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Development of aerosol decontamination factor evaluation method for filtered containment venting system

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1. Introduction

The containment of nuclear power plant should be an unbreakable barrier to prevent the release of radioactive fission product into environment. In case of a severe accident at a nuclear power plant, when the reactor vessel is breached, the molten corium will be discharged into the containment[1]. Fission products would be released from molten corium pools which are relocated into the lower plenum of reactor pressure vessel, on the concrete pit and in the core catcher[2]. In addition, steam, hydrogen and noncondensable gases such as CO and CO2 are generated during the core damage progression due to loss of coolant and the molten core-concrete interaction. Consequently, the pressure inside the containment could be increased continuously[1].

Filtered containment venting is one action to prevent an uncontrolled release of radioactive fission products caused by an overpressure failure of the containment[3]. After the Fukushima-Daiichi accident which was demonstrated the containment failure, many countries to consider the implementation of filtered containment venting system(FCVS) on nuclear power plant where these are not currently applied[4].

In general evaluation for FCVS is conducted to determine decontamination factor on several conditions (aerosol diameter, submergence depth, water temperature, gas flow, steam flow rate, pressure, operating time,...)[5]. It is essential to quantify the mass concentration before and after FCVS for decontamination factor. Additionally, aerosol size distribution is important to evaluate the generated aerosols and to understand removal process in the FCVS. This study presents the evaluation method determining decontamination factor by using filter sampling for the FCVS developed at Korea Atomic Energy Research Institute (KAERI) called Aerosol Removal Iodine ELimination (ARIEL). In addition, aerosol generation method is introduced with the result of size distribution measurement.

2. Methods and Results

2.1 FCVS development and thermal-hydraulic conditions

Figure 1 illustrates a schematic diagram of the ARIEL aerosol test setup. The aerosol test facility consists of aerosol generator (AG), N_2 gas supplier, mixing chamber (MC), and the vessel for FCVS. The FCVS consists of four main components: a venturi scrubber including liquid pool, a droplet separator (cyclone), a metal fiber filter, and a molecular sieve. For aerosol removal evaluation, the test condition for thermal-hydraulic conditions are summarized in Table 1.

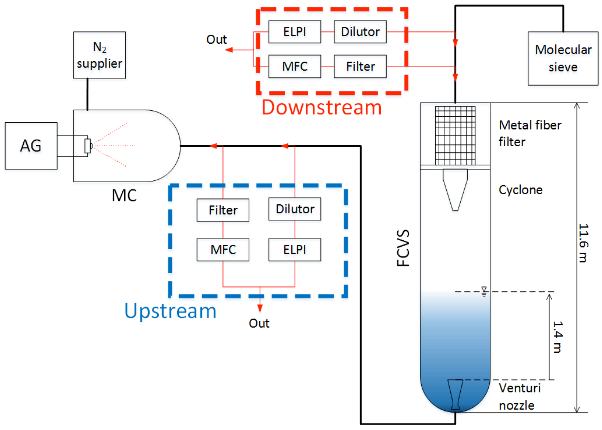

Fig. 1. Schematic diagram of the filtered containment venting system showing aerosol sampling locations.

Table 1: Thermal-hydraulic condition of aerosol removal measurement

Parameter	Value
N_2 Flow rate (kg/s)	0.068
Submergence* (m)	1.4
Pressure (bar)	2
Gas temperature (°C)	~150

*Submergence is water level from the top of venturi nozzle to the liquid surface.

