Spraying Water on Auxiliary Building to Mitigate Bypassing Aerosol in ISLOCA

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1. Introduction

In an Inter-System Loss of Coolant Accident (ISLOCA), radionuclides bypassing the containment could be released into the outside environment through an auxiliary building. Our previous study shows that the fission products are released into a pool generated within an Auxiliary Building (AB) of OPR1000 in an ISLOCA [1]. We simplified an AB and a Shutdown Cooling System (SCS) pipe line using a MELCOR code, and a pool scrubbing model were activated to assess the aerosol behavior. The initial inventory of cesium (Cs) aerosol releasing into a pool can be reduced by 28%. The recent study shows the effect of mitigation scenario such as Cavity Flooding System (CFS) and Emergency Containment Spray Backup System (ECSBS) of APR1400 in an ISLOCA [2]. A reduction rate of aerosol increases up to 53% by a pool scrubbing model in a MELCOR code. In addition, aerosol deposited on the inter-pipe line can be suspended again from the pipe heated more than 1100 K. It is necessary to suggest a new mitigation method in an AB, not the previous strategies in containment. Because the aerosol reduction caused by deposition and pool scrubbing could be relatively small by a high-temperature pipe and an uncertainty of a pool generated in an ISLOCA.

2. Methods and Results

To assess the effect of spraying water on an AB to mitigate aerosol in an ISLOCA, we modeled the operating conditions of spray, and calculated a hypothetical accident scenario in OPR1000 using a MELCOR code of version 2.2.11932.

2.1. MELCOR Modeling

In an ISLOCA, it was assumed that coolant discharging from the primary circuit was released into a room for a Low Pressure Safety Injection (LPSI) pump in an AB through a SCS pipe [1]. Here, a SCS pipe connecting a hot leg to a LPSI pump room is isolated by motor-driven valves in the normal operating condition of OPR1000. ISLOCA was occurred by rupture of a SCS pipe in front of a LPSI pump after the isolation valves opened. In a MELCOR code consisting of the various packages, we connected between a SCS pipe and a LPSI pump room (CV900) using a flow path (FL318), as shown in Fig. 1. The opening of isolation valves at the specific time was simulated by the control function.

An ISLOCA scenario without spraying water on an AB was the base case that was compared with the spray cases. Here, the ruptured size of a SCS pipe was 4 in. In the spray package of a MELCOR code, we set that the injection time, size and flow rate of droplets discharging from a spray nozzle were 6000~8000 s, 0.001 m, and 0.0133~0.0399 m^3/s, respectively, as shown in Table I.

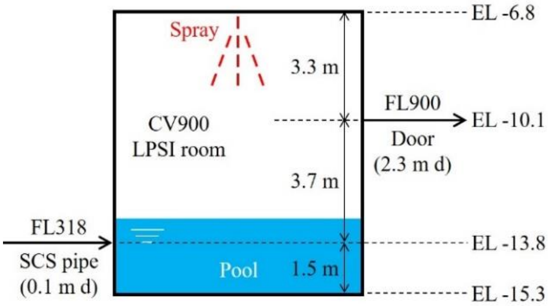

Fig. 1. Spray water on a LPSI room in ISLOCA.

Table I: Calculation cases of spraying on AB

Time (s)	Droplet rate (m^3/s)		
	0.0133	0.0266	0.0399
6000	SP900613	SP900626	SP900639
7000	SP900713	SP900726	SP900739
8000	SP900813	SP900826	SP900839

2.2. Accident Sequence

The key accident sequence of the base case was as follows: (1) ISLOCA occurred at 0 s, and it caused a reactor trip. A Main Feed Water System (MFWS) was stopped to supply, and a Main Steam Isolation Valve (MSIV) was closed. (2) Reactor Coolant Pumps (RCPs) stopped at 31 s. (3) Coolant in Safety Injection Tank (SIT) injected into the primary circuit from 1184 s to 2711 s. (4) Gap release of the fission products was started at 6593 s, (5) Lower head of a reactor vessel was penetrated at 12292 s. The sequence time strongly depends on the input variables set by users of a MELCOR code. The sequence time of the spray cases was similar with that of the base case, even though spray in a LPSI room was operated after 6000 s. The operating of spray in an AB did not cool the primary circuit, but it can affect the transport behavior of the fission products.

