Surface Measurement Systems
World Leader in Sorption Science

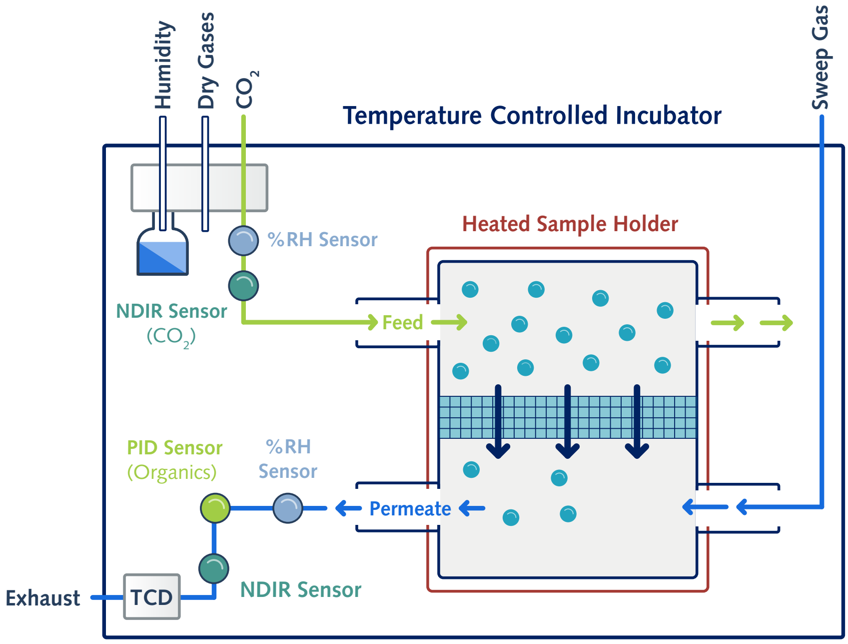
MPA Horizon

Self-contained Membrane Permeation Analyzer

Advanced cross-flow analysis to measure multi-component permeation through thin-films and membranes

MPA Horizon

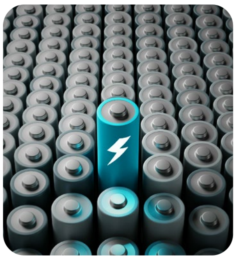
The cross-flow permeation instrument for membrane analysis



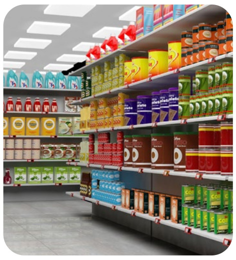
The Membrane Permeation Analyzer (MPA Horizon) is a self-contained cross-flow gas permeation instrument, purpose-built for investigating the competitive permeation of gases and vapors through membranes and barrier films.

In most membranes, the nature of the environment can influence the permeation of gases or vapors, especially the temperature and humidity. The new MPA Horizon enables the analysis of gas/vapor permeation and permeation kinetics under real-world conditions.

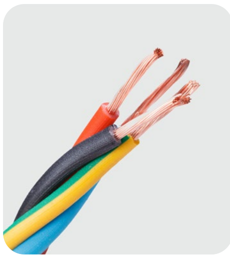
Applications:



Fuel Cells: Ion Exchange



Food & Drink Storage



Electrical Insulation

Carbon Capture & Storage

Pharmaceuticals & Cosmetics

What is Permeation?

Permeation is the movement of molecules from one side of a material to another. The MPA Horizon monitors gas and vapor permeation through membranes using its versatile sensor suite.