2.2 Aerosol generation method

Aerosol is generated by air atomizing nozzle in the mixing chamber. Figure 2a shows a configuration of the aerosol generator. For an aerosol, well-shaped spherical SiO_2 (0.7 μm of diameter) is used (Fig. 2a). The carrier liquid for a SiO_2 particle is ethanol considering the evaporation point and chemically stability. SiO_2 are well dispersed in a mixture of ethanol. The weight ratio of SiO_2 and ethanol is 1:1 to achieve a high aerosol mass concentration for an inlet condition as the containment when severe accident occurs. Mixed liquid is pressurized with nitrogen gas in the mixing tank which has the mixing blade inside to supply the liquid to the air atomizing nozzle. The nitrogen gas is also used to create a mist of atomized liquid including SiO2 particles that can be easily evaporated in the mixing chamber to generate the aerosols. Figure 2b illustrates the air atomizing nozzle and the mechanism of the gen-

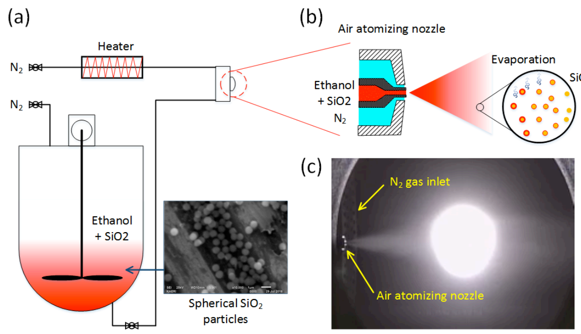

Fig. 2. Schematic diagram for aerosol generation and air atomizing nozzle and snapshot on spray nozzle in the mixing chamber.

eration of an aerosol. Figure 2c shows the snapshot of the generation of an aerosol in the mixing chamber by air atomizing nozzle.

2.3 Filter measurement

Decontamination factor is evaluated by analyzing aerosol mass concentration measured with filter method. The filter measurements are conducted at upstream and downstream within the isokinetic sampling condition. Aerosol is collected on glass fiber filter (GF/F 47 mm, Whatman), which were mounted on a specially made stainless steel filter holder, for 1799 s and 2550 s at upstream and downstream. The isokinetic sampling condition is achieved by controlling the inhalation flow rate with the MFC with the isokinetic sampling probe (5φ / 4φ, DEKATI). The mass of collected aerosols is measured by micro-balance (XP6, Mettler Toledo). Table 2 is summarized sampling conditions for the filter measurements at upstream and downstream and decontamination factor which is calculated by the ratio of the aerosol mass concentration at upstream and downstream.

Table 2: Filter measurement and decontamination factor

	upstream	downstream
sampling flow rate (lpm)	5.48	4.95
sampling period (s)	1799	2550
accumulated aerosol mass (mg)	99.717	<0.01
aerosol concentration (mg/m^3)	606.89	<0.0475
Decontamination factor, DF	>12000	

2.4 Size distribution

Aerosol size distribution is measured by the cascade impactor (Electrical Low Pressure Impactor, ELPI+, DEKATI). Figure 3 shows the averaged aerosol mass concentration by an aerosol diameter for 2000 s during aerosol generation. It is shown that the FCVS works for the given aerosol condition, ~ 0.7 μm of aerosol diamet-

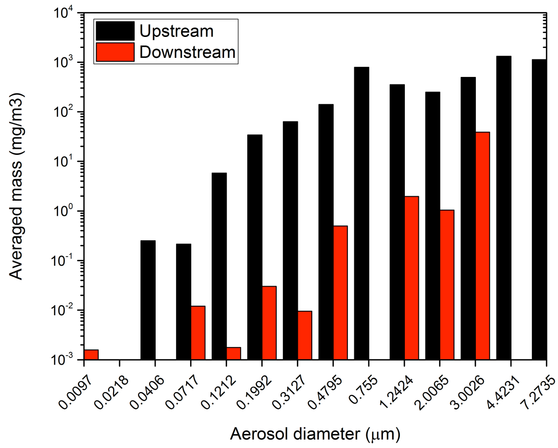

Fig. 3. Comparison of averaged aerosol mass concentration at upstream and downstream by an aerosol diameter.

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3. Conclusions

This paper presents the development of the evaluation facility for filtered containment venting system at KAERI and an experimental investigation for aerosol removal performance. Decontamination factor for the FCVS is determined by filter measurement. The result of the aerosol size distribution measurement shows the aerosol removal performance by an aerosol size.

ACKNOWLEDGMENTS

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