Advanced Technology Center

Research & Development in Gases, Equipment and Purification

MATHESON TRI•GAS

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Integrated Solutions for Total Contamination Control

Matheson Tri-Gas, Inc., (Matheson Tri-Gas) has one of the most extensive, in-house evaluation laboratories in the industry to assess the quality of gas system components. The benefit is that components designed and selected for use in Matheson equipment, such as NANOCHEM® purifiers, are of the highest quality available. "Live gas" testing ensures purifiers and other eqipment meet or exceed performance specifications in the *specific* process gas for which they are marketed.

The Matheson Tri-Gas Advanced Technology Center (**ATC**), located in Longmont, Colorado, USA, is dedicated to advanced research and development in pure gases, gas handling, microcontamination and purification technologies. Equipped with modern analytical instrumention and staffed by doctoral-level scientists and other highly-skilled researchers, ATC offers extensive analytical testing and support facilities. ATC ensures products undergo comprehensive testing before release and provides technical support to customers.

Matheson Tri-Gas offers complete and comprehensive solutions for the total control of impurities within your process.

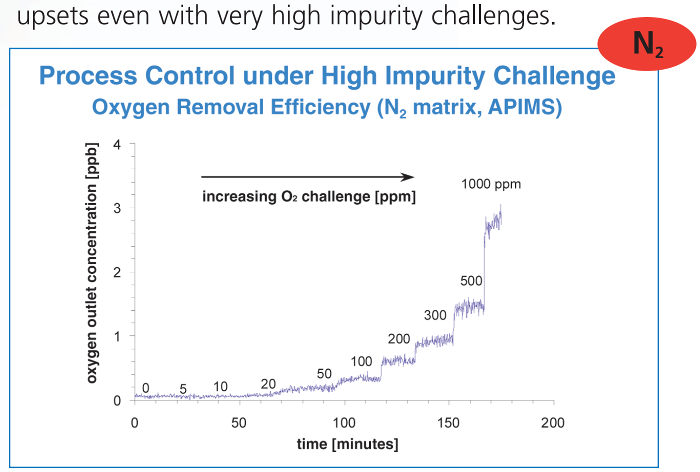
Matheson Tri-Gas offers complete and comprehensive solutions for the total control of impurities within your process. We draw upon expertise in many disciplines to design the best solution for each application:

1. Purifier Design

Optimum design of a purifier requires development of specialized purification media to remove all impurities present in a specific process gas. Matheson Tri-Gas offers 15 different purification media with the ability to purify 33 different gases.

Proper purifier design also requires knowledge of the mass transfer zone (reaction zone within the purifier bed where impurities are removed to the purifier specifications, typically detection limits). The size of the mass transfer zone (MTZ) depends upon the concentration of the impurity, nature of the purification media, reaction chemistry with impurities, operating flow rates, and the purifier size. Inefficient design can easily result in leakage of impurities.

Some competitors ignore the limitations set by the MTZ. Consequently, purifiers from the competition may offer adequate performance only with very low impurity challenges, typically 1-10 ppm. Such purifiers may not provide protection against system upsets, such as a high impurity challenge. NANOCHEM® purifiers offer unmatched performance against such system upsets even with very high impurity challenges.

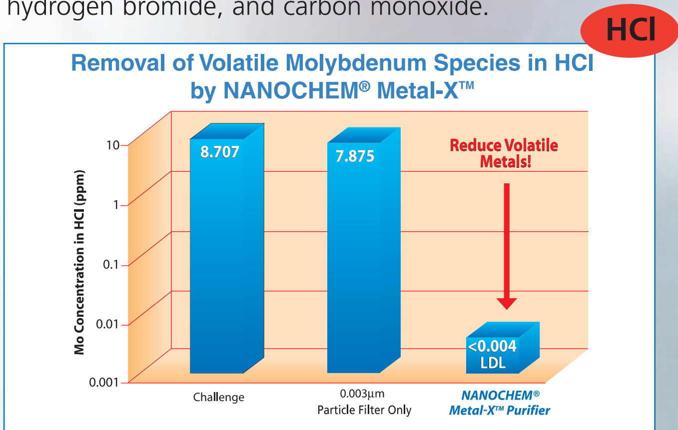


NANOCHEM® OMX™ and OMX-Plus™ purification media offer impressive efficiencies for the removal of impurities even at very high impurity challenges. Shown above is data for the removal of oxygen with a L-60 Purifier at 2 slpm N_2. Even with a 200 ppm oxygen challenge, the residual O_2 concentration in the purified gas is < 1 ppb.
Watanabe et al., J of Crystal Growth, 248, pg 67-71, 2003

2. "Live" Gas Testing

The performance of a purifier with a process gas may be very different from its behavior with an inert gas, such as argon. Many competitors do not have the facilities or analytical capabilities to test a purifier in the actual environment it will experience in the field.