Key Features

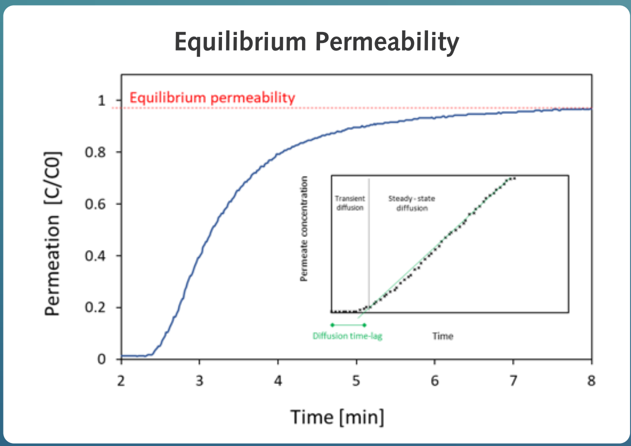


Figure 1: Example permeation plot and the metrics that can be obtained

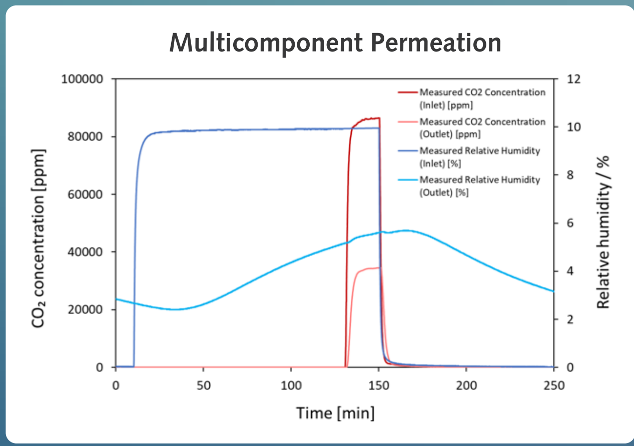


Figure 2: Multi-component permeation of humidity and CO_2 through a hydrophilic membrane

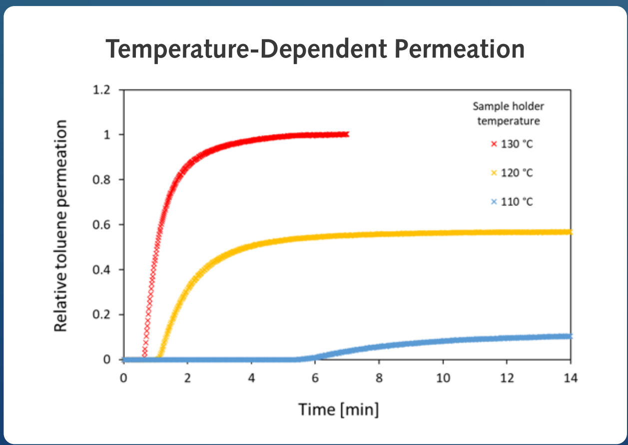


Figure 3: The effect of PET sample temperature on toluene permeation

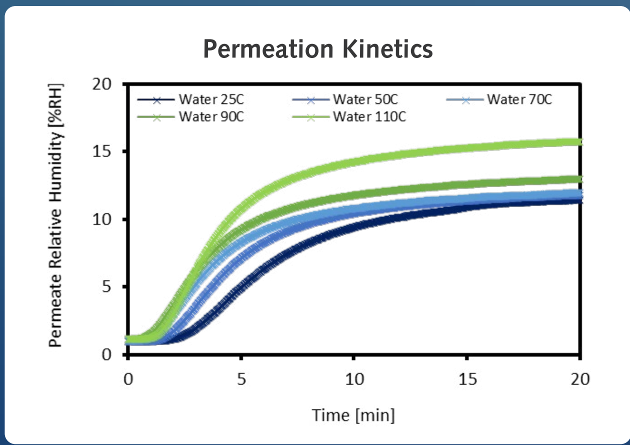


Figure 4: The change in humidity permeation kinetics with temperature through PET

Multicomponent membrane permeation

- Individual control of gases, vapors, and humidity concentrations
- Concentrations and temperatures manipulated in precise steps
- Complex multi-component methods and cycling can be performed with ease

Local heating of the sample

- Sample can be locally heated between 10-150 °C to simulate real-world conditions
- Determination of permeation and diffusion activation energies

Cross-flow gas system

- Inlet and outlet sensors for a complete understanding of permeation
- Capability to detect both the feed or permeate stream

Versatile gas/vapor sensor suite

- Individual detectors for humidity, organics, CO_2
- Universal detector for other gases using a TCD
- Further specific gas detectors, such as O_2, available on request

Hardware

Sample Holder

Our sample holder is a custom-built, simple-to-use double O-ring seal designed to accommodate small and large sample sizes up to 11 cm in diameter. Samples can be up to 0.5 mm in thickness, with thinner samples supported to prevent deformation.

Temperature Controlled Incubator

The sample holder, sensors, and humidity generation are all held within a temperature-controlled incubator to prevent any condensation and to aid temperature-sensitive experiments with fast and stable sample holder temperature equilibration.

This incubator also greatly increases the sensor reading stability when compared to products without temperature control.

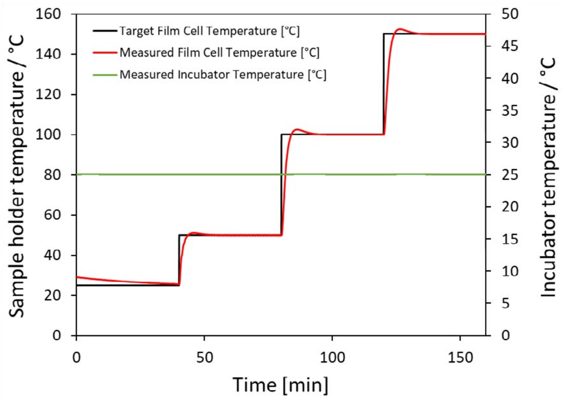


Figure 5: Sample holder heating control and incubator stability

Sensors: What Can You Run?

