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

May 12-14, 2021

Jeju, Korea

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CONTENTS

01 Research Background

- There are a lot of studies on the SGTR accident probability to increase a safety of nuclear power plant
- 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 order to evaluate risk of fission product during SGTR accident with domestic steam generator, steam generator experimental facilities were installed in KAERI
- In order to evaluate the aerosol decontamination factor inside steam generator accurately, it is necessary to understand the aerosol removal rate in the experimental facilities, such as pipes.
- In the study, aerosol loss calculations were performed to understand other uncertain factors affecting the aerosol removal rate inside the experimental facilities using calculation tools.

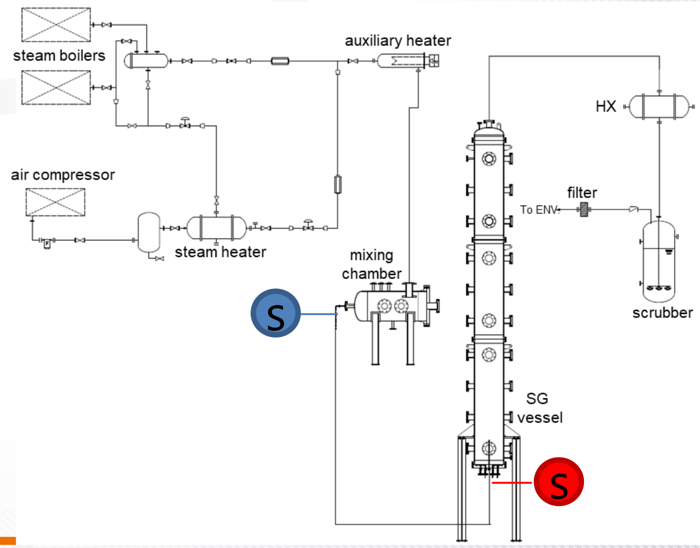


Fig. Schematics of SGTR exp. facility in KAERI

02 STGR Experimental Facility

- SGTR Experiment
  - SGTR experimental facilities in KAERI were installed, and a lot of aerosol experiments have been performed. (left figure below)
  - Properties of aerosol, such as aerosol size distribution, mass concentration were measured using aerosol sampling system (right figure) right after adding the aerosol.
  - The measuring point of aerosol mass concentration is right after the mixing chamber, but the aerosol mass concentration right before the entrance of SGTR vessel is necessary to calculate decontamination factor exactly.
  - The aerosol loss calculation is essential to increase the reliability of the experiment results.

