# Novel Methods for Reducing UHP Gas Usage in Fabs

*Customized Project; Sponsored by Intel*

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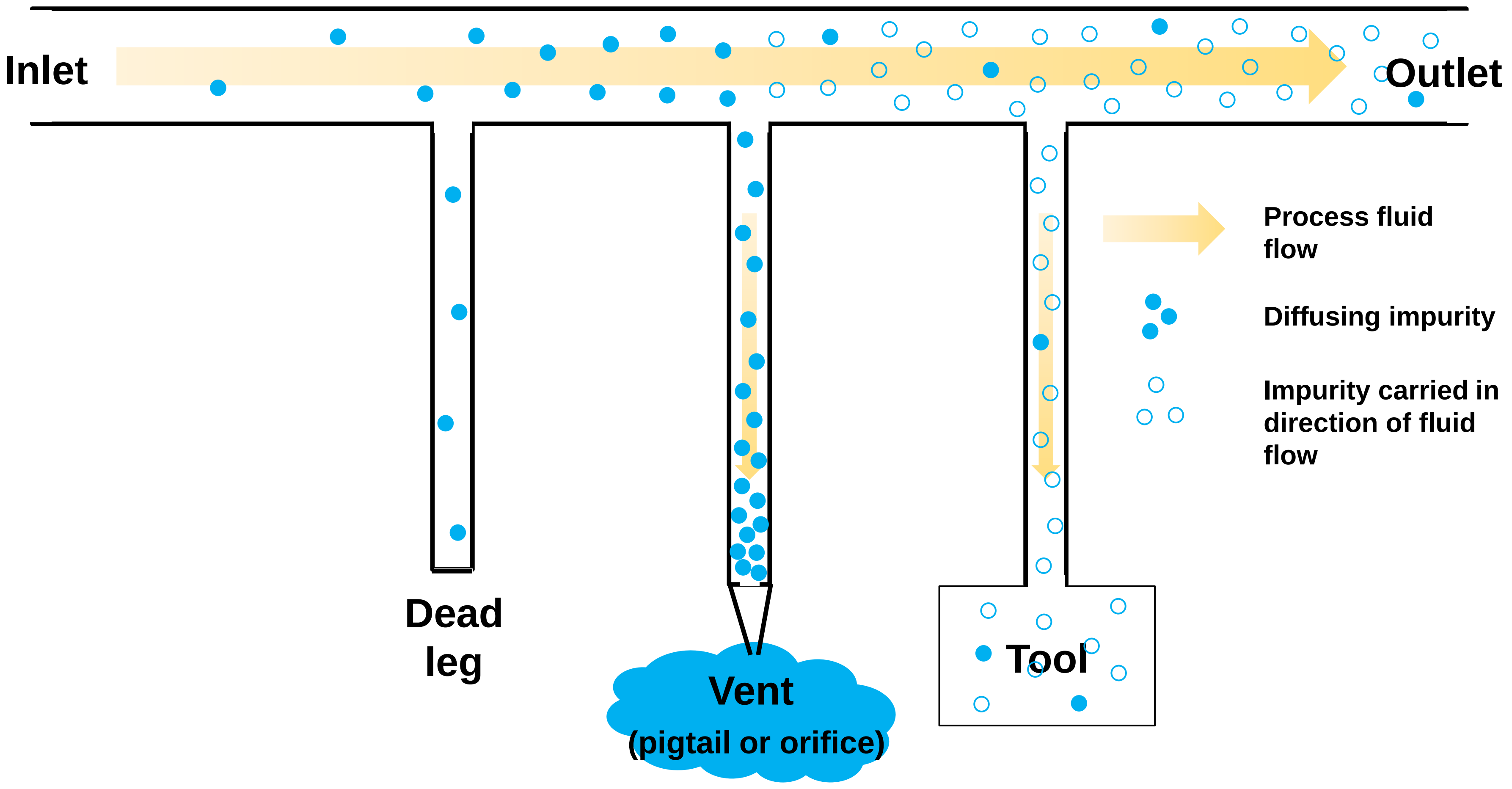
# Objectives

- **Develop techniques for reducing contamination and lowering UHP gas usage in fabs:**
  - **Subtask 1: Analysis of "*back diffusion*" as a major source of contamination**
  - **Subtask 2: Novel purge methods to remove contaminants during steady operation, start-ups, or recovery from system upsets.**

# Motivation and ESH Impact

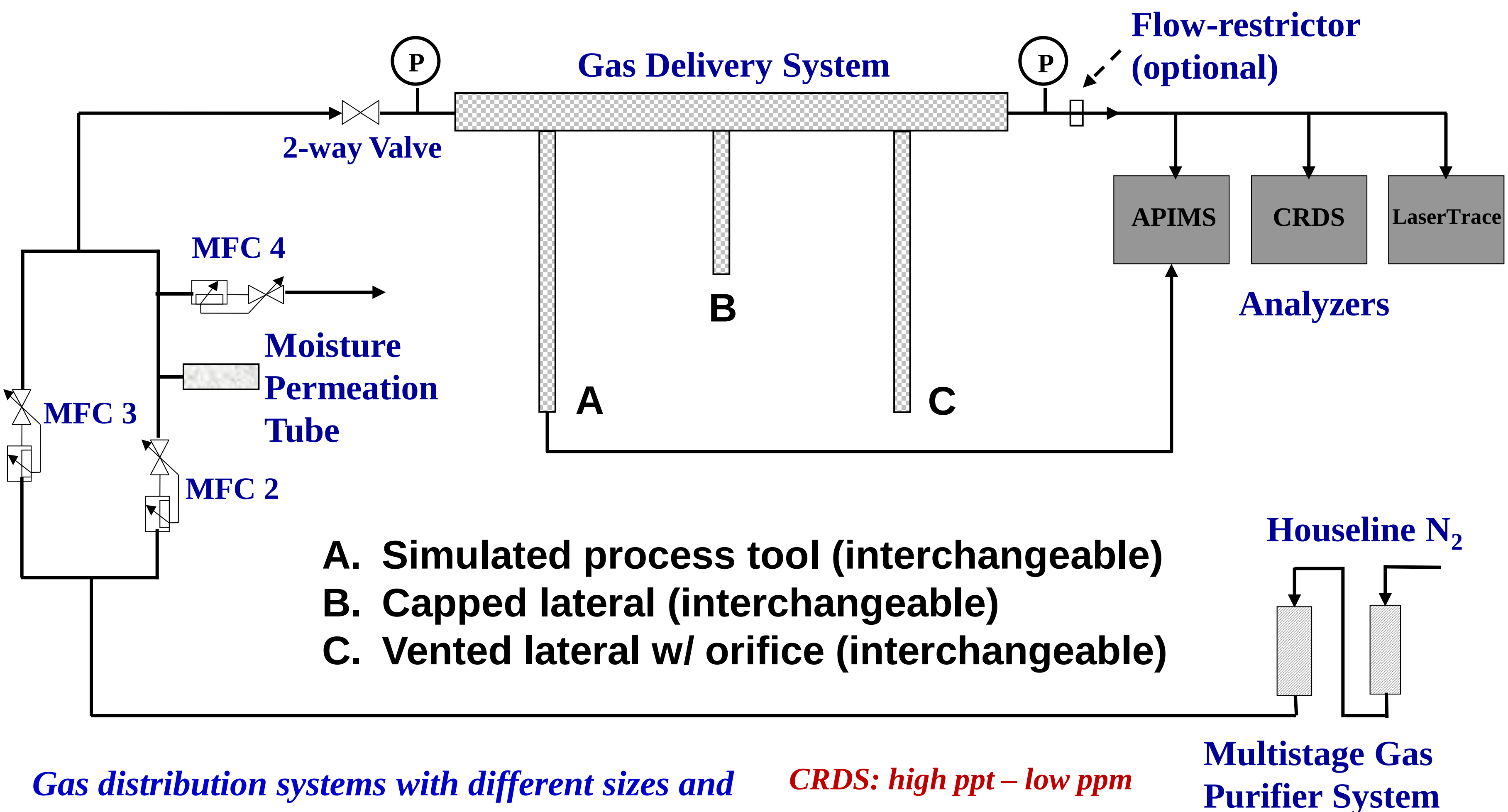
- **Contamination of gas distribution systems during operation or at start-up results in major wasting of materials, energy, and valuable tool operation time.**

