSA, QA (Quality Assurance) Program, Technical Specifications, Summary Program for Periodic Inspections,

arrangements for Physical Protection, Emergencies and Safeguards, Administrative rules for the facility and environmental radiation monitoring program.

By requiring a PSR, the Safety Authority (STUK) can demonstrate to the other authorities and to the general public that Government requirements on e.g. safety enhancement are followed. For the licensee, PSR is a learning exercise and gives a possibility to transfer plant knowledge to the younger generation.

The licensee shall submit PSR for acceptance in connection with operating license renewal application. If the operating license is granted for a significantly longer term than ten years, STUK requires a PSR within about ten years of conducting the previous PSR.

The PSR represents a review on the safety status of the plant by its licensee and in particular points out potential areas of maintenance and development of the safety standard. The assessment shall include the following documents:

- A report on fulfillment of the requirements laid down in the relevant Regulatory Guides and in Government Decisions on the general regulations for the safety, for emergency response arrangements and for physical protection of nuclear power plants
- A summary of the renewed safety analyses and conclusions drawn from their results
- Experience of the plant aging and aging management
- A description of the licensee's safety culture and safety management
- A report on licensee's actions on the basis of the Government requirement that "for further safety enhancement, actions shall be taken which can be regarded as justified considering operating experience and the results of safety research as well as the advancement of science and technology"
- A report on compliance with any terms of the operating license
- A summary of fulfillment of the requirements on the operating of a nuclear power plant in the Nuclear Energy Act.

There are no specific acceptance criteria for a PSR. The licensee shall verify that the safety factors proposed in IAEA Safety Guide NS-G-2.10 "Periodic Safety Review of Nuclear Power Plants" [IAEA 2003] have been taken into account to a sufficient degree. A written assessment of the PSR prepared by STUK will contain qualitative statements on safety factors.

A PSR is typically carried out as a project manned by experienced technical support engineers or system engineers with younger colleagues. The total expenditure covers about 10 man-years for the licensee. This figure will not include normal continuous updating of documents.

When renewal of the operating license is being applied for, STUK submits a statement on the application to the Ministry of Trade and Industry, and provides the statement with its own safety assessment. A separate PSR, which has no connection to a PSR required by the operating license approval process, is studied by STUK and STUK takes a decision of approval with STUK´s own safety assessment.

8.3 France

In France, at the request of the Nuclear Safety Authority, with reference to a ministerial decree, Periodic Safety Reviews are conducted every 10 years. They play an important role for maintaining and advancing the safety standards of plants.

The objectives of the review are:

- firstly, to compare the standard of safety of the facilities with their initial "safety reference framework" in order to identify any deterioration over time, as well as the faults and weaknesses of the safety analysis. This is the conformity examination.

- secondly, to compare the safety of the facilities with the most recent safety standards, and best international practices, in order to improve the standard of safety. This is the safety review. This review is able to identify modifications likely to bring about a significant improvement in the safety standard and establish a new "safety reference framework". Reactor outages within the next 10 years are used to deploy these safety improvements.

The review process comprises:

- an orientation phase, provisionally setting the topics and scope of the conformity and review studies,
- a study phase, the aim of which is to determine the modifications to be made
- and a modifications examination phase.

After the study phase, the choice of topics for the reactor conformity examination is finalized.

Each of the phases in principle comprises a proposal from the operator, consultation of the Advisory Committee for Nuclear Reactors (GPR) and a position from the ASN which specifies the requirements to be met. The requirements are based on the international operating feedback, the more recent safety studies and the most recent safety standards.

The Authority can look particularly at a specific topic. For instance, the third safety review of the 900 MW Reactors will comprise a large part devoted to aging management both on the technical aspects and in terms of maintaining competence.

The 14 safety factors defined in the IAEA "Safety Guides" on the PSR are covered, apart from the safety management and the safety culture (organization and administration), and the human factor which are part of the normal oversight process, with the perspective of a continuous improvement.

