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Fan Cooler Operation in Kori 1 for Mitigating Severe Accident

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1. Introduction

The Korea Ministry of Science and Technology (MOST) issued the "Policy on Severe Accident of Nuclear Power Plants" in August 2001 [1]. According to the policy it was required for the licensee to develop a plant specific severe accident management guideline (SAMG) and to implement it.

Thus the utility has made an implementation plan to develop SAMGs for operating plants. The SAMG for Kori unit 1 was submitted to the government on January 2004. Since then, the government trusted KINS to review the submitted SAMG in view of its feasibility and effectiveness.

The first principle of the developed SAMG is to use only the available facilities as it is without introducing any system change. Because Kori-1 has no mitigative facility against combustible gases during severe accident, it relies heavily both on spray and on fan cooler systems to control the containment condition. Thus one of the issues raised during the review is to know whether the fan coolers which are designed for DBA LOCA can be effective in mitigating the severe accident conditions.

This paper presents an analysis result of fan cooler operation in controlling the containment condition during severe accident of Kori 1.

2. Methods and Results

In this section the analysis method and the results obtained are described.

2.1 Fan Cooler System

Two containment recirculation fan coolers take in the containment air at elevation of 86 ft (low level upper compartment) and discharges it through a duct to a lower part of containment, thus circulating and mixing the atmosphere in case an accident occurs. The suction flow rate of one fan is 31,000 cfm and it can cool the air with a heat capacity of $50x10^6$ Btu/hr at a rated condition. Two shroud fan coolers and one cavity fan coolers will also run to mix the atmosphere. The fans are classified as safety grade and will contribute in mixing the containment atmosphere. This fan cooler plays an important role in mitigation-06 (control of containment condition) and mitigation-07 (control of containment hydrogen) of Kori 1 accident management guideline. This paper analyses the issue of whether these fans are really of use in mitigating severe accidents.

2.2 Analysed Accident Scenario

It is assumed that a LB LOCA occurs at cold leg past RCP. The break size of the double ended LOCA is 15 inch in diameter. The recirculation operation of high pressure safety injection (HPSI) and LPSI system is assumed to fail. The main and auxiliary feed-water systems are assumed to fail also. Thus, LB LOCA is progressed into a severe accident. The fan coolers are supposed to operate as soon as LOCA occurs. The CSS will spray hot waters into the containment atmosphere because LPSI recirculation operation has failed. Thus 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).

2.3 Accident Analysis using MELCOR Code

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. Figure 1 shows and compares the behavior of hydrogen concentration in the cavity for fan cooler operating case(blue dot line) with that of non-operating condition (red line). The fan coolers seem to be quite effective in controlling the pressure rise in the cavity.

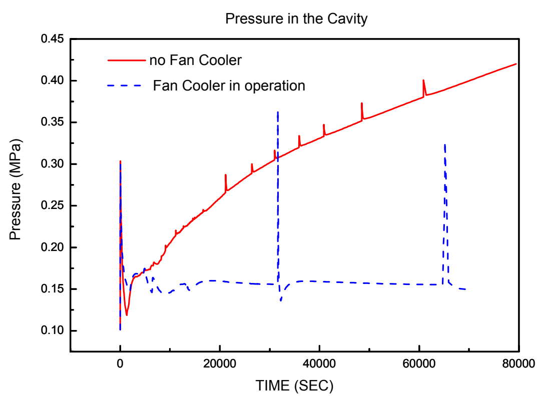


Fig. 1. comparison of pressure in cavity

Figure 2 is a plot for hydrogen concentration in the cavity. The fan coolers mix the atmosphere and thus the hydrogen concentration remains well below 10% for the period of calculation.