# Subtask 1: Back Diffusion



# Experimental Testbed

## Laterals Added to the Main Line




A. Simulated process tool (interchangeable)
B. Capped lateral (interchangeable)
C. Vented lateral w/ orifice (interchangeable)

*CRDS: high ppt – low ppm*

*APIMS: low ppt – low ppb*

*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**

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

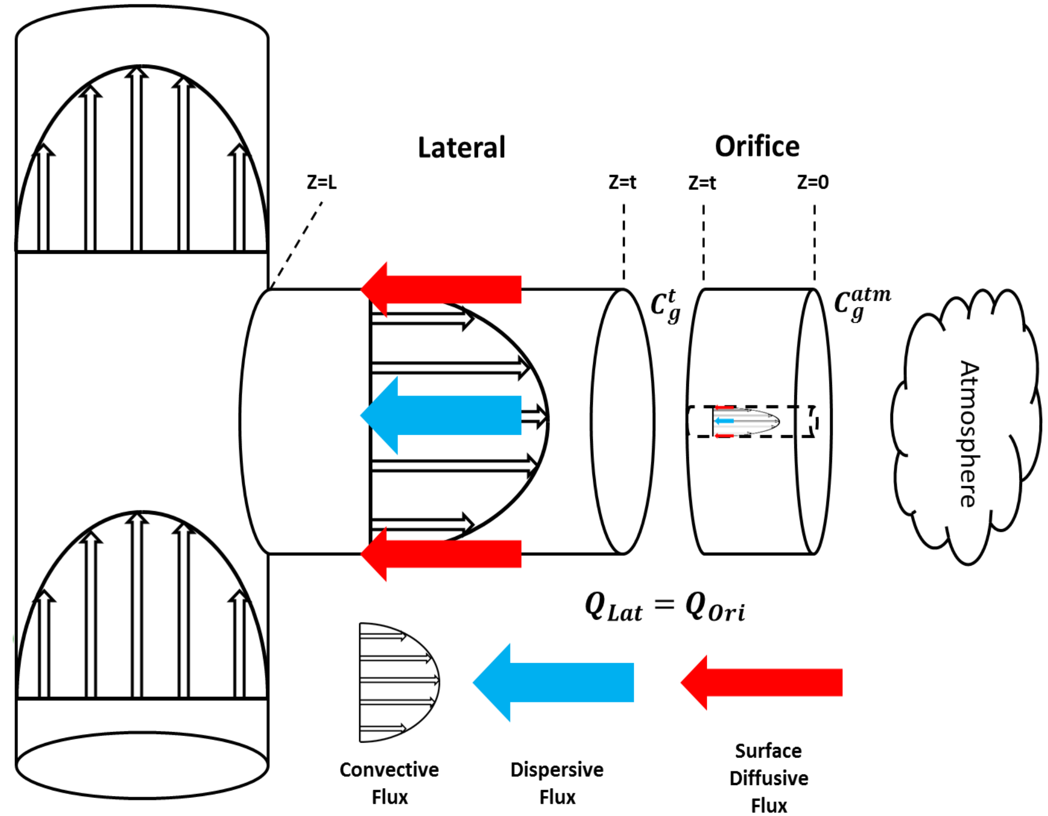
**Effective Dispersion Coefficient**

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

**Governing Equation**

Convection; Effective Dispersion

$$\underbrace{U_3\frac{dC_g}{dz}}_{\text{Convection}} + \underbrace{D_e\frac{d^2C_g}{dz^2}}_{\text{Effective Dispersion}} = 0$$




**Boundary Condition 1**

$$z = 0, \qquad D_m\left(\frac{C_g^{atm} - C_g}{t}\right) = \frac{Q_3}{A_{ori}}C_g$$

