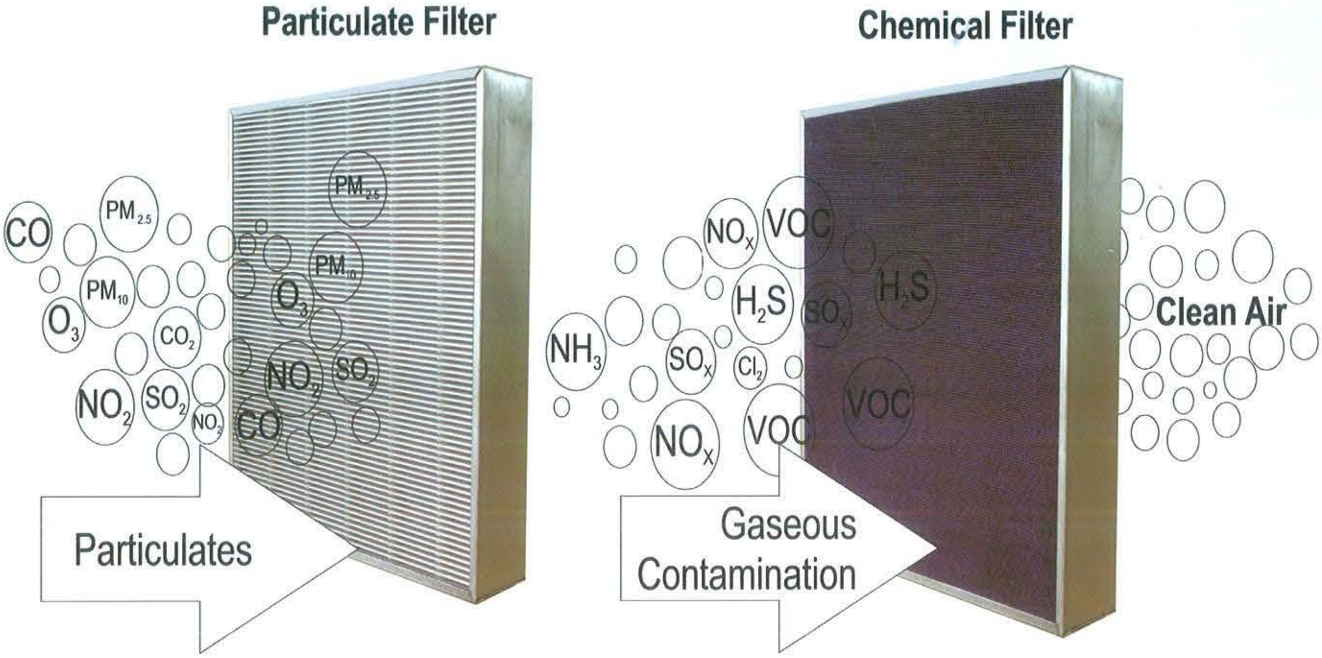

Molecular filtration

Air Filtration at Molecular Level

By Dinesh Gupta Executive Director, Bry-Air (Asia) Pvt. Ltd., Gurugram
and **Manish Kumar Jain** National Sales Manager – GPF Division Bry-Air (Asia) Pvt. Ltd., Gurugram

Abstract

Air filtration, as commonly understood and depicted in air conditioner advertisements and the print media, is about the poor quality of air around us, which mainly pertains to filtration of particulate contaminants. This article, however, will discuss various aspects of air filtration at the molecular level, i.e. filtration and removal of gaseous contaminants. Air filtration at the molecular level is often referred to as gas phase filtration.

Today, when technologies and equipment, especially in mission critical facilities, require a clean environment to function at their optimum, an understanding of molecular phase filtration is essential.

This article will also discuss the concept, need, technology trends and equipment for molecular phase filtration.

Introduction – the Basics

Molecular Phase Filtration is the filtration of gaseous contamination of the molecular scale size.

Particulate Air Filtration is the filtration process that removes solid particulates from the air.

