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CANDU Reactor Severe Accident Management Strategies for Containment Integrity

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1. Introduction

The objective of this paper is to establish basic technical information for containment integrity management strategies in CANDU reactor severe accident. For development of severe accident management strategies, plant specific features and behaviors must be studied by detailed analysis works. This analysis scope will serve to cover overall methods and analyzing results to understand containment integrity status in the most likely severe accident sequences that could occur at CANDU plant. Also analysis results could help prevent or mitigate severe accidents for identification of any plant specific vulnerabilities to severe accidents.

2. Methods and Results

In this section, analysis techniques used to model the CANDU plants and Results are described.

2.1 Mitigating capability Analysis of Hydrogen burn for Plant Specific Failure

Basically the same methodology used for PWRs is applied to CANDU plants for specific strategies from e results of Level 1 PSA analyses are grouped into plant damage states (PDSs). Containment failure mode and timing, and source term characteristics are considered in defining PDSs. [1]

<u>Evaluation methodology</u>

o. Based on Level 1 & level 2 PSA results, major event scenarios are selected as below.
-6 initiating events such as 5 internal events and 1 external event for Wolsong-1 plant
-8 initiating events such as 5 internal events and 3 external events for Wolsong-2, 3, 4 plants
o. Evaluating process of H2 concentration in containment partition with combination of containment related system configurations such as spray or air coolers
-ISAAC simplified Nodes evaluation
-GOTHIC Detailed Nodes evaluation

o. Review process of analysis results from GOTHIC or ISAAC
-Quantification of H2 concentration in containment
-Drive preventive procedure for event oriented characteristics

Table 1 and 2 show analysis results for hydrogen density in plant specific accident scenarios - Wolsong-1, 2, 3&4 plant specific features using GOTHIC.

Analysis results show various H2 concentration percent between 370 kg and 1760 kg for each different plant sequences. For Wolsong-1, there is no ignitor that H2 concentration increases up to 33%. Table 1 shows a value which represents a realistic upper bound on the hydrogen limits for severe accident management. For Wolsong-2,3,4, there are 44 ignitors to burn hydrogen that H2 concentration keep below 4%. But if ignitors are not working, H2 concentration increases up to 26%. Therefore especially Wolsong-1 steam inert or preventive H2 burn must be considered as operator reaction for proper hydrogen control. Then H2 concentration keeps below 4 %.

Table 1 H2 Concentration in Containment at Typical Initiating Events for Wolsong-1 unit using GOTHIC

Event		Internal Event					External Event
		IE-FBS -S36	IE-IA -S40	IE-SW -S40	IE-ESC -S49	IE-CL4 -S44	FIE-GR1 -S12
Amount of hydrogen generation (kg)		380.6	712.1	1760.5	1508.5	372.6	1561.3
H_2 (Vol%)	R107	10.5	17.7	32.7	24.3	8.4	25.8
	R108	10.6	17.8	32.6	24.3	8.4	25.8
	R501, R601	10.9	18.7	35.6	32.8	8.2	26.2
	R111	10.8	17.9	32.6	24.3	8.4	25.8

Table 2 H2 Concentration in Containment at Typical Initiating Events for Wolsong-2,3,4 units using GOTHIC

Event		Internal Event					External Event		
		IE-CL4 -S71	IE-IA -S32	IE-ESC -S47	IE-FBS -S15	IE-CL4 -S36	FIE-GR1 -S17	FLE-SW -C2-S2	SE-ST16 -S3
Amount of hydrogen generation (kg)		1573.9	827.4	1489.2	1206.3	382.3	1565.5	1756.1	1617.0
H_2 (Vol%)	R107	13.3	3.9	8.7	3.9	3.8	26.2	16.8	25.8
	R108	13.3	3.9	8.7	3.7	3.8	26.2	16.7	25.8
	R501, R601	13.8	3.7	9.0	3.9	3.8	26.1	17.0	26.3
	R111	13.3	3.9	8.8	3.7	3.8	26.3	16.8	25.8

