Analysis of the Source Term Behavior for a PHWR

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1. Introduction

This paper discusses the source term behavior for the source term release categories defined from the source term logic diagram. The source term release category frequencies are evaluated and the behavior of fission products inside the reactor building for the representative sequences is described.

2. Construction of Source Term Logic Diagram

Like the construction of PDS logic diagram, grouping parameters are needed to construct the source term logic diagram. These parameters are selected on the basis of appropriate attributes that impact on fission product release and accident consequences. This selected set of parameters is used as grouping criteria to define the release categories and the associated source term magnitude, composition, and timing [1].

The containment sequence characteristics selected for the Wolsong 2/3/4 source term release categories are show in figure 1 which is the source term logic diagram.

3. 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 processes of a reference are used [1].

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.

4. Source Term Characteristics for Internal Events

4.1 Source Term Category 1

STC 1 does not cause containment failure though a severe core damage occurs in the fuel channel. The sequence of total loss of instrument air (IE-IA_S32) is the most frequent sequence (37%) and this can be a representative sequence for STC 1. To simulate the sequence, feedwater, emergency core cooling and moderator cooling system are assumed to be inoperable. The local air coolers, end shield cooling and hydrogen igniters are available.

4.2 Source Term Category 2

STC 2 is a late reactor building failure with dousing spray. The sequence of a total loss of class IV power (IE-CL4_S71) is the most frequent sequence (48%) and this can be a representative sequence for STC 2. To simulate the sequence, feedwater, emergency core cooling, local air coolers and end shield cooling are assumed to be inoperable. The dousing spray and hydrogen igniters are available.

4.3 Source Term Category 3

STC 3 is a late reactor building failure without dousing spray. The sequence of total loss of end shield cooling (IE-ESC_S47) is the most frequent sequence (67%) and this can be a representative sequence for STC 3. To simulate the sequence, end shield cooling, feedwater, emergency core cooling, and dousing spray are assumed to be inoperable. The local air coolers and hydrogen igniters are available. Though the accident progresses without reactor trip initially, the reactor scram by a stepback was not modeled in the current ET. Therefore, the reactor is assumed to scram here. The reactor building failure time is 30hrs to show the effect of a late reactor building failure.

4.4 Source Term Category 4

STC 4 is a very late reactor building failure with dousing spray. The representative sequence for STC 4 is the same as STC 2 (IE-CL4_S71). The reactor building failure pressure is 570 kPa(g) to show the effect of a very late reactor building failure.
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4.5 Source Term Category 5

STC 5 is a very late reactor building failure without dousing spray. The representative sequence for STC 5 is the same as STC 3 (IE-ESC_S47). The reactor building failure time is 40hrs to show the effect of very late reactor building failure.

4.6 Source Term Category 6

STC 6 is a reactor building isolation failure. The sequence of a total loss of class IV power (IE-CL4_S76) is the most frequent sequence (33%) and this can be a representative sequence for STC 6. To simulate the sequence, feedwater, emergency core cooling, local air coolers and end shield cooling are assumed to be inoperable. The dousing spray and hydrogen igniters are available. A break size of 6inch in diameter is assumed.

4.7 Source Term Category 7

STC 7 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.

4.8 Source Term Category 8

STC 8 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.

4.9 Source Term Category 9

STC 9 is characterized by the interfacing system LOCA (Event V). To simulate the Event V sequence, a fourteen inch diameter emergency core cooling pump line is assumed to be broken in the auxiliary building. The open area between the auxiliary building and the environmental atmosphere is also assumed to be 9.29 m^2 (100ft^2). This study assumes that the safety systems such as the Emergency Core Cooling System, Shield Cooling System and Moderator Cooling System are unavailable. Dousing spray system is automatically initiated when the containment pressure exceeds 2 psig and stops when the pressure decreases below 1 psig, resulting in a cycling operation. And 72 hours of a mission time is assumed.

5. Conclusion

The representative sequences for STC 1 ~ STC 9 are analyzed in terms of their source term behavior. Table 1 shows the mass fractional of source term released into the environment for source term categories. The noble gases released to the environment for STC 6 is the largest. Comparing the amount of CsI and CsOH released to the environment for the representative sequences of STC 1 ~ STC 9, STC 9 releases more than STC 1 ~ STC8.

Table 1 The Mass Fractional of Source Term Released into the Environment for Source Term Categories (%)

STC	1	2	3	4	5	6	7	8	9
Noble Gases	4.1E-1	96.7	81.8	96.1	70.9	99.8	46.6	99.4	95.9
CsI	6.0E-3	1.2	1.1	1.1	9.3E-1	4.3	5.0	1.3	11.7
CsOH	6.1E-3	1.2	1.0	1.3	1.0	4.2	5.0	1.1	12.9

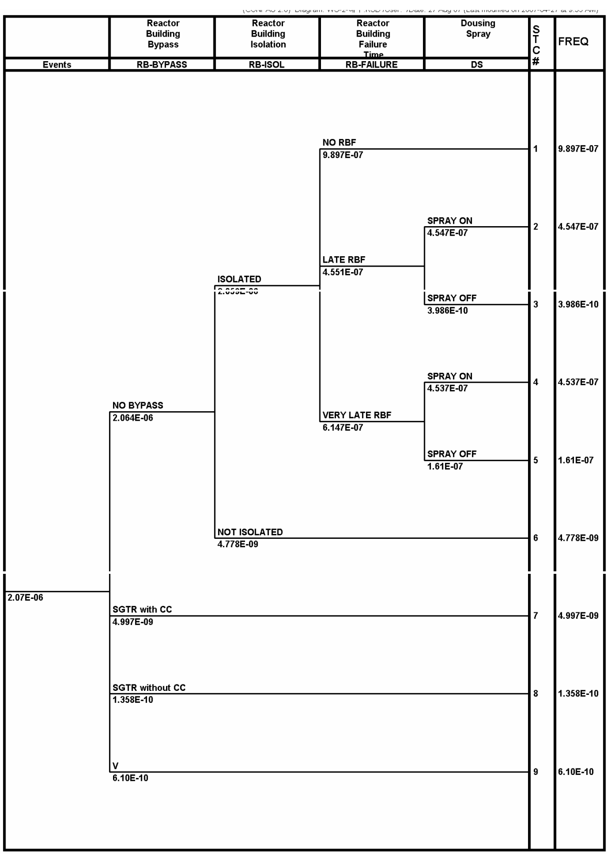

Figure 1 The Quantified Source Term Logic Diagram for Internal Events

REFERENCES

[1] KAERI. "Probabilistic Safety Assessment for Wolsong Unit 2,3,4", May, 2007.

[2] Dong Ha Kim, et. al., "Development of Computer Code for Level 2 PSA of CANDU Plant", KAERI/RR-1573/95, December 1995.