



***Integrating Perma Pure's  
Gas Sample Drying System  
Into your Equipment***

***Application Handbook***

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## Introduction – Integrating Perma Pure’s Gas Sample Dryer into Your Analyzer

This application handbook was developed to make it easier for our customers to get optimal performance of their Sample Gas Dryer in their analyzer system. Since most of you reading this guide do not normally get involved with pneumatic systems, we felt it important to make this simple to understand. After a lot of testing - plus learning tips and tricks from our customers who have successfully deployed our products - we have created a reference manual that will help get you started.

Perma Pure dryers operate by transferring moisture from the sample gas stream to a counter-flowing purge gas stream, much like a shell-and-tube heat exchanger transfers heat. Water molecules travel through the Nafion® tube wall in its chemical structure, evaporating into the purge gas stream. The differential in water vapor pressure between the two gas streams drives the reaction, quickly removing the humidity from (and thus drying) the sample gas. There are two important questions design engineers and users of these products face when deploying these products:

- 1) How do I connect or generate the purge gas with a moisture level low enough to dry the sample effectively, and
- 2) How do I measure the effectiveness of my set-up and optimize its performance?

### Definitions - Getting to Know Your Test Set-Up

We’ll begin with a basic list of the elements shown in our flow diagrams and explain the way they are used in them.

1. **Sample Gas Dryer** – The dryer is shown at the center of the diagram, and can represent any MD, PD or MD-700 dryer we make, as they all share the same operating principle.
2. **Sample Gas Flow** – In the diagram, the sample gas flows from left to right through the center of the dryer from the Wet Sample/Feed Inlet to the Dry Gas Sample Outlet.
3. **Purge Gas Flow** – The purge gas flows opposite to the sample gas, from right to left, through the purge gas inlet to the purge gas exhaust and over the dryer tube(s) located within the shell of the dryer.
4. **DP (Moisture Sensors)** – Labeled “DP” for Dew Point, two sensors are placed in the sample gas flow, one before the dryer entrance and one after the dryer exit. These are required to measure the drying performance of the system.

5. **Vacuum Pump** – A Vacuum pump is installed at the exit of the purge gas flow to pull a vacuum over the dryer tubes and drive the differential in water vapor pressure.
6. **Vacuum Gage** – A gage is placed between the purge outlet and vacuum pump to measure the vacuum placed over the Nafion tubes.
7. **Needle Valve** as Flow Restrictor – A Needle valve is used as a variable flow restrictor at the purge gas entrance in order to adjust the purge flow and thereby the vacuum pulled by the pump. Without a flow restriction forcing the pump to pull a greater vacuum the dryer performance will not improve. In production products, this restrictor can be replaced with a capillary of a known size for a fixed, repeatable result.
8. **Flow Meters** – Flow meters are placed before the entrance of the dryer to measure sample gas flow and before the entrance of the purge gas - but after the needle valve - to measure purge gas flow.

### **Two Basic Choices**

Perma Pure dryers require a purge gas with a partial water vapor pressure that is significantly lower than the sample gas being analyzed. This can be provided by either supplying the dryer with air that already has the moisture removed from it or developing a vacuum-pump based sub –system that generates the dry purge gas on the fly.

#### **Choice #1 - External Supply of Dry Air**

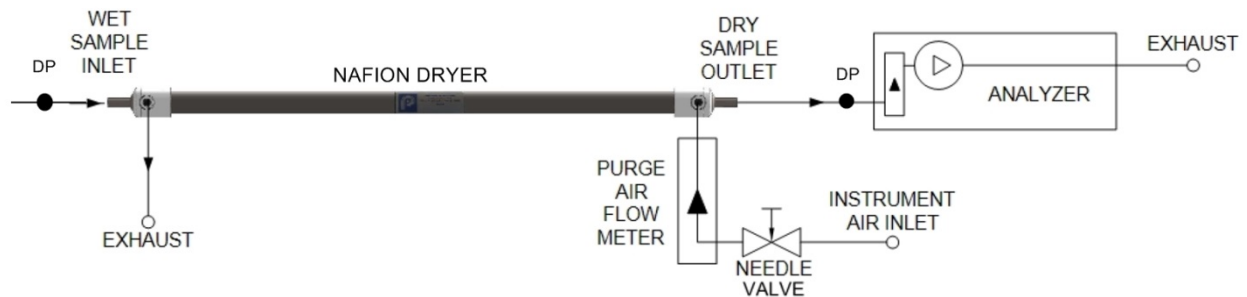
Many customers use our dryers with external sources of dried air. There are a number of options

