camfil

# CULTURAL HERITAGE

Clean Air Solutions

# The art of artifact preservation

The primary functions of museums, art galleries and libraries are to bring together collections and the public, and to preserve artifacts for future generations. Artifacts need not be ancient; they may be comparatively recent but nevertheless sensitive objects such as government records, newspapers and microfilms.

## *Display and storage conditions in museum, gallery and archive buildings*

*Conservation may be applied on a remedial basis (repair of existing damage); however, it is far more desirable and cost-effective in the long term to prevent deterioration. This approach is called "preventative conservation." Molecular filtration and particulate filtration have an important role to play within preventative conservation.*

Inappropriate environmental conditions may cause irreversible damage to vulnerable artifacts. Critical parameters include: temperature, relative humidity, lighting, particulate pollution (dust), molecular pollutants (gases) and pests.

The stability of conditions is equally important. In some cases, rapid changes can be more detrimental than a stable condition, albeit at a non-ideal level.

A synergistic relationship exists between increased temperature, increased humidity, molecular pollutants and observed rate of deterioration. Different categories of artifacts such as paper, paintings, metals and woods have their own specific storage requirements.

A very high level of care and expertise should be applied in the design and construction of buildings used for the storage and display of artifacts. Interestingly, in most collections only a small proportion of the artifacts are on display, and the bulk of the items are in storage.

If different classes of artifacts are present, the building is designed with compartmentalized spaces for appropriate microclimates.

Since it is necessary to provide good breathing air for occupants, all buildings must be ventilated to some degree. Ventilation rates typically increase with human occupancy.

Forced or natural ventilation induces "fresh" air into the building. This air will contain any particulate or molecular pollutant present in the outdoor air. External pollutants may also enter the building via "fugitive" routes such as open windows, loading bays and building defects.

In addition to outdoor sources, there are indoor sources of pollutants which may damage artifacts. These include; materials used in building construction and finish, cleaning agents, humans and, perhaps surprisingly, the artifacts themselves. The collection objects responsible for hazardous pollutants are made from cellulosic materials such as wood, paper and safety filmstock.





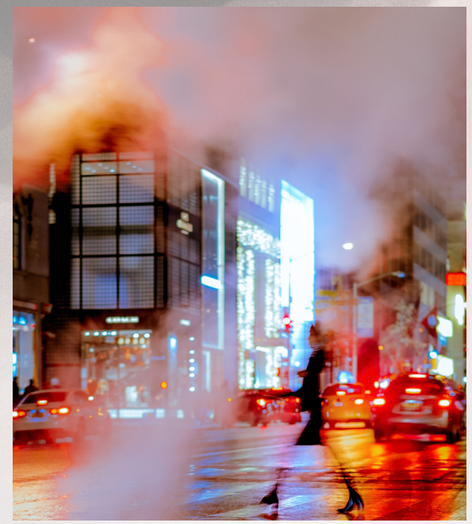
# The problem: molecular pollutants

Although there are natural sources of atmospheric molecular pollutants, such as hot water springs and volcanoes, these can be predominantly attributed to human activity such as vehicle exhaust, power generation and other combustion processes.

High concentrations of molecular pollutants, including many volatile organic compounds (VOCs), are normally associated with high population density such as cities. In terms of damage to artifacts, molecular pollutants fall into two broad categories:

- those with acidic chemical properties
- those with oxidizing chemical properties

The principal acidic precursor gases are sulfur dioxide and nitrogen dioxide. These may react with atmospheric humidity to form the sulfurous and nitric/nitrous acids. Acids cause corrosion damage to materials such as metals and marble. Other materials susceptible to damage include leather, wool, silk, paper and photographic images. The predominant oxidizing gases are ozone, nitric acid and other oxygen/nitrogen compounds.



# Particulate pollutants

Particulate pollutants arise from multiple sources including combustion processes (industrial, power generation, vehicle exhaust, smoke), vehicle tires running on roads, construction and human beings.

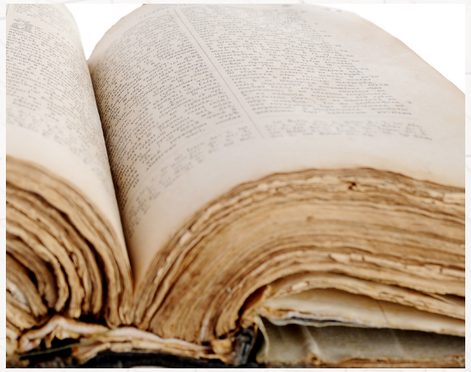
Heavy particles with metallic content are abrasive and may settle on surfaces and cause scratching. Smaller particles may remain suspended and be transported by air movement to even the most remote corners in rooms and display cabinets. Here surface deposition will lead to soiling or discoloration.

