Novel Methods for Reducing UHP Gas Usage in Fabs

Customized Project; Sponsored by Intel

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Co-PI:

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Other Researchers:

- **Jun Yan: Ph.D. research assistant professor, Chemical and Environmental Engineering, UA**

Objectives

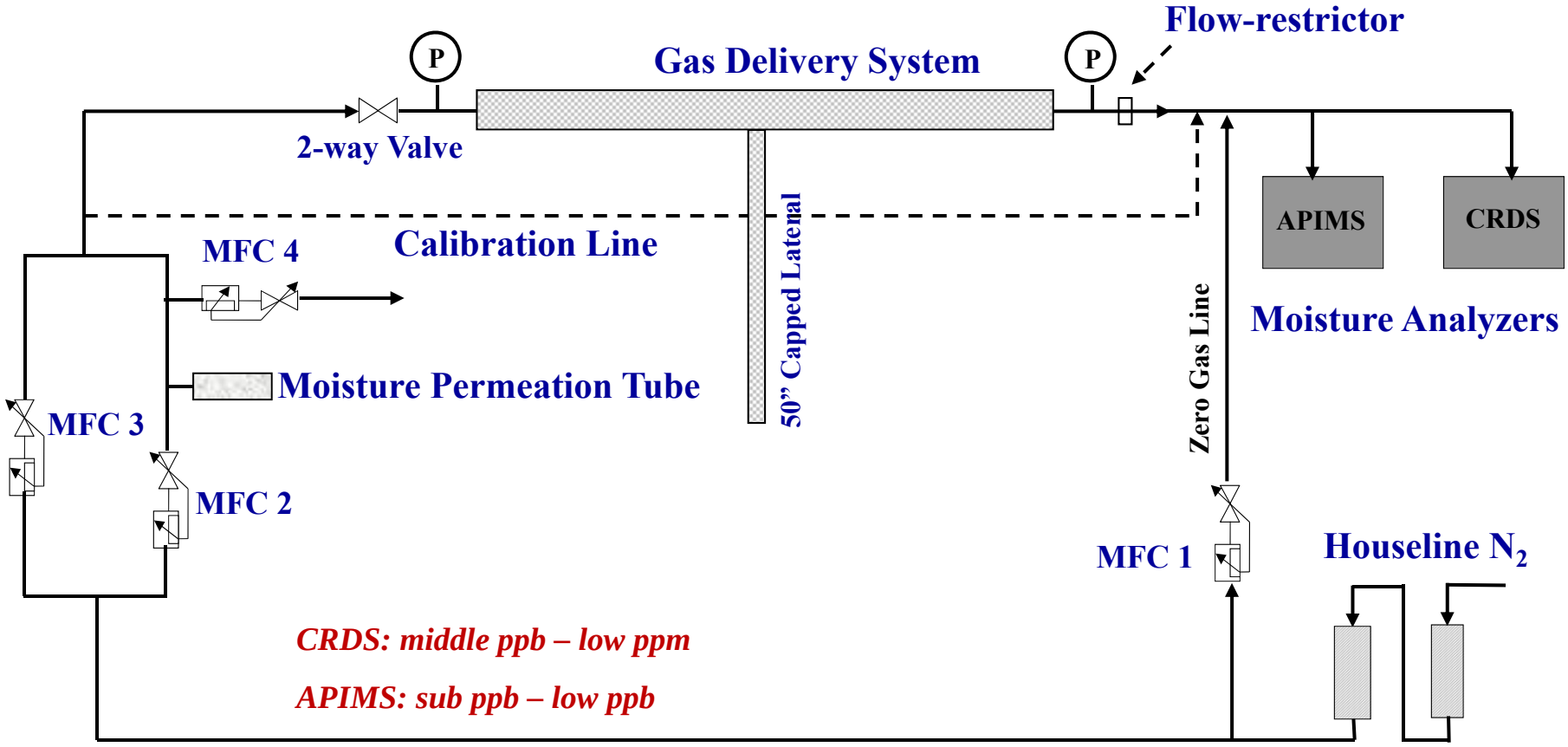
- **Develop new robust techniques and procedures for purging/removal of impurities and drying down of the ultra-pure gas distribution systems: application for start-up and/or recovery from system upsets.**
- **Develop and validate a user-friendly process simulator applicable to the purge process in complex fab gas distribution networks.**
- **Resolve the differences in the previous reports on the advantages of cyclic purging.**

