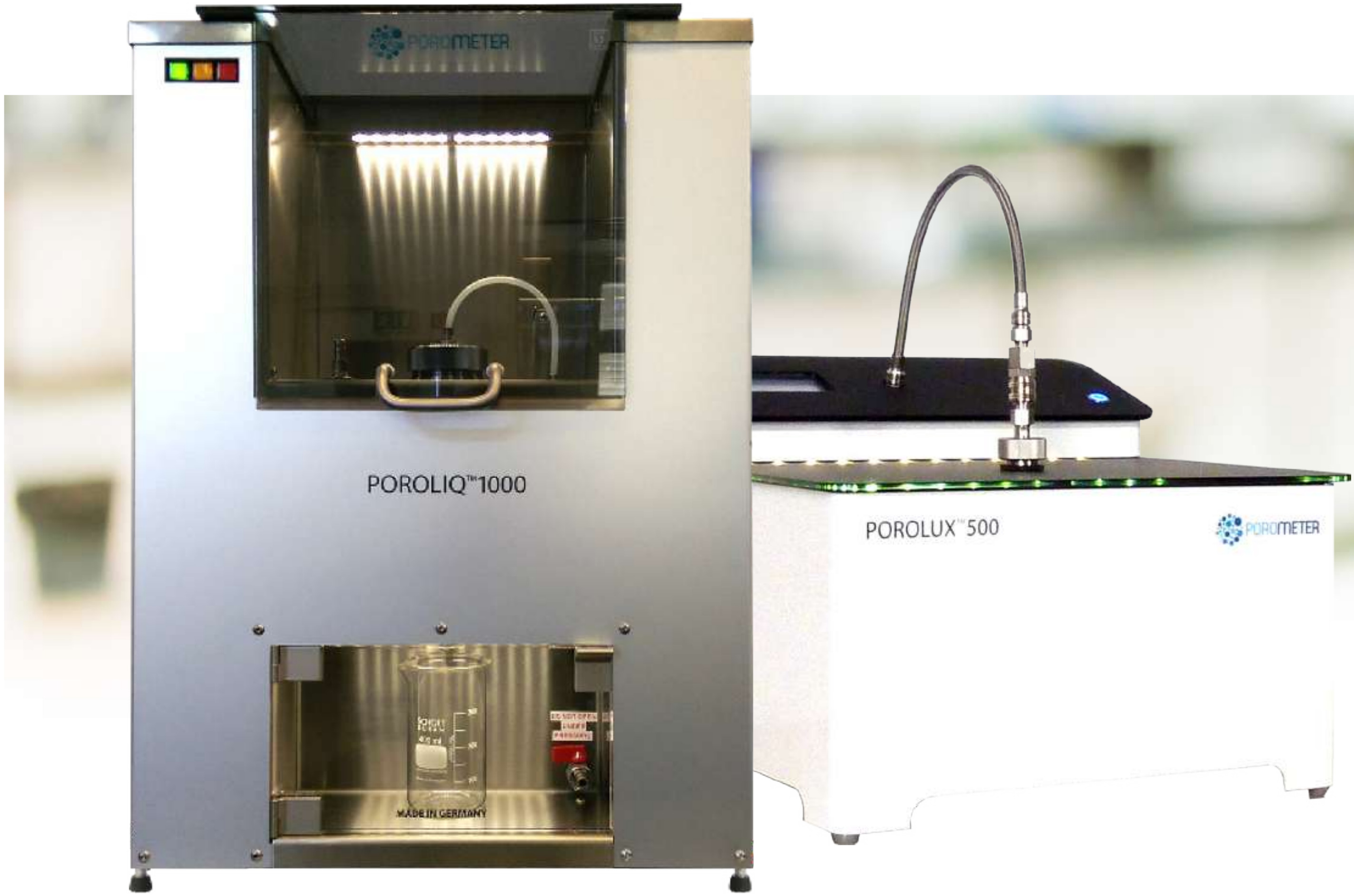


Pores & More

POROMETER
FILTER AND MEMBRANE TESTING TECHNOLOGY

- PORE SIZE DISTRIBUTION
- MEMBRANE & FILTER TESTING
- MEMBRANE SYNTHESIS
- CONTRACT TESTING

POROMETER

WHO WE ARE

POROMETER is part of the APTCO INVEST Technology and Innovation Group. APTCO is a diverse, international group of companies active in the distribution, manufacturing, service and support of scientific instruments and equipment. APTCO's member companies boast activity in analytical and materials characterization technologies (BENELUX SCIENTIFIC Group) and life sciences, biobanking and diagnostics (SOPACHEM Group). Other divisions focus on calibration services (CALIBRATION LAB) and laboratory platen presses (FONTIJNE).

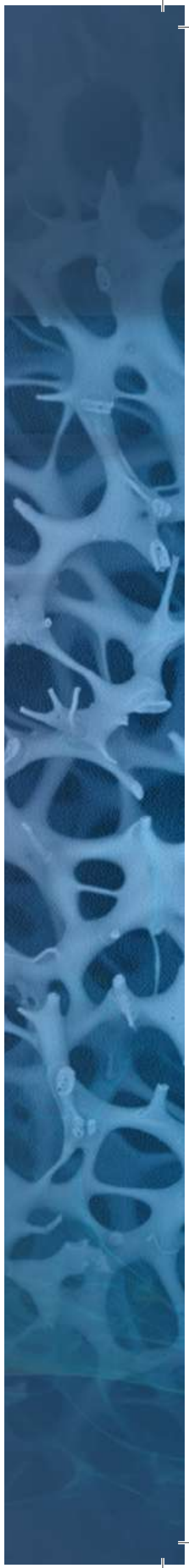
The APTCO INVEST technology and innovation group is a privately owned company. APTCO believes in long term success and sustainable growth. Our primary objectives are (1) being a reliable and successful company, (2) generate high added value to our customers and (3) offer our employees and our partners a place where they can use and develop their skills and talents.

In 2016 the APTCO Group realized sales of over 17 M€ with a team of 50 people.

OUR HISTORY

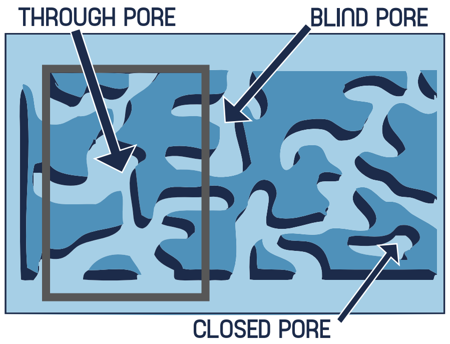
Our experience with porometers goes back to the Coulter porometer, developed in the late eighties. During many years our team has been selling and servicing many different models such as the Coulter I and II, the Xonics 3G and the Porometer 4 from Porvair, as well as the PMI porometers. For several years our team supported their customers in Europe and far beyond.

Based on many years of experience we have acquired a true understanding of porometers and their applications. Because we believed that most porometers had significant weaknesses, we joined forces with IB-FT – a German engineering company with a solid track record of engineering and manufacturing test equipment for the filter industry – to develop the POROLUX™, a range of instruments based on capillary flow porometry for testing membranes, filters, technical textiles, nonwovens, papers, hollow fibers and ceramics amongst other. Our POROLUX™ product range is widely used to measure maximum, mean and minimum pore size, pore size distribution and gas permeability with improved accuracy and reproducibility compared to other current equipment available in the market.



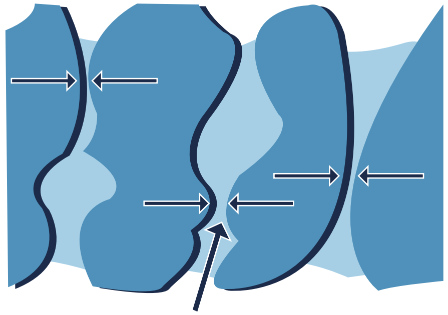
Gas Liquid Porometry

Gas Liquid Porometry, also known as Capillary Flow Porometry (CFP), measures pore size and pore size distribution of through pores in materials. The technique is based on the displacement of an **inert and nontoxic wetting liquid** embedded in a porous network by applying an inert pressurised gas. Therefore, only through pores are measured.