The MPA Horizon has a multi-purpose sensor suite built into the instrument meaning extra detectors are not required. As standard, the MPA Horizon sensors can detect:

- Humidity using capacitance probes
- CO_2 using near-infrared sensors
- VOCs (organics) using photo-ionization detectors
- Thermal conductivity detector for all other gases
- O_2 using an electrochemical optical sensor

The MPA Horizon has integrated humidity generation with fast and accurate concentration fronts thanks to precisely tuned temperatures, mass flows, and sensor calibrations.

- Achieves high humidity (<85%) even at high temperatures (60 °C) , without condensation
- High humidity stability ±0.1%RH over 6 hours
- Heated 50 mL water reservoirs

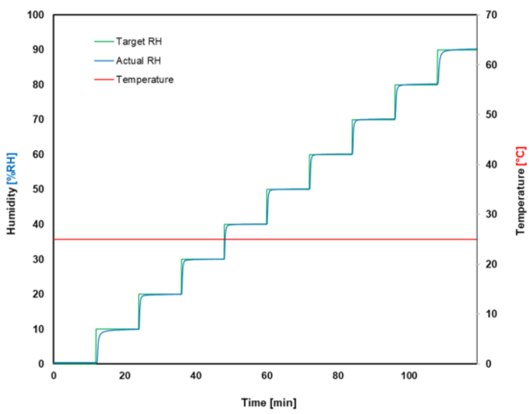


Figure 6: Stability and range of humidity at 25 °C

Controlling Your Flows

The MPA Horizon's unique design allows users to switch the gas calibrations of their MFCs via the software, allowing users to vary the gases and vapors that can be exposed to the sample. This is all housed within the self-contained unit for simple control.

The MPA uses a cross-flow system at atmospheric pressure, with the cross-flow and carrier gas tunable by the user.

As standard, users can switch the MFC calibrations for the carrier gas between:

- ✓ Oxygen
- ✓ Nitrogen
- ✓ Argon
- ✓ Carbon dioxide
- ✓ Helium

With six customizable MFCs, with flow rates up to 200 sccm, the MPA Horizon can mix wet and dry gases to create intricate concentration mixtures with humidity.

	MPA Horizon	Industry Standard
Generation of single component flows of O_2, CO_2, or water vapor (>90 %RH) in a carrier gas	✓	✓
Local heating of the sample	✓	✓
Cross-flow gas system at atmospheric pressure	✓	✓
Multicomponent permeation and detection for gases, vapors, and humidity	✓	
Sample bypass for the accurate quantification of feed gas concentrations	✓	
Alternating between detecting the feed and permeate streams	✓	

Case Study 1: Membranes for Carbon Capture

An attractive type of membrane materials for carbon dioxide removal are polymers of intrinsic microporosity (PIMs) – forming flexible and easy-to-manufacture single component membranes with high gas permeabilities and selectivity for CO_2 over N_2 and O_2 – primary components of flue gas. However, whereas the selectivity and permeability of membranes are often measured in ideal conditions, real flue gas contains a mixture of contaminants such as water which can impact the transport properties of a membrane.

The MPA Horizon was used to observe the multi-component permeation of flue gas constituents through two membranes: PIM-1 (hydrophobic) and cPIM-1 (hydrophilic). The purpose of this study was to reveal how modifying the polymer structure to be more hydrophilic changes the impact of humidity on CO_2 permeation and selectivity.

A selected humidity was first introduced to the top of the membrane for three hours, followed by a 30-minute step of 10% CO_2 whilst maintaining the selected humidity. The concentration of CO_2 permeating through the membrane was monitored to observe how the presence of humidity affects CO_2 permeation.

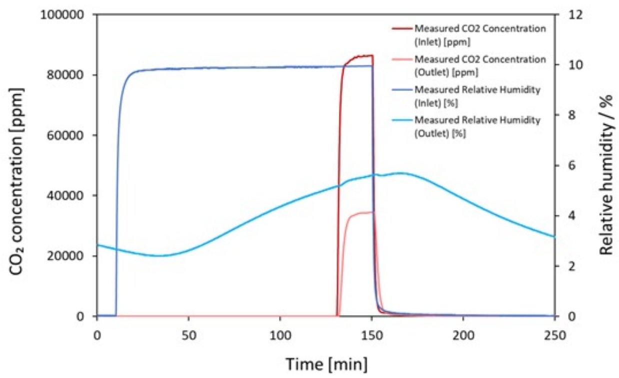


Figure 7: The impact of humidity on PIM-1 and cPIM-1 CO_2 permeation

The effects of humidity on the CO_2 permeability were evaluated for PIM-1 and cPIM-1, for which CO_2 permeability was seen to decrease by 20% and 40% respectively at 60 %RH.

