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Potential to Air Ingestion to ECCS from RWT following a Recirculation Actuation Signal

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1. Introduction

The Korean Standard Nuclear Power Plants (KSNP) has a refueling water tank (RWT) and two Containment Recirculation Sumps (CRS) as water sources of Emergency Core Cooling System (ECCS). Piping from two water sources are combined into a common pipe before the ECCS pumps [1]. The basic design concept was based on the Combustion Engineering (CE) System 80 design such as Palo Verde Nuclear Power Plants (NPP) in USA.

Recently, the Palo Verde Units 2 and 3 were shutdown due to the concern on the potential to air intrusion to ECCS pumps [2]. Because of the similitude between the Palo Verde plants and KSNP, the potential of air ingestion was questioned for KSNP. The Recirculation Actuation Signal (RAS) occurred when the RWT water level decreased to a certain value following loss-of-coolant accident (LOCA), the isolation valves of CRS are open automatically to change the ECCS water source to CRS, while the RWT isolation valves are closed manually. Concern was whether such a design has a potential to air ingestion to ECCS pumps before completion of the manual action to close RWT isolation valves or not.

Figure 1 shows a schematic figure of RWT, CRS and associated ECCS piping. In the ECCS piping design, the piping from RWT is connected to one from CRS with two check valves. The elevation of the connecting point was designed to be lower than the bottom of the RWT by 16 ft and the head loss in the CRS piping to be less than 7 ft [1]. It is expected the air intrusion to the ECCS pumps could be prevented by those design features. However, vortex could be formed in the RWT and migrated into the piping by the strong suction force due to ECCS pumps and CS pumps during the LOCA situation. Additionally, in small break LOCA (SBLOCA) situation, the containment pressure may not be high enough to press the water in CRS into ECCS pumps against the water head in RWT piping. This also increases the potential to air intrusion. If high potential is identified, a design modification for the automatic closure of RWT isolation valves may be requested.

To evaluate the potential of air ingestion, the design adequacy, and any need of plant modification, an analysis of the hydraulic transient within the ECCS piping following the RAS in KSNP was performed.

2. Code and Modeling

To analyze the hydraulic transient in the water tank and piping of ECCS of KSNP, RELAP5/MOD3.3[3], one of the best estimate thermal-hydraulic code was used. The code was known to have capability to calculate one-dimensional two-phase transient flow with noncondensible gas in the complex piping. The applicability of the code to this kind of hydraulic transient has been assessed for the experiment on water hammer in a long pipe line and applied to analysis of pressure propagation in submerged pipe [4, 5].

The portion of ECCS of interest includes RWT, CRS, pipe lines from RWT and CRS to connection point with its own isolation valve and check valve, a common pipe line to ECCS header, each pipe line from the header to HPSI pump, LPSI pump, and CS pump, respectively. Based on the geometric data of the piping, a RELAP5 input model was developed as in Figure 2. The input model has 139 hydrodynamic volumes and 138 junctions in total.

