Note:
This is a translation of the RSK statement entitled
"Zusammenfassende Stellungnahme der RSK zu zivilisatorisch bedingten Einwirkungen, Flugzeugabsturz
Teilbericht: Festlegung der Lastannahmen und Bewertung der Konvoi-Anlagen"

RSK statement
(499th meeting of the Reactor Safety Commission (RSK) on 06.12.2017)

RSK summary statement on man-made hazards, aircraft crash

Reference report: Definition of load assumptions and assessment of Konvoi plants

1 Introduction

On 17.03.2011, the Federal Environment Ministry requested the Reactor Safety Commission (RSK) in connection with the events at the Japanese plant Fukushima to prepare a catalogue of requirements for a safety review of the German nuclear power plants and to assess the results of such a review on the basis of criteria. The subject of this safety review was the assessment of the robustness of the German nuclear power plants against beyond-design-basis events.

To classify the results of the safety review, the RSK defined graded criteria for robustness. Here, a distinction is made between robustness levels for natural events, postulates and emergency measures and robustness protection levels for the man-made events also to be considered according to the RSK catalogue of requirements.

Regarding the man-made hazard of an aircraft crash, the following degrees of protection were defined for the control of such events:

Mechanical degree of protection 1
Preservation of the vital functions during the crash of a military aircraft of the Starfighter type.

Thermal degree of protection 1
Preservation of the vital functions, postulating spillage and fire of fuels in case of a crash of a military aircraft of at least the Starfighter type.

Mechanical degree of protection 2
Preservation of the vital functions at load-time function according to the RSK Guidelines or a load-time function of a medium-sized commercial airliner.

Thermal degree of protection 2
Preservation of the vital functions, postulating spillage and fire of fuels in case of a crash of a medium-sized commercial airliner.

Mechanical degree of protection 3
Design with the load-time function according to the RSK Guidelines as well as preservation of the vital functions at a load-time function of a large commercial airliner.

Thermal degree of protection 3
Preservation of the vital functions, postulating spillage and fire of fuels in case of a crash of a large commercial airliner.

The review of the RSK showed that the requirements from the load assumptions according to the RSK Guideline (crash of a military aircraft of the Phantom type) are fulfilled for all facilities currently still in operation. Due to the high basic protection of the facilities still in operation, the RSK considered it possible to fulfil the degrees of protection 2 and 3. For the confirmation of achieving degrees of protection 2 and 3 for the deliberate crash of a commercial aircraft, further safety demonstrations were considered necessary.

Leak postulate

Within the framework of the safety review for assessing the robustness regarding possible cliff-edge effects, the RSK pointed out that due to the design of the facilities against an aircraft crash with the load-time function according to the RSK Guideline, no failure of coolant-retaining pipes resulting from the hazards was and is postulated. However, in order to sound out the potential for cliff-edge effects in an aircraft crash in terms of robustness, the RSK has included in its work programme to postulate the rupture of a small-bore line in this area and to investigate the possible effects despite the design of the pipes of the reactor coolant pressure boundary against loads from the aircraft crash according to the RSK Guideline.

2 Current investigations

The Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH was commissioned by the Federal Ministry for the Environment, Nature Conservation, Construction and Nuclear Safety (BMUB) to conduct investigations to determine whether, taking into account the expected failures and impairments resulting from the mechanical impacts and kerosene fires for representative reference plants, degree of protection 2 and 3, respectively will be achieved according to the RSK safety review. These investigations shall determine the bearing capacity against the load effects from thermal and mechanical impacts as far as possible by best-estimate calculations.

One reference plant was selected for each of the following types:

- Konvoi plants
- pre-Konvoi plants
- boiling water reactor construction line 72

The calculation and assessment of the load cases for the individual plants is carried out in the order given.

The operators have also commissioned their own investigations by an engineering company experienced in this field and also investigated the effects of the postulate "Rupture of a small-bore line (DN 50) in the primary circuit during an aircraft crash with the load-time function according to the RSK Guideline". In addition, the operators carried out an analysis to determine the time after which extinguishing measures on the plant premises can be expected in case of a crash of a commercial aircraft.

At its 446th meeting on 05.04.2012, the RSK commissioned the ad hoc working group Ad-hoc-AG FLUGZEUGABSTURZ (AG FLAB) to accompany the analyses and to prepare a statement. This reference report only refers to the completed calculations and assessments of the Konvoi plants and includes the results of the analyses of the operators, as far as necessary. The RSK discussed and adopted the statement at its 499th meeting on 06.12.2017.

