Techverse, Inc.

Water transport characteristics of gas diffusion layer in a PEM fuel cell

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Presentation Outline

- Water transport in PEM Fuel Cells – DOE project
- Gas Diffusion Layer – Role and Characteristics
- Capillary pressure determinations of GDL media
- Gas permeability measurements of GDL media
- Conclusions and future activities

DOE Project - Water Transport in PEM Fuel Cells:

Advanced Modeling, Material Selection, Testing, and Design Optimization

DOE Program Monitor

CFDRC Project Mgt
- Vernon Cole – Program Manager
- Ashok Gidwani – Principal Investigator

Advisory Committee
- Ashok Singhal – CFDRC
- John Kenna – Ballard
- Greg Jackson – University of Maryland

Material Charact., Ex-Situ Expts.
- Ashok Damle – Techverse
- Ned Djilali – Univ. Victoria

Numerical Model Dev.
- Ashok Gidwani – CFDRC
- Ning Zhou – ESI
- Sanjiv Kumar - Ballard

In-Situ Cell Expts.
- Hari Dhar – BCS
- Sanjiv Kumar - Ballard

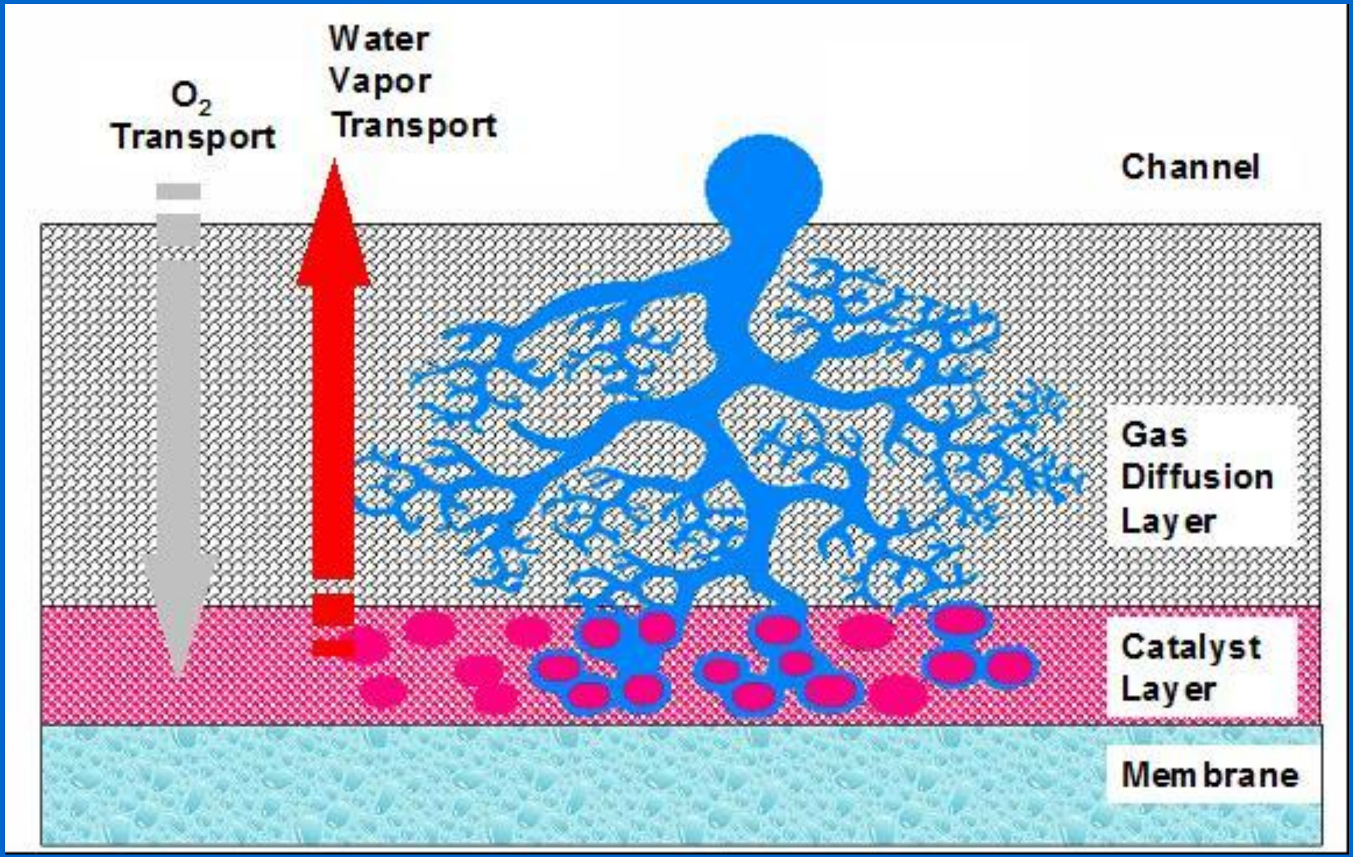
Model Validation
- Ashok Gidwani – CFDRC
- Ning Zhou – ESI
- Sanjiv Kumar - Ballard

Design Improvements
- Ashok Gidwani – CFDRC
- Hari Dhar – BCS
- Ashok Damle – Techverse

Techverse Role in DOE Project

- Characterize physical properties of PEM cell components – GDL, catalyst layer, membrane, and bipolar plate
- Material properties characterization – pore size distribution, surface area, porosity, thickness
  - Micromeritics Analytical Services
- Characterize water transport properties – contact angle, capillary pressure - water saturation relationship, single- and two-phase flow through dry and wet (saturated) GDL materials, freezing point depression, thermal and electrical conductivities
- Identify potential design and operational improvements in collaboration with other team members

