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 is currently composed of 13 scientists and experts from Finland, France, Germany, Sweden, Switzerland and USA. The ILK acts as an independent and objective advisory body to the 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.

Currently, the proof of controlling operating transients with an additional failure of the scram mechanism (ATWS – „Anticipated Transients Without Scram“) is a controversial topic in Germany. The ILK has addressed this issue and has given special attention to the international practice in its considerations. In the current statement, which was adopted on the 34th ILK meeting on March 17, 2005 in Munich, the ILK expresses its opinion on the requirements that are to be placed on the proof of controlling ATWS in pressurized water reactors.

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**INTERNATIONALE
LÄNDERKOMMISSION
KERNTECHNIK**

Baden-Württemberg · Bayern · Hessen

ILK Statement

on Requirements on Anticipated Transients without Scram (ATWS)

Für deutsche Fassung bitte umdrehen!

March 2005
No.: ILK-20 E

Executive Summary

Currently, the treatment of operating transients with an additional failure of the scram mechanism (ATWS – „Anticipated Transients Without Scram“) is a controversial topic in Germany. The discussion was triggered by the Reactor Safety Commission (Reaktorsicherheitskommission, RSK) which recommended in its statement dated May 3, 2001 to depart from the requirements on the proof of controlling ATWS incidents as laid down in the RSK guidelines for pressurized water reactors dating from the year 1981 (last modified in 1996) and not to take into account the impact of specific actively initiated measures, namely the shutdown of the reactor coolant pumps. With this statement, the ILK thus expresses its opinion on the requirements that are to be placed on the submission of proof for controlling ATWS in pressurized water reactors. As far as boiling water reactors are concerned, an investigation of ATWS is also a component of the licensing procedure. The assumptions that need to be applied in that process for giving proof of an effective pressure limitation have long been unchanged and uncontested.

The ILK has given special attention to the practice adopted in the USA, France and Finland in its considerations. In so doing, the ILK has found that the basic treatment of ATWS in Germany, the USA and France, where it is shown that the consequences remain tolerable without applying aggravating postulates, is the same. In particular, none of these countries assume that active components unaffected by the initiating event are unavailable for the control of transients. On a more detailed level, differences do, however, exist. Finland applies a different approach, but assumes like the other countries that operating systems function normally.

It is the view of the ILK that the approach taken thus far for proving the safety of ATWS events leads to a balanced reduction in risk. The initiating event already has a very low frequency of occurrence. Reliable measures exist for its control. These are also suited to cover uncertainties. The ILK thus does not see a reason for setting additional requirements. Shutting down the reactor coolant pumps during ATWS is an effective measure for favorably influencing the course of events and for mitigating their impact. The measure is reliable and does not have any negative consequences. The ILK thus recommends to maintain the approach outlined by the RSK guidelines for pressurized water reactors and especially to take the impact of a possible planned pump shutdown into account in the analysis.

With regard to the criteria to be adhered to, the ILK is of the opinion that the prescription of a permissible tension as laid down by the RSK guidelines represents a practical approach. The corresponding pressure should be determined on the basis of the permissible tension in a plant-specific way.

1 Reason for the Statement

Currently, the treatment of operating transients with an additional failure of the scram mechanism (ATWS – „Anticipated Transients Without Scram“) is a controversial topic in Germany. The discussion was triggered by the Reactor Safety Commission (Reaktorsicherheitskommission, RSK) which recommended in its statement dated May 3, 2001 [1] a departure from the requirements on the proof of controlling ATWS incidents as laid down in the RSK guidelines for pressurized water reactors [2] dating from the year 1981 (last modified in 1996). In the RSK’s opinion, the impact of specific actively initiated measures, namely the shutdown of the reactor coolant pumps, should not be taken into account in the proof-giving process.

In the view of the ILK, this discussion has a fundamental significance going beyond the individual case for giving proof of the safety of nuclear power plants. It thus expresses its opinion on the requirements that are to be placed on the submission of proof for controlling ATWS in pressurized water reactors in this statement. The ILK has given special attention to the practice adopted in the USA, France and Finland in its considerations.