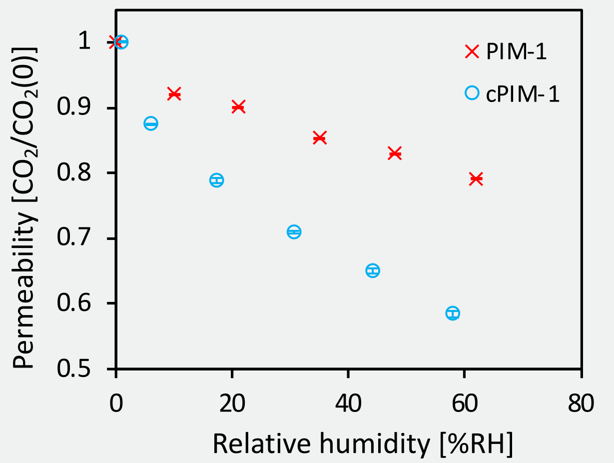


Figure 8: The impact of humidity on PIM-1 and cPIM-1 CO_2 permeation

The effects of humidity on the CO_2 / N_2 selectivity were also evaluated for cPIM-1. As shown in Figure 9, the selectivity of cPIM-1 decreases with humidity.

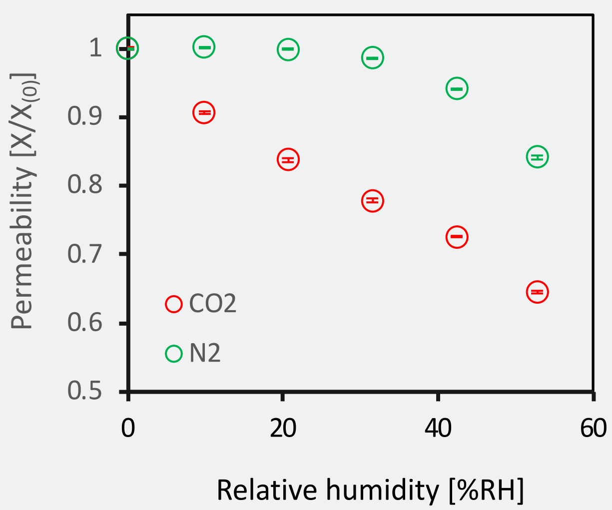


Figure 9: The impact of humidity on cPIM-1 CO_2 and N_2 permeation

Case Study 2: Permeation Through Barrier Membranes

Analyzing water permeation through barrier membranes under application conditions is vital. In the real world, the temperature and environment of a polymer can vary significantly, and these properties can have a significant impact on the polymer barrier properties. Temperature can make the polymer more flexible, increasing permeation, and VOCs can dissolve in the polymer changing its properties.

The permeation of toluene and water through two polymer films, PET and Kapton, have been evaluated under a range of temperatures and humidity. For PET, the humidity permeation was found to increase at temperatures above the glass transition temperature (>70 °C). This increase in water permeation was not observed in Kapton due to the much higher glass transition temperature of 300 °C. Therefore at higher temperatures, Kapton behaves as a better water barrier.

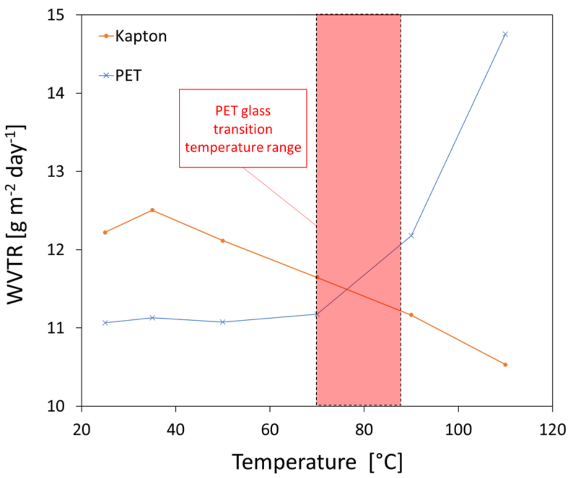


Figure 10: The change in water vapor transmission rate (WVTR) through PET and Kapton with temperature.