Water transport visualization in a PEM cell



Gas Diffusion Layer – influential for water transport

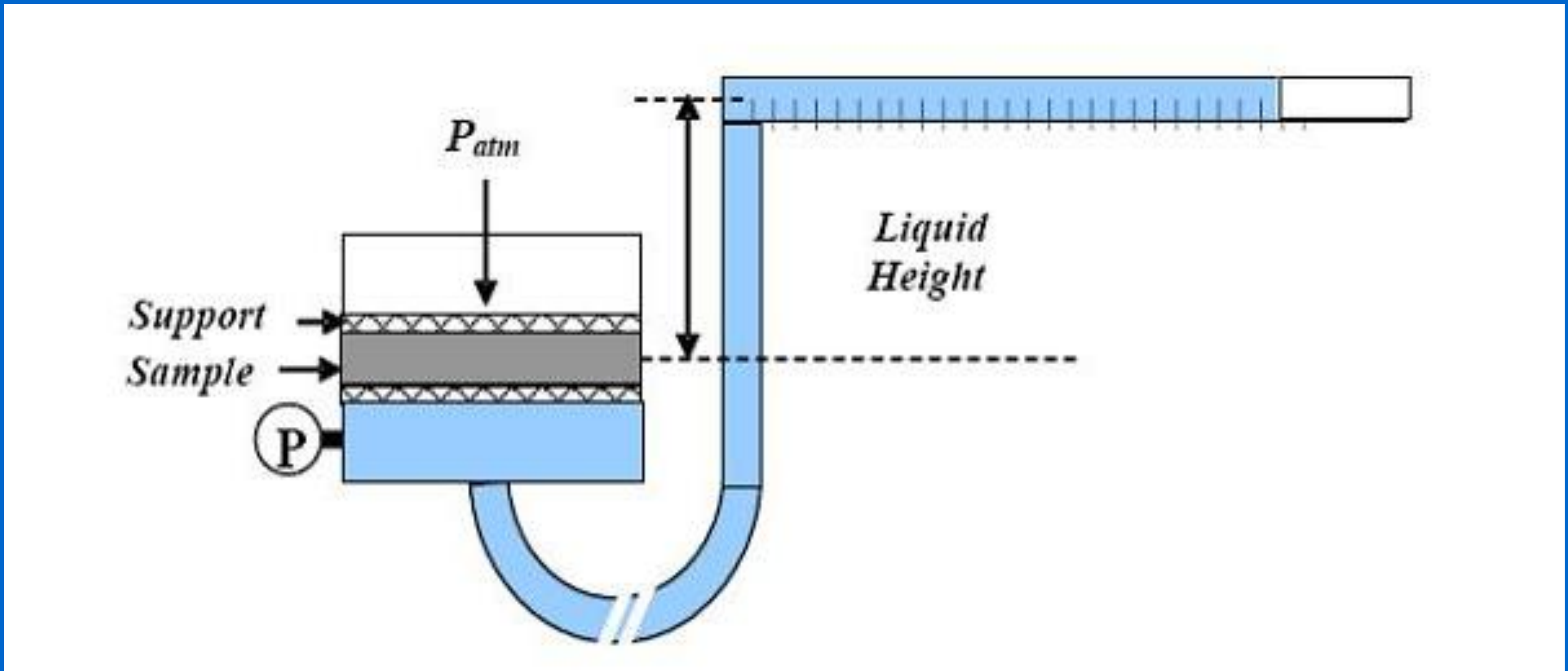
Water management in PEM fuel cells

- Too much water - blockage of gas flow paths
- Too little water – drying of membrane and reduced protonic conductivity
- At low current density – less water is formed
  - GDL must be able to hold water to prevent membrane drying
  - Need hydrophilic porosity with finer pore size
- At high current density – more water is formed
  - GDL must be able to drain and/or transport water quickly to prevent flooding
  - Need hydrophobic porosity with coarser pore size

Water transport properties of GDL

- Capillary pressure – water saturation relationship
  - High capillary pressure → small pore size and/or hydrophobicity
  - Larger hysteresis effect between water pick-up (imbibition) and drainage shows greater water holdup ability
- Gas Permeability – water saturation relationship
  - High permeability – larger pores, better water evaporation
  - Low permeability – smaller pores, slow water evaporation
  - Large difference between dry and wet media gas permeability show water hold up in GDL porosity

Capillary pressure measurements
by water displacement technique



Nguyen , et al., ECS Transactions, 3(1) 415-423 (2006)

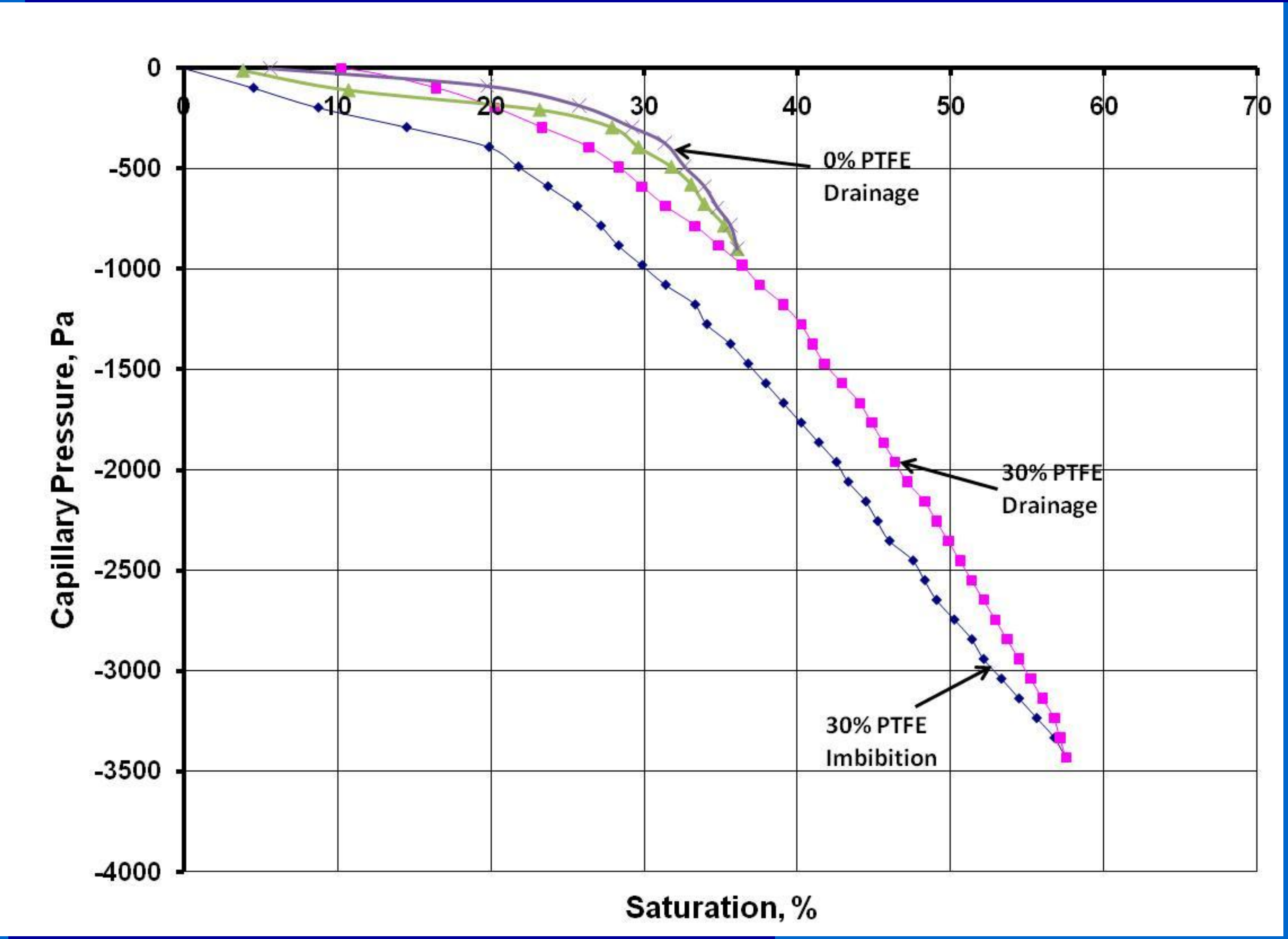
Capillary pressure measurements
by water displacement technique (cont.)

