

Celebrating



of solutions

Porous Materials, Inc. is the leading designer and manufacturer of custom scientific instruments for characterization of porosity, pore diameter, pore volume, pore surface area, liquid permeability, gas permeability, density, and integrity testing. PMI also provides consulting services to seek out solutions for characterization of porosity and analysis of porosity. The testing services division of PMI offers contract testing services for a wide variety of tests.



CAPILLARY FLOW POROMETER



Not just products...solutions.

Principle

A wetting liquid is allowed to spontaneously fill the pores in the sample and a nonreacting gas is allowed to displace liquid from the pores. The gas pressure and flow rates through wet and dry samples are accurately measured. The gas pressure required to remove liquid from the pores and cause gas to flow is given by

$$D = 4 g \cos q / p$$

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

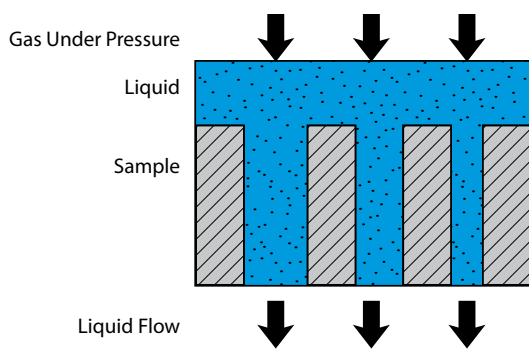


Figure 1

Principle of liquid permeability test

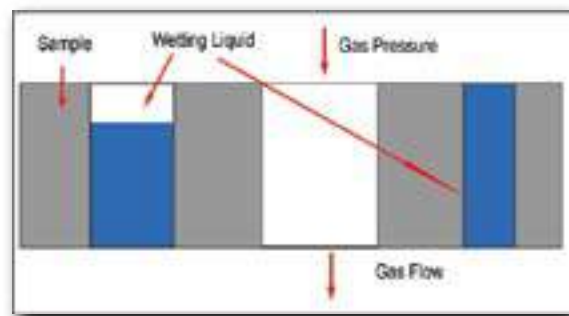


Figure 2

Basic principle behind analyzing pore structure

Description

The PMI Capillary Flow Porometer is used for R&D and quality control in industries worldwide such as filtration, nonwovens, pharmaceutical, biotechnology, healthcare, household, food, hygienic products, fuel cell, water purification, and battery. Samples often tested include filter media, membranes paper, powders, ceramics, battery separators and health care products.

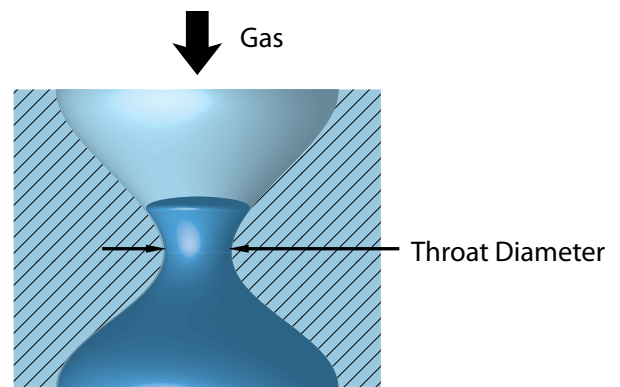


Figure 3

Typical pore analysis procedure

Application

Advanced Capillary Flow Porometers yield very objective, accurate and reproducible results, considerably reduce test duration, and require minimal operator involvement. Advanced Porometers are fully automated and are designed for linear turbulence-free test gas flow. The pressure is measured close to the sample and therefore, the correction term in the differential pressure measurement is minimized. Required amount of pressure is uniformly

applied on the o-ring seals on the sample and the need for hand tightening the cap on the sample chamber to apply pressure on the o-ring is eliminated. Automatic addition of wetting liquid reduces test time appreciably. This sophisticated instrument has found applications in a wide variety of industries.

Testing Capabilities

- Diameter of the most constricted part of a through pore (pore throat)
- Mean flow pore diameter (50% of flow is through pores smaller than the mean flow pore)
- Pore diameter range)
- Pore distribution:
 $f = -d[(f_w/f_d) \times 100] / dD$
f_w = flow rate through wet sample
f_d = flow rate through dry sample

Optional Features

- Liquid Permeability: Measuring liquid flow rate through the sample when pressure is applied on excess liquid on the sample. Volume of liquid measured using a penetrometer.
- Pressure hold test
- Hydro-head (break through pressure) test
- Integrity test
- Envelope surface area, average particle size and average fiber diameter obtained from gas flow rate through dry sample
- Multiple sample chamber
- Multiple test mode
- Shuffled smoothness test
- Burst pressure test
- Use of desired fluid including strong chemicals
- Elevated temperature test

Multi-Mode Instruments

- QC, Clamp-On, In-Plane, and Compression modes may be combined
- In-Plane test permits measurement of pore in the x-y plane
- In-Plane test permits insitu determination of pore diameter and structure of each layer of the multi-layer media

Features

- Testing of small samples as well as complete parts
- Any sample geometry (Example: sheets, rods, tubes, hollow fibers, cartridges, & powders)
- Any nonwetting liquid
- Tests in QC, research, or any number of user defined modes
- See-through sample chamber for visual observation of test available
- Real time graphic display
- Window based software for all control, measurement, data collection, data reduction, and report preparation

Specifications

- Pressure Accuracy: 0.15% of reading
- Test Pressure: 100, 200, and 500 psi instrument versions (700, 1400, 3500 kPa instrument versions)
- Pressure & Flow Resolution: 1/60,000 of full scale (1 part in 60,000)
- Maximum Pore Size Detectable: 500 μm
- Minimum Pore Size Detectable: Varies with intrusion liquid (see fig. 5)
- Flow Rates: Up to 200 SLPM (liters per minute)
- Sample Sizes:
 - Standard: 0.25" - 2.5" diameter (up to 1.5" thick)
 - Standard: 5 mm - 60 mm diameter (up to 40 mm thick)
 - Others available
- Sample Geometry: Sheets, Rods, Tubes, Hollow Fibers, Cartridges, Powders

Fluid	Surface Tension dynes/cm	Diameter μm (100 psi Porometer)	Diameter μm (200 psi Porometer)	Diameter μm (500 psi Porometer)
Water	72	0.30	0.15	0.06
Mineral Oil	34.7	0.14	0.07	0.03
Petroleum Distillate	30	0.12	0.06	0.03
Denatured Alcohol	22.3	0.09	0.05	0.02
Silwick	20.1	0.08	0.04	0.02
Porewick	16	0.07	0.03	0.014
Galwick	15.9	0.07	0.03	0.014

Figure 5

Intrusion Liquid Chart

Specifications

Parameters	CFP 1100A	CFP 1200A	CFP 1300A	CFP 1500A
Standards	ASTM F3t6, others on request	ASTM F3t6, others on request	ASTM F3t6, others on request	ASTM F3t6, others on request
Measuring principle	Flow	Flow	Flow	Flow
Pore size min	0,06 microns	0,06 microns	0,06 microns	0,06 microns
Max	500 microns	500 microns	500 microns	500 microns
Pressure range	100 psi	200 psi	300 psi	500 psi
Sample size standard (1.5"/40mm thick)	0.25"-2.5' dia	0.25"-2.5' dia	0.25"-2.5' dia	0.25"-2.5' dia
	5 mm to 60 dia	5 mm to 60 dia	5 mm to 60 dia	5 mm to 60 dia
Unique Sample Chamber	On request	On request	On request	On request
Sample geometries, (optional)	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	200 SLPM, others available on request	200 SLPM, others available on request	200 SLPM, others available on request	200 SLPM, others available on request
Flow resolution	1 in 60,000	1 in 60,000	1 in 60,000	1 in 60,000
Pressure controller	Up to 4, each controller to be selected based upon application	Up to 4, each controller to be selected based upon application	Up to 4, each controller to be selected based upon application	Up to 4, each controller to be selected based upon application
Pressure sensors	Up to 4	Up to 4	Up to 4	Up to 4
Pressure regulator switch	Auto	Auto	Auto	Auto

Special Features

Adjustable pressure on O-rings through pneumatically controlled piston-cylinder device

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

Sales & Services

Our sales team is dedicated to helping our customers find which machine is right for their situation. We also offer custom machines for customers with unique needs. To find out what we can do for you, contact us.

We are committed to customer support including specific service products, short response times & customer specific solutions. To quickly & flexibly meet our customer's requirement, we offer a comprehensive range of services.



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Bubble Point Tester
Capillary Condensation Flow Porometer
Capillary Flow Porometer
Clamp-On Porometer
Complete Filter Cartridge Analyzer
Compression Porometer
Custom Porometer
Cyclic Compression Porometer
Diffusion Permeameter
Envelope Surface Area Analyzer
Filtration Media Analyzer
Gas Permeameter
Gas Pycnometer
High Flow Porometer
In-Plane Porometer

Liquid Extrusion Porosimotor
Liquid Permeameter
Integrity Analyzer
Mercury Pycnometer
Mercury/Nonmercury Intrusion Porosimotor
Microflow Porometer
Nanopore Flow Porometer
Quality Control Porometer
Vacuapors
Vapor Permeameter
Water Intrusion Porosimotor (Aquapore)
Water Vapor Transmission Analyzer

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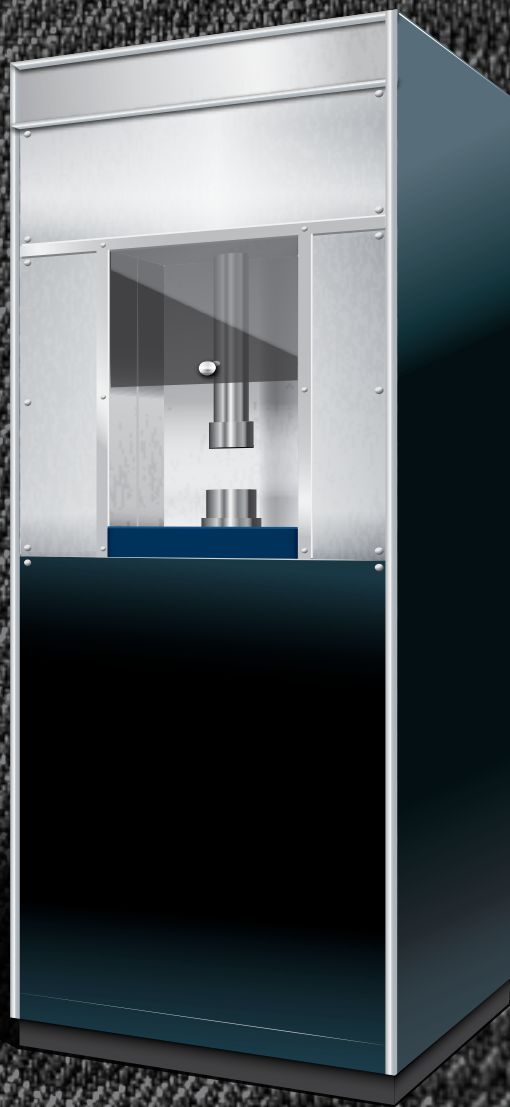


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GAS HELIUM POROSIMETER



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Principle

The Helium Porosimeter is used to measure porosity and gas permeability of samples. Fluid is allowed to axially pass through the sample. The machine measures drop in pressure and flow rate through the sample during the test. PMI software uses Darcy's Law to compute permeability. A known amount of gas is allowed

to expand in the sample chamber. Using the Ideal Gas Law, the porosity is computed from the loss in pressure.

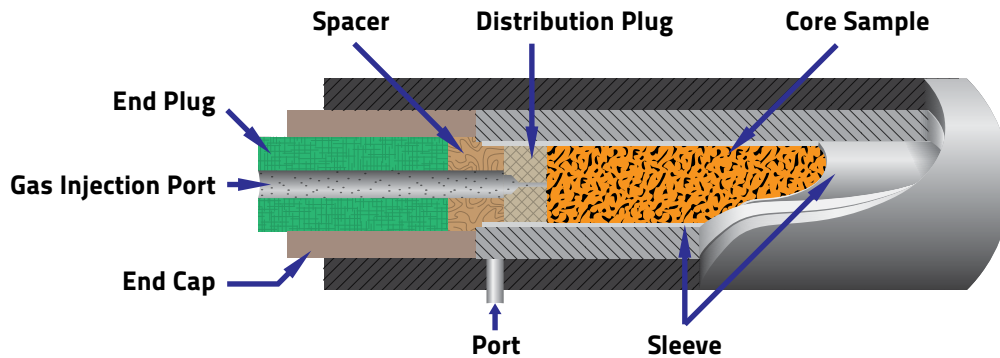


Figure 1

Core holder and sample chamber

Description

A rock sample is held in the sample chamber and compressive stress is applied. While the sample is under compressive stress, the desired properties are measured. Porosimeter & Permeameter is used to determine the properties of cut samples at certain confining pressure.

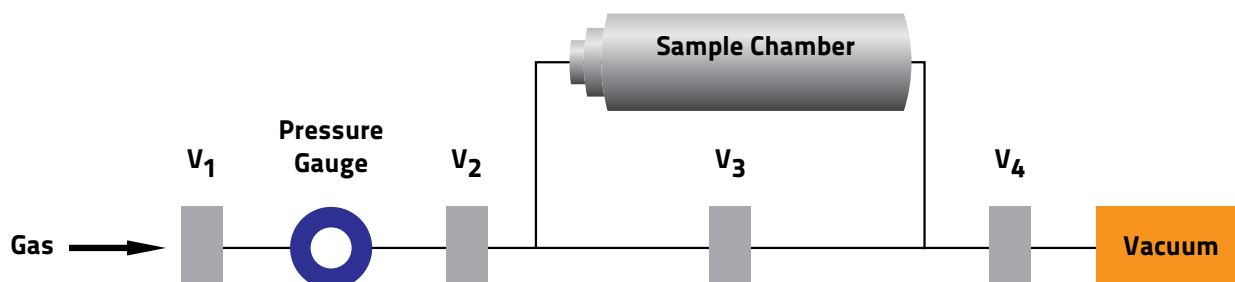
The PMI Automated Porosity & Permeability System has been specially designed for testing core samples. Core samples are held in a sleeve which (pneumatic or hydraulic) compresses the sample to the desired pressure. While the rock sample is under compressive stress, the

permeability of the sample is measured. The instrument measures the loss of a known amount of gas to computer porosity.

The equipment is fully automated. Execution of the test, data acquisition, data storage, & data management are all carried out by PMI Software. Operator involvement is minimal, and the instrument is robust and requires a minimal amount of care.

Figure 2

PMI Gas Helium Porosimeter outline for testing



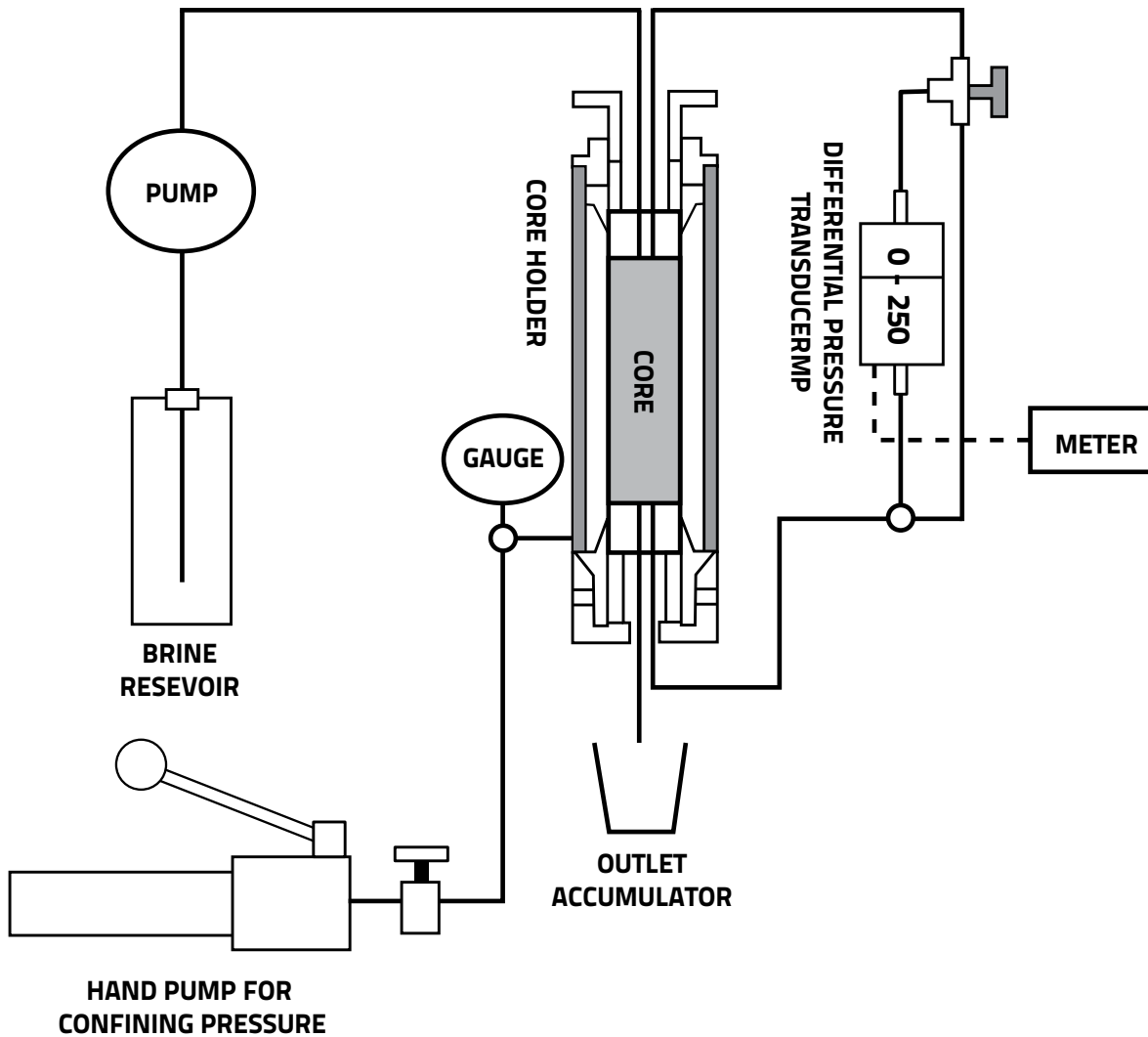


Figure 3

Outline of permeability testing setup

Application

Industries worldwide utilize the PMI Porosimeter Permeameter for R&D and quality control. Applicable industries include: Oil Refineries, Oil Exploration Industries, Geotechnical Department, Geophysics, Automotive, and Battery Development.

