Development of Mitigation System against Containment Bypass Accident

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1. Introduction

During a severe accident in a nuclear power plant, some radioactive materials could be released to the environment through paths bypassing the containment even though the containment integrity would be sustainable. Typical scenarios on the containment bypass accidents are Steam Generator Tube Rupture (SGTR) and Inter-System Loss of Coolant Accident (ISLOCA).

The radioactive material behaviors during the containment bypass accidents have been evaluated and mitigation systems against the bypassing accident have been designed and validated.

2. Evaluations of Radioactive Materials Behaviors

The steam generator (SG) tube is the pressure boundary of primary cooling system of pressurized water reactor (PWR), and one of the most important passes of the primary coolant releasing to environment when it breaks. Because the main feedwater line penetrates the containment to the other building which is not the barrier for radiological releases, the SG tube rupture (SGTR) results in the fission products of the core bypassing the containment and releasing directly to the environment via atmospheric dump valves (ADV) or main steam safety valve (MSSV). If The SGTR occurs under the severe accident condition, large amounts of fission products are expected to release to public. Although the possibility of those accidents is extremely low, the consequences of the accident need to be clarified for preparing possible countermeasures [1].

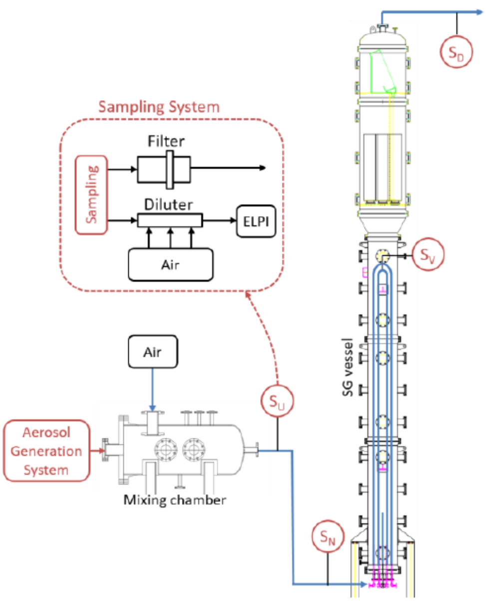

Fig. 1 Schematic of AEOLUS facility

By using MELCOR code, SGTR accidents have been analyzed to evaluate the radioactive material releases through the environments. In these analyses, the aerosol retentions in SG were neglected because of lacks of models on the aerosol removals on the tube, dryer, separator in SG. Therefore, the experimental results should support the decontamination in real SG to reveal the realistic fission product removal via SG.

AEOLUS test facility was built by the scaling analyses to simulate the aerosol removals in SG of APR1400 as shown in Fig. 1. Figure 2 shows the DF of the tests versus the submergence. As shown in Fig. 2, the aerosol DF(Decontamination Factor) increases as the submergence increases, and then saturates when the submergence reaches at some level. It should be noted that the DF at 2.5 and 3.5 m is the lower bound of DF because the aerosol mass at the downstream are less than the minimum [2].

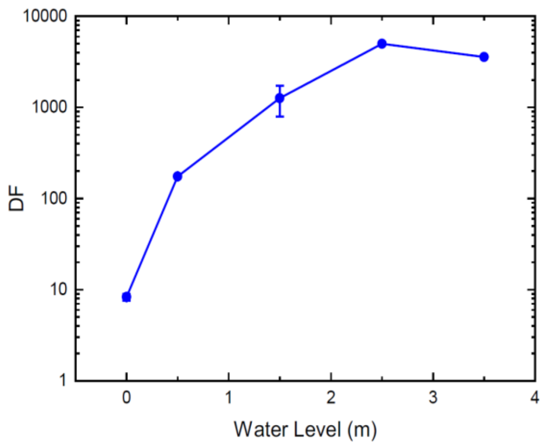

Fig. 2 Aerosol decontamination factor by submergence in SG

Most probable ISLOCA starts from suddenly opening the motor-driven valves that normally isolates the primary system in the containment building from Shut down Cooling System (SCS) connected to an Auxiliary Building (AB). Coolant in a hot leg could flow directly to a Low Pressure Safety Injection (LPSI) pump through a SCS pipe. The fission products behaviors generated during core degradation were analyzed by MELCOR code to quantify discharging amounts of radioactive materials in AB and environment [3].