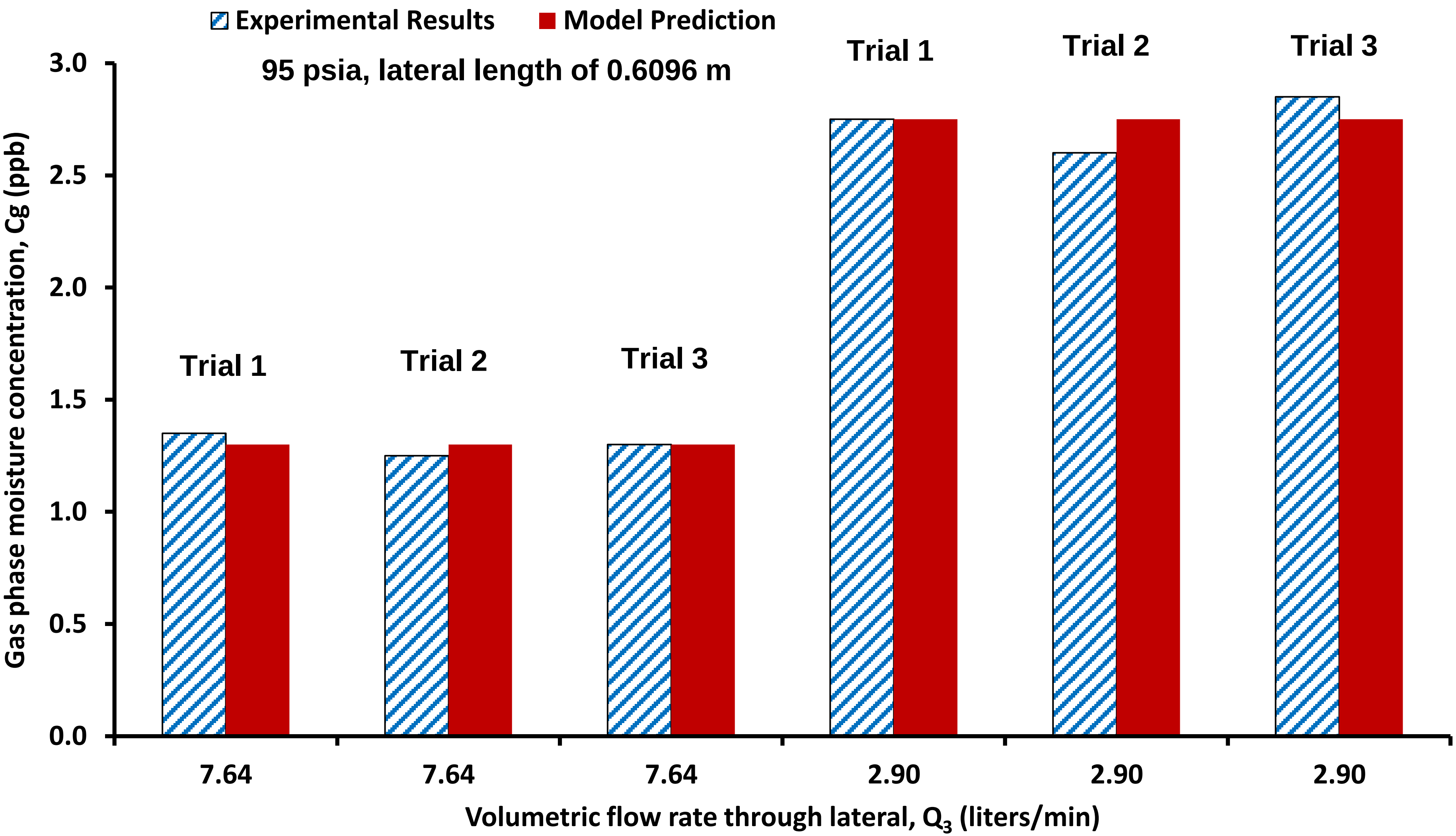
**Boundary Condition 2**

Convective Flux; Effective Dispersive Flux

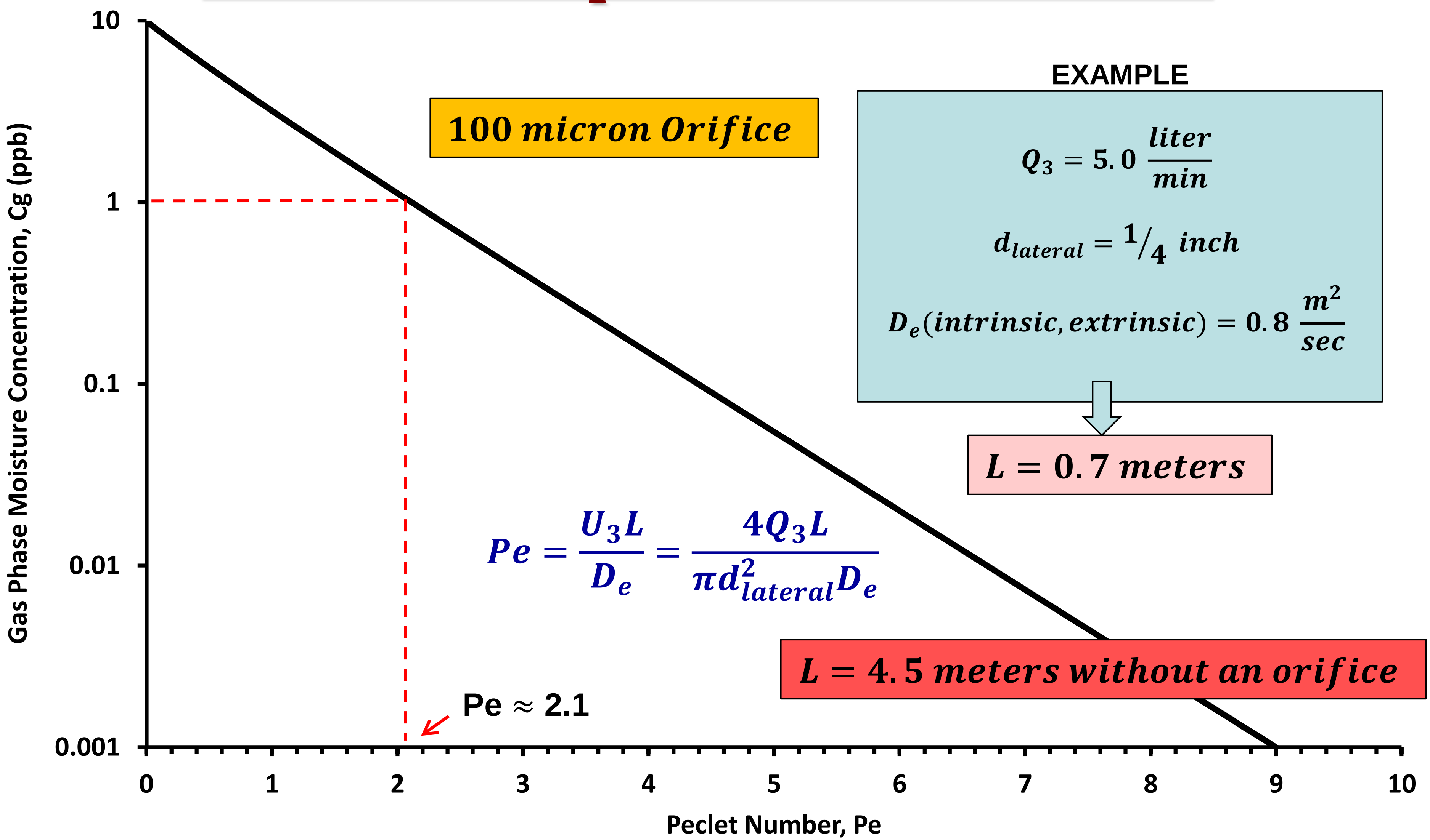
$$z = L, \qquad C_g\Big|_{z=L} = \left(\underbrace{-U_3\,C_g\Big|_{z=L}}_{\text{Convective Flux}} - \underbrace{D_e\frac{dC_g}{dz}\Big|_{z=L}}_{\text{Effective Dispersive Flux}}\right)\frac{A_{lateral}}{Q_2}$$