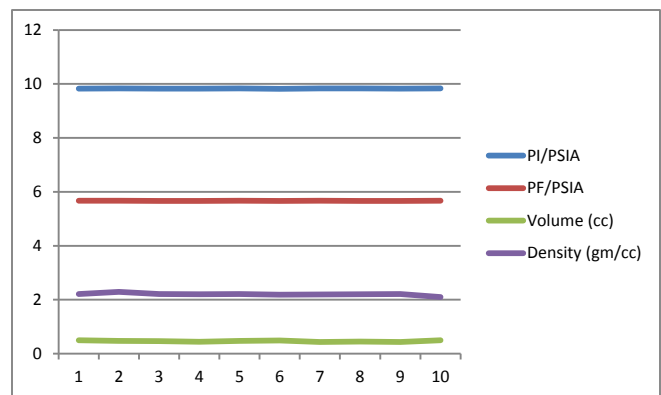


Figure 4

Typical test results

Testing Capabilities

- Gas Permeability (md) is based on the unsteady state or steady state pressure fall off method.
- Measure core porosity or pore volume under confining pressure by using Boyles Law Method
- Klinkberg Slip factor 'b'
- Klinkberg corrected permeability
- Core sample bulk volume

PMI Software

We work closely with our customers to provide the most user friendly software for porometry. 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 setting for beginners & full access to all relevant measuring parameters for advanced researchers:

Component:

- Capwin manages manual instrument control, automated measuring routines ("jobs") 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 & screen views
- Capwin user manager for comprehensive user management regarding user access, control & assignment of specific jobs
- On line diagnostic from anywhere in the world
- Links to data Bases (SAP, Lims, etc.)
- Userdefined definitions of paths & sub directories for data filling



Figure 4

Screenshots of PMI software

Features

Windows-based software handles all control, measurement, data collection, and report generation; complete manual control also possible

Compatible with Windows 97 or higher

Real-time graphical test display depicts testing status and results throughout operation

Non-destructive testing

Length of test approximately 30 minutes

Wide range of acceptable sample types and sizes

Multiple sample chambers available

Specifications

Permeability Range: 0.001md to 15 Darcy

Confining Pressure: 400 to 10,000 psi (Pneumatic/Hydraulic)

Pore Pressure: 250 psi or more

Helium: 400 psi

Air: 150 psi or more

Temperature Range: up to 250 deg (Optional)

Core Length: 0.5" to 4" & custom

Core Diameter: 1" Insert to accommodate roves of different sizes or 1.5" (others on request)

Porosity Range: 0.1 - 40%

Multiple Sample Chamber Unit, sample capacity up to 12 (all can be controlled simultaneously or individual)

Power Requirements: 110/220 VAC, 50/60 Hz

Injection Pressure: 1000 psi or higher

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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Complete Filter Cartridge Analyzer
Compression Porometer
Custom Porometer
Cyclic Compression Porometer
Diffusion Permeameter
Envelope Surface Area Analyzer
Filtration Media Analyzer
Gas Permeameter
Gas Pycnometer
High Flow Porometer
In-Plane Porometer

Liquid Extrusion Porosimotor
Liquid Permeameter
Integrity Analyzer
Mercury Pycnometer
Mercury/Nonmercury Intrusion Porosimotor
Microflow Porometer
Nanopore Flow Porometer
Quality Control Porometer
Vacuapors
Vapor Permeameter
Water Intrusion Porosimotor (Aquapore)
Water Vapor Transmission Analyzer

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Aquapore

Water Intrusion Porosimeter

Principle

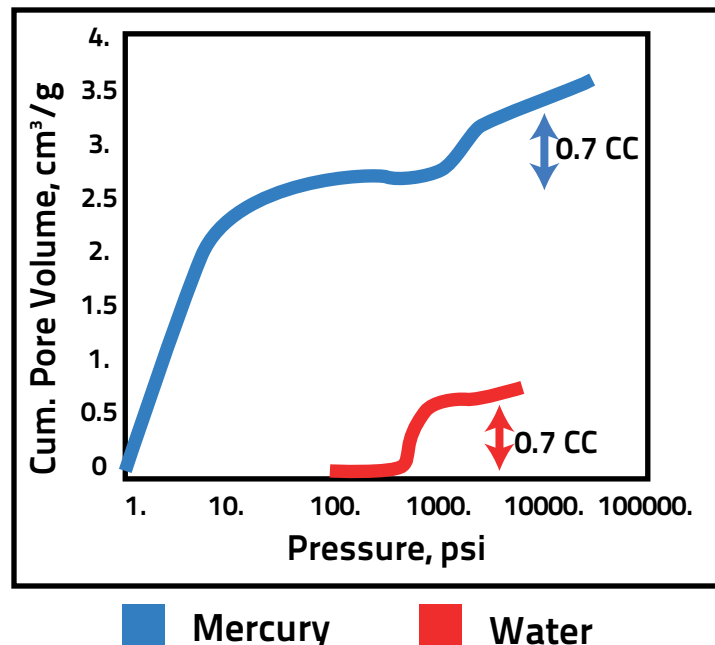
Aquapore is a liquid intrusion porosimeter used for hydrophobic pores. Water does not wet hydrophobic pores. Intrusion of water into pores occurs on application of pressure. Measured intrusion volume of water yields pore volume and measured intrusion pressure yields pore diameter.

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

p = differential pressure on water
 γ = surface tension of water
 θ = contact angle of water
 D = pore diameter

Special Features

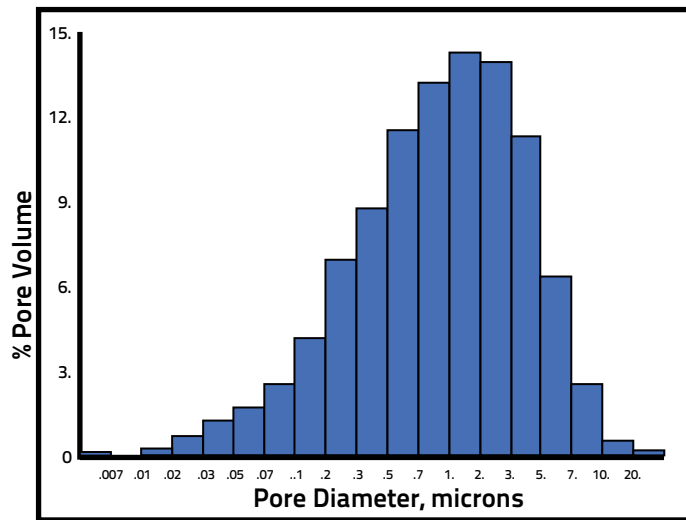
Uses no toxic materials like mercury
An order of magnitude lower intrusion pressure compared with mercury intrusion & minimal distortion of pore structure
Much less expensive instrument compared with mercury intrusion porosimeter
pore diameter range from 20 to 0.002 microns
Completely automated windows based simple operation



Capability

Measures:

- Pore volume
- Pore diameter
- Pore volume distribution
- Hydrophobic through process
- Hydrophobic blind pore



Specifications

Pure liquid (water or industrial alcohol) used with precise pressure control and pressurization - No mercury required!

Total pore volume, pore size distribution and hysteresis of pores ranging from 20 to 0.005 microns

Optical encoder utilized for measuring the change in volume

Windows controlled, fully automated test unit

Maximum pressure of 30,000 psi - custom models capable of 60,000 psi



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Compression Liquid Extrusion Porosimeter

Description

The PMI Compression Liquid Extrusion Porosimeter has the ability to test samples under compressive stress. The instrument is employed for characterization of porous materials used in many industries such as biotech, pharmaceutical, filtration, food, and environment. It produces no harmful effects on personnel or environment.

Principle

The sample is placed on a membrane in the sample chamber. The membrane is such that its largest pore is smaller than the smallest pore to be tested. The pores of the sample and the membrane are filled with a wetting liquid. Pressure on the inner piston rod is set to apply desired compressive stress on the sample. The outer piston rod is activated to apply desired pressure on o-rings. The inner piston rod is activated to apply desired compressive stress on the sample. The pressure of a nonreacting gas is increased on the sample to extrude the liquid from the pores. The differential pressure, p , required to displace liquid from a pore is related to its diameter, D , surface tension of the liquid, γ , and contact angle of the liquid, θ .

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

The gas pressure gives the pore diameter. The volume of displaced liquid gives the pore volume. Measurement of liquid flow rate without the membrane under the sample yields liquid permeability of the sample.



Figure 1

PMI Compression Liquid Extrusion Porosimeter

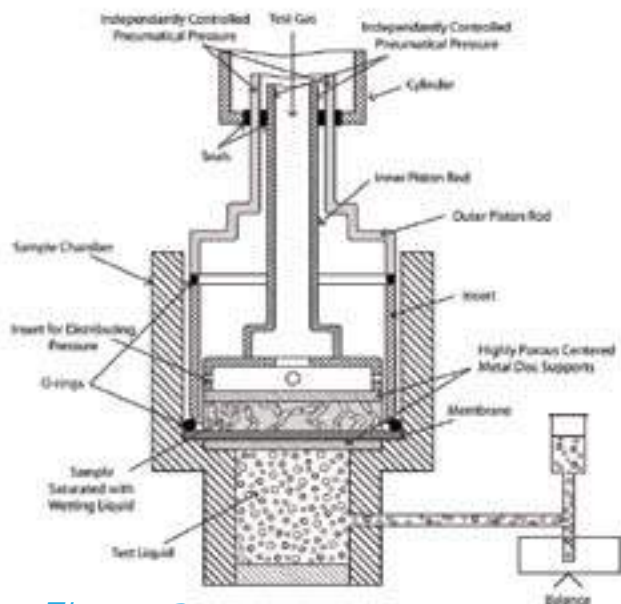


Figure 2

Principle behind the Compression Liquid Extrusion Porosimeter

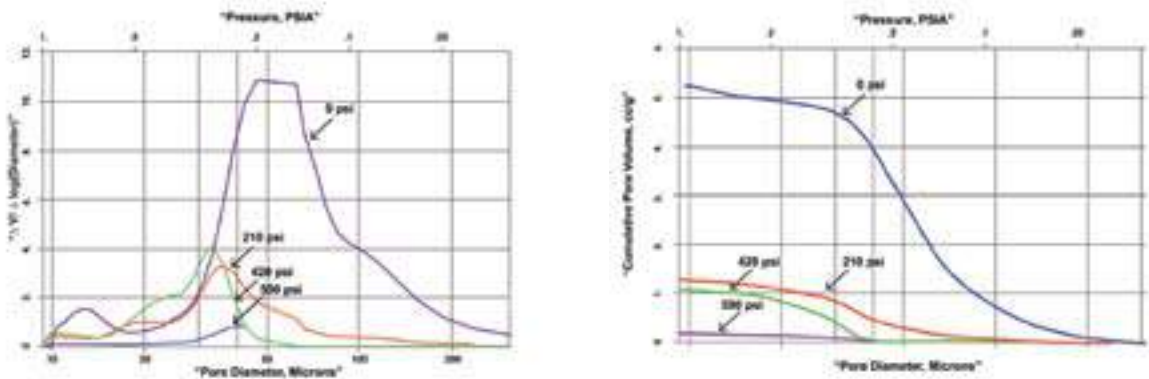


Figure 3

Typical results from PMI software

Features

- One Instrument performs like two. Measures liquid permeability like a permeameter and pore volume like a Mercury Intrusion Porosimeter
- No toxic material like mercury is used
- No health hazard
- No disposal-related cost
- Fully automated. Simple to use
- Very little operator involvement
- Highly reproducible & accurate
- A wide variety of samples can be investigated
- Pressure required almost an order of magnitude less than that required for mercury intrusion
- Can be used for pressure sensitive materials
- Only instrument capable of measuring through-pore volume
- Effects of application environment measurable (stress, temperature, chemical environment)
- Capable of measuring very large pores (up to 1000 microns)

Specifications

- Pressure Range: 0 - 100 psi (Others Available)
- Pore Size Range: 1000 μm - 0.05 μm
- Resolution: 1 in 20,000
- Intrusion Volume Range: 0.01 cc
- Sample Size: 1.5" Diameter, 1" Thick (Others Available)
- Compressive Stress: up to 1000 psi



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Liquid Extrusion Porosimeter

Application

The PMI Liquid Extrusion Porosimeter is a unique instrument with the ability to measure through-pore volume, volume distribution and liquid permeability without using mercury. The instrument is employed for characterization of porous materials used in many industries such as biotech, pharmaceutical, filtration, food, and environment. It produces no harmful effects on personnel or environment.

Principle

The sample is placed on a membrane in the sample chamber. The membrane is such that its largest pore is smaller than the smallest pore to be tested. The pores of the sample and the membrane are filled with a wetting liquid. The pressure of a nonreacting gas is increased on the sample to extrude the liquid from the pores. The differential pressure, p , required to displace liquid from a pore is related to its diameter, D , surface tension of the liquid, γ , and contact angle of the liquid, θ .

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

The displaced liquid passes through the liquid-filled pores of the membrane and its volume is measured, while the liquid-filled pores of the membrane prevent the gas from passing through because of insufficient pressure. The gas pressure gives the pore diameter. The volume of displaced liquid gives the pore volume. Measurement of liquid flow rate without the membrane under the sample yields liquid permeability of the sample.



Figure 1
PMI Liquid Extrusion Porosimeter

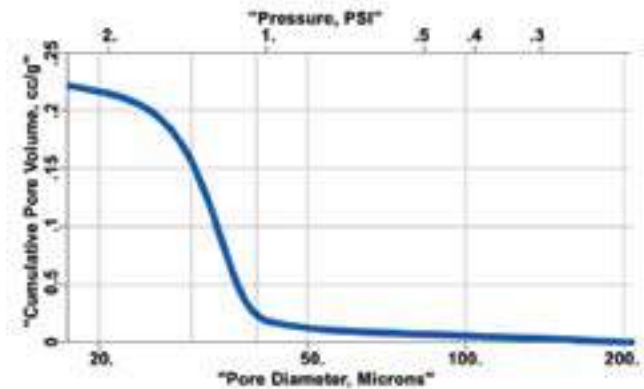


Figure 2
Pore volume vs pore diameter

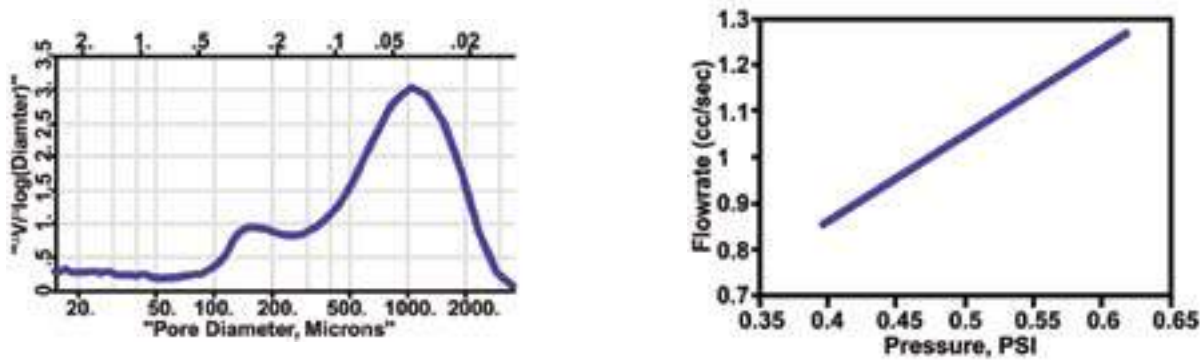


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Specifications

- Pressure Range: 0 - 100 psi (Others Available)
- Pore Size Range: 1000 μm - 0.05 μm
- Resolution: 1 in 20,000
- Intrusion Volume Range: 0.01 cc
- Sample Size: 1.5" Diameter, 1" Thick (Others Available)



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Mercury / Nonmercury Intrusion Porosimeter

Description

The PMI Mercury/Nonmercury Intrusion Porosimeter is a versatile and accurate instrument used to determine properties such as pore size distribution, total pore volume, surface area, and bulk and absolute densities of solid and powder samples. With unlimited user-defined data-points, automated data collection and reduction, and the least mercury exposure of any porosimeter on the market, PMI's Mercury/Nonmercury Porosimeter is safe, reliable, and precise.