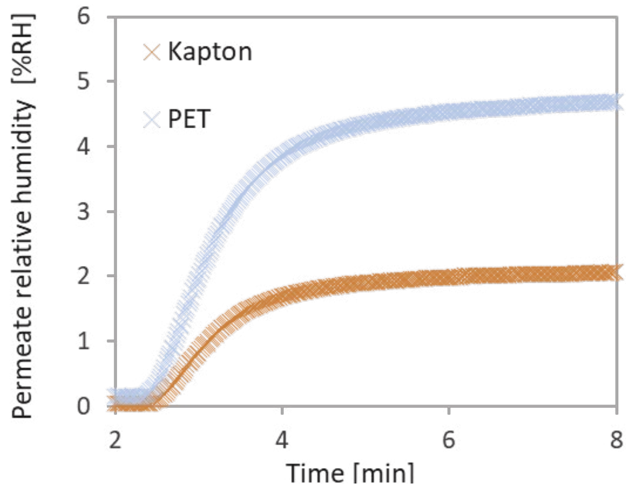


Figure 11: The permeation of humidity through Kapton and PET films at 130 °C

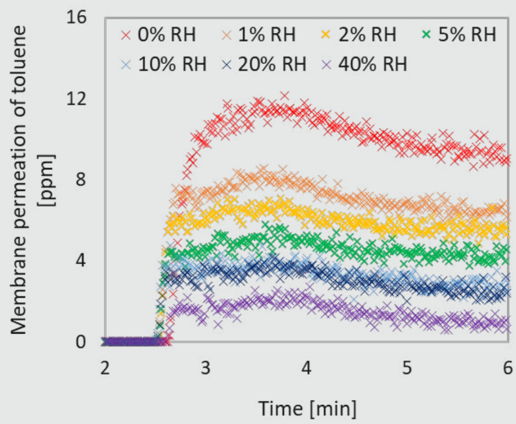


Figure 12: The change in toluene permeation through PET at 130 °C with increasing humidity.

Multi-component permeation

The permeation of toluene through PET with increasing humidity was observed by analyzing changes in the feed gas concentration after passing over the membrane. This analysis mode allows for the detection of ppm level changes in permeation. As shown in Figure 12, the permeation of toluene through PET decreases with increasing relative humidity.

Modular Capabilities

Gas Inlets

- Five gas mixing inlets on the feed side for solvent, humidity, and gases
- Check valves to prevent line contamination
- 5 feed gas MFCs with changeable gas calibrations via our software
- 1 sweep gas MFC with changeable gas calibrations via our software

Flow Path

- Accurate determination of feed gas concentrations via a sample bypass line
- Switchable flow path to detectors between feed and permeate side

Heated Reservoir

- The heated reservoir is held within the controlled enclosure
- Designed for accurate humidity generation [95%RH] up to 60 °C
- Reservoir held within a heated jacket to avoid evaporative cooling

Heated Sample Holder

(For sample activation and local heating)

- *In-situ drying of the sample between 10-150 °C*
- Local control of temperature for the observation of glass transitions

Optional:

Oxygen Sensor

A fully integrated optical oxygen sensor for the determination of oxygen permeation