ASHRAE Standard 52.2 classifies particulate filtration as:

- Pre-filtration (G class) from MERV 1 to MERV 8,

About the Authors

Dinesh Gupta is Executive Director at Bry-Air (Asia), a flagship company of Pahwa Group, with almost four decades of experience in dehumidification and indoor environmental control. He has specialized in application and engineering of environmental control equipment like dehumidifiers, energy recovery system and airgineering systems. His papers on humidity control, gas phase filtration, energy recovery systems and IAQ have been published in various technical journals. Currently, he is Chair – Student Activities and Sustainability at ASHRAE India Chapter, and its Past President.

Manish Jain graduated in 1994 as an Electronics Engineer and has experience of more than two decades in automation and controls and gas phase filtration. He is heading the Gas Phase Filtration department in Bry-Air Asia Pvt. Ltd., Gurugram.

- Medium filtration (F class) from MERV 9 to MERV 16.

The above classification caters more to domestic, commercial and industrial needs. However, for clean rooms and super clean rooms, we need to install

- High Efficiency Particulate Air filters (HEPA) (H class), and
- Ultra Low Particulate Air filters (ULPA) (U class).

While HEPA filters can control contamination up to 0.3 micron (μm), ULPA filters can even control up to 0.12 μm.

The various filters described above do take care of unwanted particulate contamination in the air. However, it is a very big challenge to control contamination of matter smaller than a particulate size of 0.12 μm and physically arrest them.

In-depth knowledge of adsorption by desiccants would help us to control contamination in such critical applications. Adsorption by various desiccants of matter (gases) having molecular diameter of a fraction of 0.1 μm in their micro/meso pores (diameter between 0.2 to 1.0 nano meter (nm)) is the starting point of filtration of gaseous contaminants.

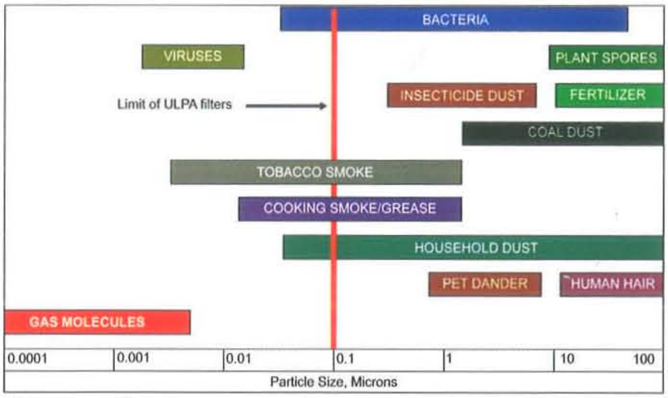

Figure 1: Airborne contamination: particulates vs. gaseous

Table 1: Unwanted gases and their sources

Sr. No.	Unwanted gas	Molecular diameter	Molecular weight	Nature of gas		Sources of gas in urban areas	Sources of gas in industrial areas
	Symbol (Constituents)	Angstrom (Å)	(g/mol)	Odorous	Corrosive		
1	H_2S (Hydrogen Sulfide)	2.6	34.08	Yes	Yes	• Combustion of fossil fuels • Drains • Land filled sites • Auto emissions • Microbiological activities, etc.	• Wood pulping • Sewage treatment • Sulfuric acid manufacturing • Fossil fuels processing • Electric power plants burning coal as fuel containing sulfur • Oil and gas extraction operations, oil refineries, etc.
2	SO_2 (Sulfur Dioxide)	2.8	64.07	Yes	Yes	• Combustion of fossil fuels • Drains • Auto emissions • Tobacco smoke, etc.	• Sulfuric acid manufacturing
3	SO_3 (Sulfur Trioxide)	2.8	80.07	Yes	Yes		
4	HF (Hydrogen Fluoride)	1.8	20.01	No	Yes	• Combustion of fossil fuels • Drains, etc.	• Fertilizer manufacturing • Aluminum manufacturing • Ceramic manufacturing • Steel manufacturing • Electronic device manufacturing
5	NO_2 (Nitrogen Dioxide)	2.3	46.01	Yes	Yes	• Combustion of fossil fuels • Auto emissions • Microbes, etc.	• All process industries
6	NH_3 (Ammonia)	2.6	17.03	Yes	Yes	• Microbes • Public toilets /drains • Refrigeration equipment • Cleaning products, etc.	• Fertilizer plants
7	Cl_2 (Chlorine)	3.2	70.9	Yes	Yes	• Refuse decomposition • Cleaning products, etc.	• Chlorine manufacturing • Aluminum manufacturing • Paper mills • Steel industries, etc.
8	O_3 (Ozone)	2.6	48	No	Yes	• Atmospheric photochemical processes mainly involve nitrogen oxides • Auto emission • Electrostatic filters photo copiers and printers, etc.	
9	HCl (Hydrogen Chloride)	3.2	36.47	Yes	Yes	• Auto emission • Fossils fuels combustion • Polymer combustion	• Oceanic processes
10	CnHn/VOC (Hydrocarbons/ Volatile Organic Compounds)	4-4.9		Yes	Yes	• Auto emission • Tobacco smoke • Microbes • Paints, etc.	All petrochemical and fertilizer industries Paper mills, etc.