# Process Simulator Verification

## Simulator Prediction

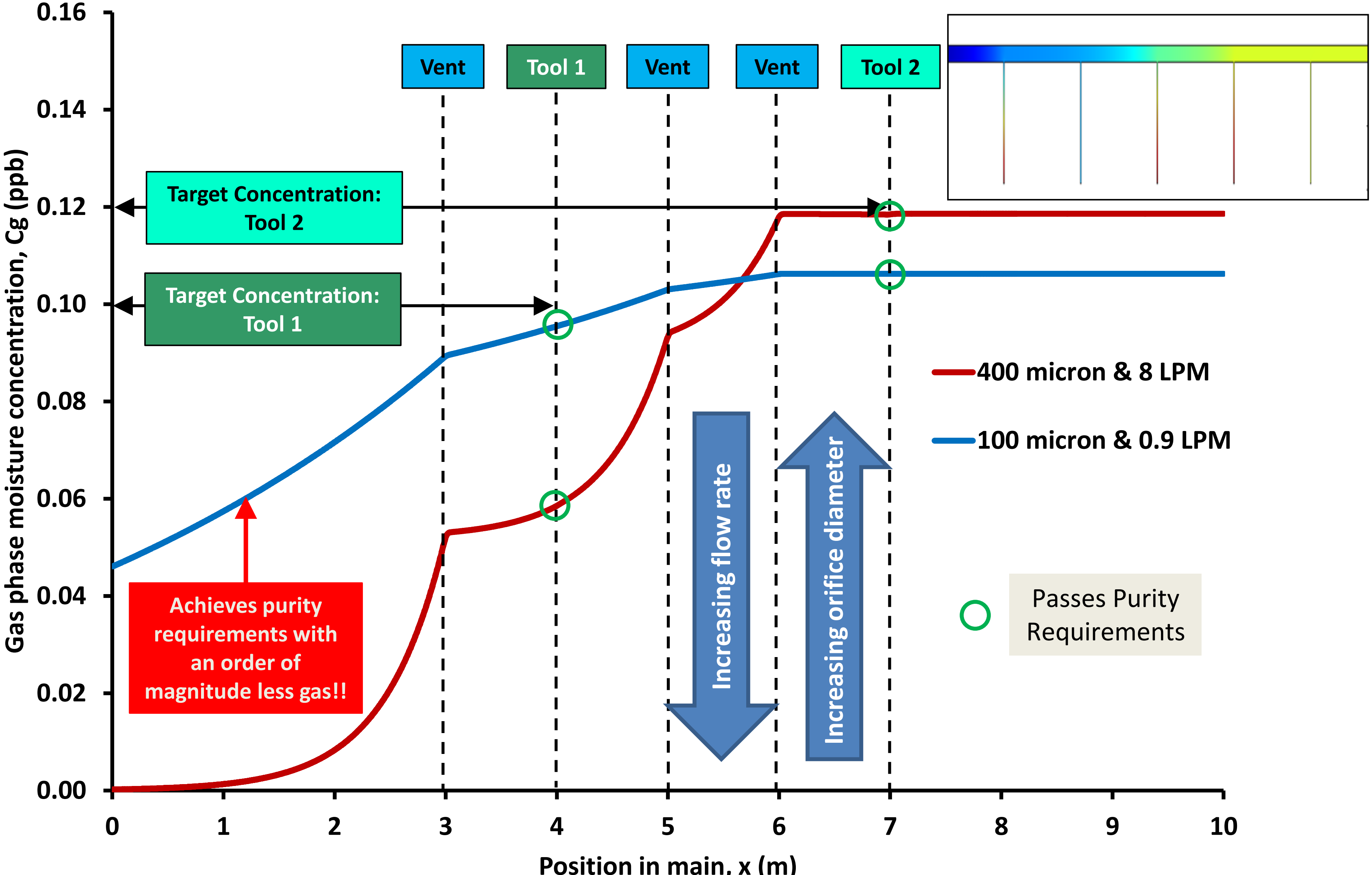


# Example: Application for Design and Selection of Operational Parameters

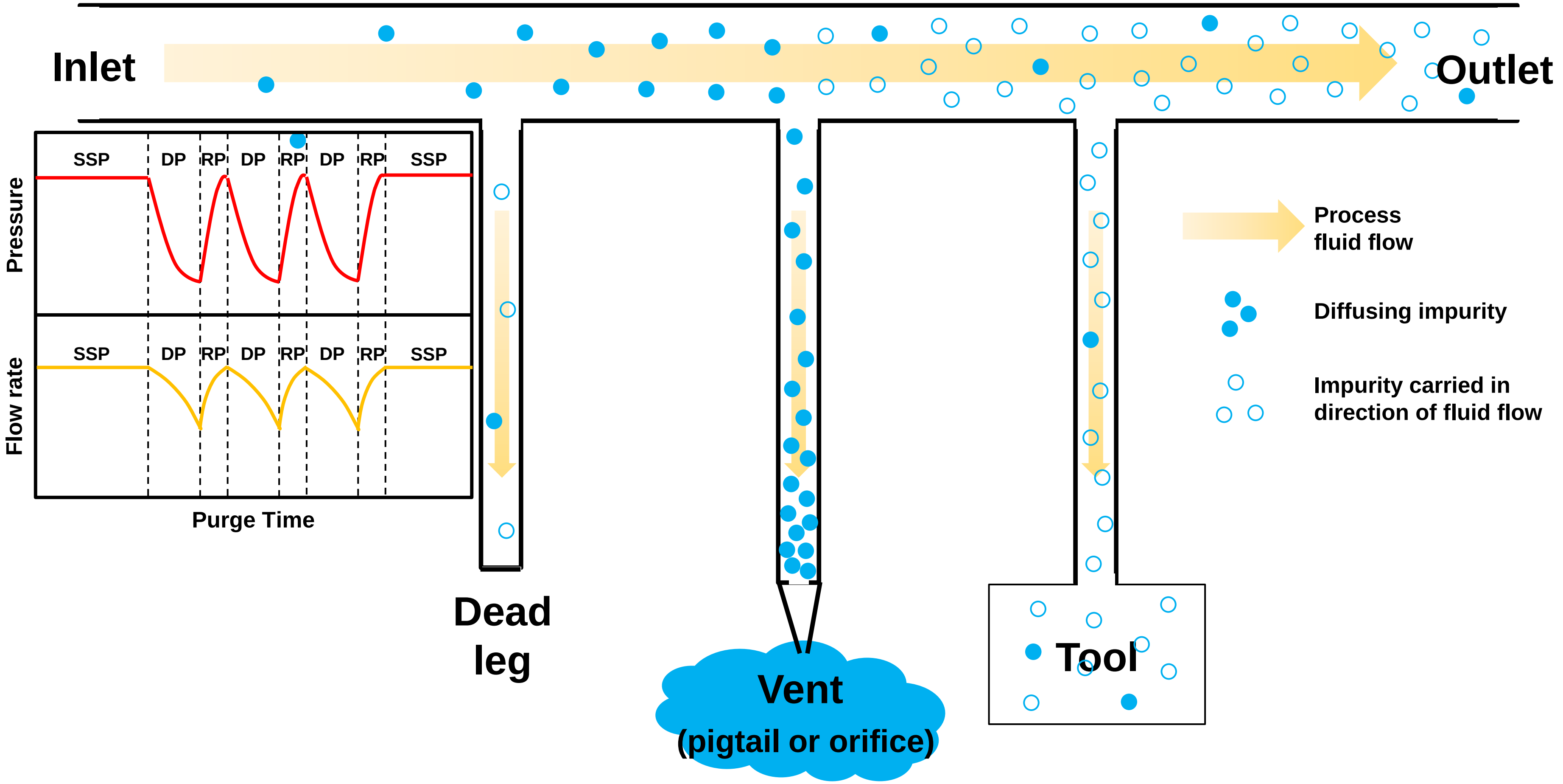


# Parametric Studies

## Effect of Flow Rate and Orifice Diameter on Gas Phase Moisture



# Subtask 2: Novel ESH-Friendly Purge Methods



# Comprehensive Purge Simulator

**Continuity equation:**

$$\frac{\partial P}{\partial t} = -P\frac{\partial u}{\partial x} - u\frac{\partial P}{\partial x}$$

