POROLUX^{TM}

THE MARKET LEADER IN CAPILLARY FLOW POROMETRY

CFP1

POROMETER nv

| Address: | Begoniastraat 17 | Phone: | +32 (0)9 252 25 35 | Email: | info@porometer.com |
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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. They are widely used to measure porosity, pore size distribution and gas permeability with improved accuracy and reproducibility compared to other porometers in the market.
We have two series of instruments, which are based on different measurement methods:

1. Pressure scan method: POROLUX™ 100 series

- A single valve is continuously being opened during the measurement
- Continuous measurement of both pressure and gas flow
- Fast and typically very reproducible results
- Very suited **for quality control work**
- Not suitable to measure samples with complex pore paths
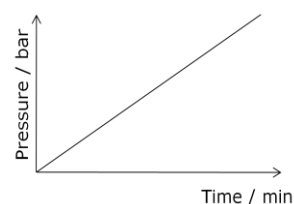
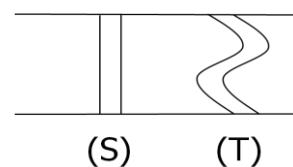## 2. Pressure step/stability method: POROLUX™ 1000 series

- Control of the pressure increase and the pressure in the most precise with a cascaded pressure control set up using a specially designed needle valve
- A data point is 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
- The most suitable **for research and development work**. Essential for samples with a complex pore structure
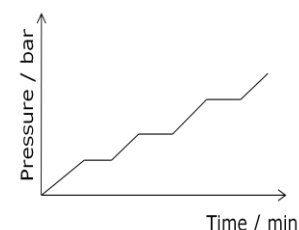
Comparison of the two methods

A sample contains pores with the same diameter but different tortuosity:
- A straight pore (S) with a pore length of 1
- A tortuous pore (T) with a pore length of 1.5

(S)   (T)

Pressure scan method	Pressure step/stability method
• Pores open at a different pressure: T opens later in time and thus at a higher pressure than S • T shows up as a pore with a smaller diameter than S	• Pore S and pore T open at a different time but due to the stability algorithms still at the same pressure • S and T will be shown as pores with the same diameter

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POROLUX™ 100

The POROLUX™100 is a gas-liquid displacement Porometer for the rapid measurement of through-pores in materials such as filters, nonwovens, textiles, paper, membranes, hollow fibres, etc.

The POROLUX™100 series uses a **pressure scan** method. In this method a single valve is opened during a measurement and the pressure and the resulting gas flow are measured continuously. This method is fast and typically generates very reproducible results. Therefore the POROLUX™100 series is very suited for QC type of work.

Measurements
The POROLUX™100 measures bubble point, maximum pore size, mean flow pore size, minimum pore size, average pore size distribution and air permeability.

Pore Size Range
Measurable pore size range from 90 nm to 500 µm equivalent diameter (depending on the wetting liquid and the machine type).

Standard Pressure Range and Flow Rates
0-7 bar (100 psi) with flow rates of up to 100 litres per minute

Sample Holders
The POROLUX™100 comes with a 25 mm sample holder. Other sample holders are available.

Hardware
The POROLUX™100 comes standard with **2 flow meters**: 5 litres/min and 100 litres/min with an automatic switch between the flow meters.

The POROLUX™100 comes standard with an advanced **pressure regulator** and an 8 bar (116 psi) **pressure sensor**.

Determination of **first bubble point** according to ASTM F 316-03. Calculated bubble point according to all scientifically accepted methods 30, 50, 100 ml/min, differential size or first flow.

Software
The POROLUX™100 uses **LabVIEW software**, the most sophisticated development suite for all precision instruments control systems. A state of the art and high performing programming system for data acquisition and instrument control; it offers a very intuitive selection of all analysis parameters:
-   Type of wetting fluid
-   Start and end pressure or max and min diameter (auto conversion)
-   The software allows the user to select the **speed of pressure increase** and the **number of pressure steps**. This way the user can easily obtain more data point and thus improve the resolution for the pore size distribution for a wide range of samples
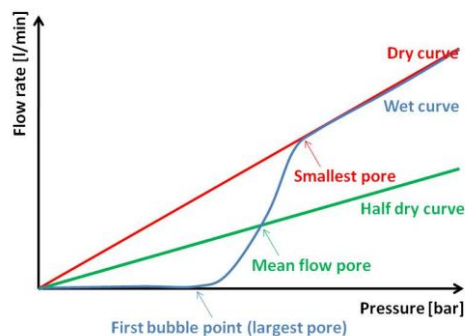
CFP3

