Novel Methods for Reducing UHP Gas Usage in Fabs: Back Diffusion Minimization

Customized Project; Sponsored by Intel

PI:

- **Farhang Shadman, Chemical and Environmental Engineering, UA**

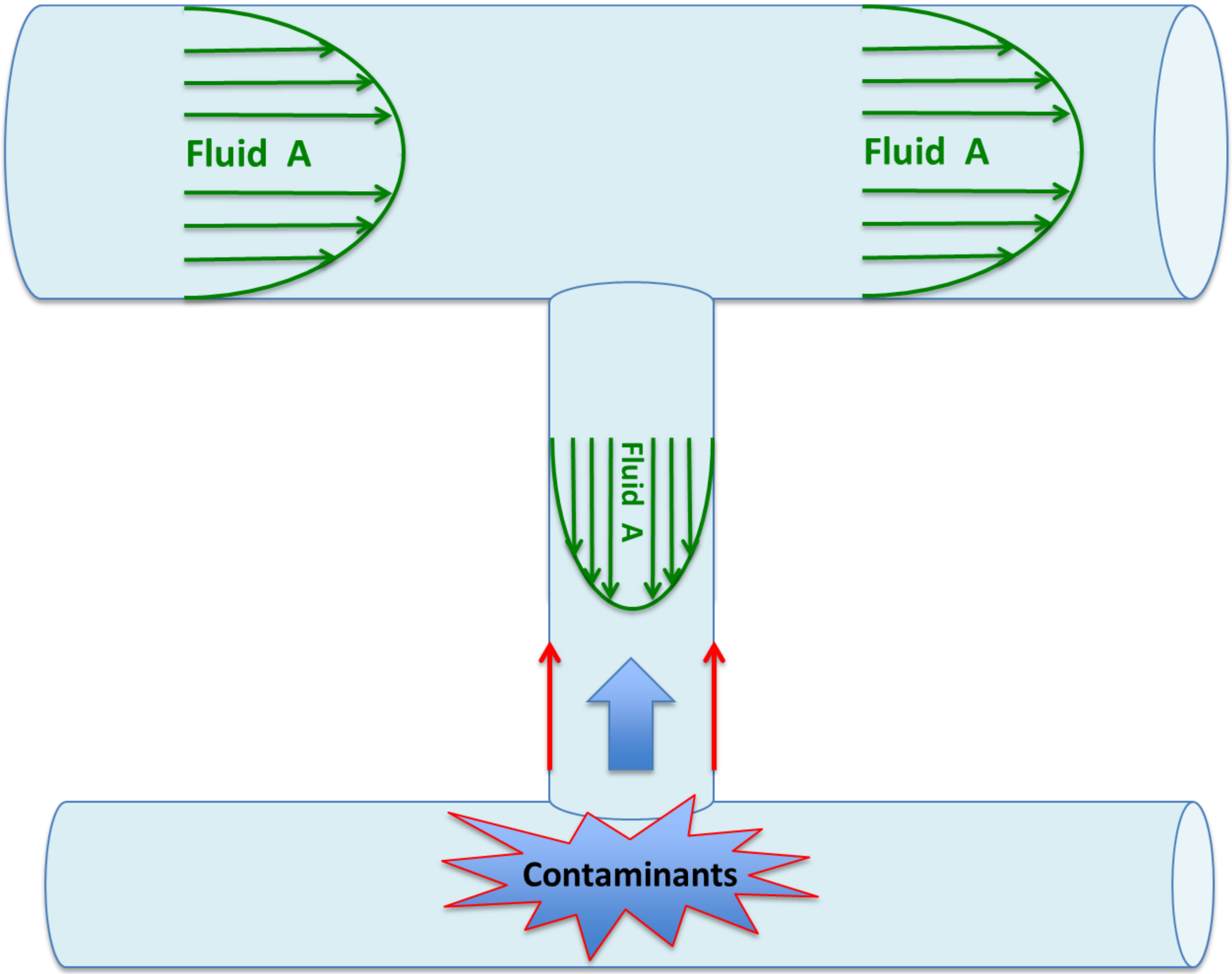
Co-PI:

- **Carl Geisert, Sr. Principal Engineer, Intel**

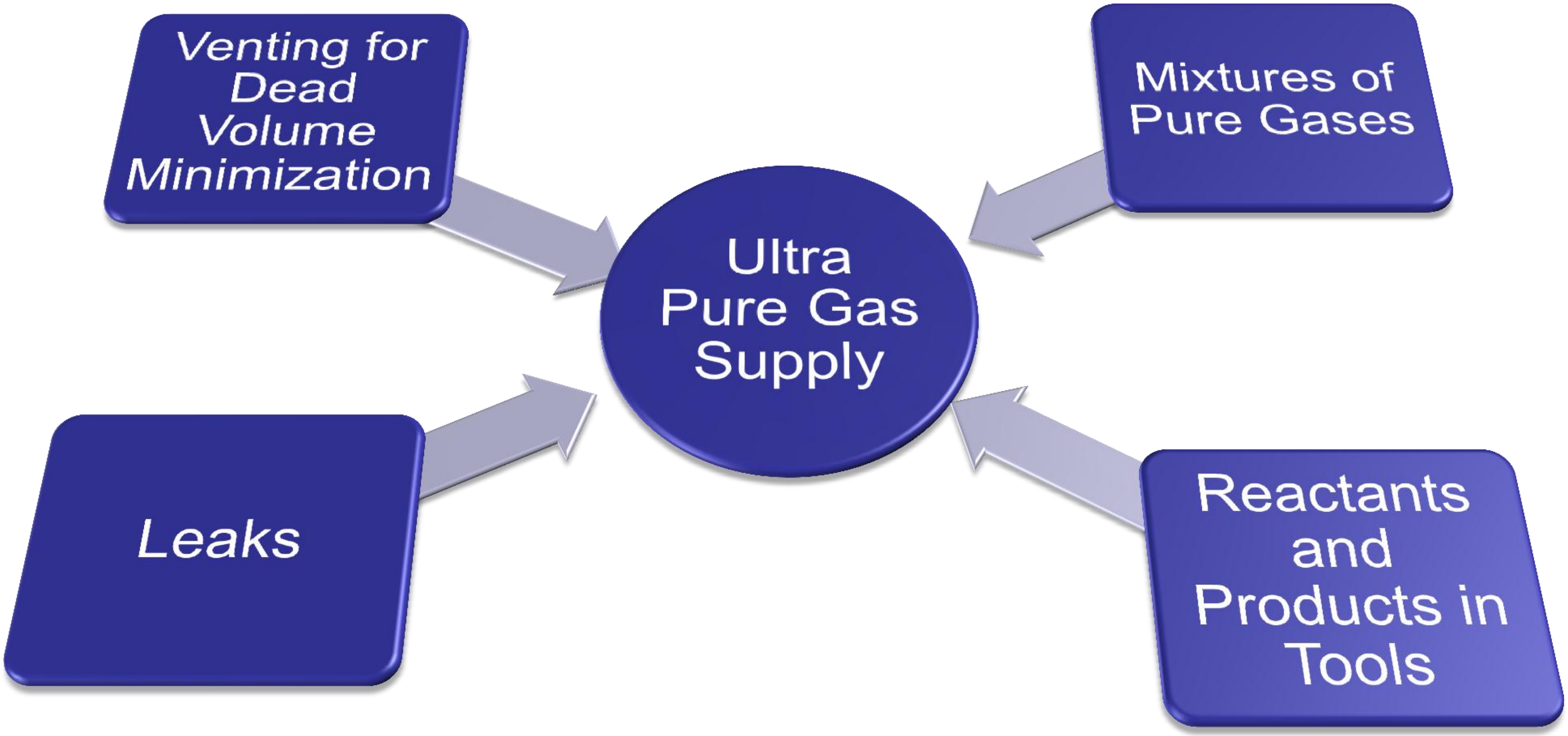
Graduate Student:

- **Roy Dittler: Ph.D. student, Chemical and Environmental Engineering, UA**

Back Diffusion Sources and Mechanisms



Back Diffusion Sources and Mechanisms



Objectives

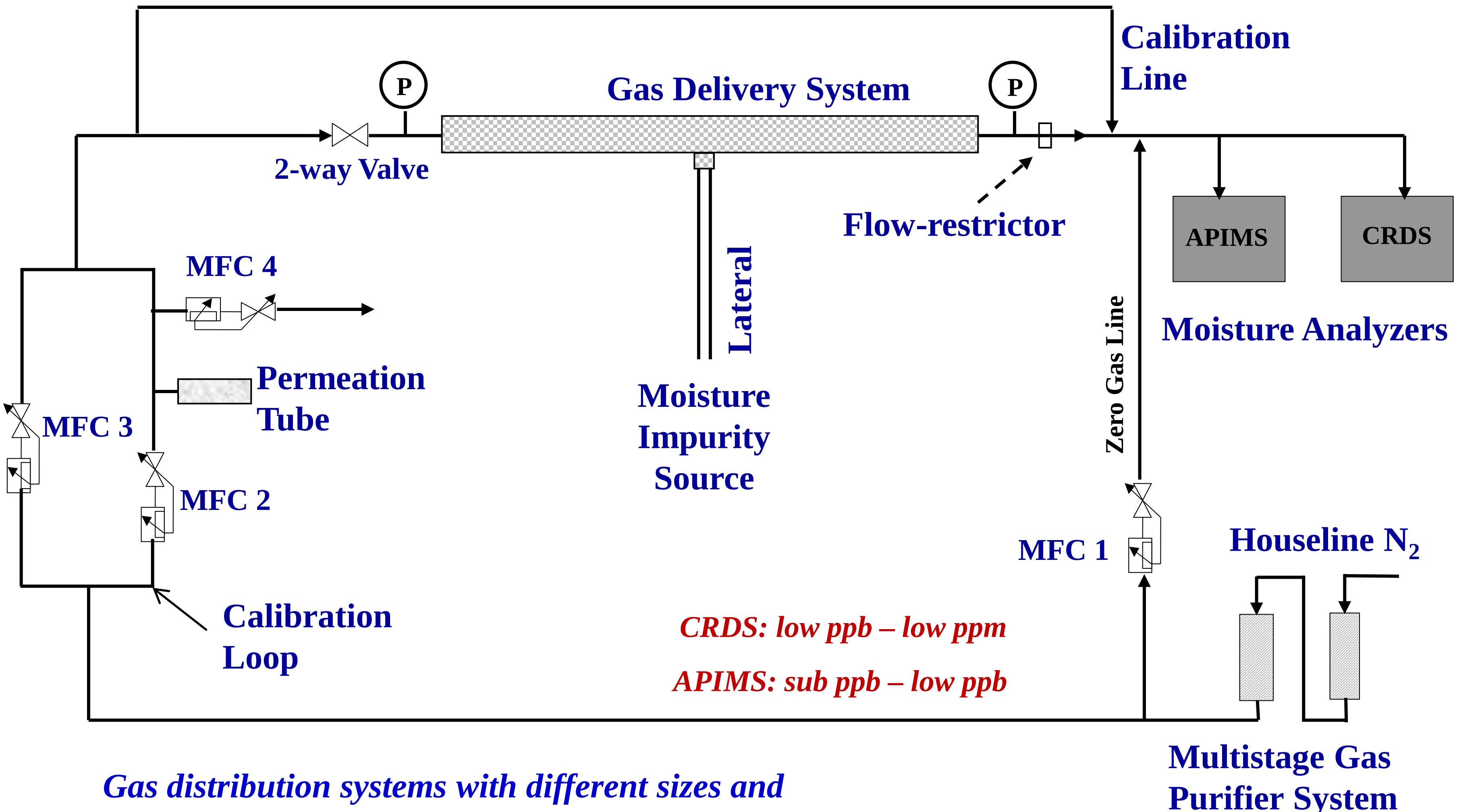
- **Developing operational parameters that will minimize back diffusion of impurities into fluidic distribution systems.**
- **Developing and validating a process simulator that can help industry design and operate systems while minimizing back diffusion, gas usage, and system dead volumes.**
- **Develop a better understanding of back diffusion since little is known or has been published on the subject.**

Motivation and ESH Impact

- **Contamination of gas distribution systems during normal operation results in major wasting of materials, energy, and valuable tool operation time.**