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.**

Experimental Testbed

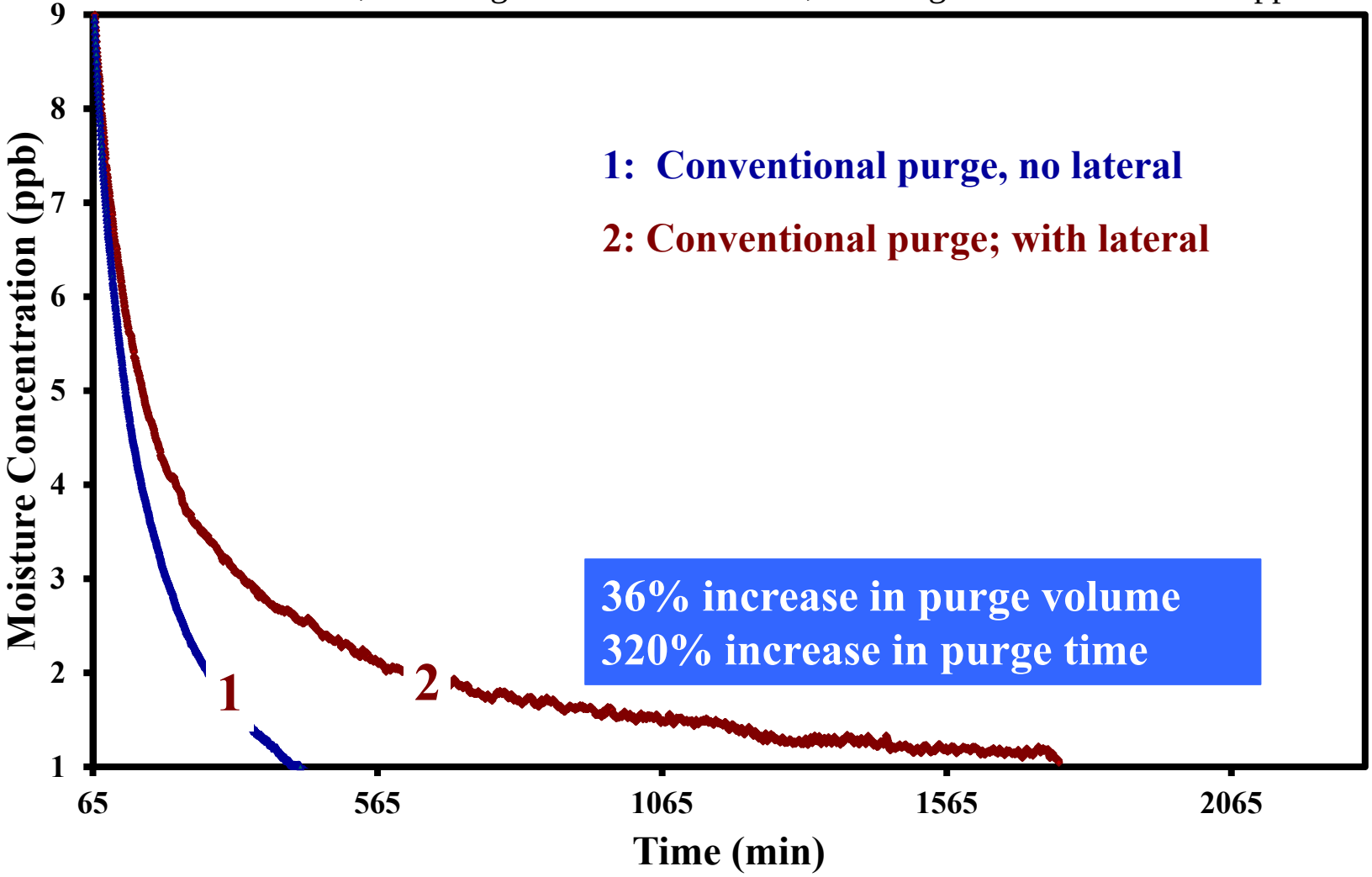
Laterals Added to the Main Line



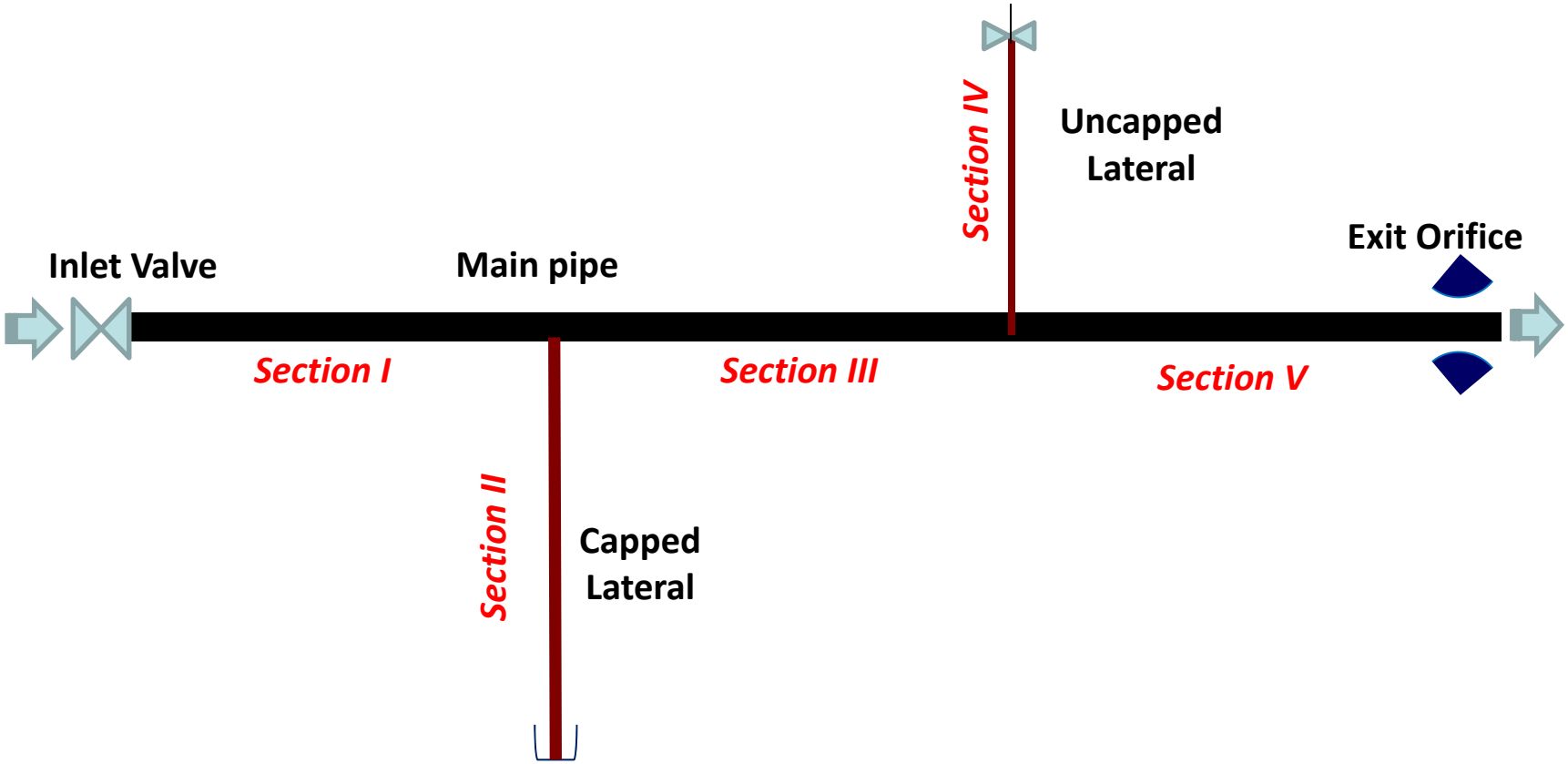
Gas distribution systems with different sizes and geometries were fabricated and provided by Intel