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

Universally available **PLC technology** (National Instruments) with:
- **24 bit resolution** pressure and flow sensors.
- Independent runtime system (the measurement is completely independent from Microsoft Windows)
- Network communication technology

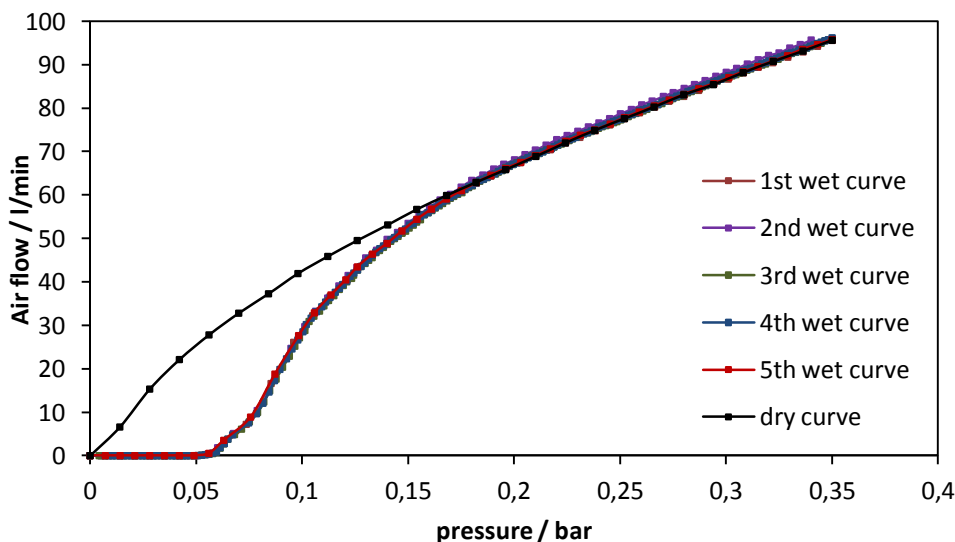Advanced service menu facilitates **diagnosis and service via Internet.**

The POROLUX™100 comes with a free 6-month trial **PoreXpert** licence. PoreXpert is a software for design, analysis and modelling of porous materials from experimental porometry data. It is a very powerful tool for prediction of properties to assist in the engineering and design of new materials. The analysis functions included in this exclusive version for POROLUX™ customers include:
- 3D Structure visualisation
- Gas and liquid permeability calculations
- Pore and throat size and connectivity distribution,
- Report of results and access to expanded functions of PoreXpert Cloud.

Dimensions
LxWxH: 510 x 510 x 455mm
Weight: 30kg

Reproducibility

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POROLUX™ 1000

Research grade gas-liquid displacement Porometer for the rapid measurement of through-pores in porous materials such as membranes, filters, paper, textiles, nonwovens, hollow fibres, etc.

The **POROLUX™1000** series uses a pressure step/equilibrate method to measure pore diameters. The inlet valve for the gas generates the initial system pressure. Subsequently, the system pressure is precisely adjusted by a specially designed needle valve that opens with very accurate and precise movements. To increase pressure, the valve opens to a precise point and then stops its movement. The pressure and flow sensors will only take a data point when the used 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.

Measurements
The POROLUX™1000 measures bubble point, maximum pore size, mean flow pore size, minimum pore size, average pore size distribution of uniform materials and air permeability.

Pore Size Range
Measurable pore size range from 13 nm to 500 μm equivalent diameter (depending on the wetting liquid).

Standard Pressure Range and Flow Rates
0-35 bar (500 psi) with flow rates of up to 200 litres per minute.

Sample Holders
The POROLUX™1000 comes with 3 sample holders: 13mm, 25mm and 47mm. Switching between sample holders is done in a matter of seconds via a quick coupling connection. The availability of 3 sample holders allows the user to analyze a wide range of structures.

Hardware
The POROLUX™1000 comes standard with **3 flow meters**:
-    30 ml/min (for accurate true bubble point detection)
-    10 litres/min
-    200 litres/min
-    Automatic switch between the flow meters

Specially designed **needle valve for linear, accurate pressure build-up**

The POROLUX™1000 comes standard with **2 pressure transducers**:
-    5 bar (72.5 psi)
-    50 bar (725 psi)
-    Automatic switch between the pressure transducers

Advanced, multilevel **stability algorithms** for characterization of complex pore structures.

