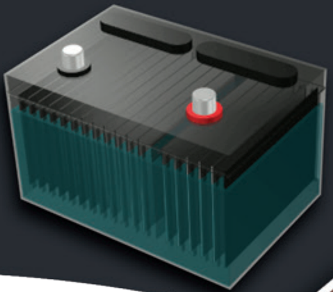
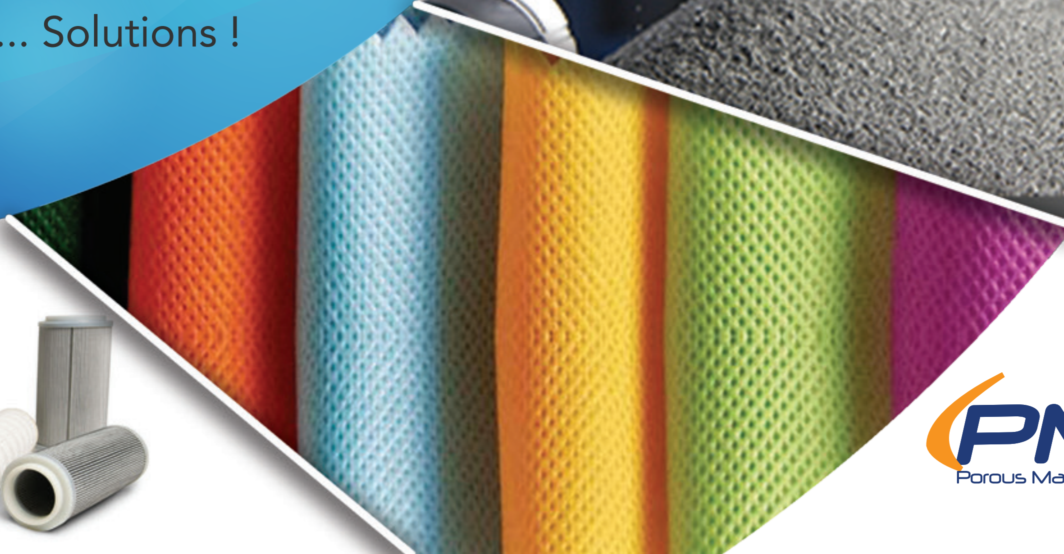


iPore™ series

Intelligent & Accurate Porometers

Not just products... Solutions !



PMI
Porous Materials, Inc.

*i*Pore Porometers

The *i*Pore is an advanced capillary flow porometer series, which yield accurate and reproducible data. The *i*Pore series porometers require minimal operator involvement with considerably small test durations. The *i*Pore porometers are designed for linear turbulence free flow of test gas, the pressure is measured closed to the sample thereby minimizing the correction in differential pressure measurement. *i*Pore series has six different models to suit varying pore size ranges and flow rates. Each model has appropriate measuring system with pressure control, sensing, acquisition and data analysis software, sample holders, various unique upgrade options, accessory and consumable kit.

*i*Pore Principle

*i*Pore is based on capillary flow porometry, where a non toxic wetting liquid is allowed to spontaneously fill the pores in the sample and a non reacting gas is allowed to displace liquid from pores. First the largest pores will get emptied, as they require lower pressure than smaller pores. As the pressure is increased, more and more smaller pores are progressively emptied. The pressure and flow rate of gas through the emptied pores provides the through pore distribution. The pressure at which through pores empty is inversely proportional to the pore size. Through pores (fig.1) are the pores connected from one side of material to the other side. *i*Pore capillary flow Porometer measures the pore throat diameter, which is the most constricted part of the entire pore path.