2 Treatment of ATWS in Germany

2.1 Classification of Events

The first important level for ensuring safety (safety level 1[1] or Level 1 according to INSAG-12 [4], see Annex) consists of avoiding incidents whenever possible by achieving a high quality of the plant and its operation. Since the occurrence of incidents cannot, however, be excluded, provisions should be taken for controlling them (once they arise). The events that need to be considered can be assigned to one of four following categories in accordance with the German safety practice:

- Category 1: Operational events

  These are events whose occurrence must be reckoned with during the lifetime of the plant, i.e., their frequency lies in the area of about once a year to once every several decades. The transients resulting from these events are mitigated by operating systems as well as by limiting systems; only in a few cases is a reactor scram initiated. These events are assigned to safety level 2 (or to Level 2 according to INSAG-12). In the case of failure of the operating systems, the safety system is available for their control.

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[1] The safety concept levels are described in the RSK recommendation dating from November 23, 1988 [3].

- Category 2: Design basis accidents

  These events determine the design of the safety system. They cover a wide spectrum ranging from events that may arise over the lifespan of a plant to those whose occurrence is not expected for the lifespan of all plants in operation in Germany, but which cannot nevertheless be excluded. For these events, proof must be given that the necessary provisions against damage are at the state of the art in science and technology. For this purpose, measures are taken that will safely control these incidents. The safety that is aimed for can be achieved, for instance, by also considering events with low probability of occurrence and by using unfavorable assumptions for this proof in addition to the event to be controlled, such as specifying the non-availability of all installations that are not part of the safety system, failure of the first expected reactor protection signal, a random failure among the systems necessary for control as well as non-availability of redundancies of safety installations as a result of maintenance measures. Furthermore, conservative assumptions for the calculations and conservative threshold limiting loads of components, etc are used for giving proof. The incidents to be considered are laid down in the accident guidelines [5]. These events are assigned to safety level 3 (or to Level 3 according to INSAG-12).

- Category 3: Beyond design basis events that do not require provisions against damage, but for which the possibility of risk reduction needs to be examined

  These are events whose occurrence does not need to be assumed due to their extremely low probability. For this reason, provisions against the damage to third parties are not required. Since also in these cases the avoidance of damage can lead to a further reduction of the remaining risk associated with plant operation, suitable measures are taken insofar as this is meaningful with reasonable means. One approach is to plan internal accident management measures that would avoid the occurrence of intolerable consequences even if the event under consideration is assumed to occur. The proof for this eventuality is given using realistic rather than conservative assumptions. In particular, it is not assumed that existing installations that remain unaffected by the event will fail. The reasoning underlying this approach is that the combination of an already highly improbable hypothetical event with improbable failure assumptions leads to a residual risk that can no longer be gauged. These events are assigned to safety level 4 (or to Level 4 according to INSAG-12).

- Category 4: Events in the Area of Residual Risk

  These represent events whose risks are so low that they are insignificant when compared to other life risks and thus can be shouldered. Paraphrasing the German Constitutional Court, they lie beyond the cognitive powers of practical reasoning. No event-specific measures are taken against these events. However, their consequences are limited by plant internal and external accident management measures. These events are also assigned to safety level 4. According to INSAG-12, they belong to Level 5.

2.2 Classification of ATWS

For operating transients in whose course a reactor scram is initiated, proof is given using conservative assumptions and margin conditions that permitted loads on plant installations are not exceeded.

In so doing, the functioning of the reactor scram is assumed because of its reliable structure and operation.

The structure and operation of the scram (system) will be sketched for the PWR of interest in this context in the following:

- In all of the cases under consideration, the reactor scram is initiated by several initiating signals and by diverse actuation devices. The reactor scram is initiated even if the failure of an entire diverse group is assumed based on common mode failure and additionally a single failure in another group is assumed. Furthermore, a variety of initiations from within the limiting system cause the insertion of several or all control rods.