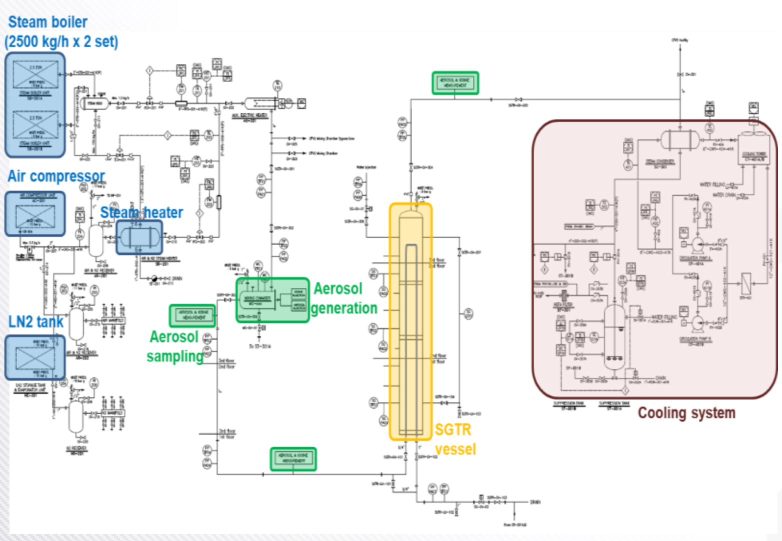


Fig. Aerosol experimental facility in KAERI

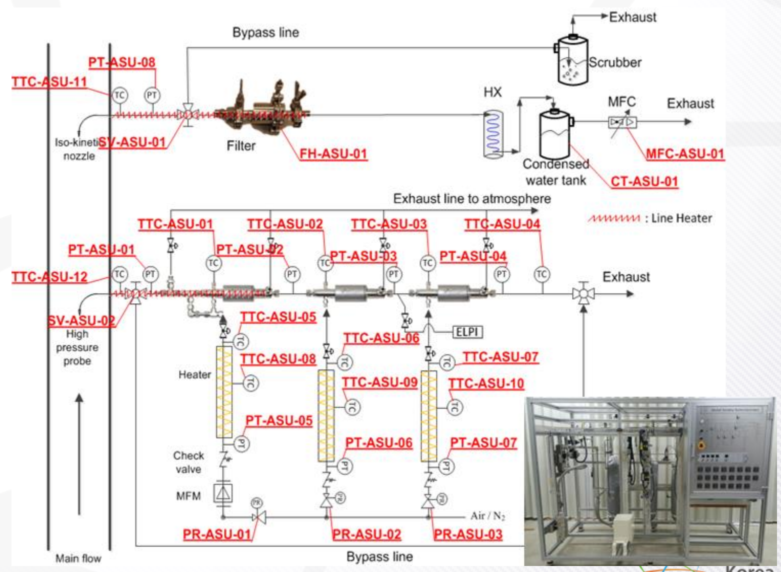


Fig. Schematics of aerosol sampling system

03 Transport Loss Calculation

- Particle Loss Calculator
  - A software to assess the aerosol removal behavior inside facility including pipes