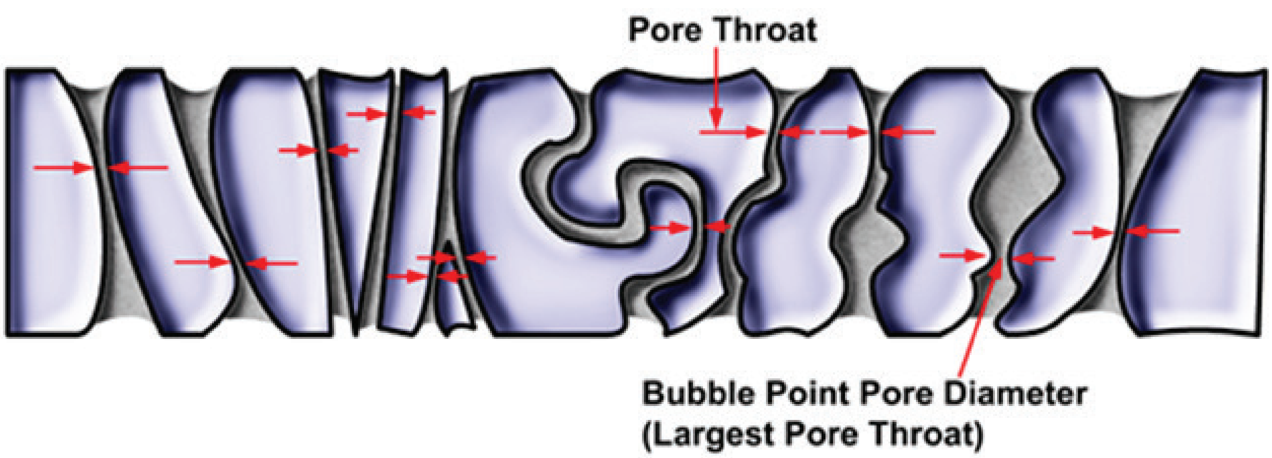


Fig.1 shows the through pores

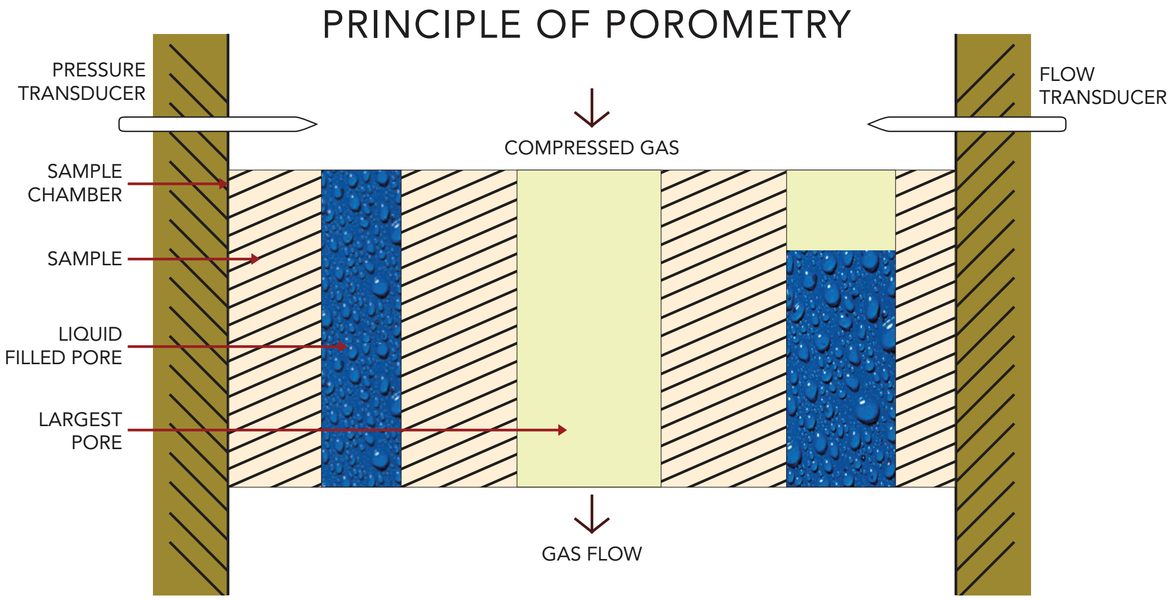


Fig. 2 Principle of Capillary Flow Porometry

Measurement Technique

The *i*Pore series capillary flow porometry allows the user to obtain several parameters and information in single measurement. Generally, a measurement with the wet sample (impregnated with wetting liquid) is carried out first. It is normally known as the "wet run" and the representation of the gas flow vs. the applied pressure i.e. "wet curve" is obtained. After the wet run the measurement of the same sample in dry state is carried out in order to register and analogous "dry curve". The half-dry curve is calculated and represented by dividing the flow values with respect to the applied pressure by 2 and it is also represented in the same graphic. From the representation of the three curves it is possible to identify relevant information about the sample: the maximum pore size (or first bubble point) is recorded when gas flow through the sample is detected, the mean flow pore size corresponds to the pore size calculated at the pressure where the wet curve and the half dry curve meet (it corresponds at the pore size at which 50% of the total gas flow can be accounted), and the minimum pore size results from the pressure at which the wet and the dry curve meet (from this point onwards the flow will be the same because all the pores have been emptied).