- A) **Instrument Quality Compressed Air** – Dried compressed or “Instrument” Air is typically found at most industrial plants and in many labs and serves as an excellent purge gas. The dew point of this purge gas is typically around -40° C. Although the air might already be free of lubricating oil and dirt, the air must be filtered to eliminate dirt and hydrocarbons being sucked in to the dryer purge inlet and deposited on the outside of the Nafion tubes. Over time this contamination will reduce the performance of the dryer by blocking its water transfer pathways. Most of our performance curves have been made from test data using instrument air as the purge gas.

- B) **Standard Quality Compressed Air** – Standard quality compressed air - which is not dried and may carry an oil mist - is often available but caution must be advised as dirt and oil in the air will collect on the dryer tubes and can cause it to lose performance over time.
- C) **Local Air Compressor** – An air compressor with an ultra-low dew point rating may be deployed locally in an analyzer station to provide clean and dry purge gas.
- D) **Nitrogen or other Cylinder gas** – Using ultra-dry cylinder gas with a typical dew point of  $-60^{\circ}$  or  $-70^{\circ}\text{C}$  can yield even lower results than shown on our performance curves. Often used for lab applications, this method might not be cost effective for continuous or high flow applications.

Note: We recommend starting your performance tests with a purge gas flow at 2x of the sample gas flow. Adjust the purge gas flow based on target performance required – you might find you can still get good performance with a flow as low as 0.5x in your application. Because using options C and D are much more expensive, reducing the flow can lower costs while still providing effective performance.

*Caution: Make sure the purge gas pressure never exceeds the sample gas pressure. Otherwise, the tubing may collapse and restrict the sample gas flow.*



**Figure 1 – Dryer Set-Up with Instrument Air**

## **Choice # 2 - Purge Gas under Vacuum with Recycled Sample Gas or Atmospheric Air**

Most of our OEMs use our dryers with the purge under a vacuum to drive the differential in water vapor pressure across the membrane, for two main reasons. First, no external source of dry, clean air is required. Second, when set up with the right vacuum pump, it is a very cost effective and reliable solution. Here it must be emphasized that every combination of flow rate, dryer and vacuum pump will have its own unique performance characteristics. You will need to set up a test system with the components shown below to properly “dial-in” the optimal performance. There are three ways you can set up Perma Pure Dryers to work under vacuum:

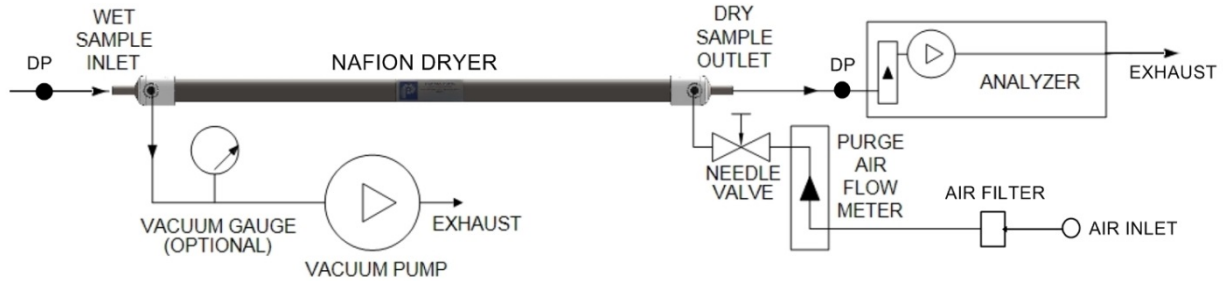
### **A) The Atmospheric Vacuum Method**

With the Atmospheric Vacuum Method, a vacuum is pulled through the purge gas path by installing the vacuum pump ahead of the purge gas outlet and a flow restriction (a needle valve or capillary tube) before the purge gas inlet. For maximum performance, the highest possible vacuum level should be achieved. This is done by continually restricting the flow of the purge gas by closing the needle valve while watching the moisture level at the DP Sensor located at the sample gas outlet. The “sweet spot” or optimal performance occurs when the vacuum is at its highest point (lowest pressure) and the flow rate is still high enough to sweep the water vapor away. See Figure 3 for a diagram of vacuum level and flow rate and its effect on drying performance.