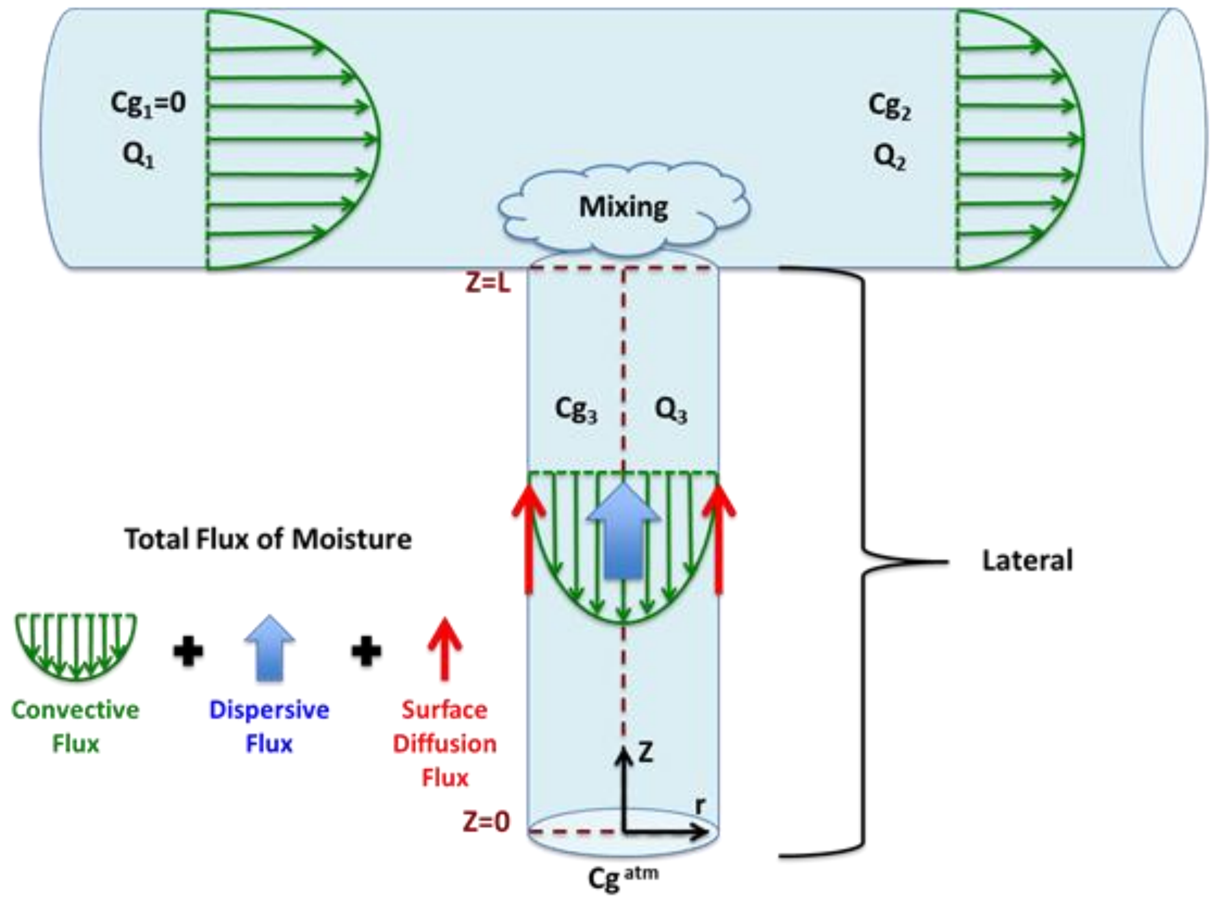
Experimental Testbed

Laterals Added to the Main Line



Gas distribution systems with different sizes and geometries were fabricated and provided by Intel

