An Assessment of Air Sampling Location for Airborne Radioactive Effluent Monitoring in Nuclear Facility using CFD

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1. Introduction

It is important to collect representative samples from nuclear stack for monitoring airborne radioactive effluent. The ANSI/HPS N13.1-1999 reported the criteria of the air sampling location in nuclear stack to make representative sampling [1]. Although nuclear facilities releasing airborne radioactive effluent should be supposed to comply with the above criteria of the sampling location, it is difficult to meet the criteria owing to various operating procedures and sampling environments. Hence, sampling locations should be assessed using appropriate methods, and the improved plan (e.g., installation of flow straighteners or static mixers) should then be considered, for items that not meet the criteria.

In this study, a numerical analysis for the flow field in the stack of the Advanced Fuel Science Building (AFSB) at the Korea Atomic Energy Research Institute (KAERI) was carried out using Computational Fluid Dynamics (CFD) method. Based on the results of a numerical analysis, this study confirmed whether the sampling location complied with the criteria. Furthermore, a suggestion has been made for the appropriate improved plan for items that do not meet the criteria.

2. Assessment of sampling location

2.1 Assessment method

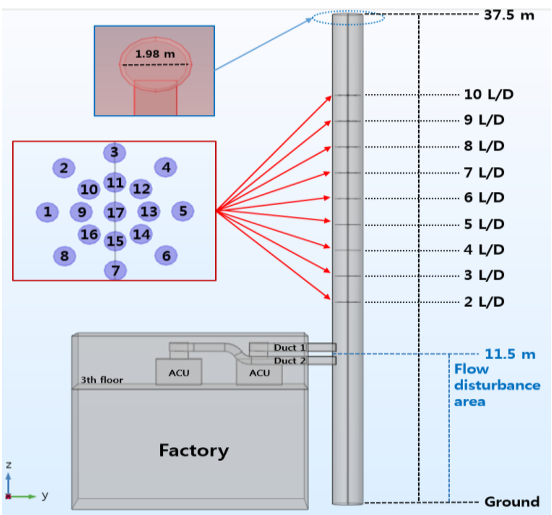

Fig. 1. Duct and stack modeling for assessment of sampling locations in AFSB (KAERI)

For the assessment, a numerical analysis was carried out using the commercial CFD program 'COMSOL'. Three-dimensional modeling at the 1:1 scale of the AFSB is shown in Fig. 1. The starting point of the flow disturbance was set to 11.5 m, and nine sampling locations were placed as a function of stack height L and diameter of stack D (L/D). In addition, each sampling location was modeled at 17 measurement points for assessment [2].

The flow range which was released from the Air Cleaning Units (ACU) was set to 22,800 m^3/h (Duct 1) and 31,500 m^3/h (Duct 2). Helium gas was selected as a tracer gas, and the diffusion coefficient was assumed 0.7335 cm^2/s. The particles size and density were set to 10 μm in aerodynamic diameter (AD) and 19.1 g/cm^3.

2.2 Assessment results

The results of an assessment for the sampling locations are shown in Table I. The coefficient of variation (COV) of the velocity profile, 5 L/D or more in height, was met. The average flow angle, the COV of the tracer gas profile and the ratio of the max value to mean value of the tracer gas concentration (Max.Ratio) were met at all sampling locations. The COVs of the particle profile, 5 L/D and 9 L/D were met. Hence, all criteria were met at 5 L/D and 9 L/D.

Table I: Assessment results

Sampling Locations	Flow Angle	Velocity	Tracer Gas		Particle
	Avg. [deg.]	COV [%]	COV [%]	Max. Ratio [%]	COV [%]
2 L/D	†11.2	43.9	†7.4	†11.7	54.8
3 L/D	†6.6	27.9	†6.4	†7.6	31.0
4 L/D	†4.6	22.2	†6.2	†6.0	23.6
5 L/D	†3.5	†18.5	†6.0	†5.2	†17.6
6 L/D	†2.9	†15.3	†5.7	†4.8	21.7
7 L/D	†2.4	†12.7	†5.5	†4.7	24.9
8 L/D	†2.1	†10.7	†5.2	†4.7	21.8
9 L/D	†1.9	†9.4	†5.0	†4.6	†15.9
10 L/D	†1.7	†8.7	†4.8	†4.5	21.3

† : Meet the criteria

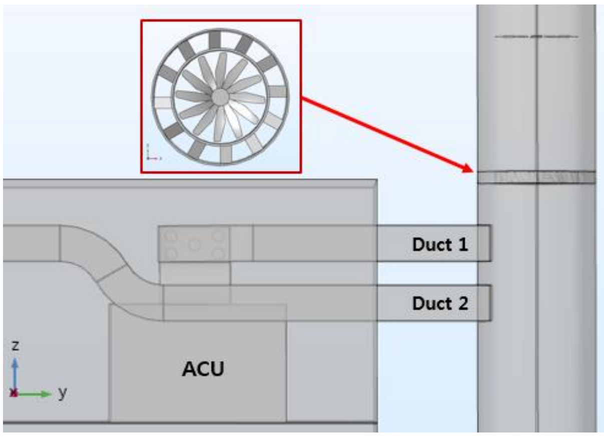

Fig.2. Modeling of the static mixer in stack

3. Improved plan for particle mixing

To get uniformity for the particle profile, a static mixer (SM) was considered [3]. A numerical analysis was carried out by modeling using the SM, as shown in Fig. 2. The SM has two sets of concentric vanes that produce rotations in the opposite directions. The position of the SM was set at 13 m. The assessment method was the same as the method executed beforehand.

