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Transport 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]. Transport 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, transport 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

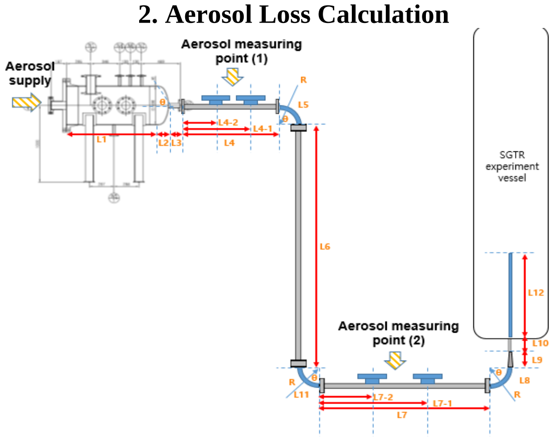

Fig. 1 SGTR experimental facility in KAERI

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 occur 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

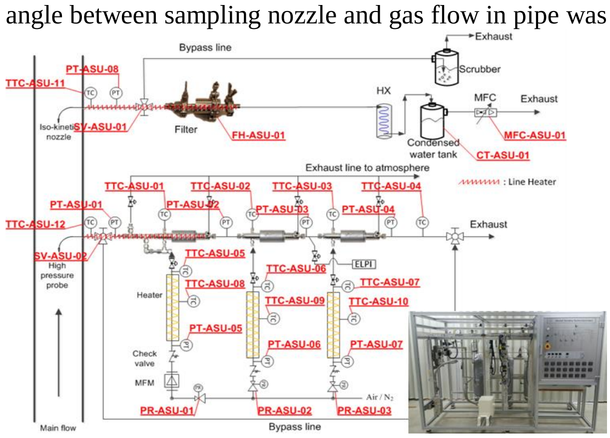

Fig. 2 Schematics of aerosol sampling system

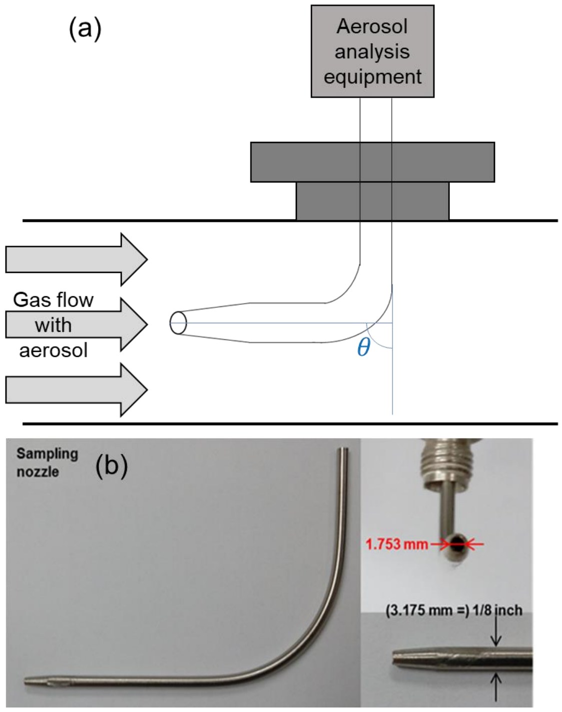

Fig. 3 Aerosol sampling nozzle. (a) sampling loss with nozzle inclination (b) sampling nozzle used in KAERI's experiment

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, such as flow rate, angle of curvature and tube diameter. In this study, it is focused on the transport loss results were obtained.

3. Calculation Results

Basically boundary conditions are necessary to run the Igor program, and thermal 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, thermal hydraulic conditions could be varied unintentionally with operation of other facility, such as air compressor, heater. In this condition, aerosol transport loss could be changed with the thermal hydraulic conditions. However, it is difficult to reflect all of the thermal hydraulic variation to the transport loss in pipe at the same time. Thus it is necessary to understand the effect of major thermal hydraulic conditions on experiment result. The effect of flow rate is shown in Fig. 4. Actual flow rate used in the experiment is about 2,500 lpm, and the effect of flow rate variation on the transport loss in pipes is investigated. Minimum and maximum flow rates are set to 2,300 and 2,600 lpm, respectively. Mass mean diameter of particle used in the experiment is about 0.7 μm. It was found that the transport loss increased sharply in the diameter larger than 1.0 μm though there was no large difference in case of 0.7 μm.

