Numerical calculation for radioactive particle sampling in a nuclear stack

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To protect environment from radioactive intimidation, monitoring of radioactive particles releasing from nuclear stack is very important. In the monitoring system of nuclear stack, sampling system should deliver a representative sample to detector or collector.

ANSI (American National Standard Institute) reported criteria of sampling position in nuclear stack, to make representative sampling, in ANSI/HPS N13.1-1999. The criteria of sampling position of radioactive particle are as following:

1. In velocity profile, COV (Coefficient of Variation) shall not exceed 20% over the center region of the stack that encompasses at least 2/3 of the stack area.

2. The average swirl angle shall be less than 20°

3. COV of particle concentration shall not be exceed 20% over the center region of the stack that encompasses at least 2/3 of the stack area.

In present study, the COV and swirl angle along the stack height were determined numerically. Using present calculation, the sampling position can be predetermined. Therefore, the sampling line from probe to detector can be minimized to reduce deposition loss. The calculation geometry was similar to Rodgers et al. (Rodgers et al., 1996). The disturbance is occurred at the interface between rectangular duct and stack. Merge angle between duct and stack is 45°.

Calculation was performed for Reynolds number of 10^5, 3x10^5 and 5x10^5 which cover normal and abnormal operating condition of nuclear facilities. Standard k-ε model was used to include turbulence effect and flow field was calculated using finite volume method.

Figure 1 shows COV as function of stack height. D is diameter of stack. As shown in figure 1, COV decreases as height increases and COV is not significantly affected by Reynolds number. This result is consistent with experimental results of Rodgers et al. COV was satisfied the criteria at distance around 4D from the disturbance. The COV can be expressed following fitting equation

\[ COV(\%) = 5.56 + 117.26 \exp\left(-0.58 \frac{z}{D}\right) \]

From above equation, the proper sampling position can be determined easily before sample system is installed.

The average swirl angle was also calculated in same Reynolds number range. For all cases, the average swirl angle was satisfied the criteria.

![Figure 1. COV as function of height of stack.](image)

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