Analysis for Passive Safety Injection of IPSS in Various LOCAs

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1. Introduction

The Fukushima accident shows us the possibility of accidents that are beyond a designed imagination. Lots of lessons can be shortly summarized into three issues. First of all, the original cause was the occurrence of a Station Black-Out (SBO). Even if engineers considered the possibility of a loss of offsite power enough to be managed, the failure of EDGs seemed to be unnoticed. The second is poor operation and accident management. They could not understand the overall system and did not check the availability of alternating systems. The third is the large release of radioactive materials outside the containment. Even if SBO occurred and the accident was not managed well, all the means must have prevented the large release out of containment.

After that, lots of problems were pointed and numerous actions were carried out in each country. The representative proposals are AAC, additional physical barrier, bunker concept and large big tank.

Integrated passive safety system (IPSS) was proposed as one of the solutions for enhancing the safety [1]. IPSS can cope with a SBO and accidents with a SBO. IPSS has five functions which are passive decay heat removal, passive safety injection, passive containment cooling, passive in-vessel retention and filtered venting system. The concept of an IPSS can be achieved by the application of one or two big tanks outside containment shown in Fig. 1.

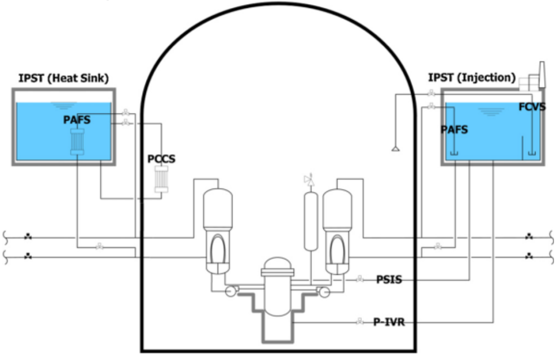

Fig. 1. IPSS on a loop-type PWR

The functions of passive decay heat removal supplying water into steam generators were simulated and analyzed in the conditions of a SBO and a SBO with MFLB for OPR1000 in the previous studies [1]. The results showed a high performance of removing decay heat through steam generator cooling by forming natural circulation in the primary circuit. The design concept of passive safety injection system (PSIS) consists of the injection line from integrated passive safety tank (IPST) to reactor vessel. The previous works were only focused on a double ended guillotine break LOCA in SBO [1].

The purpose of this paper is to analyze the performance of PSIS in IPSS for various LOCAs by using MARS (Multi-dimensional Analysis of Reactor Safety) code [2]. The simulated accidents were LOCAs which were accompanied with a SBO. The conditions of the LOCAs were varied only for the size of break. It shall show the capability of PSIS in IPSS to cope with LOCAs according to the break size.

2. Method

The reference reactor is OPR1000 as a Korean representative reactor. As SBO is assumed, both HPSIPs and LPSIPs cannot be operated. The limited use of the battery as a DC power was set. Also, the secondary circuit is isolated by isolation valves.

The location of the break is the same as the cold leg for all simulations. The size of break varies from 15 inch to 2 inch for each simulation. Even if there are so many sequences about occurrence time of SBO and LOCA, for simple condition, it is assumed that SBO and LOCA simultaneously occurred at 0 sec.

One of two IPSS is activated to supply water from an IPST into reactor vessel. Table I shows the dimensions of the IPST in IPSS.

Table I: Specification of IPST

Parameters	**Dimensions**
IPST Number	2
Water volume [m^3]	2 x 2000
Length x Width x Height [m]	13.5 x 13.5 x 11.1
IPST pressure [MPa]	0.1 (atmospheric)
IPST temperature [K]	300

IPSTs are assumed to be installed on the top of the auxiliary building outside the containment. From the installation of IPSTs, the values of the elevations related with the performance of PSIS are indicated in Table II.

Table II: Absolute elevation of main location

Parameters	**Dimensions**
Water level in IPST [m]	41.6
Bottom of IPST [m]	30.5
Nozzle on steam generator [m]	12.8
Nozzle on reactor vessel [m]	3.3
Ground [m]	0.0
Cavity floor [m]	-13.7

3. Results

3.1 SBO with LOCA (15 inches to 5 inches)

The pressure variations in the LOCAs, whose break range are from 15 inches to 5 inches, are illustrated in Fig. 2. All the values in RCS continuously decrease due to the break. The degree of pressure decrease is proportional to the break size.

