Experimental Study on Pool Scrubbing Efficiency for Aerosol with Self-priming Scrubber Nozzle Used in CFVS

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1. INTRODUCTION

Fukushima Daiichi Nuclear Power Plant accident on March 2011 initiated installation of mitigation system to minimize radiation release to the environment for protecting containment failure under postulated severe accident scenario. Due to this reason, Containment Filtered Venting System (CFVS) has been studied from the 80's up to present. Wet type scrubber as the first filtration is installed to eliminate solid and gaseous aerosol with additional equipment. Among other filtration stages, the wet scrubber is key element to eliminate the particulate aerosols from gas stream during the CFVS operation because water has an effective filtration media [1].

FNC Technology Co., Ltd has been recently developed test facilities for the self-priming scrubber nozzle performance verification of CFVS simulating postulated accident conditions [2]. In this study, the available data such as nozzle inlet concentration, inlet pressure and pool water temperature is analyzed to identify tendency of scrubbing efficiency. Scrubbing efficiency was based on Decontamination Factor, which is the ratio of initial to final concentration of a aerosols after scrubbing has occurred. Note that detailed decontamination factor all included in figure is not provided due to the data security.

2. TEST LOOP

Fig. 1 shows the schematic of aerosol scrubbing test loop to conduct the aerosol scrubbing performance tests for the self-priming scrubbing nozzle. The prototype single nozzle is submerged in the water pool. The main carrier gas is mixed in the pre-mixing tank and then supplied into the aerosol mixing tank. The aerosols from aerosol generation and feeding system is injected into the aerosol mixing tank and mixed with main carrier gas. The main carrier gas including aerosol particles supplied to the inlet of scrubbing nozzle. The aerosol sampling system is installed at the inlet and outlet of the test section to measure the aerosol concentration and estimate the scrubbing efficiency. The measurement of absolute aerosol concentration is based on the aerosol sampling in the aerosol scrubbing tests.

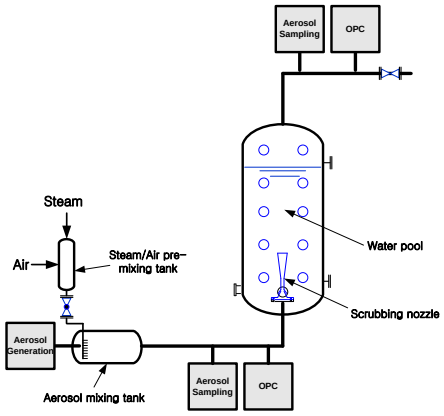

Fig. 1. Schematic of aerosol scrubbing test loop.

3. EXPERIMENTAL RESULTS

3.1 Nozzle Inlet Pressure

The decontamination factor in a self-priming scrubber was investigated at different inlet pressure as shown in Fig. 2. The experimental conditions cover a range of pressure from 1 bar (g) up to 6 bar (g). Tests with micron aerosols (3 ㎛) always higher than submicron (0.5 and 0,7 ㎛) tests regardless of the inlet pressure. Considering the little (for steam or steam mixture) or no influence (for air) of inlet pressure in terms of decontamination factor it can be expected that for a higher pressure will not significant changed.

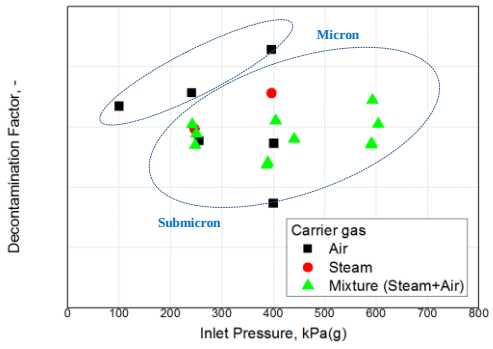

Fig.2: Decontamination Factor at different nozzle inlet pressure with different mass fraction