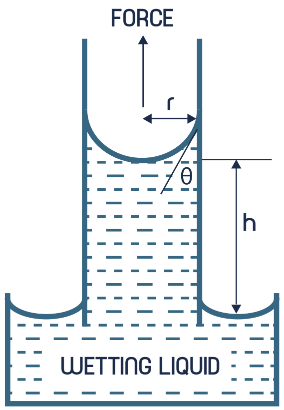
Larger pores become empty first and, as the applied pressure increases, so do the smaller ones until all through pores are empty.

The most challenging part for the gas to displace the liquid along the entire pore path is the most constricted section, also known as pore throat. The diameter measured in CFP is the pore throat, regardless of where it exactly in the pore path is.



The method depends upon the capillary rise created by the surface tension between the liquid and the gas. Therefore, a wetted pore immersed in a liquid draws the liquid up the capillary until reaching equilibrium with the force of gravity. The equilibrium conditions can be expressed as:

$2\pi\ r\ \gamma \cos\theta = r^2\ \pi\ h\ \rho\ g$ .....(1)



Where:
r= radius of the capillary (or pore)
D= diameter of the capillary (or pore)
h= height of column of liquid
γ= surface tension of liquid
ρ= density of liquid
θ= contact angle between the liquid and capillary wall
g= acceleration due to gravity

and since pressure (P) = hρg, and D = 2r equation 1 becomes

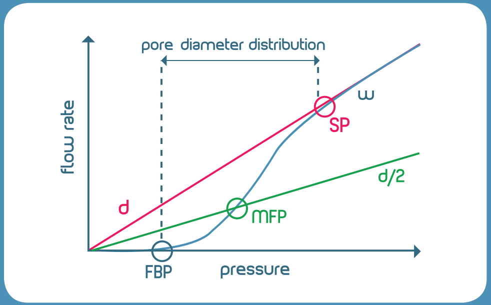
$2\pi\ r\ \gamma \cos\theta = r^2\ \pi\ P$ .....(2)
$P = 4\ \gamma \cos\theta / D$ .....(3)

Therefore, the pressure required to empty pores of a certain diameter is inverse proportional to the pore throat size and it is used to calculate the pore size accordingly equation 3, also known as the Young–Laplace formula.

PARAMETERS MEASURED

In a typical CFP test a flow of pressurized gas is applied to the porous sample impregnated with the **wetting liquid** and the flow of gas through the sample, as the liquid is displaced out of the porous network, is measured. The “wet curve” represents the measured gas flow against the applied pressure.

Following the wet curve, the gas flow against the applied pressure on the dry sample (“dry curve”) is also measured. From data from the wet curve, the dry curve and the “half-dry curve” (dividing the flow values of the dry curve by 2) information about the porous network can be obtained.



Measuring curves and resulting parameters in CFP
(w = wet curve, d = dry curve, d/2 = half-dry curve, FBP = largest pore,
MFP = mean flow pore, SP = smallest pore)

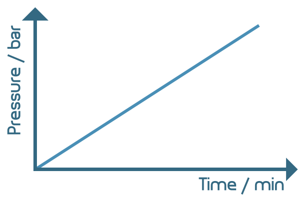
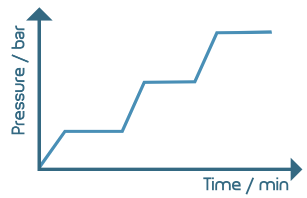
A full porometry test can provide information on:

- **Bubble point**
  Maximum pore diameter
- **Smallest pore size**
  Calculated at the pressure at which the dry curve meets the wet curve
- **Mean flow pore diameter**
  Pore size at which 50 % of the total gas flow can be accounted (half the flow is through pores larger than this diameter)
- **Gas permeability**
  In the same measurement it is possible to obtain the gas flow rate. If the material area and thickness are known, the gas permeability can also be accounted.
- **Cumulative filter flow [SUM]**
  It shows which percentage of the flow (at the Y-axis) has passed through pores with a size larger than the value at the corresponding point at the X-axis. It is also known as filter efficiency.
- **Differential filter flow [DIF]**
  It shows the percentage of flow (at the Y-axis), which has passed the pores with a corresponding size at the X-axis and the following size value at the same axis. According to ASTM this graph shows the so called “pore size frequency”.
- **Pore size flow distribution [CDIF]**
  It shows the flow distribution normalized per unit of change in size (flow changes are divided by size changes). Sometimes it is also referred to as pore size distribution.

OUR TECHNOLOGY: POROLUX™

Based on many years of experience in capillary flow porometry we have developed POROLUX™, a range of instruments for testing membranes, filters, nonwovens, papers, hollow fibres and ceramics, amongst other. They are widely used to measure pore size distribution and gas permeability with improved accuracy and reproducibility compared to other porometers in the market.

There are two series of instruments, which are based on different measurement methods:

	PRESSURE SCAN METHOD: POROLUX™ 100 SERIES	**PRESSURE STEP/STABILITY METHOD: POROLUX™ 1000 SERIES**
Control of the pressure increase	With a single valve, which is continuously being opened during the measurement	With a cascaded pressure control set up, using a specially designed needle valve
Stability algorithms	No	Yes, for pressure and gas flow
Measurements	Immediate, continuous measurement of both pressure and gas flow.  The pressure increases at a constant rate, which can be selected by the user.	A data point is only recorded when the stability algorithms (defined by the user) are met for both pressure and flow.  The porometer detects when a pore empties at a certain pressure and waits until **all pores** of the same diameter have been completely emptied before accepting a data point.
Advantages	Very suited **for quality control work**	The most suitable **for research and development work** Essential for samples with complex pore structures
Disadvantage	Pressure regulation is sometimes not linear over the entire pressure range (high P).	Slower measurements
Key words	Speed and reproducibility	Precision and accuracy

HARDWARE

The POROLUX™ porometers are state state-of-the-art and have the best technical specifications and quality. The products are made in Germany and conform to EU-guidelines and relevant product safety directives and have uniformity in manufacturing (GMP - Good Manufacturing Practice). All come equipped with all necessary hard- and software required for operation. There will be no need to later on add extra pressure sensors and/or flow meters, thus expensive upgrades are avoided. Additional accessories and options are available to give the user access to some advanced porometry options.

ACCURACY OF THE FLOW AND PRESSURE SENSORS

The highest accuracy in pressure and flow available in the market: 0.05 % F.S.

AUTOMATIC SWITCH BETWEEN PRESSURE SENSORS AND FLOW SENSORS

The POROLUX™ porometers have multiple pressure and flow sensors for an optimum performance over the operating range. The switch between pressure and flow sensors during a measurement is automatic depending on the values achieved in order to use the best sensor to optimise the accuracy and resolution at every end (low and high) of the pressure range.

RESOLUTION PRESSURE AND FLOW SENSORS: 24 BIT

Resolution is defined as the ability to discern between differences: a high resolution system resolves small differences while a low resolution one cannot distinguish small differences between two signals.

Speaking from the point of view of an instrument, resolution is understood as the smallest increment or step that can be achieved. In CFP **the only two parameters measured are the pressure applied and the gas flow through the sample** so in order to determine the resolution of a porometer **we need to look at the resolution of the flow and pressure sensors.**

A pressure or flow sensor gives an analogue signal that has to be converted into a series of digital values that we will call “steps”. The number of steps depends on how good the converter is (“bit-number”) and it is 2 to the power x, where x is the bit number. For instance, a pressure sensor in the range 0-35 bar that gives a voltage signal between 0-10 V, so 3.5 mbar correspond to a signal of 1 mV. The resolution in voltage is obtained by dividing the full scale of voltage (for example 10 V=10000 mV) by the number of steps. This is transduced into a resolution in pressure by taking the voltage measured in one step and multiplying it by the factor that relates pressure and voltage.