- The control rods themselves fall into place through their own weight. As a result, considerable force reserves exist that are able to overcome even highly increased friction forces. A number of the rods are moved during operation for control purposes. This would lead to an early detection of the mechanical jamming of the rods.

The GRS has assessed the unavailability of the reactor scram system as being less than 9 E -7 [6]. In this way, it arrives at a frequency of occurrence of < 2 E -7/a for all operating transients with failure of reactor scram. The GRS gives a frequency of occurrence of less than 1 E -7/a for the least favorable transient with additional failure of the reactor scram that is assumed in the proof giving.

As a result of this state of affairs, the outcome of all licensing processes was that the design of the reactor scram system (and possibly other safety installations required for the individual transients) provided the necessary provision against damage to third parties. For this reason, the accident guidelines [5] state that transients with a failure of reactor scram (ATWS) are not design basis accidents. The

RSK recommended already at an early stage to provide measures for protecting against ATWS and codified these in its guidelines for pressurized water reactors [2] dating from the year 1981 (last modified in 1996). This corresponds to an assignment to the Category 3, as outlined in section 2.1.

2.3 State of Proof on ATWS Control to date

The investigation of ATWS transients constitutes part of the licensing process of pressurized water reactors in Germany. According to the RSK guidelines for pressurized water reactors [2], the evolution of operating transients also needs to be investigated with respect to the assumption that the reactor scram system fails *completely*.

A more precise specification of the complete failure of the reactor scram system is, however, not given in the guidelines. The systematic investigation of the entire spectrum of ATWS cases that has been carried out in the construction phase of the PWR plants shows that the coolant pressure in the most unfavorable case (failure of the main feedwater supply) increases most if a mechanical jamming of all control rods is assumed. Consequently, German licensing practice regards the “mechanical” failure (jamming) of all control rods as the comprehensive condition. That is to say, it is postulated that neither the reactor scram is activated following its actuation, nor that control rods can be inserted into the core over the further course of the transients.

The RSK guidelines [2] contain a list of the operating transients for which it needs to be shown that even in the event of a postulated failure of the reactor scram system, the following conditions are adhered to:

- In the reactor coolant pressure boundary, the permissible tensions according to ASME Code Section III, Division 1, NB-3224 Level C Service Limits, may not be exceeded. (Note: In German practice, this requirement was considered to be met if the maximum coolant pressure remained below the 1.3-fold value of the design basis pressure).

- The boric acid system and the systems for heat removal must be designed in such a way that their functionality is ensured under these event conditions or thereafter and that the reactor can still be shut down.

For the initial and boundary conditions, it is assumed that „for the analysis of these events normal operating conditions can in principle be assumed. With the exception of the systems deemed to be non-functional, all remaining systems can be assumed to be functional given that they are not impaired by the consequences of the event, i.e., the simultaneous appearance of a single failure is not assumed; also, a simultaneous maintenance case is not postulated” [2].

For boiling water reactors, the investigation of ATWS transients is also a part of the licensing process. The coolant pressure achieved during ATWS transients is effectively limited due to the reactivity coefficients (fuel temperature coefficient, void coefficient) and due to the pressure limits of the safety and relief valves, the diverse shutdown of the reactor using the combined electromotive insertion of all control rods and the slowdown of the internal coolant pumps to minimal speed. As a result, the limiting value for the design basis pressure of the reactor coolant pressure boundary is usually not exceeded.

2.4 Measures during ATWS

To gain a better understanding of the measures required for ATWS, the course of the transient that normally places the greatest demands will briefly be sketched in the following for a convoy plant. This example deals with the complete failure of the main feedwater supply during full power and the assumed jamming of all control rods. It is assumed that the primary coolant pumps stay in operation during the entire course of the transient.

The failure of the main feedwater supply leads to a turbine trip and steam release via the by-pass station. Pressure and temperature in the steam generators rise.

The scram is requested but, contrary to expectation, is not carried out. The RESA control signal (scram control signal: RESAK in Germany) of the limiting systems initiates various measures, especially the boration via the extra borating system.

