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Effect of SIT-FD Modeling on Severe Accident Analysis Using MAAP5

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1. Introduction

A passive Fluidic Device(FD) inside the conventional Safety Injection Tank(SIT) was introduced as one of the new Engineered Safety Features(ESFs) in the APR1400 plants. To investigate the effect of FD modeling for Large Break(LB) LOCA during severe accident, the severe accident analysis code most widely used by nuclear industries, MAAP5, was used.

The modeling was done by adjusting the loss coefficient in the accumulator model of MAAP5. The SIT-FD flow rate obtained and the several results of LBLOCA without safety injection case are presented.

2. Modeling of SIT-FD and Results

In this section, some of the results obtained using MAAP5 to model a severe accident scenario of an LBLOCA without SI with and without modeling FD in APR1400 are described

2.1 Main Design Features of the APR1400 ESF

The APR1400 nuclear power plant has 2-loop, each loop consists of one hot leg and two cold legs [1]. Also one steam generator and two reactor coolant pumps are installed in each loop and one pressurizer is connected to hot leg. APR1400 adopted improved design features in order to enhance safety, economics and reliability compared with OPR1000 [2]. The new design features regarding Emergency Core Cooling System are as follows:

- Direct Vessel Injection (DVI)
- Four Safety Injection Pump (SIP)
- FD inside SIT
- Removing Lower Pressure Safety Injection (LPSI)
- In-containment Refueling Water Storage Tank (IRWST)

The safety injection system of APR1400 consists of four SITs with FD and four SIPs as shown in Figure 1 [2]. The IRWST is the water source of Safety Injection System for APR1400.

2.2 Mechanism of SIT-FD

The schematic diagram of FD is shown in Figure 2. The high flow rate is achieved through stand pipe, if the water level of SIT is higher than the top of the stand pipe. And the low flow rate is determined for a long period of time by the increased resistance of FD, if the water level of SIT is lower than the top of the stand pipe. Thus, fluidic device plays an important role in keeping the safety injection flow for a long time [3].

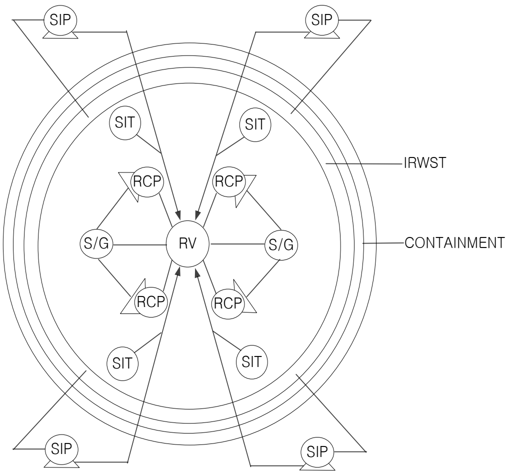

Fig.1. The APR1400 Safety Injection System

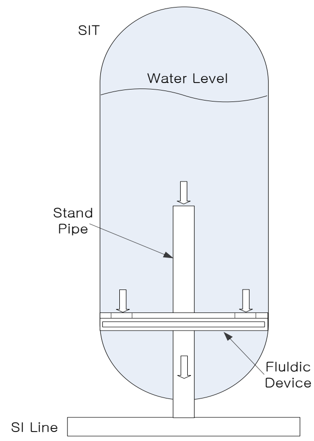

Fig. 2. Configuration of SIT-FD

2.3 Overview of MAAP5 Code

The MAAP was initially developed by Fauske & Associates, LLC (FAI) during the industry sponsored Industry Degraded Core Rulemaking(IDCOR)program in the early 1980s. The MAAP 3.0B has been widely used for Individual Plant Examination(IPE) analysis since the late 1980s in the United States and has been used for numerous plants for more than 25 years. Since the release of version 5.00 in 2008, version 5.03 was released in August 2014 (The Current version is 5.04) [4]. MAAP version 5.03 includes features related to the Fukushima accident and improved models such as Containment Filtered Vent System(CFVS) model, In-containment(ex-vessel) debris spreading, Molten-Core Concrete Interactions(MCCI) and etc.

The MAAP5 code is an integrated computer program that reflects the relationship between phenomena and simulates the thermal hydraulic behavior of feed water system and containment building, the melting of the core, the generation and migration of fission products after an accident. Also, it deals with major engineered safety systems such as emergency core cooling system and containment building spray system.

2.4 SIT-FD Modeling using MAAP5

ACCUMTANK model of MAAP5 is used for cold leg or downcomer injection accumulator and calculates the pressure in the accumulators and the water and gas flow rate from accumulators to the primary system. The flows are driven by the pressure difference between the accumulator and the primary system, and the flow area and the hydraulic resistance of the connecting pipes.

The SIT-FD in APR1400 can be modeled by using the loss coefficient(K value) of the MAAP5 accumulator model. The initial high flow is simulated using a small K value and the low flow is simulated using a large K value. As shown in Figure 3, SIT flow rate is well modeled using MAAP5 accumulator model comparing with that of RELAP5. Figure 4 also shows SIT flow rate comparing with presence or not of FD.