**Navier–Stokes equation:**

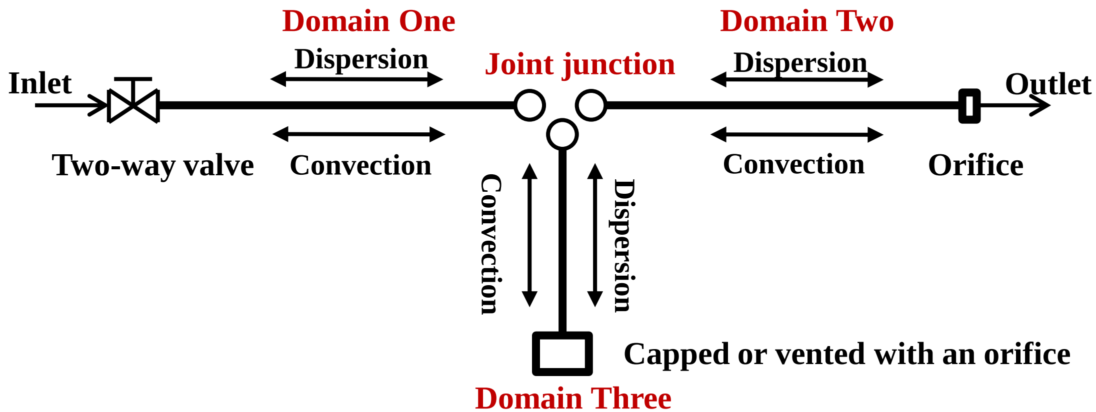
$$\frac{\partial u}{\partial t} = -\frac{RT}{PM}\frac{\partial P}{\partial x} - u\frac{\partial u}{\partial x}$$

**Moisture concentration in the gas phase:**

$$\frac{\partial C_g}{\partial t} = \underbrace{\frac{1}{\partial x}(D_L\frac{\partial C_g}{\partial x})}_{\text{Diffusion}} - \underbrace{\frac{1}{\partial x}(uC_g)}_{\text{Convection}} + \underbrace{\frac{4}{d}\left[(k_d C_S - k_a C_g (S_0 - C_S)\right]}_{\text{Adsorption and desorption}}$$

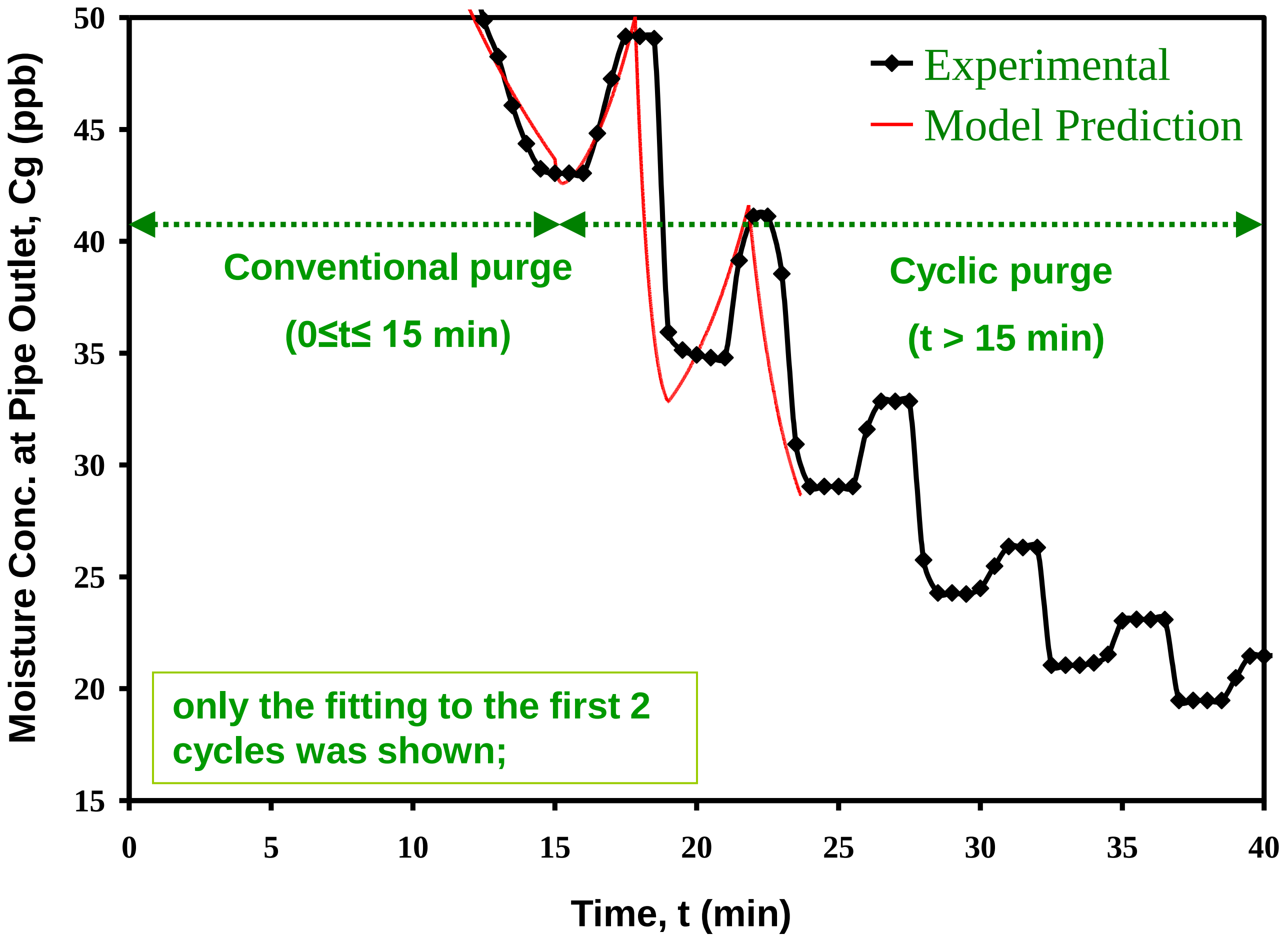
**Moisture concentration on the pipe surface:**