3 Protection concept of the German nuclear power plants against aircraft crash

For the design of the nuclear power plants still in operation, the accidental crash of a military aircraft of the "Phantom F4E type" was postulated and corresponding protective measures were taken by structural design or spatial separation of redundant equipment. The underlying load assumptions were included in the RSK Guidelines of 1979.

After the events of 11 September 2001 in the USA with a deliberately caused attack on buildings with passenger aircraft, the deliberate crash of a passenger aircraft with a terrorist purpose was also discussed. In a first study by GRS in 2002 on "Schutz der deutschen Kernkraftwerke vor dem Hintergrund der terroristischen Anschläge in den USA vom 11. September 2001" (Protection of German Nuclear Power Plants against the Background of the Terrorist Attacks in the USA of 11 September 2001), flight parameters and load assumptions were derived and the vulnerability to such an attack was generically assessed for all German nuclear power plants.

Following this study, the operators developed a concept for countermeasures for all German nuclear power plants. In addition to extending the possibility of extinguishing kerosene fires by special foam fire-fighting vehicles, measures were planned in the plants which aimed at establishing more favourable conditions for controlling such an event after an alarm. These include, in particular, reactor scram initiation as well as the staffing of the supplementary control room. These measures were implemented and taken into account for the investigations considered here.

The BMUB/BMI then issued a so-called RENEGADE framework plan, which regulates the communication processes between the National Situation and Management Centre for Airspace Safety (NLFZ) and the nuclear power plants in the event of imminent danger from RENEGADE aircraft. In addition to defining the communication and alerting paths, this framework plan and the supplementary explanatory papers also include the introduction of an alerting concept that is staggered into pre-alarm and main alarm. With the binding implementation of this concept in the BHB/NHB (operating manual/emergency manual) of all German nuclear power plants, all plants now have comparable regulations which ensure the necessary internal alerting in case of a pre-alarm (e.g. plant fire brigade and standbys), the staffing of the supplementary control room as well as the evacuation of plant areas and additionally reactor scram in case of a main alarm.

In order to protect against a deliberate crash of a passenger aircraft, attention has not only been paid to the robustness of potential targets against such events, but concrete measures have also been taken to prevent such attacks as far as possible.

It is therefore a question of a combination of precautions,

- which, on the one hand, make the hijacking of an aircraft and the targeted approach to an NPP more difficult, and

- which, on the other hand, lead to a high robustness of the NPPs against the impacts of a deliberate crash.

The hijacking of a commercial aircraft is made more difficult by technical and administrative measures to prevent terrorists from entering the aircraft and, in particular, the cockpit. The international and national requirements have been updated several times since 2001 and security measures have been further strengthened worldwide. The regulations, measures and procedures applicable in Germany for protection against attacks on air traffic security, in particular against hijackings, acts of sabotage and terrorist attacks, are summarised in the National Aviation Security Programme (NLSP) (B3-643 213/1 of July 2010; Annex 2).

The design requirements for the German nuclear power plants still in operation were specified in the RSK Guidelines and incorporated unchanged into the "Safety Requirements for Nuclear Power Plants" in 2012. The crash of a commercial aircraft is neither part of these design requirements nor included in the load assumptions for protection against third-party interference (load assumptions in terms of disruptive action or other interference by third parties).

At its meeting on 11.07.2016, the *Länder* Committee for Nuclear Energy – General Committee – stated the following: "Since – in contrast to the scenarios included in the load assumptions in terms of disruptive action or other interference by third parties – with regard to the scenario "terrorist aircraft crash" no specific provisions have been made in the regulations on disruptive action or other interference by third parties with regard to the means of action to be postulated or not to be postulated (thus, in this case the aircraft type) , it is incumbent [...] on the respective competent authorities to define the scope of investigations for the identification of measures which, taking into account the principle of proportionality, minimise or limit radiation exposure in case of an aircraft crash. All aircraft types regularly used for passenger traffic are to be included in the analysis. However, according to the current state of knowledge, the *Länder* Committee for Nuclear Energy – General Committee – assumes that, based on the RSK approach, Airbus A340-600 can generally be regarded as an exemplary aircraft type."