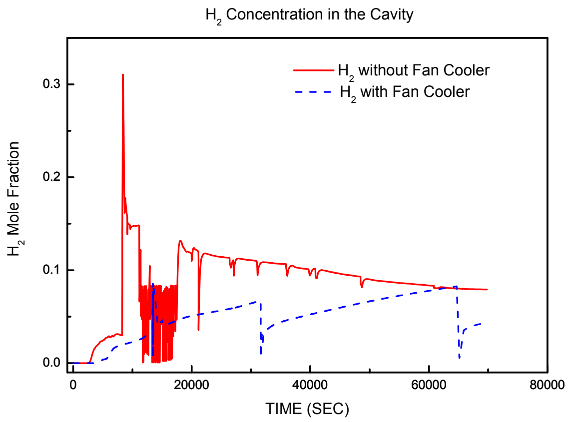
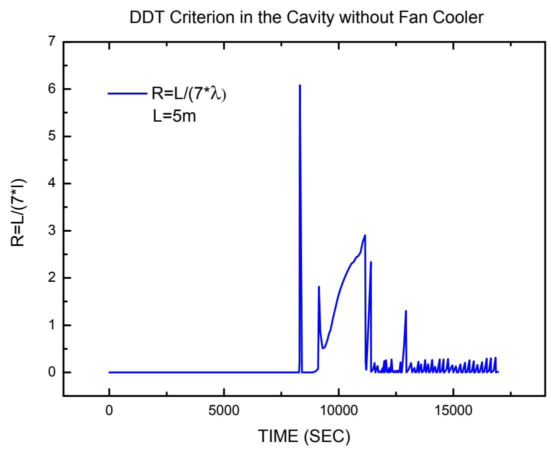


Fig.2 comparison of H^2 concentration in cavity

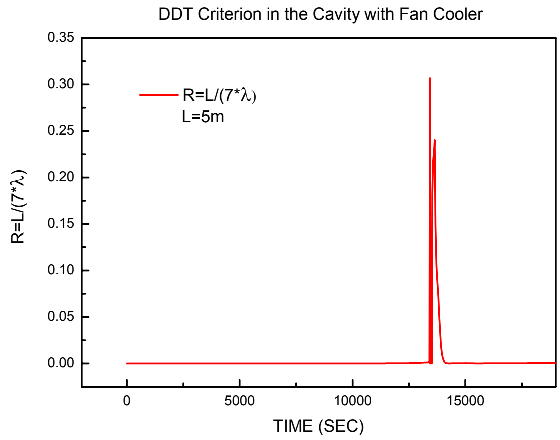
2.4 Evaluation of DDT Criterion

The possibility of deflagration to detonation transition (DDT) is evaluated using 7λ criterion proposed by Breitung [3]. The characteristic geometrical size L of reactor cavity is between 1 and 5 meters. To see clearly the difference, calculation was done for L=5m.

Applying the analytic function of Dorofeev et al. [4], we found the DDT criterion (R = L/7λ > 1, where L: characteristic geometrical size, λ: detonation cell size) is met in case fan coolers do not operate (see figure 3-a). The other case of using fan coolers as severe accident management action shows (figure 3-b) that the calculated R is well below 1 which indicates that the DDT might not occur.



(a) fan coolers not operating



(b) fan coolers operating

Fig. 3. DDT criterion in reactor cavity

3. Conclusion

Using fan coolers for mitigating severe accident is analysed in Kori 1 for an accident scenario of LB LOCA. The DDT is possible in cavity according to the 7λ criterion for some periods, based on the detonation cell width calculated by Dorofeev et al.'s analytical function in case the fans are not available. If the fans operate at a rated capacity, it contributes to well mixing the atmosphere and thus R value is below 1 which means that the DDT might not occur.

But this analysis does not prove that we can really rely on fan coolers for accident management actions because there still remains hard questions about the possibility of flame acceleration and of DDT in a long duct of fan coolers. Whether the fans can operate in a harsh condition of severe accident with dense aerosol condition is another issue to clarify.

REFERENCES

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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, Forschungszentrum Karlsrhue, 1999.