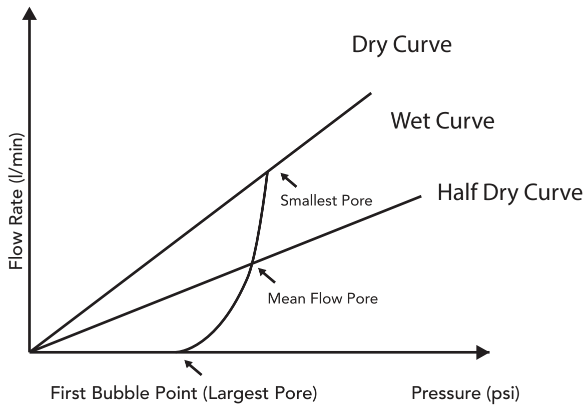


Fig.3 Parameters measured in porometry

Apart from these individual pore sizes, the same measurement permits the representation of the cumulative filter flow distribution vs the pore size, which provides information about the percentage of the cumulative total flow through the sample that goes through pores of a larger size than a certain value. Another information that can be obtained from the measurements is the corrected differential filter flow, which shows the flow distribution per unit of change in size, i.e. the increase in flow rate per unit increase in pore diameter. It is also defined as pore size distribution.

Pore Characteristics

Bubble Point

The Bubble point is one of the preliminary but important attributes measured by *i*Pore. The Bubble Point is defined by the **ASTM F-316-03** standard as the pressure at which the first continuous gas bubbles are detected, this measurement corresponds to the largest (or maximum) pore size. Besides Bubble Point, *i*Pore provides a comprehensive set of pore size and flow measurement to study the pore characteristics.

Pore Size

The pore size is calcultated using Washburn equation:

$$D = 4\,\gamma \cos\theta / p$$

Where:

D = pore diameter
γ = surface tension of liquid
θ = contact angle of liquid
p = differential gas pressure
From measured pressure and flow rates, the pore throat diameters, pore size distribution, and gas permeability are calculated.

Here the pore diameter is assumed to be that of a cylindrical pore, for membranes and other materials the appropriate pore shape factor is provided in the Capwin software , which is a multiplier to the Washburn equation.

Pore Distribution

Pore distribution is calculated by

$$f = -d[(fw/fd)x100]/dD$$

Where:
fw = flow rate through wet sample
fd = flow rate through dry sample

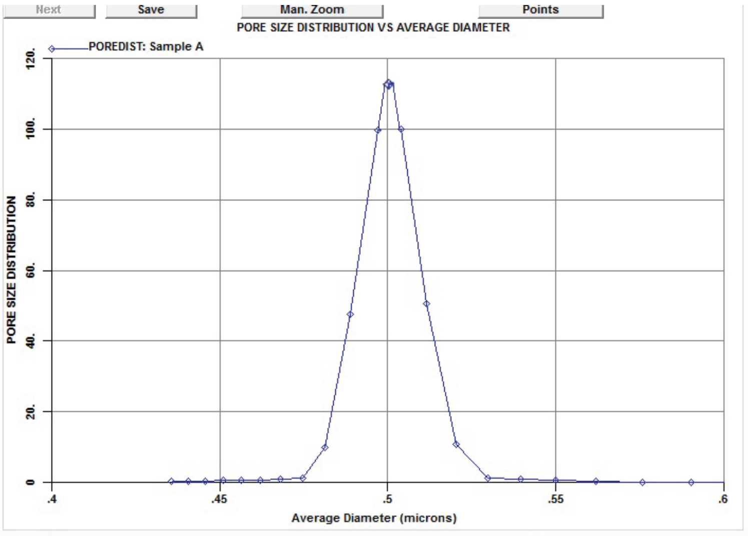


Fig.4 Pore size distribution

Pore Flow % Distribution

Pore Flow % Distribution also known as Pore size frequency is defined by ASTM Designation F 316-86 is the percentage flow through pores in a given size range.