$$\frac{\partial C_s}{\partial t} = k_a C_g (S_0 - C_S) - k_d C_s$$



# Simulator Verification

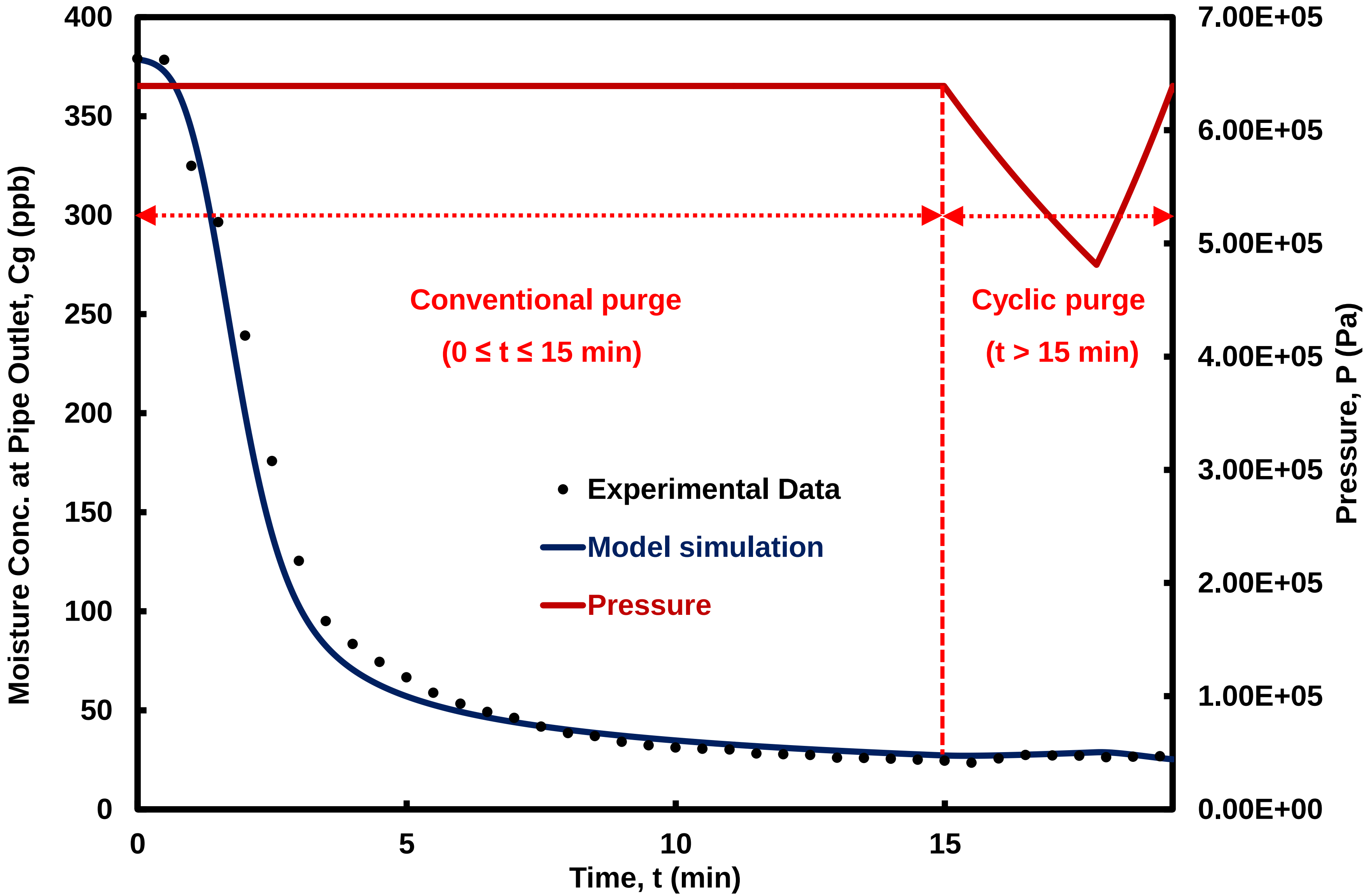
EPSS pipe with 1.5 inch OD and 76 inch length. Initial moisture conc. : 350 ppb




