Development of Test Facility for Aerosol Removal in Pipe

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1. Introduction

Fission products produced during the severe accident in nuclear power plant transport to reactor coolant system and containment. Even though the containment can act as a barrier to prevent the release of fission products to the environment, there are pathways to bypass the containment such as Steam Generator Tube Rupture (SGTR) and Interfacing Systems Loss Of Coolant Accident (ISLOCA). The pathways to bypass the containment during these accidents include connecting piping systems where the fission products are also deposited during the transport. Thus, it is important to estimate amount of fission products deposited in the pipe as quantitative manner. This study focuses on the development of test facility for fission product removal as aerosol especially in pipe.

2. Design of Test Facility

2.1 Main Phenomena

The connecting piping systems consist of pipes, valves and fittings. The pipe can be configured with straight and bend sections. Since a strong turbulent flow is developed inside the pipe during the SGTR and ISLOCA, the turbulent deposition due to turbulent eddies in a flow with a high Reynolds number is one of the key phenomena in a straight pipe section. On the other hand, the inertial impaction which is an impaction of large particles on surfaces at high velocity when flow changes direction is important phenomenon in a bend pipe.

2.2 Scaling Parameters

The test facility is designed with scaling analysis to preserve non-dimensional parameters such as the flow Reynolds number, particle Reynolds number, Stokes number and curvature ratio as; [1,2]

$$Re_{flow} = \frac{\rho D_{duct} U_0}{\mu}$$

where ρ, D_{duct}, U_0 and μ are the fluid density, pipe diameter, fluid velocity and fluid viscosity, respectively.

$$Re_{particle} = \frac{\rho D_{particle} U_0}{\mu}$$

where, $D_{particle}$ is a particle diameter.

$$Stk = \frac{C_c \rho_{particle} D_{particle}^2 U_0}{9 \mu D_{duct}}$$

where C_c and $\rho_{particle}$ are the Cunningham slip correction factor and particle density, respectively. The Cunningham slip correction factor is

$$C_c = 1 + K_n \left\{ 1.257 + 0.4 \exp\left(-\frac{1.1}{K_n} \right) \right\}$$

where K_n is the Knudsen number as;

$$K_n = \frac{2\lambda}{D_p}$$

where λ is the mean free path of main fluid.

On the other hand, the curvature ratio with above non-dimensional numbers needs to be preserved for the bend pipe section as;

$$R_0 = \frac{R_b}{a}$$

where R_b and a are the radius of curvature and pipe radius, respectively.

2.3 Test Facility

The test facility is designed to perform aerosol removal tests for the straight and bend pipe sections. As shown in Fig. 1, the main carrier gas such as steam or/and air can be supplied from the steam generator and air compressor towards a small mixing tank and mixed with aerosols supplied from an aerosol generation system. The carrier gases with aerosols flow through the straight and bend pipe sections and then are discharged into a dump tank.

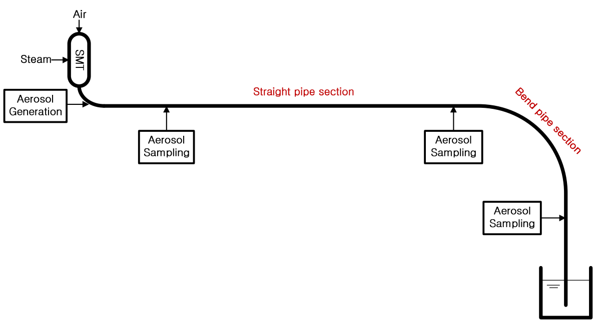

Fig. 1. Conceptual design of aerosol removal test facility in pipe

The aerosol generation and injection system is a kind of high pressure injection of aerosols based on the two-fluid nozzle. Fig. 2 shows the conceptual design of aerosol generation system. The aerosols dissolved or suspended in liquid can be filled in the supply tank pressurized by cover gas. The aerosol supply tank and nitrogen gas are connected to the two-fluid nozzle.