Effect of Laterals on the Purge Process

Main header: 1.5” OD, 76” length. Lateral: 0.5” OD, 50” length. Initial conc. 380 ppb

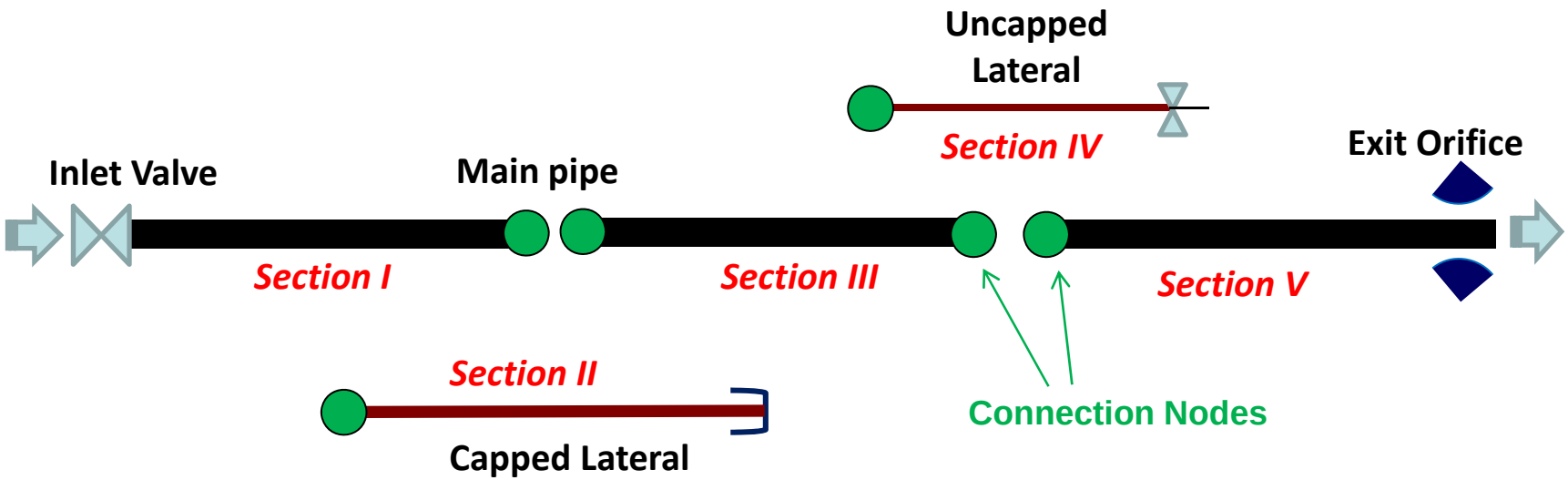


Purge Process Simulator for Systems with Laterals (Multi-Dimensional)



Modular Approach and System Linearization

(Conversion to One Dimension)



Connection Nodes

- Matching of pressure and concentration (continuity)
- Balance of gas flow and fluxes (discontinuity)

This approach can be extended to complex networks

Purge Process Simulator

System Pressure:

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

Velocity:

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

Absorbed Moisture:

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

Gas Phase Moisture:

$$\frac{\partial C_g}{\partial t} = D_L\frac{\partial^2 C_g}{\partial x^2} + \frac{\partial D_L}{\partial x}\frac{\partial C_g}{\partial x} - u\frac{\partial C_g}{\partial x} - C_g\frac{\partial u}{\partial x} + \frac{4}{d}\left[(k_d C_S - k_a C_g (S_0 - C_S)\right]$$

C_S: moisture concentration on pipe wall, mol/cm^2; C_g: moisture concentration in gas, mol/cm^3;

k_{ads}: adsorption rate constant, cm^3/mol/s; k_{des}: desorption rate constant, 1/s