Principles of Operation

The PMI Mercury/Nonmercury Intrusion Porosimeter uses mercury intrusion or intrusion of any other nonwetting liquid to determine pore volume. The Mercury/Nonmercury Intrusion Porosimeter fills the penetrometer and sample chamber with mercury under vacuum and takes a volume reading. The sample, however, is not initially intruded with mercury or other nonwetting test liquid because of the high surface tension. Gradually, increasing amounts of pressure are applied on the nonwetting liquid. For each incremental increase in pressure, the change in intrusion volume is equal to the volume of the pores whose diameters fall within an interval that corresponds to the particular pressure interval.

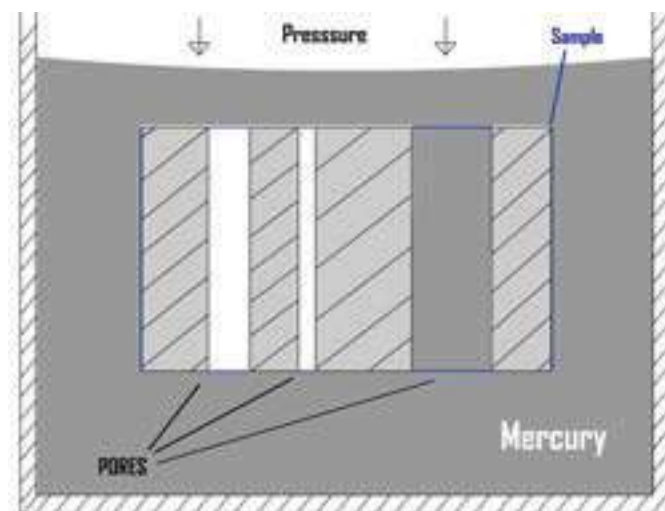


Figure 1
Principle of Operation:
Mercury Intrusion Porosimeter

Applications

The PMI Mercury/Nonmercury Intrusion Porosimeter is an excellent R&D tool. Used in various industries ranging from automotive and pharmaceutical to paper, the Mercury/Nonmercury Intrusion Porosimeter can test samples such as brake pads, catalytic converter materials, coated papers, and powder precursors.

Applicable Industries

Automotive
Chemical
Paper
Battery Separator
Filtration

Pharmaceuticals
Ceramic
Fuel Cells
Powder Metallurgy

Features

Windows-based software handles all control, measurement, data collection, and report generation; manual control also possible
Unlimited user-defined data points based on pressure, volume, or a combination
Displays both intrusion and extrusion curve
Compatible with Windows 95 or higher
Real-time graphical test display depicts testing status and results throughout operation
Length of test approximately 2 hours
Wide range of acceptable sample sizes and types
Multiple sample chambers available
Minimal maintenance required
Low level of mercury exposure
No need for sample transfer from low pressure to high pressure stations
Automatic mercury refill and clean up
All stainless steel construction

Specifications

Pore Size Range	0.0035 - 500 microns
Surface Area Range	1 - 100 m ² /g
Sample Size	2.7 cm H x 2 cm D
Pressure Range	Vacuum to 60,000 psi
Pressurizing Gas	Air or isopropyl alcohol
Pressure Transducer Range	0 - 60,000 psi
Resolution	1 in 60,000
Accuracy	0.25 % of reading
Power Requirements	110/220 VAC, 50/60 Hz (Others available)
Dimensions	72" H x 30" W x 30" D
Weight	400 lbs



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Average Fiber Diameter Analyzer

Applications

Performance of many fibrous products such as filter media, membranes, battery parts, and household products is determined primarily by factors such as fiber diameter and packing density. For many applications quick estimation of the average fiber diameter is required. The techniques that are used for fiber diameter measurements are often involved and time consuming. The PMI's completely automated average fiber diameter analyzer has the unique ability to measure average fiber diameter of bulk samples in a few minutes. It is used in industry for production control, quality control, and performance evaluation.



Principles of Operation

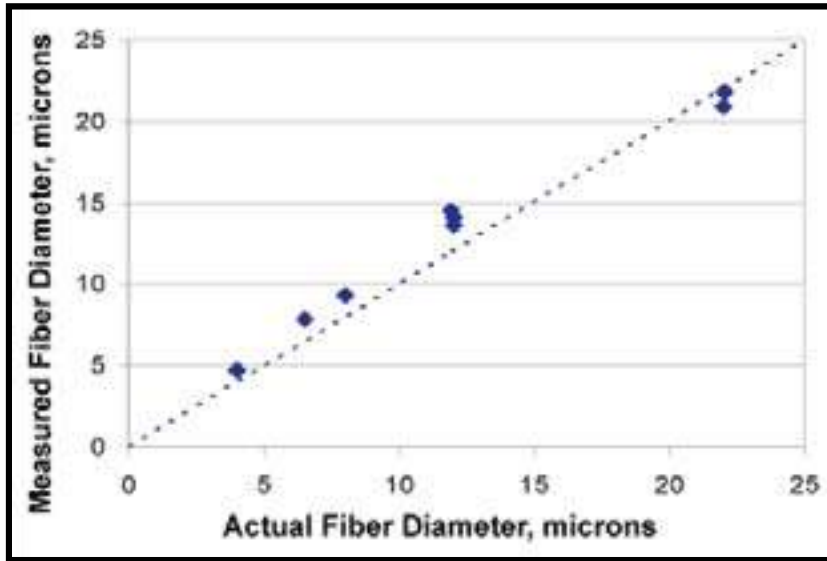
The flow rates of gas through the sample as a function of differential pressure are accurately measured and these results are used to compute average fiber diameter on the basis of the relationship reported by C.N. Davies. (C.N. Davies, The Separation of Airborne Dust and Particles, Proceedings of the Institute of Mechanical Engineers, London, 1B, 1952, pp.185-194).

According to Darcy's law, the permeability, k of a porous material to a gas is given by:

$$(F \mu l) / (A \Delta p) = k$$

where F is volume flow rate through the material at average pressure, viscosity of gas, Δp is differential pressure, and l is thickness of sample. Models of gas flow through fibrous materials suggest that permeability, k is a function of square of fiber diameter, R , and packing density, c . Packing density is fractional volume occupied by fibers and is equal to $(1-P)$, where P , the porosity, is the fractional pore volume. Davies has shown that the following relationship holds for a wide variety of fibrous materials in which the porosity P is in the range, 0.7 - 0.99.

$$(4 \Delta p A R^2) / (\mu F l) = 64 c^{1.5} [1 + 52 c^3]$$



Measured fiber diameters plotted against the actual fiber diameters

Average fiber diameter by permeability technique

Nonwoven	Porosity, P	Actual fiber diameter, microns	Measured fiber diameter, microns
#1	0.79	4.0	4.7
#2	0.79	6.5	7.8
#3		8.0	9.3
#4	0.77	12	14.0
#5	0.74	22	21.3



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Average Particle Size Analyzer

Application

Performance of many particulate products used in a number of industries such as filtration, mineral, chemical, cosmetic and chemical industries is determined primarily by the average particle diameter. For many applications quick estimation of the average particle diameter is required. The techniques that are used for particle diameter measurements are often involved and time consuming. The PMI's completely automated average particle size analyzer has the unique ability to measure average particle diameter of bulk samples in a few minutes. It is used in industry for production control, quality control, and performance evaluation.



Principles of Operation

The instrument accurately measures flow rate of gas through the sample as a function of differential pressure, calculates the envelope surface area, and uses these results to compute average fiber diameter. The envelope surface area is the external particle surface area that sees flow of gas through the sample. The envelope surface area is obtained from the flow rate and pressure drop using the Carman-Kozeny relation (Gerard Kraus, J.W. Ross and L.A. Girifalco, Surface Area Analysis by Means of Gas Flow Methods. I. Steady State Flow in Porous Media, Phys. Chem., V330-333). The average fiber diameter is obtained from the envelope surface area using the following equation:

$$D = 6 / S \rho$$

where D is the average fiber diameter, S is the envelope surface area per unit mass of the powder, and ρ is the true density of the powder.

Applications

Providing the user with an average particle diameter measurement in less than five minutes, the main application is quality control. Samples tested include pharmaceutical powders, electrode components, ceramic powders, chemical powders, metallic powders, and other porous substances.

The instrument is utilized for this function in several industries, such as:

- Chemical and Mineral
- Battery
- Pharmaceuticals
- Fuel Cell
- Powder Metallurgy
- Ceramic

Features

- Uses nitrogen or other noncorrosive gases; no expensive gas mixtures required
- Windows-based software handles all control, measurement, data collection, and report generation; manual control also possible
- Compatible with Windows 95 or higher
- Real-time graphical test display depicts testing status and results throughout operation
- Nondestructive testing
- Length of test approximately 5 minutes
- Wide range of acceptable sample types and sizes
- Minimal maintenance required



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Diffusion Permeameter

Applications

Many applications of porous materials require very low gas permeability through these materials. Such applications are found in many industries including biotech, healthcare, pharmaceutical, food, packaging, environmental, power sources and chemical industries. Determination of the magnitudes of flow rates of gas through materials used in these applications is important for evaluation of products.

Principles of Operation

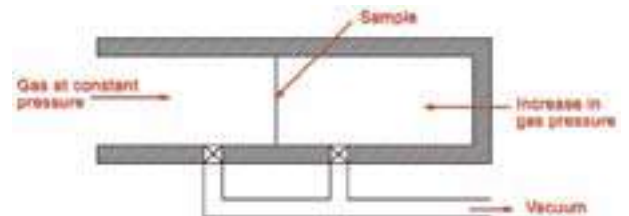
The basic principle is based on the laws of diffusion.

$$F = - M [dp/dx]$$

where F is the flux across the sample, $[dp/dx]$ is the pressure gradient across the thickness, and M is a measure of diffusivity. The instrument is designed to accurately measure pressure and flow rate. The sample chamber is evacuated. Gas pressure maintained at a constant value on one side of the sample is measured and the increase in pressure on the other side is also measured. The data are used to compute flow rate of gas per unit area of the sample per unit time as a function of pressure gradient. The gas flow rate is computed using the following relation:

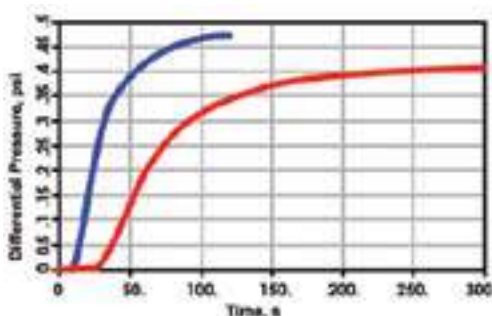
$$F = \left(\frac{VT}{P_s T_s} \right) \left(dp/dt \right)$$

where F is the gas flow rate in volume at STP per unit time, V is the volume of outlet chamber, P_s is the standard pressure, T is the standard temperature, T_s is the test temperature, and (dp/dt) is the time rate of pressure increase in the outlet chamber.

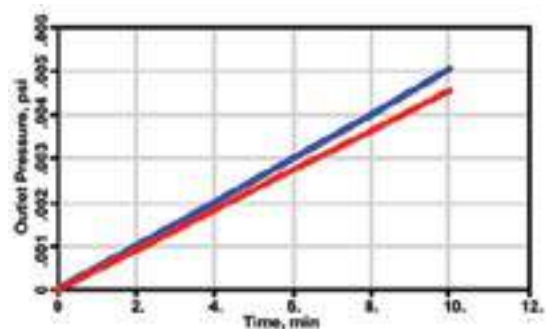


Capabilities

- Measures flow rate as low as 10^{-4} cm^3/s
- Elevated operating temperatures up to 800°C
- Elevated pressure test up to 200 psi
- A variety of gases & vapors can be tested
- Sample can be tested under compression up to 1000 psi



Vapor through Nafion Membrane



Air

Features

- The sample chamber is maintained at a constant temperature for yielding reliable & reproducible data.
- Fully Automated
- Very little operator involvement
- Robust. Minimal maintenance
- Accuracy of pressure measurement is 0.15% of reading

Specifications

Permeability Range: 0.0001 - (cc/min/cm²)

Sample Size: 1.75" - 2.5" diameter

Stock Tank: Built in, Low Pressure Sample Cell Size: 50 - 100 cc (specific to machine)

Pressure Range: 100 psi maximum differential pressure

Pressurizing Gas: Water vapor, oxygen, or other non-corrosive gas

Pressure Transducer Range:

- High Pressure Side: 0 - 100 psi
- Low Pressure Side: 0 - 10 Torr
- Accuracy (both): 0.015% of reading
- Resolution: 1 in 60,000

Temperature Control: RT - 150° C (includes Sample Chamber & Manifold)

High Temperature & Pressure Control System:

- Facilitates Testing up to 150° C
- Allows for Testing within 30 atm

Vacuum Pumping System: Turbo Pump, vacuum to 0.002 Torr

Power Requirements: 110/220 VAC, 50/60 Hz (Others available)

Dimensions: 60" H x 30" W x 28" D (specific to machine)

Weight: 500 lbs (specific to machine)

Accessories:

- Adapter plates for measuring different sample diameters
- Tools kit: Grease (1), Operation Manual (1), Adapter Plate Clip, Operation Software for WIN95/98/2000/ME/XP, Power Chord



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Envelope Surface Area Analyzer

Description

PMI's External Surface Area Analyzer (ESA) offers a simple, fast, and reliable technique for external surface area measurement - a measurement not readily achieved by static nitrogen adsorption (BET) methods. The ESA's innovative use of flow permeametry combined with its sophisticated self-adjusting viscous-flow controller enables testing of a wide range of powders and other samples, including materials with surface areas of only several square meters per gram.

Principle

The ESA operates on the principle of flow permeametry. By measuring the flow of Nitrogen (or any non-corrosive gas) through a sample at various differential pressures, one is able to deduct, through a series of equations, the external surface area of the sample.

Features

The first porometer capable of testing samples with permeabilities as low as 10^{-6} Darcies

MicroFlow models available that have the capability to determine pore sizes from 500 to 0.013 microns

Flow is determined by measuring the pressure change in a sealed reservoir as pressurized gas is applied to the sample

Inlet pressure is measured by a high accuracy differential pressure gauge

Systems can be modified to accommodate specific needs

Specifications

Pore Size Range: 0.013-500, .03-500, 0.06-500 Microns

Sample Size: 0.5" - 2.5" diameter. Others available

Shape: Discs, hollow fibers, membranes, complete cartridges, etc.

Pressure Range: 0-500, 0-200, 0-100, psi

Pressurizing gas: Clean, dry, compressed, non-corrosive air or gas

Pressure Transducer Range: 0-500, 200, 100, 25, 5 PSI

Mass Flow Transducer Range: 30 cc/minute. Others available

Pressure Accuracy: 0.15% of reading

Pressure Resolution: 1/60,000 of full scale (1 part in 60,000)

Dimensions: 10.5" H x 20.5" W x 20.5" D

Power Requirements: 110/220 V AC, 50/60 Hz

Weight: 40 lbs



Figure 1

PMI Envelope Surface Area Analyzer

Application

Providing the user with a surface area measurement in less than five minutes, the main application of the ESA is quality control. Samples tested include pharmaceutical powders, electrode components, ceramic powders, fibrous materials, and other porous substances. The ESA is utilized for this function in several industries, such as: Battery Separator Ceramic Chemical Pharmaceutical Powder Metallurgy.

Gas Permeameter

Description

The PMI Gas Permeameter provides fast and accurate measurement of gas permeability of solid/hollow cylindrical and sheet samples. Featuring nondestructive testing and fast results, PMI's Gas Permeameter is perfect for both R&D and quality control.

Applications

Industries worldwide utilize the PMI Gas Permeameter for R&D and quality control. Applicable industries include: Automotive, Battery, Biotechnology Separator, Ceramic, Filtration, Fuel Cells, Geotextiles, Nonwovens, Paper, and Textiles.

Optional Features

- Permeability measurement of high flow rate samples like cartridges
- Permeability of samples under compressive stress
- Use of elevated test temperatures and a wide variety of gases

Features

- Windows-based software handles all control, measurement, data collection, and report generation; complete manual control also possible
- Real-time graphical test display depicts testing status and results throughout operation
- Non-destructive testing
- Length of test approximately 10 minutes
- Wide range of acceptable sample types and sizes
- Multiple sample chambers available
- Minimal maintenance required
- Units in Darcy, Frazier, Gurley, and many others

Specifications

- Permeability Range: 1×10^{-3} - 50 darcies
- Sample Size: 1.75" - 2.5" diameter (others usable)
- Pressure Range: 0 - 500 psi
- Pressurizing Gas: Clean, dry or compressed air (Or any other nonflammable and noncorrosive gas)
- Pressure Transducer Range: 0 - 500 psi
- Resolution: 1 in 20,000
- Accuracy: 0.15% of reading
- Mass Flow Transducer Range: 10 cm³/min - 500,000 cm³/min
- Power Requirements: 110/120 VAC, 50/60 Hz (Others available)
- Dimensions: 30" H x 19" W x 18.5" D
- Weight: 100 lbs



Figure 1

PMI Gas Permeameter

Liquid Permeameter

Model No. LP-100

Description

The PMI Liquid Permeameter is used to perform fast and accurate measurements of liquid permeability. PMI's Liquid Permeameter is user-friendly, features non-destructive testing, and accommodates a wide variety of samples. The Liquid Permeameter also allows testing under ambient or elevated temperatures to simulate actual operating conditions.

