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Development of Aerosol Scrubbing Test Loop for Containment Filtered Venting System

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1. Introduction

As a part of a development of Korean Containment Filtered Venting System (CFVS) or Filtered Containment Venting System (FCVS), FNC Technology and partners have been designing a prototype of Korean CFVS based on a wet scrubber with a series of filtration stage.

The Korean CFVS is composed of inlet piping connected from the containment penetration to the scrubber tank. Fig. 1 shows the schematic view of the CFVS.

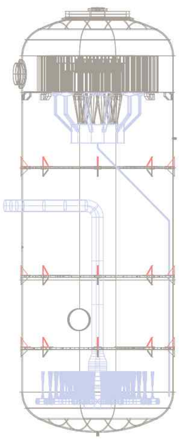

Fig. 1. Schematic view of Korean CFVS.

Numbers of scrubbing nozzles distributed from the distribution arm are installed at the lower section of the scrubber tank and are submerged in the scrubbing water pool. The scrubber tank is filled with scrubbing water with the chemical additives. The droplet separator based on a cyclone is installed above the scrubbing water pool to remove the large droplets that may clog a metal fiber filter installed at the upper section of the scrubber tank. The outlet piping is connected from the scrubber tank to the molecular sieve to chemically remove the gaseous iodine. The aerosol as a particle is physically captured in the scrubbing water pool passing through the scrubbing nozzle as well as the metal fiber filter. The gaseous iodine such as molecular iodine as well as organic iodide is chemically removed in the scrubbing water pool and molecular sieve.

The thermal-hydraulic as well as scrubbing performance for the CFVS should be verified with the experiments. The experiment can be divided into the filtration component based experiment and whole system based one. In this paper, the aerosol scrubbing test loop developed to test the thermal-hydraulic and aerosol scrubbing performance of the scrubbing nozzle with the scrubbing water pool is introduced.

2. Aerosol Scrubbing Test Loop

Since most of the aerosols might be captured inside the scrubbing water pool discharged through the scrubbing nozzle, the aerosol scrubbing test loop is designed to test the performance of the scrubber nozzle and scrubbing water pool. Fig. 2 indicates the overview of the aerosol scrubbing test loop. The aerosol scrubbing test loop consists of the thermal-hydraulic system part and aerosol system part including aerosol generation and sampling system.

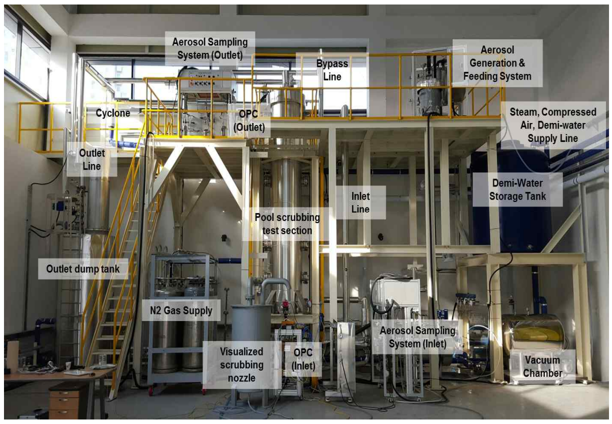

Fig. 2. Overview of aerosol scrubbing test loop.

2.1 Thermal-Hydraulic System Part

Numbers of scrubbing nozzles are installed inside the scrubbing water pool. The thermal-hydraulic system part of the aerosol scrubbing test loop is designed to test the performance of the single scrubbing nozzle as 1 to 1 scale used for the prototype of CFVS.

The single scrubbing nozzle is installed at the lower section of the scrubber tank which is 4500mm tall and 700mm inner diameter. 3” inlet and outlet piping are connected to the inlet and outlet of the scrubber tank. Six (6) view ports are evenly located along the vertical direction, so that the thermal-hydraulic behavior for the scrubbing nozzle and scrubbing water pool such as two-phase mixture discharge through the exit of the nozzle and scrubbing water level swelling can be observed. The cyclone is located at the downstream of the scrubbing tank to remove the droplets entrained from the scrubbing water pool. Since numbers of cyclone is used in the prototype of the Korean CFVS, the cyclone used in the aerosol scrubbing test loop is scaled down to preserve the pressure drop with scaled flowrate for the single scrubber nozzle. The system pressure can be controlled by the outlet control valve located at the downstream of the cyclone. The outlet dump tank which is 2500 mm tall and 1200 mm inner diameter with the inner cooler is used for the ultimate heat sink.