The Advanced Technology Center is fully equipped to handle specialty gases used in the semiconductor industry such as hydrides, corrosives and reactive gases. Matheson Tri-Gas purifiers and equipment have been tested with the actual process gas, including ammonia, arsine, phosphine, germane, silane, hydrogen chloride, hydrogen bromide, and carbon monoxide.



NANOCHEM® Metal-X™ Purification Medium Removes Killer Volatile Metals in Corrosive Gases. *Removal of volatile Molybdenum Chlorides in HCl is illustrated above. Similar performance is noted with volatile titanium chlorides. Removal of iron chlorides is also confirmed.*

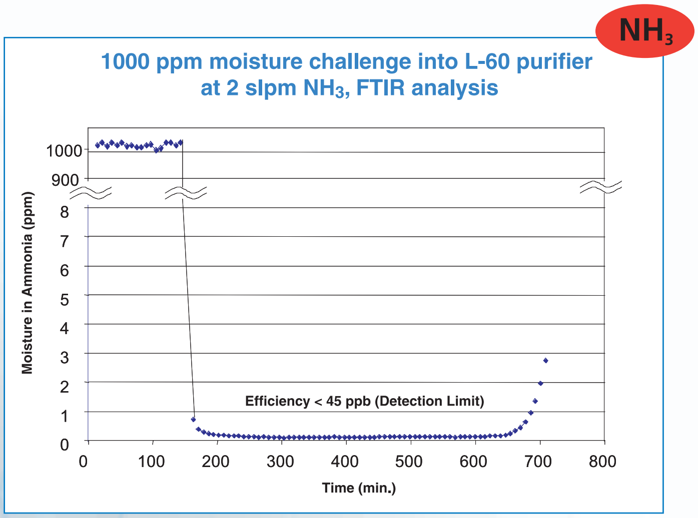
Wyse C., et al, Clean Rooms ESD/GAS, pg 7-9, June 2001

Kel-F valve seats in HBr Service, *without* NANOCHEM® purifier, 1000 cycles.

Kel-F valve seats in HBr Service, *with* NANOCHEM® purifier, 1000 cycles.

NANOCHEM® Metal-X™ Purification Medium Prevents Component Corrosion. *Photographs of Kel-F valve seats of valves in HBr service for 3 years are shown above. Deposits of corrosion products are clearly visible on the valve seats without HBr purification (above left)) causing particle emission, volatile metal emission, and leakage across the seat. Valve seats are free of corrosion products even after 1000 open/close cycles in HBr service, with HBr purified with NANOCHEM® Metal-X™ purification medium (above right).*

Torres R., et al, Fabtech, 12th edition, pg 139-146, 2000



NANOCHEM® NHX-Plus™ purification medium offers the highest lifetime and the best efficiency for the removal of moisture in ammonia.

Torres R., et al, Presented at CS-MAX, Boston, 2001

3. Analytical Capabilities

State-of-the-art analytical instrumentation at the Advanced Technology Center enables scientists to characterize purifier materials, identify the key impurity in gases, and confirm impurity removal. Such analysis also enables an understanding of how a specific impurity may affect the customer's process.

For example, Matheson Tri-Gas scientists found that **carbon dioxide, one of the key impurities in ammonia, may be present in the free form and/or as a reaction product with ammonia (*ammonium carbamate* $NH_4CO_2NH_2$).** Compared to other ammonia purifiers, NANOCHEM® NHX-Plus™ offers the best efficiency for the removal of ammonium carbamate.

Analytical instrumentation at ATC includes atmospheric pressure ionization mass spectrometry (APIMS). X-ray fluorescence (XRF), X-ray diffraction (XRD), Fourier Transform infrared spectrometry (FTIR), specialized gas chromatography (GC), atomic emission spectrometry with graphic furnace (GF/AES), thermal analysis (TA), porosimetry, and high resolution inductively coupled plasma with mass spectrometry (ICP/MS).

Purifier Material	Free CO_2 in NH_3 ppb	Chemically Bound CO_2 in NH_3 ppb
A	< 50	172
B	< 50	50
C	< 50	57
NHX-Plus™	< 50	< 30

Efficiency of different purification media for the removal of Free CO_2 and Chemically Bound CO_2 in Ammonia.