Principle

The flow of liquid through a sample is measured by the distance a column of liquid drops in relation to time and pressure. This method gives reproducible results, even for hydrophobic materials, as pressure can be applied up to 200 psi to the liquid column to force the liquid through the sample. Very low permeability samples are tested using an accurate weighing balance to measure liquid flow rate.

Applications

Industries worldwide utilize the PMI Liquid Permeameter for R&D and quality control. Samples tested include filter media, membranes, paper, and battery separators.

Industries: Rock Core, Automotive, Battery, Separator, Filtration, Geotextiles, Textiles, Nonwovens, Paper, and Food.

Optional Features

- High Temperature Operations
- Permeability of Strong Chemicals
- Liquid Permeability incorporable as part of other PMI instruments



Figure 1
PMI Liquid Permeameter

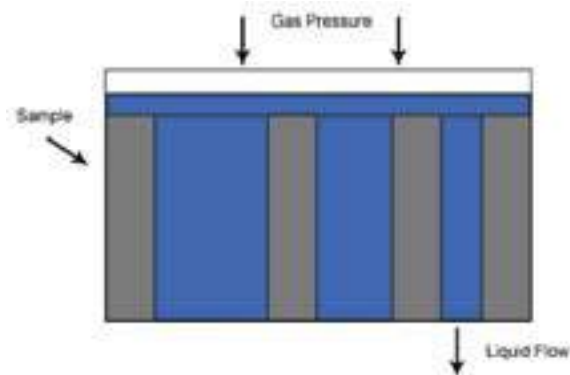
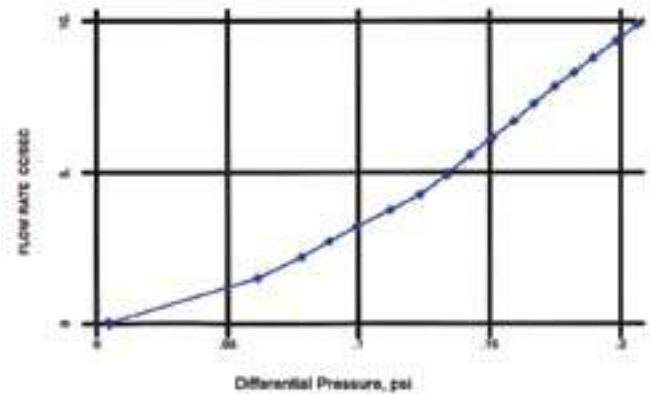


Figure 2
Principle for how the Liquid Permeameter functions.

Figure 3

Expected data from PMI Software.



Features

Windows-based software handles all control, measurement, data collection, and report generation; complete manual control also possible

Compatible with Windows 95 or higher

Real-time graphical test display depicts testing status and results throughout operation

Nondestructive testing

Length of test is approximately 10 minutes

Wide range of acceptable sample types and sizes

Multiple sample chambers available

Minimal maintenance required

A variety of materials including vegetables, meat, etc. can be tested

Specifications

Permeability Range: 1×10^{-4} - 5 Darcy

Sample Size: 1.5" to 3" in length

Pressure Range: 0 - 200 psi

Pressurizing Gas: Clean, dry or compressed air (Or any other nonflammable and noncorrosive gas)

Pressure Transducer Range: 0 - 250 psi

Resolution: 1 in 60,000

Accuracy: 0.15% of reading

Power Requirements: 110/120 VAC, 50/60 Hz (Others available)

Dimensions: 30" H x 19" W x 18.5" D

Weight: 100 lbs



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Membrane Manufacturing Apparatus

Hollow Fiber Manufacturing Machine



Flat Sheet Membrane Manufacturing Machine

Applications

PMI membrane manufacturing machines can be used to create cast flat sheet membranes and hollow fiber membranes. The machines permit adjustment of fabrication parameters so that membranes with different characteristics could be made for development, research, and many wide varieties of applications and filtration.

Principle

Solutions for making membranes are thoroughly mixed at desired temperature and pressure. The chemicals are shaped in to flat sheets or hollow fibers and allowed to coagulate at the desired temperature.

The Machines

Layout of the hollow fiber making machine is shown in Figure 1. One hundred PSI pressure tanks hold chemicals at the desired temperature and pressure. The chemicals are constantly stirred and pumped to the spinnerette. Flow regulators control the flow rates of the chemicals. The hollow fibers coming out of the spinnerette pass through a temperature controller coagulation tank and are washed. Figure 2 shows the layout of the flat sheet membrane making machine.

Figure 1
Hollow Fiber
Making Machine

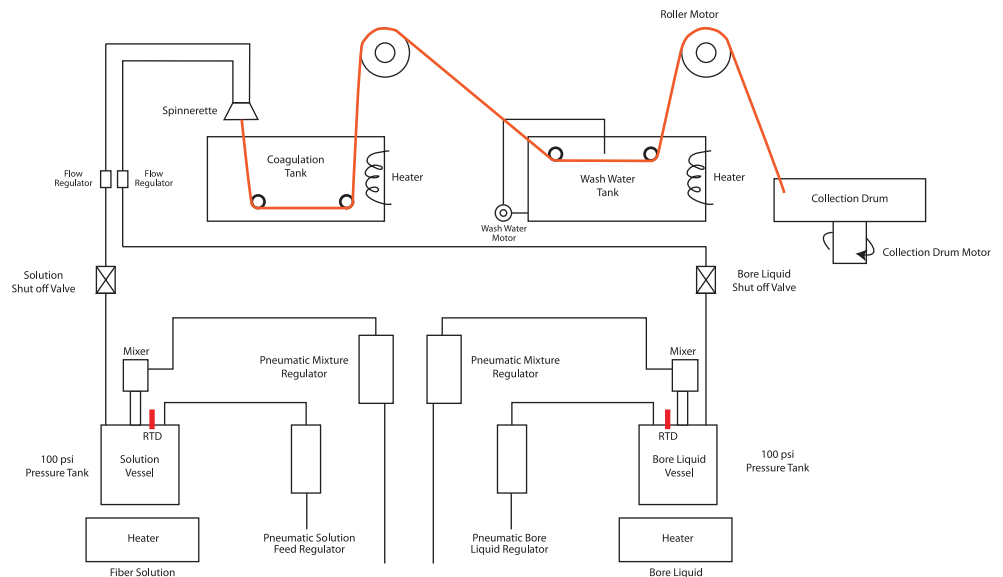
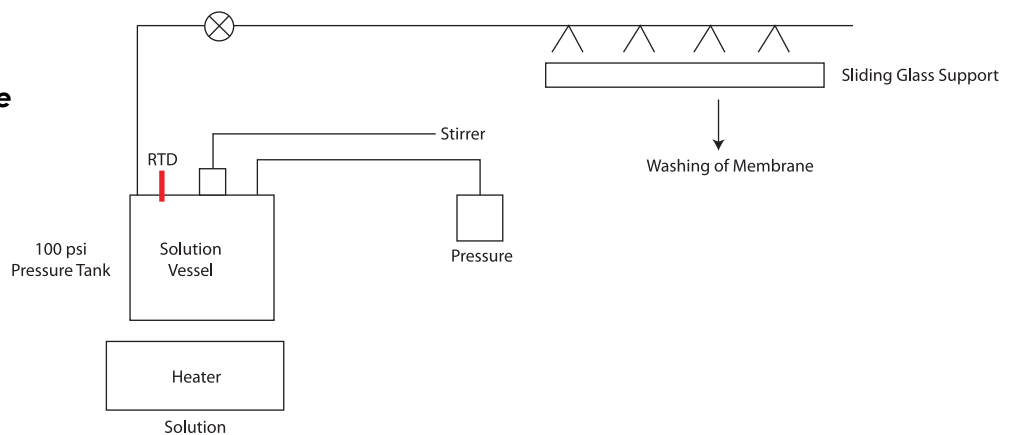


Figure 2
Flat Sheet Membrane
Making Machine



Typical Product

A variety of hollow fiber membranes and flat sheet membranes have been manufactured. Figure 3 shows typical hollow fiber membranes.

Figure 3
Hollow Fiber Membranes



Pore Structure of Membranes

The pore structures of the membranes made in the PMI membrane making machines were determined by various pore structure characterization techniques. The pore structures of hydrophobic flat sheet membranes were measured by water intrusion porosimetry. Figure 4 shows variation of hydrophobic pore volume with pore diameter. Pores have diameter from about, 50 to 0.01 microns. The pore distribution in Figure 5 shows that pores making maximum contribution to the pore volume are about - 0.04 microns in diameter. The pore volume at 20 micron is probably due to pore mouths.

Figure 4
Pore Volume and Diameter of Flat Sheet Membrane
PVDF Polymer

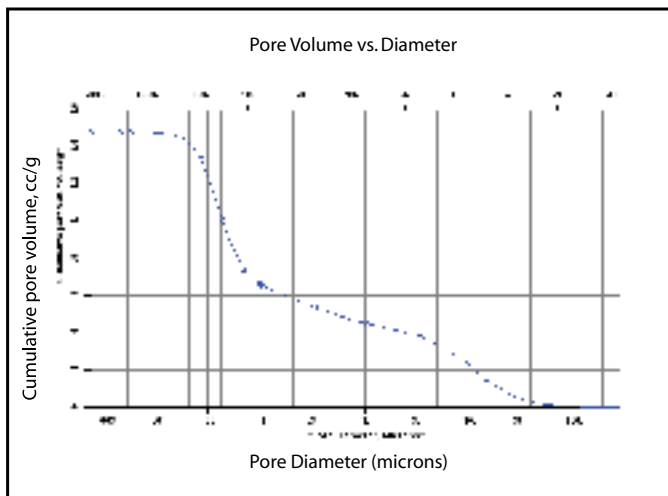
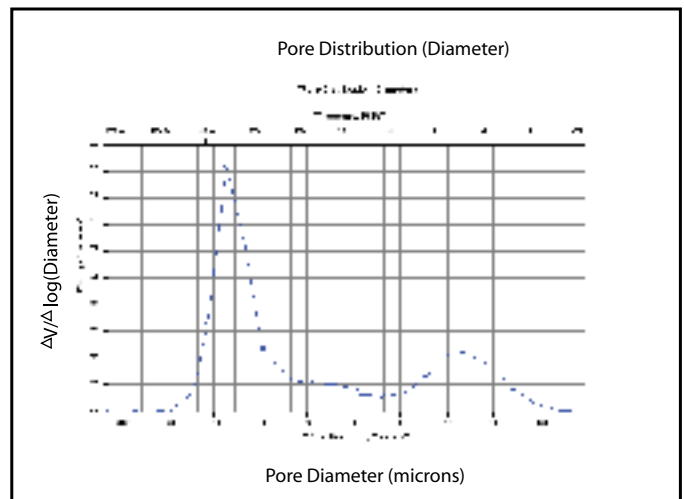


Figure 5
Pore Distribution of Flat Sheet Membrane
PVDF Polymer



Some of the hollow fiber membranes made in the PMI membrane manufacturing machines were tested by Liquid-Liquid Porometry. The presence of small pores in the membrane are demonstrated by the plot of flow rate with pressure (Figure 6). The mean flow pore diameter was 0.015 microns. Most of the pores are present over a narrow size range as demonstrated by the pore distribution in Figure 7.

Figure 6

Flow rates through dry and wet hollow fiber samples

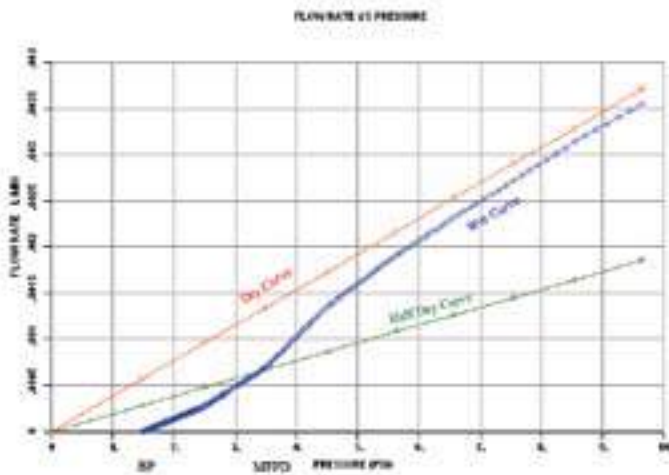
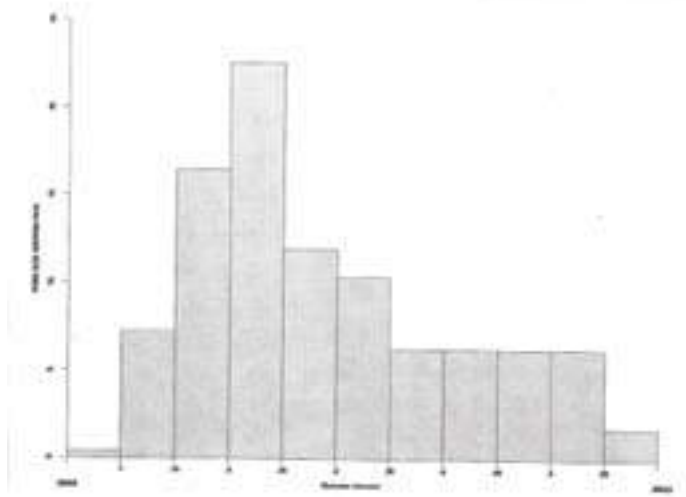


Figure 7

Pore distribution of hollow fiber membranes (Histogram)



Typical Properties for Hollow Fiber based on Polymer Type:

- Mean pore size:** 0.01-50 microns
- ID, OD and Wall Thickness:** Dependent on Spinnerette polymer before OD, Needle OD, Needle ID
- Length:** 500 ft plus

Typical Properties for Cast membrane based on Polymer Type:

- Mean pore size:** 0.01-100 microns
- Thickness:** 0.001" - 0.20"
- Length:** 3-4 ft
- Width:** 6" max



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Liquid Permeameter

Model No. LP-100

Description

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Principle

The flow of liquid through a sample is measured by the distance a column of liquid drops in relation to time and pressure. This method gives reproducible results, even for hydrophobic materials, as pressure can be applied up to 200 psi to the liquid column to force the liquid through the sample. Very low permeability samples are tested using an accurate weighing balance to measure liquid flow rate.

Applications

Industries worldwide utilize the PMI Liquid Permeameter for R&D and quality control. Samples tested include filter media, membranes, paper, and battery separators.

Industries: Rock Core, Automotive, Battery, Separator, Filtration, Geotextiles, Textiles, Nonwovens, Paper, and Food.

Optional Features

- High Temperature Operations
- Permeability of Strong Chemicals
- Liquid Permeability incorporable as part of other PMI instruments



Figure 1
PMI Liquid Permeameter

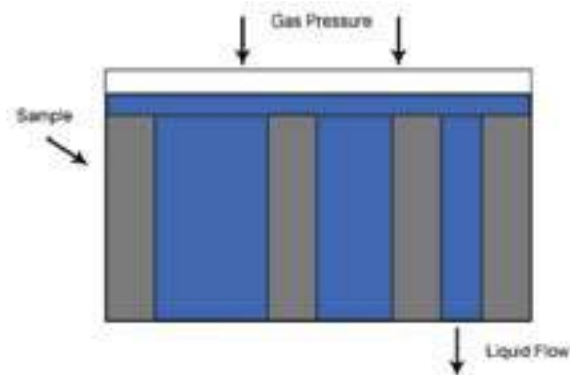
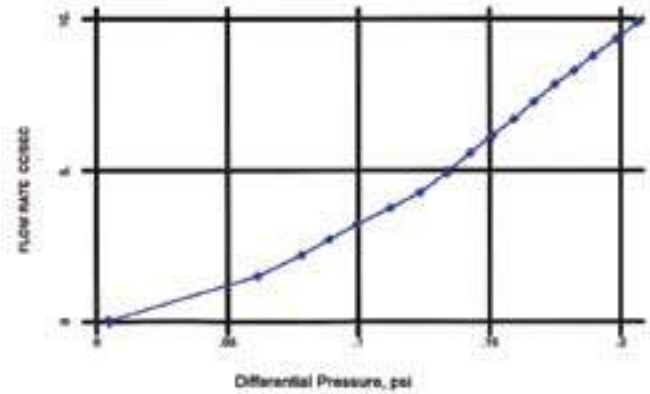


Figure 2
Principle for how the Liquid Permeameter functions.

Figure 3

Expected data from PMI Software.