4 Definition of boundary conditions

In view of the lack of nationally and internationally established procedures for the investigation of targeted terrorist attacks using a commercial aircraft, appropriate approaches for determining the impacts had to be defined, as explained below.

For this purpose, the data used in the GRS study "Protection of German Nuclear Power Plants against the Background of the Terrorist Attacks in the USA of 11 September 2001" were checked by the RSK ad hoc working group on aircraft crash (Ad-hoc-AG FLUGZEUGABSTURZ), also referring to further data from aircraft manufacturers and airlines.

In the further course, the RSK Ad-hoc-AG

- reviewed and assessed the approach and adapted the boundary conditions based on the first results of the investigations on the robustness of the German nuclear power plants in operation against the crash of a commercial aircraft,

- defined the reference velocity, the mass of the reference aircraft, the impact position and the impact angle as well as the boundary conditions for system engineering procedures and fuel fires for the calculations for a deliberate aircraft crash, and

- defined the concept for the analytical investigations on the aspects of such an aircraft crash regarding structures, systems and components.

For investigations on the robustness of nuclear power plants against the (deliberate) crash of passenger aircraft, assumptions must be made regarding characteristic values which are decisive for the resulting loads (e.g. aircraft type, associated derivable mass and velocity of the aircraft as well as quantity of kerosene). Since there is a large spectrum in air traffic in terms of these characteristic values, it is appropriate to structure the investigations in such a way that the aircraft are divided into size classes, each of which is assigned a representative aircraft.

Against this background, the RSK concretises the degrees of protection defined in its statement on the assessment of robustness after the accident in Fukushima with the following levels:

Degree of protection 1
Loads from the crash of a Starfighter military aircraft (a Starfighter aircraft covers air traffic with small aircraft types where access is not monitored, i.e. where government measures against hijacking cannot be taken).

Degree of protection 2
Loads from the crash of a heavier Phantom military aircraft and a medium-sized commercial aircraft such that the reference aircraft selected covers approximately 90 % of the possible load impacts, based on the assessment of aircraft types and the evaluation of data on aircraft movements types and on movements in scheduled and charter traffic in European airspace. This class is represented by the Airbus A 320.

Degree of protection 3
Loads from the crash of a large commercial aircraft such that the reference aircraft selected covers approximately 99 % of the possible load impacts, based on the assessment of aircraft types and the evaluation of data on aircraft movements types and on movements in scheduled and charter traffic in European airspace. This class is represented by the Airbus A 340-600.

When comparing the possible load impacts, the maximum take-off weights and the mass distribution of the aircraft types were taken into account.

The evaluation of aircraft movements in European airspace was carried out by GRS for a period of 12 months based on data from a publication by EUROCONTROL EXPERIMENTAL CENTER.

Degree of protection 1 and degree of protection2/type Phantom are no longer dealt with within the framework of the new robustness assessments by the RSK presented here since the design at the time of construction already covers the corresponding scenarios for the nuclear power plants still in operation, see RSK Safety Review 2011 (statement from the 437th RSK meeting from 11 to 14 May 2011). Therefore, the investigations were limited to the representative commercial aircraft types A 320 and A 340. The attacks on the WTC and the Pentagon were carried out with commercial aircraft (B 767 and B 757) which are between types A 320 and A 340 in size and weight.

Other aircraft, such as the A 380, as well as military or civil special aircraft (e.g. Antonow An-225), were not examined as the number of related movements is significantly lower (less than 0.5 %) than the number of movements covered by the reference aircraft. Moreover, a consideration of the load-determining characteristics shows that larger aircraft do not necessarily lead to less favourable impacts.

Regarding the selection of the aircraft types to be considered, the RSK is of the opinion that the spectrum of fast flying jet-powered commercial aircraft flown in European airspace is sufficiently covered by the selection of appropriate reference aircraft as described above. The reference aircraft used provide a good basis for an assessment of the robustness of the NPPs.

The impact velocity was assumed to be the velocity that was also used in the GRS study on the protection of German nuclear power plants against the background of the terrorist attacks in the USA of 11 September (Schutz der deutschen Kernkraftwerke vor dem Hintergrund der terroristischen Anschläge in den USA vom 11. September) and which, after further research by GRS, is regarded by the RSK as representative for a still controllable aircraft approach at the low required altitude within the scope of this robustness investigation. When determining the velocity, both the general flight conditions and the results from simulator tests and pilot interviews were taken into account.