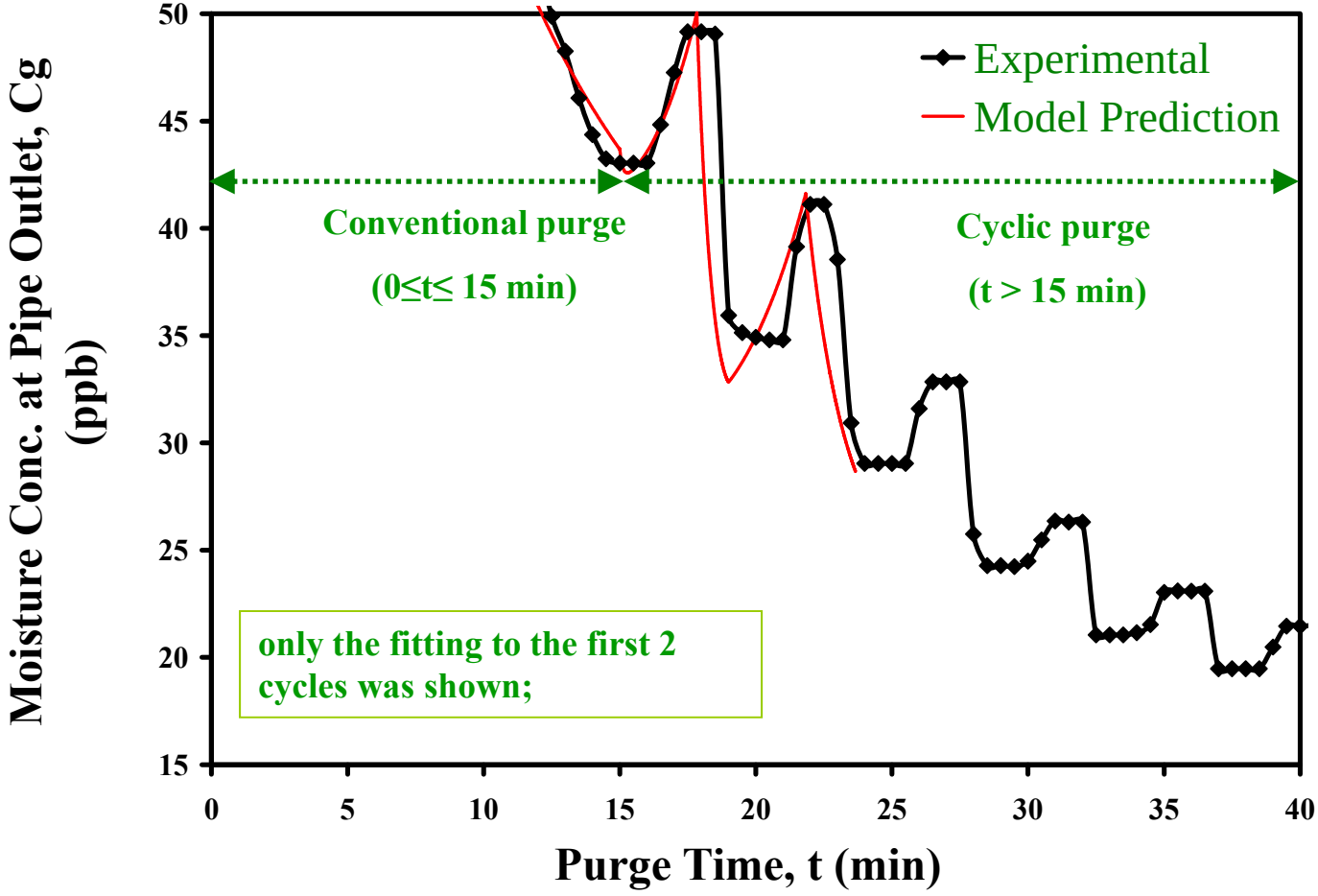
S_0: site density of surface adsorption, mol/cm^2; D_L: dispersion coefficient, cm^2/s;

u: velocity, cm/s; d: diameter; P: pressure

The simulator is scalable and applicable to various system configurations and sizes

Simulator Verification

EP SS 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

Comparison of Pressure Cyclic Purge with Conventional Purge (w/ Lateral)

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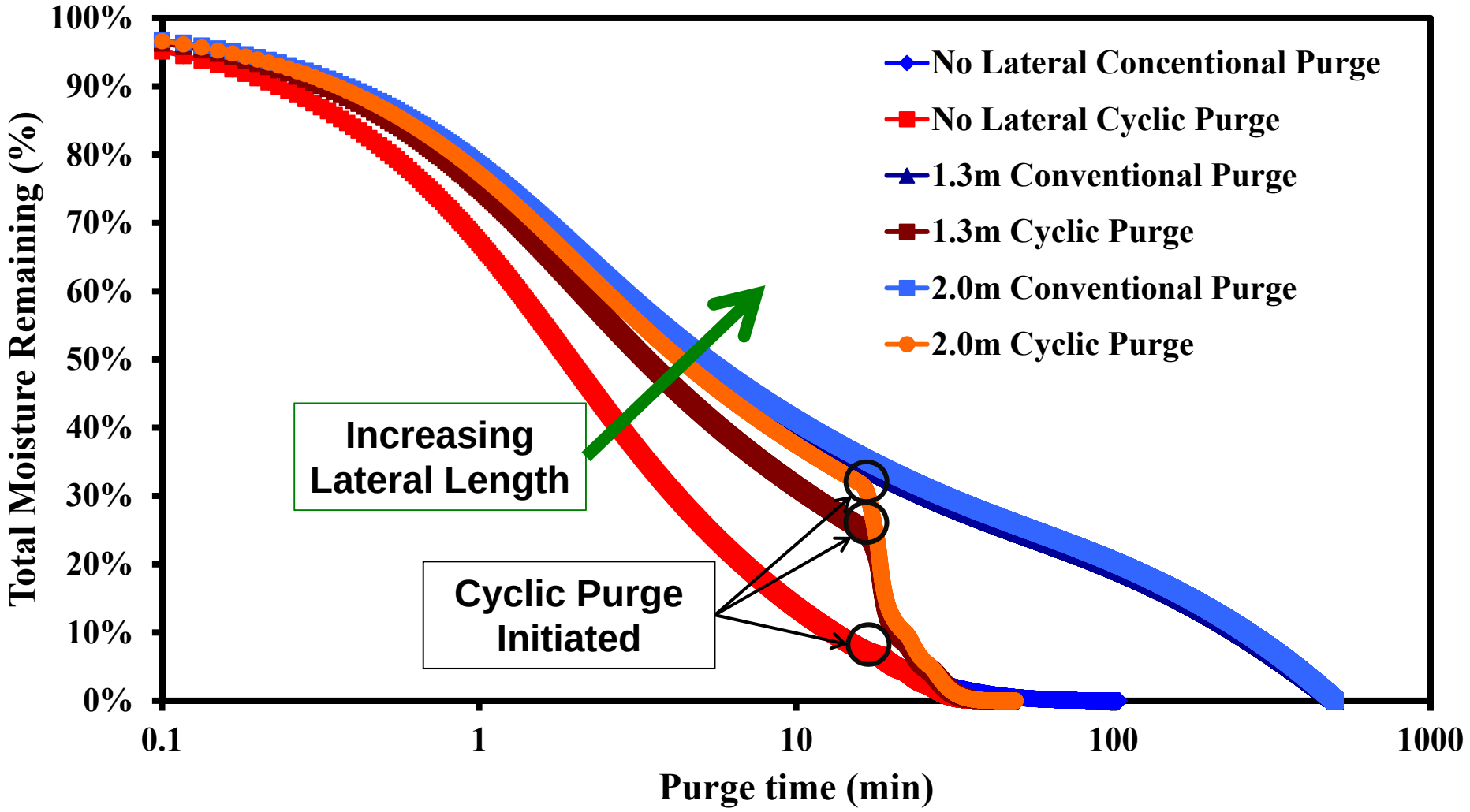