***The process simulator well predicts combination of conventional and cyclic purge processes***

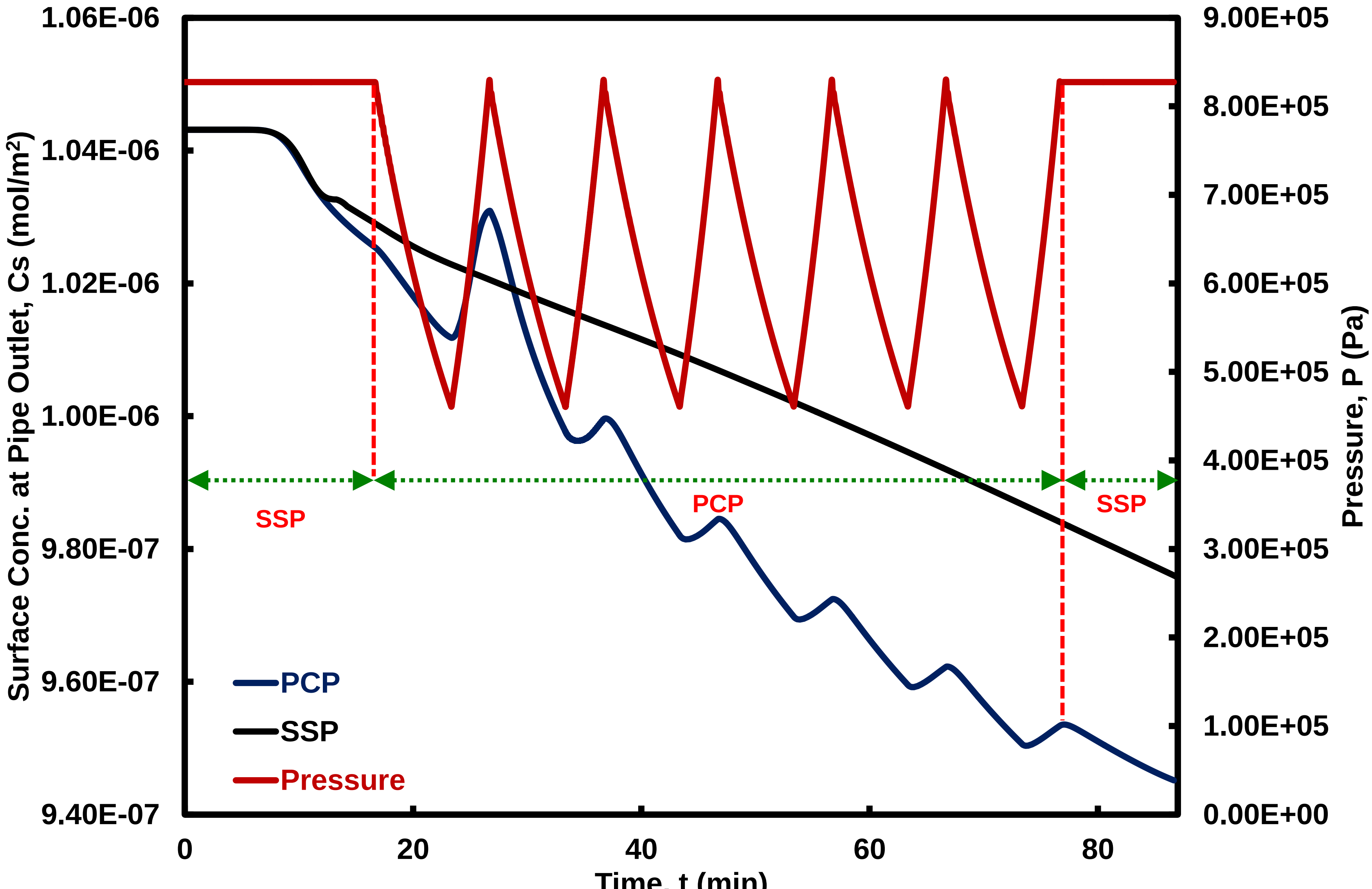
# Simulator Verification

Main header: 1.5” OD, 76” length. Lateral: 0.5” OD, 30” length. Initial conc.: 380 ppb

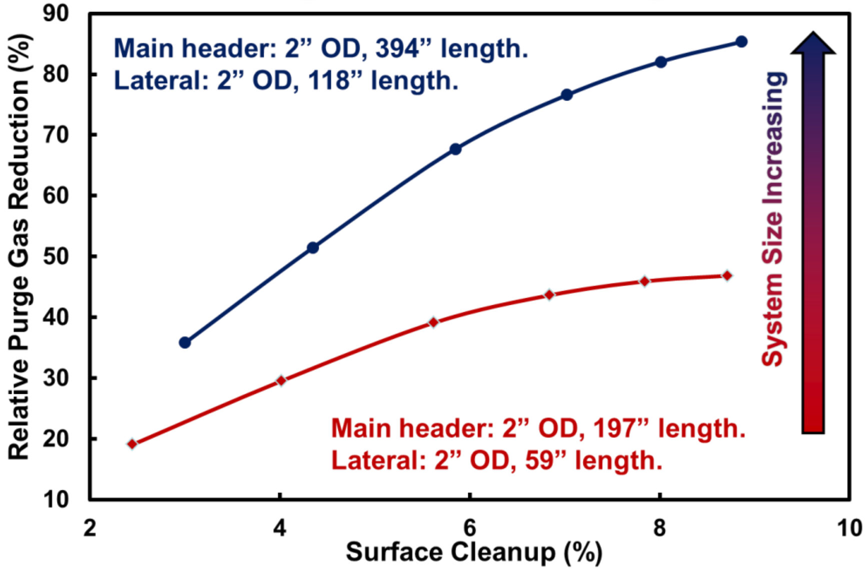


# Comparison of SSP and PCP

Main header: 2” OD, 394” length. Lateral: 2” OD, 118” length. Initial conc.: 200 ppb

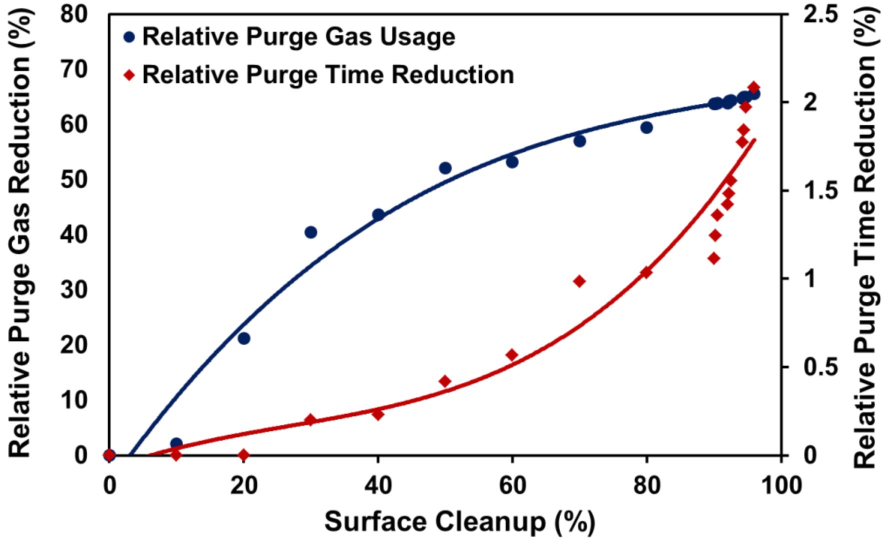


# ESH/Cost Impact:
# Gas Usage and Purge Time Reduction by PCP Process




## System Size Effect

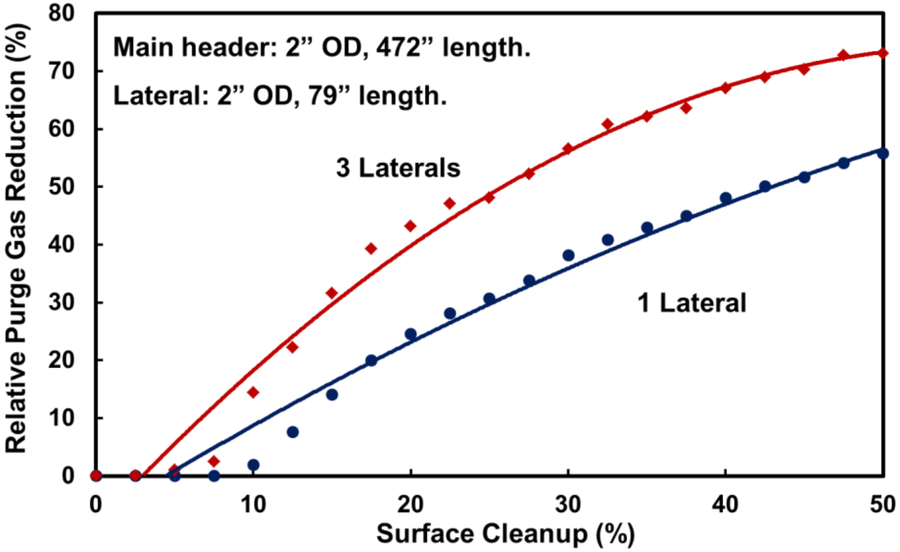
- The relative purge gas reduction increases with the surface cleanup.
- PCP advantage is greater for larger systems.