Features

Windows-based software handles all control, measurement, data collection, and report generation; complete manual control also possible

Compatible with Windows 95 or higher

Real-time graphical test display depicts testing status and results throughout operation

Nondestructive testing

Length of test is approximately 10 minutes

Wide range of acceptable sample types and sizes

Multiple sample chambers available

Minimal maintenance required

A variety of materials including vegetables, meat, etc. can be tested

Specifications

Permeability Range: 1×10^{-4} - 5 Darcy

Sample Size: 1.5" in diameter to 3" in length

Pressure Range: 0 - 200 psi

Pressurizing Gas: Clean, dry or compressed air (Or any other nonflammable and noncorrosive gas)

Pressure Transducer Range: 0 - 250 psi

Resolution: 1 in 60,000

Accuracy: 0.15% of reading

Power Requirements: 220 VAC, 50/60 Hz (Others available)

Dimensions: 30" H x 19" W x 18.5" D

Weight: 100 lbs



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Water Vapor Transmission Analyzer

Application

The PMI Water Vapor Transmission Analyzer is capable of measuring water vapor transmission through porous media such as textiles, leathers, man made materials, membranes, nonwovens, and fabrics used in numerous high technology components and consumer products manufactured by a variety of industries. The instrument has the unique ability to measure vapor transmission rate over a wide range of humidity, temperature, and pressure under gradients of humidity, temperature, and pressure encountered in application environments.



Figure 1

PMI Water Vapor Transmission Analyzer

Principle

Two independent gas streams are maintained on the two sides of a sample at the desired temperature. Humidity and gas flow rates are measured. The transmission rate through the sample is computed using mass balance.

$$(dn/dt) + [(p_{e,i} \Phi_i / P_i) M_i] = [(p_{e,o} \Phi_o / P_o) M_o]$$

Where

n = moles Φ = humidity M = flow rate
 t = time p = equilibrium vapor pressure
 i = inlet o = outlet P = total pressure

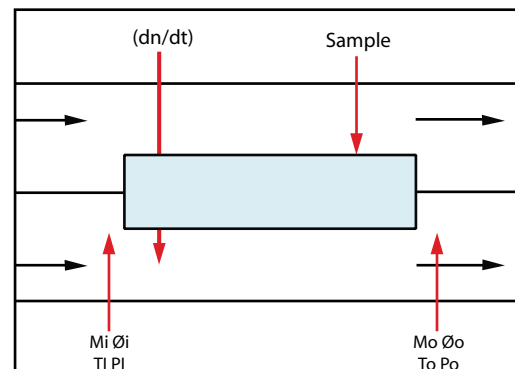


Figure 2

Basic principle of the Water Vapor Transmission Analyzer

Instrument

The sample is enclosed in a sample chamber. A part of the gas flowing through each independent stream is allowed to go through bubblers while the other part bypasses the bubblers and mixes with the gas passing through the bubblers. For maintaining constant humidity in the inlet gas stream, the flow rate in each part of the gas stream is controlled. The gas pressure is controlled by the valve at the end of each gas flow line. The valves automatically control and maintain either zero differential pressure or a finite definite pressure difference. Absolute pressure remains close to the standard pressure. The inlet and outlet flow rates and humidity are measured. The water vapor transmission rate through the sample is computed using the following relation.

$$(dn/dt) = [(p_e/P)\Phi_o - (p_e/P)\Phi_i]M_o/[1 - (p_e/P)\Phi_i]$$

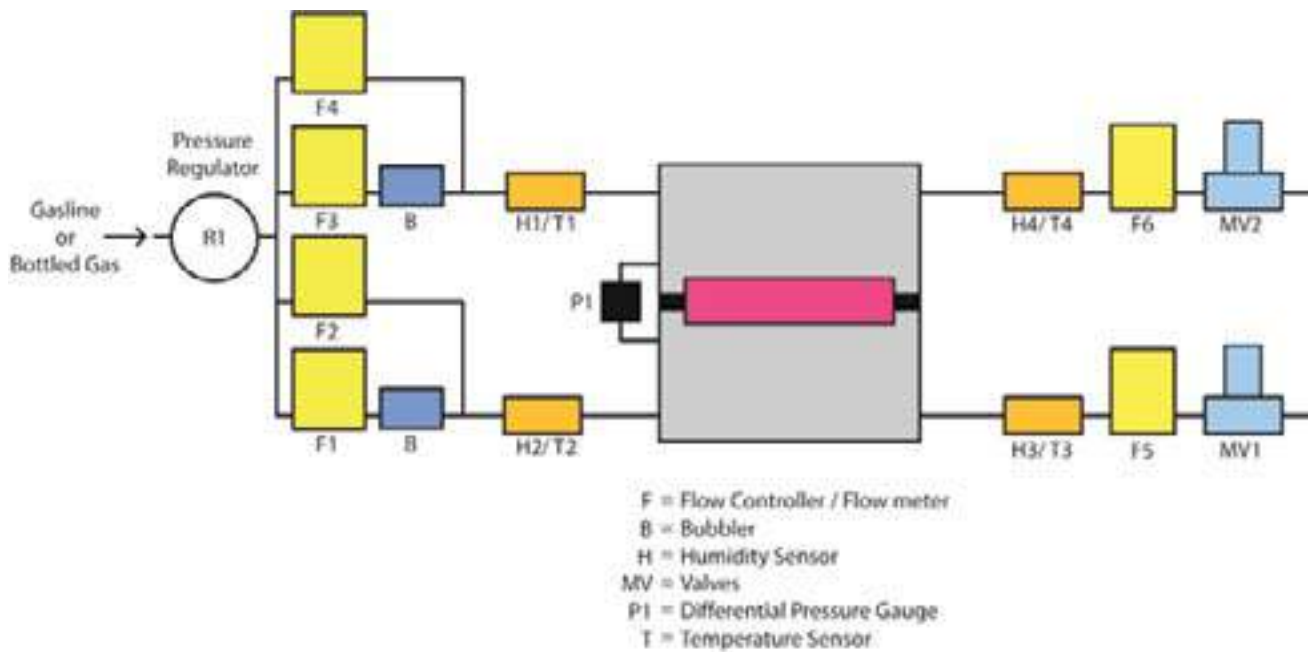


Figure 3

Diagram of basic layout of the Water Vapor Transmission Analyzer

Features

- Humidity on any side can be maintained between 5 and 95%
- Any desired pressure gradient can be maintained.
- Any desired test temperature can be achieved
- Simultaneous pressure and humidity gradients can be maintained
- Flat samples in a wide range of sizes can be accommodated
- Completely automated

Specifications

Humidity (ϕ) measurement

Range: 5 - 95%

Accuracy: $\pm 2\%$

Humidity (ϕ) control

Range: 0 - 100%

Accuracy: $\pm 1.5\%$ ($\phi = 0.5$)

$\pm 5\%$ (high & low ϕ) Accuracy: $0.4\text{ }^{\circ}\text{C}$ (low ϕ) - $0.8\text{ }^{\circ}\text{C}$

Differential pressure transducers

Range: 4 torr (2 mm Hg)

Accuracy: 0.015%

Temperature

Range: RT - $100\text{ }^{\circ}\text{C}$

Control: $\pm 2\%$

Accuracy: $0.4\text{ }^{\circ}\text{C}$ (low ϕ) - $0.8\text{ }^{\circ}\text{C}$ (high ϕ) at $100\text{ }^{\circ}\text{C}$

Mass Flow Transducers

Range: 5 L/min

Accuracy: 1%

Mass Flow Controller

Range: 2000 cc/min

Accuracy: 1%



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Bubble Point Tester

Application

PMI's Automated Bubble Point Tester (ABPT) provides reliable and accurate bubble point testing. Reproducibility of the test results is made possible by the fully automated, computer-controlled testing procedure and report generation. The ABPT is used to test for the largest through pore of materials such as filter media, filter cartridges, nonwovens, compact powders, membranes, separators, and other porous materials. The ABPT is controlled by Windows software so that data acquisition and system status display can be run with simple mouse movements.



Figure 1

PMI Bubble Point Tester

Principle

The sample of the material to be tested is soaked in a liquid that spontaneously fills the pores in the sample. Gas under pressure is applied on one side of the sample. Initially, gas does not flow through the sample because the pores in the sample are filled with the liquid. However, when the gas pressure is increased, the gas empties the largest pores of liquid at a certain level of pressure and gas begins to flow through the sample. The pressure at which the gas starts to flow through the sample is known as the bubble point pressure. Bubble point pore diameter is related to the bubble point pressure and surface tension of the liquid by the following relation.

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

D = pore diameter

γ = surface tension of liquid

p = pressure difference across the sample

θ = Constant angle

Special Techniques are used to detect bubble point pressure accurately.

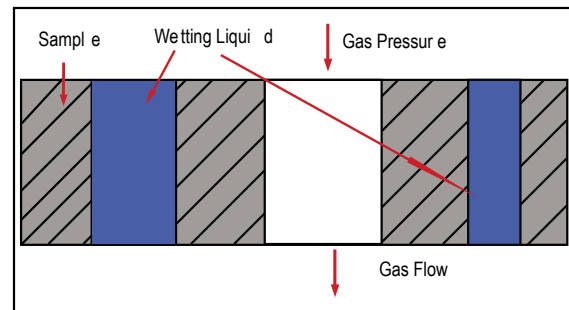


Figure 2

Basic principle for the Bubble Point Tester

Specifications

- Pore Size Range:
0.013-500, .03-500,
0.06-500 Microns
- Sample Size:
0.5" - 2.5" diameter
(Others available)
- Pressure Range:
0-500, 0-200, 0-100, psi
- Pressurizing Gas:
Clean, dry, compressed,
non-corrosive air or gas
- Pressure Transducer Range:
0-500, 200, 100, 25, 5 PSI
- Accuracy:
0.15%
- Mass Flow Transducer Range:
30 cc/minute (Others available)
- Resolution:
1/60,00 of full scale
(1 part in 60,000)
- Power Requirements:
110/120 VAC, 50/60 Hz
(Others Available)
- Dimensions:
10.5" H x 20.5" W x 20.5" D
- Weight:
40 lbs

Optional Features

- Multi-head models may contain 10 or more sample chambers for high volume testing.
- Go-No Go or Pass-Fail screening of samples.
- Clamp-On Sample chamber. No need for cutting samples or damaging the product.
- Test under compression, under elevated temperatures.
- Tests spaced evenly.
- Use of several wetting liquids.



Features

- Fast and accurate determination of largest pore size
- Use of almost any fluid
- Determines largest pore size within the range of 0.013-500 microns
- Provides consistent, objective and reproducible results
- Fully automated control reduces operation time
- Transfers data to commonly used spreadsheet programs
- Deluxe model performs integrity testing (diffusional flow)



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Cake Forming Porometer

Application

This is a unique instrument - capable of creating cakes in-situ on filtration media and characterizing pore structure characteristics of filtration media with and without cake. The cake is capable of being created under a wide range of test conditions. The instrument is used for cost effective analysis of cake filtration processes and development of appropriate technologies.

Principle

A wetting liquid is allowed to spontaneously fill the pores in the sample and a nonreacting gas is allowed to displace liquid from the pores. The gas pressure and flow rates through wet and dry samples are accurately measured. The gas pressure required to remove liquid from the pores and cause gas to flow is given by:

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

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



Figure 1
PMI Cake Forming Porometer

Effect of the Cake on Pore Structure

Sample	Bubble Point, μm	Mean Flow Pore Diameter, μm
Filter	25.94	3.11
Filter with Cake due to Oil Filtration	7.15	2.05
% Change	72%	34%

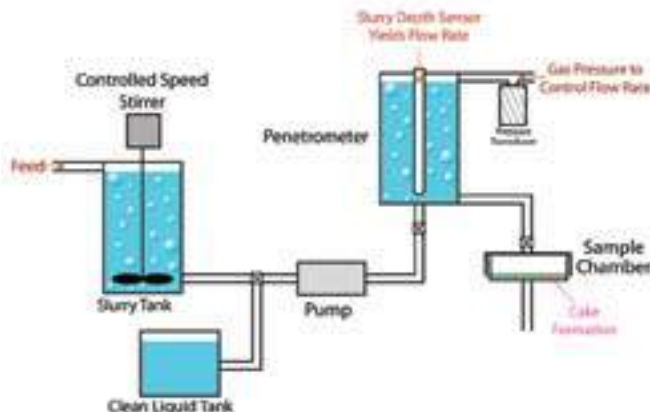


Figure 2
Outline of the basic principle behind Cake Forming Porometer

Unique Features

- 3 Sample Chambers for:
 - Pore Size Distribution
 - Cake Forming
 - Liquid Permeability
- Capable of forming cakes under user specified:
 - pressure
 - flow rate
 - concentration
- Cleaning of system to prevent clogging
- Ability to measure pore structure characteristics, including:
 - Bubble point
 - Mean flow pore diameter
 - Pore distribution
 - Liquid permeability
- Full automation for repeatable results obtainable without much operator involvement

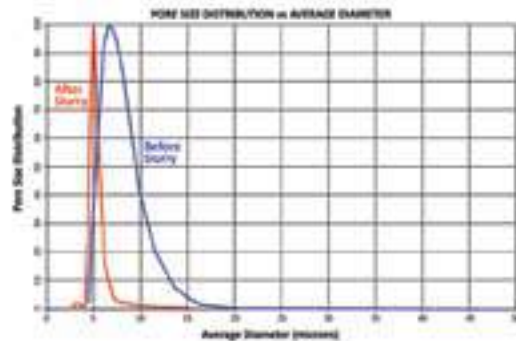


Figure 3

Pore distribution chart

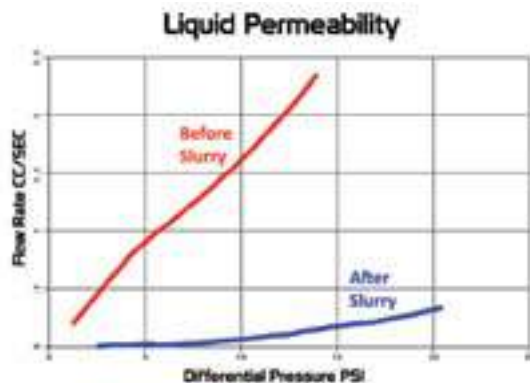


Figure 4

Variation of flow rate with change in pressure

Specifications

Pore Size Range: 0.03 to 100 microns
Permeability Range: 0.001 - 100 cc/min
Sample Size: ¼" - 2" diameter
5mm - 50mm
0" - 1" thick

Pressure Range: 0 - 110 psi
Resolution: 1 in 60,000
Accuracy: 0.15% of Reading
Power Requirements: 110/220 VAC, 50/60 Hz



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Capillary Condensation Flow Porometer

Applications

The PMI Capillary Condensation Flow Porometer has the unique ability to measure gas permeability and flow rate distribution in addition to measuring pore diameter of nanopore samples without using any toxic materials or extreme pressures and temperatures. No other instrument has such capabilities. It is utilized for characterization of porous membranes used in many industries such as biotech, pharmaceutical, filtration, food and environmental without any fear of harmful effects of high pressures and extreme temperatures on samples. Fragile samples with small pores can be easily evaluated by this technique.



Principle

At a given temperature, a vapor at a pressure less than the pressure, P_0 , of vapor in equilibrium with its liquid can condense in pores of a material. Kelvin equation gives the diameter of the pore in which condensation can occur at the relative vapor pressure, (P/P_0) .

$$\ln (P/P_0) = - [(4 \gamma V \cos Q) / (D R T)]$$

where γ is the surface tension of condensed liquid, V is the molar volume of condensed liquid, Q is the contact angle of the liquid with the pore surface, D is the pore diameter, R is the gas constant, and T is the absolute test temperature. At the lowest relative vapor pressure, (P/P_0) , condensation occurs in the smallest pore. On increase of relative vapor pressure condensation occurs in larger pores.

Features

Fully automated, simple to use, & very little operator involvement

Highly reproducible & accurate

Pressure required is very small

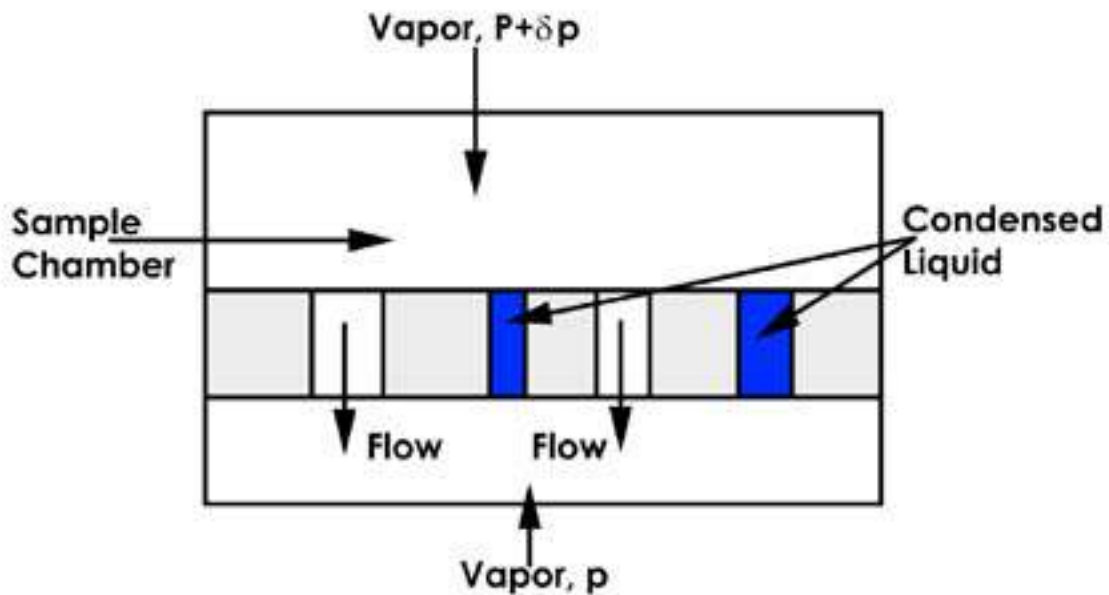
Normally liquid nitrogen temperatures are not required

A wide variety of samples can be investigated

No toxic material like mercury is used, no health hazard, no disposal related cost

Operation

The instrument is maintained at the desired temperature. Vapor is introduced into the sample chamber of known volume. The vapor pressure is monitored until the system comes to equilibrium. From the final pressure, the diameters of pores in which condensation occurs are computed. A small amount of vapor is added to one side of the sample in the sample chamber so as to raise the pressure on that side by about 10%. The decay of pressure is monitored as a function of time. Gas flow rates through the pores of the sample which do not contain condensed liquid at the maintained pressure of the vapor are computed from the time rate of pressure change. From repeated determination of flow rates at a number of vapor pressures, the flow rate distribution is computed.