Back Diffusion Process Simulator



Convective Flux

$$J_c = -U_3 C_g$$

Gas Phase Dispersive Flux

$$J = -D \frac{dC_g}{dz}$$

Surface Diffusive Flux

$$J_s = -D_s \frac{dC_s}{dz} - D_s \frac{k_a}{k_d} \frac{dC_g}{dz}$$

Total Dispersive Mass Flow Rate

$$\pi r^2 J_e = \pi r^2 J + 2\pi r J_s$$

Total Effective Dispersive Flux

$$J_e = -D_e \frac{dC_g}{dz}$$

Effective Dispersion Coefficient

$$D_e = D + \frac{2}{r} D_s K_e$$

Back Diffusion Process Simulator

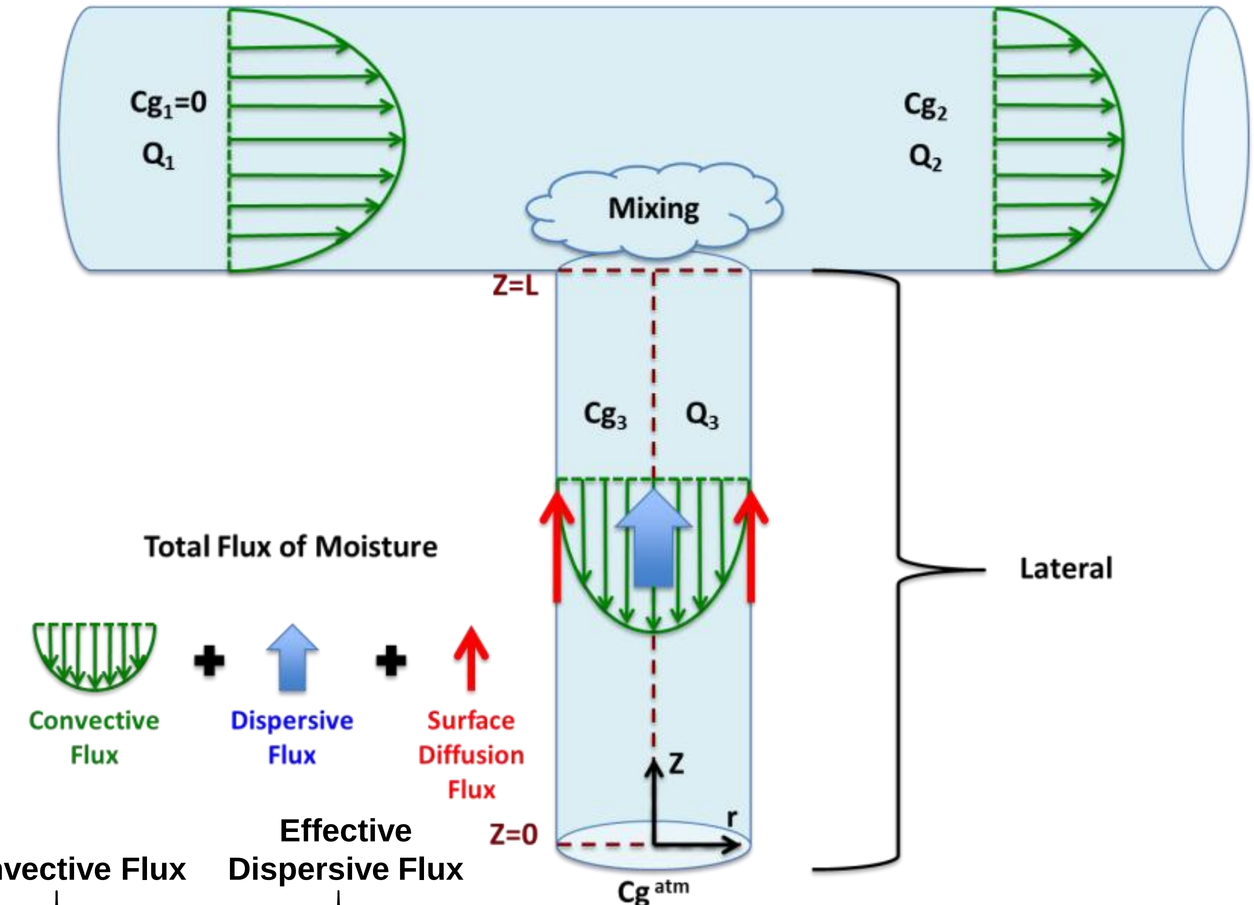
Governing Equation

Convection — Effective Dispersion

$$U_3 \frac{dC_g}{dz} + D_e \frac{d^2 C_g}{dz^2} = 0$$

Boundary Condition 1

$$z = 0, \qquad C_g = C_g^{atm}$$



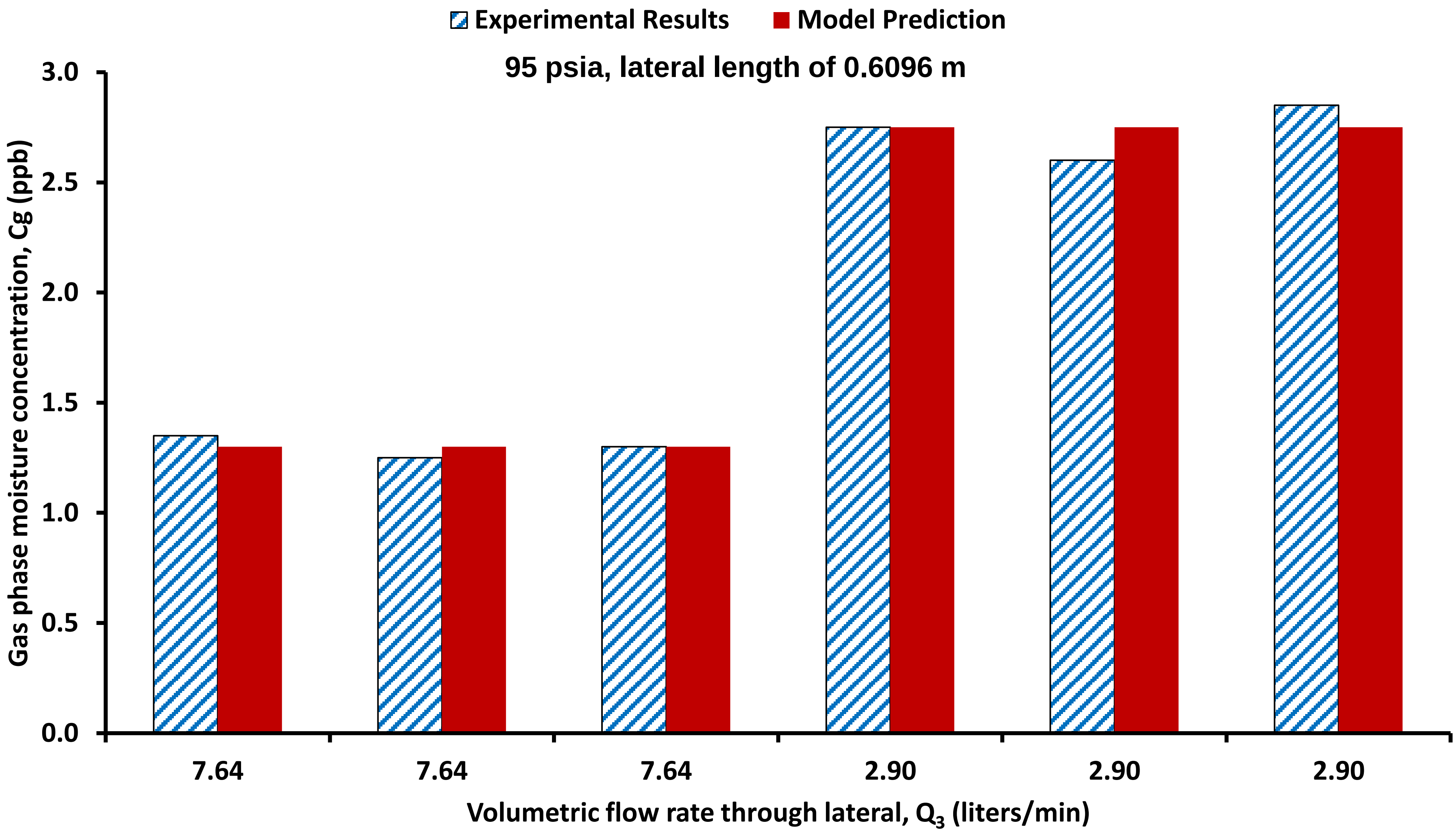
Boundary Condition 2

Convective Flux — Effective Dispersive Flux

$$z = L, \qquad C_g\Big|_{z=L} = \left(-U_3\, C_g\Big|_{z=L} - D_e \frac{dC_g}{dz}\Big|_{z=L} \right) \frac{A_{lateral}}{Q_2}$$

