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Conceptual Designs for the Performance Improvement of APR1400 SIT and Preliminary Performance Evaluation

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1. Introduction

Some evolutionary type PWRs such as APR1400 and APWR adopt advanced safety injection tank (SIT) [1, 2]. The SIT of APR1400 has a fluidic device (FD) which passively controls ECC water injection flow rate into reactor coolant system during refill and reflood phases of LB-LOCA (i.e., a high injection flow rate during the refill phase and a low injection flow rate during the reflood phase). The benefit of the FD is the elimination of the function of low pressure safety injection pump from the safety injection system.

The flow controlling performance of the APR1400 FD was evaluated using a prototypical full-scale test facility, called VAPER (Valve Performance Evaluation Rig) [3]. Even though the performance of the APR1400 FD satisfied major design and licensing requirements, further improvement of the performance is expected such as the extension of total injection period, the delay of nitrogen gas discharge.

Several conceptual designs have been being drawn out in order to improve the performance of the APR1400 SIT. The performance of some designs was evaluated using a small scale SIT test rig. The present paper introduces some of the conceptual designs and shows the performance evaluation experimental results.

2. Design Improvements and Performance Evaluation

2.1 Modified Designs

APR1400 SIT has control ports at the top surface of FD (Fig. 1). Therefore, the ECC water below the top of FD can not be used for core cooling, hindering the effectiveness of ECC water.

The design to extend the total injection period is shown in Fig. 2 (a). If the control ports are connected from the bottom surface of FD and extended downward, the ECC water below the top of FD can be used for core cooling, resulting in the extension of total injection period of about 10 seconds.

The design to delay the initiation of nitrogen gas discharge is shown in Fig. 2 (b). If the flow path from the supply port to the insert plate is changed as in Fig. 2 (b), the lowest elevation of the supply port is decreased about 500 mm compared with the standard APR1400 SIT. That is, the nitrogen gas above the top surface of ECC water can be discharged out of SIT through supply part after the water level in the supply port reaches the bottom part of the SIT, which is about 500 mm lower than the critical level of the partition plate for the standard APR1400 SIT. This modification can delay the initiation of nitrogen gas discharge about 15 seconds.

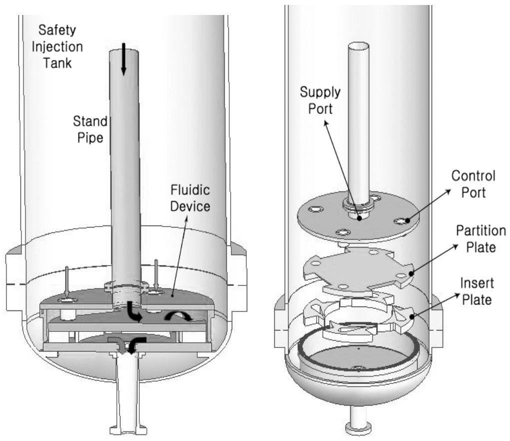
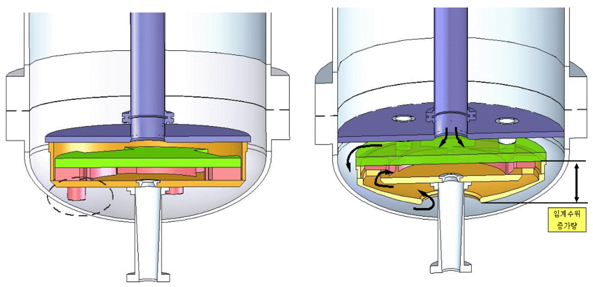


Fig. 1 Structure of APR1400 SIT.



(a) (b)

Fig. 2 SITs with modified control ports (a) and modified supply port (b).

2.2 Preliminary Performance Evaluation Results

Small scale test rig with a scale ratio of 1/3.7 was constructed to quantitatively evaluate the performance of new design SITs. The performances of the standard FD and the FD with modified control ports were evaluated at reduced pressure condition. The ECC water levels in the SIT and the stand pipe were measured with differential pressure transmitters. The injection flow rate was calculated from the ECC water level decrease rate or directly from the Coriolis mass flow meter at the downstream of SIT. The initiation of gas discharge was detected from the density measurement data of the Coriolis flow meter.

Three experiments were repeated for each model of FD, and the reproducibility of the experiments was confirmed. The major performances of each FD are summarized in Table I. As expected, the total injection time of the FD with modified control ports was extended due to the increase of effective volume of the ECC water (also in Fig. 4), without deteriorating other major performance parameters.

Another positive effect of the design modification was the increase of the stand pipe water level after flow rate turning point (at 15 second) until the water level reached the bottom of the stand pipe (at about 60 second) (Fig. 3). This resulted in the delay of the initiation of the gas discharge (Fig. 5). However, the underlying mechanism for the change of the stand pipe water level has not been identified yet.

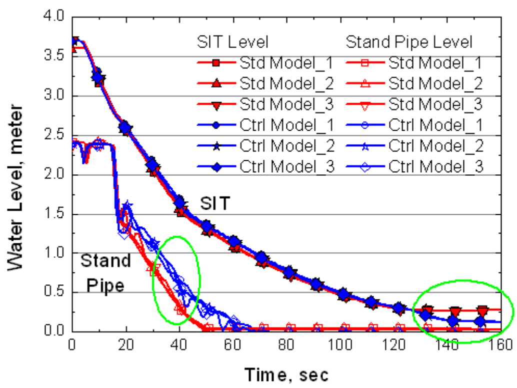


Fig. 3 Comparison of SIT and stand pipe levels.

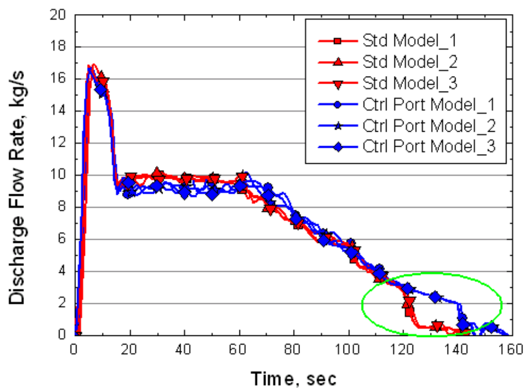


Fig. 4 Comparison of injection flow rate and duration time.

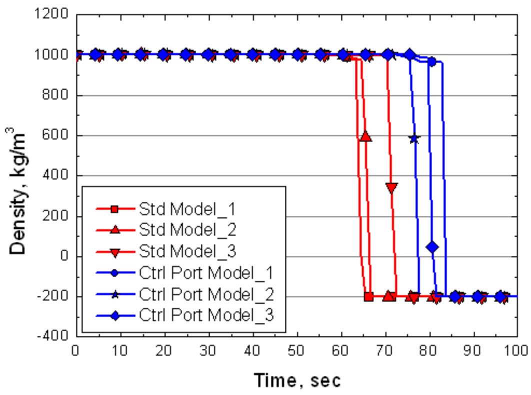


Fig. 5 Comparison of initiation time of air discharge

Table I: Performances of standard SIT and SIT with modified control port. Averages values are shown from three repeated experiments.

Model	Standard	Modified
Initial Pressure (kPa)	611	610
Initial Level (m)	3.7	3.7
Total Injection Time (s)	124	142
Initiation of Air Discharge (s)	65.7	78.7

3. Conclusions

Conceptual designs for the improvement of APR1400 SIT have been drawn, and the feasibility of the design was confirmed from the small scale test rig. In the case of the control port modification design, the total discharge time was extended and the initial gas discharge time was delayed. Performance evaluation for other conceptual designs will be carried out in the future.

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