Feasibility Study on Passive Auxiliary Feedwater System in Loss of Condenser Vacuum Accident

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1. Introduction

Nuclear leading countries are developing and constructing technology intensive pressurized water reactors (PWRs) such as AP1000 (United State), EPR (Europe), and US-APWR (Japan), and these advanced reactors adopt several passive safety features in order to enhance the safety and reliability. Domestic advanced reactor APR1400 already completed the earlier development in 2002, and technology gap from the nuclear leading countries become large. In particular, China requires technology transfer in the order of new power plant construction. Thus it is expected difficult to export the power plant to the newly developing countries without our own technology. Therefore, the improvement of competitive power and establishment of infra structure of advanced nuclear industry through innovative technology enhancement are urgent and essential to international competitive marketing. Passive safety features have been always adopted as an improved design concept in the development of innovative reactor design. Domestic nuclear industry has stated the development of APR+ as a Korean specific reactor for the export strategy. In the development of APR+ a passive auxiliary feedwater system (PAFS) has been considered as a noticeable candidate of improved design. The outline of PAFS is shown in Fig. 1[1].

Reference 2 reported that the adoption of PAFS, which can replace the auxiliary feedwater system, can prevent core damage in the accident of station black out (SBO), since Class 1E DC power operates the related valves, and 8 hours hot standby operation of plant without operation action is achievable. This PAFS contributes to the safety and economics, in that it decreases the core damage frequency 26% from 2.45E-06/r-y to 1.80E-06/r-y, and it saves the construction cost 20 million Kr-Won.

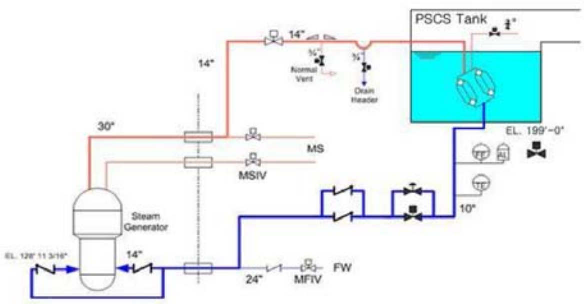


Fig. 1 Outline of PAFS

This paper discusses on the performance of PAFS for the accident of loss of condenser vacuum as a precursor of detailed design specification.

2. Description of PAFS

PAFS in APR+ is now under development, and its detailed design specification and requirement are changing depending on the progress of research. Preliminary design base and system composition at this time is introduced following subsections

2.1 Design Base

Major premise of the design requirement of PAFS is that it has to replace perfectly the AFW system. Selected principal design bases are as followings[1];

- It has to remove the residual heat of core in case of AOO and postulated accidents
- The capacity of PAFS covers at least 8 hours hot standby operation without any operator action in case of SBO in order to prevent the core damage
- All the power source is to be eliminated except the Class 1E DC

2.2 System Description

PAFS is composed of 2 independent trains, and each train covers 100% performance. PAFS piping of steam feed line starts from the main steam line upstream of main steam isolation valves (MSIVs), and the steam is condensed in condenser heat exchanger. The condensed water goes through the return line and finally merges into an economizer line. The circulation flow is driven by the natural convection due to the gravity force.

For the sake of PAFS isolation from the main feedwater system isolation during normal operation, valves and check valves are installed. Main composition of each train is as followings[1];

- Isolation valves and check valves
- Heat exchanger
- Condenser tank
- Piping

3. Performance Analysis for LOCV

3.1 Selection and Modeling of Accident

LOCV is known to be the limiting event for the PAFS. Even though PAFS is to be incorporated into

APR+, APR1400 is selected for the performance analysis, because APR+ design is not yet fixed. Selected thermally hydraulic computer code was RELAP5/MOD3.3[3].

