Analysis on Effectiveness of Methods for Fission Product Release Control in Containment

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1. Introduction

In severe accident as core damage begins, fission products are released from fuel and pores between cladding and fuel. Depending on the type of initial accident, fission products can be released to containment building, auxiliary building and released into steam generator. And each case, fission products can be released to environment through their pathways such as vent valves, MSSV, MSADV, auxiliary building exhaust fan and damaged containment.

There are several strategies that can mitigate severe accident phenomena and there are diverse methods that can be used in each case such as fixed equipment and movable equipment vehicle. Among the SAMG strategies, "Fission product release control strategy" can reduce population dose during severe accident progression. There are several methods that can be used in "Fission product release control strategy". In this study, effectiveness of those methods is evaluated. Through this analysis, priorities and technical backgrounds can be drawn for DPG (Diagnostic Process Guideline) based SAMG that would be introduced in domestic nuclear power plant.

2. Methodology and Assumptions

"Mitigation-05" (Fission Product Release Control) strategy is separated with section A, B, and C. Section A is reactor containment building release control, B is steam generator release control and C is auxiliary building release control. In other words, the target of Mitigation-05 is to controlling fission product release from reactor containment building, damaged steam generator and auxiliary building. In this study, only section A is analyzed.

2.1 Event Cases and Available Methods

The target reactor type for analysis is APR1400 and representative events are derived from "Report of Severe Accident Response Capability Evaluation for Severe Accident Management Guidelines Development Based on Diagnostic Process Guideline". [1] MAAP5.06 code, which is the latest version, is used in this analysis.

In "mitigation-05" section A is simulated in case of FP-1 and divided from FP-1-1 to FP-1-4 depending on their available method. LLOCA is selected as a representative event of low pressure accident and LOFW is selected as a representative accident of high pressure event.

2.2 Major Assumptions

Each case is calculated based on initial condition presented in table I. To evaluate effectiveness of each methods, fixed equipment is assumed available 15 minutes after entering severe accident and 2 hours for movable equipment. Analyses were ended when effectiveness had been identified. Event cases and available methods are presented in table I.

The condition for initiation of "Fission Product Release Control" action is based on the estimated whole-body dose rate within the site boundary. But because there are no ways to calculate the whole-body dose within the site boundary in this analysis, effectiveness of methods for reducing fission product release is analyzed.

The effectiveness of each method is analyzed based on decontamination and depressurization behavior in containment building. And the results of analysis are compared with the basic scenario which mitigation action is not engaged.

Table I: Initial Condition

	Method Availability
Aux. Feedwater System	N/A
Safety Injection Pump	N/A
Safety Injection Tank	Available (4ea.)
Containment Spray Pump	Available
Reactor Containment Fan Cooling	Available
POSRV(Rapid Depressurization)	Available (4ea.)
Reactor Cavity Flooding System	N/A
Movable Pump Vehicle	N/A
PAR Efficiency	75%

Table II: Event Cases and Available Methods

Case	Initial Event	Methods	Available Timing
FP-1-1	LLOCA	Containment Spray Pump	SA + 15 min
FP-1-2	LOFW	(Shutdown Cooling Pump)	
FP-1-3	LLOCA LOFW	Reactor Containment Fan Cooling	SA + 15 min
FP-1-4	LLOCA LOFW	Emergency containment Spray Backup System	SA + 2 hr

3. Analysis and Results

3.1 Case FP-1-1 and FP-1-2

In case FP-1-1, the effectiveness of containment spray pump is evaluated. Shutdown cooling pump can substitute for containment spray pump. Thus, the results of case FP-1-2 are the same. Fig. 1. and Fig. 2. represent fission product (Iodine) release fraction and containment pressure at LLOCA event. Fig. 3. and Fig. 4. represent fission product release fraction and containment pressure at LOFW event. The results of analysis show the reduction of fission product release fraction and decrease in containment pressure compared to the results of basic scenario. By the results, the goal of case FP-1-1 is judged as effective when using containment spray pump.