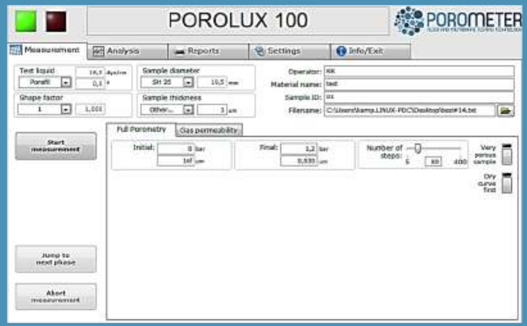
	16 bit	**24 bit**
Number of steps	65,536	16,777,216
Resolution of the voltage signal	0.15 mV/step	0.0005 mV/step
Resolution in pressure	0.525 mbar/step	0.00175 mbar/step

In conclusion, **a 24 bit system has much better resolution because it differentiates smaller different analogue signals, which translate into different pressure values.** In a 16 bit system different analogue signals are transduced into the same pressure and this leads to a certain error in the calculation of the pore sizes.

SOFTWARE

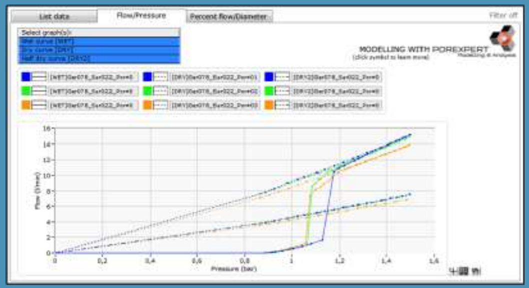
The POROLUX™ porometers use a bespoken own developed software written in LabVIEW, the most sophisticated development suite and high performing programming system for data acquisition and instrument control. The software allows intuitive selection of all analysis parameters, and the customer can easily change the measurements settings to get additional insight in the pore structure:

- Type of wetting fluid
- Start and end pressure or maximum and minimum diameter (auto conversion, units: bar, psi, Pa)
- Speed of pressure increase
- Number of data points (maximum 400): improved resolution for the pore size distribution for a wide range of samples.
- Sample diameter and thickness
- Shape factor



Data analysis includes:

- Comprehensive overview of all relevant results and input parameters
- Wet, dry and half-dry graphics
- Cumulative flow and pore size distribution graphics
- Curve overlay
- One button export to Excel, Word and pdf file
- Quick report view via HTML with any browser



The user interface of the POROLUX™ software is very easy, user friendly and multilingual. The software is available in English, German, Chinese, Russian, Spanish, Italian, Japanese and French.

ADVANCED SERVICE MENU FACILITATES DIAGNOSIS AND SERVICE VIA INTERNET

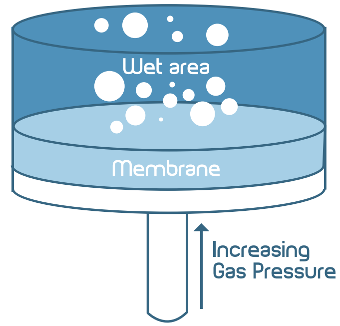
UNIVERSALLY AVAILABLE PLC TECHNOLOGY (NATIONAL INSTRUMENTS)

The POROLUX™ has its own processor and independent runtime system (the measurement is completely independent from Microsoft Windows), known as Programmable Logic Controller or PLC.

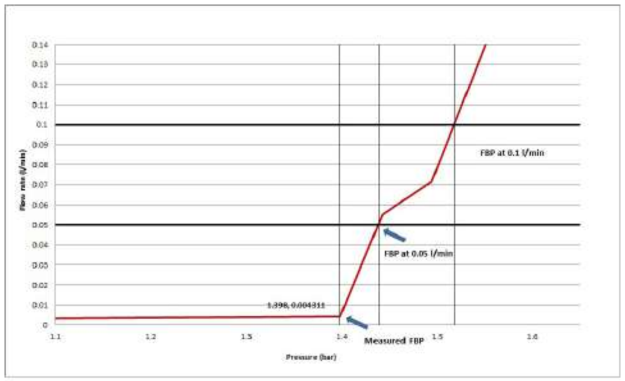
If during a measurement there is a data connection loss, the measurement and accumulation of data continues and after reconnecting the PC, the PLC will deliver data to the computer. Therefore, if there is any problem in the processor of the computer, the disturbances from the computer do not influence the acquisition of results.

CALCULATED AND MEASURED FIRST BUBBLE POINT

One of the most important parameters measured by a porometer is the **first bubble point** or FBP. This point corresponds to the largest pore(s) present inside the material.



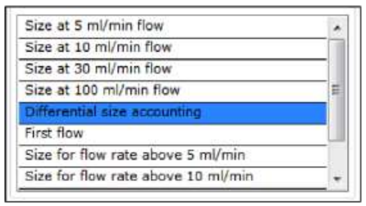
The ASTM F-316 standard defines the FBP at the pressure at which the first continuous bubbles are detected. This is based on the traditional approach of placing the sample in a housing with liquid placed on the top side. Then a pressurised gas is applied under the sample and the pressure is gradually increased over time and when a constant flow of rising bubbles is observed on the top side of the sample, it is assumed that the gas pressure has reached bubble point. However, this is a visual and, therefore, subjective approach. When do we consider that the first continuous bubbles are detected? It differs significantly depending on the person.

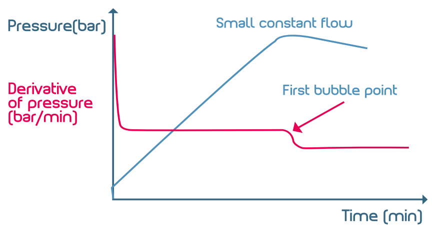


For that reason the FBP can be defined at different flow rates, e.g. at 30, 50, 100 ml/min. So for a certain target flow the pressure required to achieve it is used to calculate the pore size, using the Young-Laplace equation as previously explained. Because with this approach there is already flow at the FBP, by definition, this **calculated FBP** is always smaller than the real bubble point and thus the calculated FBP never represents the real opening of the largest pores.

There are multiple criteria to select the pressure to calculate the FBP. A POROLUX™ user has the choice to select among different calculation methods.

There is another, more accurate, approach for detecting the largest pore. It is the so-called **measured bubble point**.





The fully wetted sample inside the sample chamber forms a closed system. If we increase the pressure on the sample using a small, constant flow of gas towards the sample chamber, as the volume is fixed, this constant flow will result in a linear rise of the pressure above the sample. At the moment the first and largest pore is opened, there will be a change in the linear pressure increase. This change can be regarded as the true first bubble point of the material and this pressure is used to obtain the pore size. This method to measure the FBP shows an excellent accuracy and reproducibility.

THE PRESSURE SCAN SERIES

The POROLUX™ 100/100NW/100FM and 500 are gas liquid porometers based on the pressure scan method developed for the rapid measurement of through-pores in materials such as filters, nonwovens, textiles, paper, membranes, hollow fibres, etc.

PRESSURE AND FLOW RATES RANGE

Starting from instruments that go up to 1.5 bar (22 psi), such as the POROLUX™ 100NW, up to 35 bar (500 psi), POROLUX™ 500. The maximum flow rate can be 100 or 200 l/min depending on the model and the application. For details please see the table of specifications for each model.

