Aerosol Loss Calculation in KAERI's Steam Generator Tube Rupture Experimental Set-up

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1. Introduction

Steam generator tube rupture (SGTR) accident is one of the most important accident scenarios should be considered to ensure regulations on the severe accident in Korea. There are a lot of experiments on the SGTR accident probability to increase a safety of nuclear power plant [1-3]. In order to evaluate the amount of aerosol type fission products in the experiment quantitatively, it is important to evaluate the aerosol sampling loss and losses in pipes of experimental facilities [4]. Aerosol experiments during SGTR accident have been conducted in KAERI, and decontamination factors in dry and wet steam generator have been evaluated [5]. Aerosol loss was measured using aerosol analysis equipment, such as filter, electric low pressure impactor (ELPI), however, aerosol sampling loss occurred in sampling port was not considered in the previous studies. Moreover, aerosol loss also could occurred in the experimental facility, such as pipes between aerosol supply chamber and entrance of steam generator mock-up, as shown in Fig. 1.

In the study, aerosol loss calculations in KAERI's SGTR experimental facility have been conducted. Aerosol loss consists of two parts, sampling loss and transport loss, and both parts are considered in the calculation. In order to make calculation input, there are some uncertain factors, such as pipe curvature and sampling nozzle inclination, thus sensitivity calculations are also performed on the factors.

2. Aerosol Loss Calculation

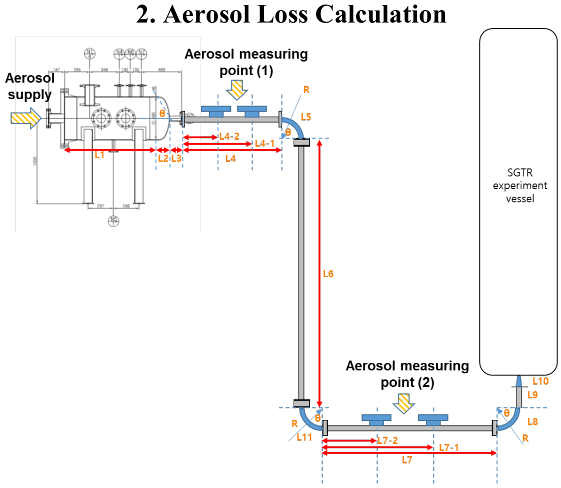

Fig. 1 SGTR experimental facility in KAERI

2.1 Aerosol calculator

To calculate aerosol loss inside pipes, commercial particle loss calculate was used, Igor Pro 6.37 [6]. The tool usually used to quickly determine aerosol sampling efficiency and particle transport losses due to passage through arbitrary tubing systems. The software employs relevant empirical and theoretical relationships found in established literature and accounts for the most important sampling and transport effects The software treats non-isoaxial and nonisokinetic aerosol sampling, aerosol diffusion and sedimentation as well as turbulent inertial deposition and inertial deposition in bends and contractions of tubing. To use the software, geometrical information of the experimental facilities should be inserted including pipe inner diameter, length, bend. In addition, thermo-hydraulic conditions are also necessary, such as gas temperature, velocity, species. Aerosol information also should be considered, aerosol species, size, density. All data required to conduct calculation has been collected and it would be reflected in the aerosol loss calculation [7].

2.2 Sampling loss

Aerosol loss could occurred not only in transport process but also in sampling process. Schematic of aerosol sampling system in KAERI is indicated in Fig. 2. Aerosol sampling nozzle used in KAERI's experiment is shown in Fig. 3(b). Aerosol sampling efficiency could be different with nozzle inclination [4]. Although the angle between sampling nozzle and gas flow in pipe was