- Since the heat generation on the primary side exceeds heat removal on the secondary side, the primary temperature and, due to the increasing volume, also the primary pressure increase very quickly. A new balance is reached at a temperature at which the generated power is lowered by the negative coolant temperature and coolant density reactivity coefficients to the value of the removed power. The primary pressure is limited and lowered by the actuation of the pressurizer valves.

- The steam generators that are not fed rapidly boil dry. The start-up and shutdown system and the emergency feedwater system begin feeding in but with their limited capacity cannot prevent further evaporation.

- When the steam generators have largely boiled dry after about 3 minutes, the heat transfer from the primary to the secondary side decreases very quickly. A new imbalance arises that is balanced out by a temperature rise in the manner described above. The associated pressure maximum is usually higher than the first.

- Subsequently, reactor power and thus primary temperature and pressure decline due to the boration of the primary cooling circuit. About 10 to 15 minutes following the start of the event, the power has been reduced to such an extent that the plant can be shut down via the steam generators that meanwhile have been refilled.

This description shows that the following functions are important for the control of the transient:

- The heat removal from the steam generators, i.e., the feeding and steam release. The corresponding systems and their automatic actuation exist independently of ATWS for the control of other incidents.

- Primary side pressure limitation. The pressurizer valves also exist independently of ATWS.

- Boration. Operating systems exist for this purpose, which have been supplemented in most plants by additional systems for feeding in highly concentrated boric acid (7000 ppm) at high pressure. For full feeding in, a signal that was introduced specifically for ATWS purposes is actuated.

The magnitude of the primary peak pressures depends on the behaviour of the secondary side, the blow-off behaviour of the pressurizer valves, and the values of the reactivity coefficients of the coolant temperature and density.

The measures described have until now been sufficient to give proof of the control of ATWS. Since cores with higher initial enrichment, higher MOX proportions and possibly longer cycle times may show less favorable reactivity effects, ATWS transients for these core loads without further active measures would lead to higher coolant pressures. It is for this reason that, in the case of ATWS, in several German plants the reactor coolant pumps are shut down by the limiting system. To achieve this, criteria for detecting ATWS (RESAK) are used. The shutdown is carried out with a time delay.

2.5 Current Discussion

The current discussion on proof submission for ATWS was set in motion by the RSK statement on ATWS events dated May 3, 2001 [1]. In this statement, the RSK takes the view “that the incident control must be guaranteed in future in the short-term range by an inherent safe core behaviour in connection with the automatic opening of the safety valves without taking credit from actively initiated measures, such as the shutting down of the reactor coolant pumps”. It refers to an earlier RSK statement dating from September 16, 1998 [7] on the use of fuel elements with high burn-up. In that statement, the RSK had requested examining ATWS events in terms of whether, for creating safety reserves, sufficiently negative moderator-temperature and moderator-density coefficients can be achieved by optimizing burn-up cycle times and gadolinium concentration so that no recourse has to be taken to an early shutdown of the reactor coolant pumps. This represented an inducement to explore possible safety reserves. A change in the margin conditions for proving control of ATWS events was not recommended by the RSK at that time. To the knowledge of the ILK, the licensees did not report to the RSK on this matter.

In the meantime, the ILK has received preliminary brief statements from the licensees. In these, it is stated that the use of gadolinium in the nuclear fuel in principle creates margins in the core design with regard to ATWS. However, even if, contrary to current practice, gadolinium were to be added to all fuel elements, the maximum boron concentration at the begin of the cycle could only be lowered by about 60 ppm. This would not be sufficient for relinquishing the pump shutdown measure for all cores.
Additionally, the licensees emphasize that the safety-related benefits of using gadolinium are countered by drawbacks in operation. In particular, the fuel burn-up achieved would be lowered and the high local power peaks around the middle of the cycle would require a temporary load reduction.