Conventional Purge Mechanism

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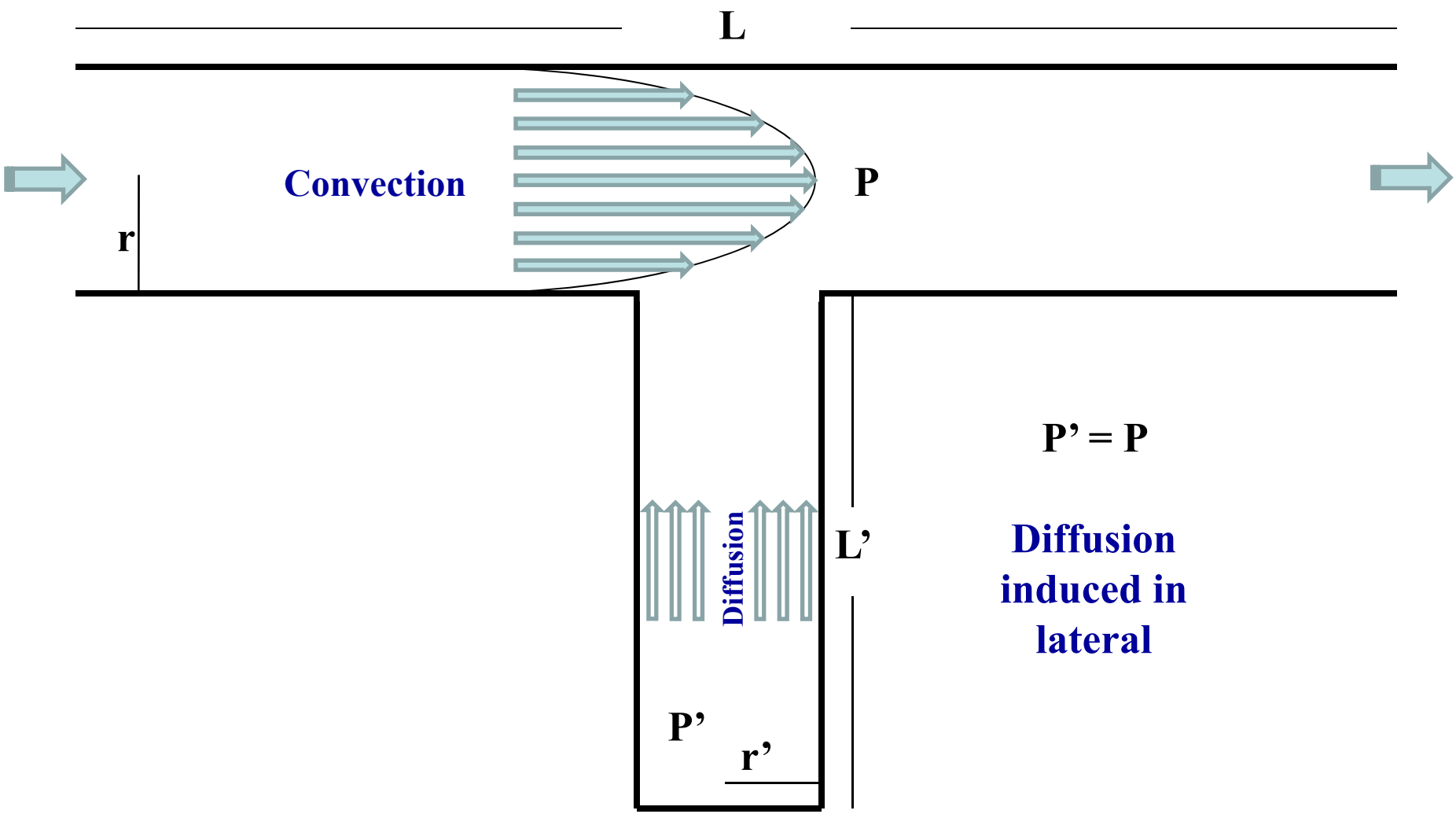