- 9 cm diameter media holder for ~ 1 - 2 cc pore volume
- 1 cc flow meter for displacement measurement
- For hydrophobic media a positive hydrostatic pressure must be applied to force water into the media
- A breakthrough pressure is first determined above which water flows continuously through the media
- Experiment is then repeated limiting the hydrostatic pressure for imbibition and drainage data
- Residual saturation measured after the experiment

Capillary Pressure Measurements

- Toray Paper
  - 0% Teflon loading (No MPL)
  - 30% Teflon loading (No MPL)
- SGL Carbon
  - 24 BC, 25 BC (~ 235 μm, MPL, 5% Teflon)
  - 34 BC, 35 BC (~ 320 μm, MPL, 5% Teflon)
  - 35 CC, 35 DC, 35 EC (10, 20, and 30% Teflon)

Capillary pressure - Toray paper

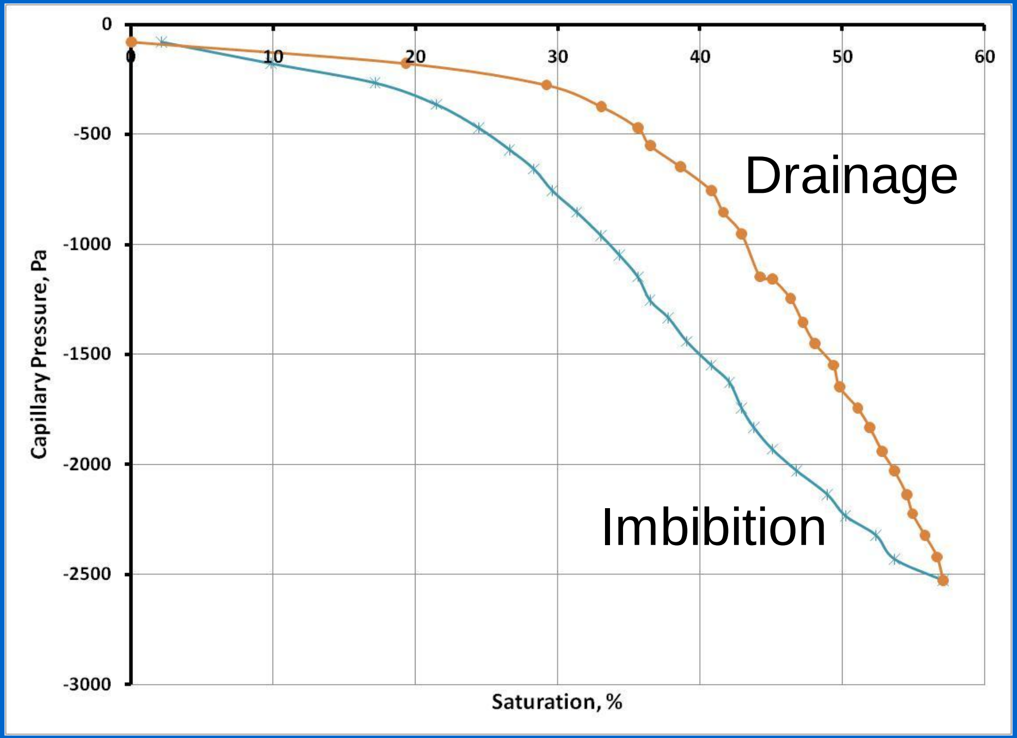


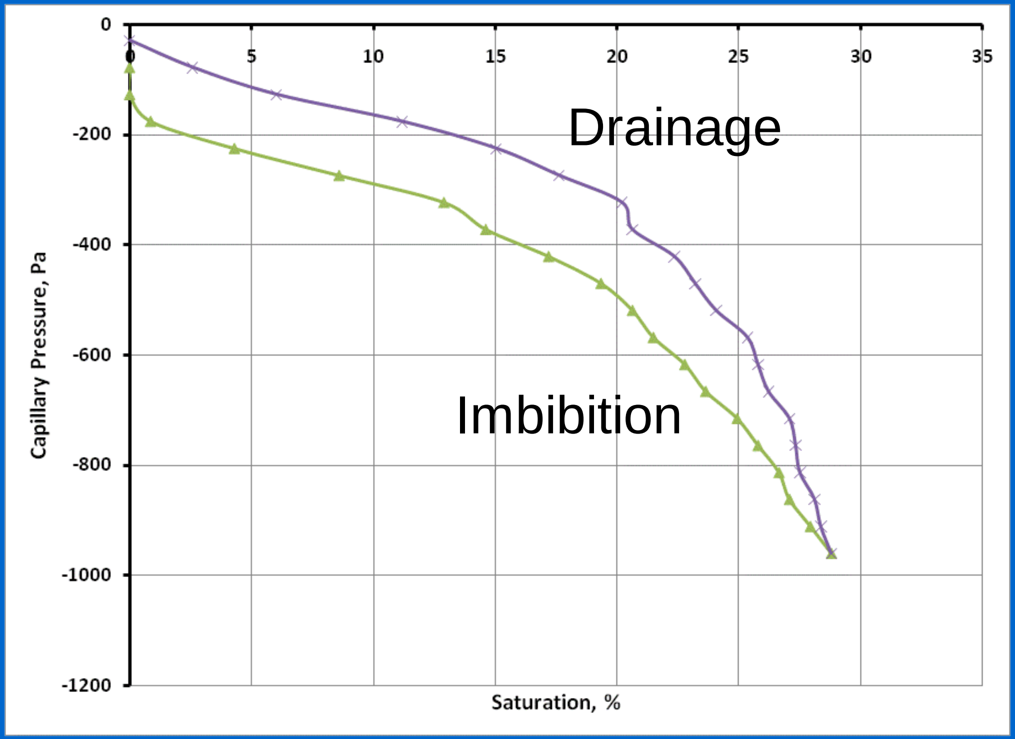
- Very little hysteresis with 0% PTFE paper
- High pressure needed for imbibition at 30% Teflon loading
- Saturation limited due to breakthrough of media