The loading situation of the aircraft, both in terms of total weight and kerosene quantity, was taken as a basis and covered a large proportion (95 %) of the real aircraft movements of the respective reference aircraft type in Germany. For this purpose, GRS evaluated the aircraft movements of the representative aircraft types in Germany for a period of one year.

When determining the impact location, possible approach scenarios were considered (approach not disturbed by obstacles) and an area of the reactor building was selected where unfavourable effects are to be expected due to the geometric conditions.

Regarding the fire scenarios, the location that has the worst effects was chosen, considering that the kerosene can get there when the aircraft crashes. A conservatively high burn-up rate was taken into account, which leads to the complete burning of the kerosene pool before possible extinguishing measures are started. In addition, it was considered whether effects on canal pipes or other buildings could lead to failures that could result in cliff-edge effects.

The entirety of the boundary conditions used represents a definition that defines a resulting load in the upper range of the loads from the possible combinations of parameter values but does not assign the most unfavourable possible individual value to each parameter.

5 Methodology of analyses and assessments

5.1 Modelling of reactor building and aircraft

The analyses of the behaviour in terms of structures, systems and components were largely carried out using best-estimate methods, also considering the influence of the scatter of single essential parameters.

The computational analyses of the structural behaviour were carried out with the ABAQUS/Explicit code, which allows elastic and elasto-plastic deformations to be determined and complex non-linear material models for highly dynamic loads to be taken into account. With the code, both the reactor building and the impacting aircraft were modelled using detailed finite element models (FE model). Both models were coupled for the calculation in order to directly determine the response of the structure to the impact of the aircraft in an overall model. The models were compared with data from the manufacturers of reactor buildings and aircraft.

The reactor building model is based on the operator's construction documentation.

The outer shell of the reactor building (secondary shielding) was modelled in detail with volume elements for the concrete and under consideration of the reinforcement. In the area of the impact point, a finer mesh with a more increased number of volume elements over the wall thickness was selected than outside the impact area. The tensile and shear reinforcement was modelled explicitly with beam elements in the impact area. In the model, the beam elements of the reinforcement were rigidly coupled with the nodes of the concrete structure.

In the building model, the essential building structures in the annulus are taken into account. These are all building structures including the uppermost solid ceiling with a thickness of 60 cm. The effect of the expansion joint (so-called EVA-Fuge, i.e. external hazard joint) between the reactor building wall and the end face of this ceiling was modelled non-linearly. After closure of the joint due to the local deformation of the reactor building, the ceiling behind it acts like an abutment which, on the one hand, supports the reactor building wall but, on the other hand, leads to an increased input of impact-induced vibrations into the annulus structures. The primary circuit and other heavy mechanical components were not modelled explicitly in the model. The masses of these components are rather added locally to the building mass.

The solid base plate of the reactor building is modelled in the FE model as a rigid plate, which is coupled to the ground via spring and damping elements.

In the structural calculations, material parameters for the concrete and reinforcement were used which, according to engineering experience, result in a description of the structural behaviour that is as realistic as possible.

The modelling approaches and the material models for the reactor building have been validated as far as possible on the basis of experiments documented in the technical literature.

In the aircraft model, the effect of the kerosene was modelled in such a way that the mass of the kerosene was added to the masses of the associated structural components of the aircraft.

The results of the coupled best-estimate calculations for the load-time function were checked and confirmed by comparison with the results of recognised simplified methods (Riera method).

In addition to the global stability of the reactor building, the coupled model described above was used to calculate local deformations and damages of the building wall in the impact area (in particular the deflection of the outer shell of the reactor building) as well as the impact-induced vibrations (floor response spectra) at positions in the building where safety-relevant components and building structures are located that are required for vital functions.

The LS-Dyna code was used in the coupled analyses carried out by an engineering company in parallel and independently on behalf of the operators. In parts, different modelling approaches and material parameters were used. The comparison with the results of these calculations allowed an additional assessment of the effects of model uncertainties on the calculation results.

5.2 Assessment of structures, systems and components with regard to impact-induced vibrations

The impact of the aircraft on the outer shell of the reactor building induces vibrations within the building. To calculate the transmission of the vibrations, the model of the reactor building described above was used. This model was used to calculate the acceleration spectra or the acceleration time history and the displacements at the attachment points of those mechanical components (“floor response spectra”) that are relevant for ensuring the vital process engineering functions.

