Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

Particle Penetration through Aerosol Transport Systems

Ha Gak-Hyeon , Lee Sung- No#
kyeonh@kepri.re.kr

1. Introduction

A typical transport systems be composed of a nozzle, straight tubes, elbows. The direction of the straight tubes can be horizontal, vertical or inclined. Elbows joining two straight tubes usually have either 45° of 95° angles. Although multiple probes are often used for same acquisition, here we shall consider only single – point sampling. The axis of the probe at the entrance of the transport system is generally set parallel to the main stream flow, although due to flow swirl, it could be at an angle. Particles can be deposited on the internal walls of any of the above mentioned components. Primary mechanisms for particle deposition in transport systems are gravitational settling, turbulent diffusion, inertial impaction and Brownian diffusion. For larger particles(>1μm aerodynamic equivalent diameter, AED) gravitational settling can play an important role, particularly in horizontal tubes wherein the gravitational vector is perpendicular to the flow direction. The influence of the gravitational field on particle deposition on tube walls decreases as the tube orientation shifts from horizontal to vertical. Brownian diffusion is the dominant mechanism for deposition of particles in the size range of < 0.1μm. For larger particles(> 1μm) the effect of Brownian diffusion is small but that of turbulent diffusion can be significant. The influence of turbine diffusion on particle deposition increases with flow velocity(flow rate) and particle size, and decreases with tube size.

2. Gravitational Settling

When a particle is released in air, it quickly reaches its terminal settling velocity, a condition of constant velocity wherein the drag force of the air on the particle , F_D, is exactly equal and opposite to the force of gravity F_G. Under this condition,

$$F_d = F_g = mg$$

Where F_d is the drag force of air on the particle, F_g is opposite to the force of gravity

$$3\pi\mu Vd = \frac{(\rho_p - \rho_g)\pi d^3 g}{6}$$

where g is the acceleration of gravity, ρ_P is the density of the particle.
The terminal settling velocity V_{TS} gives

$$V_{TS} = \frac{\rho_p d^2 g}{18\mu} \text{ for } d > 1\mu m \text{ and } Re < 1.0$$

$$V_{TS} \cong 3 \times 10^{-5} d^2\ m/s \quad \text{for } 1 < d < 100\mu m$$

3. Turbulent Diffusion

Particles carried in turbulent flow will be deposited on the walls of a conduit to a greater or lesser degree depending upon particle size and density, the average velocity of the air , and the diameter and length of the conduit. The equation from which deposition losses may be evaluated is

$$\frac{C}{C_o} = e^{\frac{-4KL}{V_a D}}$$

in where
C_o = The concentration of particles at an initial Point
C = The concentration of particles at a point of interest downstream from the initial Point
L = Distance from initial point to the of interest . cm
D = inside diameter of Sampling line . cm
V_a = Average velocity in the sampling line . cm
K = Deposition velocity. cm/s

4. Inertial Impaction

$$F_i = -\frac{3\pi\mu d}{C_c}(U - V)$$

C_c is Slip Correction Factor
U is Fluid Velocity
V is Particle Velocity

5. Brownian Diffusion

Very Small particles can be diffuse to the wall of a conduit by Brownian motion. The equations which allow an estimate to be made of deposition were derived by DeMarcus. The fraction of particles which pass through a circular cross section tube without depositing is given by

$$F_p = 0.819e^{-a} + 0.0975e^{6.5a} + 0.0325e^{-16a}$$

in which

$$a = \frac{3.66\pi DL}{Q}$$

D = diffusion constants. cm^2/sec

L = length of conduit. cm
Q = flow in cm^3/sec

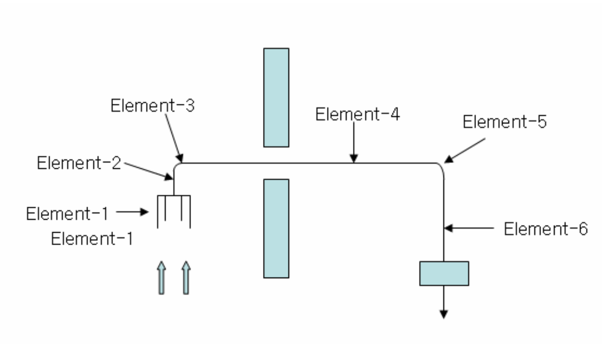
This equation is satisfactory when Fp is less than 0.78. when Fp is grater than 0.78.