On the other hand, the single scrubber nozzle with a rectangular cage surrounding a water suction side at the throat section made by the poly-carbonate is independently installed beside of the scrubbing tank for the visualization purpose shown in Fig. 3. The rectangular cage is connected to the scrubber tank to supply the scrubbing water of the different water level from the scrubber tank as an overhead tank. Using the visualization loop of the scrubbing nozzle, the hydraulic performance such as water suction behavior with different inlet gas flowrate as well as scrubbing water level can be measured. The flow behavior inside the scrubbing nozzle can be observed with a high speed camera.

Fig. 3. Scrubber nozzle for visualization.

The specification of the thermal-hydraulic part of the aerosol scrubbing test loop is shown in Table 1.

Table I: Specification of thermal-hydraulic part of aerosol scrubbing test loop

		Specification
Design pressure		10 bar-a
Design temperature		200 ℃
Building service	Steam capacity	1.5 ton/hr
	Air capacity	10 m^3/min
	N_2 gas capacity	100 m^3/hr
	Demi-water generation	0.5 ton/hr
Scrubber tank	Height	4500 mm
	Inner diameter	700 mm

2.2 Aerosol System Part

The aerosol system part of the aerosol scrubbing test loop includes an aerosol generation and feeding part and aerosol measurement part.

The aerosol generation and feeding system are shown in Fig. 4. It consists of an aerosol mixing chamber that contains the aerosol solution and gearing pump to discharge the aerosol solution. The discharged aerosol solution is injected into the inlet of scrubbing tank through a two-fluid nozzle mounted on a mixing tank. The two-fluid nozzle forms the fine aerosol droplets with the non-condensable gas such as nitrogen gas in the mixing tank. The fine aerosol droplets are carried by the main carrier gas and injected into the inlet of scrubbing tank.

Fig. 4. Aerosol generation and feeding system installed at aerosol scrubbing test loop.

The aerosol measurement system is divided into two different types. One is an on-line measurement. The other is an off-line measurement. An Optical Particle Count (OPC) is applied as the on-line measurement at the inlet and outlet of the scrubbing tank. A special sampling train including the sampling probe and dilution device is used to control the upstream condition into the measureable range of the OPC. The OPC can be used to detect whether the aerosols are supplied into the inlet of the scrubbing tank and are escaped from the outlet of the scrubbing tank. The relative scrubbing efficiency can be measured by the OPC. Fig. 5 shows the OPC with the sampling train.

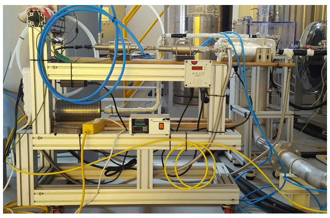

Fig. 5. OPC with sampling train installed at aerosol scrubbing test loop.

On the other hand, the aerosol sampling system with a membrane filter is applied as the off-line measurement at the inlet and outlet of the scrubbing tank. The sampling system consists of the isokinetic sampling probe, membrane filter with special filter holder, flow controller such as a Mass Flow Controller (MFC) as well as a critical orifice and cooler with condensate chamber. Since the saturated steam or high temperature non-condensable gas are used as the main carrier gas for the aerosol scrubbing test, the sampling line as well as membrane filter holder needs to be heated to prevent the aerosol loss due to the condensation during the sampling. The absolute aerosol concentration of the inlet and outlet of the scrubbing tank is measured by using the aerosol sampling with membrane filter. The aerosol concentration is estimated by measuring the aerosol mass filtered in the membrane filter at the given sampling flowrate. Fig. 6 shows the aerosol sampling system.

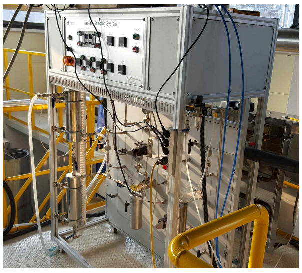

Fig. 6. Aerosol sampling system installed at aerosol scrubbing test loop.

3. Conclusions

The aerosol scrubbing test loop has been developed as a part of the Korean CFVS project. In this loop, the filtration components such as the scrubbing nozzle submerged in the scrubbing water pool as well as the cyclone as droplet separator can be tested under the CFVS operating conditions. The aerosol scrubbing performance of the filtration components including pool scrubbing behavior can be tested with the aerosol generation and feeding system and aerosol measurement system. The thermal-hydraulic performance of the filtration components can also be tested. The test results will be used to confirm the design of the filtration components and give a basis to conduct the integral verification tests of the Korean CFVS planned at KAERI.

ACKNOWLEGEMENT

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