Particles arising from vehicle engines will be oily or sooty in nature and have acidic properties. These are particularly damaging since they are sticky and cause corrosion in many materials.

Particles from construction materials, such as concrete, are alkaline and abrasive and harmful to artifacts such as paintings and textile fibers. Particles are specified according to their size and concentration, typically quantified through PM2.5 measurements and expressed in $\mu g/m^3$. If the level of particulate pollution is high then it may be appropriate the specify the amount in terms of weight, ($mg/m^3$).


| Molecular Pollutants | | | | |
|---|---|---|---|---|
| **Gas** | **Formula** | **Source** | **Susceptible Artifacts** | **Type of Damage** |
| Sulfur dioxide | $SO_2$ | External - traffic fumes, power generation | Metals, marble/limestone, paper | Acidic corrosion |
| | | | Old paintings, particularly the natural pigments (inorganic and organic) | Blackening due to sulfide formation |
| Oxides of nitrogen, particularly nitrogen dioxide | $NO_x$, $NO_2$ | External - traffic fumes | Metals, marble/limestone | Acidic corrosion |
| Ozone | $O_3$ | External - atmospheric | Paper, fabrics | Oxidation (aging) |
| Hydrogen sulfide | $H_2S$ | External - industry, wastewater treatment Internal- leather items | Old paintings, particularly the natural pigments (inorganic and organic) | Blackening due to sulfide formation |
| Organic acids – formic or methanoic acid, acetic or ethanoic acid | HCOOH, $CH_3COOH$ | Internal – wooden fixtures, wooden and paper artifacts, old film stocks | Metals and organic-based materials | Corrosion and paper degradation |
| Organics - phenol, formaldehyde | $C_6H_5OH$ | Internal - construction and furnishing materials | Various | Aging |





# Safe concentrations of molecular pollutants

Since each individual molecule can cause changes in an artifact, it can be argued that the only safe concentration of molecular pollutants is zero. In most cases, however, this is an impractical proposition.

Even without budget constraints, the optimum combination of all control factors is unlikely to produce the desired result. In any event, damage to artifacts is dose-based behavior. Not only is the concentration important, but the exposure time must also be considered.

The goal of preventative conservation is to ensure that collections remain stable over long periods of time (hundreds to thousands of years). There are no absolute definitions of acceptable concentrations of molecular pollutants because the sensitivity of different artifacts varies, and the harmful effects are influenced by other factors such as temperature and humidity.

Nevertheless, ASHRAE has established recommended limits for critical gas concentrations in these spaces.