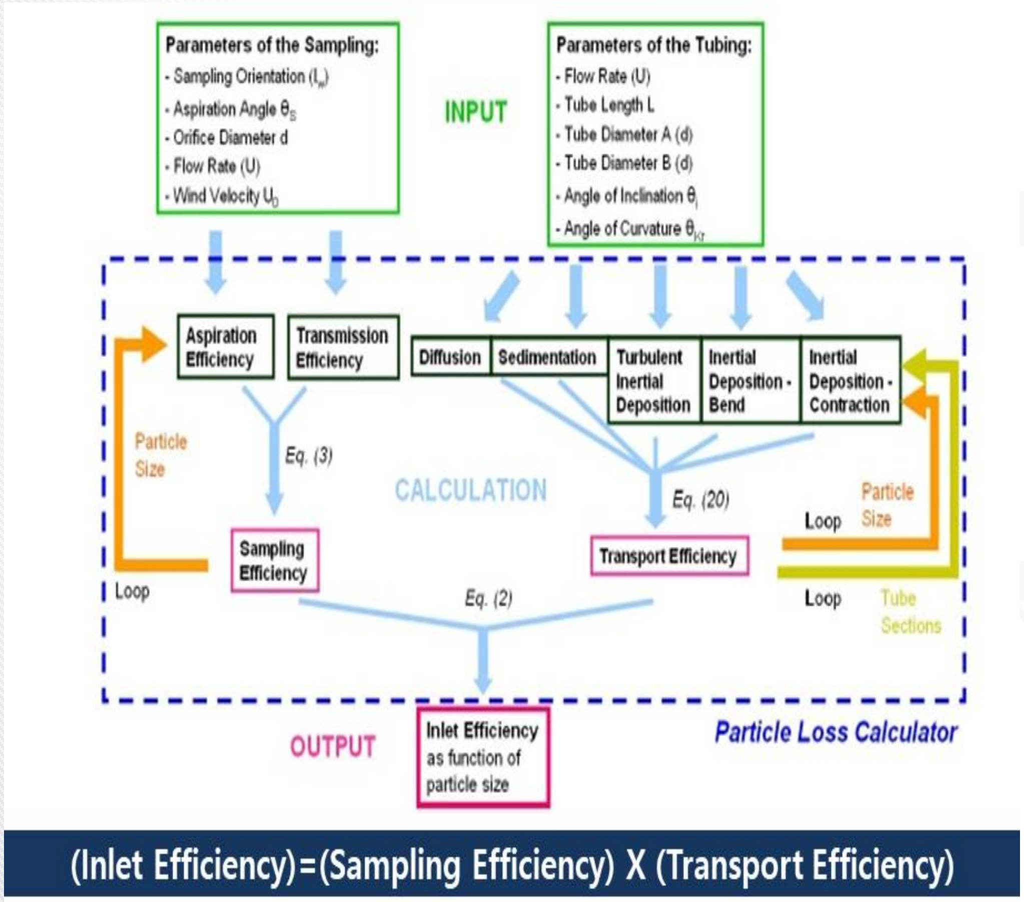


Fig. Basic working principle of the Particle Loss Calculator

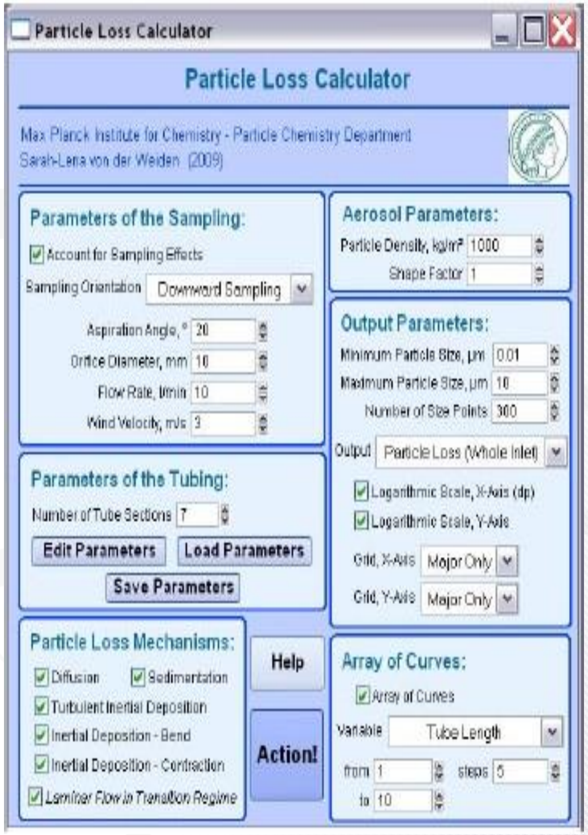


Fig. Use interface of the Particle Loss Calculator

03 Transport Loss Calculation

- Transport Loss Calculation

- To calculate aerosol loss inside pipes, commercial particle loss calculate was used, Igor Pro 6.37
- The software employs relevant empirical and theoretical relationships found in established literature and accounts for the most important sampling and transport effects.
- 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