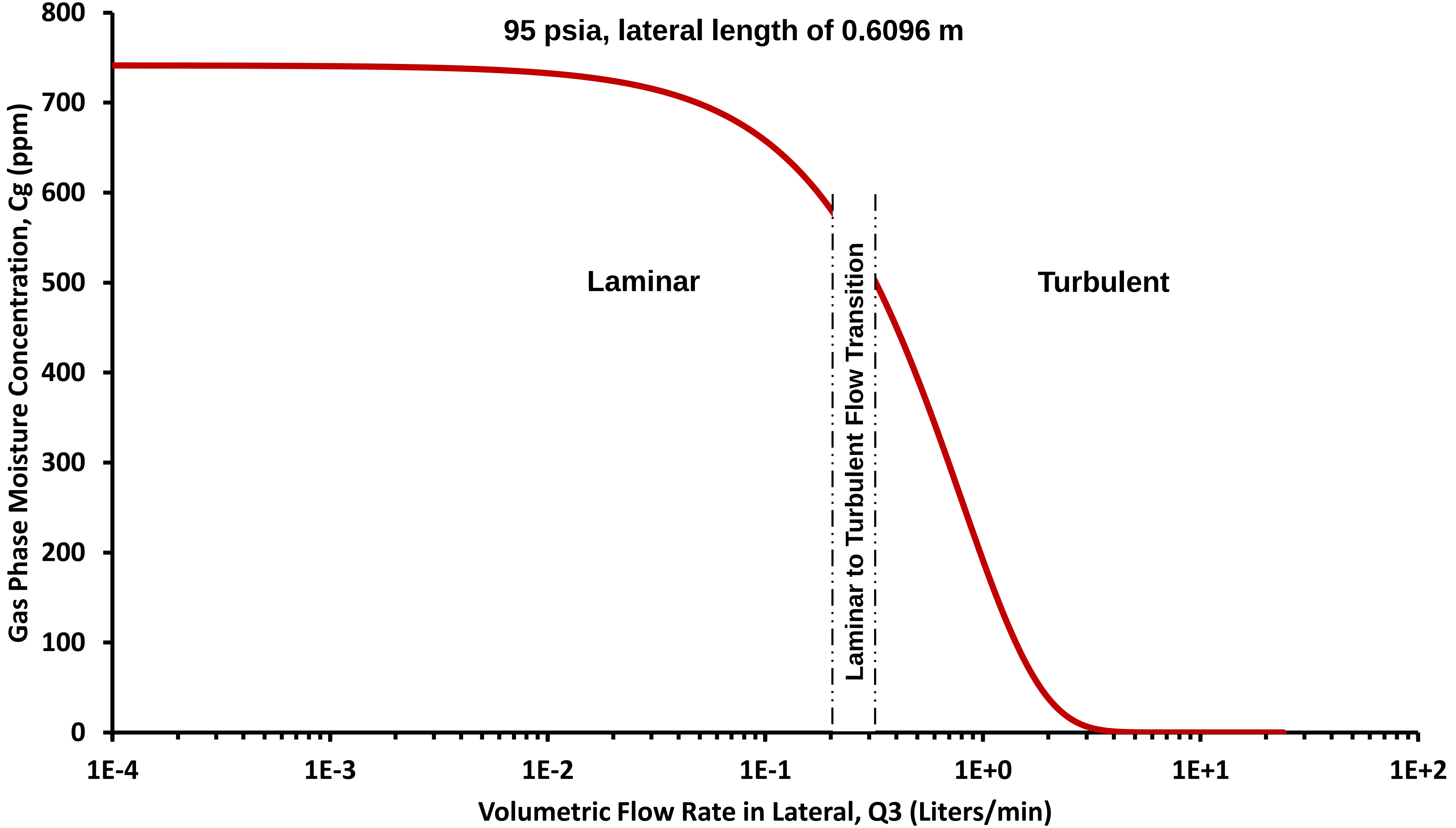
Process Simulator Verification

Simulator Prediction



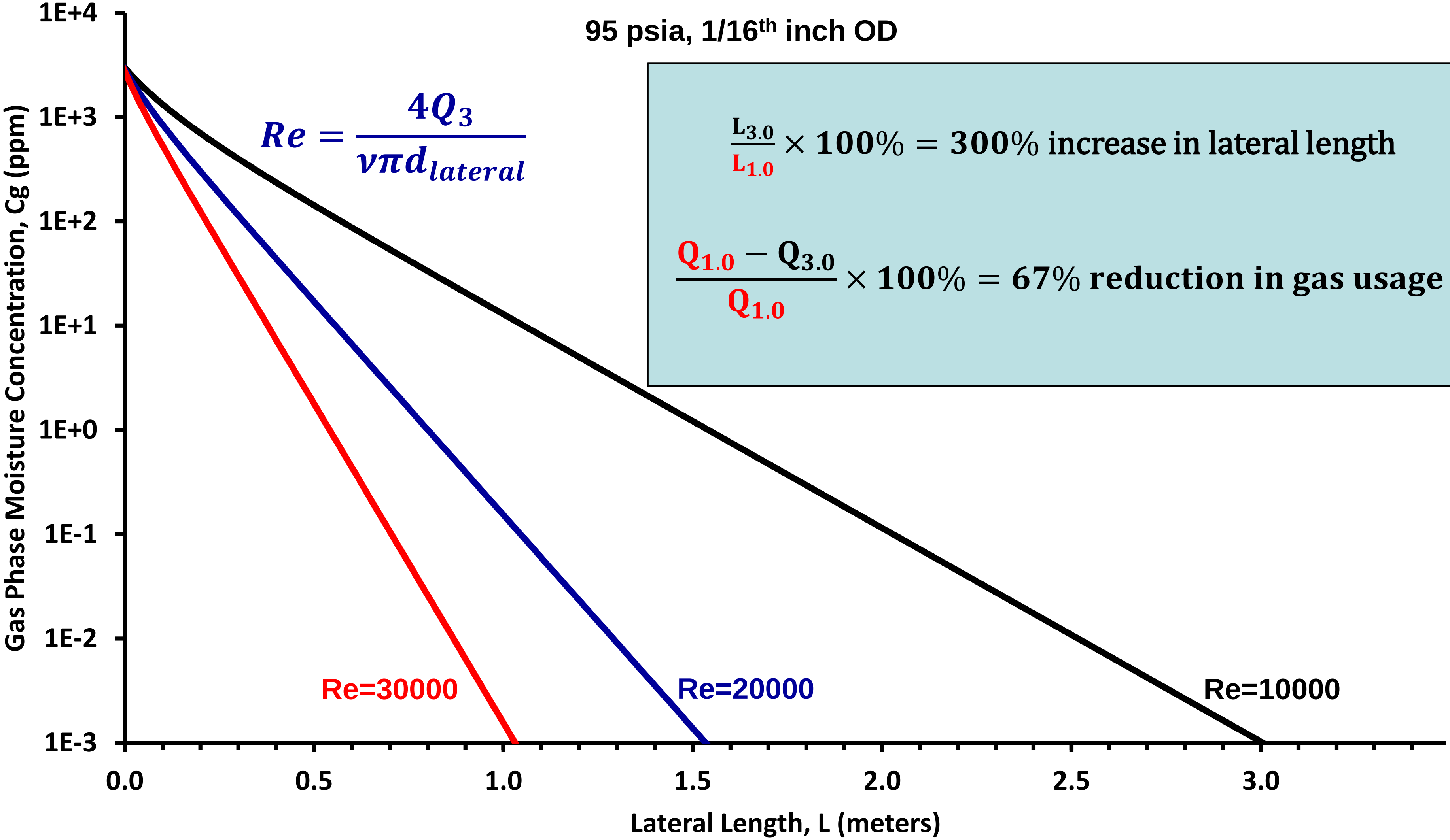
Parametric Studies

Effect of Flow Rate on Gas Phase Moisture



Parametric Studies

Effect of Lateral Length on Gas Phase Moisture