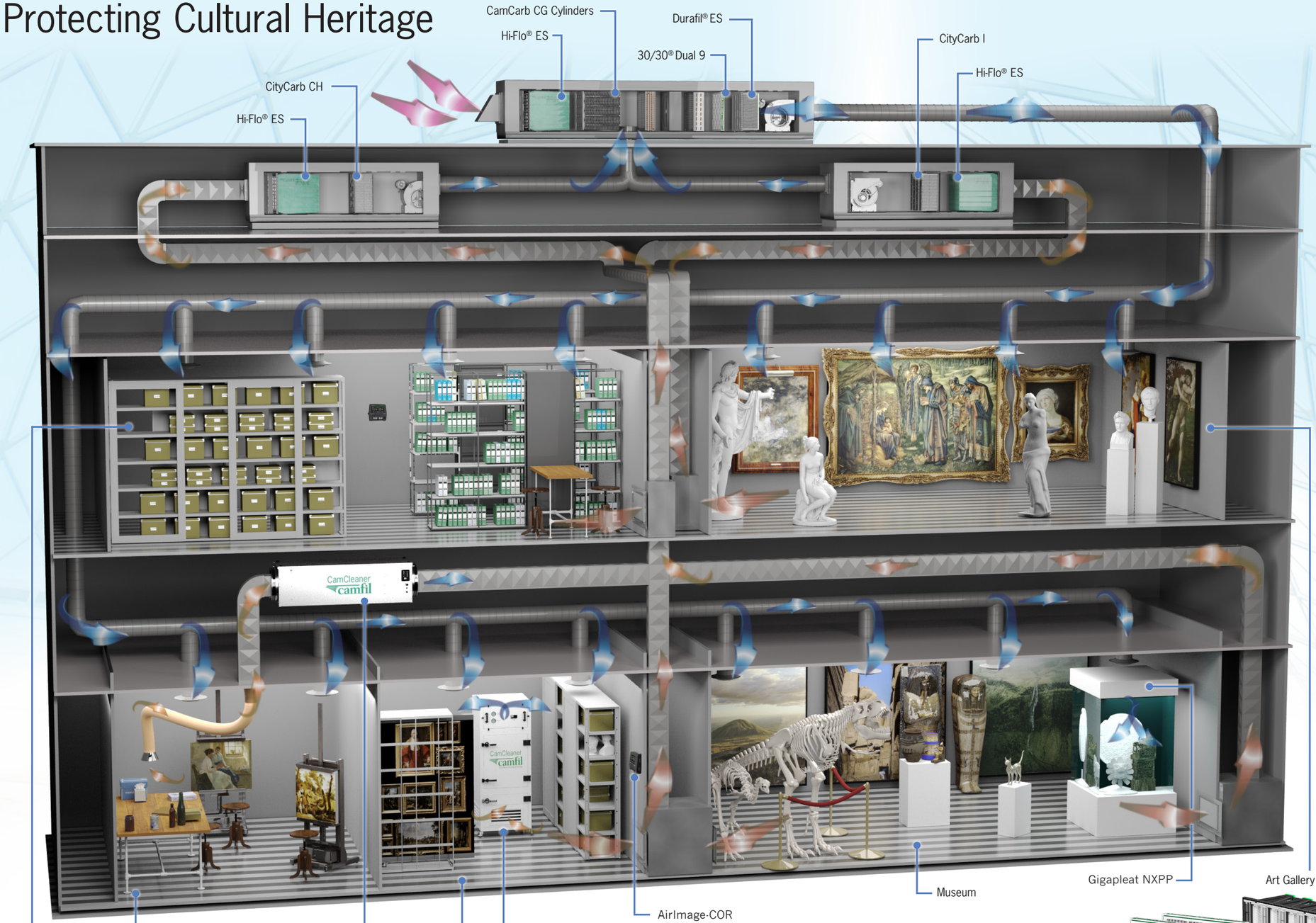
| Recommended Limits for Key Gaseous Pollutants in Parts Per Billion (PPB) per 2018 ASHRAE Handbook, Chapter 23: Museums, Galleries, Archives and Libraries | | | |
|---|---|---|---|
| **Gas** | **Formula** | **Sensitive Materials** | **General Collections** |
| Nitrogen dioxide | $NO_2$ | <0.05 to 2.6 | 2 to 10 |
| Ozone | $O_3$ | <0.05 to 0.5 | 0.5 to 5 |
| Sulfur Dioxide | $SO_2$ | <0.04 to 0.4 | 0.4 to 2 |
| Hydrogen Sulfide | $H_2S$ | <0.010 | <0.100 |
| Acetic Acid | $CH_3COOH$ | <5 | 40 to 280 |
| Formic Acid | HCOOH | <5 | 42 to 78 |
| Formaldehyde | HCHO | <0.1 to 5 | 10 to 20 |

# The solution to molecular pollutants

Molecular filtration provides a cost-effective method of controlling harmful gaseous pollutants, thereby ensuring safe conditions for storage and display. Molecular filtration is the solution accepted by cultural heritage collections around the world. Various product solutions are available depending on the nature and concentrations of gaseous pollutants, the type of artifact to be protected and the configuration of the ventilation system.

Molecular filtration may be applied in the outdoor (make-up) air system to control pollutants as well as in recirculation systems to control internally generated contaminants. Solutions for make-up air applications need to address high external concentrations and one-pass operation. Solutions for recirculation applications address lower ambient concentrations and multi-pass operation.

# Protecting Cultural Heritage




## Molecular and Particulate Filtration

Artifacts must be protected from particulate matter (PM) or dust. PM varies widely in size from very large visible entities (hair, fibers, skin particles and construction dust) to extremely fine particles less than 0.1 microns in size that mostly originate from combustion processes.

By orders of magnitude, the greatest numbers of particles suspended in the air are smaller than 1.0 micron (PM1). There are relatively few particles greater than 10 microns, and particles above 50 microns in size do not stay suspended in stationary or slow-moving air.

Dust particles cause damage through staining and abrasion. Deposited dust absorbs moisture and pollutants in the air, and as a result holds them against the surface of objects.

Dust increases the likelihood of insect and mold outbreaks. Staining and discoloration of collection items can occur if dusty items become damp. Providing the appropriate environment inside a cultural heritage building may require a combination of high-efficiency particulate and effective molecular filters.