% Flow through wet sample at pressure $p_j = (F_{w,j} / F_{d,j} \times 100)$

% Flow through wet sample at pressure $p_{j+1} = (F_{w,j+1} / F_{d,j+1} \times 100)$

% of flow through pores of diameter between D_j and $D_{j+1} = [(F_{w,j+1}/F_{d,j+1} \times 100)] - [(F_{w,j}/F_{d,j} \times 100)]$

Percentage flow through pores calculated in this manner from data in Fig.5(a) is presented as pore size frequency in Fig.5(b).

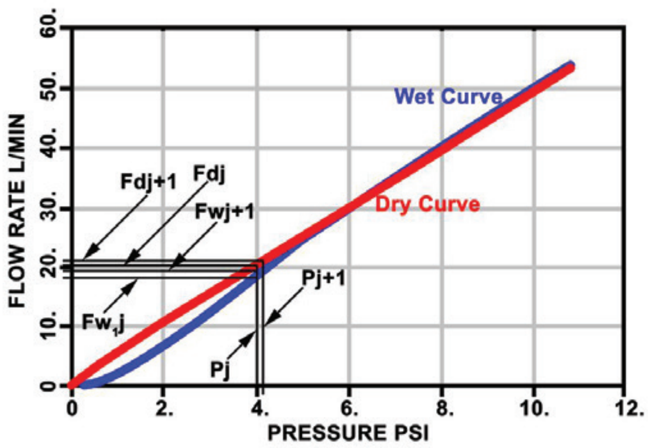


Fig.5 (a) Wet and dry curves showing flow rates at two consecutive readings.

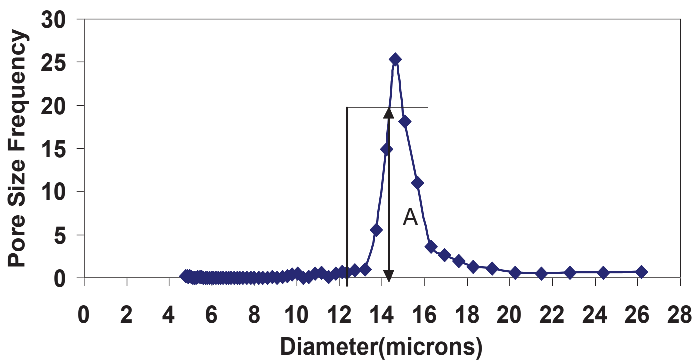


Fig.5 (b) Pore size frequency

Pore Density

Pore Density can be expressed in terms of fractional pore number distribution, f_N

$$f_N = d[(N_j / \Sigma^{\infty}_{j} N_j)]/dD$$

$$= [(f_{j+1} / \Sigma^{\infty}_{j} f_j) \times 100 - (f_j / \Sigma^{\infty}_{j} f_j) \times 100]/[-(D_{j+1} - D_j)]$$

The area under the fractional pore number distribution function in a pore diameter range gives the percentage of pores in that diameter range.

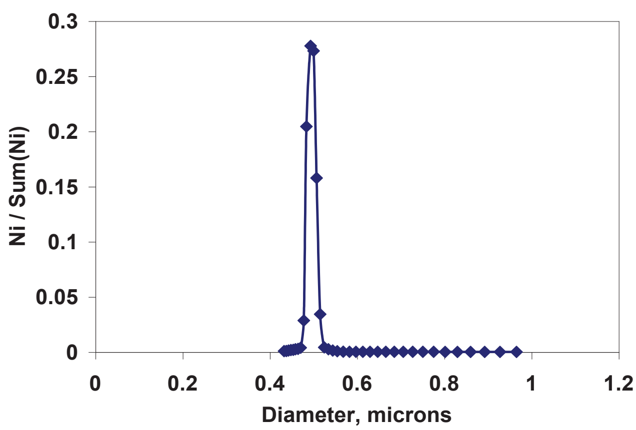
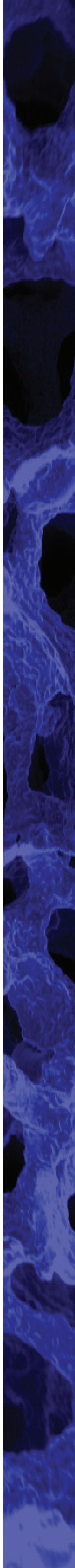