Need for Molecular Filtration

Many of the unwanted gases that contaminate and can cause serious damage resulting in huge losses are:

i. Odorous,
ii. or corrosive,
iii. or both.

These gaseous contaminants are potentially very harmful to humans as well as to equipment, especially in an environment of controlled areas housing sensitive equipment like servers in data centers.

A. Some of the environmentally conditioned areas where odorous gases cause loss of productivity are:
   (a) Animal research facilities
   (b) Autopsy rooms in mortuaries and hospitals
   (c) Call centers near a landfill area, like Mindspace in Malad, Mumbai or near an open sewage line, like in Noida.
B. Some of the environmentally conditioned areas where corrosive gases are a cause of down time of process industries are:
   (a) Petrochemical industries
   (b) Fertilizer industries
   (c) Paper and pulp industries
   (d) Medium size server rooms
   (e) Mission critical facilities, e.g. large size data centers

As shown in *Table 1*, gases typically have molecular diameter in the range of 0.0002 to 0.001 μm. The unit used for measurement is Angstrom (Å) (1 micron = 10,000 Angstrom).

This article will give more insight into the adverse effects of corrosive gases and potential filtration options currently available in the market.

Removing Corrosive Gases

As shown in *Figure 3*, the process of filtration through adsorption and neutralization through chemical reaction is commonly known as Chemisorption. The air filtration systems remove corrosive gases through the process of adsorption and neutralization.

Adsorption with Chemical Neutralization/Oxidation

- The process is specific and depends on the chemical nature of both the media and gas
- The process is instantaneous and irreversible
- Converts harmful gases to harmless solids

Major Elements to Remove Corrosive Gases

(i) Granular Media Filter

It is a combination of desiccants impregnated with chemicals like:

- Activated alumina impregnated with $KMnO_4$
- Activated carbon and activated alumina impregnated with KOH
- Activated carbon alone
- Activated carbon impregnated with H_3PO_4

(ii) Honeycomb Chemical Filters

These are desiccant honeycomb matrix filters impregnated with a choice of oxidizing agents and/or alkaline/acidic solutions like:

- Desiccant honeycomb matrix based chemical filters impregnated with $KMnO_4$
- Desiccant honeycomb matrix based chemical filters having both metal silicate and activated carbon impregnated with KOH
- Desiccant honeycomb matrix based chemical filters impregnated with H_3PO_4

Figure 4 traces how the various types of filters from carbon media to honeycomb chemical filters have evolved.