CamCleaner Vertical

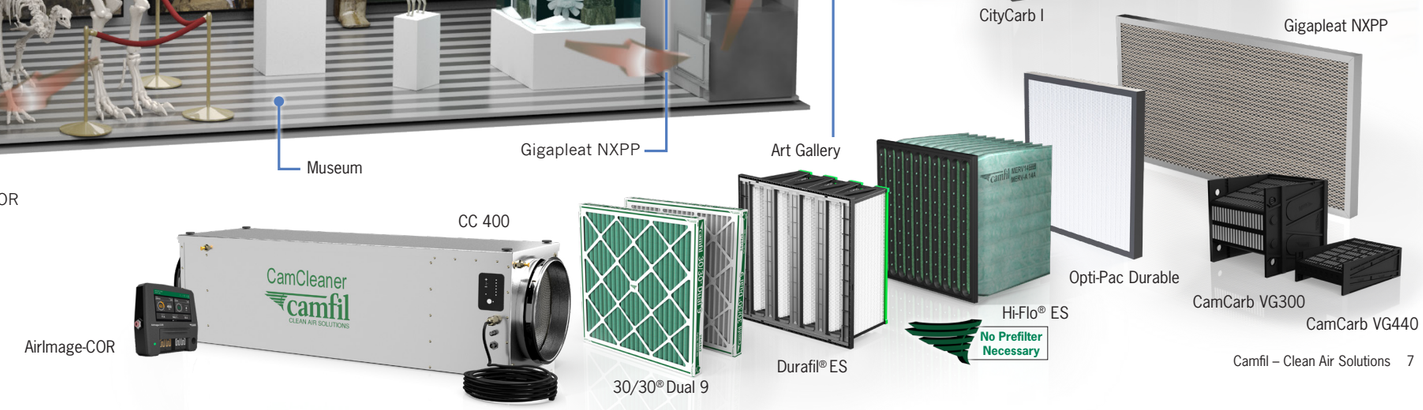

City M

CitySorb

CamCarb CG Cylinders

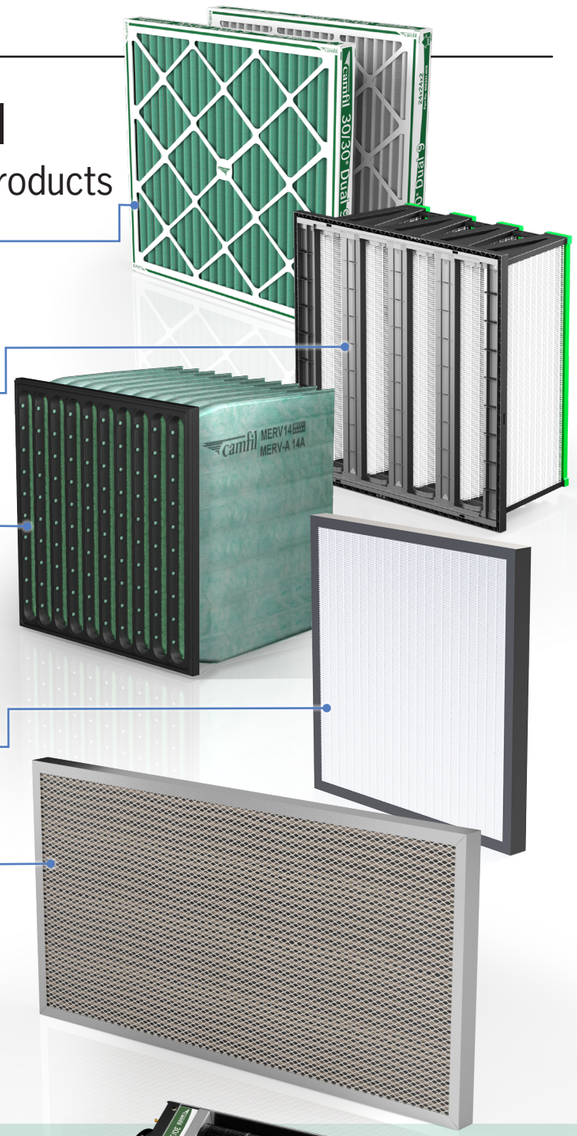
CityCarb CH

CityCarb I



# Proven Solutions by Camfil

## Molecular and Particulate Filtration Products




**30/30® Dual 9**
Camfil's unique proprietary dual-layer media offers efficiency values of MERV 9/9A and an ISO ePM10-55%. The 30/30 Dual 9 is guaranteed to last 12 months in commercial-duty applications and 9 months in industrial-level applications.