Since the plants are standardized, the studies are conducted for a series of reactors. A representative plant, which corresponds to the current safety reference framework defined by the Authority, serves as the basis for general investigations specific to the individual construction lines. The next step entails a demonstration that the results achieved in the general investigations also apply to the individual plants of the construction line. Additionally, each plant must undergo individual testing. The studies are performed by the Engineering Division of EDF with the support of the Vendor. The Nuclear Power Plants carried out the investigations specific to their Plants.

The study phase includes the deterministic safety analysis, the probabilistic safety analysis, and the hazard analysis. The requirements associated with the periodic safety review specified the specific analysis rules and acceptance criteria to be applied to these.

PSAs are used during the periodic safety review to assess the core damage frequency and its change compared with the assessment made on completion of the previous review, including an analysis of the changes in system characteristics (equipment reliability, for example) and in operating practices. In addition, identification of the main contributions to the core damage frequency highlights any weak points for which design and operation changes can be studied, or even judged necessary. The weak points can be weighted according to their significance. For the third safety review of the 900 MW Reactors, the Authority has also requested the licensee to conduct a PSA level 2 and a PSA regarding fire hazards according to a methodology developed by the Technical Support Organization (IRSN). Furthermore, the PSR should cover internal flooding during shutdown conditions, the brittle fracture risk of the reactor pressure vessel as well as a leak in the safety injection systems and containment sprays without noteworthy increase of radiological consequences. The third safety review of the 900 MW reactors was started in October 2003. A decision on the modifications resulting from this was made in 2005. These modifications can then be implemented on the first of these plants that is to be shutdown for its third 10-yearly inspection.

In the future, for the third safety review of the 1300 MW Reactors, the PSA will include the seismic and the flooding hazards. The second safety review of the 1300 MW reactors was started by ASN in April 1999. The resulting modifications were implemented in the first of these plants which was shut down in 2005 for the second time for its 10-yearly inspection.

The modifications are mainly decided on the basis of the deterministic safety analysis. A method using the PSA is being developed to more adequately assess the benefit of the modifications in terms of plant safety in order to weigh the safety improvements with regard to their benefit/cost.

Before the first ten-yearly outage associated with the safety review, the examination must rule on the acceptability of the new safety reference framework and the continued operation of the reactors following their outage.

In the event of a positive assessment, the Authority approves ("no opposition to") continued operation, for ten more years till the next Safety Review.

Overall process leads to issuing of new updated safety analysis report.

The PSR allows to reassess the safety standard, taking into account the changes in system characteristics and operating practices, the more recent safety studies and standards and the international practices. The review results in safety improvements which are grouped in sets that are incorporated during the ten yearly inspections. At the end, the safety reference framework is finally clarified and documented till the next PSR, and assurance is provided of the conformity of each plant to this reference, including its operating documentation.

8.4 Schweden

The aim of a periodic safety review, together with normal inspection activities, is to provide a basis for judging if a nuclear installation can be safely operated also in the future. At the time of the review, the installation should comply with all valid

safety rules and regulations. A review of this kind is performed every ten years.

The PSR should cover the following areas:

(1) Design and construction of the facility, including modifications

(2) Management, control and organization of the nuclear activity

(3) Competence and staffing of the nuclear activity

(4) Operations, including the handling of deficiencies in barriers and defense-in-depth

(5) Core and fuel issues as well as criticality issues

(6) Emergency preparedness

(7) Maintenance, materials and in-service inspection issues, particularly taking into account degradation due to aging

(8) Primary and independent safety review

(9) Investigation of events, experience feedback and external reporting

(10) Physical protection

(11) Safety analyses and safety reporting

(12) Safety program

(13) Retention of facility documentation

(14) Handling of nuclear material and nuclear waste

(15) Non-proliferation control, export control and transport safety.

Point (2) covers the fields {Man, Technology, Organization}, Safety Management and Safety Culture. Aging Management is considered in Point (7).