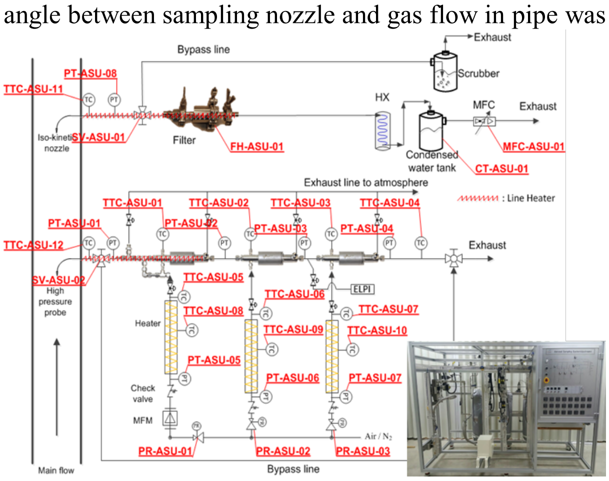

Fig. 2 Schematics of aerosol sampling system

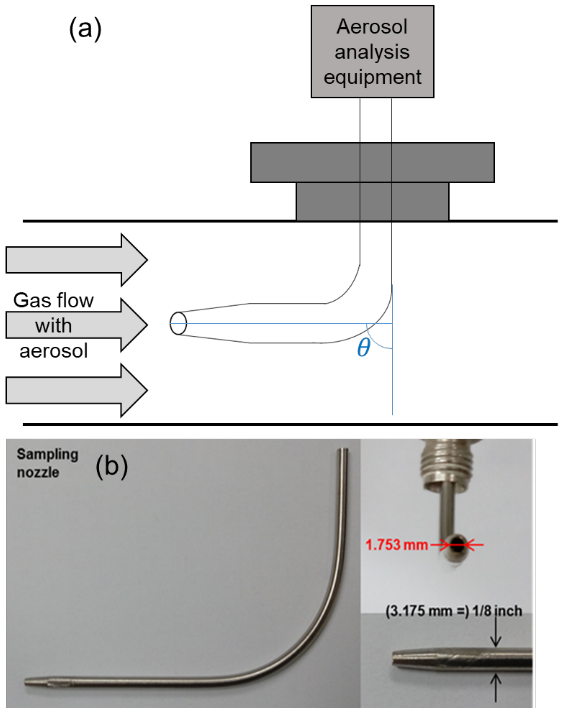

Fig. 3 Aerosol sampling nozzle. (a) sampling loss with nozzle inclination (b) sampling nozzle used in KAERI's experiment

designed to 180°, the angle could be different in real condition. Thus it is important to find the effect of inclination of sampling nozzle.

2.3 Transport loss in pipes

As shown in the Fig. 1, aerosol could be removed in pipes between aerosol supply part and SGTR experiment vessel entrance. Preliminary calculation was conducted to understand the aerosol loss in the pipe [7]. However, there are a lot of uncertain factors to evaluate aerosol loss. Thus it is necessary to conduct sensitivity calculation on the main uncertain factors. In this study, it is focused on the pipe curvatures and aerosol loss results were obtained.

3. Calculation Results

Basically boundary conditions are necessary to run the Igor program, and thermos-hydraulic conditions used in the calculation were obtained from SGTR experimental conditions [7]. Aerosol loss calculation was conducted in two different parts, one is transport loss in pipes of SGTR facility, and the other is sampling loss in sampling nozzle.

3.1 Transport loss results

During SGTR experiment, thermo-hydraulic conditions could be varied unintentionally with operation of other facility, such as air compressor, heater. However, it is difficult to reflect all different