Pressure Cyclic Purge Mechanism

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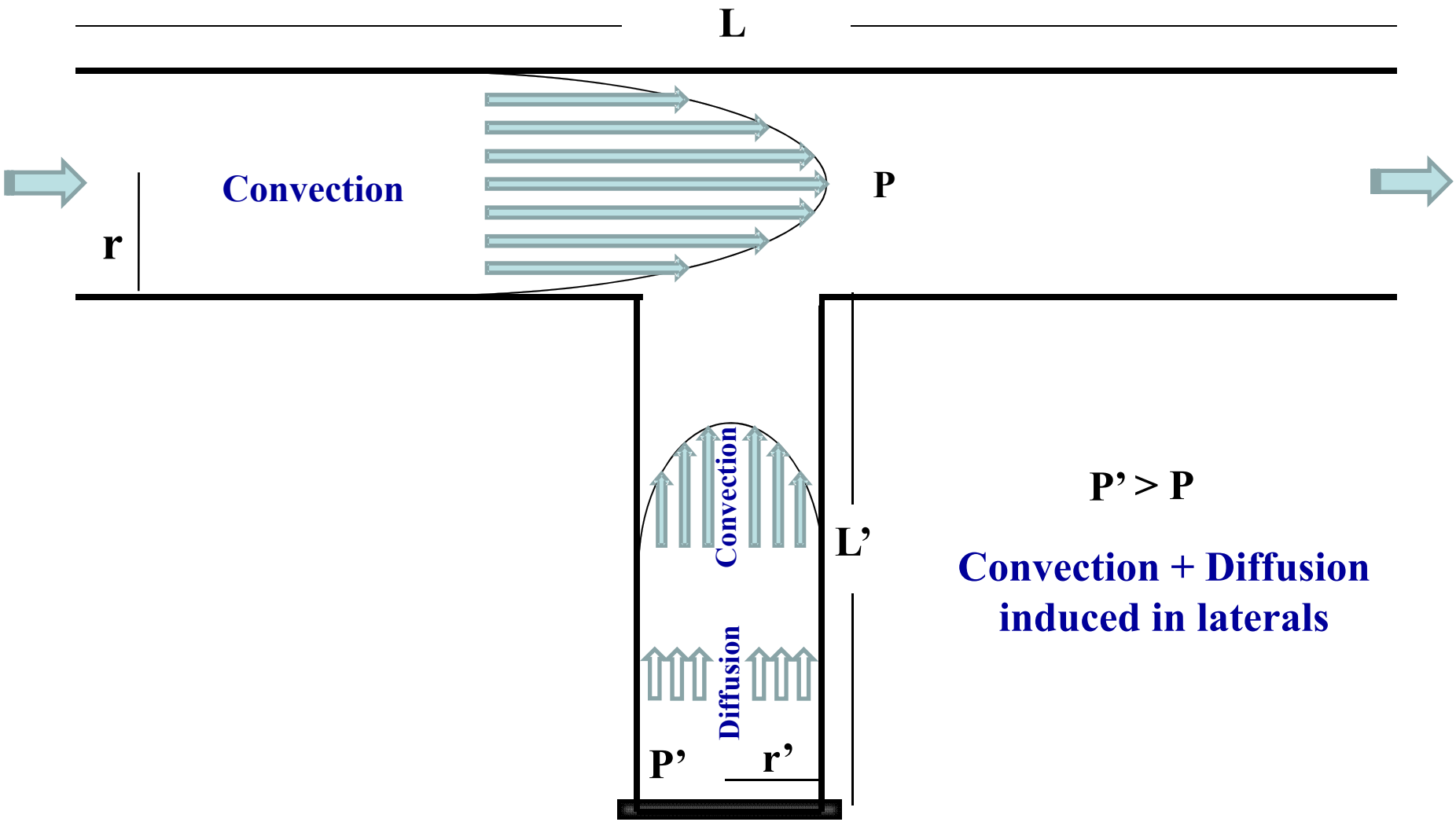
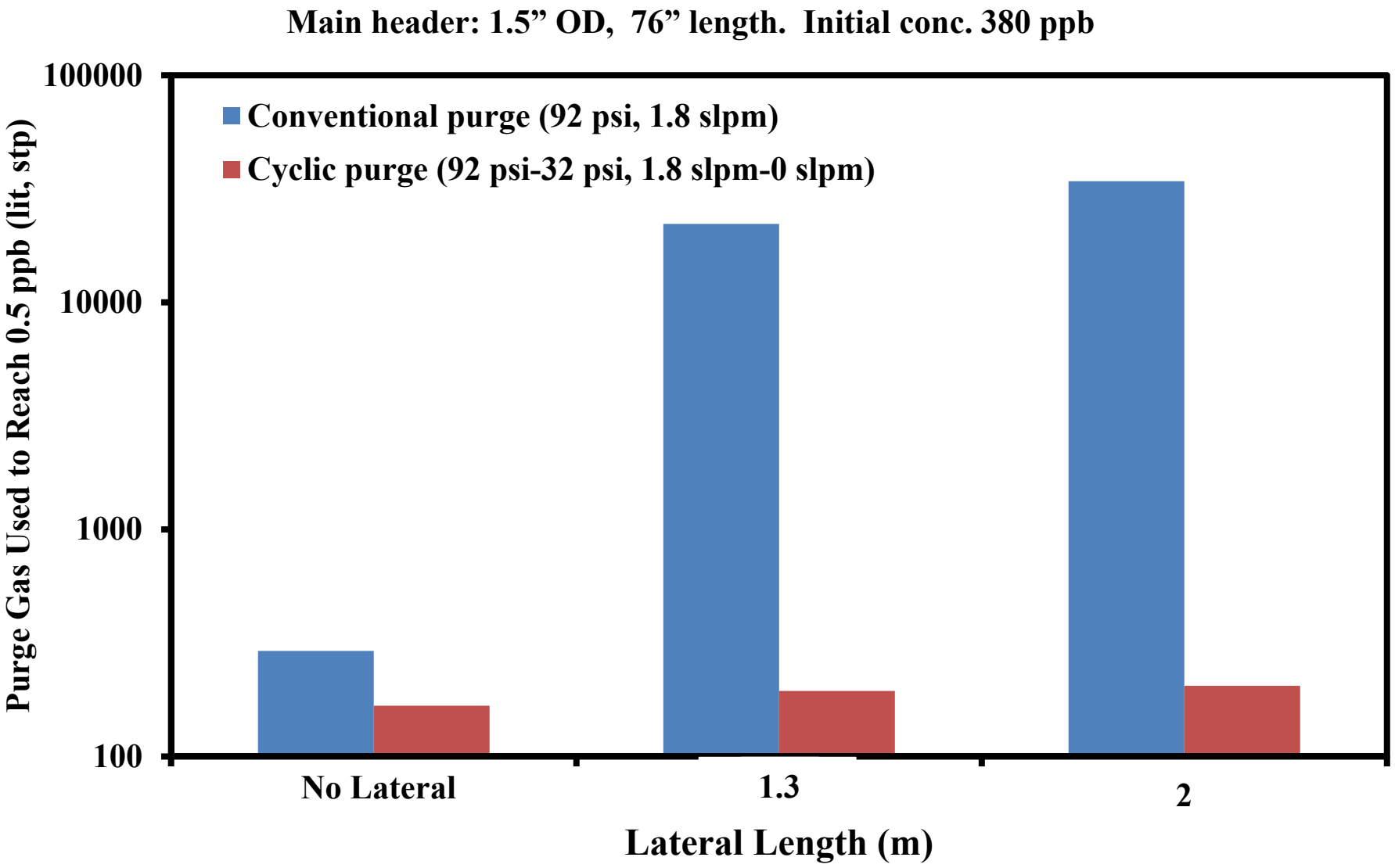
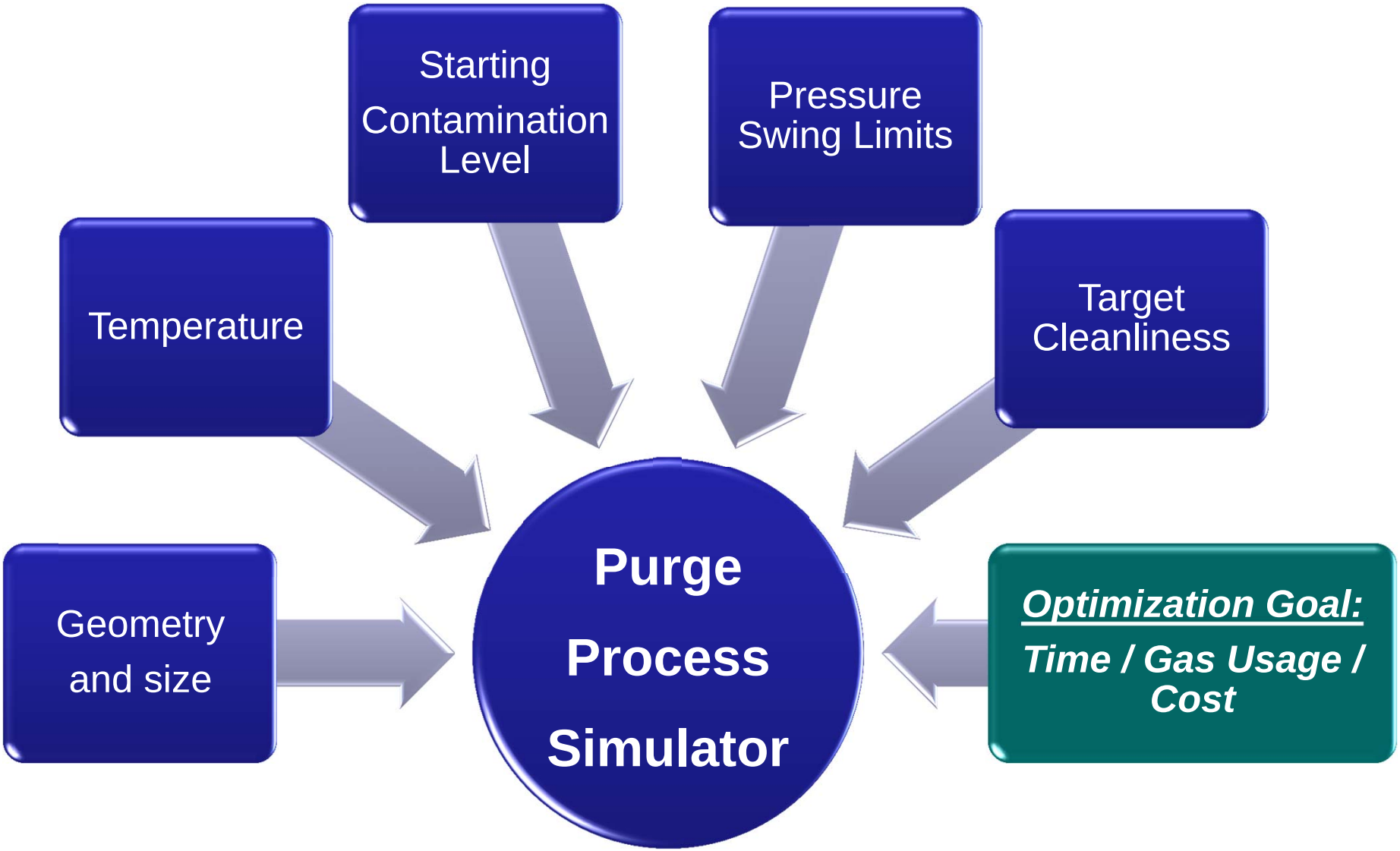


