Aerosol Removal by Dry Tube Bundle in Steam Generator

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Abstract

Aerosol removal by dry tube bundle is important to estimated realistic fission product behavior by SGTR accident

- **Steam generator tube rupture (SGTR)** is the important containment bypass accident causing possible large release of fission product to environment.

Summary

The aerosol removal by dry tube bundle were calculated and compared with experimental results.

Turbulent deposition were the most dominant mechanism of aerosol removal.

Resuspension and rebound of aerosol seems very important.

Experimental Facility

■ AEOLUS test facility

- Test facility for aerosol removal in steam generator
- Scaled down model of SG in Korean NPP.
- Separate effect tests and integral tests were done.

■ Dry bundle tests

- Aerosol removal tests by tube bundle.
- Test conditions are as below

Tab. 1 Test condition

Variable	Value
Working fluid	Air
Upstream pressure (bar)	6.9
Downstream pressure (bar)	2.3
Inlet gas temperature (ºC)	~160
Mass flow rate (kg/s)	0.17
Aerosol Particle	SiO_2 (MMD0.7μm)

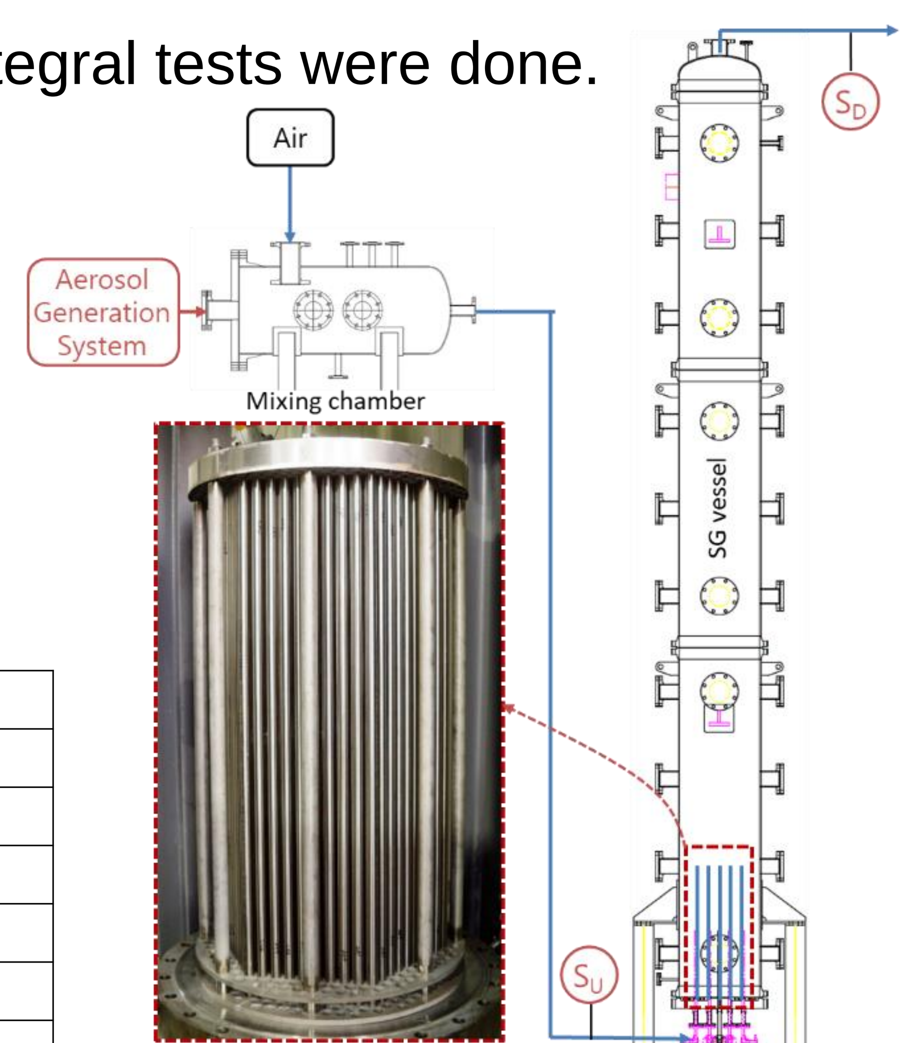

Fig. 1 AEOLUS test facility

Results of dry tests

■ Dry test results

- DF=4.0
- The aerosol mass deposited on tube initially increases to the 2nd tube, and then decreases with distance because the gas velocity decreases.
- The initial increase is due to the resuspension and rebound of aerosol.