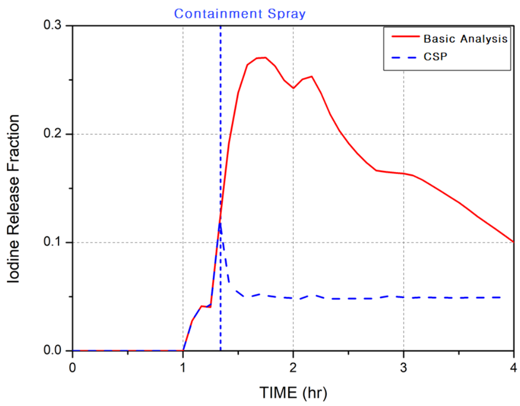

Fig. 1. FP fraction at LLOCA FP-1-1

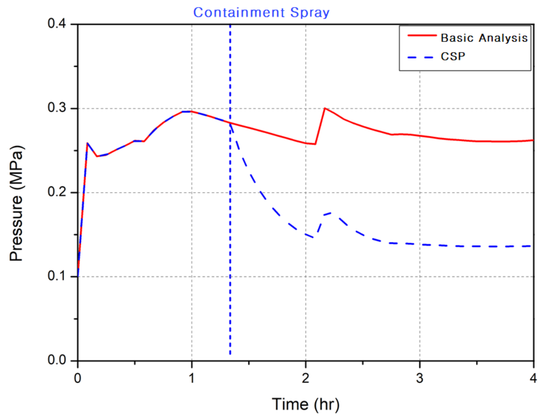

Fig. 2. Containment Pressure at LLOCA FP-1-1

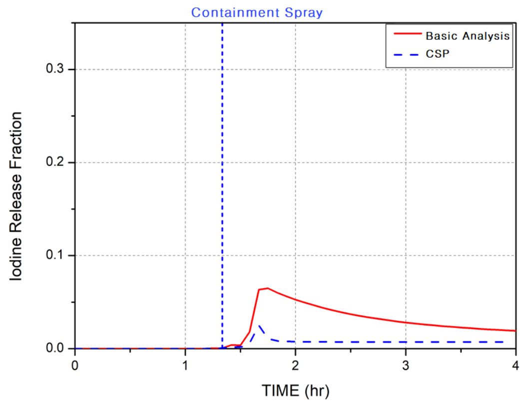

Fig. 3. FP fraction at LOFW FP-1-1

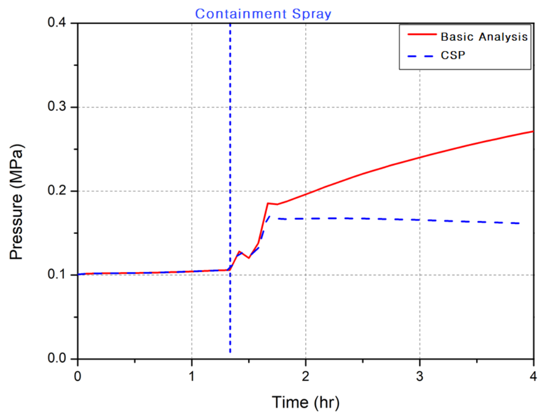

Fig. 4. Containment Pressure at LOFW FP-1-1

3.2 Case FP-1-3

In case FP-1-3, effectiveness of RCFC is evaluated. Fig. 5. and Fig. 6. represent fission product release fraction and containment pressure at LLOCA event. Fig. 7. and Fig. 8. Represent fission product release fraction and containment pressure at LOFW event. Compared to the results for FP release and containment pressure in basic scenario, release fraction of fission product decreased. But compared to case FP-1-1 which uses containment spray pump, reduction tendency in fission product release fraction is not abundantly clear. But it is because MAAP5.06 does not simulate deposition of fission product on cooling coil but only consider decontamination result from steam condensing. So, from a conservative perspective, It is judged that the effectiveness of RCFC is clearly identified.

