

Dryers & Humidifiers

Featuring Nafion® Technology

- **Very Selective Permeation**
- **No Routine Maintenance**
- **Rapid Moisture Exchange**
- **Corrosion Resistant**
- **Continuous Performance**
- **No Moving Parts**



PERMA PURE

Nafion[®]

The Perfect Moisture Exchange Material

Corrosion Resistant — Nafion is a copolymer of tetrafluoroethylene (Teflon[®]) and perfluoro-3,6-dioxo-4-methyl-7-octene-sulfonic acid (Figure 1). Like Teflon, Nafion is highly resistant to chemical attack, so it can be used with very corrosive gases.

Fast — Nafion is highly permeable to water due to the presence of sulfonic acid. Sulfonic acid has a very high water-of-hydration, absorbing up to 13 molecules of water for each sulfonic acid group in the polymer. These sulfonic acid groups form interconnected ionic channels through the Nafion tubing wall. Water absorbs onto sulfonic acid groups exposed on one surface of the tubing and then permeates very quickly through the ionic channels in the polymer and pervaporates off the opposite surface.

Selective — Unlike microporous membrane permeation, a relatively slow diffusion process, Nafion absorbs and transfers water as water-of-hydration, a very rapid, first-order kinetic reaction. Because this is a specific chemical reaction with water, other constituents are usually entirely unaffected.

Simple — When water vapor absorbs onto the tubing from the vapor phase then pervaporates from the tubing into the vapor phase, there is no net change of free energy, and no external energy is required to drive the reaction. The driving force is simply the difference in water concentration on opposite sides of the tubing wall.

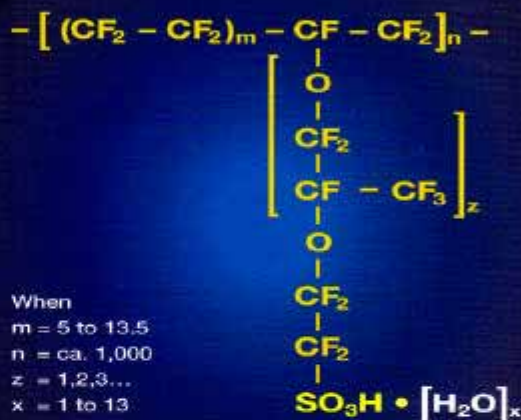


Figure 1 — Nafion Chemical Structure

APPLICATION

GAS SAMPLE DRYING

Gas sample analysis requires a clean, dry sample to produce accurate and reliable results. Filters remove entrained particles, but removing moisture from a sample without affecting the analytes is not so simple. Chillers (including Peltier devices) remove water by condensation, but water-soluble gases dissolve in the condensate and are removed as well. Desiccant dryers absorb water, but also absorb analyte gases.

Perma Pure's gas dryers are a superior alternative. They have no moving parts, require no maintenance, and continuously and highly selectively remove water from gas samples without affecting analytes, reaching final dew points as low as -45°C.

SELECTIVITY

Nafion is not only highly resistant to chemical attack, it also exhibits highly selective absorption. Most substances are completely retained. Although they do not attack or damage the Nafion tubing, some polar organic substances are absorbed and transferred. Ammonia and amines are also lost. Table 1 lists the selectivity of Perma Pure Nafion dryers and humidifiers.

Table 1— Nafion Selectivity

TOTALLY RETAINED	
Atmospheric Gases N ₂ O ₂ H ₂ Ar He	Hydrocarbons All Simple Hydrocarbons
Oxides CO CO ₂ SO ₂ SO ₃ NO _x	Toxic Gases HCN COCl ₂ NOCl
Halogens Cl ₂ F ₂ HCl HF HBr Fluorocarbons	Other Organics Ethers, Cyanides, Esters
Sulfur H ₂ S COS Mercaptans	Inorganic Acids HNO ₃ H ₂ SO ₄
SOME LOSSES	
Polar Organics Alcohols, Ketones, Organic Acids, DMSO, Aldehydes, THF	Other Ammonia, Amines, Nitriles

ABOUT PERMA PURE

Perma Pure is a member of the Halma Group, an international organization of more than 50 companies whose products serve the safety, environmental, and instrumentation markets.

Perma Pure is a world leader in specialty gas drying and humidification. In addition to our standard product lines, we custom-build dryers and humidifiers to handle gas flows up to hundreds of liters per minute.