Tab. 2 Dry test results

Variable	Value
Sampling	3 times
Sampling duration	1800 s
Average DF	4.0
Collected aerosol from the tubes (extrapolated)	117 g

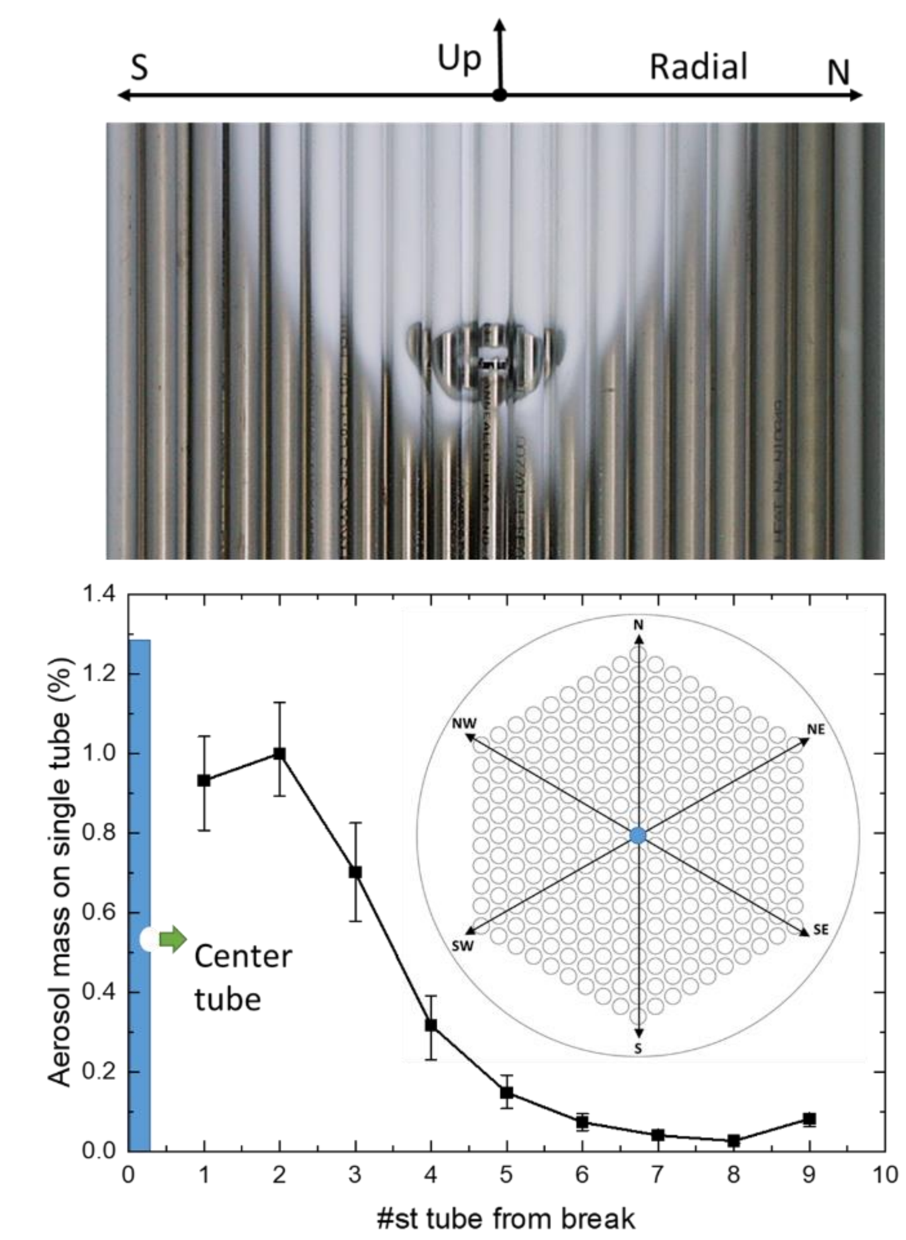

Fig. 2 Aerosol deposition by dry tests

Results

■ Aerosol removal by tube bundle by filter approximation.

- The aerosol-laden gas flow perpendicular to the tube bundle.
- The aerosol collection was calculated for each bank of tubes.
- Turbulent deposition and inertial impaction were the major aerosol removal mechanism, and were calculated with known collection efficiencies.
- The velocity flowing through the tube bundle were assumed with simple approximation.
- The results of calculation were compared with experimental one, but the calculation did not accounted for the resuspension and rebound.