In its new statement dating from May 3, 2001, the RSK does not address the results of the requested examination. It recommends not taking the shutdown of the reactor coolants pumps into account. The justification it gives is that, in its opinion, this approach does not represent the state of the art in science and technology and points to the practice adopted in the USA and in France. In current discussions between the RSK and licensees, the “active control measure” given the main attention was the shutdown of the reactor coolant pumps. The licensees brought forth the argument that the non-consideration of an existing measure amounts to a considerable aggravation of safety-related requirements since the assumption of a *complete* failure of the reactor scram system required in Germany is not customary in other countries. Additionally, within the framework of its advisory activities on the load increase at the nuclear power plant Grafenrheinfeld, the RSK demanded that according to ASME, i.e., KTA, a 1.2-fold design basis pressure should be used as the evaluation criterion rather than the 1.3-fold design basis pressure used by licensing procedures in the past (see section 2.3).

3 Treatment of ATWS in the USA

ATWS is defined as an anticipated operational occurrence followed by an additional failure of the reactor trip portion of the reactor protection system according to the so-called ATWS-rule [8]. As in Germany, ATWS events are classified as beyond the design basis accident conditions in the USA.

Proofs are given for the failure of the scram-activation and, within the framework of probabilistic considerations, partly for the mechanical jamming of the control rods.

Measures should have a real influence on the already low risk. For this reason, the comparatively likelier cases are considered and no proofs are demanded for the less probable ones:

- only anticipated transients are associated with the failure of the scram system
- the proof is not required for all core conditions but for sets of parameters that cover the majority of the cycle time
- the complete jamming of all rods is not assumed
- an additional failure of installations is not assumed; especially not of those that are provided for the ATWS event.

The proof is successful if the tensions in the reactor coolant pressure boundary of the primary cooling circuit do not exceed the value corresponding to the ASME Service Level C - a higher threshold value than for design basis accidents is permitted in this case – and if defined threshold values of the fuel design are adhered to [8].

The technical plant measures called for in the ATWS rule also concern additional equipment and active systems for automatic corrective actions to be installed besides the reactor trip system (as a diverse measure). These act to lower the failure probability of the scram actuation following operating malfunctions and are also intended to mitigate the consequences of ATWS events.

The necessary additional corrective actions are distinguished according to plant designs (Westinghouse on the one hand, Combustion Engineering (CE) and Babcock & Wilcox (B&W) on the other). A binding requirement on all PWR plants is a system that is independent and diverse from the existing reactor scram system (from the sensors to the actuators) that automatically initiates the auxiliary (or emergency) feedwater system and triggers a turbine trip when ATWS conditions are given. This system is usually known as AMSAC (ATWS Mitigating System Actuation Circuitry) or DAS (Diverse Actuation System).

Furthermore, due to their core design and the associated reactivity coefficients, plants built by CE and B&W must be equipped with a diverse scram actuation system that must span the chain from the sensors to the trip breaker allowing the insertion of control rods. This system is described as DSS (Diverse Scram System) or SPS (Supplemental Protection System).

The possibilities for mitigating tensions in the reactor coolant pressure boundary using AMSAC strongly depend on the reactivity impact of the coolant temperature and density as well as on the fuel temperature. The time period during which the reactivity impacts within a core cycle are insufficient to keep the tensions beneath the permissible threshold value is known as “unfavorable exposure time (UET)”. For Westinghouse plants, the UET can amount to 1-10 % of the core cycle time, for CE/B&W plants even up to 50 %. In CE/B&W plants a diverse actuation system (DSS, see above) was installed as a result of these long time periods during which the maximum permissible tensions would be exceeded during an ATWS event.

4 Treatment of ATWS in France

In French nuclear power plants, technical plant measures were introduced, partly via backfits, which serve to reduce the probability of occurrence of ATWS transients while also influencing their course. These measures vary between the different plant generations (900 MW-3-Loop, 1300 MW-4-Loop and 1450 MW-4-Loop plants). All plants were fitted with an automatic steam generator emergency feed-water actuator and turbine trip trigger (corresponds to AMSAC in the US plants) that are independent of the reactor protection system. Furthermore, the N4 plants (1450 MW-4-Loop) have a diverse scram actuator that initiates the control rod insertion independently of the reactor protection system. In the case of the 900 MW plants, the reliability of the scram activation was improved.

