Note:
This is a translation of the RSK statement entitled
"Konkretisierung von Anforderungen im Zusammenhang mit der 10 h-Autarkie
bei zivilisatorischen Einwirkungen von außen (Notstandsfälle)"
In case of discrepancies between the English translation and the German original, the original shall prevail.

RSK statement
(459th meeting on 20 June 2013)

Specification of requirements related to the 10-hours autarky in the event of external human-induced hazards (emergency conditions)

1 Background

In the course of the consultations within the Committee on REACTOR OPERATION (206th meeting, [1]) on the topic of assessing the non-availability of the excess water rejection function in the LAR emergency feedwater piping system in the event of activation of three-way valves in the Philippsburg nuclear power plant (Unit 2) in terms of safety, questions arose regarding the demonstration that the 10-hours autarky is maintained as defined in the RSK guidelines [2], which the Committee on PLANT AND SYSTEMS ENGINEERING was requested to consult on. Further need for consultations by the Committee arose from considerations regarding the long-term availability of the cooling of the D2 emergency diesel generators, which were triggered by the review process in the context of the EU stress test for German nuclear power plants. The need for clarification and specification in this regard relates to the following aspects:

a) Simultaneous occurrence of an emergency condition and a single failure
b) Requirements for measures to supplement the emergency feedwater supplies at the PWR
c) Operating regulations

2 Consultations within the RSK Committee on PLANT AND SYSTEMS ENGINEERING

At the 79th meeting of the RSK Committee on PLANT AND SYSTEMS ENGINEERING on 19 April 2012 [3], an overview was given of the consultations within the Committee on REACTOR OPERATION [1] as well as the issues raised and contributions to the discussions. For the 80th meeting of the Committee on PLANT AND SYSTEMS ENGINEERING 31 May 2012, the need for concretisation with regard to the 10-hours autarky required in the RSK guidelines was summarised (see 80th meeting [4]) and discussed at this and other meetings [5, 6].

The subject of the consultations were both the technical issues relating to the boundary conditions of the 10-hours autarky and to the subsequent cooldown to the switchover conditions for heat removal by the emergency core cooling system, and the associated procedures in the operating regulations.

It was discussed whether it would be possible to switch to long-term emergency core cooling with the emergency system in case the control room was not in a functional state with the available water supplies and what technical equipment could be used to refill the emergency feedwater tanks.

At the 83rd meeting of the RSK Committee on PLANT AND SYSTEMS ENGINEERING on 4 October 2012, GRS reported on PKL III tests *[PKL – Primärkreislauf-Versuchsanlage (primary coolant loop test facility)]* on cooldown without running reactor main coolant pumps with a steam generator which is isolated on the steam side. The most unfavourable cooldown conditions were found with one filled steam generator isolated on the steam-side and three active steam generators.

At the 84th meeting of the Committee on 8 November 2012, GRS reported on its analyses of the shutdown of a PWR in the event of an emergency condition until heat removal is taken over by the emergency core cooling system [8]. This requires setting a boron concentration sufficient to ensure subcriticality, cooling down the primary circuit to a temperature < 160° C and reducing the pressure in the primary circuit to a value < 35 bar. To this end, GRS presented the analyses carried out for the base case (all four steam generators are available for pressure reduction, no single failure) and for two variants with the following boundary conditions:

- all four steam generators are available for secondary-side heat removal at the start of the event; the failure of an emergency diesel generator leads to the failure of the supply to one steam generator (variant 1);

- one steam generator isolated on the main steam side, with failure of the relief valve (variant 2).

GRS established that, in the base case, cooldown is possible at 50 K/h until residual heat removal is taken over by the emergency core cooling system, with sufficient boration to ensure subcriticality. In variants 1 and 2, cooldown at 50 K/h would result in evaporation in the U-tubes of the steam generator, which is empty on the secondary side and isolated on the steam side, respectively, and complete filling of the pressuriser. In these cases, pressure reduction with a cooldown gradient of 50 K/h to a pressure < 35 bar and switchover to the emergency core cooling system for residual heat removal would therefore not be possible. Cooldown without evaporation in the U-tubes of the isolated empty steam generator analogous to the PKL tests would be possible with a gradient of about 10 K/h. With a filled isolated steam generator, an even smaller cooldown gradient would be required.