Mechanism	Parameter	Approx. Value Near field	Approx. Value Far field
Turbulent Deposition	$Sc_T \cdot Re_g^{0.5}$	~10^{0}	~10^{-2}
Inertial Impaction	Stk	~10^{-2}	~10^{-4}
Interception	d_p/D	~10^{-5}	
Gravitational settling	$\frac{v_{TS}}{U} = \frac{\rho d_p^2 C_c g}{18 \mu U}$	<10^{-7}	
Brownian diffusion	$2Pe^{-2/3}$	<10^{-5}	

Fig. 3 Aerosol removal mechanisms and their relative importance.

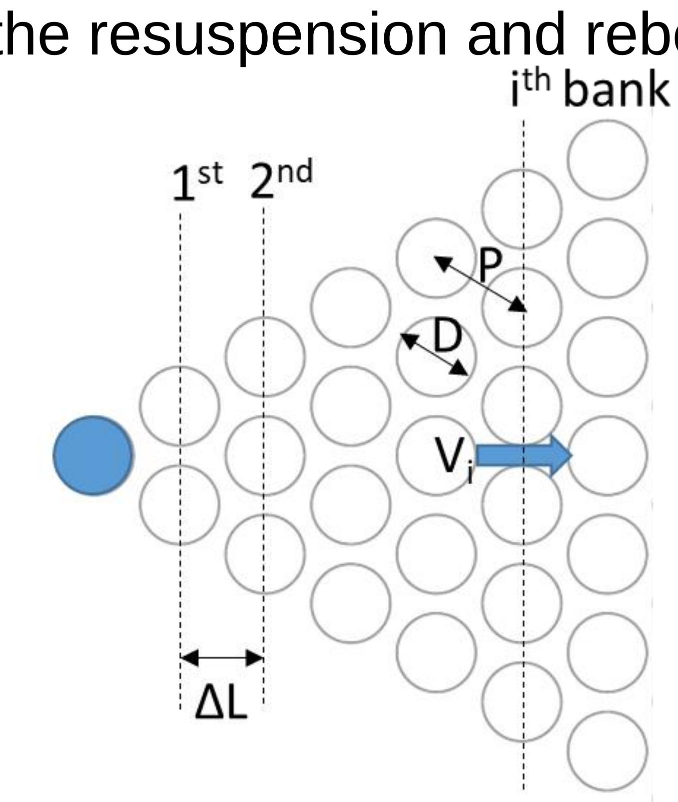

Fig. 4 Filter approximation of tube bundle for calculation

Calculation of collection efficiency

$$\eta_{TB} = 1 - exp\left(-\int_0^L \frac{4\eta_{ST}}{\pi D}\frac{\alpha}{1-\alpha} dl\right) \approx 1 - exp\left(-\sum_{i=0}^{N} \frac{4\eta_{ST}}{\pi}\frac{\alpha}{1-\alpha}\frac{\Delta L}{D}\right)$$

$$\eta_{TB\_TD} = 0.438 + 0.0713 ln(Stk_e)$$

$$\eta_{TB_{Imp\&Int}} = \frac{1-\alpha}{Ku}\left(\frac{d_p}{D}\right)^2 + \frac{2(1-\alpha)\sqrt{\alpha}}{Ku} Stk_e \left(\frac{d_p}{D}\right) + \frac{(1-\alpha)\alpha}{Ku} Stk_e$$