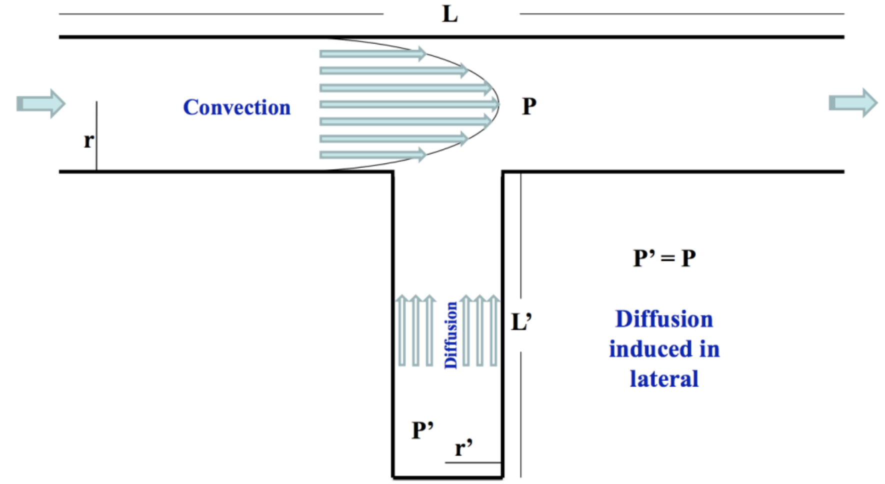


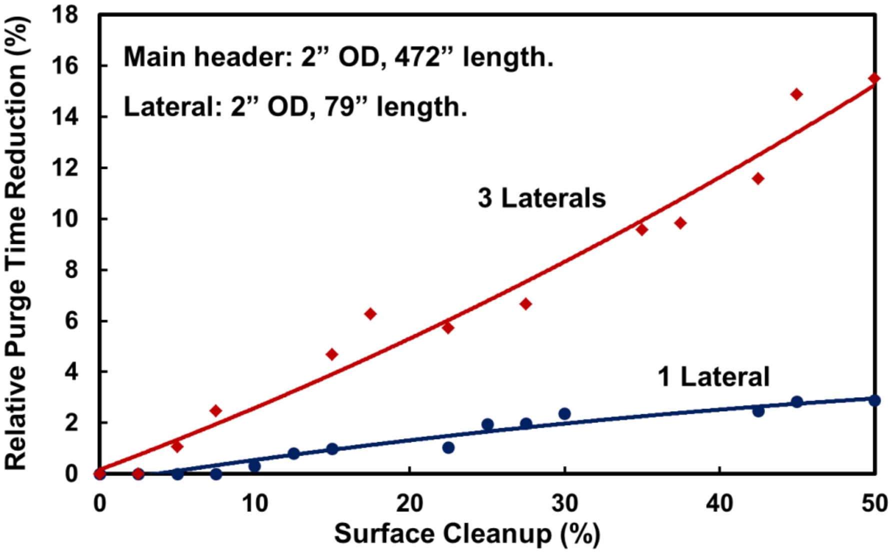

## Industrial Scale Purge Study

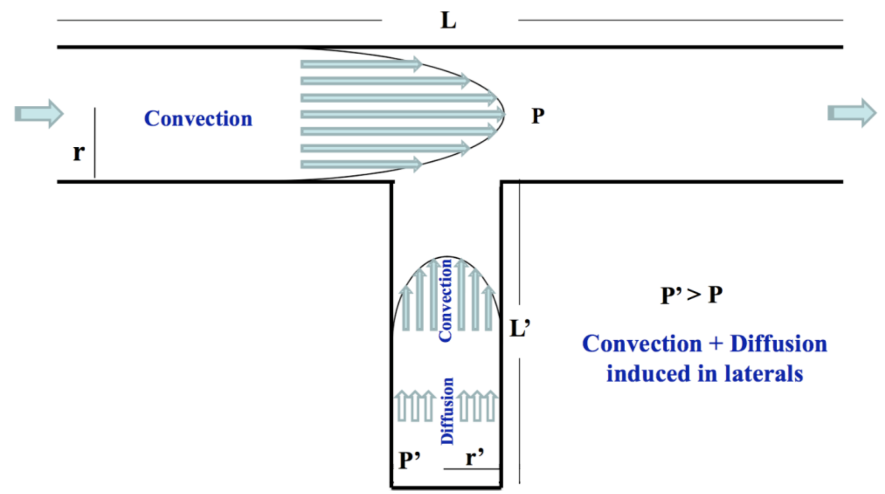
500 ft Main Section
50 ft Branches x 5

# PCP Advantage for Purging Networks



# Summary and Conclusions

- **A method is developed to study contamination back diffusion in gas distribution systems; last year's focus on comparison of flow restrictors options (pigtails, valves, and orifices).**
- **Developed robust pressure cyclic purge (PCP) methods for complex systems with multiple branches.**
- **PCP reduces the down time and gas usage for purging gas distribution systems. The advantage is greater for larger networks with branches and stagnant volumes.**
- **Successful PCP requires proper (non-trivial) selection of operational parameters. Process simulation is needed to accomplish this task.**
- **Two versions of the process simulator are developed: comprehensive version for detailed research and simplified version for fab on-site usage.**

# Industrial Interactions and Future Plans

- **Continue joint work with Intel; some technology transfer and implementation of results at Intel fabs have already taken place.**
- **Prepare a user-friendly version of the process simulator available to industry**
- **Extend the present study to other fluids, contaminants, and components**

# Acknowledgements


- **Carl Geisert and Gopal Rao (Intel)**
- **Tiger Optics (major financial support and technical assistance)**
- **Junpin Yao (Matheson Tri-Gas)**

# Publications and Presentations

- **Hao Wang, Farhang Shadman, Effect of Particle Size on the Adsorption and Desorption Properties of Oxide Nanoparticles, AIChE, September, 2012.**
- **Hao Wang, Farhang Shadman, Effect of Particle Size on the ESH Properties of Nano-Materials, Presentation, SRC TECHCON, September 2012.**
- **Hao Wang, Roy Dittler, Farhang Shadman, Application of Pressure-Cycle Purge in Dry-down of Ultra-High-Purity Gas Distribution Systems, Presentation, ASM American Inc., Auguest 2012.**
- **Hao Wang, Farhang Shadman, Effect of Particle Size on the Adsorption and Desorption Properties of Oxide Nanoparticles, SRC ERC Teleconference, April, 2012.**
- **Roy Dittler, Hao Wang, Jivaan Jhothiraman, Carl Geisert, Farhang Shadman, Reducing Ultra-High-Purity (UHP) Gas Consumption By Characterization of Trace Contaminate Kinetric and Transport Behavior in UHP Fab Environments, SRC ERC Teleconference, November, 2012.**
- **Roy Dittler, Carl Geisert, Bulk Gas Distribution Dry Down Research, Intel Corp., August 2012.**