**Durafil® ES**
A high efficiency compact filter available in MERV 11A, 13A, 14A or 16A (ISO 16890 values ePM10-70, ePM1-60, ePM1-70, and ePM1-90). The Durafil ES comes fully guaranteed to outperform all competitive products of its kind and deliver the highest energy savings possible in the industry while maintaining rated efficiency.

**Hi-Flo® ES**
A high efficiency pocket filter available in MERV 11A, 13A, 14A and 15A (ISO 16890 values ePM10-70, ePM1- 65, ePM1-70, and ePM1-80). With an optimized pocket design, the Hi-Flo ES is the ideal choice to deliver high levels of indoor air quality (IAQ) and is guaranteed to last 12 months without a prefilter.

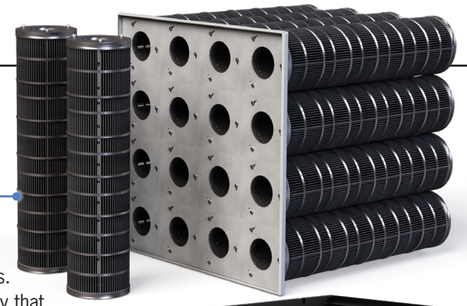
**Opti-Pac® Durable**
This new generation of fine compact filters is the ideal filtration solution for applications with restricted space. Available in fully incinerable versions. Available in 2 or 4-inch depths and multiple MERV and ISO values.

**Gigapleat NXPP and Gigalam**
Gigapleat NXPP is a high-efficiency and low energy-consumption molecular filter with extreme cleanliness (up to ISO Class 4) to avoid particle contamination or outgassing from filter components in closed vitrines. Gigalam offers the same cleanliness but in a 2-in-1 combination particulate and molecular filter.

**City M**
City M is a plug-and-play air cleaner configured with HEPA and molecular filter cartridges and is ideal for small spaces.


**CC 400**
The CC400 air cleaner can be configured with CamCarb molecular filters and ASHRAE-certified particulate filters and is the ideal solution for applications with restricted space. It is also easy to adapt to ducts and diffusers for concealed installation.





**CamCarb CG**
CamCarb CG is particularly suited to outdoor air applications. This is a robust loose-filled solution with cylindrical geometry that can be used with any Camfil adsorbent media. This product provides extremely high efficiency and long lifetime, which minimizes total cost of ownership.

**CamCarb VG300 and CamCarb VG440**
CamCarb VG modules are also robust, loose-fill solutions but with a "v-cell" configuration. VG300 is particularly suited to make-up air applications (outside AHU) and VG440 is appropriate for recirculation applications.

**CitySorb**
CitySorb is a molecular-only V-bank style filter for use when there is space for a separate final filter stage. It utilizes Rapid Adsorption Dynamics (RAD), a finely dispersed adsorbent ideal for low concentrations.

**CityCarb I and CityCarb CH**
When space is limited, a compact combination particulate and molecular v-bank filter is recommended. For outdoor (make-up) air systems, CityCarb I offers MERV 15/14A particulate performance and contains a high quality, broad spectrum adsorbent. For recirculation, CityCarb CH is a MERV 15/13A filter that contains an impregnated activated carbon adsorbent to capture VOCs and corrosive gases, such as acetic and formic acid, generated by internal sources.

# Molecular Air Cleaners

The primary focus of Camfil molecular air cleaners is the removal of odors and gases from your facility. These units can be configured to capture a wide range of contaminants specific to the application.


**CamCleaner Vertical**
The CamCleaner Vertical is a versatile air cleaner that can be configured to eliminate VOCs, corrosive gases, ozone, formaldehyde and particulates. It utilizes CamCarb CG Cylinders with targeted media and ASHRAE-certified particulate filters.

# On-site Testing

## *Air Quality Measurement*

The use of molecular filtration for the protection of cultural heritage artifacts is a critical application. The long-term stability of objects in storage or on display is dependent on the performance of the molecular filters. Camfil provides customers with support services to monitor the ongoing effectiveness of their filters.


GIGACHECK

**GIGACHECK**
A low-cost passive technique to measure indoor concentrations of gases known to be hazardous to cultural objects, including sulfur dioxide, nitrogen dioxide, ozone, hydrogen sulfide and organic acids (formic and acetic). Measurements are made over a 1 to 4-week exposure period. Sensor placement and sampling procedure do not require a specialized technician.