PCP vs. Conventional Purge (w/ Lateral)



Application of the Simulator for Process Optimization



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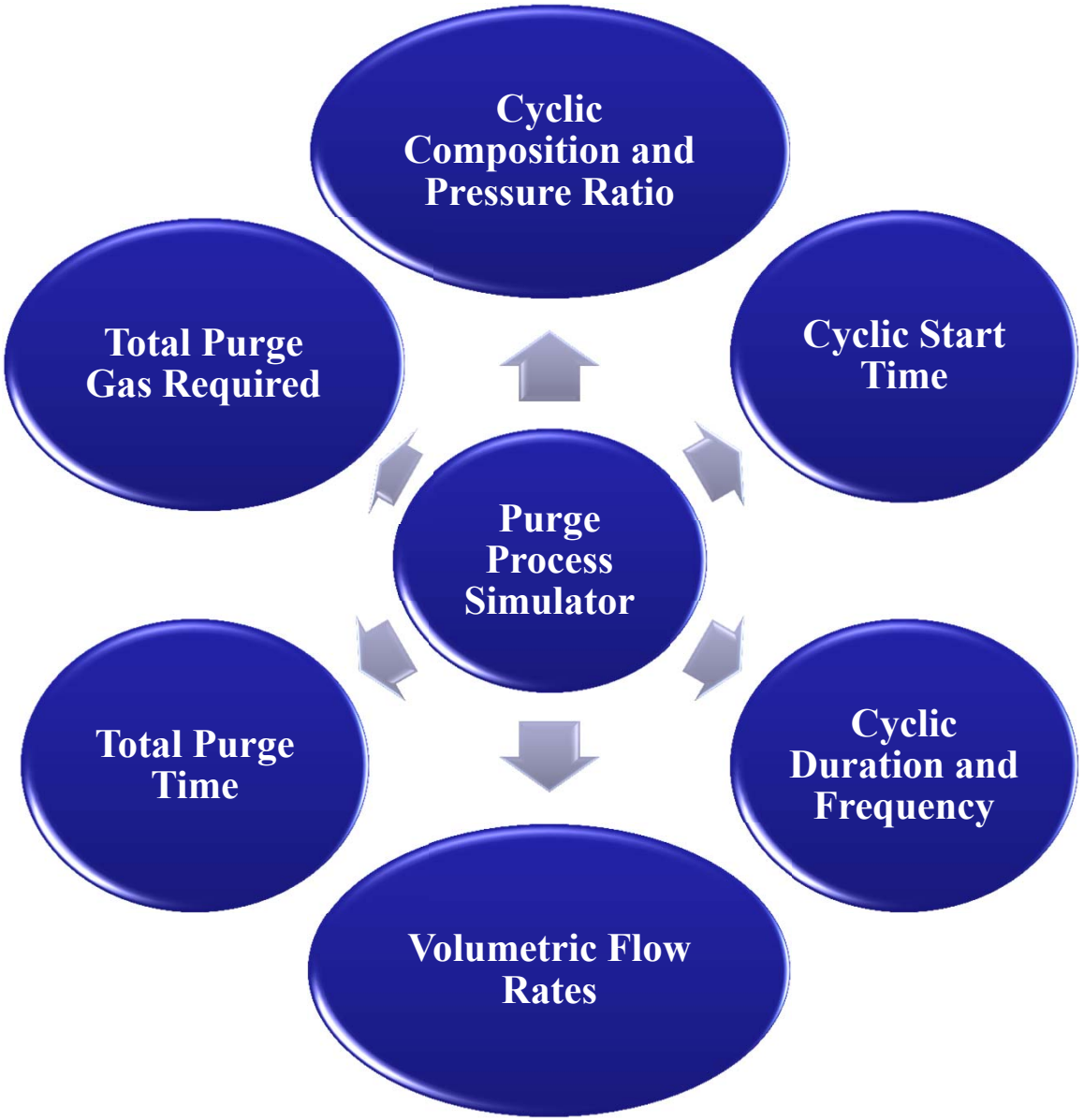
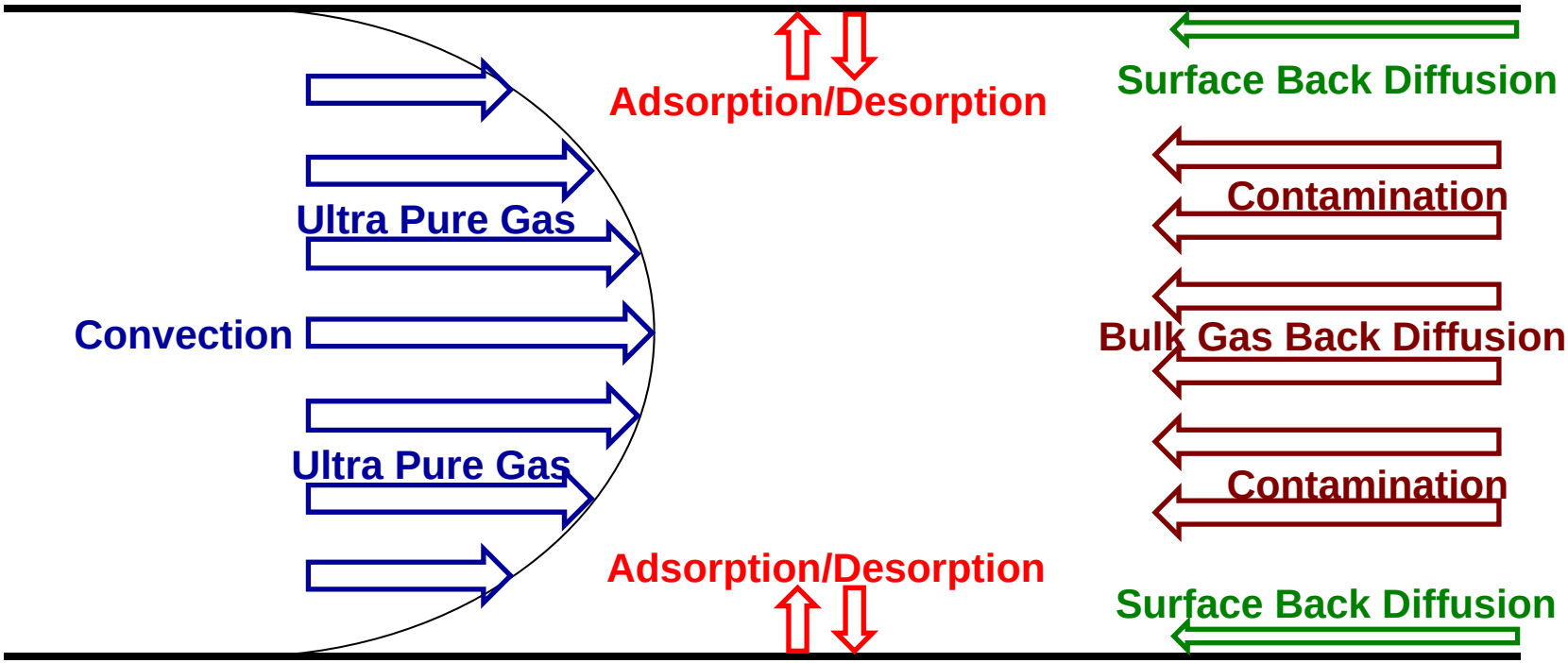


Future Simulator Update: Back Diffusion



Highlights

- Compared to conventional purge, pressure cyclic purge takes less time and less gas usage for purging gas distribution networks.
- Pressure cyclic purge has a significantly greater impact in systems with laterals and stagnant volumes.
- The cyclic purge works well only if the operational parameters are selected correctly. A simulator has been developed to facilitate and accomplish this procedure.
- A user-friendly interface has been added to the simulator core program. This interface facilitates simulator application by field engineers.

Industrial Interactions and Future Plans

- Continue work with Intel; make simulator available to other member companies; continue work on back-diffusion and removal of other gaseous contaminants.

Presentations and Papers

- **Lowering Material and Energy Usage during Purging Ultra-High-Purity Gas Distribution Systems (presenter), AIChE 2009 Annual Meeting, Nov. 2009, Nashville, Tennessee.**
- **Application of Pressure Cyclic Purge (PCP) in Dry-down of Ultra-High-Purity Gas Distribution Systems, published in *Chemical Engineering Sciences***

Acknowledgements

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