IAEA requirements on a PSR are taken into account and are normally used as the foundation.

Apart from the aforementioned list of PSR contents, only very limited formal guidelines exist. The authority likes to see what the nuclear installation itself regards as important for the assessment. The work is normally done in the form of a project. Before the start of the project, the focus and specification for the assessment are settled as an input for the project. The authority, based upon the assessment report (of the licensee) and other inspection activities, does the final assessing. The assessment by the licensee is based on the competence and experience in the project group. The persons chosen to do this work are all senior engineers with long experience in the nuclear field and in many cases also with WANO (world association of nuclear operators) activities. In some cases, the experience of external experts can be utilized. The expenditure involved for preparing and assessing a PSR amounts to about 7 man-years.

The assessment made by authority is based on the regulations from the authority, international guidelines from IAEA and others.

No different or complementary approaches are necessary for reviewing and preparing a PSR.

An approval of the assessment report is necessary to receive a prolongation of the operation permit. The findings and recommendations are incorporated in the normal planning activities. Each PSR can have objectives with a different focus. In this way, one can respond flexibly to site and international incidents.

The benefits of a PSR can be summarized as follows: It gives the nuclear installations a perspective on what is significant for future safety and also shows how lessons learned have been implemented (in terms of plant modifications).

8.5 Hungary

So far in Hungary two campaigns of performing a PSR could be distinguished: The first one started in 1996. It should replace all the lacking documents containing information needed for demonstration of safety. At that time the PSR was an overall and only tool for control of plant safety with respect to international codes and standards. In the following, the focus is on the present status of PSR in Hungary, under which the second campaign starts in 2006.

The Nuclear Safety Regulation, issued in 1997, requires in accordance with the US NRC Reg. Guide 1.70 the renewal and annual update of the Final Safety Analysis Report (FSAR). Consequently, the PSR is not a tool for controlling compliance with the current licensing basis (CLB). This is the FSAR which is considered as the living document. It corresponds to the actual plant configuration. The PSR is the tool for assessment of the over-all plant safety with regard to long-term tendencies like aging, development of science and methodologies, development of safety analysis methods, new evidence in relation to hazards, etc.. The PSR will validate the forecasts made in the license renewal program, and finally the PSR is used to demonstrate plant safety as against best international

practice. According to the nuclear safety code (vol. 1), the PSR is a licensee obligation. The PSR is not a tool for prolongation of operational license. The operational license is limited in time by design lifetime of the plant (30 years), but the license might be renewed in a specific license renewal procedure, which is a two step process.

The Hungarian regulation explicitly describes the expected contents of the PSR. It practically follows the IAEA Safety Guide NS-G-2.10 [IAEA 2003] with 14 safety factors. Safety culture and aging management are treated, whereas MTO aspects have not yet been applied.

The Hungarian Atomic Energy Authority (HAEA) issued occasional, plant specific and detailed content requirements in the form of an appendix to regulatory resolution for the preparation. At the moment a newly developed draft guide summarizes the gathered experience. This draft refers to many IAEA publications. An internal procedure gives the administrative frame for the regulatory assessment of the PSR, with some instructions about checking the formal completeness and unambiguities. Thus, the character of the requirements may be seen as being prescriptive. The detailed content requirements in the form of regulatory resolutions are legally binding. From a technical point of view, the quality management systems used in the licensee and authority organizations should ensure the participation of knowledgeable staff.

The PSR documentation is assessed in the light of the above-mentioned detailed requirements concerning its content. The general criteria are stated in the Act on Atomic Energy (sec. 9). The specific criteria are embedded in the FSAR, since this document represents the design safety, and it discusses the plant level design basis with the corresponding system and equipment specific design requirements.

