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Safety Evaluation for the Combustible Gas Burning during Severe Accident of Kori 1

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1. Introduction

The Korean Ministry of Science and Technology (MOST) issued the “Policy on Severe Accident of Nuclear Power Plants” in August 2001 [1]. It stipulated the licensee to evaluate the probabilistic safety assessment (PSA), to provide severe accidents prevention and mitigation capability, and to implement a severe accident management program (SAMP).

Korea Hydraulic and Nuclear Power Company (KHNP) has developed its own implementation plan according to the Policy on Severe Accident of Nuclear Power Plants. The MOST approved the KHNP’s plan with a condition that the evaluation of severe accidents prevention and mitigation capability should be included in the SAMP [2].

Committed by the MOST, Korea Institute of Nuclear Safety (KINS) is reviewing the licensee’s PSA results and SAMP for Kori 1. One of the safety issues for this review is the risk due to the burning of combustible gases such as H_2 or CO_2 during severe accident. Since Kori 1 does not have the combustible gas control system such as hydrogen igniter or passive autocatalytic recombiner (PAR), a detailed analysis is required concerning the combustible gas behavior in the containment.

2. Evaluation Methods and Results

In this section, the analysis methods of plant response for the selected accident scenario are described.

2.1 Containment spray system

The containment spray system of Kori 1 does not have the heat exchanger. The water in the containment recirculation sump is cooled by the heat exchanger of low pressure safety injection (LPSI) system during recirculation mode. If the LPSI recirculation operation fails, the containment spray system (CSS) will spray hot water. The failure frequency of LPSI recirculation operation is analyzed to be 8.3E-5/ry.

2.2 Assumptions and accident scenario

It is assumed that a LB LOCA occurs at the cold leg past RCP. The break size of the double ended LOCA is a diameter of 15 inch. The recirculation operation of high pressure safety injection (HPSI) and LPSI system is assumed to fail. The main and auxiliary feed-water systems, the containment fan cooler system (CFS) are assumed to fails also. Thus, LB LOCA is progressed into a severe accident. It is assumed that the CSS will spray hot water because the LPSI recirculation operation fails. So, the selected severe accident scenario is the following:

LBLOCA x (MFW & AFW is failed) x (SIT is actuated) x (HPSI &LPSI are actuated) x (HPSI &LPSI recirculation are failed) x (CSS is actuated) x (CFS is failed)

2.3 Severe Accident Analysis of Kori 1

MELCOR code which was developed by US NRC is used to analyze the selected severe accident scenario. The containment is modeled by 28 control volumes. The initial conditions of combustible gas burning at the selected accident scenario of Kori 1 are obtained by MELCOR analysis. The concentration of hydrogen, steam and oxygen were calculated. Figure 1 shows behavior of hydrogen concentration.

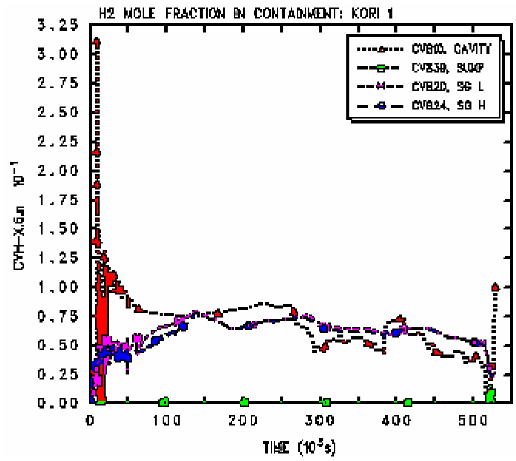
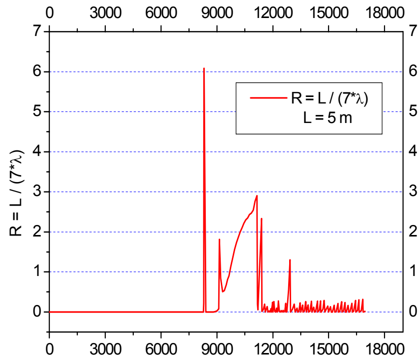