$$Ku = \alpha - \alpha^2/4 - 3/4 - (1/2) ln\alpha$$

Velocity assumption

$$V_i = \frac{1}{2^i} V_o$$

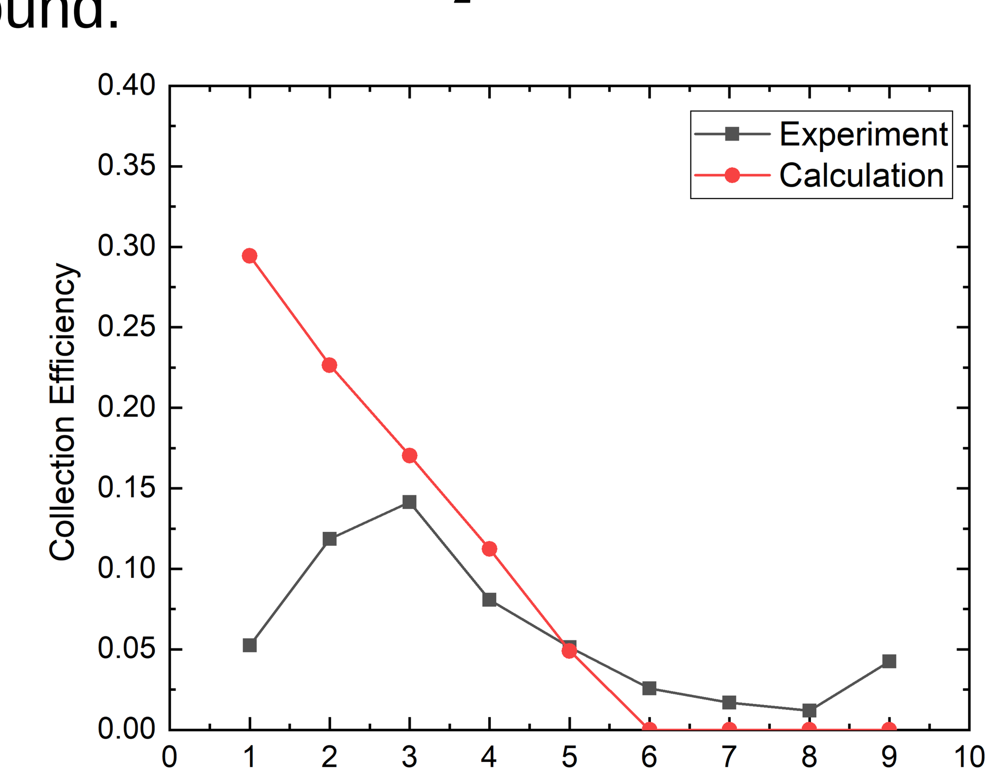

Fig. 5 Collection efficiencies of i-th bank tubes

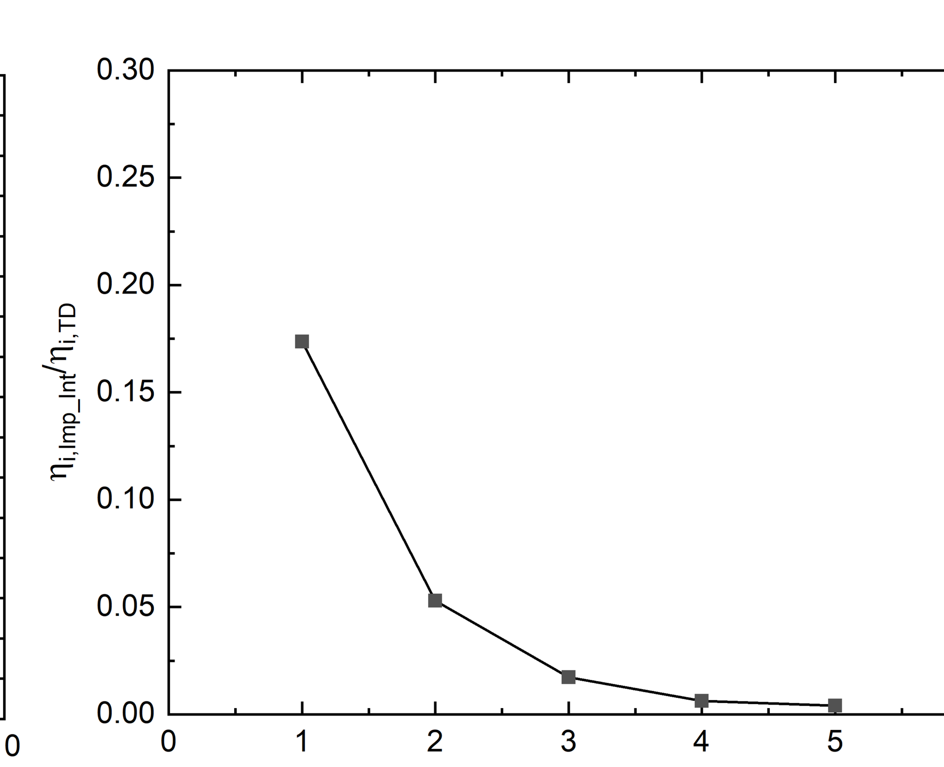

Fig. 6 Relative importance of impaction versus turbulent deposition