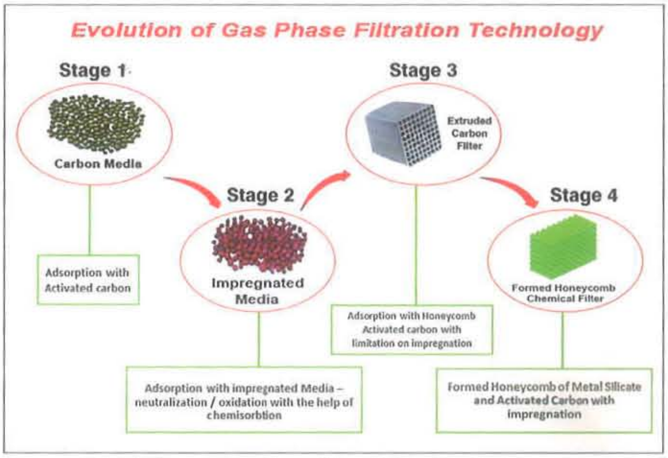

Figure 4: Evolution of gas phase filtration technologies

Classifying Reactive Environments

International Society of Automation (ISA) had defined severity levels on account of unwanted gases in instrumentation and control rooms way back in 1985. Keeping in view the implementation of Restriction of use of Hazardous Substances (ROHS) under the directive from the European Union as per 2002/95/EC replacing lead (being carcinogenic) with silver, and electronic circuits getting further miniaturized, led to ISA revising the 1985 Standard in 2013, which is as per *Table 2*.

continued on page 70

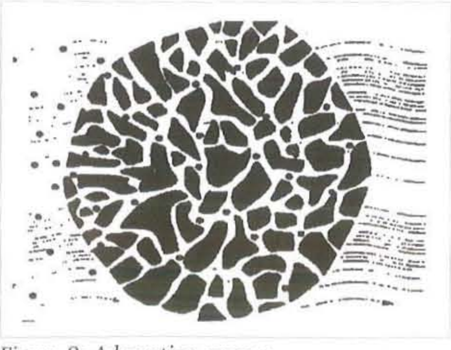

Figure 2: Adsorption process

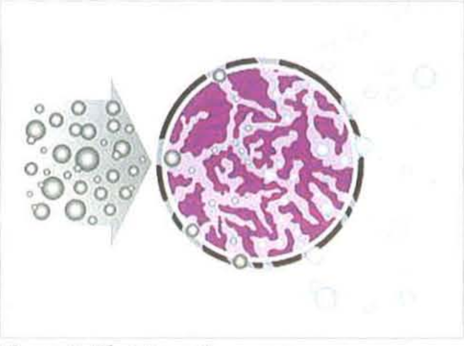

Figure 3: Chemisorption process

continued from page 68

Table 2: Classification of reactive environments

Class	Severity Level	Angstroms (Å) per 30 days		Comments
		Copper Corrosion	Silver Corrosion	
G1	Mild	< 300 Å	< 200 Å	Corrosion is not a factor in electronic equipment reliability
G2	Moderate	300 Å – 999 Å		Effect of corrosion is measurable and may be a factor in electronic equipment reliability
G3	Harsh	1,000 Å – 1,999 Å		High probability that corrosive attacks will occur; should prompt further evaluation and result in environmental controls
GX	Severe	> 2000 Å		Only specially designed and packaged equipment is expected to survive

The ISA standard also defines in terms of gaseous concentration levels as per *Table 3.*

Table 3: Contaminant concentrations versus severity levels

Concentration of Gases (in ppb) as per ISA 71.04: 2013				
Contaminants	G-1 (Mild)	G2 (Moderate)	G3 (Harsh)	GX (Severe)
H_2S	< 3	< 10	< 50	> 50
SO_2	< 10	< 100	< 300	> 300
Cl_2	< 1	< 2	< 10	> 10
NO_X	< 50	< 125	< 1250	> 1250
HF	< 1	< 2	< 10	> 10
NH_3	< 500	< 10000	< 25000	> 25000
O_3	< 2	< 25	< 100	> 100

Measuring Severity Levels in Corrosive Environments

Typically, there are two types of measurement methods:

1. ***Corrosion Classification Coupons (CCC)***

   Corrosion classification coupons have two pure metal strips of silver and copper.

   These coupons are placed in the room, where environment severity has to be measured, for a period of 30 days.

   The thickness of the layer of corrosion that forms on metal strips determines the severity level as per ISA 71.04: 2013 Standard.

2. ***Real Time Atmospheric Corrosion Monitors***

   These instruments help to access severity levels on real time basis. The real time measurements in typically 24 hours are extrapolated for 30 days to know the severity levels as per the ISA standard.

   In addition to severity levels due to airborne gaseous contaminants, these instruments also measure room temperature, RH and optionally the differential pressures, to give the complete corrosion parameters.

   Real time atmospheric corrosion monitors can be further classified in two technologies:

   - One is based on Quartz Crystal Microbalance (QCM), which measures the rate of increase of corroded metal sensors mass.
   - The other determines the rate of electrical resistance increase of corroded metal strips.