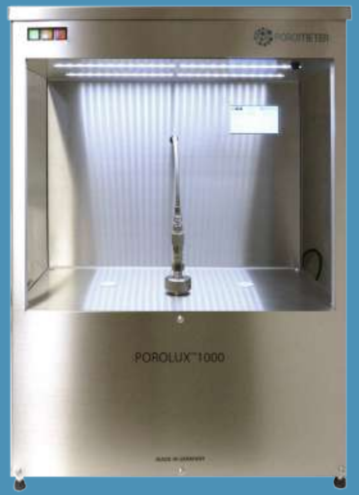
PRESSURE SCAN SERIES PRODUCT OVERVIEW

PRODUCT OVERVIEW	POROLUX™ 100	POROLUX™ 100NW	POROLUX™ 100FM	POROLUX™ 500
Max pressure	7 bar/100 psi	1.5 bar/22 psi	2.5 bar/36 psi	35 bar/500 psi
Min pore(1)	0.091 µm	0.427 µm	0.250 µm	13 nm
Max pore(1)	500 µm	500 µm	500 µm	500 µm
Max flow	100 l/min	200 l/min	200 l/min	200 l/min
Pressure sensors	8 bar	2 bar	3 bar	0.5-5-50 bar
Switching of the pressure sensors	Not applicable	Not applicable	Not applicable	Automatic
Flow sensors	5-100 l/min	10-200 l/min	10-200 l/min	10-200 l/min
Switching of the flow sensors	Automatic	Automatic	Automatic	Automatic
Accuracy of pressure and flow sensors	0.05 % F.S.	0.05 % F.S.	0.05 % F.S.	0.05 % F.S.
Resolution of pressure and flow sensors	24 bit	24 bit	24 bit	24 bit
Calculated FBP	Yes	Yes	Yes	Yes
Measured FBP	No	No	No	No

(1) Depending on the wetting fluid

THE PRESSURE STEP/STABILITY SERIES

The **POROLUX™ 1000** series comprises research grade gas liquid porometers for the rapid measurement of through-pores in porous materials based on the pressure step/stability method. The target pressure is achieved by combining an inlet valve for the gas, which generates the initial pressure, and a specially designed needle valve, which subsequently adjusts very precisely the pressure. The pressure and flow sensors will only take a data point when the user defined stability algorithms are met for both pressure and flow. In this way, the POROLUX™ 1000 detects the opening of a pore at a certain pressure and waits until all pores of the same diameter are completely opened before accepting a data point. This results in very accurate measurement of pore sizes and allows a calculation of the real pore size distribution.



PRESSURE AND FLOW RATES RANGE

Three instrument models are available, one of them optimised for low pressure applications up to 8 bar (116 psi) and two of them that operate up to 35 bar (500 psi). The maximum flow rate, depending on the model and the application, can be 10, 100 or 200 l/min. For details please see the table of specifications for each model.

PRESSURE STEP/STABILITY SERIES PRODUCT OVERVIEW

PRODUCT OVERVIEW	POROLUX™ 1000	POROLUX™ 1000LP	POROLUX™ 1000LF
Max pressure	35 bar/500 psi	8 bar/116 psi	35 bar/500 psi
Min pore(1)	13 nm	80 nm	13 nm
Max pore(1)	500 µm	500 µm	500 µm
Max flow	200 l/min	100 l/min	10 l/min
Pressure sensors	5-50 bar	1-10 bar	5-50 bar
Switching of pressure sensors	Automatic	Automatic	Automatic
Flow sensors	10-200 l/min	5-100 l/min	0,5-10 l/min
Switching of flow sensors	Automatic	Automatic	Automatic
Accuracy of pressure and flow sensors	0.05 % F.S.	0.05 % F.S.	0.05 % F.S.
Resolution of pressure and flow sensors	24 bit	24 bit	24 bit
FBP regulator	5-30 ml/min	5-30 ml/min	5-30 ml/min
Measured FBP	Yes	Yes	Yes
Calculated FBP	Yes	Yes	Yes

(1) Depending on the wetting fluid

ADVANCED LIQUID PERMEABILITY OPTION (LIQ1000)

The liquid permeability extension for the POROLUX™ 1000 performs a fully automatic measurement of the flow of liquid through a membrane or filter at a predefined pressure. The liquid is collected in a receptacle and the weight recorded by the balance is automatically transferred to the operating software, which calculates the liquid permeability. This method is easy, user friendly, very accurate and is strongly recommended when a lot of liquid permeability measurements are envisaged.

The advanced liquid permeability extension consists of:
- A hardware extension (LIQ1000BAL): includes the liquid tank, an external sample holder, tubing and connections and a balance.
- A software extension (SWLIQ1000).

SPECIFICATIONS

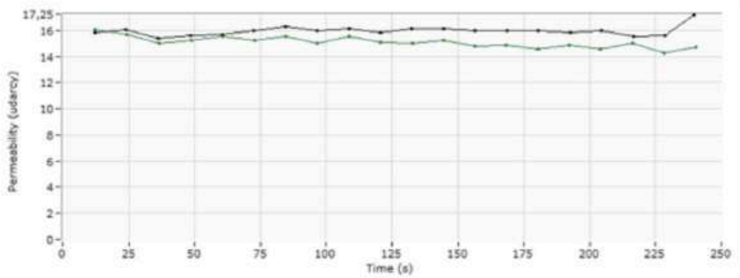
- Operating pressure up to 6 bar (a 10 bar vessel is also optionally available)
- Liquid tank capacity: maximum filling level 6 liter
- Maximum test time 3600 sec
- Sample holder: standard 25 mm diameter, maximum 3 mm thickness. Other standard sizes (13 and 47 mm diameter, up to 10 mm sample thickness) and custom-made sample holders available upon request, please contact us.
- Membrane test cell made of stainless steel
- Liquid tank made of stainless steel
- Includes a balance automatically connected to the operating PC. Balance range: 0.05-8.2 kg.

MEASUREMENTS

The liquid tank is filled in with the testing media and it is connected to the POROLUX™ 1000 using an extension hose. On the liquid side, an external sample holder is connected to the reservoir and the drain is led into a glass beaker.

The user defines the time that a chosen pressure has to be maintained and during this time the liquid flow through the sample will be determined by measuring the weight of the liquid that went through the sample on a balance. This weight increase will be recorded by the POROLUX™ 1000 software.

The equipment is designed to work with water as test media. The addition of solutes may affect certain properties of water, such as density and dynamic viscosity, which are relevant for the permeability.



Time (s)	Specific mass flow (g/min/cm^2)	Permeability (udarcy)	Pressure (bar)	Flow (l/min)
12,2	1,866	15,84	4,972	0,0055
24,2	1,892	16,09	4,965	0,0056
36,2	1,808	15,38	4,965	0,0054
48,6	1,831	15,59	4,960	0,0054
60,6	1,842	15,68	4.961	0.0055

SAMPLE HOLDERS

STANDARD SAMPLE HOLDERS

All POROLUX™ porometers come with a 25mm sample holder. Other standard sample holders have a diameter of 13 or 47 mm.

POROMETER can create costumer specific designs for special samples: thick samples, large diameter samples, assembled filter-setups, etc. Please contact us for details and price.

UNIVERSAL SAMPLE HOLDER FOR MULTIPLE SAMPLE DIAMETERS AND THICKNESS

- Universal sample holder with inserts for samples of 5, 10, 20, 30 and 40 mm diameter
- Compatible with samples of thickness up to 10 mm
- Maximum pressure: 10 bar

HOLLOW FIBRE AND TUBULAR SAMPLE HOLDER (SHHF)

The characterisation of the pore distribution of hollow fibres and tubes requires relatively high pressures and a limiting factor is often the burst pressure of the hollow fibre. Therefore, safety is often as concern.

We have developed a stainless steel sample holder in which one or more hollow fibres can easily be glued. With this sample holder very reproducible results can be obtained.