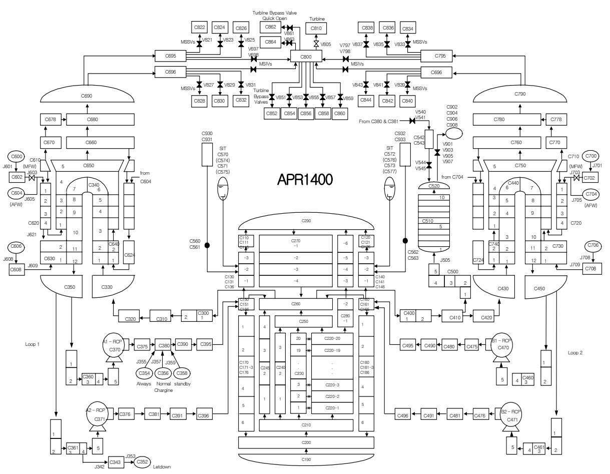


Fig. 2 Nodalization of APR1400

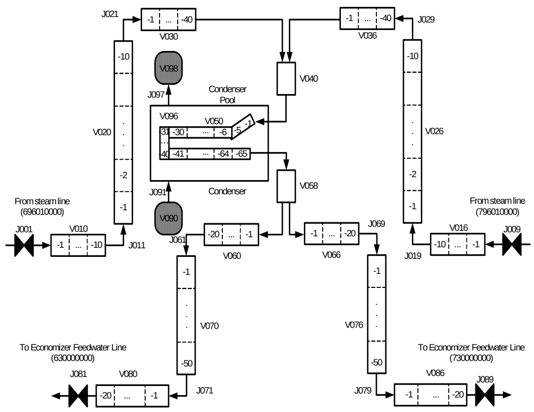


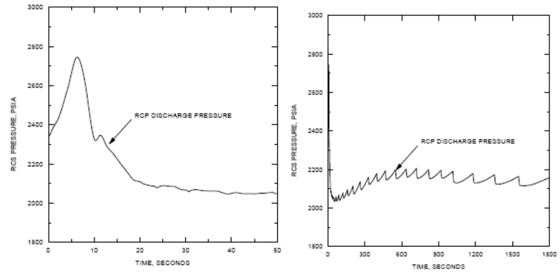
Fig. 3 Nodalization for PAFS

Reference geometry data for PAFS were taken from reference 4. In particular, the condenser heat exchanger is horizontal U-tube type with inlet and outlet headers. Nodalization of APR1400 is shown in Fig. 2 and detailed nodalization for PAFS is shown in Fig. 3. For the comparison AFS case instead of PAFS was also assessed.

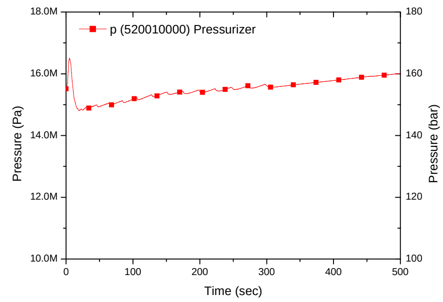
3.2 Results

Following the initiation of LOCV with loss of off-site power (LOOP), a turbine, main feedwater pumps, and reactor coolant pumps stop, and the decreased heat removal in primary system results in instantaneous pressure rise. After reactor shutdown by RCS low flow, the pressurizer pressure begins to decrease, as shown in Fig. 4. The AFW and PAFS was initiated about 300 sec..

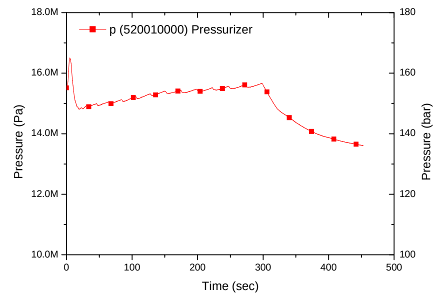
PAFS shows better cooling performance than AFW. This is thought mainly because the flowrate by PAFS is far larger than the AFW in earlier phase of its initiation.



(a) SSAR Results



(b) RELAP5 Result for AFW



(c) RELAP5 Result for PAFS

Fig. 4 Results and Comparison to SSAR: Pressurizer Pressure Behaviors

4. Conclusions

This paper shows the desirable prospect of PAFS in APR+. As the development of its specific design goes on, more detailed performance analysis will be carried out.

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