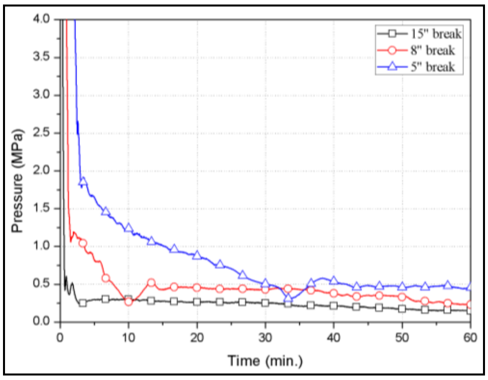

Fig. 2. Pressure in pressurizer

Due to the natural depressurization from the break in RCS, the mass flow rate is formed by the pressure difference induced by the elevation difference and the pressure in reactor vessel downcomer. Fig. 3 shows the variation of mass flow rate for the cases of 15, 8 and 5 inches break.

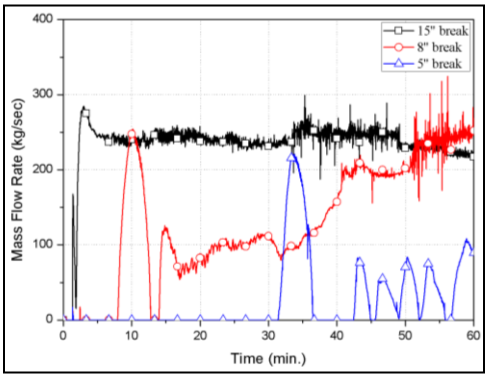

Fig. 3. Mass flow rate from IPST to reactor vessel

3.2 SBO with LOCA (4 inches to 2 inches)

The LOCAs whose break sizes are less than 4 inches were simulated for longer time than one hour. That is because the pressure in the primary loop slowly decreases. Fig. 4 shows the pressure variation in pressurizer. For the cases of 4 and 3 inches, the values of pressure reach the operation pressure for passive safety injection although it takes more than one hour. The mass flows are formed, but fluctuated due to the high pressure.

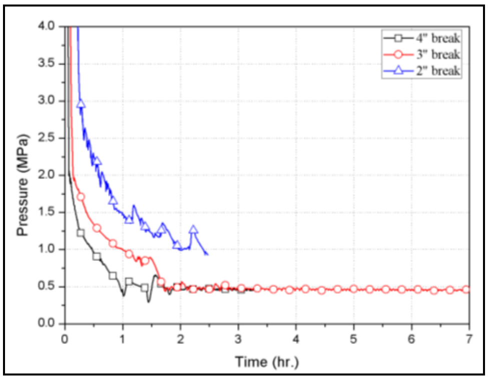

Fig. 4. Pressure in pressurizer

Fig. 5 shows that the cases of 4 and 3 inches can be cooled by passive safety injection. However, in the case of 2 inches, cladding is damaged due to the high temperature.

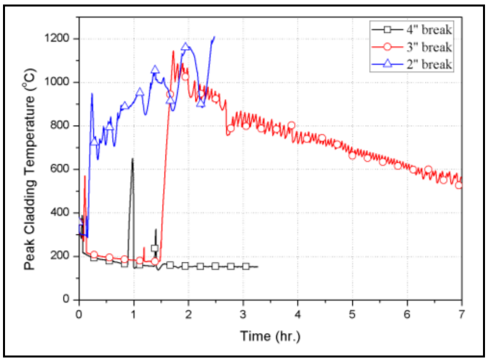

Fig. 5. Peak cladding temperature

4. Conclusions

The LOCAs, which were differently set upon the break size on the cold leg, were simulated with the condition of SBO by MARS code. The results showed that the LOCAs with the break size larger than 3 inches could be mitigated by gravity injection of PSIS in IPSS. Accordingly, the installation of large tank on the top of the auxiliary building would enhance the coping ability for LOCAs in spite of loss of AC power.

For the cases whose break size is smaller than 2 inches, the decay heat removal through supplying coolant into steam generator is expected to form the natural circulation in the primary loop. As the further study, the specific consideration about the overall containment pressure is needed for long time cooling.

REFERENCES

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[2] J.J. Jeong, et al., Development of a multi-dimensional thermal-hydraulic system code, MARS 1.3.1. Ann. Nucl. Energy 26 (18), 1611-1642, 1999.