Analysis of the Steam Generator Tube Rupture Source Term for a PHWR

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1. Introduction

The reactor building bypass sequences are distinctly different from the non-bypass sequences in that there exists a direct flow path from the primary system to outside the reactor building boundary which bypasses the main reactor building gas volume. Hence the gravity fallout and engineered mitigation features inside the reactor building become ineffective for reducing a fission product release into the environment. Consequently, bypass sequences can result in relatively large source term releases soon after the onset of a core damage. The reactor building bypass sequences can be further subdivided into a steam generator tube rupture (SGTR) group and an interfacing system LOCA (ISLOCA or Event V) group, because their radionuclide release pathways are different. Both of these have been defined by a plant damage state attribute as a “Reactor building Bypass” [1]. The purpose of this paper is to analyze the steam generator tube rupture source term for the Wolsong plants.

2. Methodology of Source Term Evaluation

A particular release category consists of a group of Containment Event Tree end points which have similar source term release characteristics. Once the release categories are set up, various accident sequences are allocated to that category.

To select the representative sequence for a specific release category, the following processes are used:

1) Select the plant damage state (PDS) with the largest contribution to the release category’s total frequency
2) Among the accident sequences corresponding to the PDS, choose the dominant sequence for the release category. This defines the initiating event and the status of the various plant systems
3) The CET and plant accident sequence definitions are retrieved to determine if any special phenomenological conditions have to be specified
4) A reactor building failure pressure, failure time and failure condition are specified based on the release category definition

In this study, deterministic analyses of representative sequences from each significant release category were performed with an accident progression source term assessment code. The ISAAC (Integrated Severe Accident Analysis Code for CANDU Plant) computer code [2] is used for this purpose.

3. Accident Analyses

Nine source term categories (STCs) have been developed for grouping the core damage sequences. For the SGTR sequences, two source term categories of STCs 8 and 9 are developed. As the amount of fission products released through the main steam safety valves are different, the SGTR with a crash cooldown and the SGTR without a crash cooldown are treated separately.

3.1 SGTR with crash cooldown

STC 8 is characterized by the steam generator tube rupture with a successful crash cooldown. The dominant sequence is defined as multiple steam generator tube rupture with a successful reactor shutdown, loop isolation and crash cooldown. The dormant emergency core cooling (ECC) injection and moderator cooling system fail, but the feedwater is supplied to the steam generators.

Figure 1 shows that the mass fraction of CsI stayed in the reactor building and delivered to the environment. The mass fractions of the noble gases, CsI and CsOH released to the environment for this sequence are summarized in Table 1. Through the forced-open main steam safety valves, CsI coming from the fuel channel is delivered to the environment via the broken U-tube and the steam generator secondary side. About 4.9% is released into the environment. As the pressure tube fails after 8 hours, most of the CsI is transported into the calandria and about 11.4% is deposited there. While 9.8% of the CsI remains in the Loop 1 PHTS, negligible fraction is deposited in the Loop 2 PHTS and reactor building (RB).

About 46%, 4.9% and 4.9% of the initial inventories of the noble gases, CsI and CsOH are released to the environment, respectively, as shown in Table 1, because the fuel in Loop 2 remains undamaged throughout the accident.

3.2 SGTR without crash cooldown

STC 9 is characterized by the steam generator tube rupture without (w/o) a crash cooldown. The representative sequence is defined as multiple steam generator tube rupture with successful reactor shutdown and loop isolation. The failure of the dormant ECC is followed by a crash cooldown operation failure. Though the safety-related systems are not requested, feedwater to the steam generators is assumed to fail.

As the crash cooldown operation fails, the main steam safety valves (MSSVs) open only when the secondary side pressure reaches the set point of the MSSVs. Therefore, the fission products escaping from the fuel are trapped inside the reactor building as long as the MSSVs are closed.

Figure 2 shows the mass fraction of CsI stayed in the reactor building and delivered to the environment. The mass fractions of the noble gases, CsI and CsOH released to the environment for this sequence are summarized in Table 1. About 1.3% is released into the environment. As the calandria fails around 38 hours, most of the CsI whose fraction is about 27.0%, is transported into the reactor building and about 48.0% stays there. 24.0% and 27.0% of the CsI remains in the Loop 1 and Loop 2 PHTS, respectively.

About 96%, 1.3% and 1.3% of the initial inventories of the noble gases, CsI and CsOH, respectively, are released to the environment, as shown in Table 1.

4. Conclusion

The representative sequences for STC 8 (SGTR with crash cooldown) and for STC 9 (SGTR without crash cooldown) are analyzed in terms of their source term behavior. The noble gases released to the environment for STC 8 is about half of that for STC 9, because Loop 2 remains intact in STC 8 representative sequence. Comparing the amount of CsI and CsOH released to the environment for the representative sequences of STC 8 and STC 9, STC 8 releases more mass than STC 9 due to the forced-opening of the MSSVs. Hence it can be suggested that a crash cooldown operation be avoided if the accident turns out to be a SGTR.

Table 1 Fractional Source Term Release to the Environment for SGTR categories

STC	8 (SGTR with crash cooldown)	9 (SGTR without crash cooldown)
Noble Gases	4.6E-01	9.6E-01
CsI	4.9E-02	1.3E-02
CsOH	4.9E-02	1.3E-02

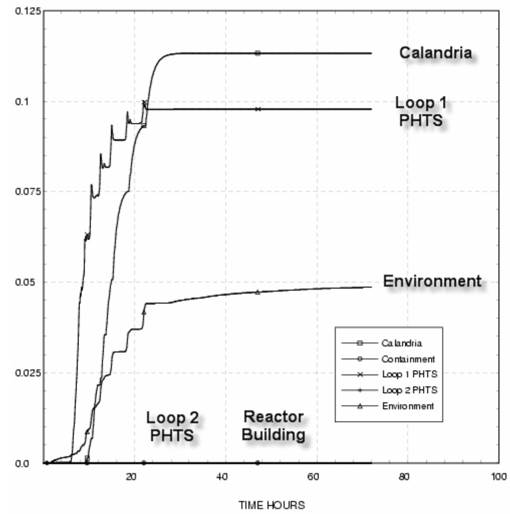

Figure 1 The Mass Fraction of CsI in the Reactor Building and the Environment for the SGTR with crash cooldown

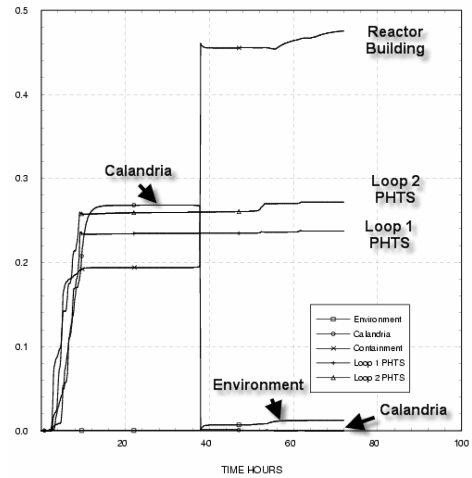

Figure 2 The Mass Fraction of CsI in the Reactor Building and the Environment for the SGTR w/o crash cooldown

Acknowledgement

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[1] KHNP. "Probabilistic Safety Assessment for Wolsong Unit 1", December, 2003.
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