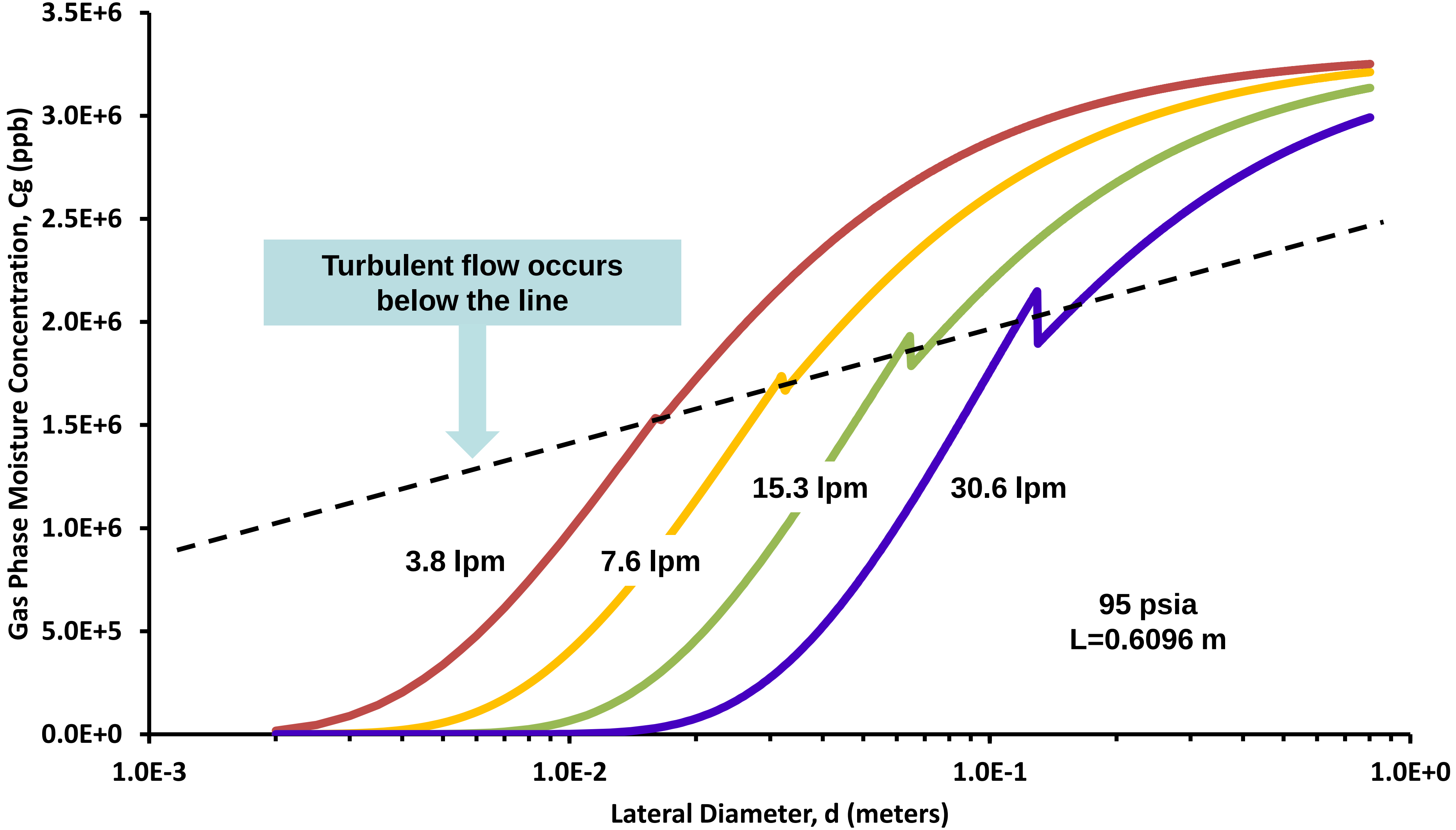
$$Re = \frac{4Q_3}{\nu \pi d_{lateral}}$$

$$\frac{L_{3.0}}{L_{1.0}} \times 100\% = 300\% \text{ increase in lateral length}$$

$$\frac{Q_{1.0} - Q_{3.0}}{Q_{1.0}} \times 100\% = 67\% \text{ reduction in gas usage}$$