When the reactor building depressurizes, either through long term heat losses or due to intentional efforts, steam condenses out of the atmosphere. If the reactor building has been in a steam inert, or non-flammable state due to the presence of steam, the decreasing steam content in the reactor building atmosphere may lead to a flammable condition. This hydrogen is likely to be released to the reactor building, although the release mechanism from the reactor vessel is dependent on the severe accident scenario. Nevertheless, guidelines have been established for estimating the hydrogen concentration in the reactor building atmosphere, if more detailed plant information is not available. [2]

2.2 Mitigating capability Analysis of Containment Vent for Plant Specific Failure

For development of accident management strategies, various initiating scenarios are selected by logical category schemes for Wolsong units 2, 3, 4 as typical CANDU plant.

Figure 1 and 2 show analysis results for vent effectiveness in the majority of accident scenarios. If venting has occurred, or if the reactor building is superheated, then different statuses come. If venting has occurred, there are two sets of figures which illustrate the difference in the containment pressure for same node. For Wolsong-1, if venting is available, containment pressure decreases below $4\mathrm{x}10^5$ Pa below containment design pressure such as 30 inches diameter-venting. Venting should be properly actuated by operator for depressurization as shown figure 1. Also, released CSI source term surely may decrease due to venting as Figure 2.

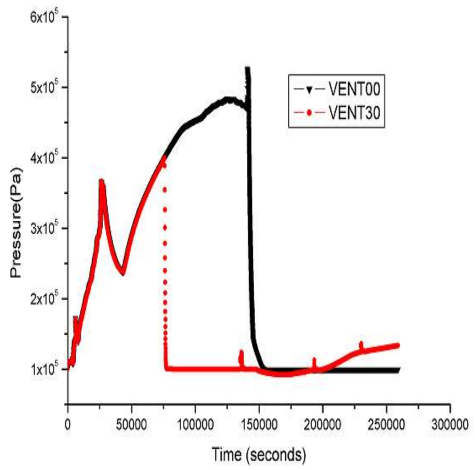

Figure 1 Typical Containment Pressure at with Vent00 / Vent30 for Plant Specific Features –Wolsong-1 Loss of PHTS Coolant

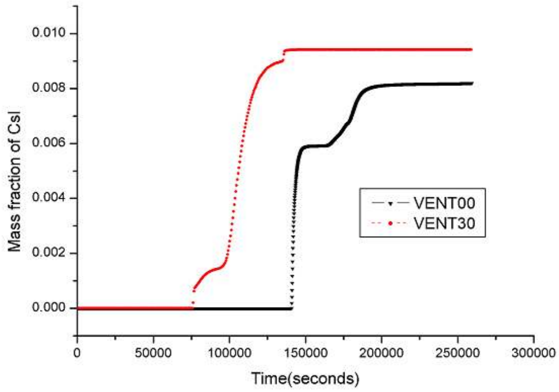

Figure 2 Released CSI Mass Fraction with Vent00 / Vent30 for Plant Specific Features –Wolsong-1 Loss of PHTS Coolant

3. Conclusions

In order to select the useful severe accident management strategies, plant specific features must be identified by logical schemes using detailed studies for the characteristics of CANDU plants. The hydrogen concentration, temperature, pressure and source term information should be used in conjunction with other plant data. Therefore steam inert or preventive H2 burn must be considered as operator reaction for proper hydrogen control. Then H2 concentration keeps below 4 % especially for Wolsong-1. Also, venting should be properly actuated by operator for depressurization using interfacing pipe in containment such as 30 inches diameter-venting.

Acknowledgements

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REFERENCES

[1] USNRC, "Individual Plant Examination: Submittal Guidance", NUREG-1335, August 1989

[2] KEPCO, "Risk Monitoring System Development for Wolsong units 2,3,4", 2007.5