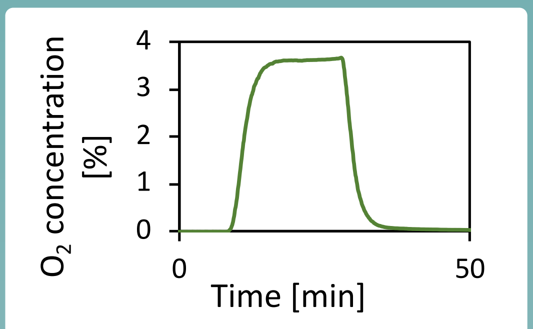
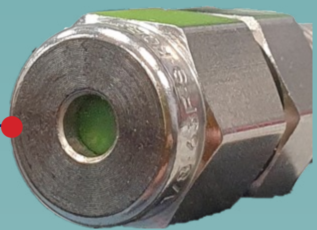
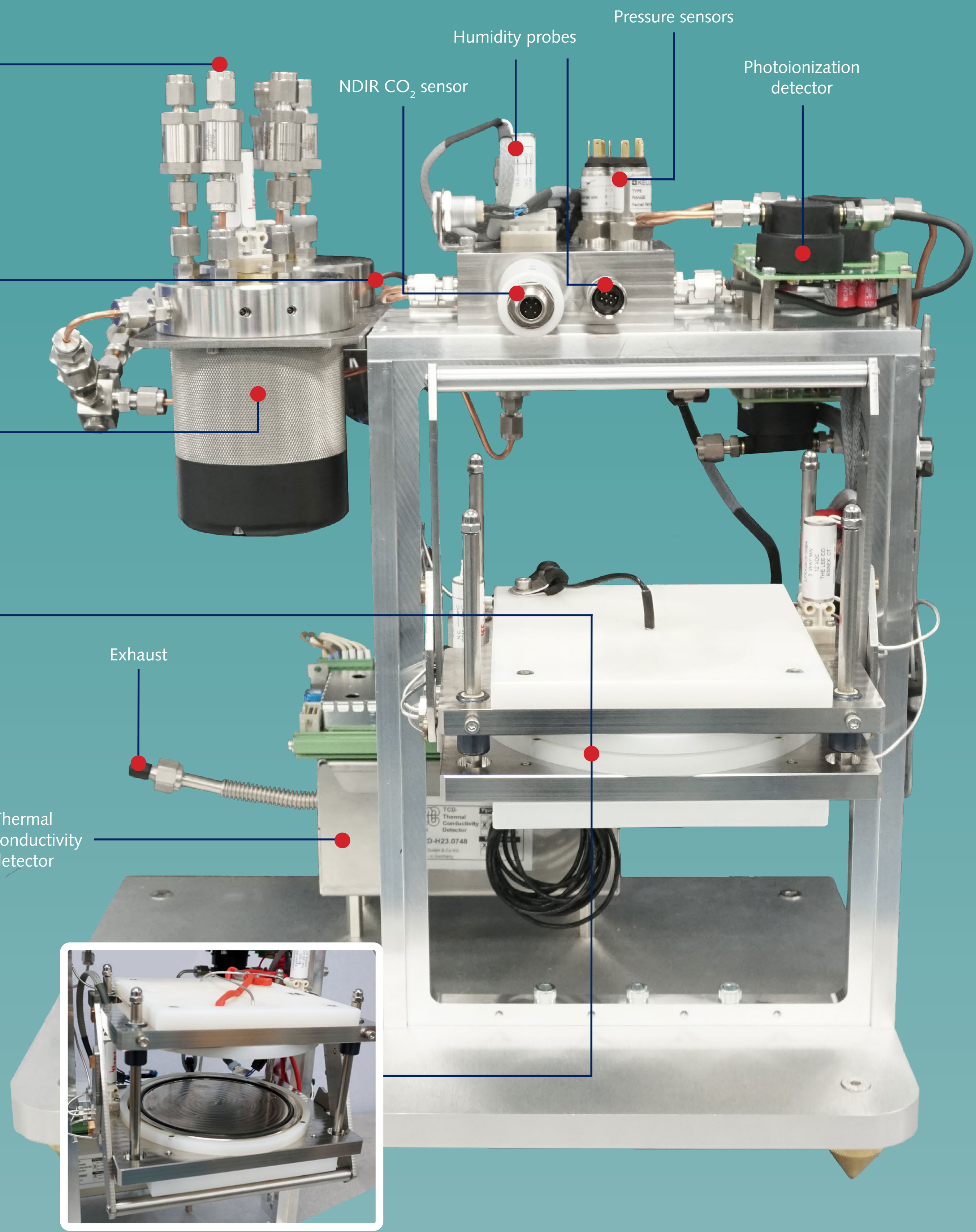


