A study on the particle penetration in RMS's particle transport system

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1. Introduction

In nuclear facilities, a radiation monitoring system (RMS) monitors the exhaust gas containing the radioactive material. Samples of exhaust gas are collected in the downstream region of air cleaning units (ACUs) in order to examine radioactive materials. It is possible to predict an amount of radioactive material by analyzing the corrected samples. Representation of the collected samples should be assured in order to accurately sense and measure of radioactive materials. That is why the selection of sampling location is important.

The diameters of tubes used in particle transport system are generally 3/4" and 1 1/2".The radius of curvature is mainly 5 times of tube diameter. Sometimes, a booster fan is additionally added to enhance particle penetration rate.

In this study, particle penetrations are calculated to evaluate particle penetration rate with various design parameters (tube lengths, tube declined angles, radius of curvatures, etc).

2. Methods

The 'ANSI N13.1-1969'[1], (Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities) and 'ANSI/HPS N13.1-1999[2]', (Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities) are representative design criteria for representative sampling. They suggests the design requirements regarding the selection of the sampling position. Evaluation items are the uniformity of the velocity distribution of the particles, the flow angle, the concentration distribution of tracer gas and aerosol particle distribution. Acceptance criteria of ANSI/HPS N13.1-1999 are summarized in table 1. In particle transport system, particle penetration are should be higher than 50%.

In this study, particle penetration rates are calculated using the 'Deposition 2001a'(Nuclear Regulatory Commission, USA NRC). It is a certified program to evaluate particle penetration rate in particle transport tubes. This program is capable of calculating the loss of particles in probe, tubes, bending tubes, fitting, etc.

Table 1 ANSI/HPS N13.1-1999

Item		Acceptance Criteria
Sampling system	Flow angle	The average resultant angle shall be less than 20º.
	Velocity profile	COV* shall not exceed 20% over the center region of the stack that encompasses at least 2/3 of the stack area.
	Tracer gas concentration profile	COV shall not exceed 20% over the center region of the stack that encompasses at least 2/3 of the stack area.
	Aerosol particle concentration profile	COV shall not exceed 20% over the center region of the stack that encompasses at least 2/3 of the stack area.
Particle transport system	Particle penetration	The resultant penetration shall be more than 50%.

*COV: Coefficient of Variation

3. Results

3.1 Penetration with several tube lengths

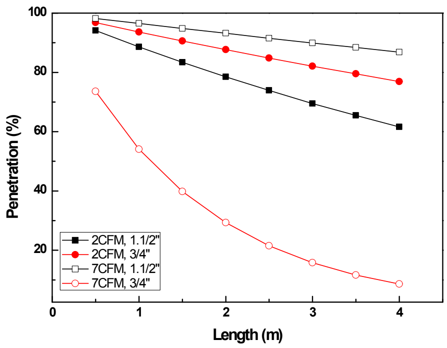
Particle penetration rates are calculated with several tube lengths. Considered tube lengths are from 0.5 *m* to 4.0 *m* and diameters of tube are 1 1/2" and 3/4". Considered directions is both of horizontal and vertical directions. Flow rates sucked in RMS are 2 CFM and 7 CFM

In cases of horizontal tube, the longer the tube length, the lower the particle penetration rate as shown in Fig. 1(a). The particle penetration rate is the highest at the flow rate of 7 CFM and the diameter of 1 1/2". In the same flow conditions, the particle penetration rate is higher in the case of the large diameter of tube. Particle penetration rate in 3/4" tube is low as flow rate increases. In the case of 3/4" tube and 7 CFM, especially, the particle penetration rate is sharply lowered. In cases of vertical tubes, particle penetration rates are similar except the case of 3/4" tube and 7 CFM as shown in Fig. 1(b).

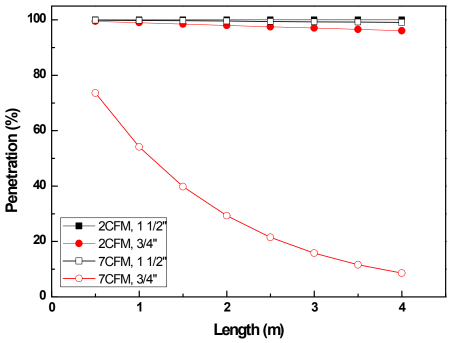
3.2 Penetration with several tube declined angles.

Particle penetration rates are calculated with several tube declined angles. Considered tube declined angles are from 0º to 90º from the horizontal plane. Tube sizes are 1.1/2" and 3/4". Flow rates sucked in RMS are 2 CFM and 7 CFM.

It can be seen that the particle penetration rate is increases as the declined angle of tube increases. But, there is no change of the particle penetration rate in the case of 3/4" tube and 7 CFM.