Chungnam Natonal University Mechanics Professor

$$F_p = 1 - 1.09a^{\frac{2}{3}} - 0.328a + 0.0097a^{\frac{4}{3}}$$

6. Particle Penetration

6.1 Simulation Model

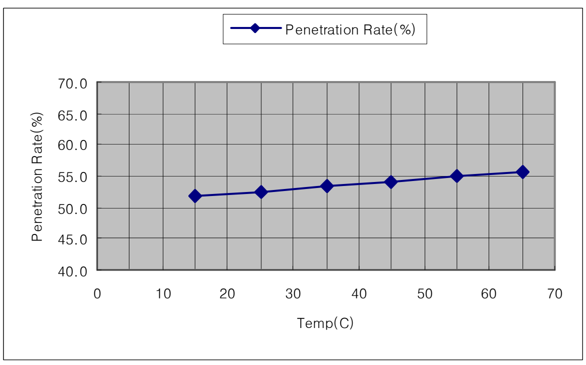


6.2 Variable Factors

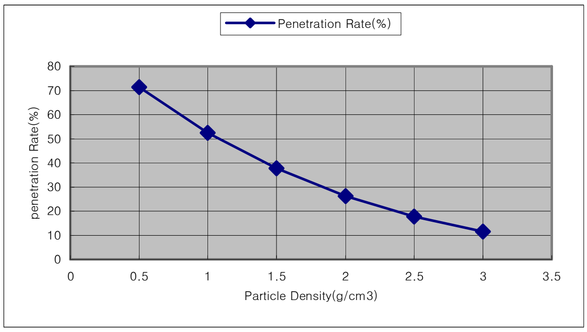
In this paper, temperature, particle density, tube diameter, Particle size are selected the variables of simulation

items	Variable Values	Remarks
Ambient Temp.(^{o}C)	25	Variable
Ambient Pr.(mmHg)	760	Fixed
Particle Density (g/cm^3)	1	Variable
Flow Rate(cm^3/sec)	943cm^3/sec	Fixed
Tube Dia.(mm)	25.4	Variable
Free Stream Velocity(m/s)	10	Fixed
Element 1 Nozzle(Probe)	Shrouded	Fixed
Element 2 Tube length(m)	0.2	Fixed
Element 3 Elbow	90^o	Fixed
Element 4 Tube Length(m)	1(Horizontal)	Fixed
Element 5 Elbow	90^o	Fixed
Element 6 Tube Length(m)	2(Vertical)	Fixed
Particle Size (μm)	10	Variable
Particle Disperse	Mono-disperse	Fixed

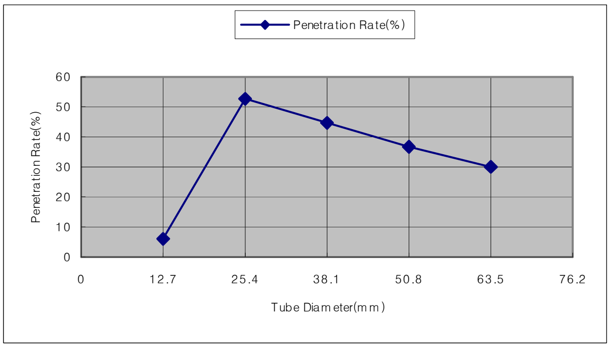
6.2.1 Temperature



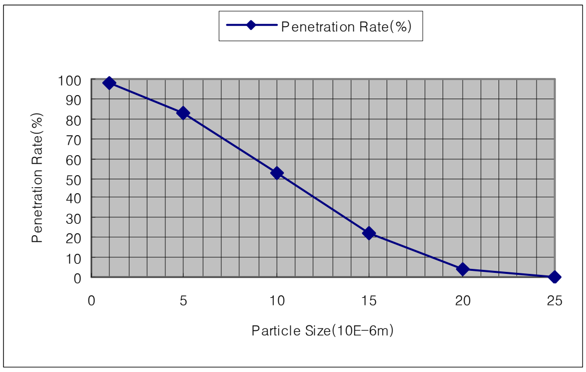
6.2.2 Particle Density



6.2.3 Tube Diameter



6.2.4 Particle Size



7. Conclusion

In this paper, four variables are changed and a simulation is performed . As a results, the more temperature increase, the more particle penetration rate increase. The more particles density increase, and particle size increase, the more penetration rate decrease. In tube diameter, 24.5mm tube has most excellent particle penetration rate.

REFERENCES

[1] NUREG/GR-0006, US NRC, 1993.
[2] DOPOSITION 2001.a Manual and Soft Ware
[3] Aerosol Technology, "Properties, Behavior, and Measurement of Airborne particles, William C.Hinds, 2nd, 1999
[4] ANSI/HPS N13.1-1999, "Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities, USA, 1999
[5] ANSI/HPS N13.1-1969, "Guide To Sampling Airborne radioactive materials in Nuclear Facilities,,1969