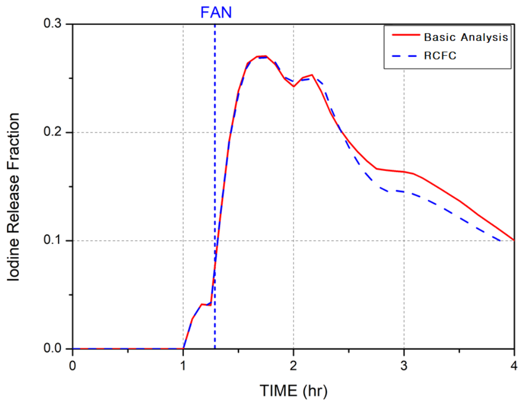

Fig. 5. FP fraction at LLOCA FP-1-3

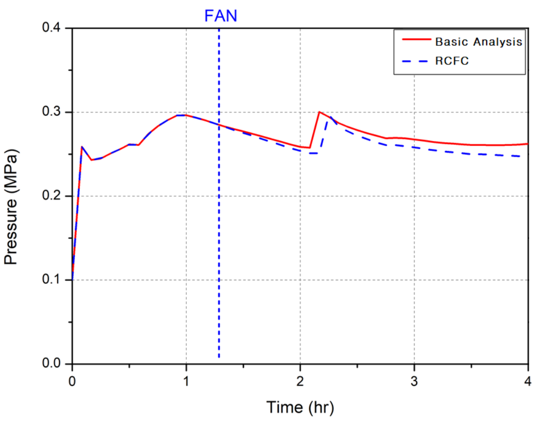

Fig. 6. Containment Pressure at LLOCA FP-1-3

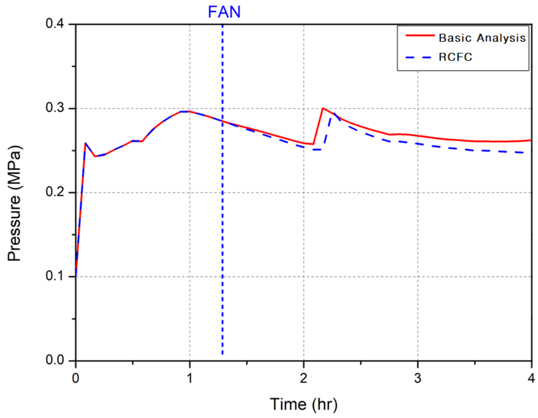

Fig. 7. FP fraction at LOFW FP-1-3

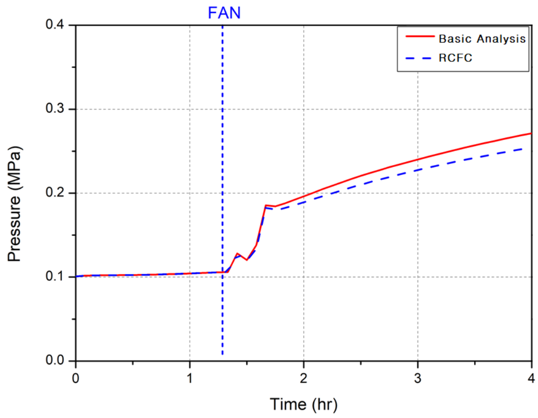

Fig. 8. Containment Pressure at LOFW FP-1-3

3.3 Case FP-1-4

In case FP-1-4, the effectiveness of ECSBS is evaluated. Fig. 9. And Fig. 10. represent fission product release fraction and containment pressure at LLOCA event. Fig. 11. And Fig. 12 represent fission product release fraction and containment pressure at LOFW event. Compared to the results of basic scenario, the results of analysis show that the release fraction of fission product and containment pressure decreased. Because the flow rate of ECSBS is smaller than containment spray pump, the effectiveness of ECSBS is smaller than the case FP-1-1. But it shows meaningful reduction of FP release fraction and decrease of containment pressure. So, effectiveness of ECSBS is identified.

