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Estimation of hydrogen concentration during severe accident in Wolsong plants

Youngho JIN, Dong Ha KIM
Korea Atomic Energy Research Institute
P.O. Box 105 Yusong, Daejeon KOREA
yhjin@kaeri.re.kr

1. Introduction

Hydrogen is generated during severe accident. Main source of hydrogen generation is oxidation of zircaloy. In CANDU, there exists a lot of zircaloy in the calandria. The fuel bundles are made up of 37 zircaloy-4 tubes containing natural UO_2 pellets. Fuel channel consists of zirconium-niobium alloy pressure tube surrounded by zircaloy-2 calandria tube[1]. All inner reactor structures are made of zircaloy. The total mass of zircaloy in the core is 43,282 kg. This amount is much greater than that for KSNP, which has about 20,000 kg of zircaloy.

Wolsong 2, 3, and 4 units equipped the hydrogen control system which is intended to mitigate the effects of a post-accident hydrogen accumulation, preventing hydrogen from reaching deflagration or detonation levels by using controlled ignition as soon as the hydrogen concentration reaches flammable limits. The system consists of 44 hot surface igniters powered from Class III and manually backed-up by emergency power supply. The igniters are distributed in the fueling machine vaults and the reactor building dome area[2]. Following a LOCA, the system is initiated not by the high hydrogen concentration, but by the high containment pressure or activity because Wolsong 2, 3, and 4 units do not have the hydrogen concentration monitors.

During the station blackout, the hydrogen will be accumulated because the hydrogen igniters are not working. It is important to turn on the hydrogen igniters based on the hydrogen concentration when the power is restored long after its loss because the hydrogen burn may results in the failure of containment if the burn occurs at the high hydrogen concentration.

This paper provides a simple method which gives a rough estimate of hydrogen concentration in the reactor building during severe accident progression.

2. Estimation of amount of hydrogen generated

ISAAC 2.0.2 code[3] is used to estimate the amount of hydrogen generated during severe accident progression.

ISAAC code employed the suspended debris bed model for the relocation of debris. User may choose a single node or multi-nodes for the suspended debris bed. When a user chooses to use multi-nodes for the suspended debris bed, relocation from higher node to the nodes below is calculated. When the suspended debris bed mass exceeds a specified mass limit (user input), lower parts of calandria tubes can not support the suspended debris bed, resulting in a global core collapse. User may choose an oxidation model in the suspended debris with/without heat transfer from suspended debris.

To investigate the amount of hydrogen generated, three kinds of accidents are analyzed. These accidents are a large LOCA, a small break LOCA and a total loss of feedwater accident. These accidents represent the low, medium and high PHTS pressure accidents, respectively. For each accident, four cases are run. Case 1 dose not allow the oxidation in the suspended debris bed and no heat transfer from the suspended debris bed. Case 2 allows the oxidation in the suspended debris bed and no heat transfer from the suspended debris bed. Case 3 allows the oxidation in the suspended debris bed and heat transfer from the suspended debris bed. Case 4 is same as Case 3 except that this case used 2,500 tons of debris as the criteria of a global core collapse instead of 25 tons(default value).

The amount of hydrogen generated for various accidents are summarized in Table 1.

Table 1. The amount of hydrogen generated for the various accident scenarios (kg)

	Case1	Case 2	Case 3	Case 4
Large LOCA	155	419	358	686
Small LOCA	153	445	254	652
Total loss of feedwater	152	447	279	630

3. Hydrogen concentrations in the reactor building

Table 1 shows that the amount of hydrogen generated heavily depends on the oxidation model and not much depends on the accident type. Case 1 shows the lower limit of the hydrogen generation and Case 4 shows the upper limit of the hydrogen generation. Case 3 is the best estimate of the hydrogen generation.

Hydrogen concentration in the reactor building can be calculated by following steps below [4], and illustrated in the Figure 1.

1. Find the number of moles for the amount of hydrogen generated.
2. Use the steam tables to find the partial pressure of steam using the reactor building temperature at saturated conditions. The values for T must be guessed, and then iterate through step 5.
3. Find the partial pressure of hydrogen for the given amount of hydrogen.
4. Find the partial pressure of air for the given amount of hydrogen.
5. Determine whether the reactor building temperature guessed in step 2 is correct by checking if the partial pressures add up to the correct total pressure. If not, return to step 2 with new assumption for the reactor building temperature.
6. Find the hydrogen fraction. Plot the hydrogen percentage versus the containment pressure for the given amount of hydrogen.

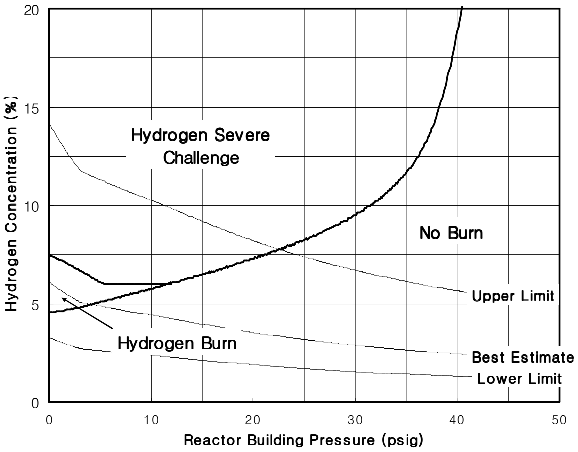

Figure 1. Hydrogen concentration in the reactor building during severe accidents in the Wolsong nuclear power plants.

REFERENCES

[1] "Wolsong NPP 2/3/4 Final safety analysis report," KEPCO, 1995

[2] "Hydrogen control system," Design Manual, Wolsong NPP 2/3/4, 86-68460-DM-001, Rev.0, AECL, 1993

[3] "ISAAC Ver. 2.0.2 New Features and Improvement," FAI FAI/05-109, 2005

[4] "Severe accident management guidance, Vol.3 Background document," page CA-3 15-16, Westinghouse Owners Group, 1994