Hydrogen Behaviour in the IRWST of APR1400

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1. Introduction

The combustible gas control in the APR1400 containment is done both by the 26 Passive Autocatalytic Recombiner (PAR) units and by the 10 glow plug igniters [1]. This Hydrogen Mitigation System (HMS) is designed to preclude detonations in containment that might jeopardize containment integrity or damage essential equipment.

The applicant for the Design Certification for APR1400 performed analyses of hydrogen distribution and combustion for LOCA, Station Blackout (SBO) and Loss of Feedwater (LOFW) using MAAP4 code to evaluate the hydrogen control system. The accident sequences were selected with a screening review on the Probabilistic Safety Assessment (PSA) Level 1 results. The results show that hydrogen concentrations for the containment after instantaneous peaks during source term releases are from 8% to 14% for each accident condition. Most of them would be outside of the flammability limit or in a region of mild deflagration. However, hydrogen concentrations could reach 81% in the IRWST for SBO, which was confirmed by GOTHIC analysis by the applicant.

Recently Kim et al. [2] presented the similar analysis result for a SBO sequence using GASFLOW code. The mass and energy source term was calculated by MAAP code. Highly accumulated hydrogen could be released into the annular compartment and result in flame acceleration and Deflagration-to-Detonation (DDT). So they proposed a design modification such as installation of partition walls around spargers to facilitate steam production. However, the source of hydrogen and steam was obtained from a MAAP calculation and the analysis was based on an assumption that dry hydrogen is released into the atmosphere of the IRWST.

Since the previous results show that hydrogen combustion could challenge the containment integrity for some SBO sequences, a confirmation analysis is required, using MELCOR code that can deal with the whole phenomena from the reactor core to the containment. This paper introduces the status of the on-going KINS independent analysis of hydrogen behavior inside and around the IRWST following a SBO accident.

2. Analysis Methodology

For the selected SBO sequence all emergency diesel generators fail, but secondary heat is removed for 8 hours through turbine-driven auxiliary feedwater pumps. All safety injection tanks are available. Recovery of offsite power is not assumed, but PARs can remove hydrogen at all times following the initiation of an accident.

The reactor coolant system (RCS) model includes core, primary and secondary coolant system. The core is modeled as 5 radial rings, 16 axial levels including top and bottom end fittings. Fig. 1 shows the RCS model for APR1400. As for the containment the 51-cell model is used for this specific analysis as shown in Fig. 2. The IRWST has 16 control volumes and 3 axial levels in which 6 cells are azimuthally separated, as shown in Fig. 3.