In the deterministic approach that is used to give proof of ATWS control as specified in the safety analysis report, an electrical failure of the reactor scram system is assumed and partly the mechanical failure of single control rods is postulated.

The analyses take into account diverse scram signals or rod insertion control functions and other active measures also. With regard to the core design, the demand for a control of ATWS events through sufficiently negative coolant temperature and coolant density coefficients for 95 % of the cycle time is specified.

Within the framework of probabilistic safety analyses, the accident sequences in ATWS analyses are considered both with electrical and mechanical failures of the reactor scram system. Mechanical failure no longer corresponds to a complete jamming of all control rods but instead only refers to the failure to insert a part of the control rods, depending on the initiating event under consideration.

The French authorities require that proof be given that, as a result of ATWS events, the maximum permissible coolant pressure (225 bar) is not exceeded and that the minimal DNB (Departure from Nucleate Boiling) ratio is not violated.

5 Treatment of ATWS in Finland

Finland presently operates two pressurized water reactors of Russian design with significant modifications due to Finnish requirements. In addition, the licensing procedure for the construction of an EPR has been started. Therefore the Finnish requirements are of special interest.

Finland [9] uses a classification of events which comprises:

1. Anticipated operational transients with frequencies of > E -2/a
2. Postulated accidents
   a) Level 1 with frequencies of E -3/a to E -2/a
   b) Level 2 with frequencies below E -3/a

In addition, severe accidents are considered with the main goal to prevent with good certainty events which compromise the containment function.

ATWS is classified as postulated accident level 2. Special conditions are defined for its analysis which partially differ from those for other postulated accidents:

- different causes for ATWS are considered, among others the mechanical failure of all control rods to enter the core
- a single failure is assumed for the relief and safety valves of the pressurizer

- however, no additional failure in safety or operational systems is assumed; in particular, the shutdown of reactor coolant pumps is taken into account
- calculational parameters are assumed in the same way as in other postulated accidents, i.e. conservatively
- Xenon is in equilibrium in full power transients and zero for low power transients.

The acceptance criteria are that the number of damaged fuel rods may not exceed 10 %, the consequences of the accident may not endanger the coolability of the fuel and the highest temperature of the cladding may not exceed 1200 °C.

These requirements are used for the EPR and they were applied at the nuclear power plant Loviisa when modifications and backfitting measures were analysed for power upgrading in the late 1990s.

6 Comparison of the German, American, French and Finnish Approaches

The basic treatment of ATWS in Germany, the USA and France, where it is shown that the consequences remain tolerable without applying aggravating postulates, is the same. On a more detailed level, however, differences do exist. This aspect is of special significance since the evaluation of ATWS incidents and corresponding countermeasures – as opposed to the limitation to the deterministic point of view in Germany – are essentially based on probabilistic safety assessments in the USA and recently also in France and thus depend on the probability of occurrence.

Countermeasures are provided for in the nuclear power plants of both countries that are activated once specific criteria are reached. These are comparable in the USA and in France (AMSAC, diverse scram actuation systems). As the consequences of the transients are reduced by other measures (mostly the later insertion of rods), the shutdown of the reactor coolant pumps upon detection of ATWS is not planned either in the USA or in France. However, the available countermeasures – insofar as they do not become unavailable as a result of the initiating event – are taken into account in the safety reviews both in the USA and in France.

The proof-giving objective of adhering to permissible pressures or pressures on the reactor coolant pressure boundary applies in all compared countries. Additionally, in the USA proof is given of the tube cladding integrity and in France the proof of adhering to the minimum permissible DNB-ratio.

The spectrum of transients investigated is comparable across the countries considered.

