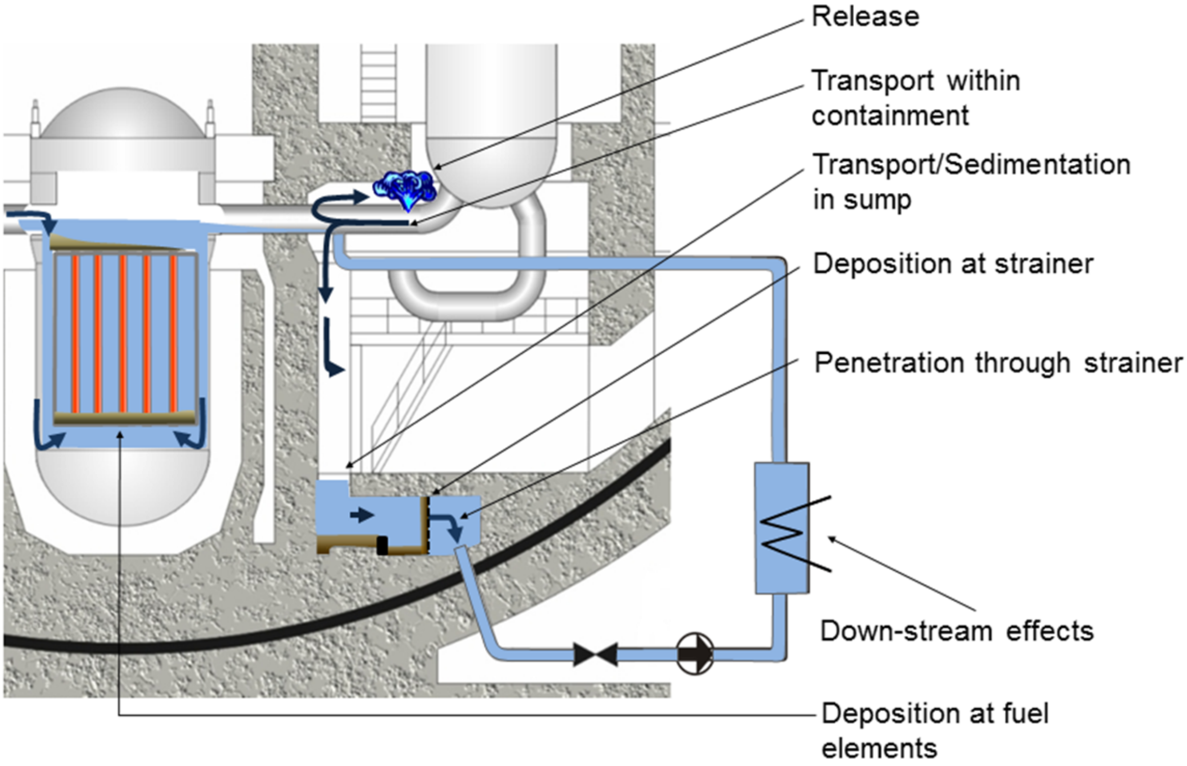
# Reliability of Core Cooling and Cooling Systems in Case of a LOCA with Release of Insulation Material

## Sump Clogging Issue

The following description of the sump clogging issue is based on the paper: "LOCAs with release of insulation material: generic aspects and international solutions", published at Kerntechnik 76/1 /KT7601/.

In the case of a Loss-of-coolant-accident insulation material in the surrounding of the broken pipe can be hit by water or steam jet. The insulation material will be partially removed from the pipes and fragmented. Some parts will be retained by walls, floors and equipment (e.g. gratings) within the containment. The remaining part will be washed into the sump. Depending on the flow velocity and water temperature part of the material will sediment on the floor of the sump. After starting the emergency core cooling (ECC) pumps insulation material together with the sucked water will reach sump screens and down-stream components.




The retention capability of the strainers depends in particular on the mesh size in case of a grid or on the hole diameter in case of perforated plates. According to the properties of the retained filter cake an additional pressure drop across the strainer will be caused. The strainer could clog under worst case conditions. In any case the strainer has to resist the additional loads also in a long-term core cooling operation mode. Sufficient flow through the strainer has to be ensured to operate the emergency core cooling pumps without cavitation. The sump water pumped through the reactor core might be polluted by debris. There is a danger of deposition of this debris at the spacers and inlet strainers of the fuel elements and core cooling can be at risk.
Because of the importance of the residual heat removal a LOCA with release of insulation material is a design basic accident and the control of accident has to be shown.

There exist strong dependencies between the processes and components involved in sump clogging. These dependencies make the evidence of efficiency of measures difficult. Some examples can clarify that:

- To calculate the amount of insulation material at strainers and to make experiments the amount of released insulation material, its fragmentation and mixture of different materials is important to know. Depending on the leak size and leak position, the debris release can vary in a wide area.
- The retention of released material depends on the size of fragments.
- A high flow velocity in sump area results in a lower sedimentation rate into sump.
- A higher retention at strainers can result in a better retention especially for small particles. The head loss across strainers can strongly increase and endanger the mechanical integrity of the strainers. On the other hand, a good retention for small particles will be necessary to prevent clogging within the fuel bundles.