Fig. 1. H_2 concentration in containment

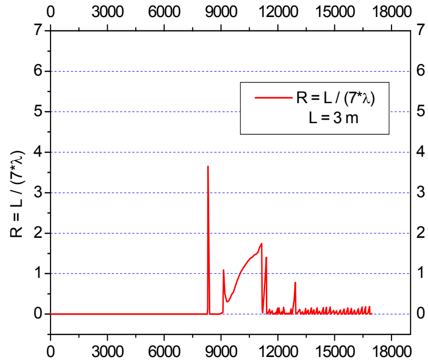
2.4 Evaluations of DDT and FA Possibilities

The possibility of deflagration to detonation transition (DDT) is evaluated using 7λ criterion by Breitung [3]. The characteristic geometrical size, L, of reactor cavity is between 1 and 5 meters, but it is hard to fix one definite value. Therefore, the sensitivity studies are done assuming that the characteristic lengths are 5, 4, 3, 2, and 1 m.

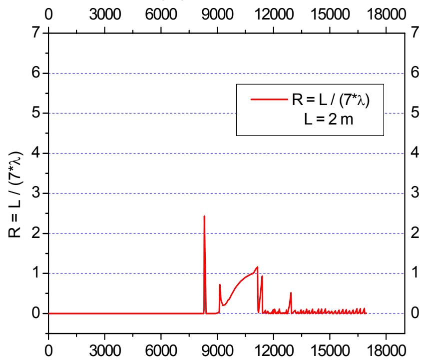
Appling the analytic function of Dorofeev et al. [4], we found the DDT criterion ($R = L/7\lambda > 1$, where L: characteristic geometrical size, λ: Detonation cell size) is satisfied in the reactor cavity for L of 5, 4, 3, and 2 m (see Figure 2) respectively.



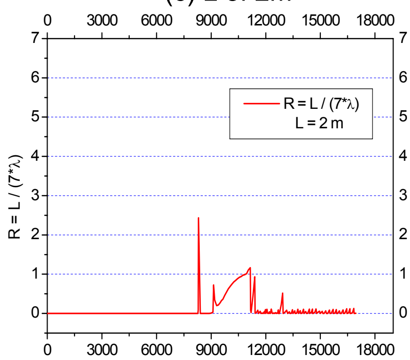
(a) L of 5m



(b) L of 3m



(c) L of 2m



(d) L of 1m

Fig. 2. DDT possibility in reactor cavity

The flame acceleration criterion ($\sigma/\sigma^* > 1$, where σ : the ratio of densities of reactants and products, i.e., expansion ratio, σ^* : critical value determined by Le, the Lewis number and β, the Zeldovich number) is also satisfied in the reactor cavity when there is a large release of hydrogen from the reactor pressure vessel (RPV) failure (at 8,290 second after initiation of accident).

3. Conclusion

Hydrogen behavior in the reactor cavity has been analyzed for a LB LOCA accident of Kori 1. The peak hydrogen concentration is estimated to be 31% during core melting period. The combustion-regime shows that DDT and flame acceleration are possible in the reactor cavity. The DDT is possible according to the 7 λ criterion for some periods, based on the detonation cell width calculated by Dorofeev et al.'s analytical function. As for the flame acceleration, the sigma-criterion is met when the peak hydrogen concentration occurs. These results show some measures such as PAR or H_2 igniters against the hydrogen risks may be required for Kori 1 to assure the integrity of the containment and nearby equipments required for safe shutdown against severe accidents.

REFERENCES

[1] The Ministry of Science and Technology, Policy on Severe Accident of Nuclear Power Plants, August 2001.

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[3] NEA/CSNI/R(2000)7, "Flame Acceleration and Deflagration-to-Detonation Transition in Nuclear Safety", August 2000.

[4] S.B.Dorofeev, et al., "Evaluation of Limits for Effective Flame Acceleration in Hydrogen Mixtures,"IAE-6150/3, RRC "Kurchatov Institute" Report FZKA-6349, Forschungszen-trum Karlsruche, 1999.