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First Bubble Point

One of the most important parameters measured by a porometer is the **first bubble point** or FBP. It defines the largest pores present in the material. ASTM F-316 defines the FBP as the pressure at which the first continuous flow of bubbles is detected. The FBP can be defined at different flows, e.g. at 30, 50, 100 ml/min. Because with this approach there is already flow at the FBP, by definition, the 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 is another, **measured FBP** approach to detect the largest pore size. The fully wetted sample and sample chamber all the way up to the specially implemented small flow controller form a closed system. If the pressure on the sample increases using a small, constant flow of gas towards the sample chamber, the pressure will slowly increase. As the volume is fixed, the constant flow will result in a linear rise of the pressure above the sample. When the first and largest pore is opened, there is a change in the linear pressure increase. This change can be regarded as the true first bubble point. This method shows an excellent reproducibility.

The POROLUX™1000 offers both methods for obtaining the first bubble point:
- **Calculated bubble point** according to all scientifically accepted methods e.g. 30, 50, 100ml/min, differential size or first flow
- **Measured bubble point** (selectable flow rate to detect the bubble point: 5-30 ml/min)

Software

The POROLUX™1000 uses **LabVIEW software**, the most sophisticated development suite for all precision instruments control systems. A state of the art and high performing programming system for data acquisition and instrument control; it offers a very intuitive selection of all analysis parameters. Data analysis includes:
- Comprehensive overview of all relevant results and input parameters
- Wet, dry and half-dry graph
- Cumulative flow and pore size distribution graph
- Curve overlay
- One button export to Excel, Word and pdf file

Universally available **PLC technology** (National Instruments) with:
- **24 bit resolution** pressure and flow sensors.
- Independent runtime system (the measurement is completely independent from Microsoft Windows)
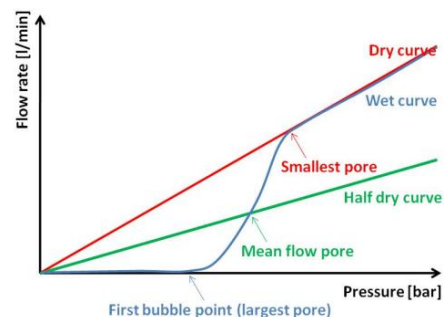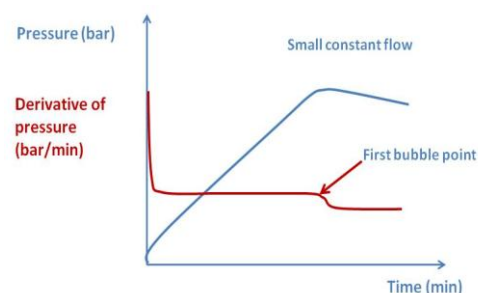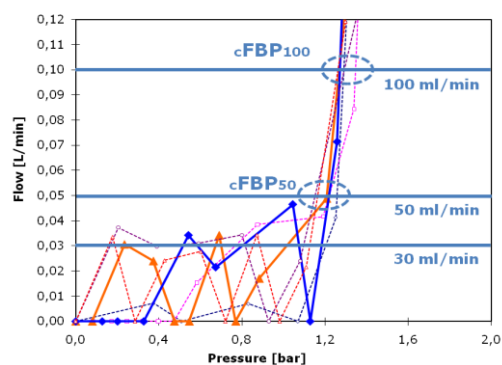- Network communication technology

Advanced service menu facilitates **diagnosis and service via Internet**

The POROLUX™1000 comes with a free 6-month trial **PoreXpert** licence. PoreXpert is a software for design, analysis and modelling of porous materials from experimental porometry data. It is a very powerful tool for prediction of properties to assist in the engineering and design of new materials. The analysis functions included in this exclusive version for POROLUX™ customers include:
- 3D Structure visualisation
- Gas and liquid permeability calculations
- Pore and throat size and connectivity distribution,
- Report of results and access to expanded functions of PoreXpert Cloud.