What are the types of equipment available for removing corrosive gases?

Equipment for removal of unwanted corrosive gases are broadly classified as under:

- ***Thin Bed***

  For recirculation of air to clean within an enclosed space.
- ***Deep Bed***

  These are generally designed to clean fresh air inducted into the controlled space for pressurization.

The above two concept categories can involve both types of chemical filters:

- Granular type
- Honeycomb type

Figure 5: Deep bed and thin bed

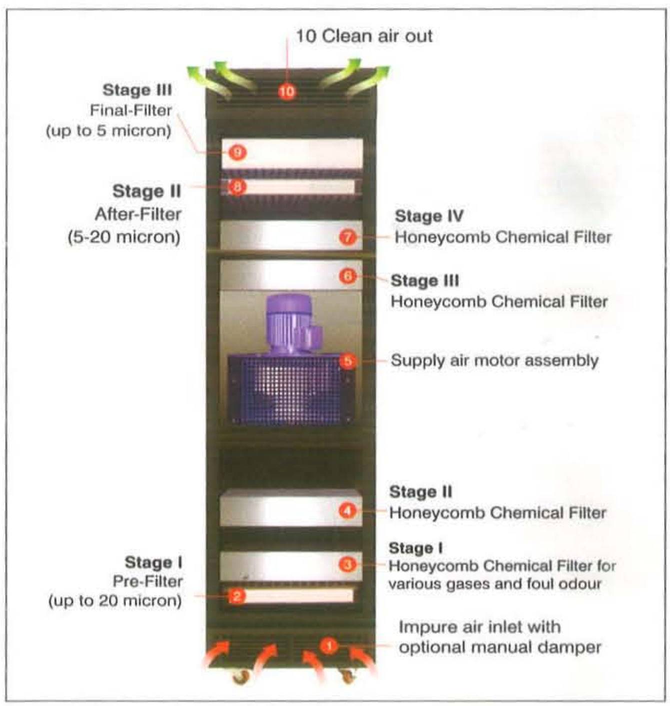

Figure 6: Internal view of the system

continued on page 72

continued from page 70

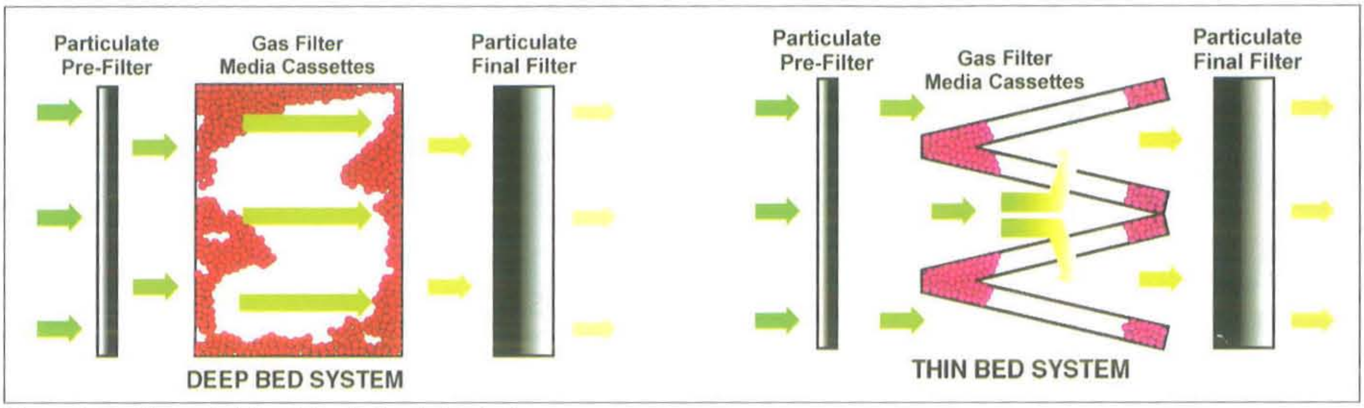

Figure 7: Working principle of deep bed and thin bed

Installing the Equipment

Gas phase filtration systems are typically installed in three ways:

1. Re-circulation option (as shown in *Figure 8*),
2. Pressurization option (as shown in *Figure 9*), and
3. Re-circulation + pressurization option (as shown in *Figure 10*).

