Comparison of Isokinetic Stack Sampler Models Under a Variety of Sampling Conditions

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May 2009

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Northwest Richland, Inc.

The Big Picture

Washington State "Radiation Protection" Code Requires Radionuclide Potential Emissions Meet Applicable Technology Standards.

Includes the ANSI N13.1 "Sampling and Monitoring Releases of Airborne Radioactive Substances from Stacks…".

ANSI N13.1 Requires Modeling of Stack Sampling Performance.

-- Which is the subject of this paper --

Models Stack Sampling Variations

1. Aerosol Particle Size

2. Turbulent Flow

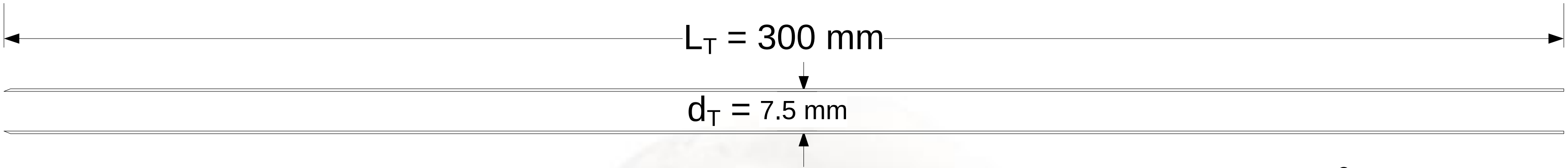
3. Variance Between a Stack and a Sampler’s Flow Velocity (i.e., Anisokinetic Conditions)

Compares Two Isokinetic Sampler Models

1. DEPO Freeware by McFarland et al., 2001a.

2. Handbook “Aerosol Sampling; Science, Standards, Instrumentation, and Applications”, by Vincent et al., 2007.

Isokinetic Sampler Design



Stack Velocity (V_T)= 10 m/s

Particle Diameter (d_P)= 10E-6 m

Air Viscosity (u_a)= 0.018 g/m-s

Air Density (p_a)= 1.2E3 g/m^3

Particle Density (p_p)= 1.0E6 g/m^3

Gravity (g)= 9.8 m/s^2

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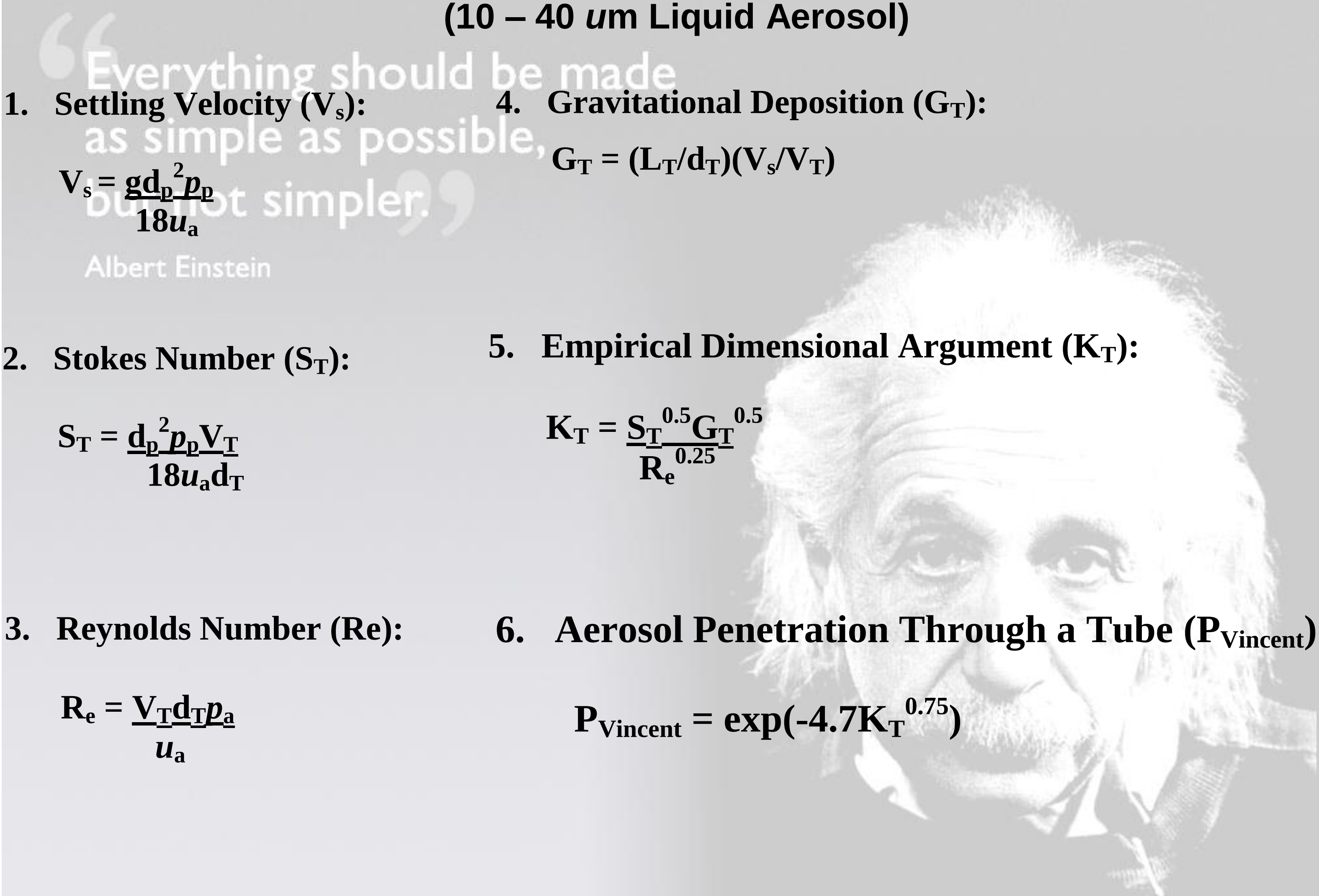
Vincent Isokinetic Equations