Specifications

Pore size range: 0.2 – 0.0005 μm

Pressure: 15 psi

Accuracy: 0.15% of reading

Resolution: 1 in 60,000

Flow rate: As low as 10^{-4} cm³/s

Power: 110/220 VAC, 60/50 HZ



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CARTRIDGE BUBBLE POINT TESTER

Description

The cartridge bubble point tester accommodates cartridges having a wide range of sizes. It facilitates quick and easy loading and unloading of cartridges. Performs speedy high volume testing and measures pores on all sides of the cartridge. Conserves the wetting liquid by circulating from a storage tank, and ventilates the sample chamber. It has many applications throughout the filtration industry.



Principle

A wetting liquid spontaneously fills the pores of a porous material. Wetting liquids is less than the surface free energy of the filtration media with air wetting liquid can be removed from the pores by increasing differential pressure of a nonreacting gas on the sample. The testing technique involves measurement of gas flow rates through a wet sample as a function of differential pressure. The gas pressure needed to displace a wetting liquid from the largest pore is related to the pore diameter.

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

where, p is differential inert gas pressure on the wetting liquid in the pore, γ is the surface tension of the wetting liquid, θ is the contact angle of the wetting liquid with the pore surface of the filtration media, and D is pore diameter.

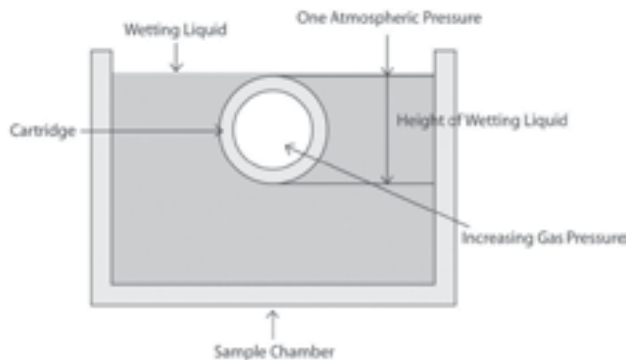
Detectable Pore Sizes

Fluid	Surface Tension, Dynes/cm	Minimum Pore Size, μm	Maximum Pore Size, μm
Water	72	1	800
Mineral Oil	34.7	0.7	700
Petroleum Distillate	30	0.6	700
Denatrued Alcohol	22.3	0.5	600
Silwick	20.1	0.4	500
Porewick	16	0.33	400
Galwick	15.9	0.3	400

Any other wetting fluid can also be used for testing.

Application

The measured differential pressure yields the largest through pore throat diameter. The table below shows the range of wetting liquid sample sizes.



Unique Features

- **Accommodation of a wide range of Cartridge Sizes**

- Deep sample chambers, detachable head attachments, and movable clamping heads make this an extremely versatile machine.

- **Quick Loading & Unloading of Cartridge for Speedy Testing**

- The cartridges are loaded in the sample chamber simply by using two levers. The horizontal lever is used to move the clamping head forward and backward to allow for cartridge length, and the rotating lever is used to lock the cartridge

- **High Volume Testing**

- The machine has two sample chambers, and each is provided with horizontal lever and a rotating lever for quick and easy loading and unloading

- **Automatic Wetting of Sample**

- The wetting liquid is automatically added to the sample chamber by an inlet inside the chamber. Enough liquid is added to adequately cover the sample

- **Testing of Pores on All Sides of the Cartridge**

- A rotating cartridge holder allows for even and equal testing on all sides of the sample. The speed at which the sample rotates can be adjusted by the user.

- **Conservation of Wetting Liquid**

- The liquid is automatically drained from the sample chamber and pumped to a storage tank, which is then used to fill the sample chamber again.

- **Ventilation of the Test Chamber**

- A ventilation fan constantly removes vapor of the wetting liquid from the sample chamber. The vapor is disposed of in an appropriate manner, and the operator is prevented from inhaling the vapor from the wetting liquid.

- **Fully Automated Operation**

- Little user involvement is needed



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Clamp-On Porometer

Application

The PMI Clamp-On Porometer provides pore structure information quickly and accurately for your quality control, production control or R&D needs. The need for cutting samples from bulk material is eliminated.



Figure 1

PMI Clamp-On Porometer

Principle

The pores in the part of the material to be tested are spontaneously filled with a wetting liquid. The test head is clamped on the material and gas pressure behind the sample is slowly increased to displace the liquid in the pore and increase gas flow. The flow rate of gas is measured as a function of gas pressure. The flow rate versus pressure data is also generated using a dry sample. Pressure is related to pore diameter.

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

where D is the pore diameter, γ , is the surface tension of liquid, θ is the contact angle of liquid, and p is the differential gas pressure. From these data the characteristics of the pore structure are calculated.

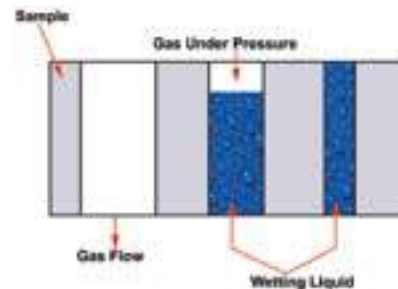


Figure 2

Principle for the Clamp-On Porometer

Testing Capabilities

- Bubble Point
- Mean Flow Pore Diameter
- Gas Permeability
- Frazier Permeability
- Gurley Permeability
- Pressure Hold
- Pore Size Distribution

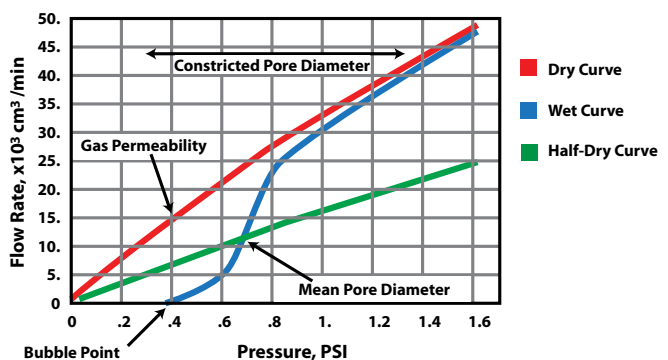


Figure 3

Flow rate over change in pressure

Applications

Industries world-wide, ranging from the filtration industry to the battery industry, use the PMI Clamp-On Porometer for R&D and quality control. Materials often tested include: filter media, membranes, nonwovens, paper, powders, ceramics and battery separators.

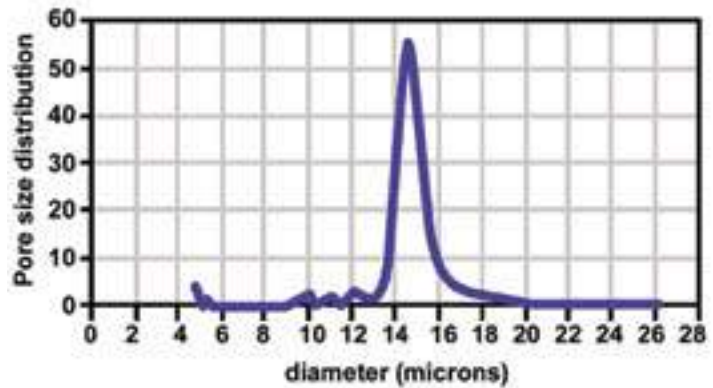


Figure 4

Pore size distribution chart

Features

On-line sample testing possible

No need for cutting the sample and damaging the product

Fast testing

Fully Automated Operation

Windows Based

Determination of product uniformity by performing tests at multiple locations of the product without creating any damage

Highly Reproducible

Minimal Maintenance



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Compression Porometer

Description

The pore structure characteristics of products experiencing considerable stress during service could be appreciably different from those evaluated in the laboratory. This award winning instrument provides a unique opportunity for evaluating the component under true service conditions.

Principle of Operation

A fully wetted sample sandwiched between two porous and rigid plates is placed in the sample chamber. The plates are much more porous than the sample. Compressive stress is applied on the plates. Gas pressure behind the sample is increased. When the pressure is sufficiently high, the largest pore is emptied and gas starts to flow. With increase in pressure, smaller pores are emptied and the flow rate increases through the sample. The flow rate and pressure are measured using wet and dry samples. These data are used to calculate the effects of compressive stress on pore size and pore distribution. The pore size is obtained from differential pressure.

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

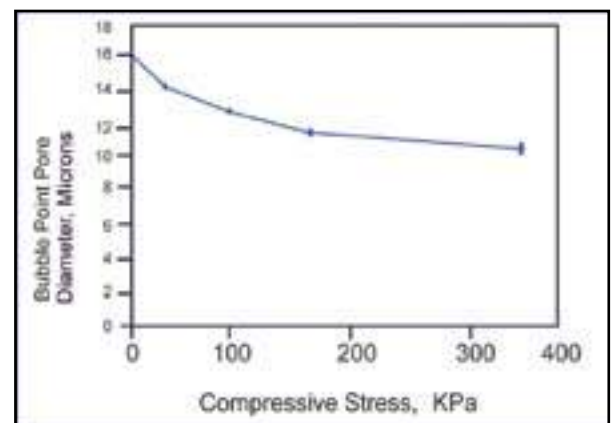
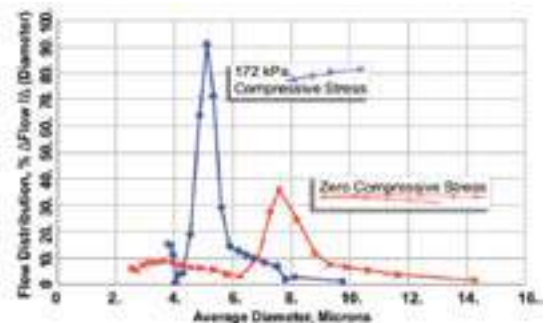
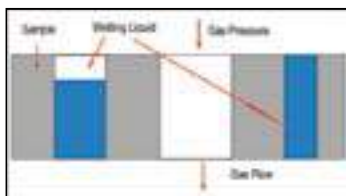
D= pore diameter

γ = surface tension of liquid

θ = contact angle of liquid

p= differential gas pressure

The Compression Porometer, thus, characterizes porous materials under conditions of their actual use.



Features

- Measures effects of compressive stress on the largest pore diameter (bubble point), the mean flow pore diameter, pore distribution, and permeability.
- Fully Automated
- Windows based software for data acquisition, storage and reduction
- Compressive stress adjustable by the operator

Applications

The Automated Compression Porometer is designed to characterize the pore structure of a material under compression. Industries worldwide use the PMI Compression Porometer for R&D and quality control. Samples often tested include filter media, membranes, paper and battery separators. The instrument permits tests to be carried out under simulated true service conditions.

Industries

Automotive, Battery Separator, Filtration, Geotextiles, Textiles, Nonwovens, Paper, Fuel Cells

Specifications

Pore Size Range: 0.013 - 500 microns

Permeability Range: 1×10^{10} - 1×10^6 (microflow in cc/sec/m/torr)

Sample Size: 0.5" - 2.5" diameter

Pressure Transducer Range: 0 - 500 psi

Resolution: 1 in 20,000

Accuracy: 0.15% of reading

Pressurizing Gas: Clean, dry, and compressed air
or nonflammable and non-corrosive gas

Mass Flow Transducer Range: 10 cm³/min - 500,000 cm³/min

Power Requirements: 110/120 VAC, 50/60 Hz (Others Available)

Dimensions: 30" H x 19" W x 18.5" D

Weight: 100 lbs



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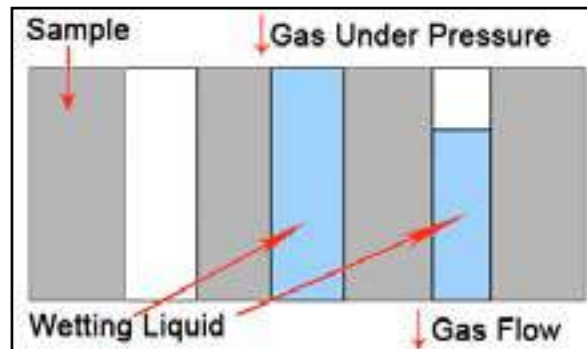
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Cyclic Compression Porometer

Principles of Operation

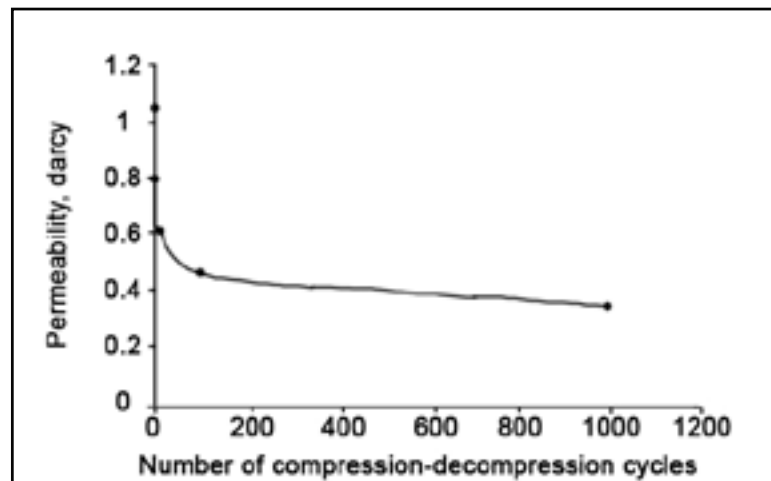
The instrument applies cyclic stress on a sample and measures the pore structure characteristics after a desired number of cycles. The sample is loaded in the sample chamber and is subjected to stress cycles in the specified stress limits. At the end of the desired number of stress cycles, the pressure of a nonreacting gas on one side of the sample is increased to initiate gas flow through pores. The gas pressure and flow rates are measured. The pores in the sample are spontaneously filled by a wetting liquid. The gas pressure and flow rates are measured through the wet sample. After acquisition of data, the sample is re-wetted and again subjected to cyclic compression. Pressure and flow rates are measured after the desired number of cycles.

The test is continued to acquire data as a function of number of stress cycle.



Features

- After desired number of stress cycles
 - automatically interrupts analysis
 - performs tests
 - acquires data
 - continues to cyclically stress the sample
- Very little operator involvement
- Operator adjustable
 - stress limits in a cycle
 - number of cycles after which data is to be acquired
 - stress free duration for data acquisition
 - total number of cycles
- Concurrent measurement of compressive strain in the sample as a function of stress cycle
- Windows based simple operation



Specifications

Pore Size Range:
0.013 - 500 microns

Resolution:
1 in 60,000

Permeability Range:
 1×10^{-3} - 50 darcies

Accuracy:
0.15% of reading

Sample Size:
1.75" - 2.5" diameter

Mass Flow Transducer Range:
 10^3 /min - 500,000 cm^3 /min

Pressure Range:
0 - 500 psi

Power Requirements:
110/120 VAC, 50/60 Hz
(Others Available)

Pressurizing Gas:
Clean, dry, and compressed air or
nonflammable and noncorrosive gas

Dimensions:
30" H x 19" W x 18.5" D

Pressure Transducer Range:
0 - 500 psi

Weight:
100lbs

Effects of Cyclic Compression on Pore Diameter of Felts

Material	Maximum Compressive Stress, psi	# of Cycles	% Change in Bubble Point	% Change in Mean Flow Pore Diameter
Felt #1	500	15	-71.1	-30.3
Felt #2	750	2000	-68.4	-15.8



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Fuel Cell Porometer

Description

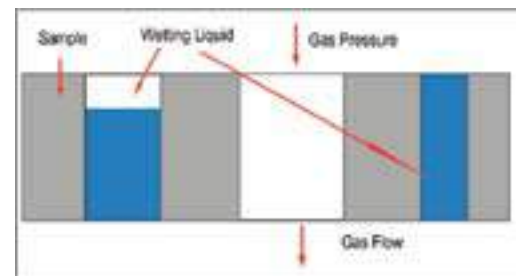
The PMI Fuel Cell Porometer provides fully automated through-pore analysis including pore-throat diameter, pore size distribution, mean flow pore diameter, and liquid & gas permeability. The porometer's versatility allows the user to simulate operating conditions. The instrument has special features to measure the effects of compressive stress on a sample, test temperature, sample orientation, and layered structure on pore structure characteristics. The fully automated, user-friendly Fuel Cell Porometer is an asset in quality control and R&D environments.