Fig.6 Pore fraction distribution

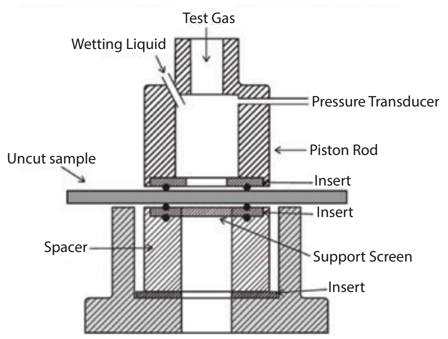


SPECIFICATIONS

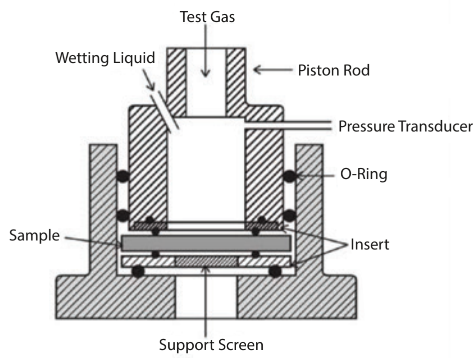
MODEL	iPore ™ 1020	iPore ™ 1050	iPore ™ 1100	iPore ™ 1200	iPore ™ 1300	iPore ™ 1500
Standards	ASTM 316, others also	ASTM 316, others also	ASTM 316, others also	ASTM 316, others also	ASTM 316, others also	ASTM 316, others also
Measuring Principle	Flow	Flow	Flow	Flow	Flow	Flow
Pore Size (min)	0.3 µm	0.1 µm	0.06 µm	0.03 µm	0.02 µm	0.013 µm
Pore Size (max)	200 µm (upto 500um with X option)	100 µm (upto 500um with X option)	80 µm (upto 500um with X option)	80 µm (upto 500um with X option)	80 µm (upto 500um with X option)	80 µm (upto 500um with X option)
Pressure Range Accuracy ±0.05% of FS	20 psi	50 psi	100 psi	200 psi	300 psi	500 psi
Sample Size Standard	0.25″-2.5″ dia upto 1.5″ thick 5mm to 60mm dia upto 40mm thick	0.25″-2.5″ dia upto 1.5″ thick 5mm to 60mm dia upto 40mm thick	0.25″-2.5″ dia upto 1.5″ thick 5mm to 60mm dia upto 40mm thick	0.25″-2.5″ dia upto 1.5″ thick 5mm to 60mm dia upto 40mm thick	0.25″-2.5″ dia upto 1.5″ thick 5mm to 60mm dia upto 40mm thick	0.25″-2.5″ dia upto 1.5″ thick 5mm to 60mm dia upto 40mm thick
Large or Small Sample Size	On request	On request	On request	On request	On request	On request
Sample Geometries* *Sample holder selection required	Sheets, rods, tubes, hollow fiber, cartridge, powder, etc	Sheets, rods, tubes, hollow fiber, cartridge, powder, etc	Sheets, rods, tubes, hollow fiber, cartridge, powder, etc	Sheets, rods, tubes, hollow fiber, cartridge, powder, etc	Sheets, rods, tubes, hollow fiber, cartridge, powder, etc	Sheets, rods, tubes, hollow fiber, cartridge, powder, etc
Flow Rate	200SLPM, others available on request	200SLPM, others available on request	200SLPM, others available on request	200SLPM, others available on request	200SLPM, others available on request	200SLPM, others available on request
Flow Resolution	1 in 60,000	1 in 60,000	1 in 60,000	1 in 60,000	1 in 60,000	1 in 60,000
Pressure Sensors Solid state temperature compensated	Upto 4	Upto 4	Upto 4	Upto 4	Upto 4	Upto 4
Pressure Regulator Switch	Auto	Auto	Auto	Auto	Auto	Auto