(10 – 40 *u*m Liquid Aerosol)



1. **Settling Velocity (V_s):**

$$V_s = \frac{g d_p^2 p_p}{18 u_a}$$

2. **Stokes Number (S_T):**

$$S_T = \frac{d_p^2 p_p V_T}{18 u_a d_T}$$

3. **Reynolds Number (Re):**

$$R_e = \frac{V_T d_T p_a}{u_a}$$

4. **Gravitational Deposition (G_T):**

$$G_T = (L_T/d_T)(V_s/V_T)$$

5. **Empirical Dimensional Argument (K_T):**

$$K_T = \frac{S_T^{0.5} G_T^{0.5}}{R_e^{0.25}}$$

6. **Aerosol Penetration Through a Tube ($P_{Vincent}$):**

$$P_{Vincent} = \exp(-4.7 K_T^{0.75})$$

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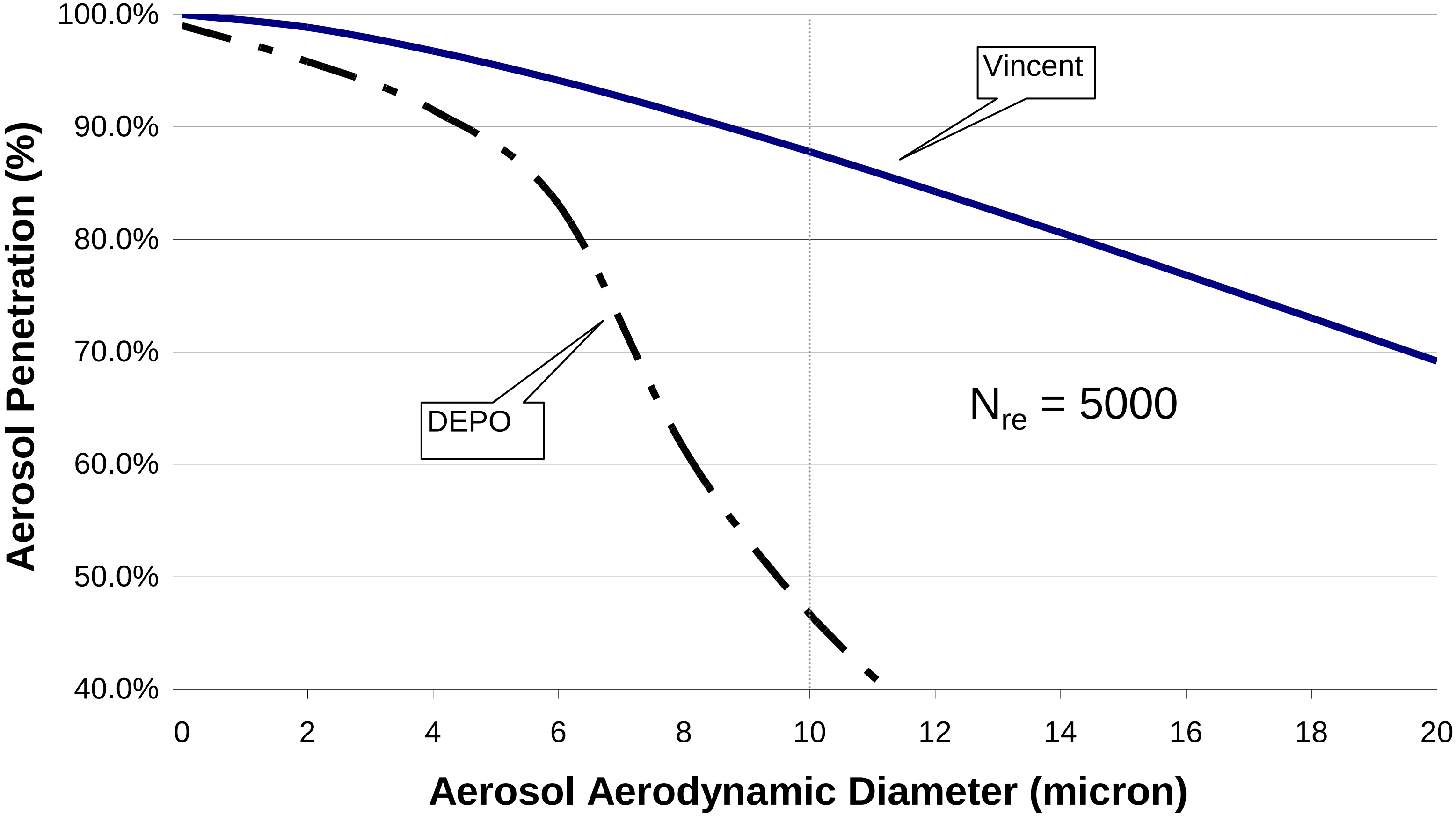
DEPO Model Predicts Substantially Less Aerosol Penetration Compared to Vincent



