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A Simulation of Aerosol Flow in the Model of the Gas Transport System of NPP

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1. Introduction

Aerosols consist of two phase. The solid or liquid particles and gas are mix, and particles are suspended in the gas. This paper investigates the properties and behavior of the aerosol particles. Particle motion in gas is resisted by the gas, the gravity force, the surface roughness inside of pipe and flow path direction, etc. Aerosol also develops at nuclear Power Plant (NPP). NPP's aerosol is released to the atmosphere through the stack. Radioactive particles can be emitted through the stack. Sampling line was installed at the proper place at the stack. Sampling aerosol flow through Radioactivity Observation Equipment and return the stack. Sampling is performed by nozzle which is located inside Stack. ANSI/HPS N13.1-1969 describe many small nozzles in proportion to stack size and iso-kinetic conception. But single nozzle(probe) is recommend and more gets the sampling representative in ANSI/HPS N13.1-1999. But domestic all KSNP are designed and operated by ANSI/HPS N13.1-1969. The diameter of sampling nozzle is very small and multi nozzles according to ANSI/HPS N13.1-1969. Small diameter nozzle can be easily plugged, so sampling representation is not insured. If sampling nozzles are plugged, Radioactivity Observation Equipment is not detected the release of radioactive particles to atmosphere. Therefore the surround people of NPP can be exposed by discharging radioactive particles. In this paper, compare ANSI/HPS N13.1-1969. with ANSI/HPS N13.1-1999. rule. Also, particle behavior is simulated through the Deposition code. The variables of simulation are particle size and tube diameter.

2. The basic equation of the particle motion

Generally, external forces which affect the particle motion are viscous resistance, gravity, buoyancy, inertia force, electric force, Brown diffusion , acoustic pressure, etc. But the consideration of all above forces is very difficult and complex. So, in this paper, gravity force, inertia force, and Brown diffusion are considered

$$m_p \frac{dV}{dt} = F_g + F_i + F_b$$

Where m_p is particle mass. And V is particle velocity

2.1 F_i *is GravityForce*

$$F_g = m_p g$$

2.2 F_i *is Inertia Force*

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

C_c is Slip Correction Factor

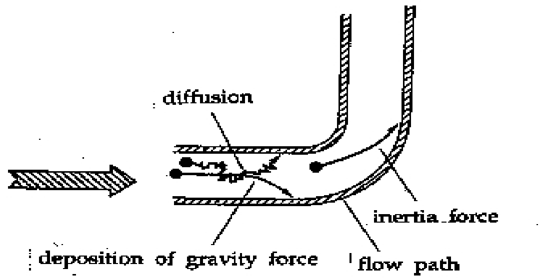
U is Fluid Velocity

V is Particle Velocity

2.3 F_i *is Brown Diffusion*

$$F_b = -\frac{3\pi\mu d}{C_c} V + m_p \alpha(t)$$

α(t) is diffusion motion and stokes random acceleration



3. Comparison ANSI/HPS N13.1-1969 vs and ANSI/HPS N13.1-1999

There are two important different aspects. One is iso-kinetic sampling has been replace by numerical criteria for the sampling performance of extraction nozzle and transport line. The other is the concept of acquiring a representative sample is not based on rules for sample location and multi-point extraction, but rather on the premise that at any location where the contaminant concentration and the fluid momentum can both be demonstrated to meet numerical criteria for acceptable mixing, a representative sample can be obtained by extraction from a single point in that profile.

items	ANSI/HPS-1969	ANSI/HPS-1999
Performance base	Iso-kinetic condition at nozzle in net	Performance scope and quantitative base
Nozzle no.	Multi	Single
Nozzle type	Circle, rectangle	Shrouded circle
Nozzle performance	Base not provide	TR[1]:0.8– 1.3, AR[2] :0.8-1.5
Particle transfer base	None	Particle penetration rate
Flow control	None	given
Particle distribution Characteristic	Not given	Given

*. TR[1] : Transmission Ratio, AR[2] : Aspiration Ratio

4. Aerosol Penetration

Penetration, P_j, of particle through the jth component of a transport system is defined as;

$$P_i = \frac{C_{e,i}}{C_{i,i}}$$

where $C_{e,i}$ is particle concentration at the exit plane of a component and $C_{i,i}$ is particle concentration at the enlet plane of a component.