- The pressure can be applied from the outside to the inside or vice versa
- Maximum pressure: 35 bar*
- Includes replaceable O-rings
- Resistant to silicone and epoxy glues
- Easy cleaning of the assembly

*This is the maximum pressure that the hollow sample holder can withstand. The maximum pressure allowed in each experiment will depend on the mechanical resistance of the hollow fibre.

IN-PLANE POROMETRY SAMPLE HOLDER

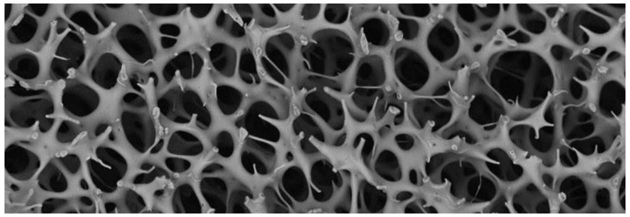
Special parts and accessories to carry out in-plane porometry measurements. Only available for 47mm sample holders.

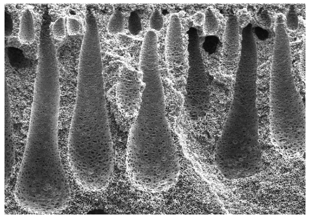

POROLUX
500
POROMETER
MADE IN GERMANY

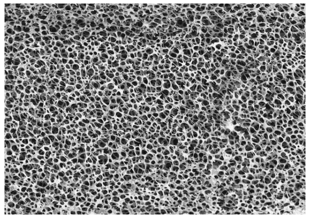
APPLICATIONS

MEMBRANES

Gas Liquid Porometry (GLP) can be applied to the characterisation of polymeric and ceramic membranes for micro and ultra-filtration applications with pore sizes ranging from 500 μm down to 15 nm. Flat sheet, tubular and hollow fibres can be measured by using an appropriate sample holder. The figure on the right shows the wet, dry and half dry curves of a full porometry test of a flat sheet commercial polymeric membrane used in water treatment.

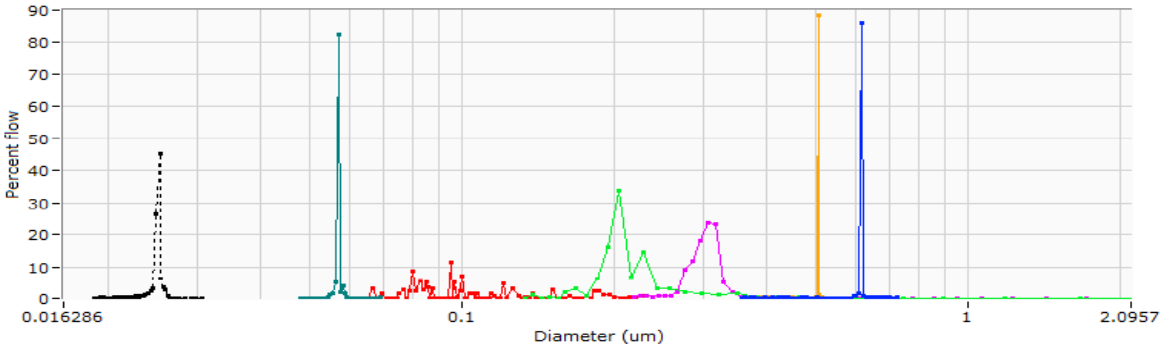


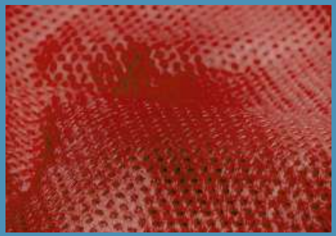




Different types of membranes can be easily measured, from materials and structures with very narrow to wider pore size flow distributions:

- Black: flat sheet ultrafiltration polysulfone membrane.
- Grey blue: flat sheet battery separator.
- Red: flat sheet PAN membrane porous support for gas separation membranes.
- Green: hollow fibre commercial polymeric membrane.
- Purple: flat sheet polycarbonate nuclepore filter.
- Yellow: flat sheet polycarbonate commercial polymeric track-etched membrane.
- Blue: flat sheet cellulose acetate commercial polymeric membrane for microfiltration.



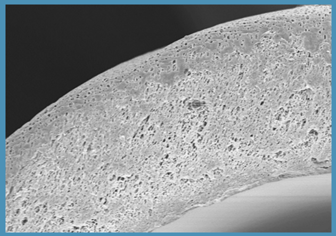


NONWOVENS

GLP measurements of melt blown and spun bound materials, were carried out by using a POROLUX™ 100NW porometer. The POROLUX™ 100NW is specially designed for nonwoven characterisation and it is based on the pressure scan method. The method is fast and typically generates very reproducible results, which makes the POROLUX™ 100NW very suited for quality control.

PAPER

The POROLUX™ 100 has been optimised for the pressure range between 1-5 bar (0.64 μm-0.128 μm) and it is specially indicated for paper testing. Different paper types (printing paper, cigarette, etc.) have been characterised with a POROLUX™ 100.



HOLLOW FIBRES

The characterisation of hollow bre membranes by capillary ow porometry can be challenging, given the fact that the samples might burst or collapse under pressure. The POROLUX™ 1000 has an specially designed Sample Holder for Hollow Fibres (SHHF) which permits attaching the hollow bres in two di erent ways, depending on the direction of the gas ow (inside-out or outside-in). The bottom connector parts with di erent bore diameters are available, for measuring is possible to measure bres of variable diameter.

BATTERY SEPARATORS

The structure and properties of the separator are very important because they affect the battery performance (energy and power density, cycle life and safety) to great extent. Therefore, an accurate characterisation of the pore size distribution and the permeability of the separator is fundamental to understand how it works and to identify routes of improvement. This is how our POROLUX™ 1000 porometer can help.

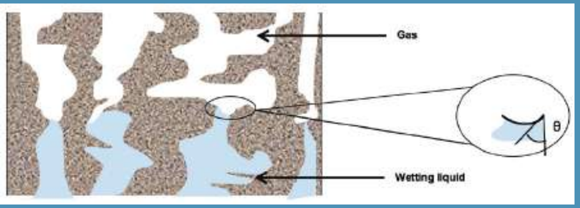
POROUS ROCKS

GLP has proven to be a promising and environmentally friendly alternative to mercury injection porosimetry for petrophysics applications. It permits obtaining several parameters and information with good accuracy and reproducibility in one individual and fast measurement, reducing the measuring time from several hours to minutes. The POROLUX™ 1000 has been used successfully to measure flow relevant parameters of cretaceous sandstones.

Liquid Liquid Porometry

The POROLIQ™ 1000 is a Liquid Liquid Porometer (LLP). This rapid, precise method employed by the POROLIQ™ 1000 allows for testing of pore size down to 2nm and, compared to other techniques, uses lower pressures for characterisation of traditional micro-, nano-porous materials.

HOW DOES THE POROLIQ™ 1000 WORK?



It is the first LLP equipment based on a pressure driven concept, which guarantees the maximum accuracy, especially when measuring pore sizes in the submicron range.

A measurement consists first of complete saturation of the porous membrane with a wetting liquid. The subsequent displacement of the wetting liquid from the pores is achieved by a second, immiscible liquid (displacement liquid). The pressure (P) required to expel the wetting liquid out of the pore depends on its diameter (D) as expressed by the Young-Laplace equation $P=4*\gamma*\cos\theta/D$, where γ is the interfacial tension betwen the wetting and displacement liquid. Typical interfacial tension values lie between 0.35 and 4 mN/m. This allows pores as small as 2 nm to be probed or, in comparison to traditional gas liquid porometry, for the use of more moderate pressures to test traditional submicron pore size ranges.

By measuring the flow rate of liquid thorugh the sample, a complete pore size distribution can be obtained.