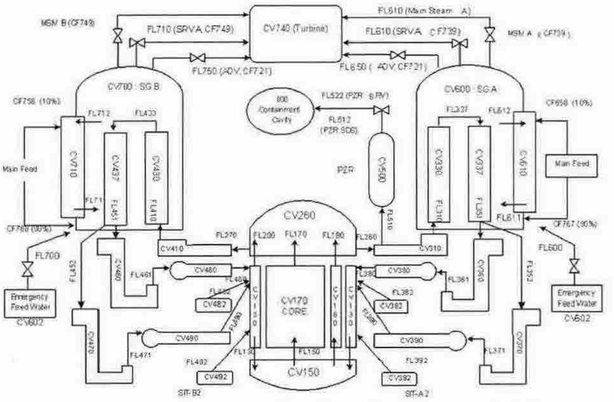


Figure 1. Reactor Coolant System model for APR1400

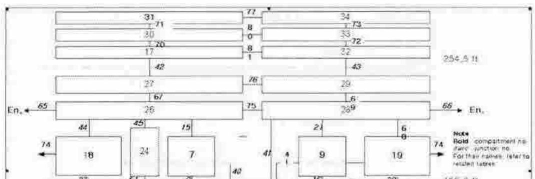


Figure 2. Containment model

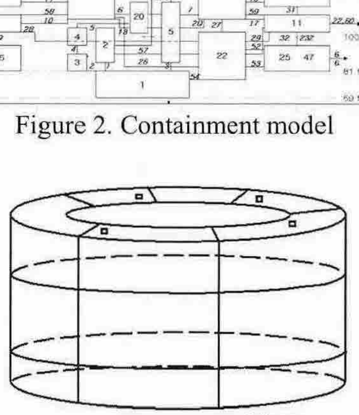


Figure 3. 16-Cell IRWST model

3. Analysis Results

Following a SBO accident, hydrogen and steam are discharged from Pilot Operated Safety and Relief Valves (POSRVs) of the pressurizer into the IRWST through spargers. Although the water temperature of the IRWST pool is below saturation as shown in Fig. 5, steam concentration in the IRWST atmosphere increases from 10% to more than 30% after the beginning of discharge in Fig. 8(a). It means that the assumption of dry hydrogen release may be very conservative. Fig. 7 shows that gases have forward and reverse flow through relief dampers on the IRWST ceiling following the accident. Therefore consumption of oxygen by passive catalytic recombiners does not drop its concentration too much. Fig. 8 shows rough estimation of flame acceleration and DDT possibility. The IRWST could have DDT and annulus region an accelerated flame.

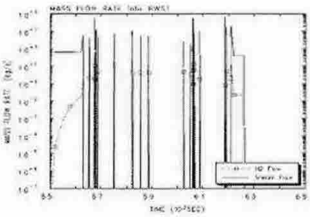


Figure 4. Hydrogen and steam source into the IRWST

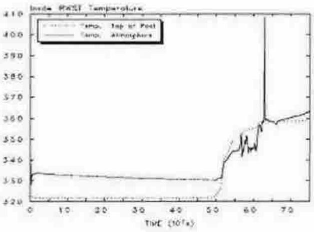


Figure 5. Temperatures of water pool and atmosphere of the IRWST

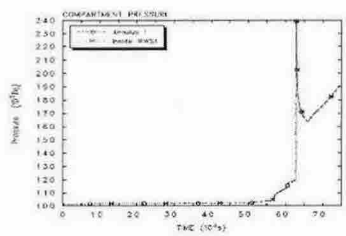


Figure 6. Pressure inside the IRWST and the rest of the containment

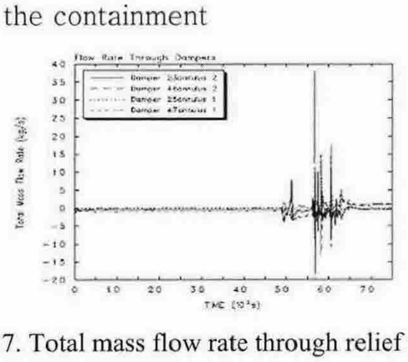
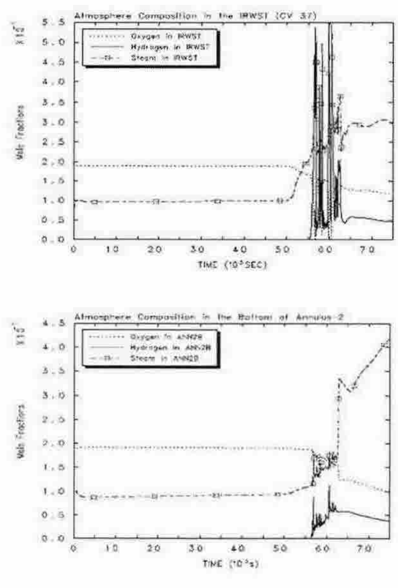


Figure 7. Total mass flow rate through relief dampers



(a)

(b)

Figure 8. Gas composition in the atmosphere of the IRWST (a) and the Annulus region (b)

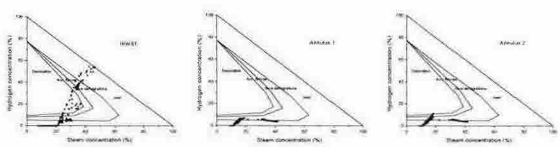


Figure 9. Combustion regimes at 373K in gas mixtures of IRWST, Annulus 1 and Annulus 2 region respectively

4. Conclusion

Even with the subcooled water in the IRWST pool, steam concentration in the atmosphere increases continuously during the POSRVs' discharge period. Reverse flow through relief dampers makes up oxygen into the IRWST. Rough estimation shows that DDT is possible in the IRWST and flame acceleration in the annulus region.

More detailed estimation of combustion regimes for the above regions is required in the future. Further analysis is also necessary for the sequence of recovery of AC power.

REFERENCES

[1] Korea Electric Power Corporation, "Standard Safety Analysis Report : Korean Next Generation Reactor," Chapter 19.2, 2000.

[2] Jongtae Kim et al., "Hydrogen control in the APR1400 containment for the Hypothetical Station Blackout Accident," Proceedings of the Korean Nuclear Society Spring Meeting, May 2004.