In France, the complete mechanical failure of *all* control rods is no longer considered due to probabilistic analyses. Accordingly, the transients can be terminated by inserting the control rods using, for instance, a diverse actuation of the reactor scram. In the USA, this assumption is considered for some plants within the framework of probabilistic investigations. In Germany, the starting point for ATWS analyses is the assumption of the *complete* non-availability of the control rods and the control of this event is required with the stated framework conditions. It should be noted that the question of reactor coolant pump shutdown is only relevant to this scenario. If only a failure of the actuation is postulated so that a diversified actuation leads to rod insertion, the limit pressures are not reached in the German plants anyhow.

In the USA and France, due to the low probability of occurrence of the failure of the reactor scram system, the proof of ATWS control is made with moderator temperature and moderator density coefficients that do not cover the whole operating cycle, but instead cover about 95 % of it in France and in some of the US plants, and less for other US plants. In other words, it is tolerated that during a specific segment of the cycle, in the case of an ATWS event the corresponding limit values are exceeded. In Germany, the proof is required for reactivity coefficients covering the entire cycle.

In contrast, the Finnish approach differs significantly. ATWS is considered as a postulated accident and is analysed using deterministic failure postulates and conservative boundary conditions. Unlike in the German approach for design basis accidents, operational systems are assumed to remain functional. If an ATWS event occurs at the EPR the main coolant pumps are either switched off after about 1 minute as a result of low steam generator level or shutdown immediately in case of offsite power loss. This limits the increase of reactor pressure and is taken into account in the analysis.

The Finnish approach is different from the Safety Requirements developed for the EPR by the French GPR (Groupe permanent d'experts pour les réacteurs nucléaires) in cooperation with German experts [10]. The latter requirements are practically identical with the RSK guidelines.

Practical consequences for the analysis results follow from the assumption of a single failure in the pressurizer valves. The redundancy required by this assumption calls for a higher integral blow off capacity of the valves.

7 Evaluation and ILK Recommendations

As far as can be discerned, the RSK continues to view ATWS as a beyond design basis accident. The suggestion of not considering active countermeasures such as shutting down the reactor coolant pumps when giving proof on ATWS events is thus inconsistent with the usually applied treatment of measures for risk minimization. An aggravating deterministic assumption is added to an analysis that is realistic in principle. To the knowledge of the ILK, the RSK does not justify this suggestion in terms of content, but only by comparing it with the practice in the USA and France.

A deterministic boundary condition for the analysis could be justified by arguing that it ensures clarity of approach for treating a risk-relevant subject matter. However, this does not apply in this particular case. Summing up all the upper estimates of all considered ATWS events given in [6] results in a frequency of occurrence of less than < 2 E-7/a, and for ATWS after failure of the main feedwater system, a value of less than < 1 E-7/a is produced. In [6], the GRS does not treat ATWS events in detail and justifies this by stating that, in its view, the contributions towards frequency of system damage cases and of core melts are negligible. The RSK agrees that pump shutdown is helpful for controlling ATWS events. Negative safety-related impacts of pump shutdown are not given. Thus, the ILK is of the opinion that the suggested deterministic specification represents a disproportionate complication of the safety proof for ATWS that does not however in actual fact improve the safety of the plant.

The ILK regards as an essential point that no safety-related justification for not considering the pump shutdown can be discerned. The control of ATWS events rests on a series of active measures as described above, including heat removal from the steam generators and the accelerated boration of the primary cooling circuit. To extract one single measure from this set and to apply additional conservative requirements on it carries the danger of muddying the inner logic of the safety concept.

