PSA-study of

Internal Flooding Events

at Ringhals 2 in Sweden

performed by

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Ringhals 2 PSA

Ringhals 2 is a 2660 MWt PWR of Westinghouse design taken into operation in 1975.

PSA has been performed in different campaigns since the 1980:ies.

The current PSA study is plant specific and covers both the risk of core damage, PSA level 1, and the release of source term, PSA level 2, for power operation and the shutdown states.

Almost all relevant internal events have been considered together with important external events, like extreme weather conditions, and area events like fire and internal flooding.

The flooding analysis is based on a detailed deterministic study

All relevant water systems and buildings (that are mentioned in the deterministic study) have been considered.

Efforts have been made to study the flow paths and find out exactly which rooms that are affected by each initial pipe rupture.

154 pipe ruptures have been identified and analysed as initiating flooding events.

In most cases crack breaks are assumed

As is usual in a PSA flooding analysis, the conservative assumption that all flooding sensitive equipment in the flow path fails, is made.

In most cases this means that no distinction needs to be made regarding high and low energy systems (crack breaks or guillotine breaks).

In this analysis, crack breaks are usually assumed since these breaks are more likely to occur.

Exceptions where guillotine ruptures are analysed

For ruptures in the rubber expansion joints connecting main cooling water system to the condenser and for pipe ruptures in the freshwater system and the saltwater system special cases are defined for guillotine ruptures.

The reason for this is that the flow rates in these cases are very high (several cubic meters per second), and parts of the turbine or auxiliary building may be completely flooded.

Guillotine ruptures for these systems are not analysed for each room, instead one flooding case has been defined for each relevant system and building.

Other conservatisms in the modelling

In most cases the system that causes the flooding is assumed to be unavailable, although in many cases only one train is affected.

The assignation of transients is conservative.

Assigned transients

The following transients are used:

- T2, Transient not affecting RCS pressure boundary
- T3, Loss of main feed water
- T6, Shutdown due to requirements in R2 Technical Specifications

Transients have been assigned to the different initiating events according to how it has been done in the fire analyses.

To take into account that the system where the pipe rupture took place might be unavailable a comparison has also been made with the CCI analysis.

Pipe rupture frequencies

- The frequencies for the initiating pipe ruptures have been calculated based on the report *Pipe Rupture Frequencies for Internal Flooding PRAs, Revision 1. EPRI, Palo Alto, CA:2006. 1013141.*

- The report is based mainly on U.S. PWR and BWR experience from 1970 through 2004.

The EPRI report ”*Pipe Rupture Frequencies for Internal Flooding PRAs*”

The scope of piping systems considered in the report is selected to capture all piping systems that represent risk significant internal flooding sources.

Pipe rupture frequencies are given per year and unit pipe length for different water systems, divided into different pipe diameters. The different flood modes spray, flooding and major flooding are considered.

Separate failure rates have been developed for rubber expansion joints in circulating water system.

Pipe length estimations for different rooms and systems

Median estimates of the pipe lengths in a BWR or PWR plant are listed in the EPRI report for different pipe types and diameters.

A rough estimate of the pipe length in a given room was derived by dividing the total length of piping evenly between the rooms containing that kind of piping.

The estimates for “important” systems and rooms were checked by inspection.

Contribution of internal flooding to the overall core damage frequency

Internal flooding contributes less than 3 % to the overall core damage frequency.

This is a lot less than fire events or other transients like the loss of offsite power.

Contributions to the total core damage frequency for flooding

Initiating pipe rupture	Relative contribution (%)
A crack break in room H 1.25 in the auxiliary building	54,8
A guillotine rupture in room H 1.25 in the auxiliary building	24,9
A crack break in room H 3.15 in the auxiliary building	1,4

All other breaks contribute less than 1 % each.

Room H 1.25 will be rebuilt, which will reduce the impact of flooding further.

Summary of the internal flooding analysis

- The PSA-model gets more complex with all the extra analysis cases.
- Information about the effects of different flooding events is given for all relevant rooms and systems.

Thank you for the attention

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