The assessment as to whether these components maintain their integrity and, if necessary, their functionality despite the loads that occur was carried out in multiple steps:

a) In a first step, the determined spectra were compared with the spectra or load assumptions used for the original design of the respective components for earthquakes and aircraft crashes. As far as the new spectra resulted in lower loads than in the design, the assessment could be completed positively.

b) As far as the new spectra resulted in higher loads than those assumed in the design (e.g. for higher frequencies in the spectrum compared to the original loads from aircraft crash), the displacement to be expected at the component was considered. For displacements < 1 mm, the assessment could also be concluded positively since such small displacements due to the play in the supports and the elasticity in the components certainly do not lead to damage.

c) If a and b could not be confirmed, the design and installation documents of the corresponding components were used for verification. In individual cases, a positive assessment was possible if the design of the component covered higher loads than the currently determined spectra (e.g. larger loads from other load cases such as LOCA, large reserves in the maximum stress ratio for this load case, larger verified accelerations on the shaking table).

d) If a – c do not allow a positive assessment, it is possible to recalculate the bearing capacity of the components e.g. using FE methods. This was made use of for the assessment of the flooding pools of the Konvoi plants.

6 Results for Konvoi plants

6.1 Results for degree of protection 2

- **Behaviour of the outer reactor building wall in the area of the point of impact**
  There is neither wall penetration of the reactor building (outer shell) by aircraft structures nor displacement of the concrete structures, which can bridge the joint between the outer building wall and the internal building structures. Entry of kerosene into the reactor building is excluded.

- **Global stability of the building**
  The global stability of the building is not questioned.

- **Impact-induced vibrations, effects**
  In the lower frequency range (comparable with the frequencies excited by the earthquake), the design values for the acceleration of components are in each case undercut with the impact-induced vibrations. In the upper frequency range, the accelerations underlying the design against aircraft crash are slightly exceeded in some cases, which, however, cannot cause any danger to components with the low vibration amplitudes determined.

- **Fire impacts**
  The effects of an external fire do not endanger building structures or the systems and electrical equipment necessary to control the event. This was not explicitly considered for the aircraft category degree of protection 2 but was derived from the considerations for degree of protection 3 by which it is covered.

6.2 Results for degree of protection 3

- **Behaviour of the outer reactor building wall in the area of the point of impact**
  There is no wall penetration of the reactor building (outer shell) by aircraft structures. The entry of kerosene into the reactor building can therefore be excluded. The maximum displacement of the concrete structures leads to the joint between the outer building wall and the internal building structures being bridged locally which, on the one hand, leads to a partial transfer of impact loads to the internal structures (ceilings and walls in the annulus) and, on the other hand, to a supporting effect for the outer building wall. This leads to local damage at the contact point, but not to a failure of the internal building structures. A shock transfer of impact loads to the containment was not detected.

- **Global stability of the building**
  The global stability of the building is not questioned. For large parts of the building, the structures respond elastically .

- **Impact-induced vibrations, effects**
  In the lower frequency range (comparable with the frequencies excited by earthquakes), the design values of accelerations for the equipment relevant for safety and therefore designed to withstand external hazards are in each case undercut with the impact-induced vibrations in the building areas remote from the point of impact (containment and the components located in the lower part of the annulus). In the upper frequency range, the accelerations underlying the design against aircraft crash are exceeded in some cases, which, however, cannot cause any danger to components with the low vibration amplitudes determined.

  Due to the bridging of the joint between external and internal building structures during a load impact, the induced vibrations in the annulus at the level of the point of impact were considered in more detail for this load case with regard to their effects on safety-relevant components. As a result, it can be seen that the accelerations on which the design against aircraft crash is based also in this case are only exceeded in the upper frequency range. With regard to the vital functions, it could be demonstrated that the required number of necessary components in the redundants remote from the impact location is maintained. The integrity of components with flooding potential was also demonstrated for the area close to the point of impact.

  For the equipment that is not relevant for safety and therefore not designed to withstand external hazards, it was assumed in general terms that there could be a loss of integrity, especially in the case of water-carrying pipes and containers. However, the analysis shows that even with the maximum amount of water to be postulated in the annulus, there will be no flooding of components required for vital functions and that these thus retain their functionality.