THE MOST ACCURATE LLP ON THE MARKET

- Based on the pressure step/stability method: a data point is only recorded when the user-defined stability algorithms are met for both pressure and flow.
- Detects the opening of a pore at a certain pressure and waits until all pores of the same diameter are completely opened before accepting a data point.
- The POROLIQ™ 1000AQ uses a combination of three ultrasensitive liquid flow sensors to measure exactly and accurately flow rates from 0.16 µl/min (to detect the displacement of wetting liquid out of the pores from the very beginning).
- Ideal for full characterization of hollow fibers at low pressures.

PARAMETERS MEASURED

- First Flow Point (FFP) size,flow and pressure
- Mean Flow Pore (MFP) size and pressure
- Smallest Pore Size (SP) pressure and number
- Mean Pore Diameter (MPD) and pressure
- Cumulative flow distribution
- Pore size flow distribution
- Total pore number
- Total pore area (% and μm^2)
- Liquid permeability

SPECIFICATIONS	POROLIQ™ 1000AQ	POROLIQ™ 1000ML
Measuring principle	Pressure driven	Pressure driven
Max. Pressure	40 bar	40 bar
Measurement range	0.3 μm - 2 nm	1 μm - 2 nm
Flow range	0.16 μl – 10 ml/min	1 μl – 10 ml/min
Sample holders	Flat sheet 25mm diameter Hollow fibre	Flat sheet 25mm diameter Hollow fibre
Special sample holders	Available upon request	Available upon request
Pressure sensors	50 bar	50 bar
Displacement liquid	Water	Multiple liquids

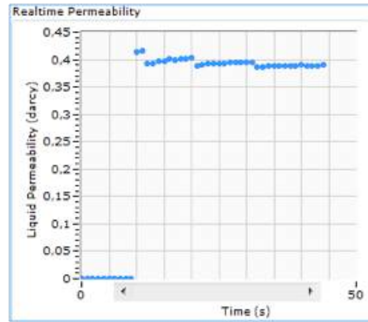
Automatic switch between the pressure sensors and the flow meters during a measurement
- The best sensor is automatically selected to optimise the accuracy and resolution in the full pressure and flow range

OPERATING SOFTWARE

- LabVIEW™ software for data acquisition and instrument control with intuitive selection of all analysis parameters
- Universally available PLC technology (National Instruments) with own runtime system
- Easy export of results to Excel, Word and pdf file
- Windows compatible
- Advanced service menu facilitates diagnosis and service via Internet

LIQUID PERMEABILITY TESTER (LPT 400)

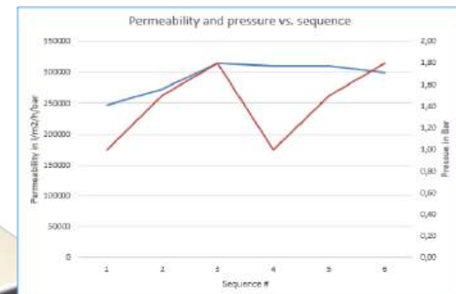
The Liquid Permeability Tester (LPT 400) is designed to determine the liquid permeability and the Silt Density Index (SDI) in technical materials in a pressure range between 50 mbars and 4 bars.



A fully automatic program runs the selected test. The liquid is collected in a receptacle and the weight recorded by a balance is automatically transferred to the operating software, which calculates the liquid permeability.

MEASUREMENTS

- Liquid permeability
- Possibility to perform single or up to 3 measurements simultaneously (at one constant pressure level or on varying pressure levels).
- Duration of each cycle: up to 10 min.
- Real time permeability vs time graphic display
- Permeability results are displayed in Darcy and in l/(m^2*h*bar)



Sample data:		Sample Holder	1
Material:	Test Material 1	Thickness (mm)	1,0
Sample ID:	1	Diameter (mm)	25,0

Test data:	Liquid permeability		Pressure
Sequence #	darcy	l/m^2/h/bar	bar
1	0,5887	246900	1,00
2	0,6528	273200	1,50
3	0,7517	314500	1,80
4	0,7379	310600	1,00
5	0,7391	310000	1,50
6	0,7142	299400	1,80

SILT DENSITY INDEX (SDI)

SDI measures the percent drop per minute in the flow rate of water through a filter, averaged over a period of time.

- In each cycle, the system measures the time required for 500 ml of fluid to pass through the sample, following by sample flushing step for 15 min before starting the next cycle.
- Possibility to carry out up to 12 repeated cycles.

Sample data:		Sample Holder	1
Material:	1	Thickness (mm)	1,0
Sample ID:	Material1	Diameter (mm)	25,0

Test data:		Silt density index	Pressure
Sequence #		SDI	bar
1		1,83	0,5
2		1,39	0,5
3		0,41	0,5
4		-2,19	0,5

SPECIFICATIONS

Operating pressure	50 mbar-4 bar
Liquid tank	10-27 liter, made of stainless steel
Membrane test cell	Round samples of 25mm diameter, maximum 10 mm thickness Square samples of 50*50 mm, maximum 10 mm thickness Made of stainless steel
Flow / balance range:	0.05-8.2 kg. In process approx. 0-6 l/min real flow
Dimensions and weight	L*W*H: 630*470*1,680 mm, weight: ca. 70 kg

- Custom-made samples holders available upon request, please contact us.
- Includes a balance automatically connected to the operating PC

DEAD-END FILTRATION CELLS

The dead-end filtration module for single feed liquid filtration (stirred cell) is built in stainless steel and it is suitable for both water or solvent based feed solutions. The most important features of the stirred cell include:

- Internal magnetic stirrer bar ensuring a homogenisation and reducing concentration polarisation and membrane fouling
- Full safety models available up to 40 bar
- Membrane diameter 52 mm
- Includes a CE marking certificate

All stirred cells are provided with porous metallic support grids and NBR and EPDM rubber O-rings to ensure tight sealing. To assure full functionality with feeds of diverse chemical nature, different types of specifically designed rubber O-rings from Kalrez® or Viton® are available.

HIGH THROUGHPUT MEMBRANE TESTING (SPIDER™)

The High Throughput (HT) dead-end filtration module for single feed liquid filtration, SPIDER™ is built in stainless steel and it is suitable for both water or solvent based feed solutions. In one single experiment it is possible to carry out either 8 or 16 simultaneous dead-end filtrations (depending on the SPIDER™ model), which supposes an extreme gain of time compared to conducting the same experiments one by one with a single cell.

The most important features of the SPIDER™ include:
- Common feed reservoir for the multiple membranes tested in the same run.
- Magnetic stirring ensuring a homogenisation and reducing concentration polarisation and membrane fouling.
- Total feed volume on demand.
- Full safety models available up to 40 bar.
- Optional heating by using a hot stirrer bottom plate.

Some examples of applications include:
- Water desalination.
- Membrane optimization for micro pollutants (e.g. drugs and/or colorants) removal from water.
- Recovery of high added value products (e.g. homogeneous catalysts).
- Membrane molecular weight cut-off characterisation tests using standardized polymers (e.g. PEG, PS) with known molecular weights and radii in different solvents.
- Solvent permeability characterization tests.
- Quality control.

Different solutions are available to better suit the needs of our customers. The most common version is the SPIDER™ with a sample holder with 8 membrane positions of 22 mm Ø for operating pressures up to 40 bar.

MEMBRANE MODULE (SAMPLE HOLDER)

The membranes are placed on the sample holder, which can accommodate either 8 or 16 membranes. Once the chamber is sealed, the feed reservoir is filled with the selected feed solution and the desired pressure is applied. The individual permeates are collected at a function of time in separate bottles for further analysis. The remaining retentate at the end of the experiments can also be collected.

The membrane module is built in stainless steel and can have either 8 or 16 sample positions, of different membrane diameter.

The SPIDER™ is provided with porous metallic support grids for each membrane position and EPDM rubber O-rings to ensure tight sealing. To assure full functionality with feeds of diverse chemical nature, different types of specifically designed rubber O-rings from Kalrez®, Viton® are available. The user can then select the necessary set of resistant rubber material according to the used solvents and the operating pressure.