Nafion

Advantages

- **Perma Pure dryers and humidifiers transfer water much more selectively than competing techniques.**
- **Gas streams can be dried down to a dew point of -45°C (75 ppm of water) or humidified up to 100%.**
- **Moisture exchange occurs in a fraction of a second.**
- **The process is continuous and self-regenerating.**
- **The device is compact, highly corrosion resistant, and rugged.**
- **There are no moving parts and no routine maintenance is required.**

APPLICATION

FUEL CELL HUMIDIFICATION

Certain types of fuel cells require the inlet hydrogen and oxygen gas streams be humidified to improve efficiency. While many technologies exist to humidify gas streams, precise, continuous humidification with minimal cost is not easy. Enthalpy wheels consume power, suffer from seal issues, and fail if liquid water enters the device. Ultrasonic devices can clog and must be controlled to match air flow requirements.

Perma Pure's gas humidifiers are a superior alternative. They continuously humidify the inlet gas stream, have no moving parts, and require no power. They can operate under a wide range of conditions, providing consistent humidification.

PRINCIPLES OF OPERATION

When gas passes through Nafion tubing, water is absorbed by and moves through the walls of the tubing. The movement of water is driven by the humidity gradient between the inside and outside of the tubing. A gas stream normally needs to reside in the device for less than one second in order to reach the proper humidity.

Most Perma Pure® dryers and humidifiers enclose one or more strands of Nafion tubing in a shell with fittings to supply a counter-current gas flow (Figure 2). This shell and tube design is proven to be very efficient for moisture and heat transfer.

ME™- Series moisture exchangers, however, consist of Nafion tubing protected by polypropylene braiding. When gas passes through the Nafion tubing, the humidity level of the gas equilibrates with ambient humidity. These moisture exchangers can be used to either dry or humidify gas streams.

NAFION GAS DRYERS

In a Perma Pure Nafion dryer, a dry purge gas flowing over the exterior surface of the Nafion tubing continuously extracts water vapor from the gas stream inside the tubing. The purge gas carries away water vapor from the gas stream, drying the gas stream without exposing it to condensate or any material that might absorb constituent gases.

If an external dry purge gas supply is not available, the gas stream itself may be used to carry away the excess water in a self-purging process. Water vapor pressure differential is the driving force behind the movement of water through Nafion. If the gas passes through the dryer and then through a needle valve, the resulting stream has a lower total pressure and therefore a lower water vapor pressure. This stream can be used as a purge gas to dry the sample. As long as the flow rate of this reduced-pressure gas recycled stream is twice that of the sample passing through the dryer, the sample can be completely dried.

Nafion always retains some water, since not all the water can ever be removed from the sulfonic acid sites within the Nafion. The amount of water retained depends on the temperature environment of the dryer. Once the water content of the wet gas matches the residual water level in the tubing, there is no longer a gradient, and drying stops. At ambient temperature (20°C), this characteristic limits drying to a lowest dew point of about -45°C, corresponding to a water content of approximately 75 ppm.

NAFION GAS HUMIDIFIERS

Perma Pure humidifiers operate as either water-to-gas humidifiers or gas-to-gas moisture exchangers. The water-to-gas humidifiers have water on one side of the tube wall and the gas to be humidified on the other. These humidifiers offer the greatest amount of humidification, as all the sulfonic acid sites on the water side of the Nafion tubing are continuously saturated. In this method of humidification, hot water should be used to optimize performance. Because the water is going from the liquid phase to the vapor phase, there is a net loss of energy, and the tubing is cooled. This will cool the gas stream slightly and may reduce the moisture exchange efficiency unless hot water is used.

Gas-to-gas humidifiers use counter-flowing wet and dry gas streams to move water from one stream to the other. These units are more energy efficient, as they do not require any additional power or heat. Our gas-to-gas exchangers can operate as heat exchangers as well, transferring most of the heat from the wet stream to the dry stream in the process of humidification.

TEMPERATURE, PRESSURE, AND CHEMICAL RESISTANCE

Nafion tubing is stable at temperatures up to 160°C and tolerates internal pressures over 80 psig. As noted previously, its chemical resistance is similar to Teflon, and very few things can attack it. Even high concentrations of very corrosive gases like hydrogen fluoride or hydrogen chloride can be treated.

In addition to Nafion tubing, Perma Pure dryers and humidifiers often include a shell and fittings, and multi-tube units contain a chemically-resistant epoxy header. Dryers and humidifiers with single strands of Nafion tubing tolerate any gas that the fittings tolerate. Units with Nafion tubing bundles are somewhat more sensitive due to the epoxy. Shells and fittings are available in stainless steel, fluorocarbon polymer, or polypropylene.