Figure 1
Fuel Cell Porometer

Principle

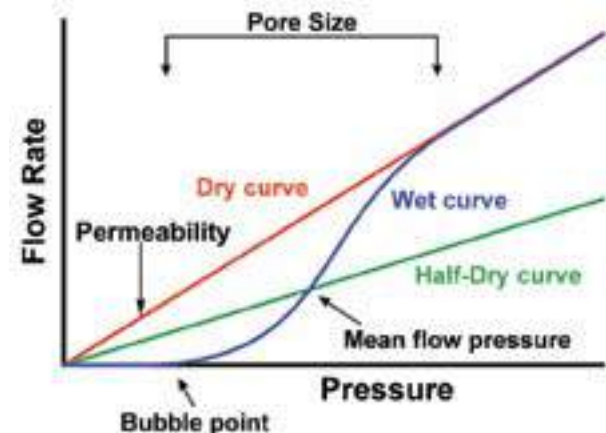
The flow rate of an inert gas through the dry sample is measured with increasing pressure. The sample is brought in contact with a wetting liquid, the liquid spontaneously fills the pores in the sample, and the flow through the wet sample is measured with increasing differential pressure.



Features

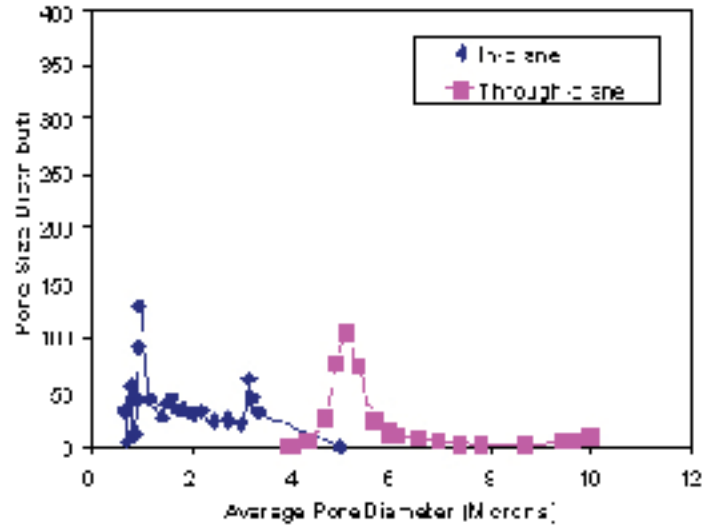
Measured flow rates through dry and wet samples with increasing differential pressure are used to compute many characteristics.

- Pore throat diameters
- The largest pore throat diameter
- Mean flow pore diameter
- Pore distribution
- Gas permeability
- Through pore surface area (Envelope Surface Area)



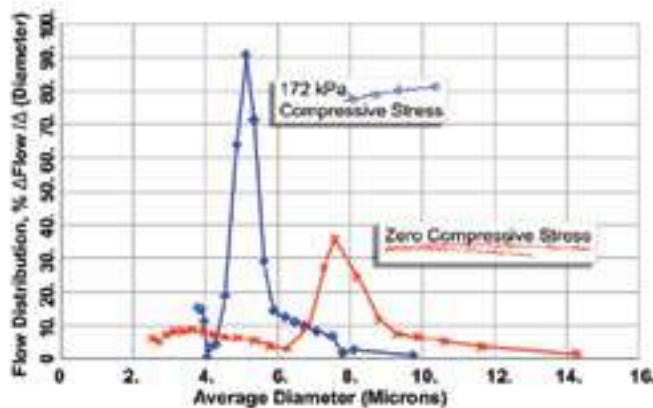
Applications

The performance of many fuel cell components is determined primarily by the characteristics of the pore structure. Flow of reactants and products is determined by the pore size and pore distribution of electrodes, wide range of gas humidity found in many applications can change the pore structure, components subjected to compressive stress during operation can considerably modify the pore size, pore structure of each layer of multilayer composites often used as fuel cell components can determine the performance of the fuel cell, and reaction rate of reactants is governed by the surface area of through pores. The Fuel Cell Porometer is designed to measure all the relevant pore structure characteristics of fuel cell components.



Unique Features

- Characteristics measurable using gas with 0 to 100 % humidity
- Test temperatures can be 200°C and in special situations 800°C
- Pore size measured in samples under compressive stress of up to 1000 psi
- Pore structure of each layer of a multilayer composite
- Pore diameters down to about 0.013 μm



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HIGH FLOW CARTRIDGE TESTER

Application

The instrument is specially designed for the determination of pore distribution and liquid permeability of high flow cartridges and other products like crucibles and cylinders. Multiple sample chambers can be provided to allow for high volume testing.

Principle

The pores of the sample are filled with a wetting liquid. Gas pressure needed to permit flow through the wet cartridge is measured. The pore diameter, D , is computed using the following relation:

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

where γ is surface tension, θ is the contact angle of the liquid and p is differential pressure needed to empty pores of diameter D . The flow rate through a dry sample is also measured. The flow rate of liquid through the cartridge is measured with increasing differential pressure. Liquid permeability is computed using Darcy's Law and the measured flow rate.

For pore distribution testing air flow rate and pressure for each chamber are accurately controlled. For liquid permeability measurement, separate liquid supply system is provided to each liquid permeability chamber so as to provide enough liquid for liquid permeability.

Typical Results

Liquid flow rate measured through a cartridge as a function of differential pressure is shown in figure 3. The liquid permeability is computed from the liquid flow automated using the PMI Cartridge Tester software.



Figure 1

The image above displays a High Flow Cartridge Tester with 4 chambers.

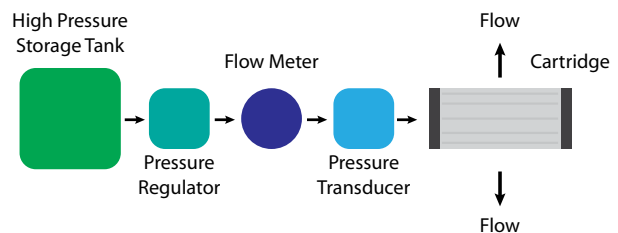
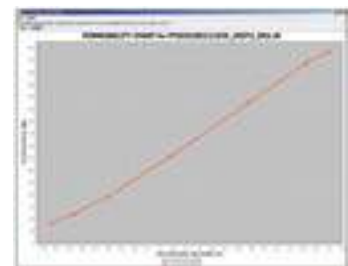


Figure 2

The diagram displays the mechanical principle.

Figure 3

Image from Cartridge Tester software.



The typical sample chamber for a crucible is shown in figure 4. The crucible rests on the inner lip of the sample chamber. Pressure will be applied on both ends of the crucible forming a seal. The test gas is introduced via an inlet in the piston rod on one side of the crucible.

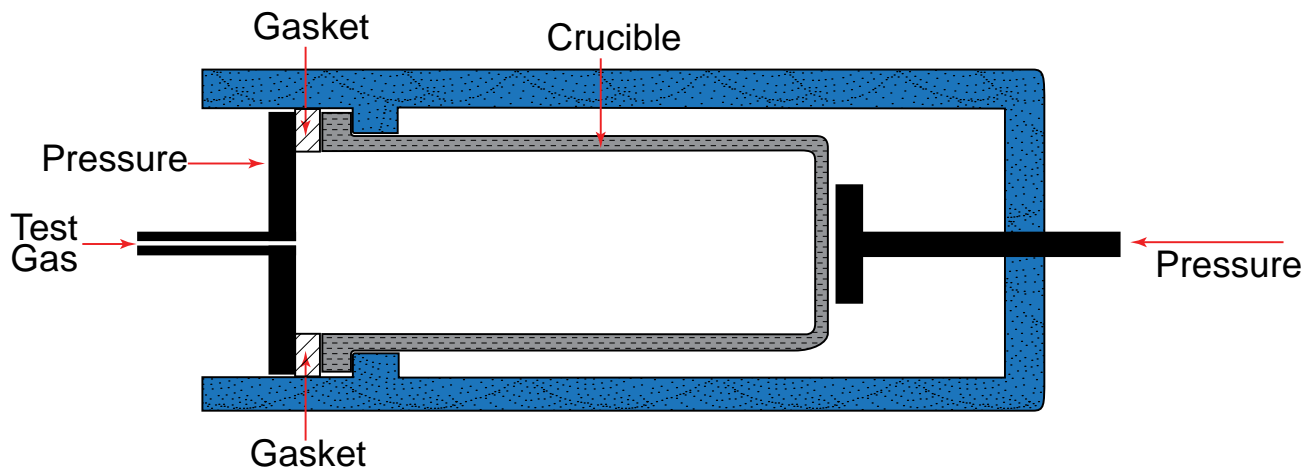


Figure 4

Crucible Sample Chamber

Features

- Movable heads allow for various cartridge sizes
- Optional adapters for unique cartridges
- Automated wetting and gas into samples
- Automated drain system
- Chambers for Pore Distribution Test and Liquid Permeability Test

Specifications

- Pressure Range: 0 - 5 psi
- Number of Chambers: 1-4
- Air Flow Rate: 1 million liters/minute
- Pressurizing Fluid: Clean, dry, compressed gas or nonflammable, noncorrosive liquid
- Power: 110/220 VAC, 50/60 Hz



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In-Plane Porometer

Application

The sample chamber of the In-Plane Porometer is such that gas is allowed to displace liquid in pores to move radially from the center to the periphery of a sheet shaped sample. Suitable sample configurations give in-plane pore structures of multi-layered materials. The instrument measures:

- Pore diameter and distribution in the x-y plane, and in the x, y and z directions.
- Permeability in x-y plane and in the x, y and z directions.
- Pore size and distribution of layers of a composite.

Principle

A wetting liquid is allowed to spontaneously fill the pores in the sample and a non-reacting gas is allowed to displace liquid from the pores in the radial direction. The gas pressure and flow rates through wet and dry samples are measured and the pore structure characteristics are computed using the following equations:

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

The differential gas pressure, p , required to remove liquid from pores and cause gas flow is related to surface tension, γ , contact angle, θ , and pore diameter, D .

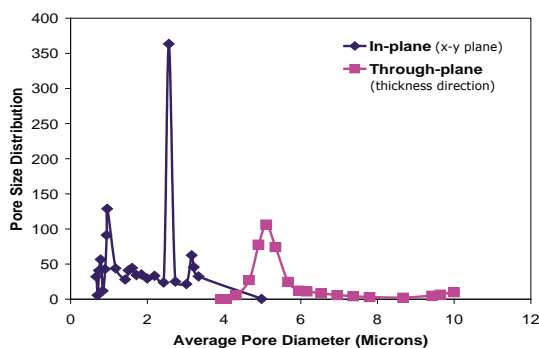


Figure 1

PMI In-Plane Porometer

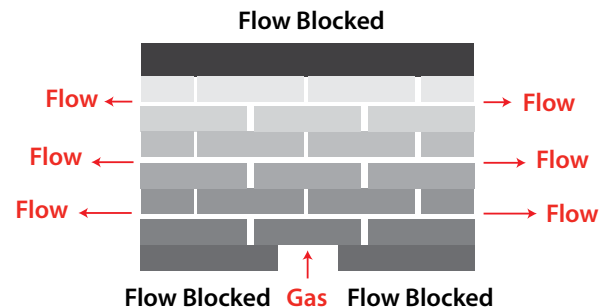


Figure 2

The principle behind the In-Plane Porometer

Figure 3

Pore distribution

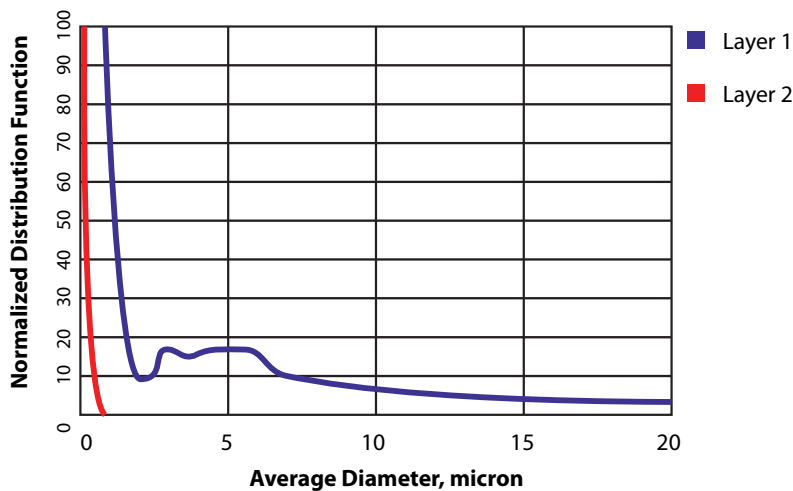


Figure 4
Average pore diameter

Directional Characteristics

Direction	Bubble Point Pore Diameter, μm	Mean Flow Pore Diameter, μm	Permeability, Darcy
x	27.1	3.86	5.3
y	39.1	3.39	6.9
z	63.0	15.2	22.5

Specifications

Pore Size Range

0.013 - 500 microns

Permeability Range

1×10^{-10} - 1×10^{-6}

Sample Size

0.5" - 2.5" diameter

Pressurizing Gas

Clean, dry, compressed air or nonflammable, non-corrosive gas

Pressure Range

0 - 500 PSI

Pressure Transducer

Range

0 - 500 PSI

Mass Flow Transducer Range

10 cc/minute - 500 L/minute

Power Requirements

110/120 VAC, 50/60 Hz

(Others available)

Dimensions

30" H x 19" W x 18.5" D

Weight

100 lbs

Resolution

1 in 60,000

Accuracy

0.15% of reading



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Liquid-Liquid Porometer

Standard & Nanoflow versions Available

Application

Designed for pore structure characterization of materials such as membranes, filter media, ceramics, paper, textile, etc., having very small pore sizes. It is capable of measuring pore diameters, pore distribution and liquid flow rate of materials having very low permeability.

Principle of Porometry

A wetting liquid spontaneously fills the pores of the material. Two immiscible wetting liquids are selected. Liquid 1 with lower surface tension is used to fill the pores of the sample. Liquid 2 is added to the top of the sample and is pressurized to displace the first from the pores and flow through the empty pores. The flow rate of Liquid 2 is also measured without wetting the sample with Liquid 1. The pore diameter is related to the surface tension of the two liquids. The flow rates yield pore distribution and liquid permeability.

$$D = 4 \gamma_1 \cos \theta_1 / p$$

Where:

D = pore diameter

γ_1 = Interfacial surface tension of liquids

$\cos \theta_1$ = contact angle of liquid 1 on pore surface

p = differential pressure applied on the sample by liquid 2

Test Procedure

Two immiscible & saturated wetting liquids such as silwick and alcohol are taken. Pores are filled with silwick and alcohol is pressurized to displace the silwick and flow through the pores. The amount of liquid flowing out is measured in balance. Alcohol flow rate and differential pressure are measured. Because surface tension of silwick and alcohol are low, contact angles are taken as zero. Mean flow pore diameter and pore distribution are computed like CFP.



Figure 1

PMI Standard Version LLP



Figure 2

PMI Nanoflow Version LLP

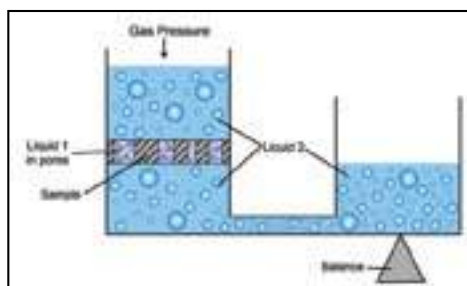


Figure 3

Basic design for analysis procedure

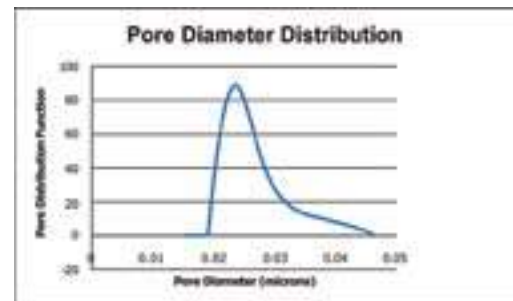
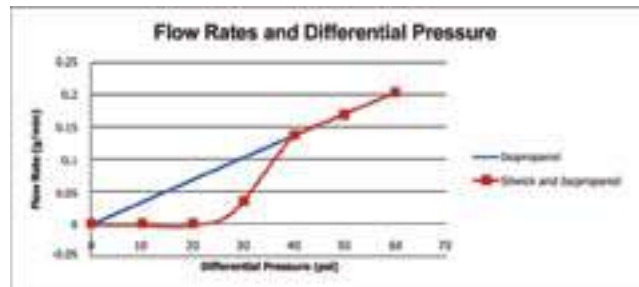
Unique Features

- Pore diameters down to several nanometers are measurable
- Pressures needed are much less than those for capillary flow porometer
- Very low liquid permeability measured
- Fully automated, user friendly operation

Typical Test Results

Software interface showing test parameters and a data table. The table has columns for 'NECESSARY PRESSURE (psi)', 'A', 'B', 'C', 'D', and 'NECESSARY FLOW (cc/min)'. The data rows show values for various test conditions.