4. The results of a comparative assessment

The results of a comparative assessment before and after the SM modeling are shown in Fig. 3-5. After modeling the SM, the sampling locations meeting the criteria of the velocity profile were 4 L/D (13.2%) or more in height. The average flow angle was increased sharply. The sampling locations that met the criteria of the average flow angle were 3 L/D (18.0°) or more in height. The COV of the tracer gas profile and the Max.Ratio was met at all of the sampling locations. The sampling locations that met the criteria of the particle profile were 5 L/D (15.8%) or more in height.

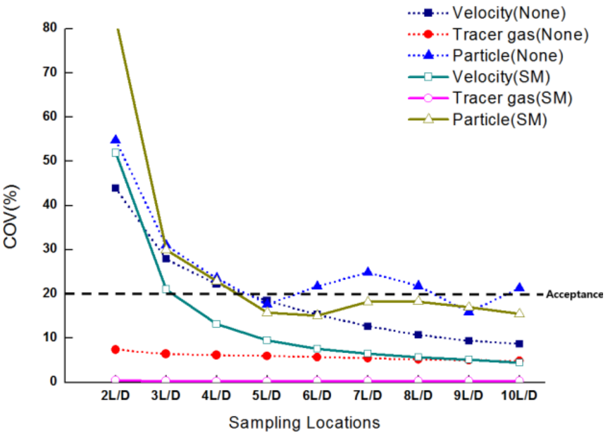

Fig. 3. The results of a comparative assessment for the velocity, tracer gas and particle COV

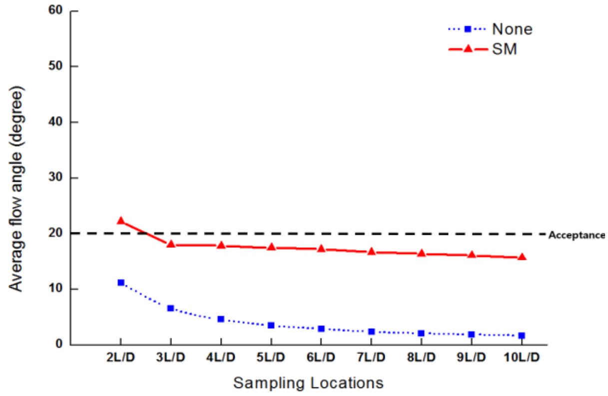

Fig. 4. The results of a comparative assessment for the average flow angle

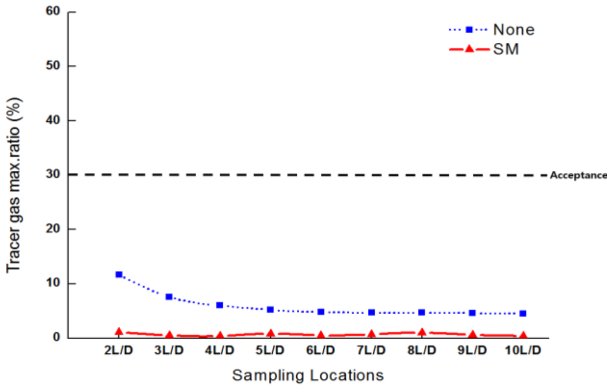

Fig. 5 The results of a comparative assessment of the Max.Ratio

5. Conclusions

As a result of the assessment for the criteria at the sampling location required by ANSI/HPS N13.1-1999 using CFD, it were confirmed that the criteria was met at 5 L/D and 9 L/D. Furthermore, after modeling using the SM as a method for getting uniformity for the particle profile, it was confirmed that the criteria were met at 5 L/D or more in height. Hence, installing an SM in the stack for getting uniformity for the particle profile and meeting all the criteria is being considered. Methodologies used in this study can be used as a method for assessing an air sampling location for both new and current facilities.

REFERENCES

[1] American national Standards Institute, Sampling and Monitoring Release of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities, ANSI/HPS N13.1, 1999.

[2] United States Environmental Protection Agency, Sample and velocity traverses for stationary sources, 40CFR60 Appendix A, Method 1, 1989.

[3] McFarland, A.R., Gupta, R. and Anand, N.K., Suitability of Air Sampling Locations Downstream of Bends and Static Mixing Elements, Health Physics, 77(6), pp. 703-712, 1999.S