Estimation on the Aerosol Particle Penetration in RMS Sampling Line

Kwang Chu Kim [a*], Man Heung Park [a]
[a] *Korea Power Engineering Company, Inc., 257 Yongudaero, Giheung-gu, Yongin-si,Korea*
[*] *Corresponding author: kkc@kopec.co.kr*

1. Introduction

In the nuclear industry, Radiation Monitoring System (RMS) is used to either provide information on radioactive substances released to the atmosphere to the operators or to provide near-real time warnings if levels of radionuclide air emissions exceed facility limits. Exact sampling information enables the operators to institute appropriate control measures and to notify public safety officials that a problem exists. Therefore, they are an essential part of the risk management strategy for nuclear power plant and are the first place where radioactive releases to the atmosphere can be detected. To guarantee the reliable performance of RMS, it is important to install sampling nozzle (probe) at a location where a representative sample can be extracted, or to be designed to minimize the losses in transport line. In this study, estimation of the particle penetration in a RMS sampling line is performed by DEPOSITION software and some improvements ways to meet the criteria are suggested.

2. Technical Description

2.1 ANSI/HPS N13.1 Requirements

ANSI/HPS N13.1 was first issued in 1969 as a guide for sampling the airborne radioactive materials. Since then, this standard was revised in 1999 with an improved technical basis development. This standard presents a new approach to representative sampling. Emphasis is on extractive sampling from a location in a stack or duct where the contaminant is well mixed. This standard sets forth guidelines and performance criteria for the use of air sampling probes, transport lines, sample collectors, sample monitoring instruments, and gas flow measuring methods. Generic sampling system can consist of several components as shown Fig. 1. Transport system that extracts particles and transports consists of nozzle and transport line. Nozzle should be placed at a location where a representative sample is extracted and meets ANSI/HPS N13.1 criteria. ANSI (American National Standards Institute) N13.1 criteria demands that the Coefficients of Variation (COVs) of the normalized concentration and velocity profiles should be within ±20% over the center 2/3 of the stack or duct, and that flow angle should be within 20 degrees [1]. This can be estimated by numerical analysis or experiment. After sampling location in duct or stack is fixed, penetration of aerosol particles in transport line should be estimated. This is because aerosol particles can be deposited on internal surfaces of transport systems as a result of the actions of mechanism that cause particles to move transverse to air flow streamlines. Transport line generally consists of tubing and connectors. Connectors can be bends, expansions, contractions, flow splitters, or mixing elements. ANSI specifies that at least 50% of 10 ㎛ aerosol particles must penetrate the sampling system from the free stream in the stack or duct to the collector or analyzer.

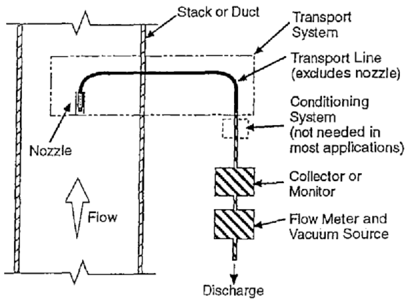

Fig. 1. Schematic of the generic sampling system.

2.2 DEPOSITION Program

Estimations of particle losses in sampling system can be performed by computer software, hand calculations or tests. As an example, the U.S. Nuclear Regulatory Commission (NRC) has made available PC-based software, DEPOSITION, for calculating the losses of aerosol particles in transport system [1-2]. It includes models for losses in certain types of nozzles, straight tubes, bends, and fittings that serve as transitions in tube diameter, either to enlarge or reduce the diameter.

3. Results and Discussion

Fig. 2 is the schematic of the first designed transport line selected for penetration analysis. It consists of 20 elements including probe. Each and total penetrations are calculated using DEPOSITION program. Sampling is assumed to be extracted by commercial probes and user defined probe. User defined probe is the general type of probe and is assumed that shroud diameter is 2 times of tube diameter and the velocity reduction ratio of the shrouded nozzle (free stream velocity divided by the velocity in the shroud) is 3 [2-3]. Fig. 3 shows a single point shrouded probe of commercial RF series. Tube diameter of transport line is 3/4 inch and the used input parameters and values are shown in Table I. All cases don't meet the criteria as shown in Table 2.