Capillary pressure – SGL Carbon GDL Media

- All media grades exhibited quick breakthrough when the MPL was facing incoming water
  - Hydrophilic MPL, low resistance of substrate
- 24BC and 34BC exhibited quick breakthrough regardless of orientation – finer pore size distribution
- Water breakthrough observed at isolated locations on GDL surface limiting water saturation of media
- All Teflonated grades (35BC, 35CC, 35 DC, and 35EC) required significant hydrostatic pressure for imbibition but no clear effect of Teflon content

Capillary pressure – SGL Carbon GDL Media



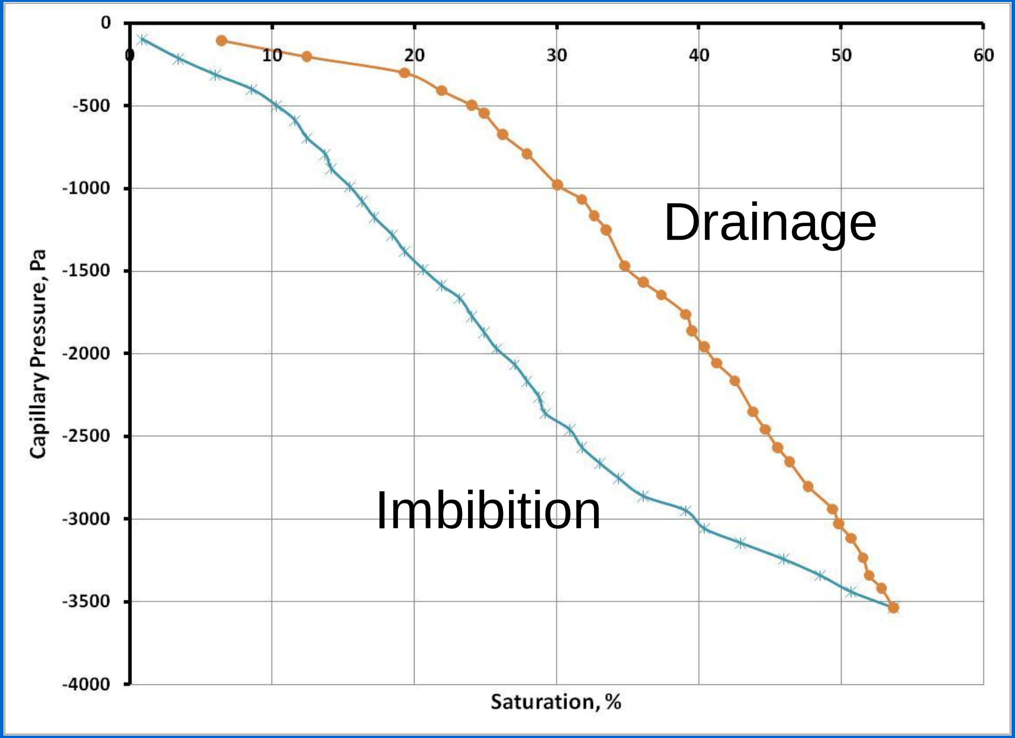


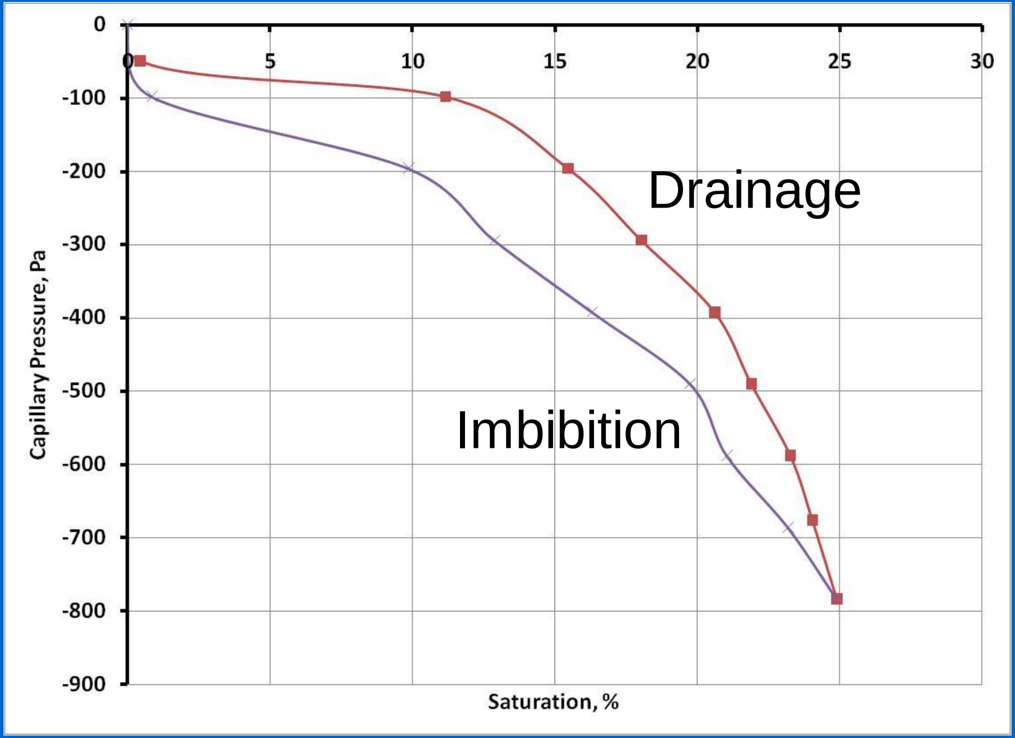
35 BC - 55% saturation , -2500Pa

35 CC - 28% saturation , -1000Pa

Breakthrough pressure depends on macropores in the media