The Committee pointed out that for variants 1 and 2 considered by GRS, possibilities exist and could be used to restore heat removal via the “failed” steam generator after ten hours, so that these variants would then be transferred to the base case conditions.

3 Assessment criteria

The RSK guidelines [2], Chapter 22.2, Systems for Post-Incident Heat Removal, Emergency System, define the following:

(1) *In case the control room is not in a functional state it shall be assured that the emergency system will bring the plant into a safe state without any manual intervention and that the plant can remain in this state for at least 10 hours. In addition, it shall be possible, with the aid of the emergency system by a blowdown on the secondary side, to bring the plant into a state which will permit the subsequent residual heat removal through the special emergency residual heat removal system. No redundancy is required for this emergency residual heat removal system.*

Emergency measures need not be automated if there is sufficient time available prior to their initiation or if their initiation can be provided for by administrative measures. Local auxiliary measures may be reverted to for the long-term control in an emergency case.

(2) *In detail, the emergency system shall comply with the following safety-related requirements:*

1. *Components and subsystems of the emergency system shall be protected against external events and events caused by third parties.*

2. *A consistent separation of the emergency system from other nuclear power plant systems shall prevent the function of the emergency system from being unacceptably affected by damage caused in plant areas which may be destroyed. This applies not only to process systems but also to energy supply systems and the reactor protection system.*

Regarding the single failure concept, the RSK guidelines [2], Chapter 19.1, Aircraft Crash, define the following:

(7) *The design against an aircraft crash need not be based on the assumption of a simultaneous occurrence of a single failure nor on the assumption that repair work will be carried out at the same time.*

(8) *If the control of such an aircraft crash requires the function of safety systems before 30 minutes have elapsed, a single failure in active system components shall be postulated. When discussing the long-term residual heat removal phase it shall be demonstrated that, if necessary, repair work can be carried out in time on the safety features required for the long-term residual heat removal phase.*

Regarding the simultaneous occurrence of an emergency condition and a single failure, the “Interpretations of the Safety Criteria for Nuclear Power Plants” on the “Single Failure Concept – Principles for the Application of the Single Failure Criterion” [7] state the following:

As a matter of principle, internal events and external impacts shall be equated as far as the application of the single failure concept is concerned.

In the case of internal events having a very low probability of occurrence (such as ATWS), in the case of external impacts having a very low probability of occurrence (such as aircraft crash or explosion shock wave), and in the case of chains of events having a very low probability of occurrence, which are not design basis incidents as defined in § 28(3) of the Radiation Protection Ordinance, there is no need to postulate either a simultaneous occurrence of a single failure or a simultaneous repair case.

The requirements for coping with emergency conditions contained in the "Safety Requirements for Nuclear Power Plants" [9], adopted on 20 November 2012, essentially correspond to the requirements in the RSK guidelines [2].

Regarding the simultaneous occurrence of an emergency condition and a single failure, Annex 4 "Principles for applying the single fault criterion and the maintenance" of the "Safety Requirements for Nuclear Power Plants" requires the following:

2.4 (1) For safety-relevant equipment required to cope with very rare human induced external hazards in all operational modes neither a single failure nor a maintenance case have to be postulated (degree of redundancy n+0).

2.4 (2) For the function of equipment required to cope with very rare human induced external hazards within the first 30 minutes after the impact, a single failure in active system components of these equipment shall be postulated (degree of redundancy n+1). For equipment not required within the first 30 minutes neither a single failure nor a maintenance case have to be postulated (degree of redundancy n+0).

The RSK recommendation "Regulations on plant states after occurrence of an accident" [10] and the RSK's recommendations regarding the robustness of German nuclear power plants [11], [12] are also used as assessment standards for the specification of requirements in connection with the 10-hours autarky.