FEATURES

- 16 bit A/D Pressure sensor resolution
- Temperature compensated linear thermal mass flow sensor(upto 2 flow sensors)
- Flow sensor settling time of < 1 sec
- Flow sensor temperature coefficient (SPAN/ZERO) of < 0.05%/°C(15-60°C)
- Testing of small samples as well as complete parts
- Any sample geometry (Example: sheets, rods, tubes, hollow fibers, cartridges & powders) can be used with selection of appropriate sample holders (options available)
- Any nonwetting liquid
- Tests in QC, research or any number of user defined modes
- Real time graphic display
- Window based software for all control, measurements, data collection, data reduction and report preparation
- Automatic piston movement to close the chamber while starting the test
- Region of interest doesn't change due to automatic piston movement
- Measurement of pressure close to the sample to minimize pressure drop correction
- Straight flow path avoiding turbulence
- Versatile sample chamber for a variety of samples and test modes
- Pore Structure ctharacteristics:
    - Mean Pore Size
    - Pore Size Distribution
    - Pore Flow % Distribution
    - Pore Number Distribution
    - Bubble Point (the largest through pore throat diameter)
    - Bubble Point Mean flow pore diameter (50% of flow is through pores smaller than the mean flow pore)
    - Pore Surface Area
    - Gas Permeability in many desired units including Frazier, Gurley, Rayl & Darcy
    - Liquid Permeability
    - Diameter of the most constricted part of a through pore (Pore throat)
    - Unlimited Data Points



Sample Chamber



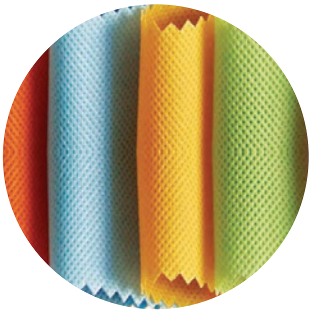
Sample Chamber with Spacer

Fig.7 Sample Chamber

APPLICATIONS

- Filtration Industry

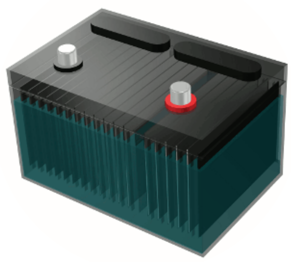
- Geotextiles/Textiles Industry



- Nonwovens Industry

- Paper Industry

- Pharmaceutical/Medical Industry



- Battery/Fuel Cells Industry

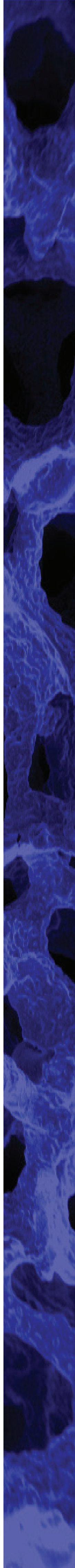
- Powder Metallurgy Industry

- Chemical Industry

- Biomolecular Engineering

- Ceramic Industry

- Automotive Industry



SOFTWARE

We work closely with our customers to provide the most user friendly software for porometery. PMI Capwin software is updated to meet customer needs & requirements. The comprehensive software can be used for all PMI porometers. The software is customized to offer convenient operation with default settings for beginners and full access to all relevant measuring parameters for advanced researchers.

- Capwin manages manual instrument control, automated measuring routines and report print out or graph
- Capwin Data manager for interactive evaluation of measured data as well as providing sophisticated tools for creating reports & generating templates for graphs, tables and screen views
- Capwin user manager for comprehensive user management regarding user access control
- Remote diagnostic from anywhere in the world
- Links to databases, outputs to: MS Excel, Text files, and other formats upon request
- User defined paths and sub directories for data filling

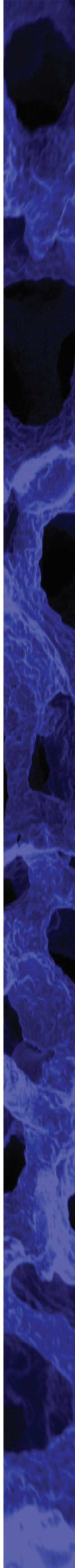
SALES & SERVICE

We at Porous Materials Inc., have dedicated sales team helping thousand's of our customers identify the right solution for their scientific problems. We are also proud to offer customized instruments for your unique needs. Our service and applications team is committed to effective support with short response times, we offer comprehensive range of solutions from new and customized systems, calibration and maintenance to testing services.
Explore more about us at www.pmiapp.com

*Disclaimer: *We are continously improving our products,*
Design is subject to change without prior notice.