HIGH THROUGHPUT GAS SEPARATION (HTGS)

The new High Throughput Gas Separation (HTGS) system is a device designed to run up to 16 different membrane-based separations of variable single and mixed gas feeds simultaneously. Up to 5 gases (O_2, CO_2, CH_4, N_2 and H_2) can be mixed at a set flow. The on-line analysis option permits screening mixed gas selectivities, in comparison to single gas permeation experiments.

IDEAL FOR MEASURING

- Membrane permeability: single and mixed gas
- Membrane selectivity: mixed gas
- Physical ageing and plasticisation effects
- Long term membrane performance (up to several days)

MAIN FEATURES

- Fully automated: all parameters are set and the system runs the processes autonomously
- Feed and purge lines minimise the 'dead volume' between separation and analysis
- Control of feed composition, pressure, temperature and flow rates
- Automatic selection of feed or permeate line to be analysed
- Complies with the latest safety standards regarding:
  - Cabinet construction
  - Tubing design
  - Component selection
  - Hardware
  - Software security functions
  - Gas edit surveillance and according alarms
- CE marked: conformity with valid EU-guidelines and directives.

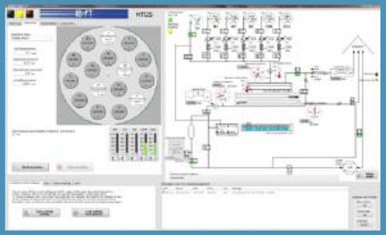
Pressure Range	0-35 bar
Flow Range	0-10 l/min for individual gases up to 30 l/min for gas mixtures
Temperature range	maximum 80 °C
Individual sample area	2.24 cm^2
Resolution (pressure and flow sensors)	24 bit

The HTGS is sold as a complete package, including:

- Permeation cell module for 16 flat sheet membrane samples:
    - Each sample position is provided with a porous metallic support grid and O-rings to ensure tight sealing
    - Individual adjust of different sample thickness
    - Retentate purge system to ensure homogenous feed composition throughout the entire experiment
    - Optional heating of the module is available
- Control devices
- Compact gas chromatograph (CGC) equipped with two thermal conductivity detectors (TCD), which can analyse gases at ppb level, and three columns:
    - Parabond Q (2 m x 0.32 mm): used as pre-column
    - Molecular sieve column (5 m x 0.32 mm): for the detection of H_2, O_2 and N_2 at the first TCD
    - Parabond Q (12 m x 0.32 mm): for the detection of CH_4 and CO_2 at the second TCD
- Integrated software for the measurement setup, mass flow control, measurement of the flux and triggering of the CGC
- Electrical cabinet
- A vacuum pump for evacuation of all gases into a fume hood

OPERATING SOFTWARE

- LabVIEW™ software for data acquisition and instrument control with intuitive selection of all analysis parameters
- Universally available PLC technology (National Instruments) with own runtime system
- Integrated reporting: easy export of results to Excel, Word and pdf file
- Windows compatible
- Advanced service menu facilitates diagnosis and service via Internet



OPTIONAL HOLLOW FIBRE HIGH THROUGHPUT PERMEATION CELL

Each individual hollow fibre sample is placed inside a stainless steel tube and secured by gluing the ends of the fibre to the tube ends. Each tube assembly can be mounted individually on the bottom part of the standard flat sheet sample holder of the HTGS. The gas flow direction during the experiment is from the inside to the outside of the hollow fibre.The upper part of the tubes is attached to a top plate. A gas reservoir for the feed gas mixture guarantees a uniform composition before it goes through the membrane.

Each individual tube has a permeate collection line that can be directed to either the compact gas chromatograph of the HTGS (for analysis of the composition) or to the permeability measuring line. The gas retentate mixture can also be analysed.

- Maximum operating pressure allowed with the hollow fibre membrane module: 10 bar
- Maximum effective length of the individual hollow fibres inside the tube: 120 mm

Membrane synthesis: automatic coating machine (MEMCAST™)

The automatic film coater MEMCAST™ is ideal for the synthesis of flat sheet polymeric membranes by coating a thin film of a polymer solution followed by the immersion of the films in a coagulation bath to obtain the final membrane via wet phase inversion. Reproducible film layers can be prepared, either self standing (e.g. coating directly onto glass, stainless steel, etc.) or on various substrates (e.g. nonwoven, polymeric supports, etc.).

The design minimises movement during film application in order to obtain smooth and consistent films. It is robust, durable, easy to clean and very user-friendly.

	MEMCAST™	MEMCAST™ PLUS
Coating size	ca. 340 * 500 mm	ca. 340 * 500 mm
Coating speed	0.4 up to 10 cm/s	0.4 up to 10 cm/s
Temperature range	Room temperature	Up to 80 °C

COMMON TO ALL MODELS:

- Includes a flat coating plate.
- Easy mechanism to attach/detach the coating support, allowing fast immersion in a coagulation bath
- Automatic return of the pushing mechanism at the end of the coating length
- Optional stop of the pushing mechanism during application to determine the length of the coating

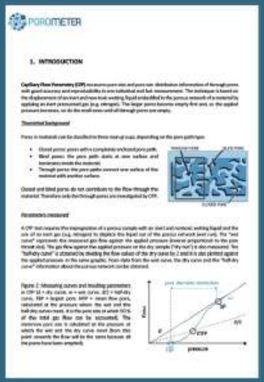
Dimensions (approx.) 780 x 490 x 320 mm
Weight (aprox) 29 kg (64 lb)

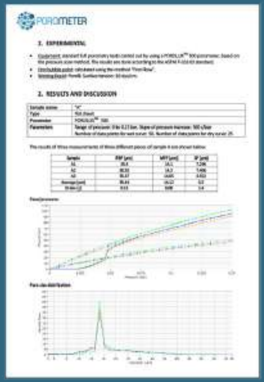
A wide range of single line and high throughput casting knives is available offering different coating thickness, ranging from 50 μm up to 1000 μm. The user can select the number of coating lines, comprised between 1 and 8.

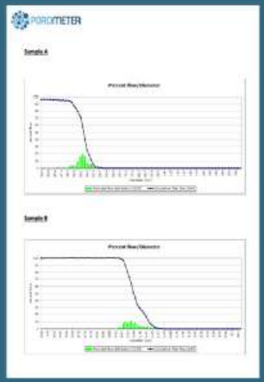
Contract testing

In addition to the sale, rent, and lease of instruments, POROMETER also offers a full testing laboratory – samples can be submitted in all quantities from 1 to hundreds, and a fee paid in exchange for professional analysis and results in a detailed report.

The POROMETER analytical services laboratory is fully-equipped with a complete line of porometers to carry out sample analyses on a paid basis, and even handles live demonstrations on request. One of our measurement experts will carry out the requested tests – taking careful note of all desired parameters and using method development techniques for "unknown" or challenging samples. The hands-on analysis team at POROMETER has vast experience in testing a dazzling array of sample types – from polymeric membranes, to fabrics to nonwovens, paper, ceramic disks, filter media and rocks, and countless others!







Of course, in exchange for the fees you receive a full report describing the background of the method used, the techniques followed, and of course including raw data and calculated results. The POROMETER software packages all boast XML, Excel, and many other convenient output formats for easy processing and handling. Any special observations, challenges, or general behaviours of the materials will be noted and presented.

Representative tests offered (for flat sheet, tubular and hollow fibre samples):

- Gas Liquid Porometry
- First Bubble Point
- Liquid Liquid Porometry
- Gas permeability
- Liquid permeability
- Image analysis (SEM)
- Others on request

Do not hesitate to contact us to have your samples measured!