Dimensions
LxWxH: 510 x 510 x 755mm. Weight: 50kg   **CFP6**

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Accessories for POROLUX™

All our POROLUX™ equipments come standard equipped with all necessary hard- and software required for operation. They only need to be connected to compressed gas and power.

The POROLUX™ has multiple sample holders, pressure and flow sensors for an optimum performance over its full pressure and pore size range. There will be no need to later on add extra pressure sensors and/or flow meters. Thus expensive upgrades are avoided. For the POROLUX™ there are additional accessories available giving the user access to some advanced porometry options.

Liquid permeability

The flow of liquid through a membrane of filter at a predefined pressure can be measured in order to know the liquid permeability. The test can be performed using the gas permeability mode of the POROLUX™ with the liquid permeability option accessory.

A solvent tank is placed in between the pressure control and the sample. When the tank is pressurized to a certain pressure, the solvent that will flow through the sample can be related to the amount of gas flowing to the solvent tank. The amount of filtered liquid can be collected on a balance placed underneath the sample holder. Thus the filtered volume can also be monitored as a function of time. This feature permits using both aqueous ad organic solvents.

Hydrohead kit

The measurement is carried out by using the POROLUX^TM 1000 unique bubble-point measuring mode. Water is added on top of the sample and the instrument performs a FBP test, in which the break-through pressure of a water column on the sample is measured.

Once the sample is in the sample holder, a small volume of water is added above the sample. The pressure on the sample is slowly increased by a small, constant flow of gas. At the moment the water is pushed through the sample there will be a change in the linear pressure increase. The hydrohead pressure is defined and the pressure at which a steady volume flow of water is obtained (ISO 811-1981).

Universal Sample holder

- Universal sample holder with inserts for samples of *40, 30, 20, 10, 5 mm.*
- Compatible with samples of large thickness (up to 1 cm).
- Easy connection through the quick connector as for the standard sample holders.
- Easy cleaning: it stands aside the instrument. This facilitates the use of dirty water, highly viscous oils and such as wetting liquids for actual filter testing.
- Maximum pressure: 10 bar.
- Available on all systems.
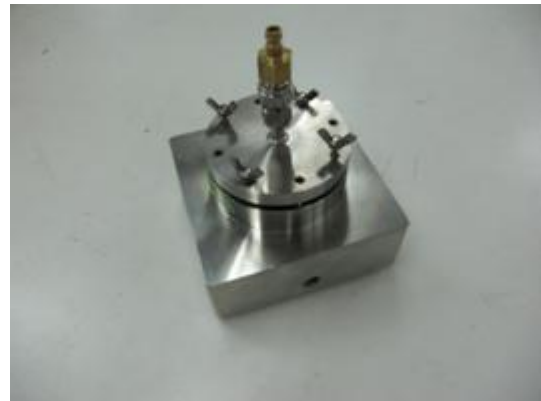
Specially designed large sample holders

Samples with low pore densities can benefit from the increase in size of the sample holder in order to obtain stable and readable gas flows.

Besides the use standard sample holders with a diameter of 13, 25 and 47 mm, POROMETER can create costumer specific designs for special samples: large cylinders, assembled filter-setups, etc.


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Hollow fibre and tubes sample holder

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. Our engineers 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
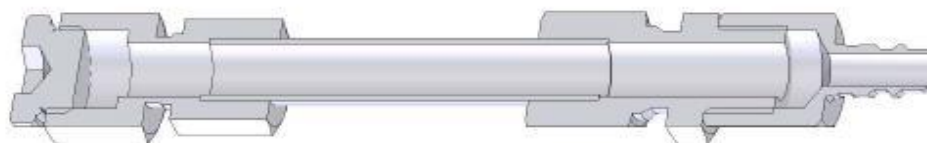
Compression porometry

Accessory to test the pore structure under compressive strength. The sample is placed in a special sample holder placed on a tensile/compressive bench top test frame. Applicable force range 0.05 to 5000 N. Displacement resolution 5µm.

Extended temperature module

Accessory for measuring samples at elevated temperatures. The environmental chamber provides a means for performing tests within a temperature range from RT to 220 °C. An internal fan provides efficient air circulation which minimizes temperature gradients. A digital controller ensures accurate temperature control. Contact us for sub-zero temperature testing. Can be combined with compression porometry.

Comfort kit

- It includes a set of LED lights and a magnifying glass.
- Useful to check if the sample has been properly wetted and/or if the sample has not been damaged as a result of high pressure and/or high flow during the analysis.
- Available for the POROLUX^{TM} 1000.