Capillary pressure – SGL Carbon GDL Media



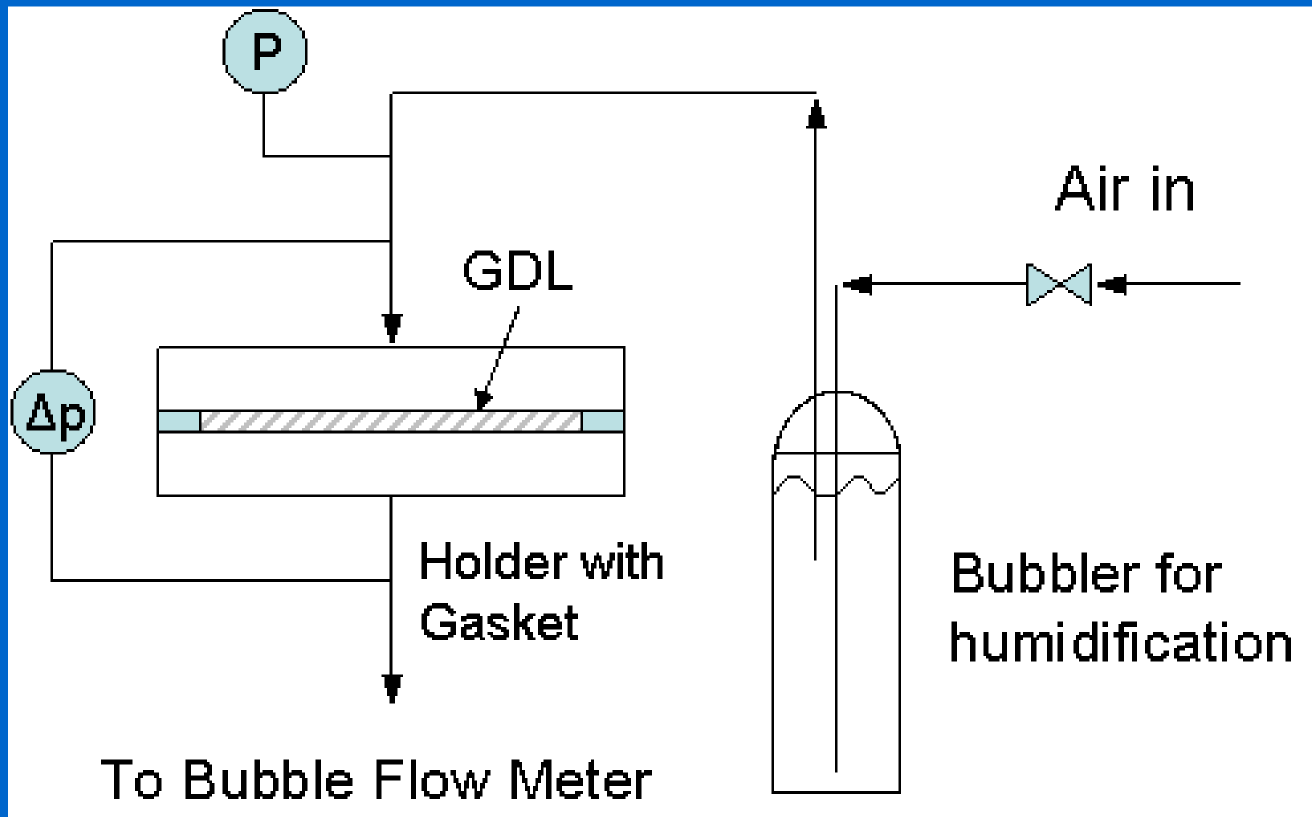


35 DC - 53% saturation, -3500Pa

35 EC - 25% saturation, -800Pa

Greater Teflon content appears to enhance hysteresis effect

Through-plane Permeability Measurements



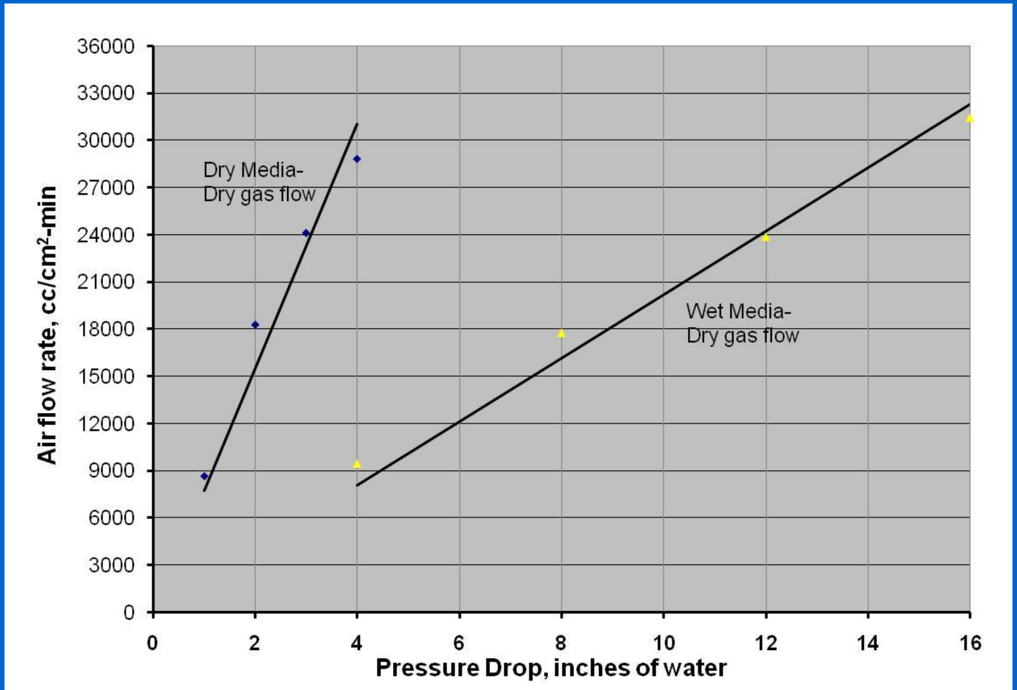
Through-plane Permeability Measurements

- Dry air permeability measured with dry GDL
- For wet permeability measurements GDL is initially filled with water under pressure. Humidified air is forced through media expelling some water. Steady state wet media air permeability is then determined with both humidified air and dry air.
- Very little difference in wet permeability of GDL with dry air or humidified air flow.
- Gas flow in wet media occurs through channels opened by water expelled from media with gas Δp.