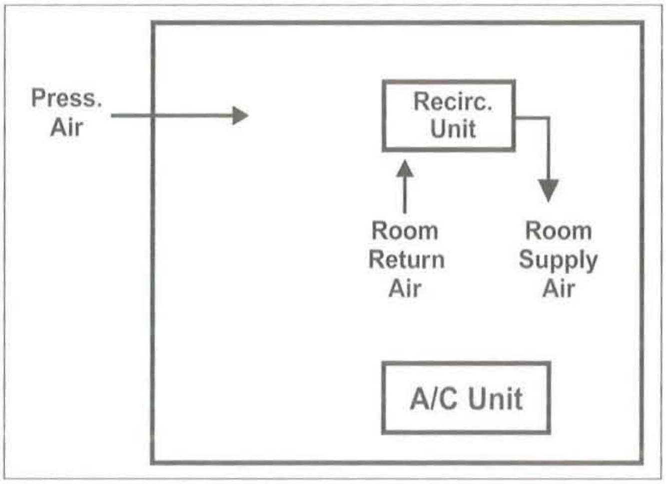

Figure 8: Re-circulation option system used for server/data center application

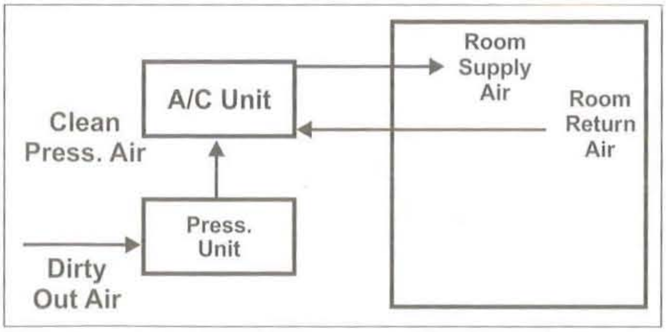

Figure 9: Pressurization option system used for cleaning fresh air

Precautions for Ensuring Proper Filtration

1. Room should be reasonably airtight
2. Pressurize the room and try to maintain minimum positive pressure of 2.5 mm

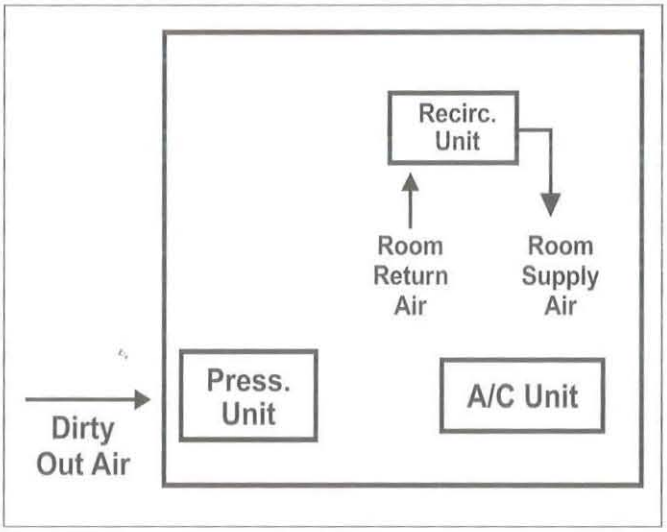

Figure 10: Re-circulation + pressurization system type

3. Continuously monitor air quality in a controlled environment and at equipment outlet
4. Regular equipment maintenance services
5. Avoid acidic or chlorinated agents for cleaning
6. RH-temperature sensors interlocking with BMS to cut human intervention

Conclusion

Server rooms, data centers and mobile/base switching centers are mushrooming in urban areas. Knowledge of filtration at the molecular level (more commonly referred to as gas phase filtration system) helps in keeping such facilities with minimum downtime.

With the increase in automation in process industries, the need for protecting their control rooms against corrosion from unwanted gases using gas phase filtration has become the need of the hour.

We hope this article would help in better understanding of the basics of air filtration at the molecular level and the need for gas phase filtration. This article, however, only gives an overview of the dynamics involved.