Initially, the RWT level was assumed to be 8 ft above

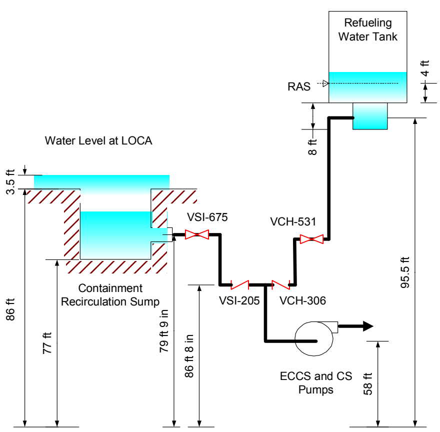

Fig. 1 Schematic of RWT, CRS and pipng

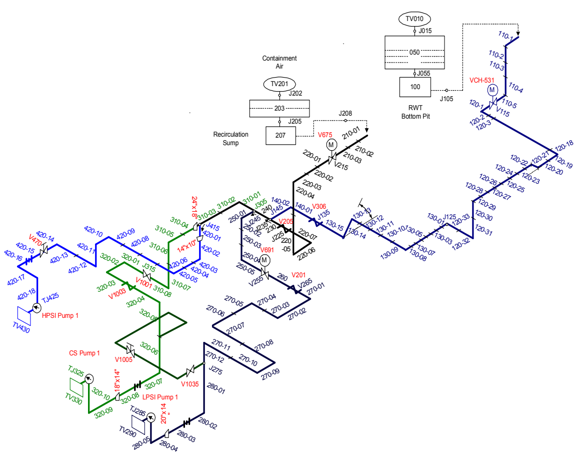

Fig. 2 RELAP5 Modeling of ECCS piping of KSNP

the tank bottom. Water temperature was conservatively assumed to 77°F under atmospheric pressure based on the Technical Specification of KSNP [1]. The CRS and containment was assumed to be filled up to 3.5 ft. The water temperature was assumed to 200°F based on the LOCA analysis result [1].

A steady state initialization to pressure distribution along the system was conducted for 200 sec. At 200 seconds, two ECCS pumps and CS pumps start at their full flow rates. It was modeled that the RAS occurred at 4 ft above the tank bottom, the CRS isolation valve open within 30 seconds after RAS, the RWT isolation valve remained open to maximize the possibility of air ingestion, and the LPSI pump was stopped at RAS with coast-down for 100 seconds. The pressure of the containment atmosphere and RWT atmosphere were assumed to be 14.7 psia throughout the transient, which corresponded to situation of small break LOCA. Sensitivity study was performed for a case of SBLOCA with tripping the CS pump, a case of large break LOCA and a case of the RWT isolation valves closure in 3 minutes in SBLOCA.

3. Results and Discussion

Using the input model described above, RELAP5 transient calculation was conducted until 840 sec. To understand the air intrusion behavior, the calculated void fractions of all volumes in the pipe from the RWT to RWT check valve were plotted as function of time and space in Figure 3. In the figure, node 1 means the first cell at RWT downstream. The RWT check valve was represented by 56th cell. The horizontal pipe section whose elevations were higher than adjacent cells includes cells from 21 to 35. As in the figure, voiding was progressed downstream to the 40th cell. Approximately 700 sec, the cells 25~35 were emptied and continued to void until the end of the transient, while the upstream cells were refilled with water. It indicated a migration of noncondensible gas from the RWT tank to the pipe section of higher elevation. However such a noncondensible gas movement was not further expanded, thus RWT check valve were filled with water throughout the transient.

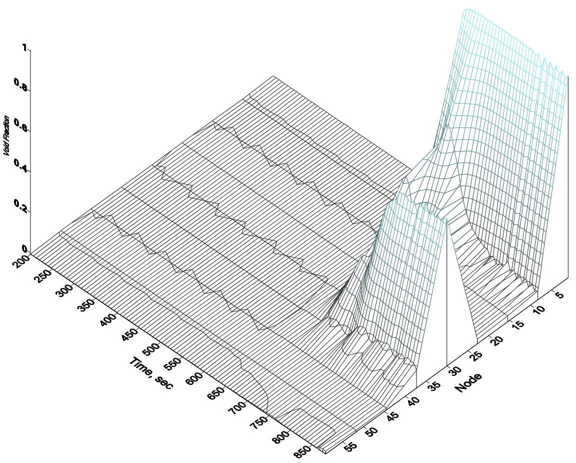

Fig. 3 Void Fraction Distribution in the RWT Pipe

From those result, it was found that Refueling Water Tank (RWT) level can be decreased further even after RAS and the actual switchover of water source from RWT to Containment Recirculation Sump (CRS) was completed at RWT level zero. It was also found that some of the air from the RWT can be introduced into the pipe at RWT downstream and they could be migrated into the pipe portion of higher elevation. However, the potential to air ingestion into ECCS pumps can be ignored since the RWT check valve is filled with water of 15 ft in depth throughout the transient for the worst scenario. And the quick closure of RWT isolation could prevent further the possibility of air ingestion.

REFERENCES

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