The basic concept for treating ATWS events in the USA and France is comparable to that laid down in the RSK guidelines [2]. It is not evident that the differences in terms of individual topics lead to a less conservative treatment in Germany. In many important points, e.g., regarding the assumption of a mechanical jamming of *all* control rods and the coverage of the *complete* cycle, the German requirements place the highest demands. A requirement to ignore individual measures for subareas of the transients does not exist – with the exception of the controversial RSK recommendation – in any country. It is frequently the case that for comparable general objectives, there is variation in implementing concrete measures for the different plant concepts. This applies not only in the beyond design basis area but also in the design basis area. In the ILK's view, the state-of-the-art in science and technology is determined by the requirements placed on giving proof of safety and not on individual measures taken to comply with these requirements. As described above, in both the United States and in France, the measures for controlling ATWS differ for plants made by different manufacturers or for different construction lines. For this reason, the ILK also considers the lack of pump shutdown in both countries, as opposed to its requirement in Germany, to be insubstantial. Incidentally, pump shutdown in German plants is only required in order to cover the assumption of a mechanical jamming of all rods. This assumption exceeds the common practice adopted in both countries. Thus the ILK considers the line of reasoning equating a non-consideration of pump shutdown with the international state-of-the-art as inappropriate. The Finnish approach also does not support the RSK requirement. In Finland, ATWS is classified as a postulated event and is therefore superimposed with deterministic postulates. Although this leads to similarly improbable event combinations as the RSK requirement, the general disregard of existing equipment is not required. In particular the shutdown of the main coolant pumps – which the RSK proposes not to take credit of – is taken into account.

In summary, it is the view of the ILK that the approach taken thus far for proving the safety of ATWS events leads to a balanced reduction in risk. The initiating event already has a very low frequency of occurrence. Reliable measures exist for its control. These are also suited to cover uncertainties. The ILK thus does not see a reason for setting additional requirements.

Shutting down the reactor coolant pumps during ATWS is an effective measure for favorably influencing the course of events and for mitigating their impact. The measure is reliable and does not have any negative consequences. *The ILK thus recommends to maintain the approach outlined by the RSK guidelines for pressurized water reactors and especially to take the impact of a possible planned pump shutdown into account in the analysis.*

With regard to the criteria to be adhered to, the ILK is of the opinion that the prescription of a permissible tension as laid down by the RSK guidelines [2, chapter 20] represents a practical approach. The corresponding pressure should be determined on the basis of the permissible tension in a plant-specific way.

8 References

[1] Reaktorsicherheitskommission (Reactor Safety Commission, RSK)
Statement of the RSK to ATWS Events, Annex 2 to the minutes of the 340. RSK meeting, May 3, 2001

[2] Reaktorsicherheitskommission (Reactor Safety Commission, RSK)
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9 List of abbreviations

AMSAC	ATWS Mitigating System Actuation Circuitry
ASME	American Society of Mechanical Engineers
ATWS	Anticipated Transients Without Scram
B&W	Babcock & Wilcox
CE	Combustion Engineering
CFR	U. S. Code of Federal Regulations
DAS	Diverse Actuation System
DNB	Departure from Nucleate Boiling
DSS	Diverse Scram System
EPR	European Pressurized Reactor
GPR	Groupe permanent d'experts pour les réacteurs nucléaires
GRS	Gesellschaft für Anlagen- und Reaktorsicherheit
KTA	Kerntechnischer Ausschuss (Nuclear Safety Standards Committee)
MOX	Mixed oxide
PWR	Pressurized Water Reactor
RESA	Reaktorschnellabschaltung (Reactor trip)
RSK	Reaktorsicherheitskommission (Reactor Safety Commission)
SPS	Supplemental Protection System
StrlSchV	Strahlenschutzverordnung (Radiation Protection Ordinance)
UET	Unfavorable Exposure Time

Annex

Levels of Defence in Depth according to INSAG-12 [4]

Levels	**Objective**	**Essential means**
Level 1	Prevention of abnormal operation and failures	Conservative design and high quality in construction and operation
Level 2	Control of abnormal operation and detection of failures	Control, limiting and protection systems and other surveillance features
Level 3	Control of accidents within the design basis	Engineered safety features and accident procedures
Level 4	Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of severe accidents	Complementary measures and accident management
Level 5	Mitigation of radiological consequences of significant releases of radioactive materials	Off-site emergency response

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ILK-01	ILK Statement on the Transportation of Spent Fuel Elements and Vitrified High Level Waste (July 2000)
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)
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