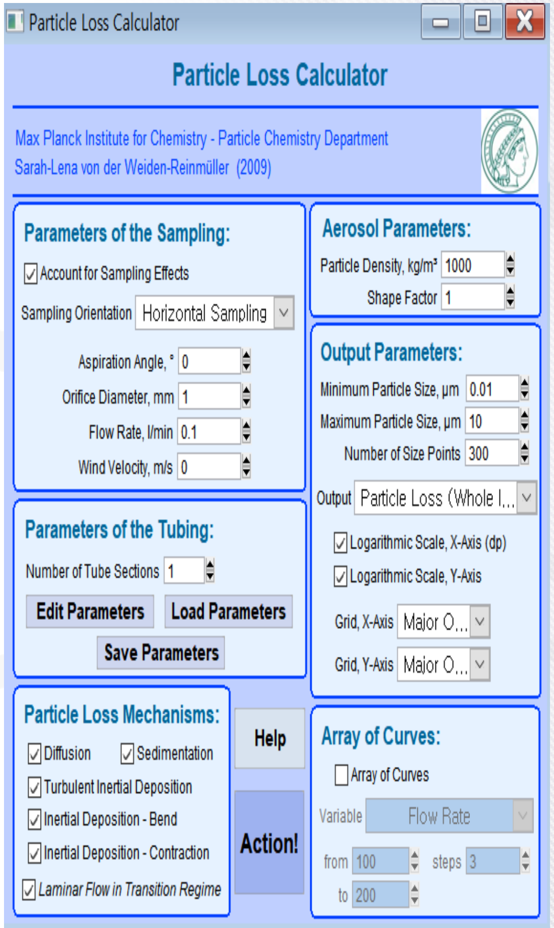


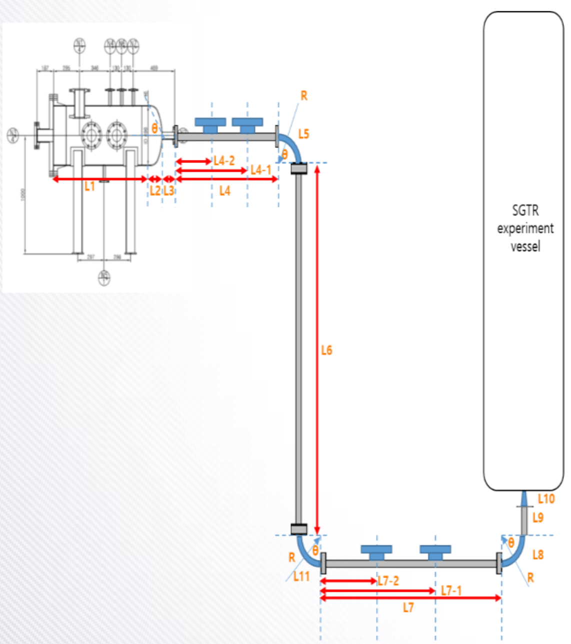
Fig. Main parameters of particle loss calculator

04 Simulated Result

- Boundary conditions

  - In order to calculate the aerosol loss inside SGTR facility, it is necessary to reflect the geometry of the facilities.

  - In addition, major thermal-hydraulic conditions that was used as experiment conditions were also considered.



region	Length(mm)	Dia. (mm)	Angle(°)	Curvature
L1	1000	496	58	-
L2	229	-	-	-
L3	140	52.5	-	-
L4	L4-2 : 564	52.5	-	-
	L4-1 : 964		-	-
	L4 : 1325		-	-
L5	108	52.5	90	69
	157			100
	206			131
L6	7050	52.5	-	-
L7	L7-2 : 570	52.5	-	-
	L7-1 : 1170		-	-
	L7 : 1870		-	-
L8	108	52.5	90	69
	157			100
	206			131
L11	108	52.5	90	69
	157			100
	206			131

Fig. Geometrical information of SGTR facility

Table Thermal hydraulic conditions of SGTR experiment

Variables	Value
Flow rate	0.2 kg/s
Gas species	Nitrogen
Pressure	6 bar(a)
Temperature	423 K
Gas density	4.7698 kg/m^3