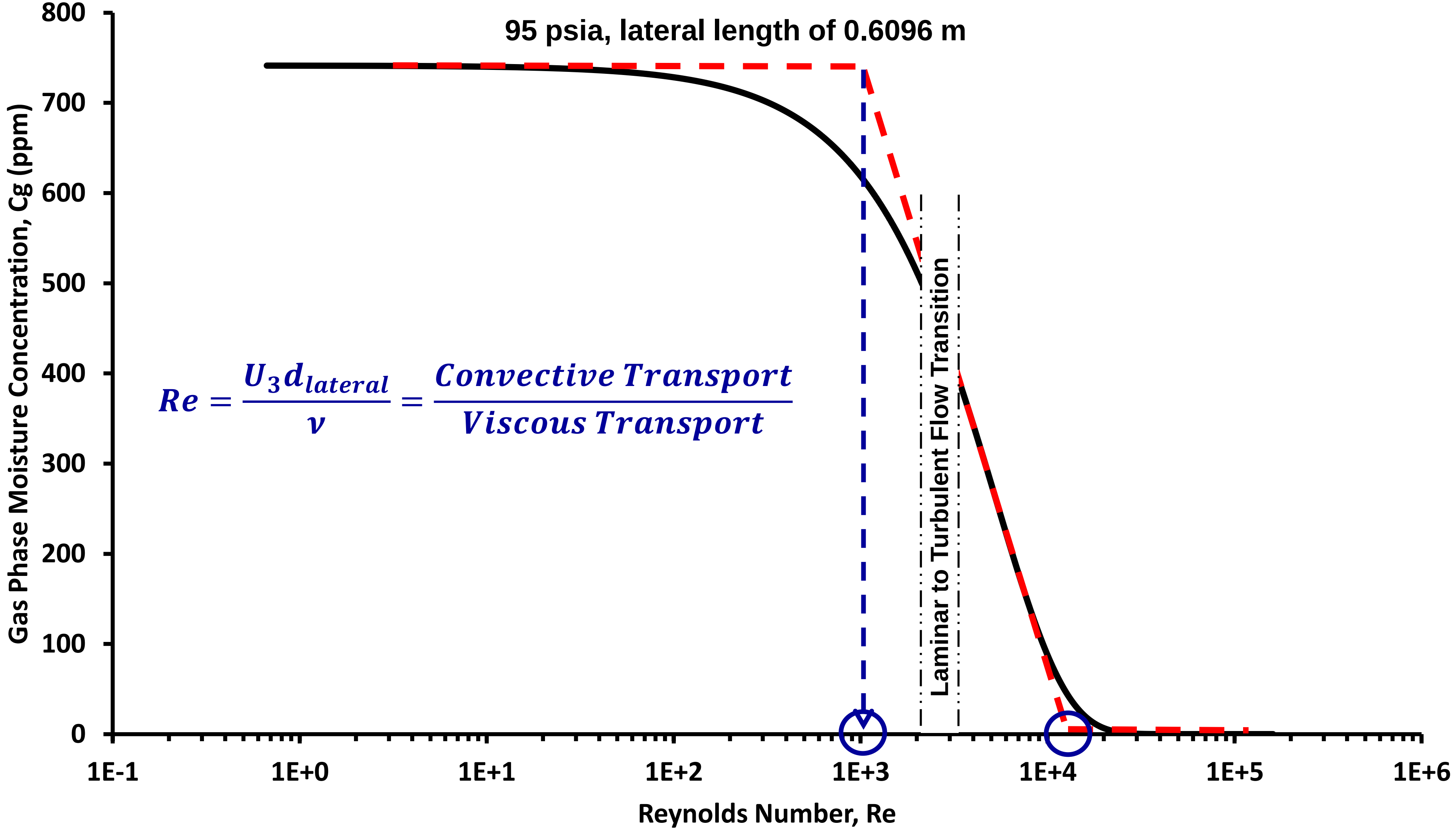
Parametric Studies

Effect of Lateral Diameter on Gas Phase Moisture



Parametric Studies

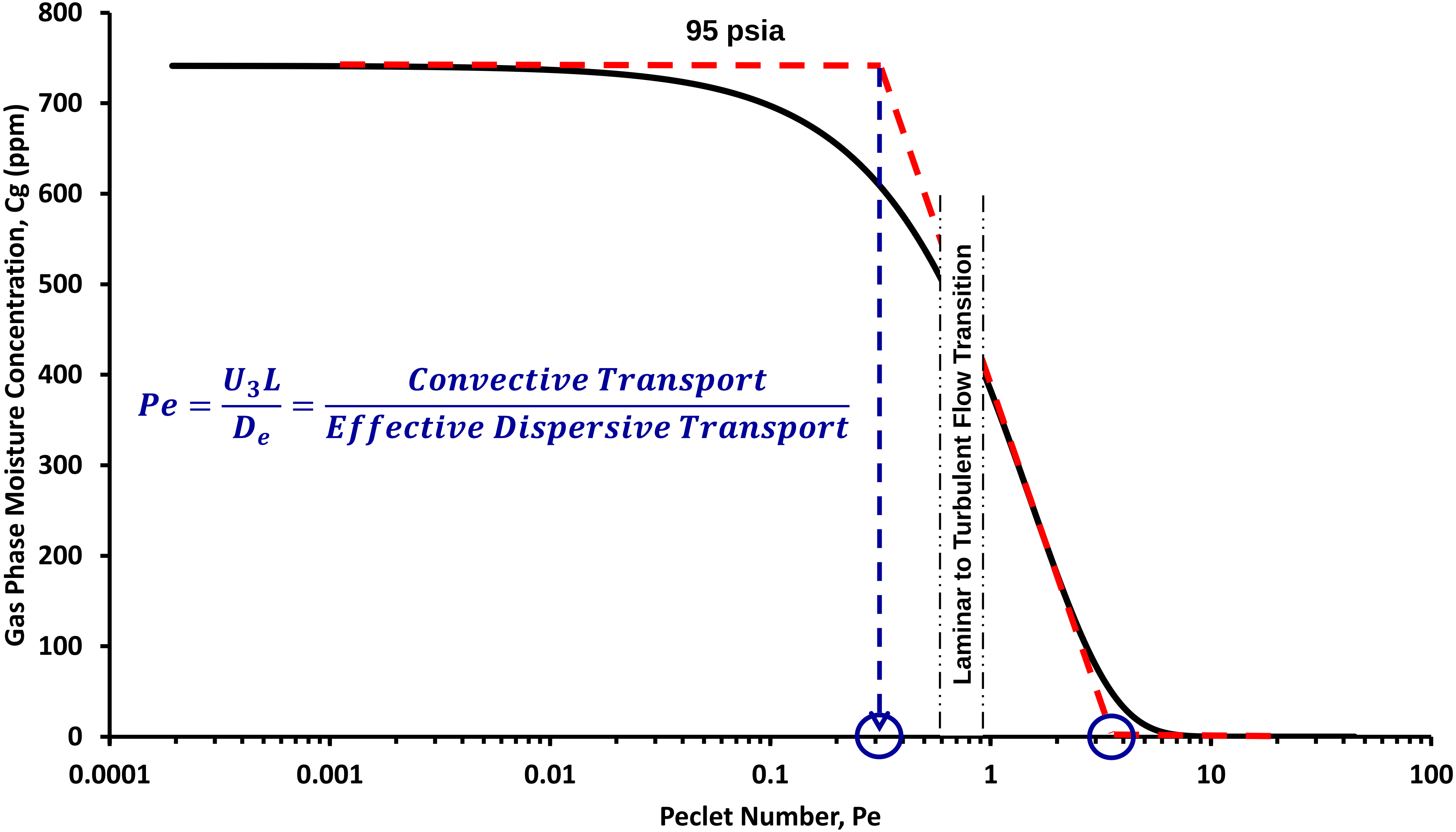
Effect of Reynolds Number on Gas Phase Moisture



$$Re = \frac{U_3 d_{lateral}}{\nu} = \frac{Convective\ Transport}{Viscous\ Transport}$$