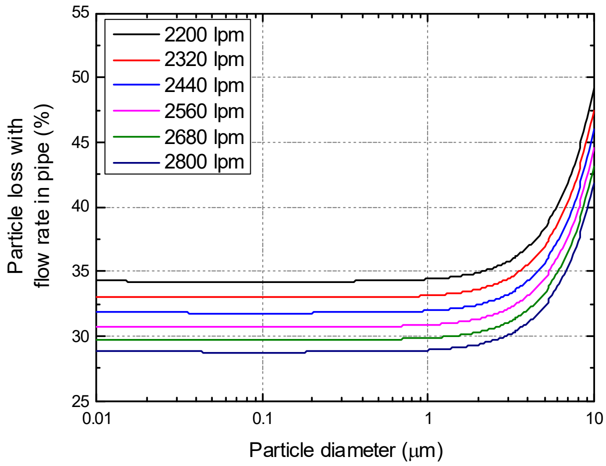

Fig. 4 Particle loss with flow rate in pipe

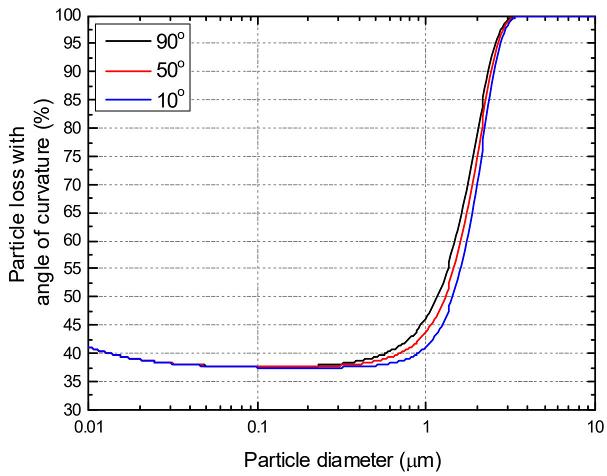

Fig. 5 particle loss with angle of curvature

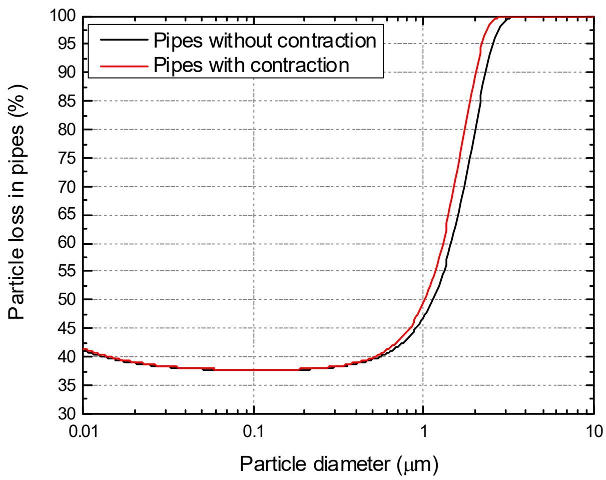

Fig. 6 particle loss with/without contraction

conditions on experiment result. Thus it is necessary to understand the effect of major thermos-hydraulic conditions on experiment result. The effect of flow rate is shown in Fig. 4. Actual flow rate used in the