Figure 13: Oxygen permeation detected using a built-in optical sensor

Injection Port

An in-line port for the injection of headspace concentrations or contaminants

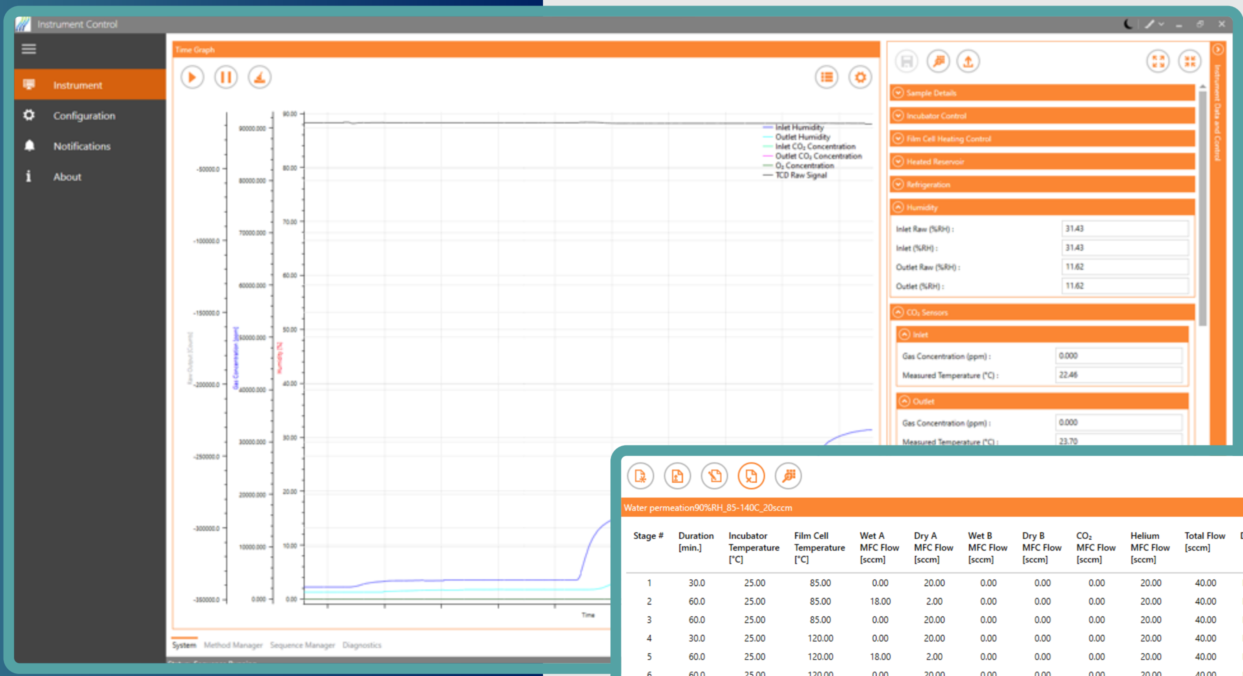




Purpose-built Software

The instrument control software package provided with the Horizon allows the live plotting of data from all the MFCs, sensors, and heating units and comes with a method and sequence builder for creating complex experiments.

Control Software



Water permeation90%RH_85-140C_20sccm

Stage #	Duration [min.]	Incubator Temperature [°C]	Film Cell Temperature [°C]	Wet A MFC Flow [sccm]	Dry A MFC Flow [sccm]	Wet B MFC Flow [sccm]	Dry B MFC Flow [sccm]	CO_2 MFC Flow [sccm]	Helium MFC Flow [sccm]	Total Flow [sccm]	Detection Side	Flow Path
1	30.0	25.00	85.00	0.00	20.00	0.00	0.00	0.00	20.00	40.00	Permeate Side	Film Cell
2	60.0	25.00	85.00	18.00	2.00	0.00	0.00	0.00	20.00	40.00	Permeate Side	Film Cell
3	60.0	25.00	85.00	0.00	20.00	0.00	0.00	0.00	20.00	40.00	Permeate Side	Film Cell
4	30.0	25.00	120.00	0.00	20.00	0.00	0.00	0.00	20.00	40.00	Permeate Side	Film Cell
5	60.0	25.00	120.00	18.00	2.00	0.00	0.00	0.00	20.00	40.00	Permeate Side	Film Cell
6	60.0	25.00	120.00	0.00	20.00	0.00	0.00	0.00	20.00	40.00	Permeate Side	Film Cell
7	30.0	25.00	140.00	0.00	20.00	0.00	0.00	0.00	20.00	40.00	Permeate Side	Film Cell
8	60.0	25.00	140.00	18.00	2.00	0.00	0.00	0.00	20.00	40.00	Permeate Side	Film Cell
9	60.0	25.00	140.00	0.00	20.00	0.00	0.00	0.00	20.00	40.00	Permeate Side	Film Cell
10	1.0	25.00	10.00	0.00	2.00	0.00	0.00	0.00	2.00	4.00	Permeate Side	Film Cell

Analysis Software

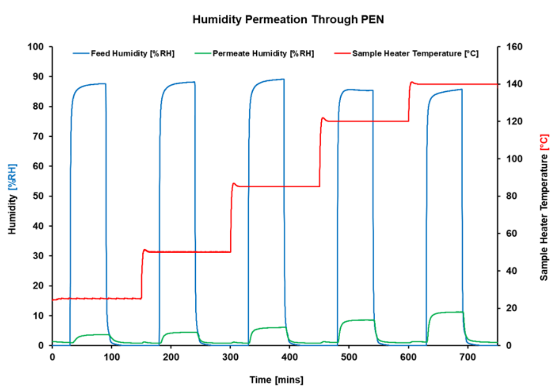


Figure 14: Graph produced from the MPA analysis suite macro

All data files from the MPA are saved as encrypted files for extra security. These files may be exported as text using the software and opened in our analysis software Excel macro.