NECESSARY PRESSURE (psi)	A	B	C	D	NECESSARY FLOW (cc/min)
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
0.001	0.001	0.001	0.001	0.001	0.001
0.01	0.01	0.01	0.01	0.01	0.01
0.1	0.1	0.1	0.1	0.1	0.1
1	1	1	1	1	1
10	10	10	10	10	10
100	100	100	100	100	100
1000	1000	1000	1000	1000	1000



Specifications

Pressure Range:

0 - 500 psi

Resolution:

1 in 60,000

Sample Size:

5mm - 50mm diameter foil to 1" Thick (Others Available)

Pore Size Range:

0.5 - 0.002 microns

Flow Resolution:

0.0001 cc/min



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Microflow Porometer

Description

The PMI Microflow Porometer is a Capillary Flow Porometer with the ability to measure pore structure and permeability in nearly impermeable materials. This instrument is user-friendly and fully automated. The Microflow Porometer is an asset in quality control and R&D environments.

Principle of Operation

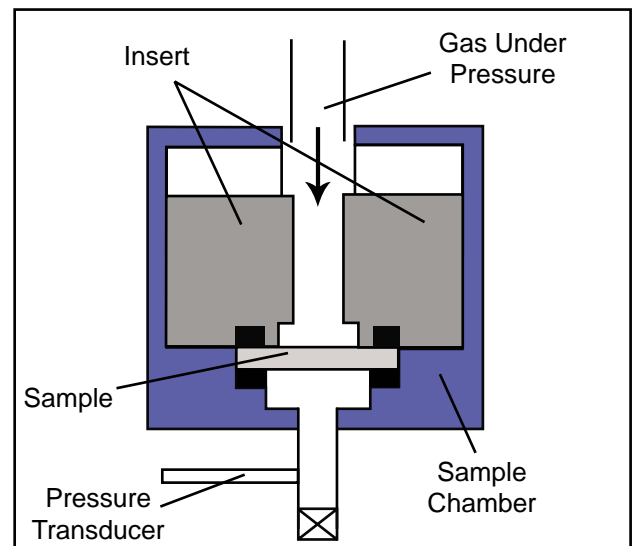
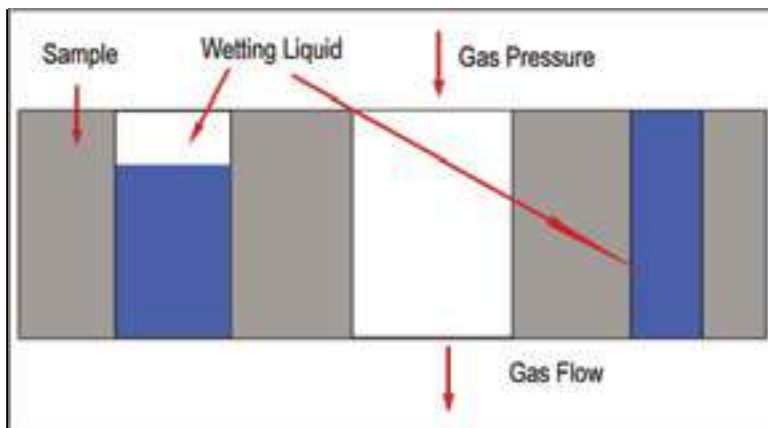
In this instrument a pressure transducer is located on the downstream side of the sample and the time rate of pressure change in the known volume of the downstream side of the sample chamber is used to compute very small flow rates.

$$F = (V T / T P) (dP / dt)$$

Where F is flow rate at standard temperature, T , and standard pressure, P , V is the volume of the downstream side of the sample chamber, T is test temperature, t is time, and P is test pressure. Flow rate through dry sample is measured with increasing differential pressure. The sample is wetted and flow rate is measured as a function of differential pressure, p, which is related to pore diameter, D, contact angle, θ , and surface tension,

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

where σ and θ are surface tension and contact angle of wetting liquid respectively.

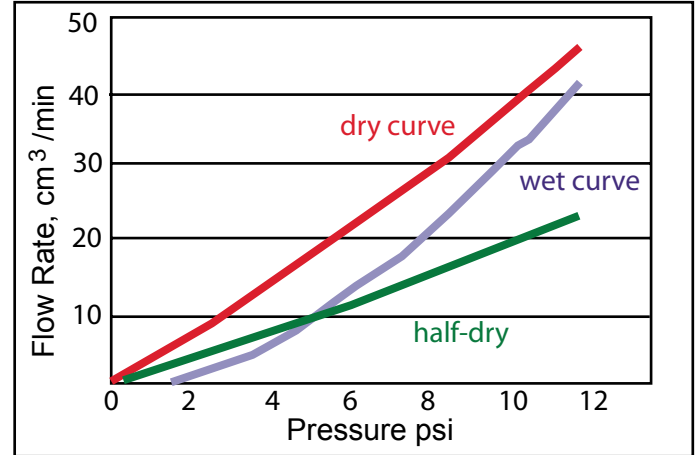
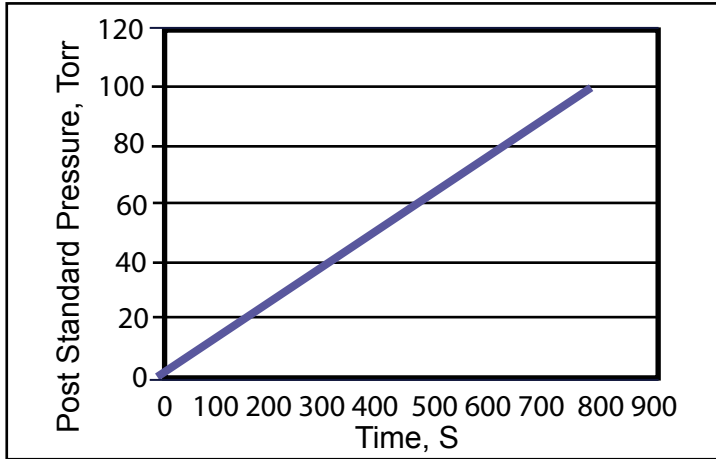


Features

- Samples permitting very low flow rate can be tested
- Very low permeability can be measured
- Fully automated
- Windows based simple operation

Many optional features possible:

- Sample under compressive stress
- Elevated Temperature test
- Determination of In-Plane Structure



Specifications

Pore Size Range: 0.013 - 500 microns

Permeability Range: 1×10^{-10} - 1×10^{-1} (microflow in cc/sec/m/torr)

Sample Size: 0.5" - 2.5" diameter

Pressure Transducer Range: 0 - 500 psi

Resolution: 1 in 20,000

Accuracy: 0.15% of reading

Pressurizing Gas: Clean, dry, and compressed air
or nonflammable and non-corrosive gas

Mass Flow Transducer Range: 10 cm³/min - 500,000 cm/min

Power Requirements: 110/120 VAC, 50/60 Hz (Others Available)

Dimensions: 30" H x 19" W x 18.5" D

Weight: 100 lbs



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Integrity Analyzer

Description

The PMI Integrity Analyzer provides fully automated analysis of filter integrity. The integrity test detects small amounts of flow through the sample before the bubble point is reached. The user-friendly Integrity Analyzer features nondestructive testing and can test a wide variety of samples. The integrity test can also measure bubble point.

Principle

A fully wetted sample is placed in the sample chamber and the chamber is sealed. Gas is then allowed to flow into the chamber behind the sample with increasing pressure. A flow meter is located in front of the sample and is used to detect gas flow through the sample prior to any pore being emptied of liquid, thus, the integrity is determined. When the pressure reaches a point that can overcome the capillary action of the liquid within the largest pore, the bubble point has been found. After determination of the bubble point, the pressure is increased and the flow is measured until all pores are empty.

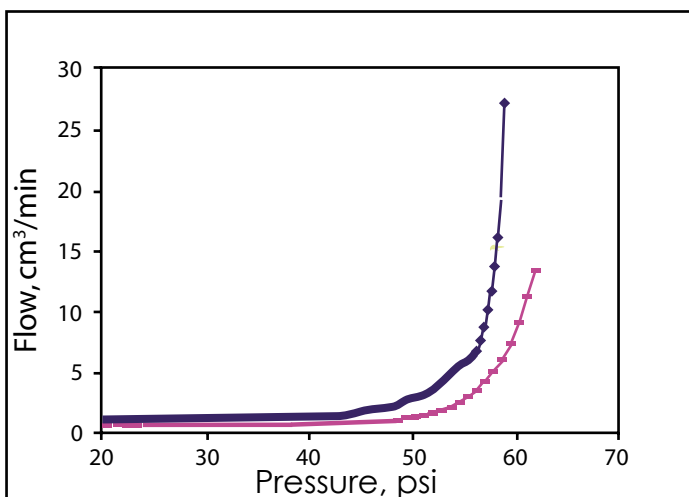


Figure 1

Flow Rates

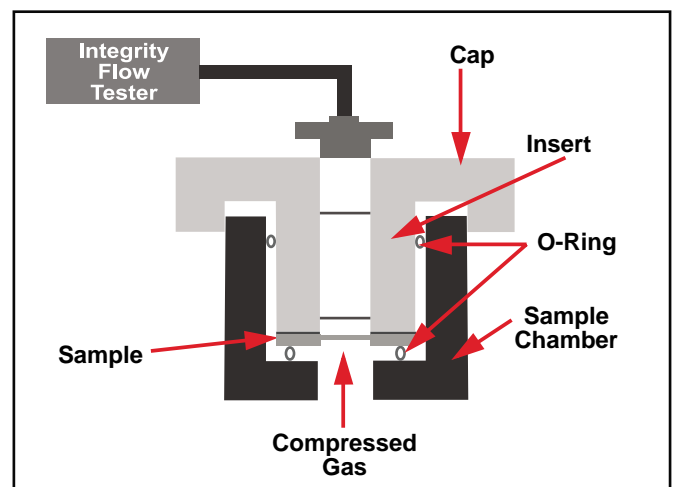


Figure 2

Outline of the basic principle of the Integrity Analyzer

Specifications

Pore Size Range	0.013 - 500 microns
Permeability Range	1 x 10 ⁻⁵ - 50 darcies
Sample Size	1.75" - 2.5" diameter
Pressure Range	0 - 500 psi
Pressurizing Gas	Clean, dry, and compressed air or nonflammable and noncorrosive gas
Pressure Transducer Range	0 - 500 psi
Resolution	1 in 20,000
Accuracy	0.15% of reading
Mass Flow Transducer Range	10 cm/min - 500,000 cm/min
Power Requirements	110/120 VAC, 50/60 Hz (Others available)
Dimensions	30" H x 19" W x 18.5" D

Industries

- Automotive
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- Nonwovens
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- Battery
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- Biotechnology
- Fuel Cells
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Quality Control Porometer

Principles of Operation

A fully wetted sample is placed in the sample chamber. The chamber is sealed, and a nonreacting gas is allowed to flow into the chamber to a value of pressure sufficient to overcome the capillary action of the fluid in the pore of the largest diameter, empty the pore, and initiate gas flow through the sample. This is the Bubble Point Pressure. The pressure is further increased in small increments, resulting in flow that is measured until the pores are empty of fluid. Such flow and pressure data are generated using a dry sample. The results are used to compute pore parameters and pore distribution. Pressure required to remove a wetting liquid is related to pore diameter.

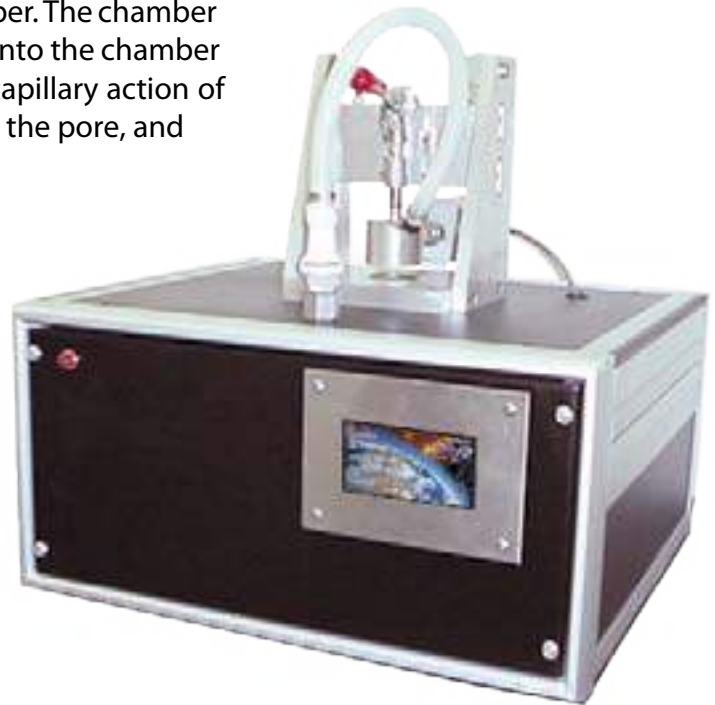
$$D = 4\gamma \cos \theta / p$$

p = Differential gas pressure on the sample

γ = Surface tension of wetting liquid

θ = Contact angle of wetting liquid

D = Pore diameter

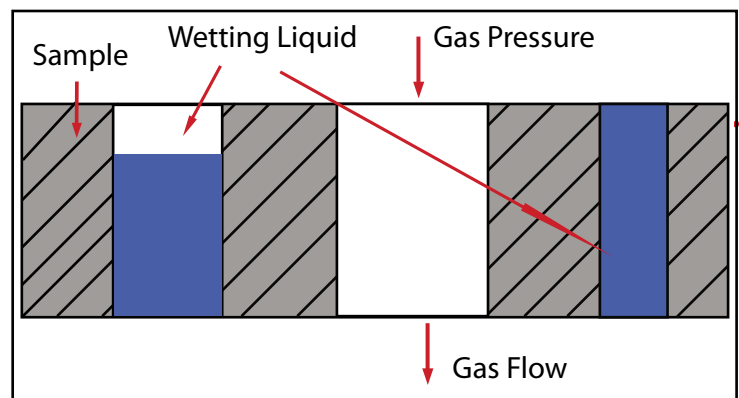


Applications

The unique features of the instrument, especially its ability to generate highly reproducible data quickly, make it highly suitable for quality control and process control operations. The instrument is used in these applications in a wide variety of industries.

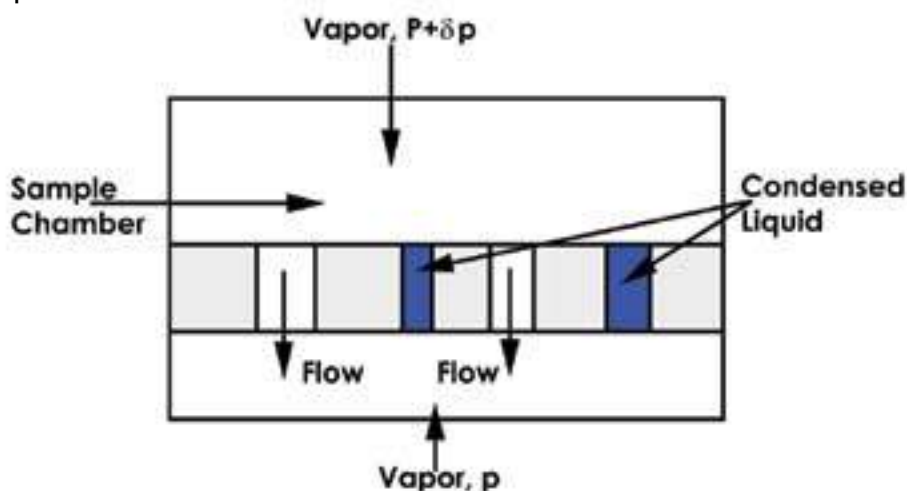
Features

- Fully automated and user friendly
- Only a few minutes per test
- Preset test parameters
- Very little operator time and involvement
- Ideal for quick generation of highly reproducible data
- Uses a variety of sample shapes and sizes
- Very little maintenance



Operation

The instrument is maintained at the desired temperature. Vapor is introduced into the sample chamber of known volume. The vapor pressure is monitored until the system comes to equilibrium. From the final pressure, the diameters of pores in which condensation occurs are computed. A small amount of vapor is added to one side of the sample in the sample chamber so as to raise the pressure on that side by about 10%. The decay of pressure is monitored as a function of time. Gas flow rates through the pores of the sample which do not contain condensed liquid at the maintained pressure of the vapor are computed from the time rate of pressure change. From repeated determination of flow rates at a number of vapor pressures, the flow rate distribution is computed.



Specifications

Pore size range: 0.2 – 0.0005 μm

Pressure: 15 psi

Accuracy: 0.15% of reading

Resolution: 1 in 60,000

Flow rate: As low as 10^{-4} cm^3/s

Power: 110/220 VAC, 60/50 HZ



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