4 Specification of requirements and derivation of recommendations

In the consultations of the Committee on PLANT AND SYSTEMS ENGINEERING, considerations regarding the long-term maintenance of the cooling of the D2 emergency diesel generators, which were triggered by the review process in the context of the EU stress test for nuclear power plants, revealed a need for clarification and concretisation with regard to the following aspects:

a) Simultaneous occurrence of an emergency condition and a single failure
b) Requirements for measures to supplement the emergency feedwater supplies at the PWR
c) Operating regulations

As to a): Simultaneous occurrence of an emergency condition and a single failure

Section 3 shows that the requirements of the nuclear rules on the simultaneous occurrence of an emergency condition and a single failure, as they existed until the adoption of the "Safety Requirements for Nuclear Power Plants", had not been standardised. While, on the one hand, according to the "Principles for the

Application of the Single Failure Criterion" [7], the simultaneous occurrence of a single failure or outage for repair together with the emergency condition was not to be postulated, on the other hand, according to the RSK guidelines [2], a single failure was to be postulated in the active system components of those safety systems whose function is required for the management of an aircraft crash before 30 minutes have elapsed.

Despite the requirements in [2], in the chapter on external hazards[1] during power operation operating manuals for PWR plants state with reference to [7] that the simultaneous occurrence of a single failure or outage for repair and external hazards is not postulated.

With the adoption of the "Safety Requirements for Nuclear Power Plants" [9], it is required that for the function of systems and equipment required within the first 30 minutes, a single failure in active system components of these equipment shall be postulated. The relevant requirement in the "Safety Requirements for Nuclear Power Plants" [9] thus corresponds in essence to the requirements in Chapter 19.1 of the RSK guidelines [2].

However, discussions in the Committee on PLANT AND SYSTEMS ENGINEERING have shown that there is still room for interpretation with regard to the determination of the functions of systems and equipment required within the first 30 minutes. In this respect, the RSK recommends the following concretisation:

Functions that are demanded within the first 30 minutes and whose effectiveness is required to achieve and maintain a controlled plant state during the 10-hours autarky period should also be ensured taking into account a single failure.

As to b): Requirements for measures to supplement the emergency feedwater supplies at the PWR

The operation of the D2 emergency diesel generators is essential for plant shutdown after the 10-hours autarky period and for continued residual heat removal if no other power supply is available or can be established in the short term. For this purpose, the provision of sufficient operating and auxiliary supplies (diesel, lubricating oil) as well as sufficient supply of demineralised water or water for diesel cooling is to be ensured. In addition, continued supply to the steam generators may have to be ensured.

The Committee uses the following information as a basis for its consultations:

- The reserves of demineralised water in the emergency feedwater tanks are sufficient for steam generator supply and diesel cooling at least during the 10-hours autarky period, but must be supplemented thereafter if the steam generator supply and the power supply to the required consumers are not ensured by other means. Otherwise, the D2 emergency diesel generators would fail due to insufficient cooling, which would affect the secondary and primary residual heat removal systems assigned to the D2 emergency diesel generators.

- If the 100 K/h cooldown is started automatically during the autarky period due to coolant pressure < 131 bar AND Δp > 30 mbar (differential pressure between containment and atmosphere), this does not result in less favourable conditions since, on the one hand, more emergency feedwater is injected into

[1] External hazards refer to the very rare events of aircraft crashes and blast waves.

the steam generators during the autarky period but, on the other hand, this reduces the amount of rejected demineralised water from the diesel cooling system.

- There are various options in the plants for providing additional water/demineralised water supplies that are required after the autarky period. In some plants, there are make-up options via permanently installed and D2-supplied systems (e.g. well water systems) or pipes from the service water system, which is designed to withstand external hazards, to the emergency feedwater building. Additional injection options utilise supplies in buildings that are not designed against external hazards but are spatially separated, although a functional D1 power supply is required. There are also other make-up options, which are described, e.g., in emergency manuals.

In the opinion of the Committee on PLANT AND SYSTEMS ENGINEERING, the cooling water supply to the D2 emergency diesel generators (as well as the supply to the steam generators, if necessary) should be designed to be reliable and effective as part of the emergency measures to be provided for even after the demineralised water reserves in the demineralised water tanks have been used up.