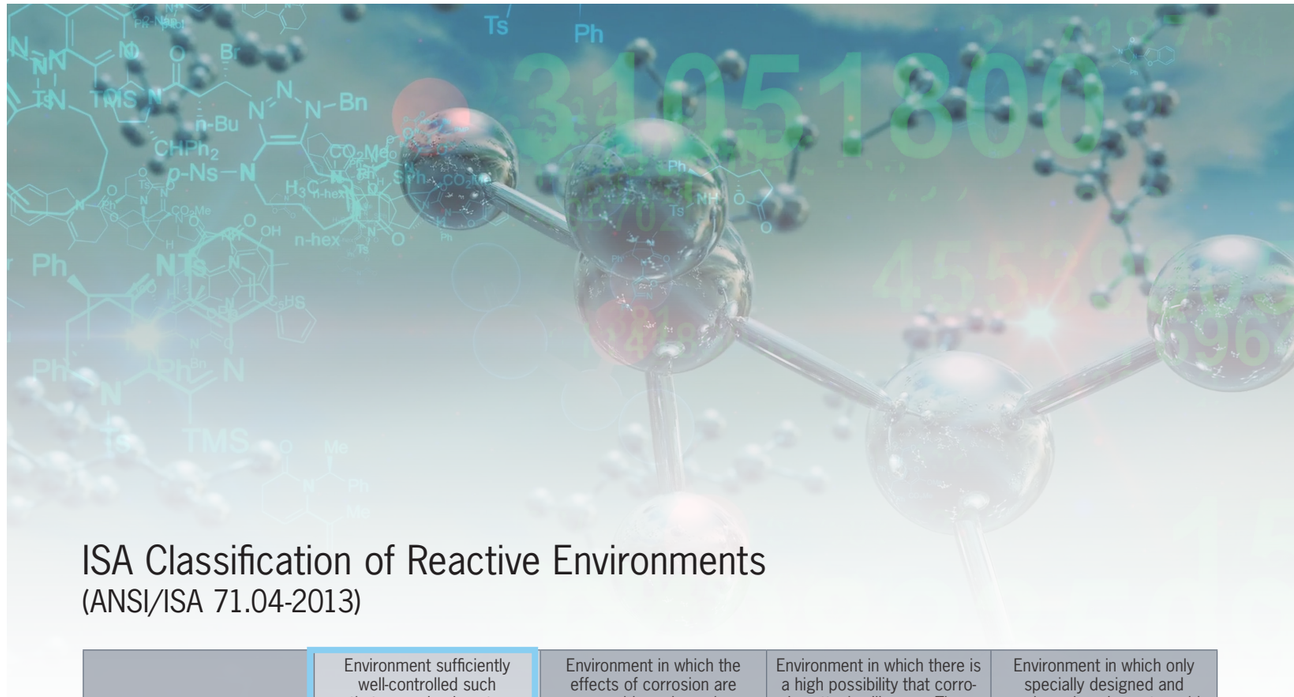

Corrosion Coupons

**CORROSION COUPONS**
A low-cost passive technique for measuring the corrosivity of indoor air according to ANSI/ISA 71.04-2013. This technique is useful for the protection of metallic objects and other materials which may be sensitive to acidic gases. The coupon comprises a strip of high purity copper or strips of copper and silver. These are exposed for a 30-day period and then the resulting corrosion layer is analyzed in Camfil's laboratory.


AirImage-COR

**AIRIMAGE-COR**
Camfil's AirImage-COR corrosion control monitor instantly measures corrosive gases in the air to indicate when air filters need changing.





## ISA Classification of Reactive Environments
(ANSI/ISA 71.04-2013)

| | Environment sufficiently well-controlled such that corrosion is not a factor in determining equipment reliability. | Environment in which the effects of corrosion are measurable and may be a factor in determining equipment reliability. | Environment in which there is a high possibility that corrosive attack will occur. These harsh levels should prompt further evaluation resulting in environmental controls. | Environment in which only specially designed and packaged equipment would be expected to survive. |
|---|---|---|---|---|
| Security level | G1 (MILD) | G2 (MODERATE) | G3 (HARSH) | GX (SEVERE) |
| Copper reactivity level* | <300 | <1000 | <2000 | >2000 |
| Silver reactivity level* | <200 | <1000 | <2000 | >2000 |