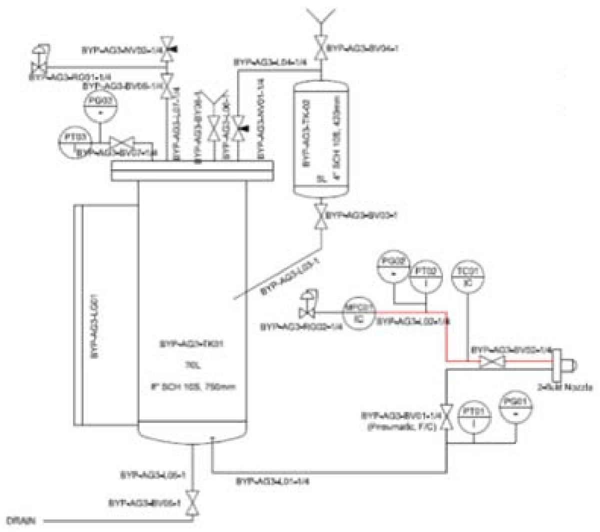

Fig. 2. Conceptual design of aerosol generation system

The aerosol concentration is measured at the inlet and outlet of straight and bend pipe sections. The aerosol measurement is a filter based sampling method which uses a glass fiber filter in a filter holder. The mass of sampled aerosol on the filter is weighed by a micro-balance and is converted into the concentration. Fig. 3 shows the conceptual design of aerosol sampling system.

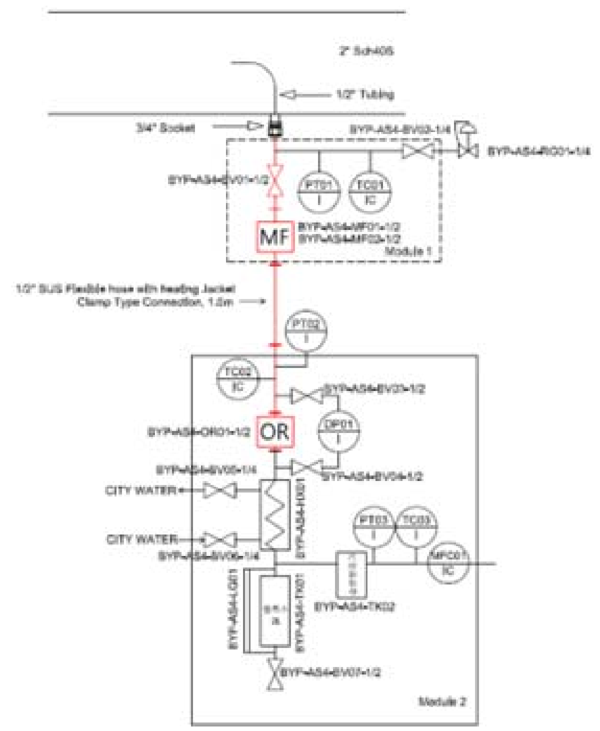

Fig. 3. Conceptual design of aerosol sampling system

The aerosol sampling system consists of two parts as module 1 and module 2. Module 1 is a main part which includes the sampling probe and filter holder. Module 2 is an auxiliary part which consists of the flow control and post-treatment of sampled gases.

2.4 Capability of Test Facility

The designed test facility for aerosol removal in pipe has following capabilities in terms of test conditions as shown in Table I.

Table I: Capability of Test Facility

Main carrier gas	Steam	Air
Pipe size (mm)	2inch	
Inlet pressure (bar-a)	1.5-5	
Inlet temperature (℃)	111-152	30-152
Flow rate (kg/s)	≤ 0.3	≤ 0.25
Flow Reynolds number	≤ 515,000	≤ 324,000
Particle Reynolds number[1)]	≤ 97	≤ 61
Stokes number[1)]	≤ 2	≤ 2

Note [1)] In case of 10 ㎛ of SiO_2

3. Conclusions

The test facility is developed to perform the aerosol removal in pipe. It consists of a straight and bend pipe sections with the aerosol generation and sampling systems. The steam and air can be used as the main carrier gases. The test facility has capability to manage aerosols under high pressure up to 5bar-a and high temperature up to 152℃. The test results will be used to estimate the aerosol deposition in piping systems such as the containment bypass accident like the ISLOCA.

Acknowledgements

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