Modelling with PoreXpert®

PoreXpert® is the world's best expert software for modelling and simulation of porous materials. Developed at the University of Plymouth (UK), PoreXpert® opens up a huge new world of virtual reality to simulate the filtration characteristics, wettability, permeability and geometry of porous samples.

INTEGRATED WITH POROLUX™ POROMETERS

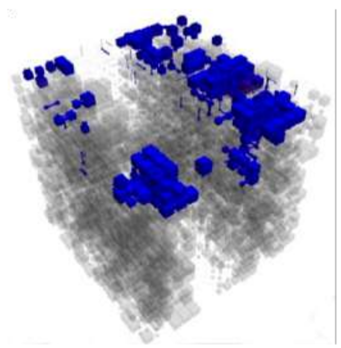
PoreXpert® is designed for porometry exclusively to interface with POROLUX™ porometers. Any porous material measured with a POROLUX™ porometer can be simulated. The only additional information required is the porosity.

We believe in the unique and powerful synergy between POROLUX™ and PoreXpert® to achieve a complete integrated solution. In this way we can help or customers to identify approaches for improving the properties of a filter or understand different behaviours of porous materials.

All POROLUX™ porometers come with a free trial PoreXpert® demo licence.

POREXPERT® APPROACH

Starting from a POROLUX™ data file, PoreXpert carries out multiple fitting operations to find the appropriate numerical parameters to simulate the sample. Using the best fit, PoreXpert® builds a unit cell, which is a reconstruction of a porous material with a three-dimensionally inter-connected network of voids. If a material with such structure was created and measured with a POROLUX™ porometer, it would give exactly the same experimental porometry results.



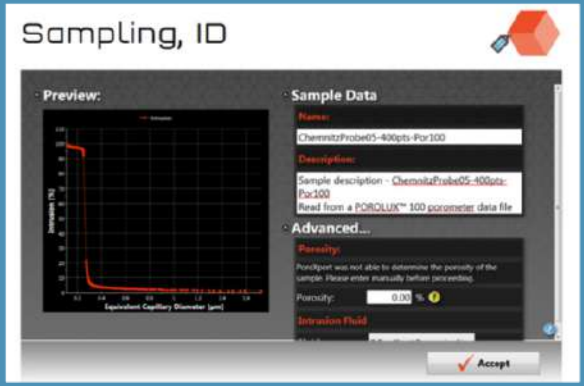
For instance, this image shows the extent of wetting across a PoreXpert® reconstruction of a porous ceramic with 20% porosity and a fully interconnected structure, showing the solid phase as transparent and the extent of wetting (blue) after 20 milliseconds. The PoreXpert® Targeted Modification feature simulates how changes in the pore structure will affect the properties of a material and makes PoreXpert® a very powerful tool especially for design and optimisation of filters and new materials in research and development work.

There are many other multiple calculations and features available depending on the version of PoreXpert®. However, all features are available to users of any version of PoreXpert®, by purchasing processing time on the PoreXpert® Cloud or PoreXpert® Professional Cloud servers.

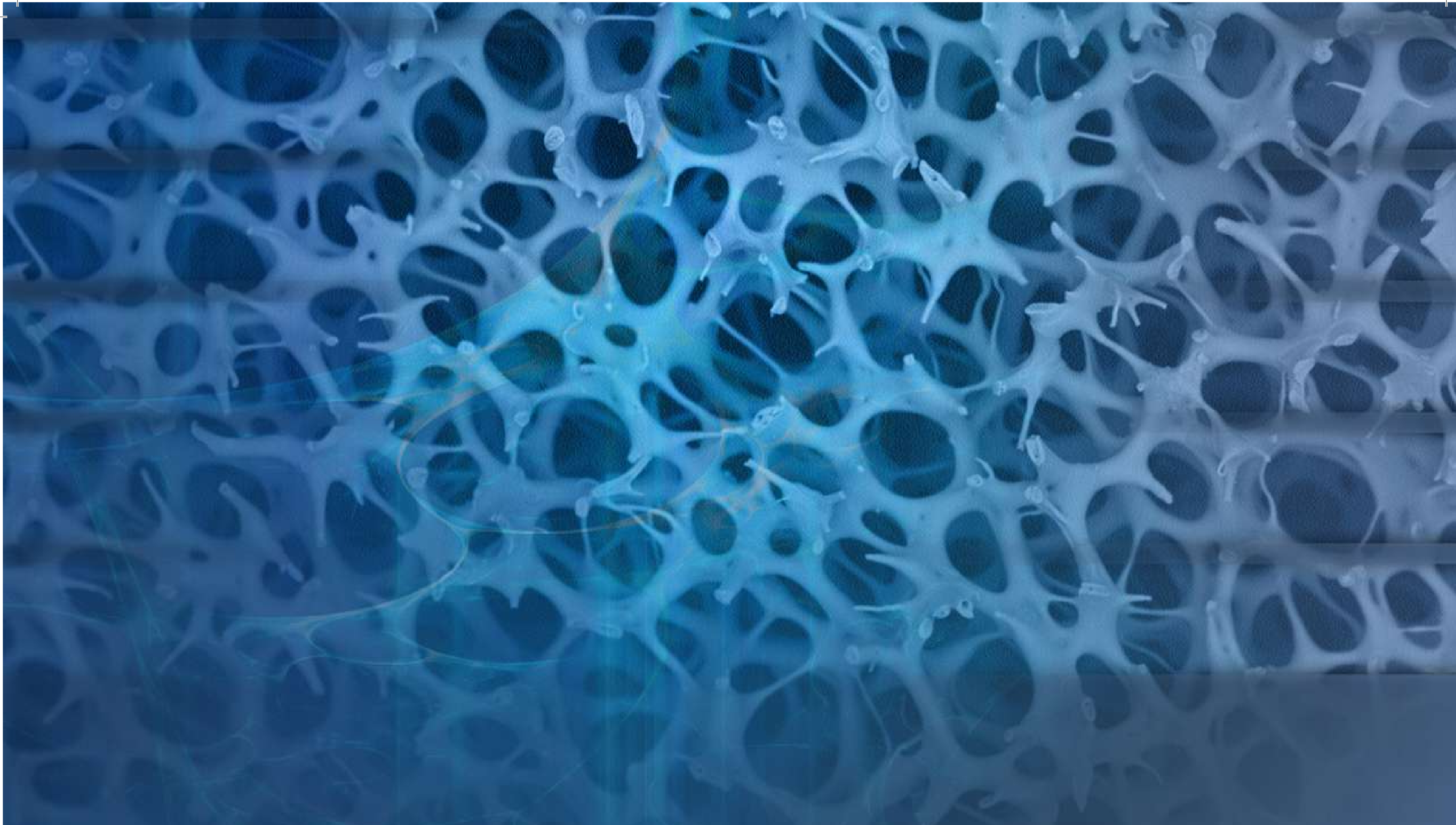
FOR FURTHER DETAILS, VISIT THE WEBSITE: WWW.POREXPERT.COM.

SPECIFICATIONS

- Automatic import of POROLUX™ porometer data files
- Up to 108,000 void features
  - 30 x 30 x 30 cubic structure
  - Cuboidal structures
- Virtual reality visualisation
  - Capillary bundle
  - 3D void network
- Targeted modification
  - Feature resizing
  - Feature removal
- Filtration
  - Visualisation
  - Efficiency graphs
- Fluid migration
- Fluid uptake
  - Wetting
  - Non-wetting
- Permeability
- Tortuosity
- Thermal conductivity
- Pore and throat size distribution
  - By number
  - By volume
- Connectivity distribution
  - By number
  - By volume
- Microtoming
- Reporting
  - PDF
  - Spreadsheet
- Batch mode operation
  - Parallel processing of operations
- Content distribution
- User editable materials database
- Free PoreXpert® file viewers (PoreXtract®) for mobile phones and tablets (iOS and Android) and for Windows
- Online help system
- German and Italian user interfaces



Some of our customers



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