**In angstroms, Å, normalized to a 30-day exposure.*

| | | DESIRED CONDITION | | | |
|---|---|---|---|---|---|
| COPPER REACTIVITY LEVELS (Å/month) | | G1 (MILD) | G2 (MODERATE) | G3 (HARSH) | GX (SEVERE) |
| | | <300 | <1,000 | <2,000 | >2,000 |
| GROUP | GAS | | GAS CONCENTRATION (parts per billion) | | |
| A | Hydrogen sulfide ($H_2S$) | <3 | <10 | <50 | >50 |
| | Sulfur dioxide ($SO_2$) | <10 | <100 | <300 | >300 |
| | Sulfur trioxide ($SO_3$) | | | | |
| | Chlorine ($Cl_2$) | <1 | <2 | <10 | >10 |
| | Nitrogen oxides (NOx) | <50 | <125 | <1,250 | >1,250 |
| B | Hydrogen fluoride (HF) | <1 | <2 | <10 | >10 |
| | Ammonia ($NH_3$) | <500 | <10,000 | <25,000 | >25,000 |
| | Ozone ($O_3$) | <2 | <25 | <100 | >100 |

# Performance testing of molecular filters

Customers using molecular filtration to protect heritage objects from airborne chemical contaminants should expect to know how the filters will perform in their situation. After all, ambient winter conditions in Montreal will be very different from those during summer in Florence.

The globally applicable ISO 10121[1] standard for testing the performance of molecular filters fulfills this purpose. This test is a laboratory procedure and allows adsorbents and full-size filters to be challenged with application-real concentrations of gases and the efficiency and lifetime to be determined using sensitive upstream and downstream gas detectors.

Furthermore, the procedure allows for the temperature and relative humidity, which both affect performance, to be adjusted and set at values that represent the intended point of use.

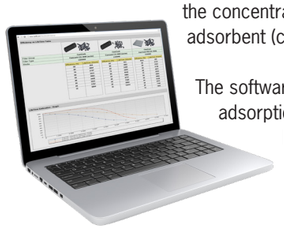
[1] *ISO 10121 Parts 1 and 2, Test methods for assessing the performance of gas-phase air cleaning media and devices for general ventilation.*

# Lifetime simulation software for molecular filtration solutions

One of the most frequent customer questions about molecular filtration relates to the lifetime of a filter. To allow Camfil to provide meaningful data, we have developed a unique simulation software program, Molecular Contamination Control Lifetime Determination (CLD), in which we model the customer application and the selected filter solution.

The outputs from the software are a table and graph showing filter efficiency over time. Importantly, the software simulates filter performance under real-world process conditions.

The software takes into account the key factors that affect the performance of molecular filters: the gas/vapor to be controlled, the concentration, type of adsorbent, amount of adsorbent (contact time) and temperature.



The software has been developed using adsorption theory, many years of application knowledge, field measurements and results of extensive product testing in Camfil's unique molecular filtration test laboratory.



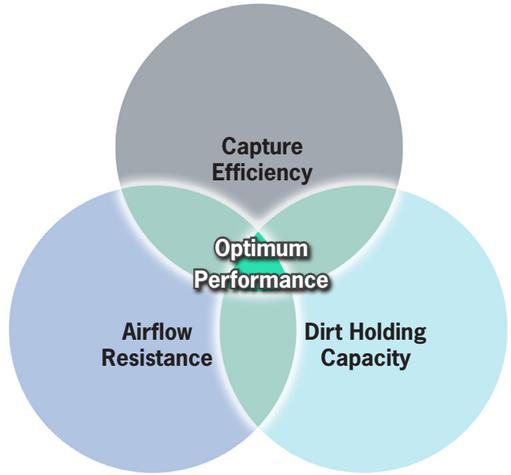
# Particulate Air Filters and Optimum Performance

## *Air filters have three main performance characteristics.*

Particle Capture Efficiency is a measurement of how effective a filter is at removing specific sizes of particulate matter from the airstream. This is often defined as MERV value and should be maintain for the duration of the filter's service life.

Dirt Holding Capacity defines how much particulate matter the filter can hold while in-service. A high DHC equates to long service life with fewer changeouts.

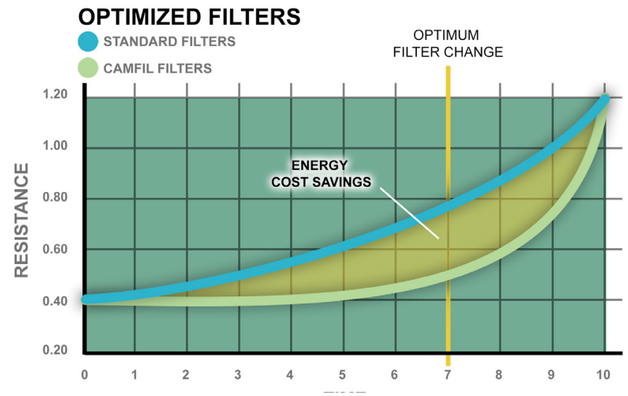
Airflow Resistance refers to the pressure differential upstream vs downstream. Low airflow resistance requires less fan energy while providing the required airflow.