04 Simulated Result

Transport loss

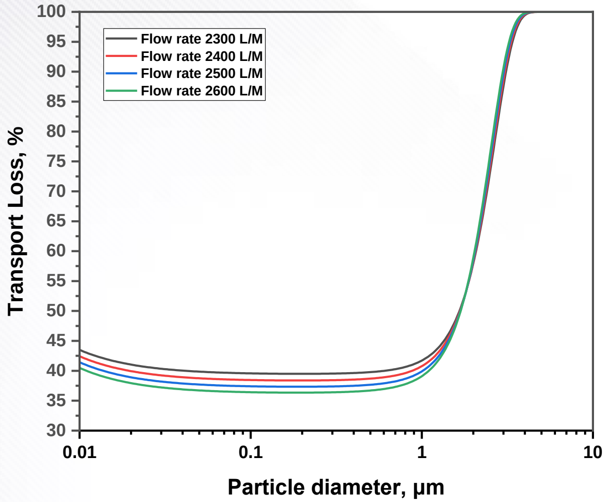


Fig. Transport loss with flow rate in pipe

$$Stk_i = \frac{\rho_i V_e d_i^2}{9 \mu D_0}$$

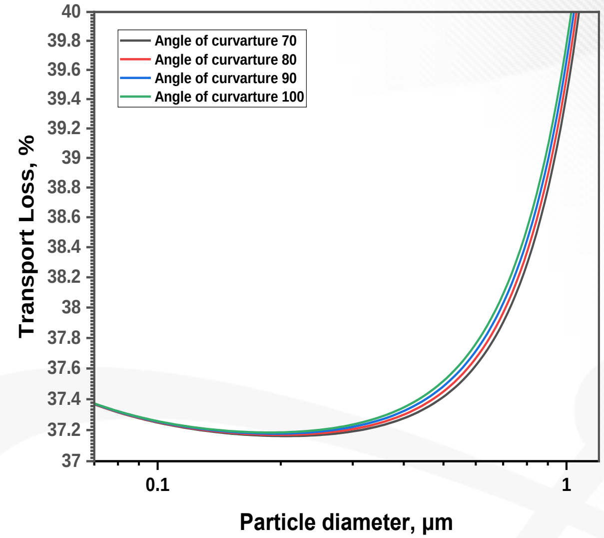


Fig. Transport loss with angle of curvature

- In the sensitivity calculation of flow rate, it was found that transport loss increased sharply in the diameter larger than 1.0 μm though there was no larger difference in case of 0.7 μm.
- 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.
- 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.

04 Simulated Result

Transport loss

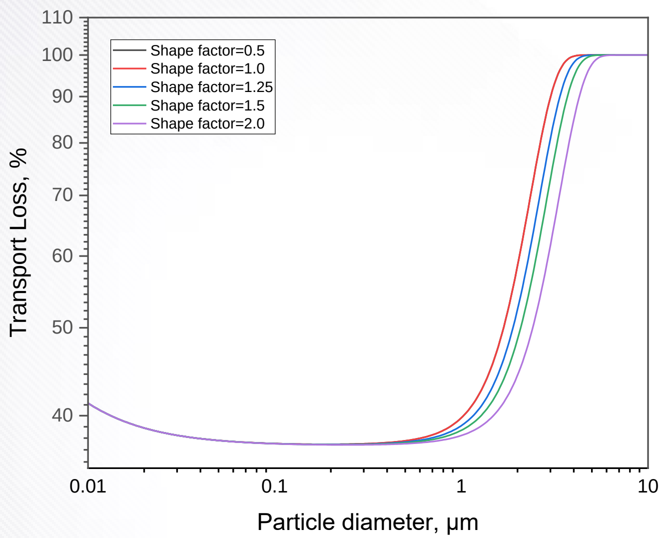


Fig. Particle loss with aerosol shape factor

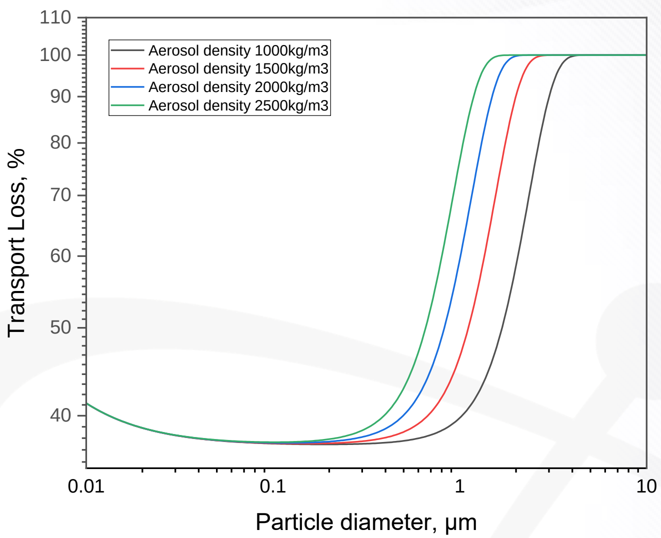


Fig. Particle loss with aerosol density.