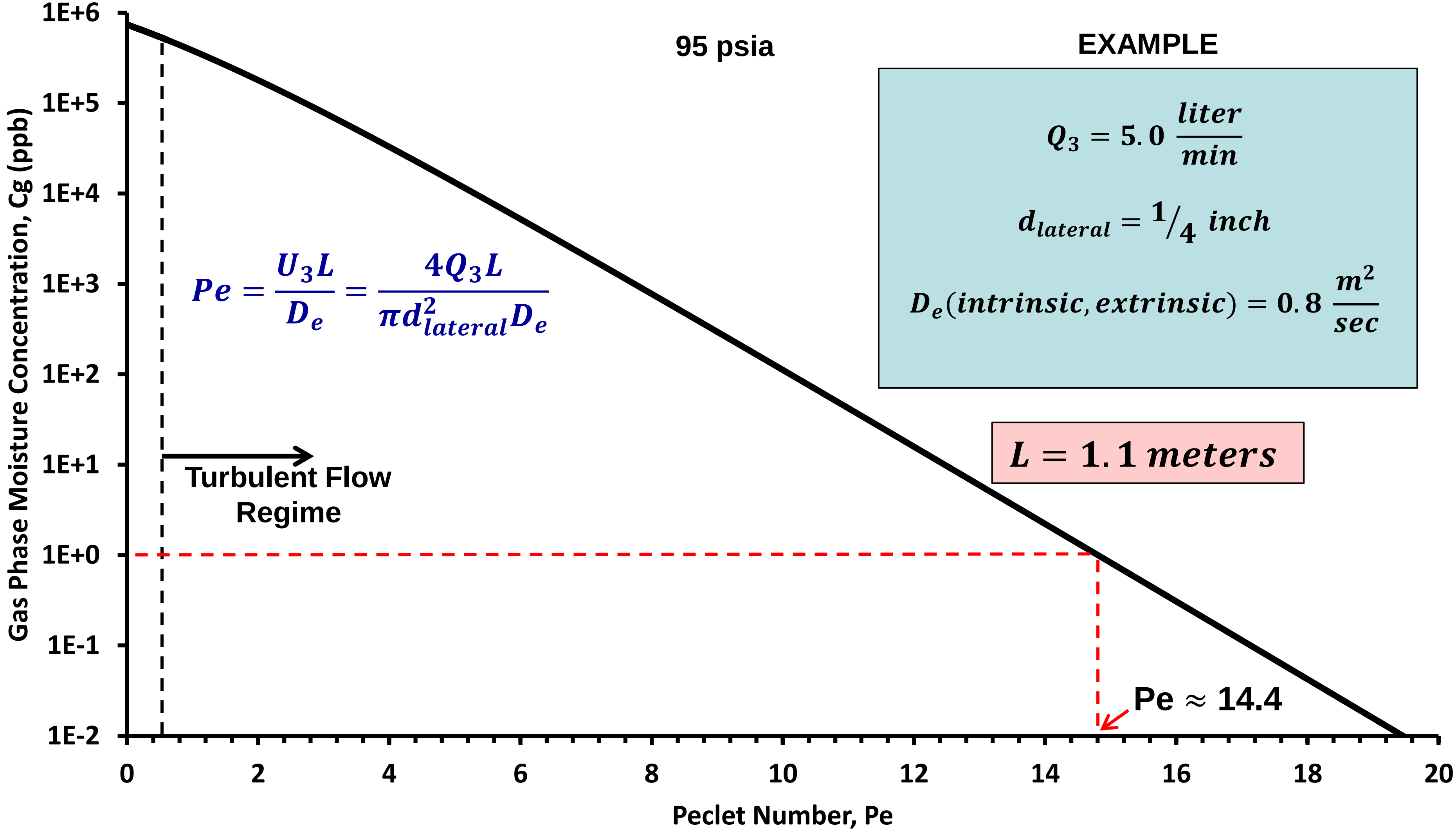
Parametric Studies

Effect of Peclet Number on Gas Phase Moisture



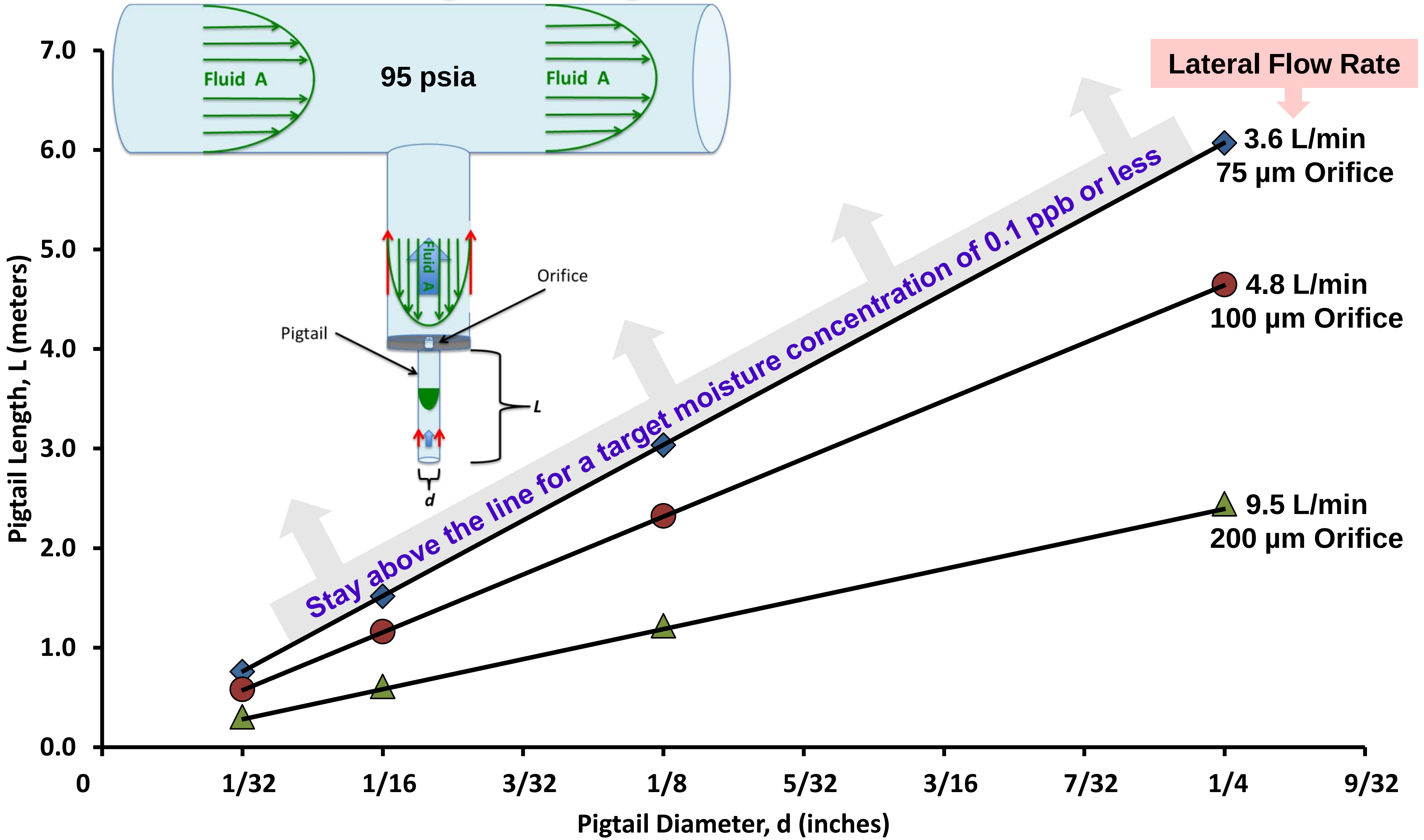
Parametric Studies

Effect of Peclet Number on Gas Phase Moisture



Parametric Studies

Pigtail Length and Diameters



Highlights

- The experimental approach allowed for the observation of back diffusion in an adjustable and controllable manner.
- The process model accurately predicted experimental results and was invaluable in performing parametric studies.
- The moisture contamination due to back diffusion was a strong function of lateral diameter, length, and gas flow rate through the lateral.
- Characteristic groups were identified that allowed us present generalized correlations that would help in the design and operation of UHP fluidic systems being exposed to a source of contamination
- This methodology was expanded to include an orifice and pigtail in series and was effective in determining a design that will safeguard against the back diffusion of impurities into both bulk and process gases.

Industrial Interactions and Future Plans

- Continue our work with Intel on novel impurity control strategies to reduce gas usage
- Making the process simulator available to industry
- Extend the present study to other fluids, contaminants, and components

Acknowledgements

- Carl Geisert, Intel
- Tiger Optics support team
- Junpin Yao, Matheson Tri-Gas Inc.