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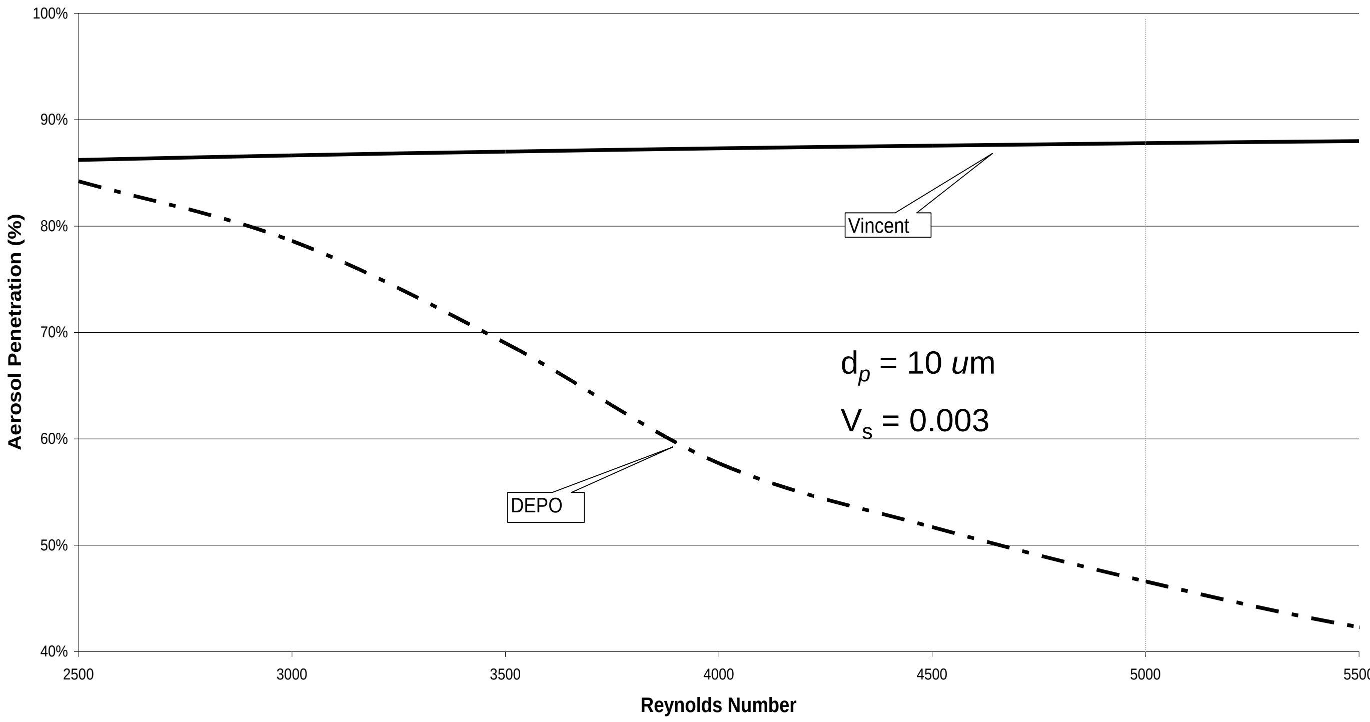
DEPO Predicts Substantial Aerosol Loss During Turbulent Flow



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Vincent Anisokinetic Equations

(25-70 *u*m Silica Aerosol)