To improve aerosol retention models for ISLOCA accidents, some experiments related the aerosol depositions in SCS pipe [4] and aerosol scrubbing in breakpoint [5] have been performed.

3. Developments of SGTR Mitigation System

To mitigate the radioactive material releases through the SGTR accidents, a mitigation system was proposed as shown in Fig. 3. The concept of the mitigation system is that all radioactive materials releasing from RCS(Reactor Cooling System) by SGTR were guided back through the containment before the environmental releasing. The mitigation system consists of a depressurized tanks, pipe and valve which connects from the SG or MSL(Main Steam Line) to the depressurized tank. The depressurized tank plays roles of depressurizing the gas from SG to the containment and decontaminating the radioactive materials through nozzles and water pool in the tank.

A MACACON facility was built to verify the mitigation system as shown in Fig. 4. Tests have been performed to quantify the aerosol retention capacity in the depressurized tank. DFs for aerosol were measured in 100 to 300 as a vertical nozzle in the depressurized tank.

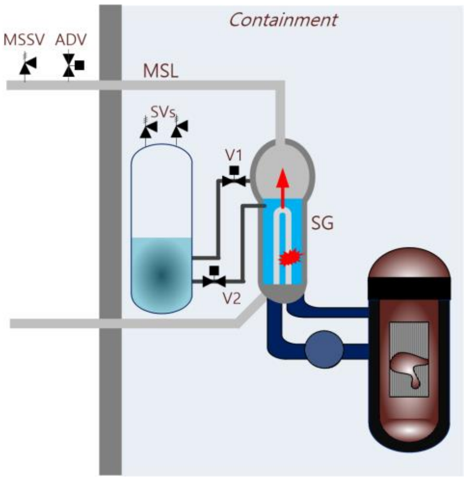

Fig. 3 Schematics of SGTR mitigation system

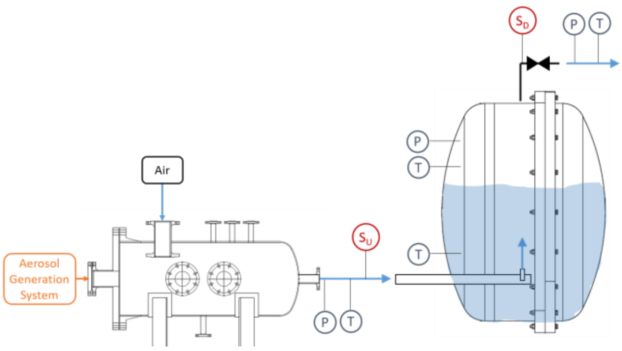

Fig. 4 Schematics of MACARON facility

To mitigate the radioactive material releases through the ISLOCA accidents, a mitigation measures such as spraying system in the auxiliary building has been proposing and analyzing by MELCOR code to verify the performance.

3. Conclusion and Future Works

The radioactive material behaviors during the containment bypass accidents have been evaluated and mitigation systems against the bypassing accident have been designed and validated.

The radioactive materials releasing to the environment during SGTR and ISLOCA were analyzed by MELCOR code and mitigation systems were proposed. Aerosol retention tests were performed in SG and mitigation system against SGTR to improve the aerosol retention models and to verify the performance of the mitigation system.

The mitigation measures against SGTR and ISLOCA would be optimized and tested by experimental facilities. A domestic accident scenario analysis code named by RAINCOAT would be also developed to evaluate the radioactive material behaviors and finally to verify the performances of the mitigation systems during the containment bypass accidents.

ACKNOWLEDGMENTS

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