2.3. Mitigation Rate of Cesium Aerosol

Mass of Cs releasing into the outside environment was reduced by spray scrubbing in an AB as well as pool scrubbing. This study calculated the mitigation rate defined by dividing the difference between Cs mass in the environment at the time of Lower Head Penetration

(LHP) of the spray case and that of the base case by that of the base case, as shown in Table II. The mitigation rate at the injection time of 6000 s, i.e., the cases of SP900613, SP900626, and SP900639, increased with the increment of an injection rate. The change of the mitigation rate at the injection rate of 0.0133 m^3/s was relatively small, as shown in the comparison of SP900613, SP900713, and SP900813. The cases of SP900626, SP900726, and SP900826 showed that the mitigation rate at the injection rate of 0.0266 m^3/s increased at the faster injection time.

Table II: Mitigation rate of Cs released into the environment

Cases	Time of LHP (s)	Mitigation rate
SP900613	12705	-12%
SP900713	13808	-9%
SP900813	10470	-12%
SP900626	13054	-43%
SP900726	14634	-35%
SP900826	12549	-26%
SP900639	12482	-46%
SP900739	12563	-47%
SP900839	13129	-39%

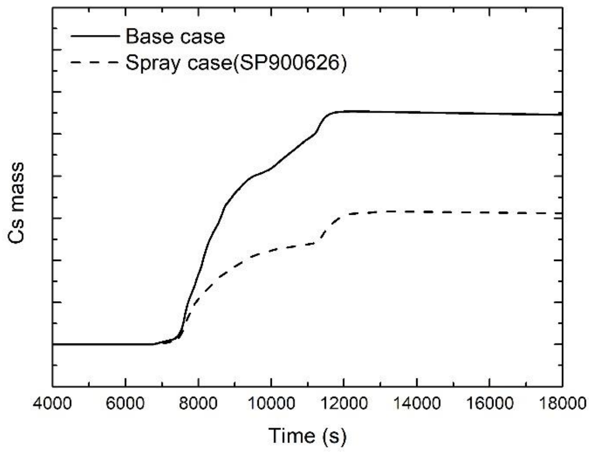

Fig. 2. Cs mass released into the outside environment.

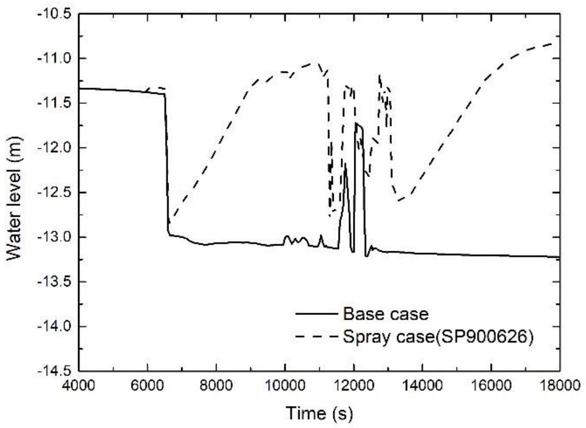

Fig. 3. Water level in a LPSI pump room.

In the case of SP900626, mass of Cs releasing into the outside environment from 6650 s to 10800 s was reduced than the base case, as shown in Fig. 2. During the same period, the water level in a LPSI pump room was linearly increased by spraying, as shown in Fig. 3. Cs aerosol was released into a pool, because the elevation of a SCS pipe was below the water level. The water level decreased dramatically at 11250 s, even though the operating of spray was kept continuously. The water level fluctuated greatly at the time that the lower head of a reactor vessel was penetrated, and it linearly increased again from 1330 s. The increased water level and the operating spray will not affect the aerosol removal in an AB after the occurrence of LHP, because most of the fission products will be released into the containment.

3. Conclusion

This study assessed the effect of spraying water on an Auxiliary Building (AB) of OPR1000 to mitigate cesium (Cs) aerosol in a hypothetical scenario of Inter-System Loss of Coolant Accident (ISLOCA). It was assumed that the fission products discharging from the primary circuit was released into a room for a Low Pressure Safety Injection (LPSI) pump in an AB through a Shutdown Cooling System (SCS) pipe ruptured in 4 in. In a LPSI room, we modeled the spraying conditions such as injection time, size and flow rate of droplets using a MELCOR code of version 2.2.11932. The accident sequence of the spray cases was similar with that of the base case without spraying water on an AB. Mass of Cs releasing into the outside environment was reduced by spray scrubbing as well as pool scrubbing. The mitigation rate based on the mass difference of Cs at the spray case and base case increased with the increment of an injection rate and at the faster injection time. Mass of Cs releasing into the outside environment of the spray cases was reduced than that of the base case while the water level in a LPSI pump room was linearly increased by spraying. This result can contribute to evaluate the new mitigation strategies, and to assess the source term in a hypothetical ISLOCA scenario.

ACKNOWLEDGMENTS

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