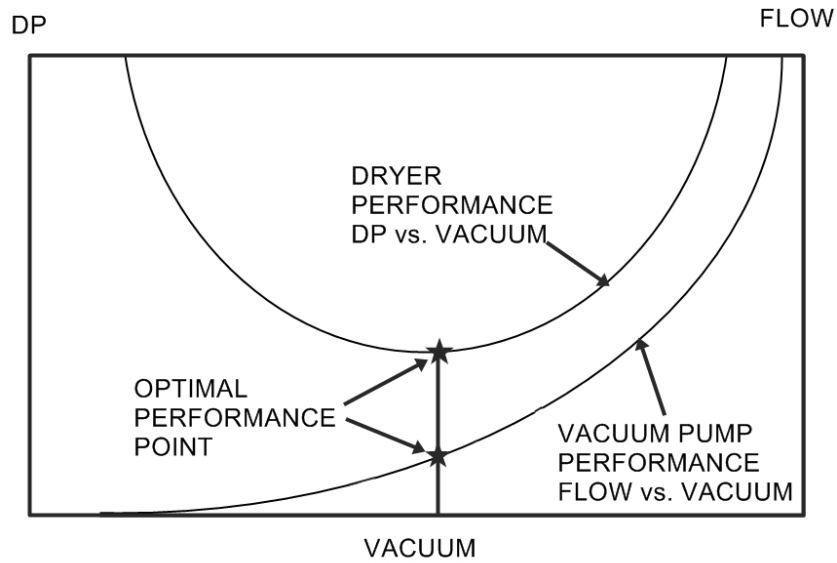
*Advantages:* No external air source is needed

*Disadvantages:* The drying performance will be dependent upon the moisture level of the atmospheric air. The effect of the ambient moisture level is less, however, as the vacuum level increases.

*Notes:* The air must be filtered to eliminate dirt and hydrocarbons in the ambient air from being sucked in to the dryer purge inlet and deposited on the outside of the Nafion tubes. Over time this contamination will reduce the performance of the dryer by blocking its water transfer pathways.



**Figure 2 – Dryer Set-Up with the Atmospheric Vacuum Method**



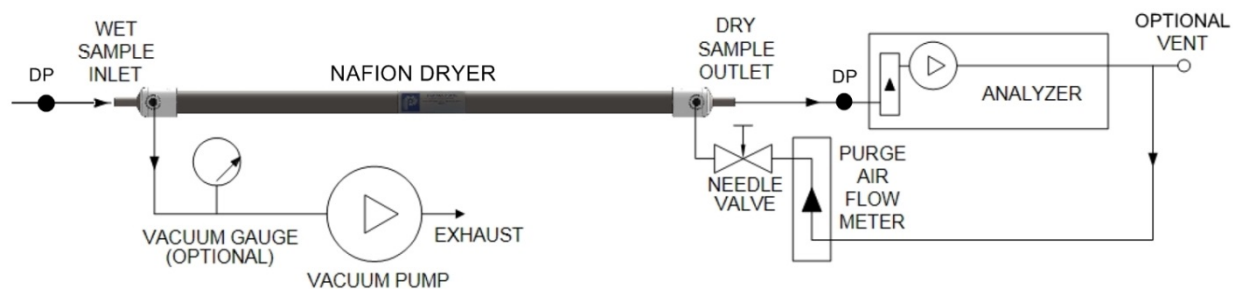
**Figure 3: Optimum Performance Point for Dryers Working Under Vacuum**

## B) The Recycled Sample Gas (Reflux) Method

The Recycled Sample Gas (Reflux) Method is similar to the Atmospheric Vacuum Method, except that the full amount of the sample gas is routed back to the dryer as the purge gas after it leaves the analyzer. The purge gas path (shell side of the dryer) is kept under vacuum by installing the vacuum pump at the purge gas outlet and a flow restriction (a needle valve or capillary tube) before the purge gas inlet. For maximum performance, the highest possible vacuum level should be achieved. This is done by continually restricting the flow of the purge gas by closing the needle valve while watching the moisture level at the DP Sensor located at the sample gas outlet. The “sweet spot” or optimal performance occurs when the vacuum is at its highest point and the flow rate is still high enough to sweep the water vapor away. See Figure 3 for a diagram of vacuum level and flow rate and its effect on drying performance.