If there are n components in a sampling system, it is assumed the overall penetration PT, can be calculated as through each component were independent, which gives

$$P_T = P_1 \times p_2 \times p_3 \times \dots \times P_N = \prod_{j=1}^{n} P_j$$

4.1 Particle deposition in Inlet Nozzle(probe)

Based on the experimental work of Fan et al.(1992), a correlation was developed for wall losses (Wl) in inlet probes. The correlation of wall losses(%) is given by:

$$Wl = a\,\{1 + \frac{L}{Fr}\}^b R_s^c Re^d$$

where a=176.9, b=-9.190, c=0.559, d=-0.216 and

Rs =2Stk/Pl$^{0.5}$

2 pStk : drag force effect

Pl : lift force

4.2 Penetration through Elbows

Their equation for penetration through 90o bends

$P = 10^{-0.963Stk}$

4.3 Penetration through straight tubes

$$P = \frac{C_x}{C_o} = exp\,\{\frac{-\pi d_t V_e x}{Q}\}$$

where Q : Volumetric flow rate

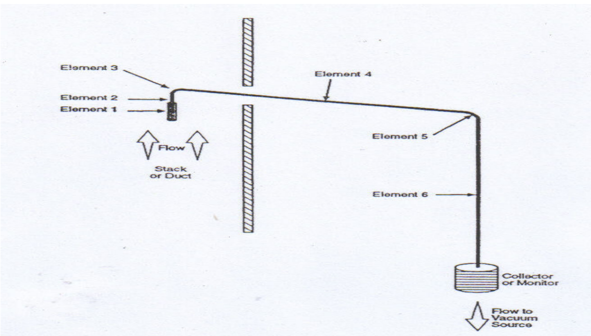
C_x : aerosol concentration at a distance x from the inlet of a tube

D_t : tube diameter

V_e : effective velocity for particle deposition

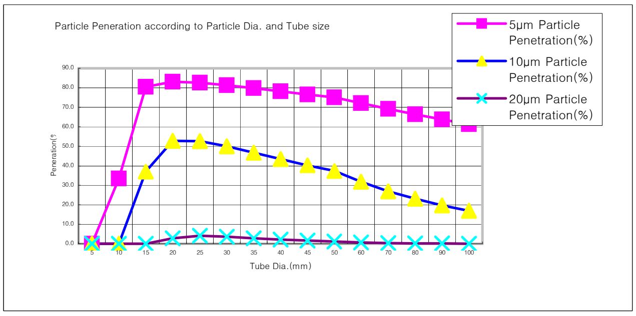
5. Simulation

The function of Sampling Transport System is very important factor to get the representative sampling. Simulation tool in this paper used the Deposition code.



items	Variable Values	Remarks
Ambient Temp.(^{o}C)	25	Fixed
Ambient Pr.(mmHg)	76	Fixed
Particle Density (g/cm^3)	1	Fixed
Flow Rate(cm^3/sec)	943cm^3/sec	Fixed
Tube Dia.(mm)	variable	Changed
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)	Variable	Changed
Particle Disperse	Mono-disperse	Fixed

Simulation results are as follows;



6. Conclusion

In this paper, two variables(tube size, particle size) are changed and the simulation is performed . As a results, the more small particle size(AD, Aerodynamic Diameter), the more particle penetration rate is increased. And 20μm ~25μm particle size have the most penetration rate. Big size particles were more effected by gravity and inertia force. But other factors(humidity, Pressure, Laminar or Turbulent Flow, Nozzle(probe) Type, inner surface condition of tube, and stack flow condition, Temperature etc.) are also the elements of verification and study.

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