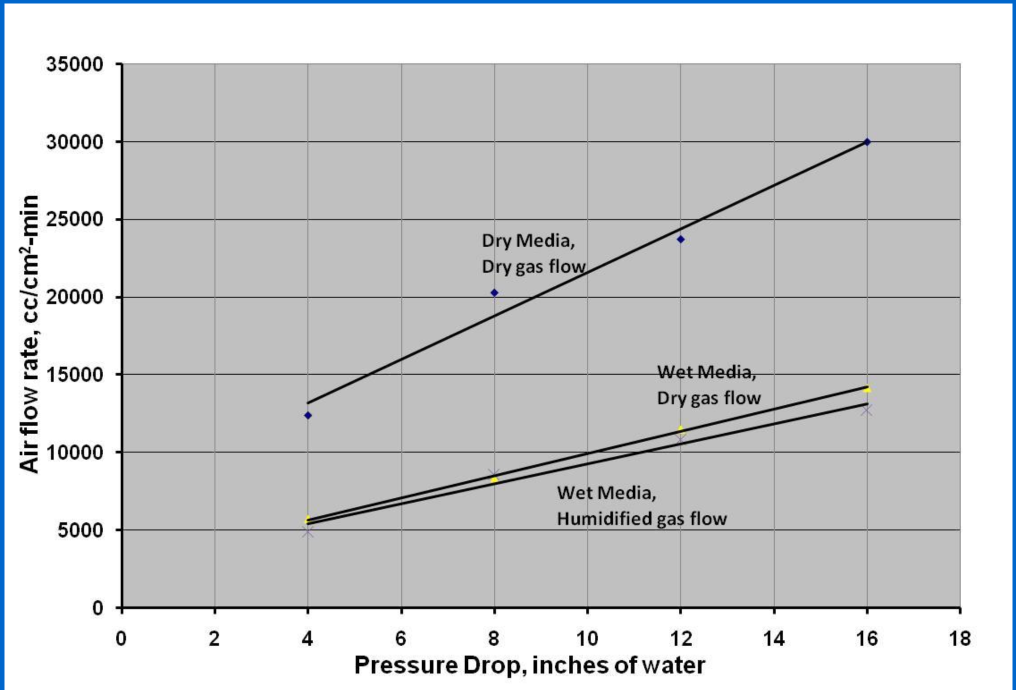
Gas permeability measurements of GDL media

- Toray Paper
  - 0% Teflon loading (No MPL)
  - 30% Teflon loading (No MPL)
- SGL Carbon
  - 24 BC, 25 BC (~ 235 μm, MPL, 5% Teflon)
  - 34 BC, 35 BC (~ 320 μm, MPL, 5% Teflon)
  - 35 CC, 35 DC, 35 EC (10, 20, and 30% Teflon)
- Toray paper exhibited much greater air permeability than SGL media due to lack of MPL