(a) horizontal



(b) vertical

Fig. 1. Penetration with several tube lengths

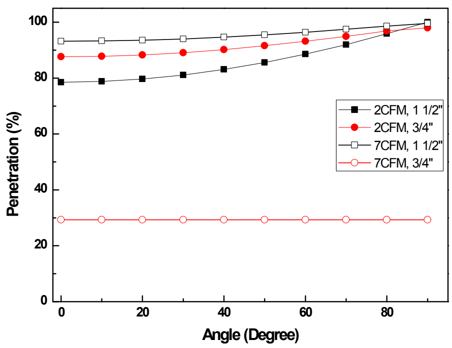


Fig. 2. Penetration with several tube declined angles

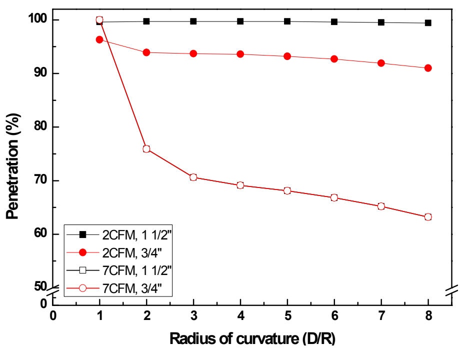


Fig. 3. Penetration with several radius of curvatures

3.3 Penetration with several radius of curvatures

Particle penetration rates are calculated with several radius of curvatures. The radiuses of curvatures for bending tube are from 1D to 8D (D: tube diameter). Considered tube diameters are 1 1/2" and 3/4". Flow rates sucked in RMS are 2 CFM and 7 CFM.

In the cases of 2 CFM, the particle penetration rates are higher than those in 7 CFM as shown in Fig. 3.

3.4 Penetration with the tube sizes

Particle penetration rate in simple particle transport system with different tube sizes are evaluated. The model of particle transport system is 3 cases as shown in Fig. 4. Each model is composed of a probe, tubes (horizontal & vertical), and bending tube as shown in Table 2. Flow rates sucked in RMS are 2 CFM and 7 CFM.

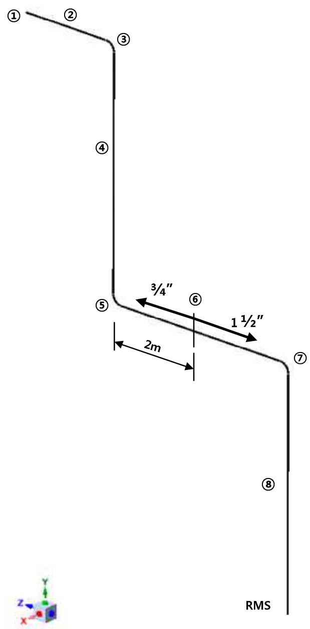


Fig. 4. Schematic diagram of sample transport system

Table 2 Transport system

No.	Component	Direction	Length/ Angle	Tube Size (inch)
1	Probe	-	-	
2	Tube	Horizontal	2 m	① 3/4" ② 1.1/2" ③ 3/4" & 1.1/2"
3	Bend (5DR)	Horizontal to vertical	90°	
4	Tube	Vertical	5 m	
5	Bend (5DR)	Vertical to horizontal	90°	
6	Tube	Horizontal	4 m	
7	Bend (5DR)	Horizontal to vertical	90°	
8	Tube	Vertical	5 m	

Table 3 Results of penetration

Item	2 CFM		7 CFM		2 CFM	7 CFM
	1 1/2"	3/4"	1 1/2"	3/4"	3/4" & 1 1/2"	3/4" & 1 1/2"
Total penetration (%)	47.9	49.5	73.4	0.0	43.0	0.1

Calculated total particle penetration rates are summarized in Table 3. As flow rate increases, the particle penetration is high in the 1 1/2” tubes, but low in the 3/4” tubes. In the case of 3/4” and 1.1/2” tube, the particle penetration is about 43.0% in 2 CFM, and the particle penetration is about 0.1% in 7 CFM. In this case, the particle penetration highly depends on the flow rate and the size of the tube.

4. Conclusions

The particle penetration rates have been calculated for several elements in the particle transport system. In general, the horizontal length of tube and the number of bending tube have a big impact on the penetration rate in the particle transport system. If the sampling location is far from the radiation monitoring system, additional installation of booster fans could be considered in case of large diameter tubes, but is not recommended in case of small diameter tube. In order to enhance particle penetration rate, the following works are recommended by priority.

1) to reduce the interval between sampling location and radiation monitoring system
2) to reduce the number of the bending tube

REFERENCES

[1] ANSI N13.1-1969, “Guide to sampling airborne radioactive materials in nuclear facilities”, American National Standard Institute, 1997.
[2] ANSI/HPS N13.1-1999, “Sampling and Monitoring Releases of Airborne Radioactive Substances From Stacks and Ducts of Nuclear Facilities”, January, 1999.