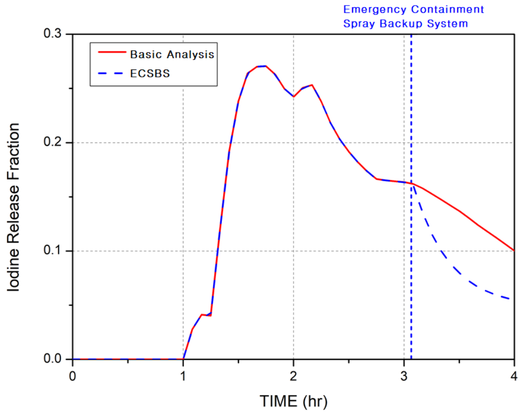

Fig. 9. FP fraction at LLOCA FP-1-4

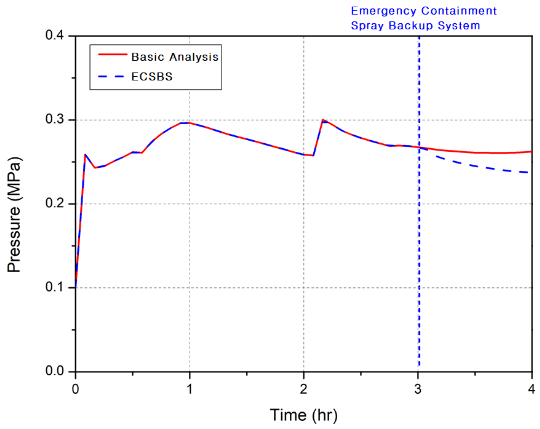

Fig. 10. Containment Pressure at LLOCA FP-1-4

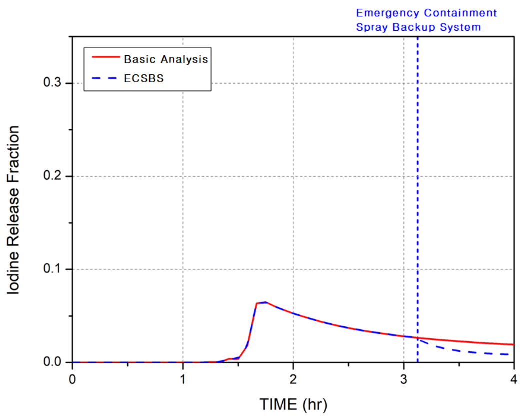

Fig. 11. FP fraction at LOFW FP-1-4

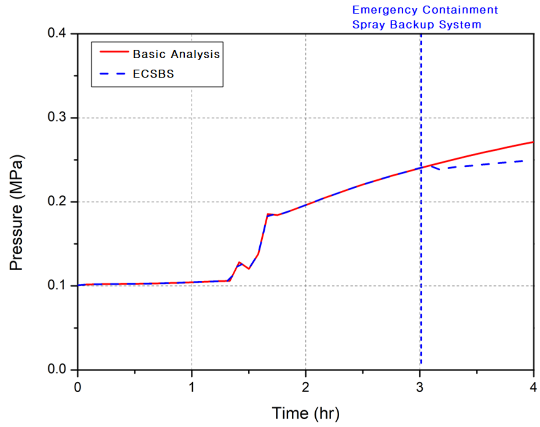

Fig. 12. Containment Pressure at LOFW FP-1-4

3. Conclusions

In these analyses, the effectiveness of diverse methods for "Fission Product Release Control Strategy" is evaluated in APR1400 reactor type. And all the methods for the strategies are identified as effective. The results of these analyses can be applicable when establishing DPG based general SAMG and description of technical background.

REFERENCES

[1] Report of Severe Accident Response Capability Evaluation for Severe Accident Management Guidelines Development Based on Diagnostic Process Guideline, KHNP, 2024.
[2] Integrated SAMG, Mitigation-05 Fission Product Release Control SKN34, KHNP, 2017.
[3] SKN34 Mitigation-05, Description of Technical Background, KHNP, 2017.