Against this background, the RSK recommends that within the framework of an overall external hazards concept for the secured water supply of the emergency feedwater system, a possibility for water supply via permanently installed systems (including power supply) that are also functional under these conditions should be available after the reserves of the emergency feedwater tanks have been used up (taking into account the degree of protection of buildings and their spatial separation). Manual measures, such as installing connecting pieces within buildings that are accessible and designed against emergency conditions or which can be postulated to be undamaged due to spatial separation, are permissible. The capacity of these secured available make-up systems must be sufficient to ensure the safe operation of the required D2 emergency diesel generators and the continued supply to the steam generators (when necessary).

If retrofits are required in plants to fulfil this recommendation, it should be demonstrated that sufficient water make-up will be available until the retrofits are implemented. If other injection options are used in addition to permanently installed systems, the practical applicability of these options should be demonstrated, taking into account the given circumstances.

As to c) Operating regulations

Regarding the measures and procedures to be described in the operating regulations for emergency conditions, it must be taken into account:

- that different consequential damages may occur due to external hazards, and,

- that after automatic stabilisation of the plant in the controlled state “hot, subcritical”, a procedure must be defined in the operating regulations as to how the plant can be transferred to the “cold, subcritical, unpressurised” state after the autarky period, depending on the plant state and system availability, and then kept in this state in the long term.

Therefore, from the RSK's point of view, it is necessary that the operating regulations:

- contain specifications for examining the plant state with regard to the availability of the systems and equipment required for further event control and management, and

- specify necessary measures, including the refilling of the demineralised water tanks, in an appropriate and sufficiently detailed manner on the basis of the plant-specific options available. These specifications should also take into account automatic shutdown during the 10-hours autarky period and the occurrence of a single failure.

5 Summary of the results

In summary, the RSK makes the following recommendations:

Specification of the requirement regarding the simultaneous occurrence of an emergency condition and a single failure

The RSK recommends that functions that are demanded within the first 30 minutes and whose effectiveness is required to achieve and maintain a controlled plant state during the 10 hours autarky period should also be ensured taking into account a single failure.

Specification of requirements for measures to supplement the emergency feedwater supplies at the PWR

The operation of the D2 emergency diesel generators is essential for plant shutdown after the 10-hours autarky period and for continued residual heat removal if no other power supply is available or can be established in the short term. For this purpose, the provision of sufficient operating and auxiliary supplies (diesel, lubricating oil) as well as sufficient supply of demineralised water or water for diesel cooling is to be ensured. In addition, continued supply to the steam generators may have to be ensured. In the opinion of the RSK, the cooling water supply to the D2 emergency diesel generators (as well as the supply to the steam generators, if necessary) should be designed to be reliable and effective as part of the emergency measures to be provided for even after the demineralised water reserves in the demineralised water tanks have been used up.

On this issue, the RSK recommends,

- that within the framework of an overall external hazards concept for the secured water supply of the emergency feedwater system, a possibility for water supply via permanently installed systems (including power supply) that are also functional under these conditions should be available after the reserves of the emergency feedwater tanks have been used up (taking into account the degree of protection of buildings and their spatial separation). Manual measures, such as installing connecting pieces within buildings that are accessible and designed against emergency conditions or which can be postulated to be undamaged due to spatial separation, are permissible. The capacity of these secured available make-up systems must be sufficient to ensure the safe operation of the required D2 emergency diesel generators and the continued supply to the steam generators (when necessary).

- that, if retrofits are required in plants to fulfil this recommendation, it should be demonstrated that sufficient water make-up will be available until the retrofits are implemented. If other injection options are used in addition to permanently installed systems, the practical applicability of these options should be demonstrated, taking into account the given circumstances.

Recommendation on specifications in the operating regulations

From the RSK's point of view, it is necessary that the operating regulations

- contain specifications for examining the plant state with regard to the availability of the systems and equipment required for further event control and management after the 10-hours autarky period, and

- specify necessary measures, including the refilling of the demineralised water tanks, in an appropriate and sufficiently detailed manner on the basis of the plant-specific options available. These specifications should also take into account automatic shutdown during the 10-hours autarky period and the occurrence of a single failure.

References

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