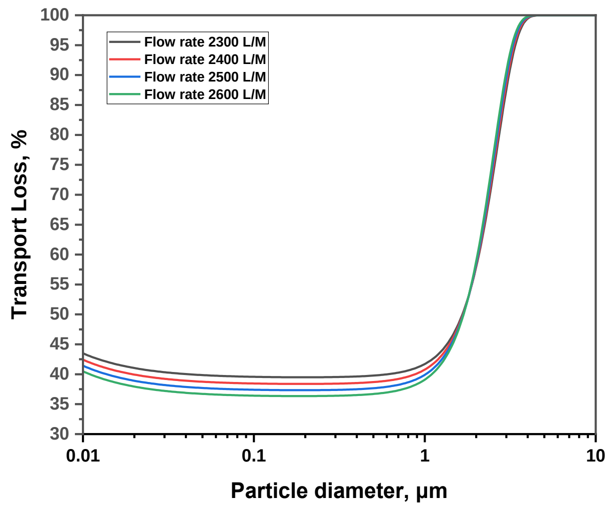

Fig. 4 Transport loss with flow rate in pipe

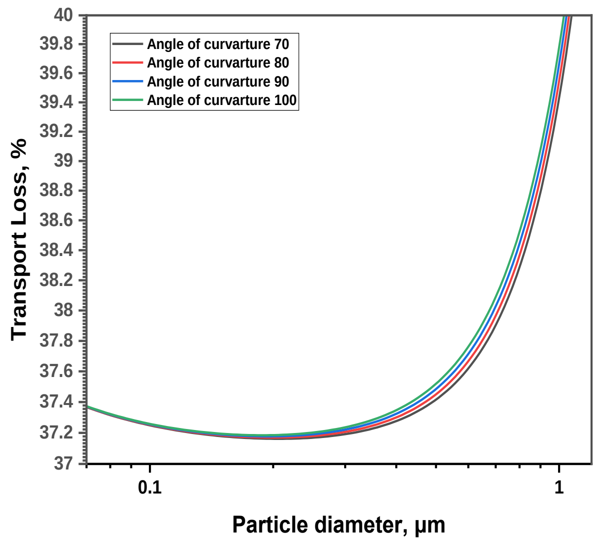

Fig. 5 Transport loss with angle of curvature

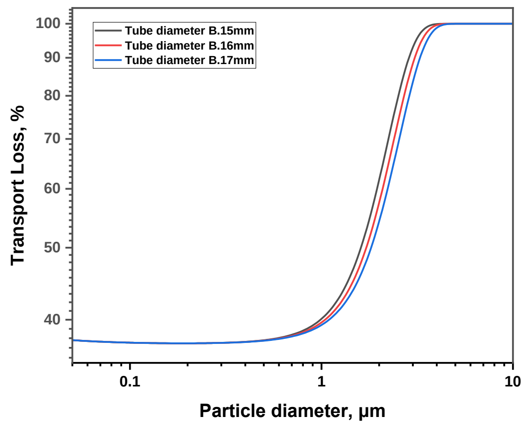

Fig. 6 Transport loss with tube diameter B

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. It was found that the effect of curvature could be ignored in area of particle size smaller than 0.3 µm because the small particle can follow the flow well. However, the effect of the curvature could be significant if the particle size increased. As increasing the angle of curvature, transport loss is gradually increased in the large particle size area over than 1.0 µm. It is expected that the result was originated from inertial impaction effect in bend pipe.

Generally, 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 right before entering SGTR experimental vessel considering geometry of steam generator tubes. Thus the effect of pipe diameter on the transport loss was found with the calculation. The result is presented in Fig. 6. The pipe sizes considered in the calculation were 15, 16 and 17 mm. From the result, as the diameter of pipe is increased, the transport loss is decreased. It was found that as increasing pipe diameter, transport loss is inversely decreased.

3.2 Sampling loss results

Aerosol loss also could occur in aerosol sampling system as shown in the Figure 2. The aerosol sampling nozzle was aligned by considering the flow direction. However, the angle of curvature of the sampling nozzle could be varied in a real condition through installation process. It was investigated that the effect of the nozzle angle of curvature on the sampling loss, and the result will be applied to the calculation of aerosol mass concentrations obtained from the experimental result. In the PLC, aspiration angle was changed from 0^o to 20^o, and the results are indicated in Figure 7. In case of 0^o, there was no sampling loss with aspiration angle. In case of particle diameter smaller than 1.0 µm, the sampling loss was lower than 10%. It means that the sampling loss could not be important to a certain point in case of small particle size area.

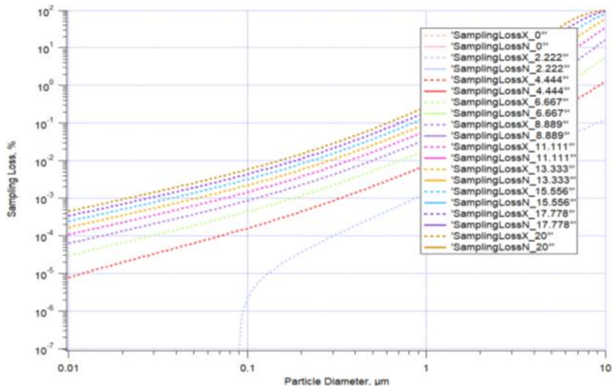

Fig. 7 Sampling loss with aspiration angle

4. Conclusion

Aerosol calculation with Igor Pro was conducted and sensitivity calculation on major uncertain parameters was also performed. The effect of transport loss was found considering experimental conditions.

It is confirmed that as increasing the angle of curvature, transport loss decreased. Transport loss was increased as flow rate decreased and the transport loss is inverse to the size of pipe diameter. Furthermore, it is found that aerosol transport loss was sharply increased as changing flow rate in the aerosol size of 1.0 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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