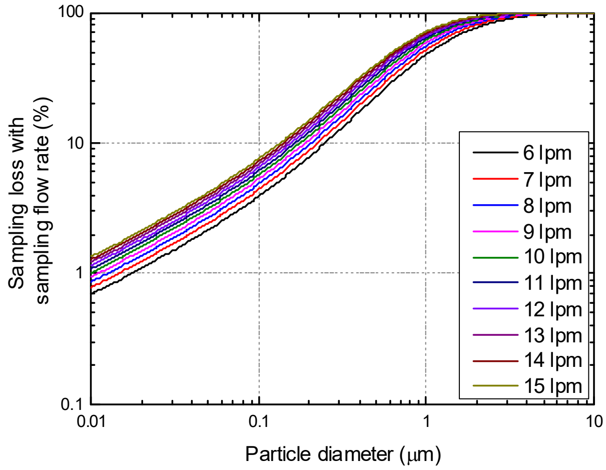

Fig. 7 sampling loss with flow rate

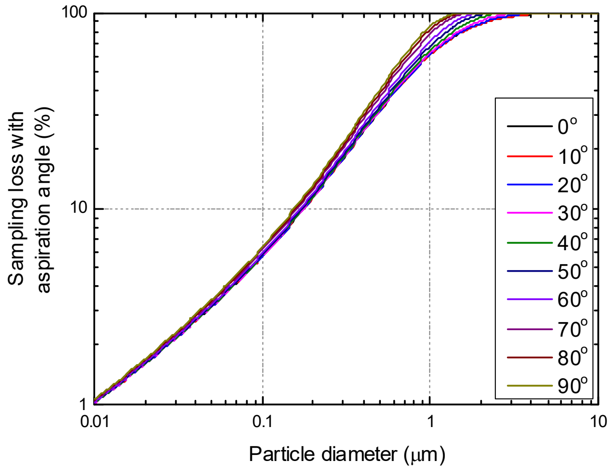

Fig. 8 sampling loss with aspiration angle

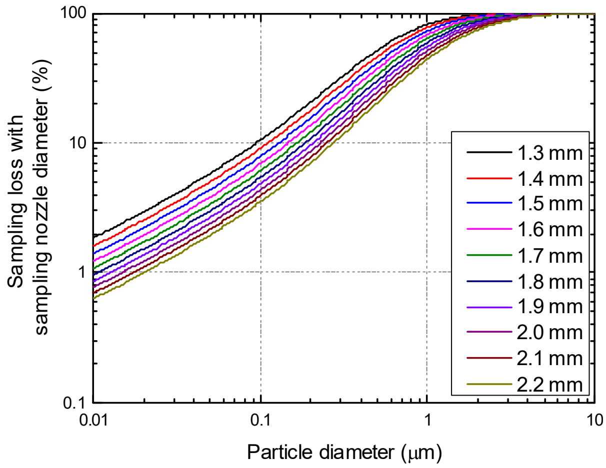

Fig. 9 sampling loss with nozzle diameter

experiment is about 2,500 lpm, and the effect of flow rate variation is investigated. Minimum and maximum flow rates are set to 2,200 and 2,800 lpm, respectively. Mass mean diameter of particle used in the experiment is about 0.7 μm, and about 5% difference of particle loss is shown in the area between maximum and minimum flow rates.

The experiment facility contains not only straight pipes but curved pipes, as shown in the Fig. 1. Although the length could be known from design data, the angle of curvature of pipe could be different. Thus the effect of angle of curvature was calculated, the result is indicated in Fig. 5. The effect of curvature could be ignored in area of particle size larger than 4.0 μm and smaller than 0.1 μm. However, the effect is noticeable in 0.7 μm. As decreasing the angle of curvature, particle loss is also decreased. It is expected that the result was originated from inertial impaction effect in bend pipe.

The inner diameter of pipes in the Fig. 1 is 2 inches. In real experimental facility, the pipe diameter is decreased to 3/4 inches before entering SGTR experimental vessel considering geometry of steam generator tubes. Thus the effect of pipe contraction at the end of pipe was found, it is presented in Fig. 6. In small particle size area lower than 0.4 μm, the effect of pipe contraction could be ignored. However, as increasing the particle size, the effect would be important. This is because that larger particle could be removed easily with impaction on the contraction wall.

3.2 Sampling loss results

Aerosol calculations for sampling nozzle also have been conducted by changing one of the three parameters, sampling flow rate, aspiration angle and orifice diameter in the aerosol sampling nozzle.

In the experiment condition, sampling flow rate is set to satisfy iso-kinetic condition, however, the sampling flow rate could be varied with changing thermo-hydraulic conditions in flow inside pipe. Thus understanding the effect of sampling flow rate on particle loss could be important. It was found that as increasing sampling flow rate, sampling loss is also increased, as shown in Fig. 7. In particle size of 0.7 μm, the particle loss could be changed to about 20% from 6 lpm to 15 lpm of sampling flow rate.

Aspiration angle of sampling nozzle is also one of the important factor to determine aerosol sampling efficiency. Generally, an angle of 0° between flow and sampling nozzle is recommended to reduce particle loss. However, the angle could not be 0° exactly in real condition. The effect of aspiration angle on particle loss is indicated in Fig. 8, and it is found that the sampling loss could be increased with changing aspiration angle in the particle size of 0.7 μm.

The effect of sampling nozzle orifice diameter is also shown in Fig. 9. As increasing nozzle diameter, particle loss is decreasing with less wall resistance. However, to determine the sampling nozzle diameter, other factors should be considered, such as sampling flow rate, flow velocity.

4. Conclusion

Aerosol calculation with Igor Pro was conducted and sensitivity calculation on major uncertain parameters was also performed. The effect of sampling loss and transport loss was found separately considering experimental conditions. It is confirmed that as increasing the angle between main gas flows in pipe and sampling nozzle, sampling loss increased. Sampling loss also increased as flow rate increased and the sampling loss is inversely proportional to the size of orifice diameter. Furthermore, it is found that aerosol transport loss could be varied to aboug 5% as changing tube curvature in the aerosol size of 0.7 μm. Sensitivity calculation will be performed with considering other uncertain parameters to find out the effect of the factors. After that, the results will be reflected in KAERI's aerosol experimental results.

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