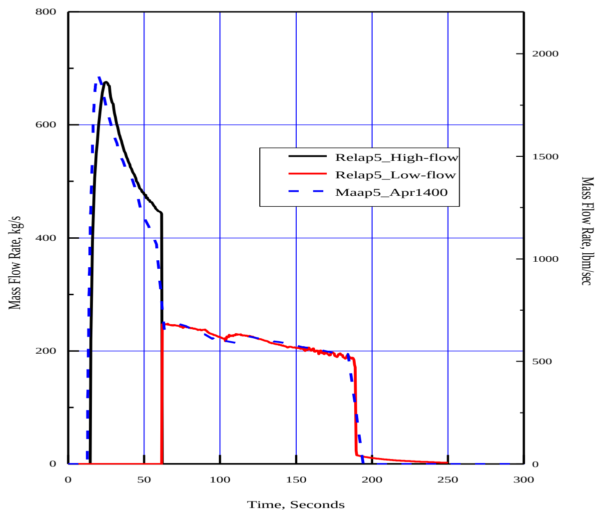

Fig. 3. SIT Flow Rate

2.5 LBLOCA without Safety Injection(SI) Analysis

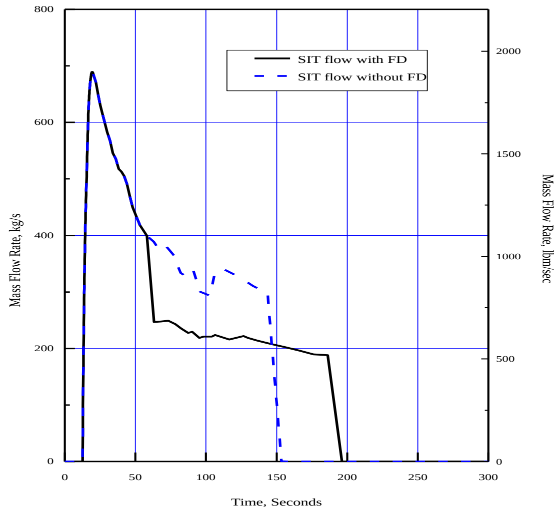

Fig. 4. SIT Flow Rate with or without FD

The FD inside SIT is designed to enable more effective cooling during reflood phase by controlling the flow of SIT. The use of passive type SIT-FD will ultimately contribute to lowering the core damage frequency of APR1400 compared with existing nuclear power plants [5].

The LBLOCA without SI accident was selected to identify the effect on severe accident sequence analysis and consequences if SIT-FD is not modeled properly. It is assumed that the SI pump, which is the active safety injection system, does not work after a double ended guillotine break in the primary cold leg for LBLOCA without SI accident case. The inactivation of SIP causes rapid core damage and melt with excessive hydrogen generation, and the core melt can relocated to the lower plenum and cause failure of the reactor vessel. Table I and Figure 5 show the results of the effect of SIT modeling on the Figures-of-Merit(FOM) and hydrogen production in the core, respectively.

Table I: Comparison of Performance Figures-of-Merit

	SIT w/o FD Modeling	SIT-FD Modeling
Time of Core Uncovery	1.70 sec	1.70 sec
Time of SIT injection	12.7 sec	12.7 sec
Time of 1^{st} Relocation to Lower Plenum	14385.30 sec	14777.22 sec
Time of First Vessel Failure	15578.80 sec	16170.88 sec
Time of Vessel Failure	15578.80 sec	16170.88 sec
Fraction of Clad Reacted in Vessel	38.81 %	36.55 %
CsI Mass Fraction in Containment	55.5 %	52.9 %

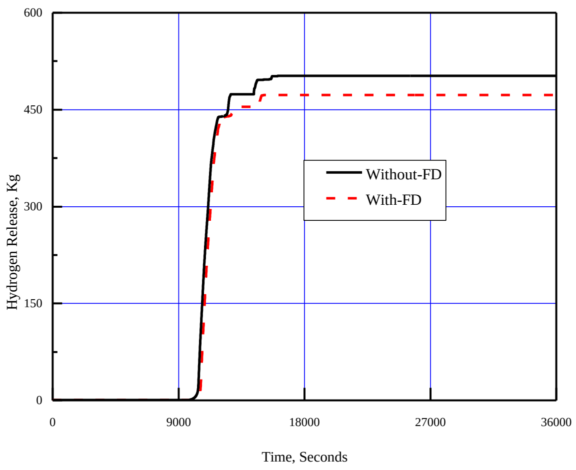

Fig. 5. Mass of Hydrogen Generated

3. Conclusions

The behavior of SIT-FD was modeled using accumulator model of MAAP5 by adjusting the loss coefficient to simulate the LBLOCA without SI during severe accidents in APR1400 plant. The results show that the time of vessel failure was delayed by about 10 minutes and the mass of Hydrogen generated was reduced by 29 Kg. It demonstrates that the proper modeling of the ESFs in APR1400 plant is necessary to get better insight for severe accident analysis.

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