Additional function:

-X	Extended Range (Extra Pressure Gauge): up to 4 set pressure gauge
-P	Pneumatic clamp-on device
-E	Extended Accuracy (Extra Flow Meter): up to 4 set Flow meter
-I	Integrity Test
-S	Surface Area/ Fiber Diameter
-CR	Chemical Resistance Option (KOH)
-L	Liquid Permeability (Penetrometer Type)
-ALD	Automated Wetting Liquid Dispenser
-TL	High Temperature for Liquid Permeability
-TG	High Temperature for Gas Permeability
-F	Frazier Permeability
-G	Gurley Permeability
-R	Rayles Permeability
-M	Sheffield Smoothness Test
-N	In-Plane
-CC	Cyclic Compression Test
-C	Compression Test
-HC	Bubblers with Humidity Control
-B	Burst Pressure Test
-H	Hydrohead Test
-D	Microflow (Low Flow)
-HF	High Flow (up to 2,000 L/min)



PMI PUBLICATIONS

Review Papers

Advances in Pore Structure Evaluation by Porometry: Akshaya Jena and Krishna Gupta. Chemical Engineering & Technology journal, Aug 2010

Characterization of Pore Structure of Filtration Media: Akshaya Jena and Krishna Gupta. Fluid Particle Separation Journal, Vol. 4, No.3, 2002, pp. 227-241

Liquid Extrusion Techniques for Pore Structure Evaluation of Nonwovens: Akshaya Jena and Krishna Gupta. International Nonwovens Journal, Fall, 2003, pp. 45-53

Advances in Characterization Techniques: Krishna Gupta. Oral Presentation, 2004

Characterization of Pore Structure: Foundation - Akshaya Jena. Oral Presentation, 2004

Filtration Media and Membrane Industry

Criteria for Selection of Pore Structure: Characterization Techniques for Filtration Media- Dr. Akshaya Jena & Dr. Krishna Gupta. Apr. 2011

Cake Forming Porometer: Advanced Technology for Evaluation of Filtration Media - Dr. Akshaya Jena & Dr. Krishna Gupta. Achema, 2010

Characterization of Pore Structure of Nanopore Membranes: Dr. Akshaya Jena & Dr. Krishna Gupta. Achema, 2009

Homogeneity of Pore Structure Characteristics of Filtration Cartridges: Dr. Akshaya Jena and Dr. Krishna Gupta

Advanced Technology for Evaluation of Pore Structure Characteristics of Filtration Media to Optimize Their Design and Performance: Akshaya Jena and Krishna Gupta. Short Course, Filtration, 2002

Characterization of the Pore Structure of the Complete Filter Cartridges: Using High Flow Porometry - Akshaya Jena and Krishna Gupta. AFS Topical Conference, 2004

Recent Advances in Techniques for Porosity Characterization of Membranes: - Akshaya Jena and Krishna Gupta. Conference Proceedings, The Membrane Society of Korea, 2005

Characterization of Water Vapor Permeable Membranes: Akshaya Jena and Krishna Gupta. Desalination, Vol. 149, 2002, pp. 471-476

Characterization of Pore Structure of Filtration Media Containing Hydrophobic and Hydrophilic Pores: Akshaya Jena and Krishna Gupta. AFS 16th Annual Meeting, 2003

Homogeneity of Pore Structure of Filtration Media: Akshaya Jena and Krishna Gupta. AFS 15th Annual Technical Meeting, 2002

Use of Multiple Test Techniques For Evaluation of Complex Pore Structure: Akshaya Jena and Krishna Gupta. AFS 15th Annual Technical Meeting, 2002

Characterization of Depth Filtration Media: Tamara Nicholson, Akshaya Jena, and Krishna Gupta. 9th WFC Proceedings, 2004

Textiles, Geotextiles, and Fibers Industry

Pore Structure of Advanced Textiles: Dr. Akshaya Jena & Dr. Krishna Gupta

A Novel Technique for Determination of Vapor Transmission Rate through Textiles: Akshaya Jena and Krishna Gupta. Journal of Industrial Textiles, Vol. 31, No. 4, April 2004, pp. 273-281

In-Plane and Through-Plane Porosity in Coated Textile Materials: Akshaya Jena and Krishna Gupta. Journal of Industrial Textiles, Vol. 29, No. 4, April 2000, pp. 317-325

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