- From the sensitivity studies on aerosol shape factor and density, it was found that the aerosol density is important factor to decide the particle loss inside the experimental setup. Especially, particle loss is important in case of large particle size, because of aerosol settling
- Shape factor also affects the particle loss in case of large particle size, however, the effect of the shape factor is not crucial as the factor of density

$$V_{ts}=(\rho_p d_a^2 g C_C)/(18\mu\chi)$$

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04 Simulated Result

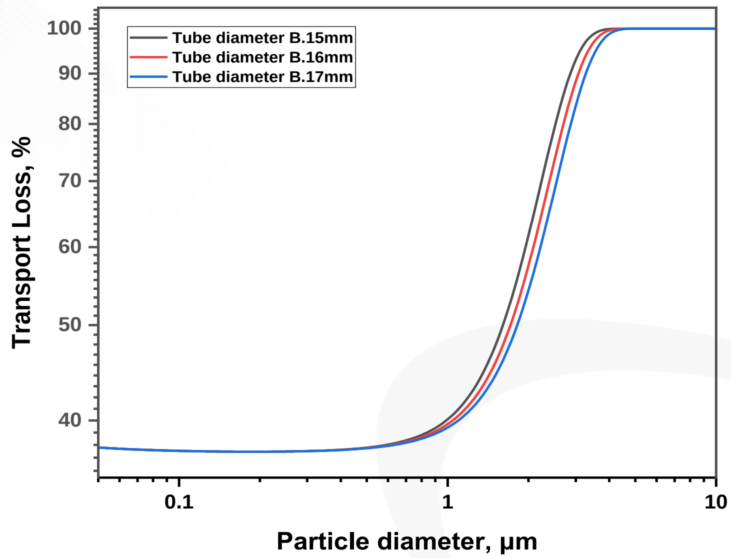

Fig. Transport loss with tube diameter B

- The pipe sizes considered in the calculation were 15, 16 and 17 mm
- 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.

04 Simulated Result

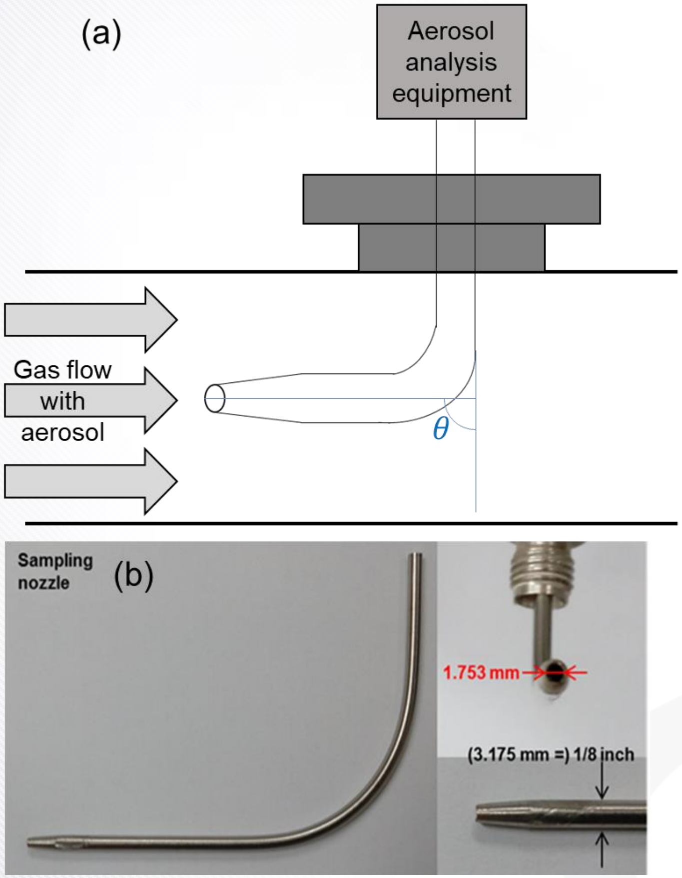

Fig. Aerosol sampling nozzle. (a) sampling loss with nozzle inclination (b) sampling nozzle used in KAERI's experiment

- Aerosol calculations for sampling nozzle also have been conducted by changing one of the two parameters, sampling flow rate and aspiration angle 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.