3.2 Pool Water Temperature

Fig. 3 indicates that the decontamination factors are plotted against the tested pool water temperature. Pool water temperature is significantly influenced by carrier

gas composition. Pool water temperature maintains near or above steam saturation temperature when carrier gas contains steam. However, no influence was observed for the air tests. An increase in DF with higher pool temperature is obtained from the test results in related to the steam and air/steam mixture tests. It may due to the fact that deposition by thermophoresis increases as the temperature gradient in injection gas flow and pool water temperature increases. Also, Tests with micron aerosols (3 ㎛) always higher than submicron (0.5 and 0,7 ㎛) tests regardless of the pool water temperature. The pool water temperature range to be tested from ambient temperature (initial pool water temperature at atmospheric condition) up to 159 ℃ (saturation temperature at 6 bar absolute).

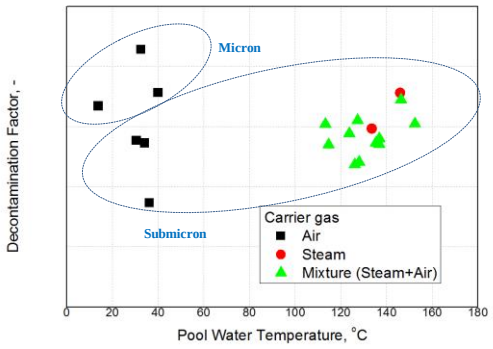

Fig.3: Decontamination Factor at different pool water temperature with different mass fraction

3.3 Comparison with Pool Water Temperature

The decontamination factor for different steam mass fraction in a carrier gas is represented in Fig. 4. It shows an increase in the decontamination factor with an increase mass fraction of steam. This reason is the improved impaction between the bubble and aerosol due to condensation. The increase in scrubbing efficiency at higher steam mass fraction may be due to aerosol growth by condensation followed by inertial interception when saturated steam was injected into scrubbing nozzle throat where the flowing gas contacts relatively cold liquid droplets. Also, the decontamination factor for the micron aerosols is always higher than the submicron test cases regardless of the steam mass fraction. The carrier gas steam fraction will change depending on the containment atmospheric conditions influenced by accident scenario.

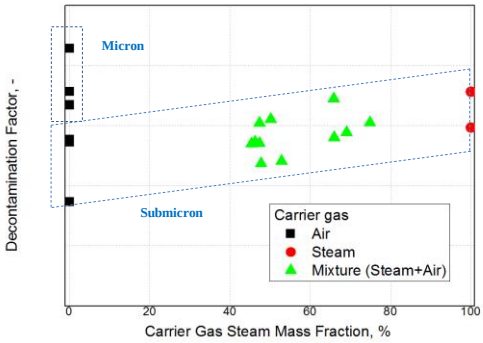

Fig.4: Decontamination Factor at different steam mass fraction

4. CONCLUSION

The pool scrubbing experiment using self-priming scrubber nozzle performed to study the decontamination factor for particulate aerosols ranging from 0.5 to 3 micrometer. Based on the experimental results, the followings are concluded.

- The results indicated that the decontamination factor remain unaffected by the nozzle inlet pressure.
- The decontamination factor was increased with increasing steam mass fraction due to the condensation effect.
- The decontamination factor was increased with increasing in the pool water temperature. The temperature difference between pool water temperature and steam saturation temperature can improve the scrubbing efficiency by thermophoresis removal mechanism.
- Aerosol size was most significant factor on the decontamination factor irrespective of the other test parameter; inlet pressure, carrier gas steam mass fraction and pool water temperature.

ACKNOWLEDGEMENT

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REFERENCES

[1] WGAMA, Status Report on Filtered Containment Venting, NEA/CSNI(2014)7, 2014.
[2] D.Y. Lee et al., Aerosol Scrubbing Performance Test for Self-Priming Scrubbing Nozzle Submerged in Water Pool, Transactions of the Korean Nuclear Society Autumn Meeting, Gyeongju, Korea, October 27-28, 2016.