This macro allows for easy data analysis and graphical plotting, an example graph is shown to the left in figure 14. It also includes calculations of permeation and WVTR.

Specifications

Construction Materials

Custom-built manifold: 316 stainless steel
Seals: Viton® or equivalent, Kalrez® optional
Tubing: 1/16 or 1/8 inch 316 stainless steel

Gas Flow Control

Control Range 0-200 SCCM
Turn-down Ratio up to 1000:1
Calibrated gases N_2, CO_2, He, O_2, Ar

Temperature Control

Incubator control
Controls entire generation and measurement system
Control Range: 5°C to 60°C
Control Accuracy: ±0.2°C

Local sample heater
Control Range: 10°C to 150°C
Control Accuracy: ±1 °C
Heated diameter: 120 mm

Sample Dimensions

Variable sample diameter
Standard width 11 cm
Thickness <0.5 mm

Humidity Generation

Water Reservoirs
50 mL easy-change reservoir
Heated to avoid evaporative cooling

Generation
0 – 98% for 5-60 °C [1]

Measurement
Measurement Range 0-100% RH
Accuracy (5-40 °C) ± 0.8% RH
Accuracy (40-85 °C) ± 1.5% RH

Gas & Vapor Sensors

CO_2 Measurement
0 – 25% vol, atmospheric pressure
Accuracy: Exact [3] or 0.05 %vol. of inlet concentration

Organics Measurement
0 – 98% for 5-60 °C
Low-range sensor 1 ppb-40 ppm
Mid-range sensor 0-4000 ppm
High-range sensor 0-10000 ppm

TCD Gas Measurement
Measurement Range 0-100%

O_2 Measurement
Measurement range 0-100%
Accuracy* (<1% O_2) ± 0.02%
Accuracy* (100% O_2) ± 2%

WVTR Measurement
(80 cm^2) 0.05 – 500 g m^{-2} day^{-1}

System Information

Dimensions: 520 mm (W) x 980 mm (H) x 610 mm (D)
Weight: 80 kg (180 lb)
Electrical: 200 – 240 v, 50/60 Hz, 1500 VA

System Software

Instrument Control Software
- Live data view and plotting
- Full control over parameters
- Powerful custom methods and sequences
- Multiple component permeation and detection
- Multiple concentration or temperature cycles
- Temperature changes in a single experiment

MPA Analysis Software
- Easy graphical plotting
- Permeability calculations
- Calculation of water vapor transmission rate (WVTR)
- Calculation of diffusion lag time

Footnotes
*10 – 40 °C
[1] Humidity factory calibrated at 25 °C and 60 °C. Calibrations at other temperatures upon request.

What is water vapor transmission?

The water vapor transmission rate (WVTR) is a measure of humidity permeation through a membrane of a specific area over 24 hours (g_{water}/ m^2/ day). On the MPA horizon, we measure this WVTR using the capacitance humidity probes, and the WVTR can be measured between 0.009 - 800 g / m^2 / day over a wide range of temperatures, with multiple components present. Parameters such as O_2 and CO_2 transmission rate can also be calculated using the MPA Horizon.

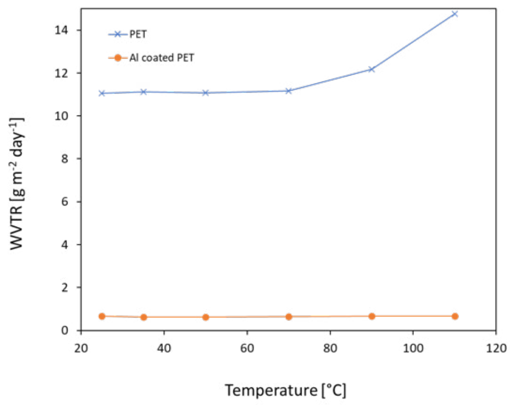


Figure 15: Water vapor transmission obtained from the MPA Horizon

Why do we need multi-component permeation?

The real-world application of membranes and films introduces materials to any number of fouling or swelling agents that affect the performance of these materials to act as efficient barriers or sieves.

Therefore, to realistically assess the film or membrane performance, the permeation of target gases and vapors must be performed in the presence of the multiple components to simulate real-world conditions.

About Surface Measurement Systems

Surface Measurement Systems Ltd. develops and engineers innovative experimental techniques and instrumentation for physico-chemical characterization of complex solids, solving difficult problems in materials research. With over 30 years of continuous innovation, every instrument is built with the cumulative knowledge and experience of our world-leading team of sorption scientists. This makes us the preferred sorption partner of universities, research institutes, corporate R&D, and global government organizations, who we work with and support in pioneering the future of materials research.

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