Because of such dependencies a worst case discussion is difficult. Different scenarios have to be considered.

**Leak Size**

Due to the "break preclusion" concept to primary coolant, main steam and main feedwater lines, only the control of a postulated 0.1 A leak (i.e. 10 % of pipe sectional area) in these lines had to be shown as far as dynamic consequences are concerned (i.e. jet and reaction forces, pressure waves). For lines without break preclusion leak sizes up to 2A have to be investigated.

**Insulation Material**

Experimentally it was shown that mixtures of different types of insulation material and especially deposition of corrosion products may result in head losses exceeding design values of the strainers. In the German NPPs, the insulation materials are generally encapsulated in cassettes. For all German NPPs insulation material was exchanged to reduce mixtures of different types of insulation material, e.g. mixtures of mineral wool and microporous material, and mixtures of different types of mineral wool, e.g. MD2, RTD2 and MDK.

**Strainers**

The load of fibers at the strainers is between 0.2 and 0.4 kg/m² for a leak with an assumed maximum release of insulation material and in case of operation of all ECC trains. For a combination of maximal release of insulation material and operation of only two ECC trains more than 0.4 kg/m² can be deposited at the strainers. In such cases the design limit for the head loss at the strainer could be exceeded. A qualified head loss monitoring was installed in PWRs with fibrous insulation. Capabilities for backflushing were realized to ensure limitation of head loss across the strainers. The backfitting measures were implemented. The efficiency of the measures is demonstrated and approved by the supervision authorities of the responsible German states.

The penetration of insulation material through the strainers can lead to high deposits on the spacers of the fuel elements and, as a consequence, to high head losses. Because of the uncertainties in the evidence of sufficient core cooling, it was decided to install sump strainers with mesh size 2 x 2 mm.

**ECCS pumps**

Calculations performed for all German PWRs indicate that the NPSH drop due to strainer clogging will not cause cavitation of the recirculation pumps.

**Chemical Effects**

Experiments have shown an increase of the head loss across the filter cake at the strainers 10 hours after leak opening due to the deposition of erosion and corrosion products. Corrosion and erosion products may be generated from zinc coated step gratings within the jet of borated water from the leak or from covering by borated water.

Due to the use of boron acid and LiOH the water chemistry is simple compared to NPPs with other types of chemical buffers. Therefore no other mid-term chemical effects than erosion and corrosion of the zinc coated step gratings are expected.

**Long-term Effects**

In long term experiments (over appr. two years) strong corrosion of zinc coated step gratings covered by borated water was observed. Therefore the strainers and all holding structures should be manufactured by using austenitic material to ensure long term mechanical stability. Alternatively the design limit of the head loss across the strainers should be reduced in case of extra-long term post-LOCA operation.

**BWRs**

For BWRs the holistic approach for PWR has to be used correspondingly. Special attention has to be given to the transport to control rod drive room and the condensation chamber. Additionally the transport via the overflow line from the control rode drive room to the pressure suppression pool and the re-suspension of sedimented material within the pressure suppression pool have to be taken into account. For the two BWRs of KWU-type 72 the evaluation of the proof of evidence is under progress and is planned to be finished until end of 2014.

**Further Investigation**

Experimental work initiated by licensees has been in progress for years. Actual issues are to investigate e.g. chemical effects on zinc coated step gratings and the validation and further development of CFD calculations for transport and sedimentation of debris in sump water. Effect of zinc accumulation at heated PWR fuel elements will be investigated at the HZDR/IPM within a research project founded by BMWI from 2012 to 2014.

## Requirements

In general the accident management in case of a LOCA should fulfill the Safety Standards of the Nuclear Safety Standards Commission on “Residual Heat Removal Systems of Light Water Reactors” /KTA3301/. The assessment in case of a LOCA with the release of insulation material is based on the RSK requirements from 2004 and 2008 /RSK374, RSK406/ in detail. A holistic approach using postulates, experimental results and calculations was developed for PWRs.

## References


/KTA3301/ Safety Standards of the Nuclear Safety Standards Commission, KTA3301, residual Heat Removal Systems of Light Water Reactors, KTA, November 1984

/KT7601/ A. Bröcker and W. Pointer, LOCAs with release of insulation material: generic aspects and international solutions, Kerntechnik 76/1, 2011

/RSK374/ RSK Statement, Requirements for the demonstration of effective emergency core cooling during loss-of-coolant accidents involving the release of insulation material and other substances, RSK 374th meeting, July 22, 2004

/RSK406/ RSK Statement, Loss-of-coolant accidents involving the release of insulation material and other substances in pressurized water reactors – removal of deposits on sump strainers, RSK 406th meeting, March 13, 2008