Gas permeability measurements – Toray Paper

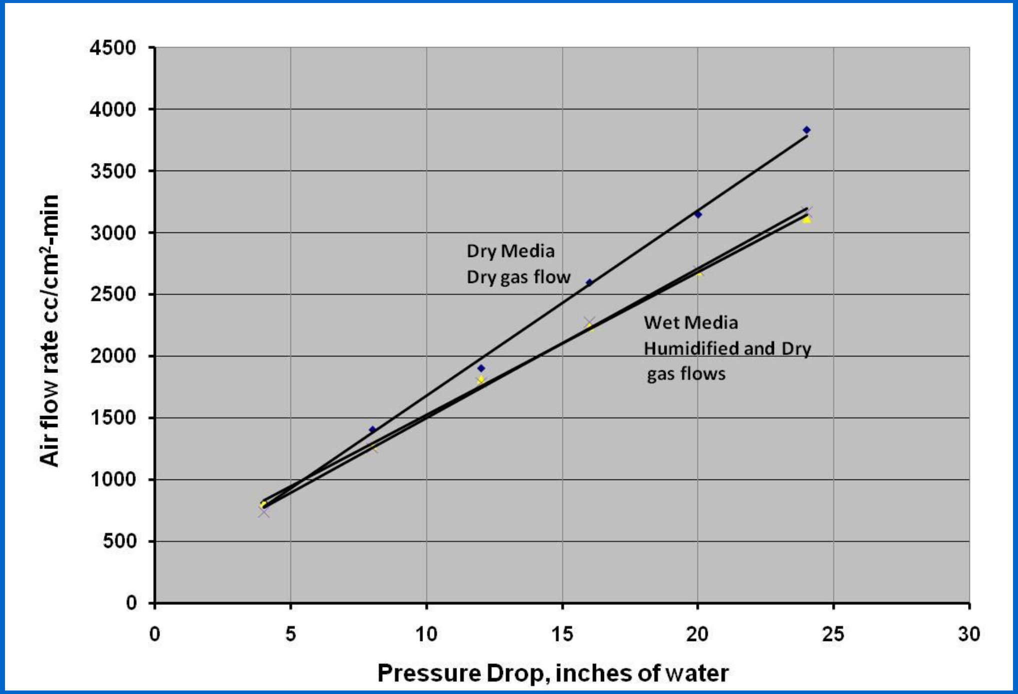


Toray paper 0% Teflon loading

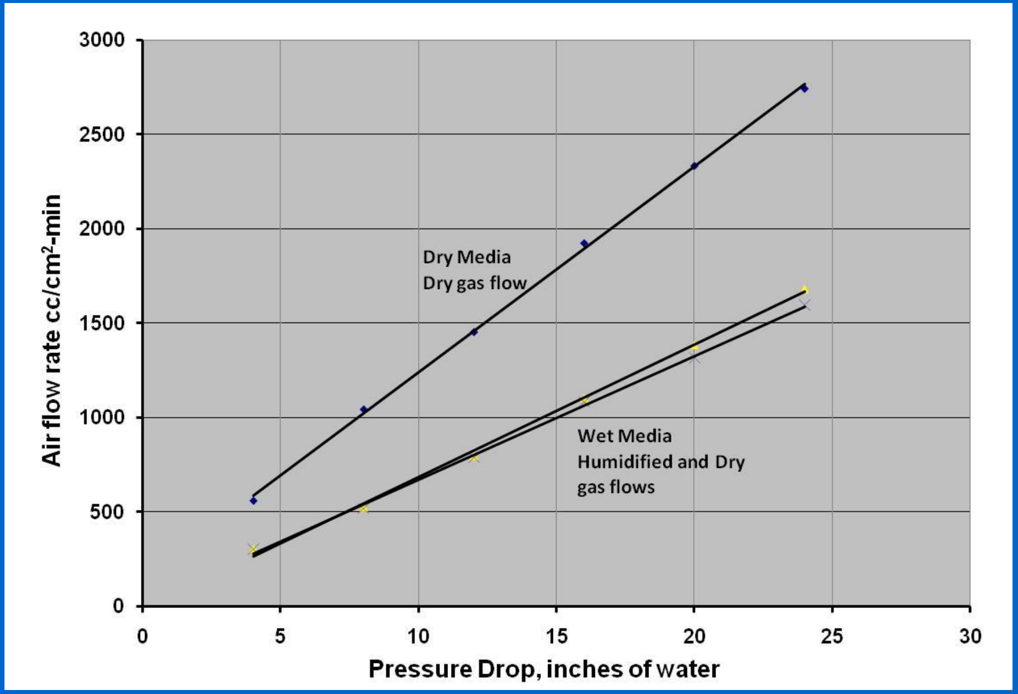


Toray paper 50% Teflon loading

Gas permeability measurements – SGL Media



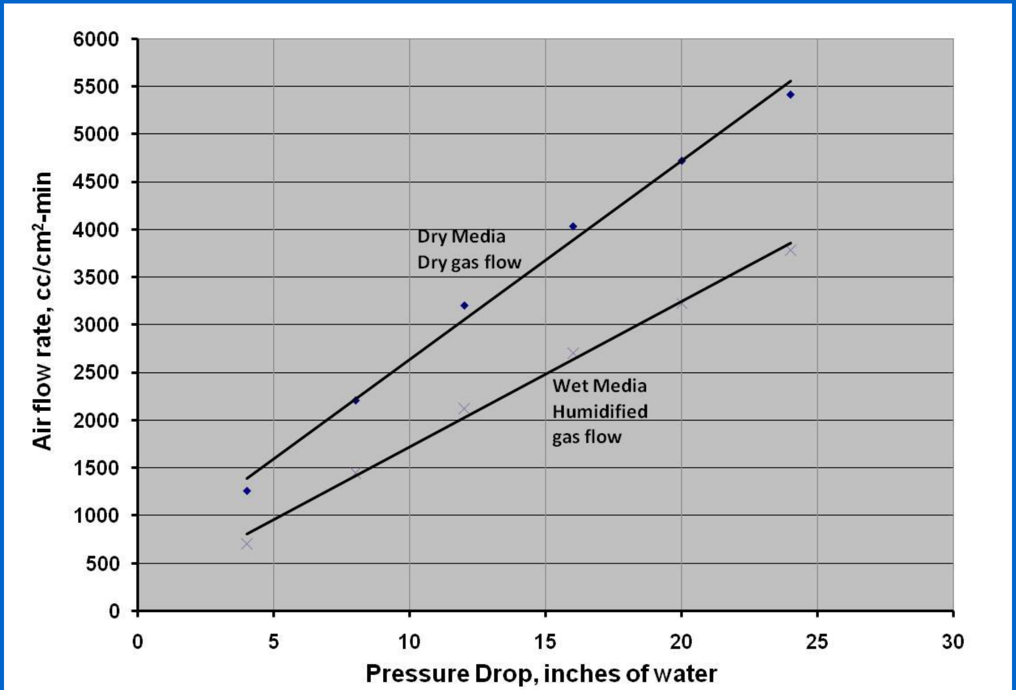
24 BC



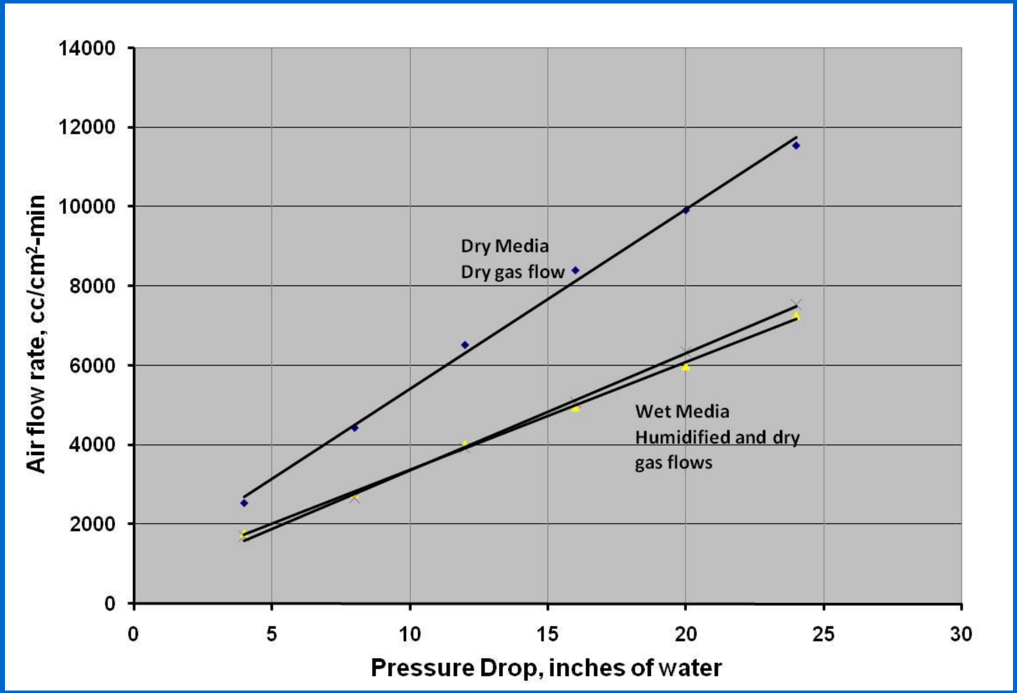
34 BC

These media are similar except for thickness as reflected here

Gas permeability measurements – SGL Media



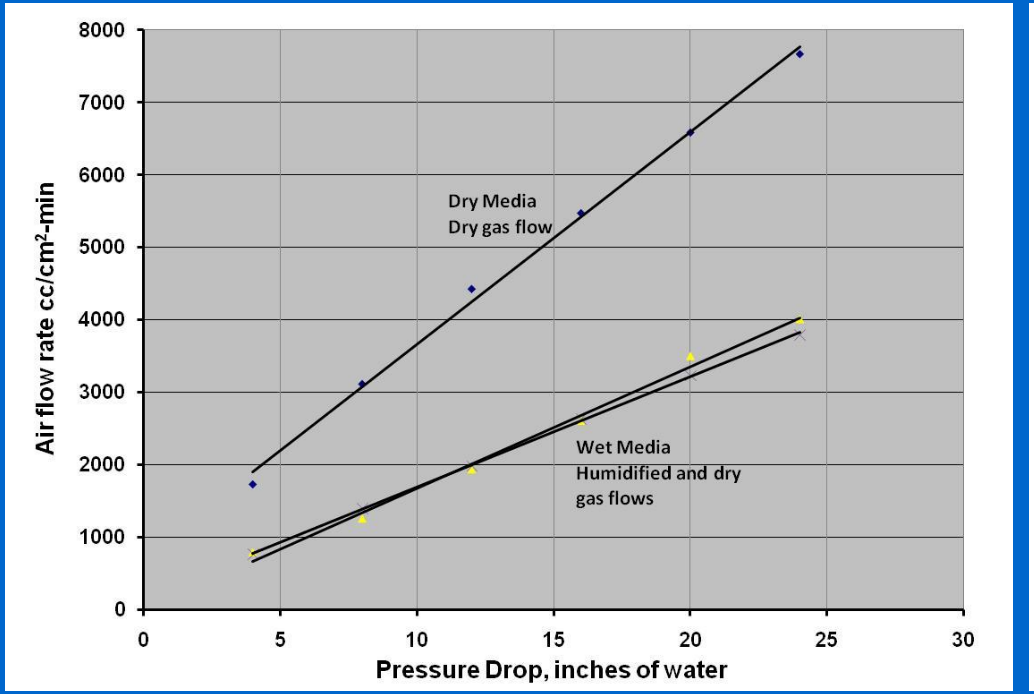
35 BC

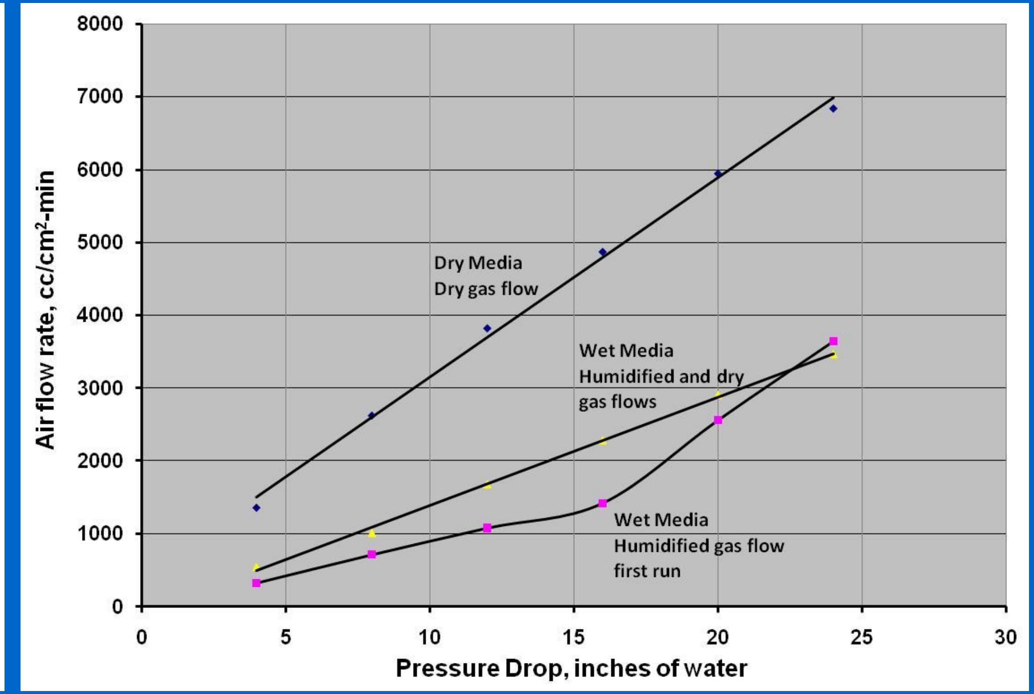


35 CC

The observed difference is consistent with capillary pressure data indicating earlier breakthrough for 35 CC media

Gas permeability measurements – SGL Media





35 DC **35 EC**

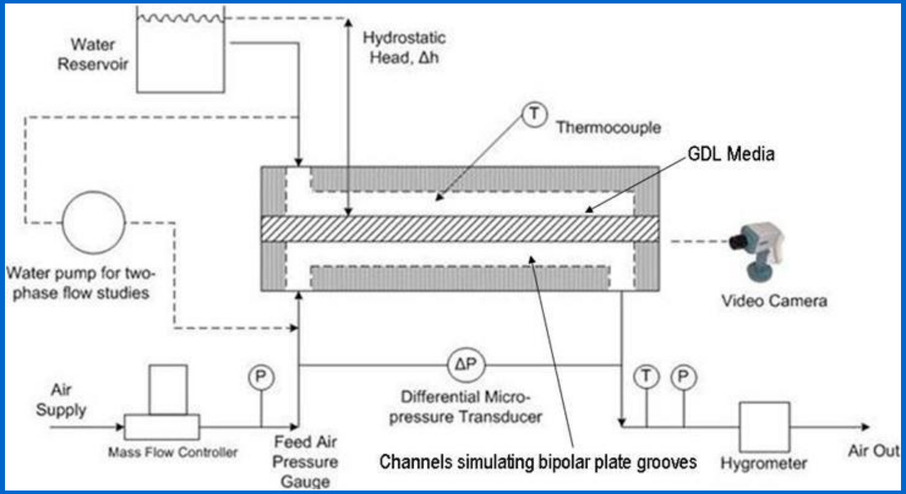
Reduction in air permeability in wet media correlates with Teflon content, increasing from 40% to 55% reduction with Teflon content 5% to 30%.

Results and Conclusions

- Capillary pressure and permeability correlations were determined for Toray and SGL media
- Inhomogeneous media pore structure leads to water breakthrough at isolated locations on GDL surface predominantly influencing water/gas transport
- All Teflonated grades (35BC, 35CC, 35 DC, and 35EC) required significant hydrostatic pressure for imbibition but no clear effect of Teflon content
- Reduction in air permeability in wet media correlates with Teflon content, increasing from 40% to 55% reduction with Teflon content 5% to 30%

Future activities

- Characterization and evaluation of blank GDL media with progressively increasing Teflonization
- Evaluation of catalyst layer water/gas transport behavior
- Thermal and electrical conductivity of components
- Visualization of water transport through cell components with ex-situ GDL/channel experiments
- In-plane permeability



Schematic of water transport Visualization apparatus

Acknowledgement

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