*Advantages:* No external air source is needed – the continuous reflux operation provides a stable and consistent drying performance

*Notes:* Make sure the sample gas is clean enough to be used as the purge gas. If corrosive, the materials used for the gas flow must be chemically compatible with the sample gas.



**Figure 4: Dryer Set-Up with Recycled Sample Gas (Reflux) Method**

### **C) The Split Sample (Reflux) Method**

The split sample method is similar to the Reflux Method previously described except that it channels a portion of the sample gas through the Nafion tubing serving as the purge gas *before* the analyzer. Choose the split sample method if it is not possible or practical to route the analyzer exhaust back to the gas dryer. A similar set up with the vacuum pump and flow restriction as already described will need to be created. The dryer must be up-sized for the increased flow rate adding the portion used for the purge gas to the sample gas flow rate required for the analyzer. Additionally, the right purge gas amount will need to be selected to provide optimum drying performance. This can be between 30% and 100% of the analyzer sample flow, depending on the level of vacuum being applied. To find that best performance point, start with 100% of the sample gas flow required by the analyzer and increase the level of vacuum according to the method described in the Recycled Sample Gas (Reflux) Method to find the optimal performance point for that purge gas flow rate. Reduce the purge gas flow in 10% increments and repeat the process until the best performance point is found. The performance of your drying system is increased by reducing the split sample percentage because the overall flow through the dryer is decreased. We have seen optimal purge gas percentages as low as 30% in our testing, depending on the dryer and flow rate. Your results will vary.

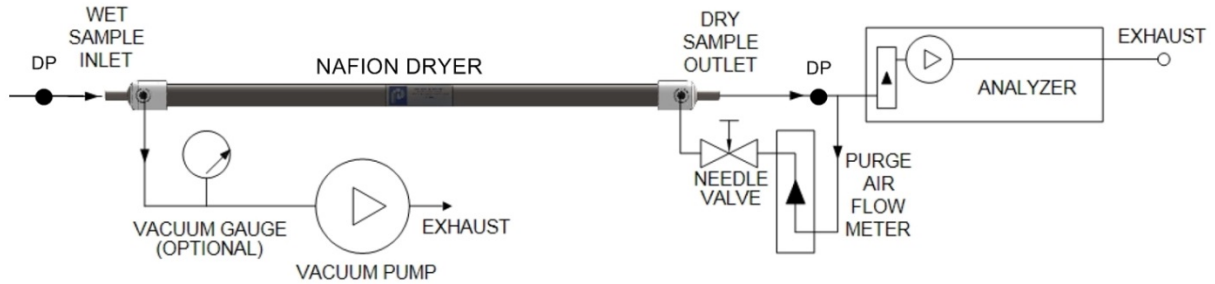
As an illustration, let's say that we find that 30% of the sample gas flow is sufficient for use as the purge gas. An analyzer requiring a 10 LPM sample stream would be split into 10 LPM to the analyzer and 3 LPM to the purge flow for a total of 13 LPM.

*Advantages:* No external air source is needed – the continuous reflux operation provides a stable and consistent drying performance

*Disadvantages:* The dryer must be up-sized to accommodate in increased flow rate of the sample and purge gas. Some experimentation is required to find the optimum performance point.

*Notes:* Make sure the sample gas is clean enough to be used as the purge gas. If corrosive, the materials used for the gas flow must be chemically compatible with the sample gas.





**Figure 5: Dryer Set-Up with Split Sample Gas Method**

**Combination Dryer Methods** – In order to get to target dryness levels lower than what the Nafion-based products allow, a combination of dryers is often used. The Nafion-based dryer can be used as the first stage, removing up to 95% of the moisture in the gas stream. This set-up effectively extends the service life of the secondary stage (desiccant or cryo trap), greatly reducing costs and extending equipment service intervals.