4. Expertise in Materials Science

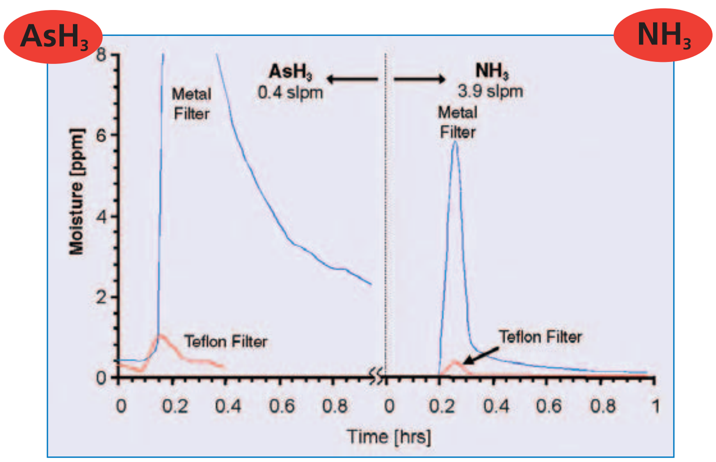
Selection of the right materials of construction can be critical in some applications. For example, "conventional" wisdom suggests that all-metal particulate filters should offer better performance than polymeric filters, since metal filters can be baked at elevated temperatures. However, this belief is really applicable to inert gases, such as argon or nitrogen.

Results can be very different with reactive gases. The figure below shows the large amount of moisture initially emitted, when a new particle filter is exposed to arsine and ammonia. Such a moisture surge can contaminate the process and require long dry-down times.

Hydrophobic materials, such as Teflon, that have been properly dried, retain significantly less moisture than stainless steel. Moisture tends to adsorb very strongly on stainless steel. Even extended heating at elevated temperatures with an inert gas is not sufficient to release all physisorbed moisture. Polar gases, such as ammonia, interact more strongly with stainless steel and can displace the adsorbed moisture. Additionally, some reactive gases, such as arsine and hydrogen chloride, can chemically react with surface metal oxides, resulting in moisture formation.

$$Fe_2O_3 + 6HCl \rightarrow 3H_2O + 2FeCl_3$$

Matheson Tri-Gas evaluates the performance of different components in reactive gases before installation to select appropriate materials in purifiers and equipment.



Moisture outgassing from Teflon and Metal particulate filters in arsine and ammonia service (Testing by FTIR)

Watanabe et al., J of Crystal Growth, 248, pg 67-71, 2003

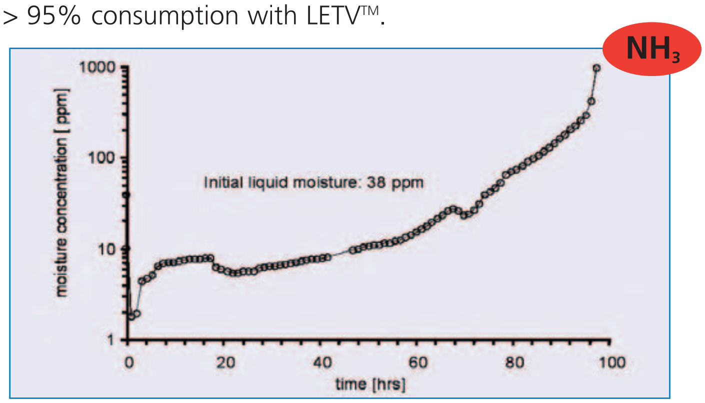
5. Gas Handling & Delivery

Matheson Tri-Gas provides guidance on the proper handling and delivery of reactive gases, enabling customers to get optimum performance with Matheson Tri-Gas equipment, such as gas cabinets and purifiers.

Matheson Tri-Gas scientists pioneered studies on the proper use of liquefied gases to avoid deleterious effects of Joule Thomson (J-T) Expansion and Cooling. Improper operation can result in condensation and metal emissions in service with ammonia and corrosive gases, such as hydrogen chloride, hydrogen bromide and dichlorosilane.

With liquefied gases, moisture partitions between the liquid and gas phase inside the cylinder. Moisture initially concentrates in the liquid phase due to its high solubility and low vapor pressure. As the gas is withdrawn, the level of moisture in the gas phase increases significantly with cylinder usage. This effect results in process instability unless appropriate safeguards (gas purification and the use of specialized delivery equipment) are taken.

New delivery systems, such as Liquid Extraction Total Vaporization (LETV™) offer the ability of *consistent* gas quality throughout cylinder consumption. Cylinder usage can be increased from a typical 60 - 70% consumption to > 95% consumption with LETV™.



Gas-phase moisture concentration during lifetime of NH_3 Cylinder. *Cylinder initially contained ~ 38 ppm H_2O in liquid phase. H_2O in gas phase is ≤ 10 ppm up to ~ 55-60% cylinder consumption, after which H_2O concentration increases rapidly. Similar results are noted with HCl. (Testing by FTIR).* *Funke H. et al., J of Electronic Materials, 30, pg 1438-1447, 2001*

6. Technical Support

Matheson Tri-Gas offers unmatched technical support, worldwide, by phone, e-mail and field support personnel. Technical specialists are available to discuss your application and suggest the best complete solution.

Matheson Tri-Gas offers complete contamination control solutions, drawing upon expertise in hardware design & testing, as well as gas handling, delivery, analysis, purification and abatement.

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