To meet the criteria, transport line layout is revised as shown in Fig. 4. The number of elements is minimized to 8 in considering site circumstance. 12.5° slope is given in horizontal line to increase gravity effect.

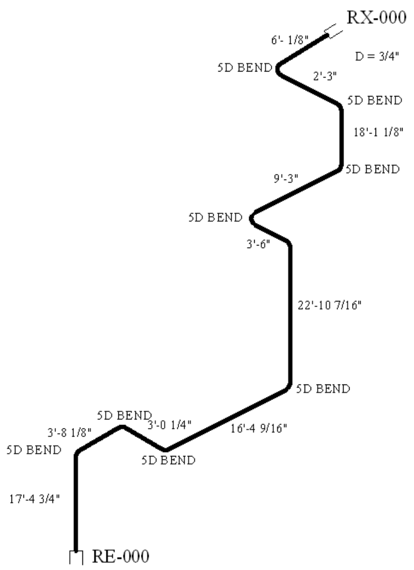

Fig. 2. Schematic of the first designed transport line.

Fig. 3. Example of a single point shrouded probe of commercial RF series.

Table I: Input parameters and values

Input Parameter	Value
a. Gas temperature	108.3 deg
b. Gas pressure	812.7 mmHg
c. Particle density	1 g/mL
d. Flow rate	69.9 L/min
e. Tube diameter	19.05 mm
f. Free stream velocity	6.1 m/s
g. Particle diameter	10 ㎛

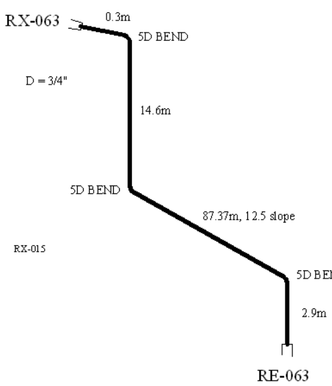

Fig. 4. Schematic of the revised transport line.

Table II shows the total penetration results in the original layout and the revised layout. Compared with the first layout, total penetration in the revised layout is improved but just RF-2-112 and 113 meet the criteria. Generally, single point shrouded probe shall be selected based on a range of stack velocities and sampling flow rates. Therefore, considering the flow conditions in this sampling line shown in Table I, RF 112 series probe seems to be suitable based on the specification shown in Table III.

Table II: Total penetration results in the original layout and the revised layout

	Original	Revised
Elements	20 EA	8 EA
RF-2-111 Probe	23.0 %	43.9 %
RF-2-112 Probe	27.1 %	51.7 %
RF-2-113 Probe	27.6 %	52.7 %
User defined Probe	23.8 %	45.4 %

Table III: Range of stack velocities and sample flow rates recommended in commercial RF series probes.

Probe Designation	Nominal Sampling Rate, L/min	Free Stream Velocity Range, m/s
RF-2-111	57	0 to 24
RF-2-111	85	1 to 25
RF-2-112	57	0 to 16
RF-2-112	85	1 to 25
RF-2-113	57	0 to 5

4. Conclusions

In this study, particle penetration in sampling system was estimated using numerical analysis. The revised layout to improve the penetration was compared with the original layout that does not meet the ANSI/HPS N13.1criteria.

Some ways can be suggested to improve the particle penetration. First, use the excellent probe because probe is the first element and other elements penetration values are multiple to probe penetration value in sequence. Second, diminish the line length between inlet and outlet. This can decrease the friction loss. Third, minimize the number of elements in transport line. This is because many elements like bending or fitting increase the geometrical loss. Finally, give the slope in horizontal line to increase gravity effect.

Estimation methodology applied to this study can be helpful to the optimal layout, verification or design revision of RMS sampling line to meet the criteria.

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] Andrew R. McFarland, Sampling Emissions from Stacks and Ducts of the Nuclear Industry, 3rd International Nuclear Industry Forum, Avignon, France, 2006.

[3] Andrew R. McFarland and John C. Rodgers, Single Point Representative Sampling with Shrouded Probes, Los Alamos, New Maxico 87545, 1993.