04 Simulated Result

Sampling loss

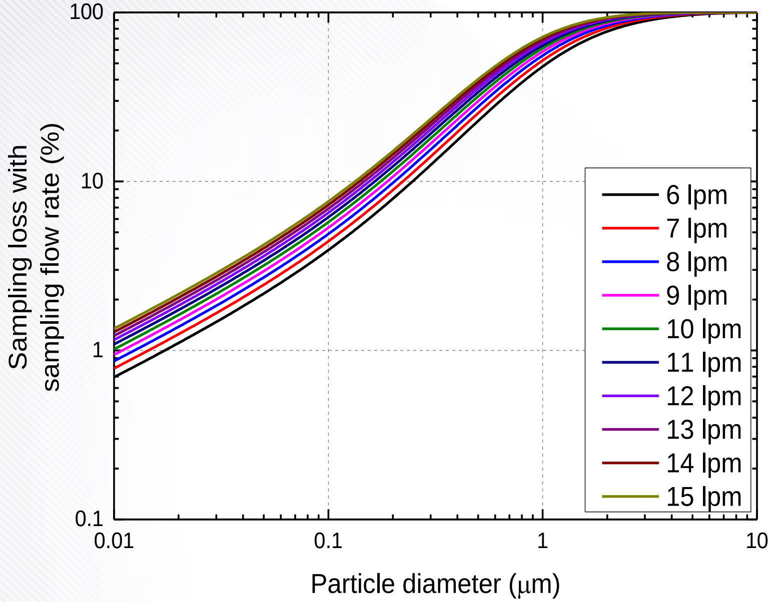

Fig. sampling loss with flow rate

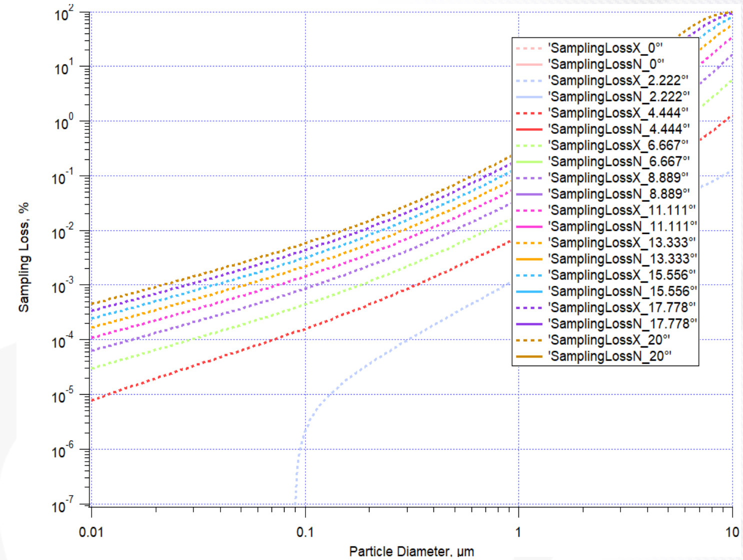

Fig. sampling loss with aspiration angle

- As increasing sampling flow rate, sampling loss is also increased. 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.

- It is found that the sampling loss could be increased with increasing aspiration angle

05 Conclusion

- The effect of transport loss was found considering experimental conditions.
- It is confirmed that as increasing the angle of curvature, transport loss increased.
- Transport loss was increased as flow rate decreased and the transport loss is inverse to the size of pipe diameter.
- 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.

THANK YOU