- **Fire impacts**
  The effects of an external fire do not endanger building structures or the systems and electrical equipment necessary to control this event. If a kerosene pool burns below the valve compartment, there

will be no inadmissible temperatures for components in the valve compartment that are required for vital functions.

6.3 Results for postulated leakage in the reactor coolant pressure boundary

The plants to be considered have been designed in such a way that the integrity of the reactor coolant pressure boundary is also ensured during accelerations such as can occur in the case of design earthquakes or the postulated impact of a fast flying military machine (load-time function according to RSK Guideline) as a result of induced vibrations. In the design, a loss of coolant due to a leak is therefore not postulated for these events. Despite the design of the piping of the reactor coolant pressure boundary to withstand loads from the aircraft crash according to the RSK Guideline, the RSK had included in its work programme to postulate the rupture of a small pipeline in this area and to investigate the possible effects.

Due to the margins in the design of the plants determined above it is not to be expected that a leak with loss of coolant will occur as a result of vibrations induced by the impact of a commercial aircraft of degree of protection 2 or 3 with increased accelerations in higher frequency ranges. Nevertheless, the rupture of a line connecting to the reactor coolant pressure boundary for the load-time function was postulated in accordance with the RSK Guideline. Simultaneous occurrence of two beyond-design-basis events (crash of a commercial aircraft and rupture of a line connecting to the reactor coolant pressure boundary) was not postulated.

The RSK defined the following boundary conditions for the investigation:

- leakage rate corresponding to a DN 50 leak from a rupture of a line connecting to the reactor coolant pressure boundary at the most unfavourable location,
- skilled staff available so that credit can be taken from manual controls after two hours,
- crediting only of equipment and systems which are protected by structural measures or spatial separation against the effects of the impact of an aircraft on the reactor building,
- investigation of the event sequence with shutdown of the plant to a state in which the leakage in the reactor coolant pressure boundary can be compensated with the emergency core cooling pumps in sump operation if the plant is subcritical.

The operators submitted a study with the following conservative assumptions: unavailability of the auxiliary power supply as well as the D1 system and thus the operational feed water supply, the volume control system and the pumps of the emergency core cooling and residual heat removal system, with the following results:

- Due to the postulated small leak, the pressure in the reactor containment rises and the fast secondary cooldown (100 K/h) is actuated automatically relatively soon. The level in the steam generators is maintained by the emergency feedwater system.

- As the pressure in the primary circuit drops as a result of the secondary-side shutdown, the leakage rate decreases continuously, so that the filling level in the primary circuit can be maintained above the upper edge of the core, first by injections via the hot-leg accumulators and then for a longer period (after just under two hours) by the extra borating system. In this constellation, secondary-side heat removal and core coverage would be ensured for more than ten hours, even if no measures were taken by the plant personnel during this time.

- Thus, there is sufficient time for the plant personnel to actuate the emergency core cooling and residual heat removal system so that the primary circuit can be refilled and to switch over to primary-side heat removal.

The RSK states that with these results it was shown that an aircraft crash scenario with the load-time function according to the RSK Guideline with an additionally postulated small leak due to the rupture of a line connecting to the primary circuit does not result in cliff-edge effects and is controlled.

7 Conclusions

With this reference report, the RSK concluded its consultations on the topic “aircraft crash” for the Konvoi plants. The RSK concludes the following:

The entirety of the boundary conditions used represents a specification that defines a resulting load in the upper range of the loads from the possible combinations of parameter values but does not assign the most unfavourable possible individual value to each parameter.

The fulfilment of the requirements from degrees of protection 2 and 3 could be demonstrated. No evidence of cliff-edge effects was found for any of the impacts considered. The vital functions for the control of the events are maintained to the extent required.

The boundary conditions and assumptions for the reference plant also apply to the other Konvoi plants or cover these plants. This applies equally to the evaluation of results and the resistance against the load effects.

This shows that even in the event of a deliberate crash of a large commercial aircraft onto one of the Konvoi plants still in operation, cooling of the fuel elements in the reactor and fuel pool is maintained so that releases of radioactive material from fuel damage are not to be expected.

In addition, it was shown that an aircraft crash scenario with the load-time function according to the RSK Guideline with an additionally postulated small leak due to the rupture of a line connecting to the primary circuit does not result in cliff-edge effects and is controlled.