1. Stack Velocity/Sampler velocity (R):

   $R = V/V_s$

2. Ratio Coefficient (G):

   $G = 2 + 0.62/R – 09R^{0.1}$

3. Impaction Efficiency (*B*):

   $B = 1-(1/(1+S_T G))$

4. Anisotropic Aspiration through Nozzle ($A_{aspiration}$):

   $A_{aspiration} = B(R-1)+1$

5. Aerosol Penetration Through a Nozzle & Tube ($P'_{Vincent}$):

   $P'_{Vincent} = (A_{aspiration})(P_{Vincent})$

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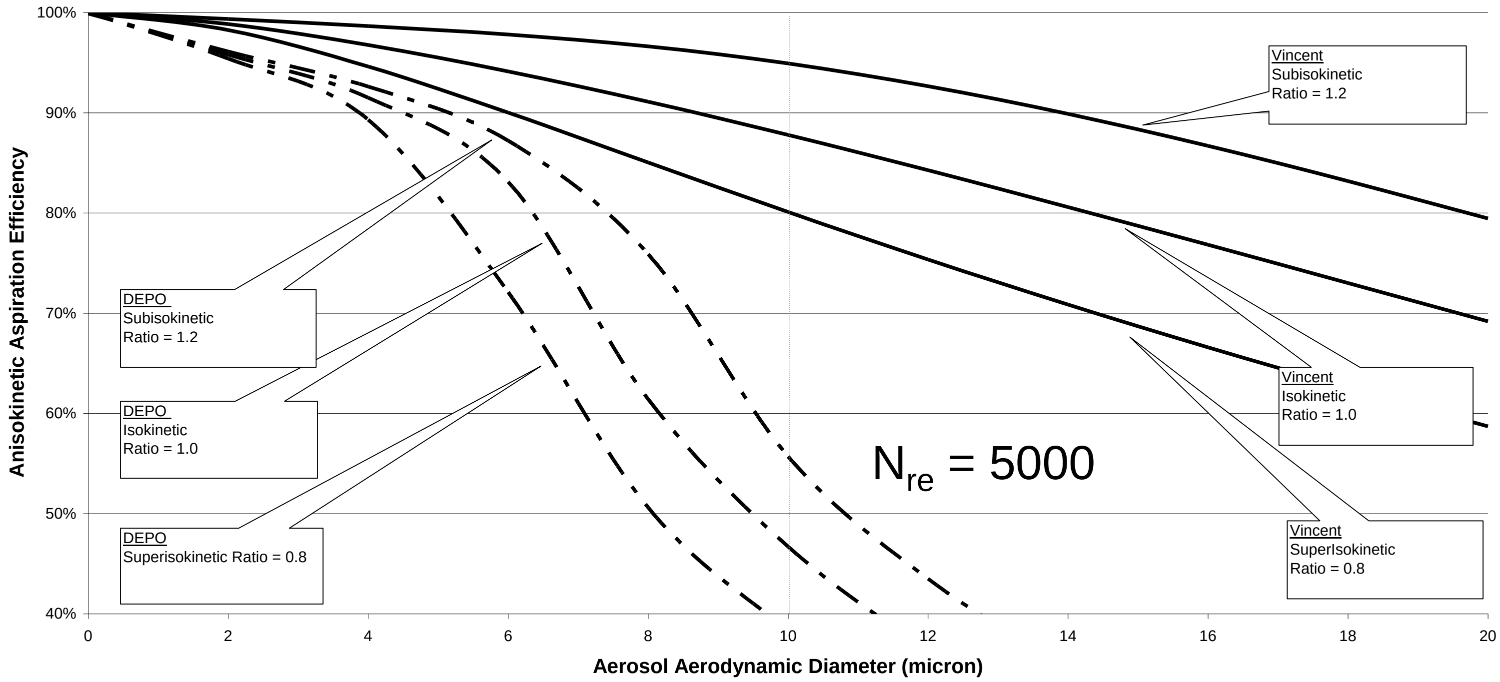
Models Predict Similar Affects From Anisokinetic Sample Velocity Variations



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Both Models Have Limitations

1. Liquid Particles vs. Solid Particles

2. Based on Quasi-Steady State

3. Large Model Extrapolations

4. Compounding Conservatism

Practical Considerations

1. Upstream Rust
   - Settle In Sample Tube

2. Filter Paper Limited Flowrate
   - Size Limited to 47 mm

Recommend ANSI N13.1 Revised To *"Keep It Simple"*

For Example Provide Probe Design Standards:

1. <30 Degree Nozzle Angle.
2. >1/4 Inch Nozzle diameter.
3. Nozzle Reynolds Number <10,000.
4. Transport Tube Reynolds Number >2000.
5. <20 Feet Transport Length to Collection Point.
6. >5R Transport Tube Bends.
7. Electrically Grounded.
8. Conducting Materials of Construction.
9. Periodic Inspection Criteria.