CFP9

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All our POROLUX™ systems come with **PLC technology**[1] and **LabVIEW multilingual software**, **24 bit resolution** pressure and flow sensors and remote **service via Internet**. All our instruments include a 6-month trial **PoreXpert** licence, a powerful software for design, analysis and modelling of porous materials from experimental porometry data.

Pressure SCAN series product overview

Product overview	POROLUX™ 100	POROLUX™ 100NW	POROLUX™ 100FM	POROLUX™ 500
Max pressure	0.7 MPa/100 psi	0.15 MPa/22 psi	0.25 MPa/36 psi	3.5 MPa/500 psi
Min pore[2]	0.091 µm	0.427 µm	0.250 µm	13 nm
Max pore[2]	500 µm	500 µm	500 µm	500 µm
Max flow	100 l/min	200 l/min	200 l/min	200 l/min
Sample holders	25 mm	25 mm	25mm	25 mm
Pressure sensors[3]	8 bar	2 bar	3 bar	0.5-5-50 bar
Flow sensors[3]	5-100 l/min	10-200 l/min	10-200 l/min	10-200 l/min
Calculated FBP	Yes	Yes	Yes	Yes
Measured FBP	No	No	No	No

Pressure STEP/STABILITY series product overview

Product overview	POROLUX™ 1000	POROLUX™ 1000LP	POROLUX™ 1000LF
Max pressure	3.5 MPa/500 psi	0.8 MPa/116 psi	3.5 MPa/500 psi
Min pore[2]	13 nm	80 nm	13nm
Max pore[2]	500 µm	500 µm	500 µm
Max flow	200 l/min	100 l/min	10 l/min
Sample holders	13-25-47 mm	25 mm	13-25-47 mm
Pressure sensors [3]	5-50 bar	1-10 bar	5-50 bar
Flow sensors [3]	10-200 l/min	5-100 l/min	0,5-10 l/min
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] National Instruments
[2] Depending on the wetting fluid
[3] Intelligent, automatic switching between pressure and flow sensors

POREXPERT

PoreXpert™ is a new modelling and simulation software, developed at the University of Plymouth (UK), designed for porometry exclusively to interface with **POROLUX™** porometers. The software opens up a huge new world of virtual reality, in which one can not only simulate the filtration characteristics, wettability, permeability and geometry of porous samples, but also optimises their design using PoreXpert™ Targeted Modification™.

Integrated with POROLUX™ porometers
PoreXpert™ exploits the improved accuracy of the POROLUX™1000 series porometers, derived from their pressure step/stability method. It also works with the POROLUX™100 series. Any porous material studied with a POROLUX™ porometer can be simulated – the only additional information required is the porosity.

Traditional approach
You may not realise it, but when you analyse porometry curves, you are implicitly assuming a capillary bundle model. A PoreXpert™ example, based on a POROLUX™ data file, is shown on the right. Such a structure type is appropriate for a few samples – for example track-etched membranes.
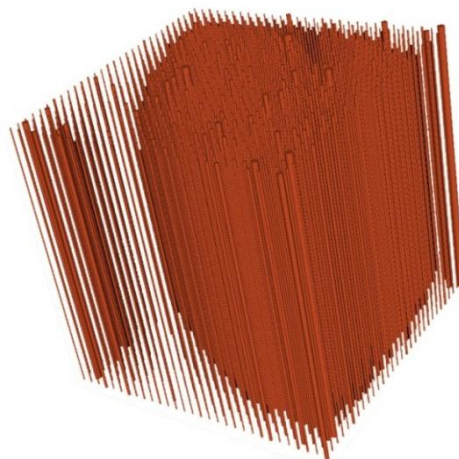
PoreXpert™approach
However, most porous materials have a three-dimensionally inter-connected network of voids. Shown on the right is the PoreXpert™ reconstruction of a porous ceramic with 20 % porosity and a fully interconnected structure, showing the solid phase as transparent and the extent of wetting (blue) after 20 milliseconds. As it can be seen, the wetting of the structure is not completed. By selecting other times, PoreXpert™ can simulate the extent of wetting across the structure.
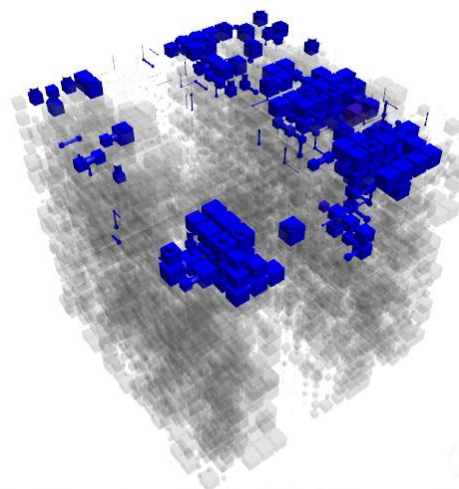
The shapes of the voids are simplified – boxes connected by cylinders – but shape is usually irrelevant – it is the volume of each pore, its cross-section, and the way it is connected that matters, and all these characteristics are quantitatively matched to the experimental properties. So based on a structure designed by PoreXpert™, if a material with such structure was reconstructed and measured with a POROLUX™ porometer, it would give exactly the same experimental porometry results.