The licensee staff preparing the PSR may have an assertive attitude, while the regulatory staff should have a questioning attitude. Additionally, the licensee staff consists mainly of engineers, who are very familiar with their systems. The PSR tasks are performed by an in-house team and external technical support organizations (TSO). Besides the formation of the PSR-team, a quality assurance (QA) program for the PSR is developed. The members of the PSR-team are prepared for their work by training, methodical studies, and special trial activities.

The authority staff should take a more general view; they form an assessment group. The group consists of inspectors, while expert institutions are also involved in the evaluation. The authority has a training program in which many topics from the FSAR are covered periodically, especially when new research results emerge. There is no specific training for PSR assessment within the authority.

The first PSRs with their exceptional objectives required about 200 man-years. Each PSR per twin units (1995-1996 units 1 and 2, 1997-1999 units 3 and 4) took 2 years; the assessment by the authority took approximately 3 man-years.

During the present PSR campaign, probabilistic safety analyses (PSA) are performed. The studies consist of PSA level 1 with internal events, PSA level 2, internal fire and flooding, earthquake, cooling of the spent fuel pool, lifting of heavy loads, and boron dilution faults. The PSA results together with a deterministic procedure (engineering judgment, formal comparison with regulations) are used for setting up a timeline for plant improvements.

The benefits of a PSR are seen in the identification of the safety upgrading needs and their temporal weighting, in a source for training and education, in a basis for the national report to be submitted in the framework of the international safety convention, and in the communication of plant safety to the public and to the international environment, which respects the PSR as an IAEA preferred tool for justification of plant safety.

8.6 IAEA

The IAEA Safety Guide NS-G-2.10 "Periodic Safety Review of Nuclear Power Plants" [IAEA 2003] issued in 2002 is a revision of the previous document of 1994 and it falls under the Safety Requirements "Safety of Nuclear Power Plants: Operation". It has served as a basis for the comparison made by WENRA under its program on harmonization [WE 2006]. WENRA covers its requirements under Issue P in the area of safety verification.

"PSRs are considered an effective way to obtain an overall view of actual plant safety, to determine reasonable and practical modifications that should be made in order to maintain a high level of safety and to improve the safety of older NPPs to a level approaching that of modern plants. In this connection, it is useful to identify any lifetime limiting features of the plant in order to help evaluate whether a proposed modification is worthwhile …..the first PSR should be undertaken about ten years after the start of plant operation and subsequent PSRs every ten years."

Within the period of ten years it is expected to see a change in standards, R & D results to be integrated through design and operational changes, technology

evolution or even lack of former components availability especially in I & C area. It also involves evaluating the international operating experience feedback, the effect of previous plant modifications and the aging effects. It allows also to take into account the management of the plant organization, the staffing and avoids loosing too much of staff expertise in the operator or the regulator.

A PSR should cover all safety aspects of the installation, such as all facilities and systems, structures and components covered by the license (including waste management facilities and on-site simulators) and their operation together with staff and organization. It includes also radiological protection, emergency planning, environment impact.

The safety factors to be covered under a PSR and proposed in the IAEA document include the following:

- Plant: design, actual conditions of safety systems and components, equipment qualification, aging.
- Safety analysis: deterministic and probabilistic, hazard analysis
- Performance and experience feedback: safety performance, use of operating experience from other plants, research findings
- Management: organization and management, procedures, human factors, radiation protection, emergency planning
- Environment: radiological impact on the environment
- Global assessment: based on the review of the individual safety factors and on agreed upon corrective actions and safety improvements.

Quality Assurance as well as Safety Culture and Radiation Protection are not considered as separate factors since they are integral part of safety. But it is recognized that the list can be adapted to specific considerations, installations. They should be agreed upon with the Regulator prior to the undertaking of the PSR by the licensee.

The primary responsibility of conducting the PSR and reporting its findings lies with the operating organization. The Regulator has the responsibility (see figure 2) of specifying or approving the requirements, reviewing the conduct, the findings and the corrective actions or safety improvements and finally reporting to the government and the public.