The temperature-resistant properties of the dryers and humidifiers are dependent on the materials of construction. The maximum temperature for polypropylene shells and fittings is 100°C, and for fluorocarbon 150°C. Stainless steel devices are limited by Nafion tubing to 160°C unless Nafion tubing bundles are used, where the epoxy limits the maximum temperature to 150°C. The maximum internal pressure for all dryers and humidifiers is limited by the Nafion tubing to 80 psig unless reinforced.

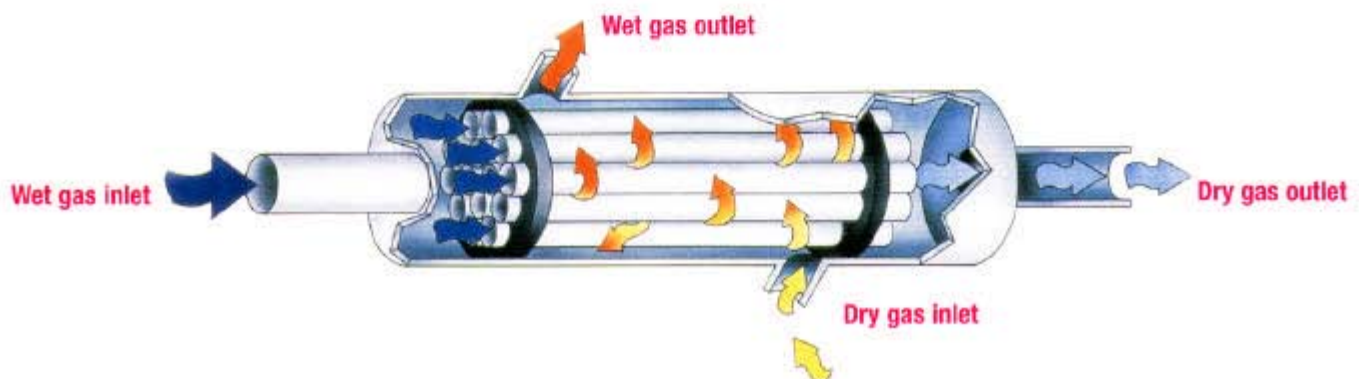


Figure 2 — Dryer & Humidifier Schematic

PRODUCT CHART

MD™- SERIES GAS DRYERS

- Single-tube dryers for flow rates up to 4 LPM
- Various size tubing available to provide wide range of performance
- Lengths up to 144 inches can be coiled to meet tight packaging requirements
- Shell and fittings available in polypropylene, fluorocarbon polymer, or stainless steel
- Typically used in gas chromatography, infrared, and other moisture-sensitive gas analysis equipment



For more information, request brochure #103

PD™- SERIES GAS DRYERS

- Multi-tube dryers for high-flow sample and process applications
- Rigid or flexible housings available in a variety of materials up to 72 inches long
- Easily incorporated into sampling systems or analyzers
- Commonly used for drying samples in emissions monitoring, process monitoring, and particle measurement



For more information, request brochure #104

ME™- SERIES MOISTURE EXCHANGERS

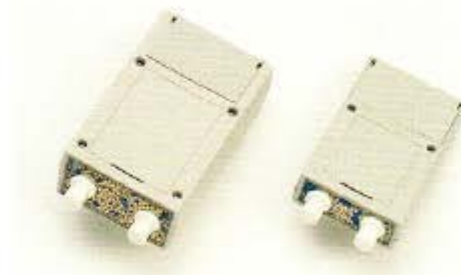
- Equilibrate humidity levels in gas streams with surrounding environment
- Various connectors, tubing lengths, and diameters available
- Special units available to handle high-pressure gas streams
- Applications range from patient breath drying for anesthesia monitoring to calibration gas humidification in industrial settings



For more information, request brochure #101

DM™- SERIES DESICCANT MEMBRANE DRYERS

- Compact, portable dryers for flow rates up to 1 LPM
- No purge gas required
- Replaceable desiccant with color change indicator surrounds Nafion tubing
- For use with portable analyzers or in temporary drying applications



For more information, request brochure #102

MH™ AND PH™- SERIES HUMIDIFIERS

- Single- and multiple-tube units available to humidify gas flows from milliliters to hundreds of liters per minute
- Use either liquid water or saturated gas stream to humidify
- Humidify up to 100% RH
- Applications include analytical humidification, particle measurement, fuel cells, and constant-humidity chambers



For more information, request brochure #106

In addition to the dryers and humidifiers in this brochure, Perma Pure designs and builds many other products for the gas conditioning markets including:

- Complete gas sample conditioning systems
- Coalescing and particulate filters
- Heatless desiccant dryers
- Ammonia scrubbers
- Zero air generators
- Eductors

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Brochure #100