PoreXpert™ is therefore a very powerful tool especially for design and optimisation of new materials in research and development work.

How does it generate a structure so much more complicated than a capillary bundle?
By using a Bayesian statistical approach to incorporate additional information – for example the porosity, the way the whole shape of the porometry curve interacts, and the likely relationships between the sizes of neighbouring features.

Geometric characteristics
Once the structure has been generated, its characteristics can be easily measured – for example the sizes of the voids within it, and whether the structure contains 'ink bottle' or dead end pores in which liquid or particles may become trapped.

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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
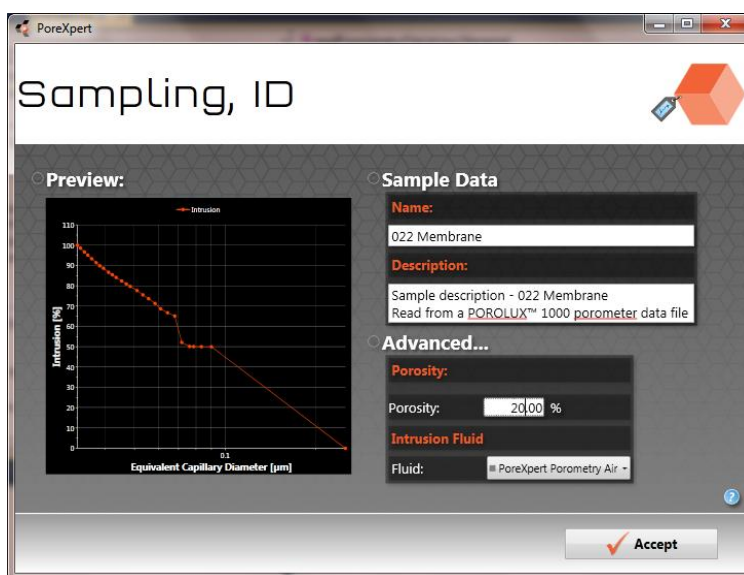
PoreXpert™ sampling screen –all screens are user friendly and jargon-free
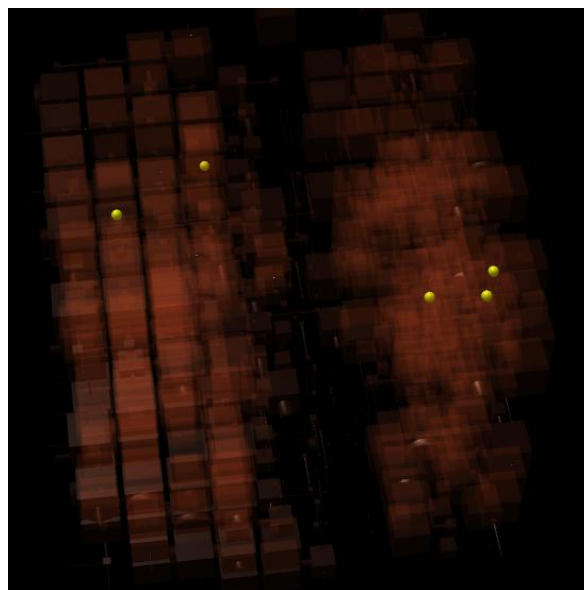
PoreXpert™ filtration virtual reality visualisation - captured particles are shown in yellow.

Features depend on the version of PoreXpert™ being used. 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

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