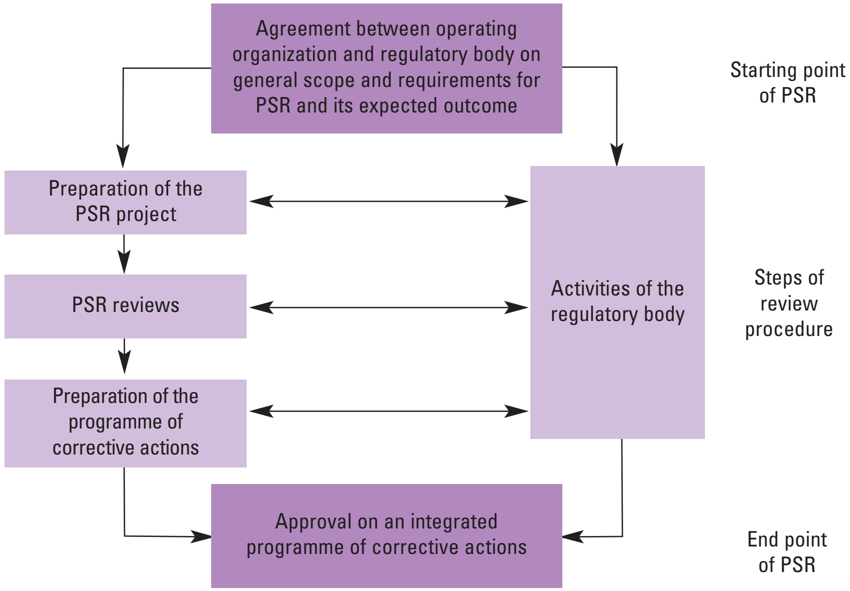

Figure 2: Workflow of the PSR process according to IAEA

As a conclusion of the performance of the PSR, not all safety aspects can be totally meeting the current safety level of modern plants since back-fitting cannot always be done. When significant deviations or differences/shortcomings are reported, they should induce an associated risk assessment and a "risk judgment" should be made on the acceptability of continued operation with all other shortcomings being fixed by corrective actions. PSA, expert judgment and remaining lifetime are important tools and considerations at this point.

Recommendation

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Recommendation

10 Acknowledgements

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11 List of Abbreviations

ASN	Autorité de Sûreté Nucléaire; French supervisory authority
BMU	Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety)
BWR	boiling water reactor
CDF	core damage frequency
CLB	current licensing basis
EdF	Electricité de France
FSAR	Final Safety Analysis Report
GPR	Groupe permanent chargé des réacteurs nucléaires
HAEA	Hungarian Atomic Energy Authority
I & C	Instrumentation and Control
IAEA	International Atomic Energy Agency
ILK	Internationale Länderkommission Kerntechnik (International Committee on Nuclear Technology)
IRSN	Institut de Radioprotection et de Sûreté Nucléaire
KTA	Kerntechnischer Ausschuss (Committee for Nuclear Engineering)
LERF	large early release frequency
MTO	Man, Technology and Organization
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
NS-G	Nuclear Safety – Guide
PSA	Probabilistic Safety Analysis
PSR	Periodic Safety Analysis
PWR	pressurized water reactor
QA	Quality Assurance
R & D	Research and Development
RHWG	Reactor Harmonization Working Group
ROP	Reactor Oversight Process
RSK	Reaktorsicherheitskommission (German Reactor Safety Commission)
SDP	Significance Determination Process
SSA	Safety Status Analysis
STUK	Säteilyturvakeskus, Finnish Radiation and Nuclear Safety Authority
USA	United States of America
WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulator´s Association

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ILK-02 ILK Statement on the Final Storage of Radioactive Waste (July 2000)

ILK-03 ILK Statement on the Safety of Nuclear Energy Utilisation in Germany (July 2000)

ILK-04 ILK Recommendations on the Use of Probabilistic Safety Assessments in Nuclear Licensing and Supervision Processes (May 2001)

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