*70% of HVAC cost is from the energy required to move air through the system*

All air filters exhibit a resistance to airflow which increases as the filter loads with dirt. To maintain proper airflow, the fan must repeatedly speed up to compensate which requires additional energy and drives up cost.

Camfil's 5-Star Premium air filters maintain a lower average pressure drop which reduces energy usage. The same engineered techniques that deliver low resistance also increase surface area which extends service life two, three and up to four times longer than standard air filters.




# Performance testing of particulate filters

ASHRAE 52.2 with Appendix J is the test standard that assigns the familiar MERV-A value on a scale of 1 – 16 and most accurately reveals the real-world performance of an air filter. ISO 16890 is a relatively new global standard that classifies filter efficiency against ePM1, ePM2.5 and ePM10 particle sizes.

Both test standards include procedures to account for the drop-off in particle capture efficiency when any benefit from an electrostatic charge is lessened. In environments where the presence of fine particulates in the air can damage irreplaceable artifacts, air filter selection should always be based on either the MERV-A or ISO 16890 value.

## 5-Star ECI Rating

Camfil air filters are rated as 5-Star filters through the Energy Cost Index (ECI) program. Based upon a five-star scale, the Energy Cost Index is an indicator of what a filter will cost over its lifetime. The best rating – five stars – indicates that the filter is the most energy-efficient, longest lasting filter available.


All Camfil's 5-Star Premium Air Filters have performance guarantees. The filters will substantially reduce HVAC-related energy consumption, require less frequent change-outs, reduce waste and maintain their rated particle capture efficiency.

# AirImage-COR Corrosive Gas Monitor

## Visualize Corrosive Gases Before Damage Becomes Irreversible

Corrosion is typically not recognized until it's too late, resulting in damage that could have been prevented. Camfil's AirImage-COR corrosion control monitor instantly measures corrosive gases in the air to indicate when air filters need changing to keep sensitive electronic equipment protected and valuable assets preserved.


### Preserve Valuable Assets and Protect Sensitive Equipment

**Why AirImage-COR?**

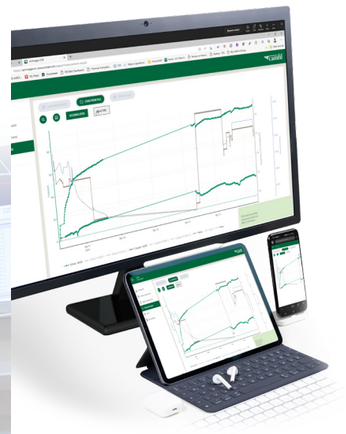
- Only corrosion monitor with touchscreen display
- First monitor to offer both data and Wi-Fi connections
- Simple setup with the Progressive Web Application
- Most accurate sensors engineered for real-time corrosion monitoring

*The Most User-Friendly Corrosive Gas Monitor*




*Making the Invisible … Visible* Know exactly when to change your air filters

View Data Remotely on Any Desktop or Mobile Device



Electrical equipment manufacturers will guarantee performance only when concentrations of corrosive gases are maintained below specified levels (G1-GX.)

Cultural heritage preservationists set the requirement to protect valuable artifacts.

5" Touchscreen Display

Most Accurate Sensors Engineered for Real-Time Corrosion Monitoring

Simple Installation and Communications

Power Source
USB-C

Wired Connectivity
- Ethernet
- USB
- Analog 4-20 mA
- RS485

Wireless Connectivity
- Wi-Fi
- Bluetooth
- GPRS Compatibility with Mobile Devices

ISA classification of reactive environments (ANSI/ISA 71.04-2013)

| COPPER REACTIVITY LEVELS (Å/month) | | G1 (MILD) | G2 (MODERATE) | G3 (HARSH) | GX (SEVERE) |
|---|---|---|---|---|---|
| | | < 300 | < 1,000 | < 2,000 | > 2,000 |
| GROUP | GAS | GAS CONCENTRATION (parts per billion) | | | |
| A | Hydrogen sulfide ($H_2S$) | < 3 | < 10 | < 50 | 50 |
| | Sulfur dioxide ($SO_2$) | < 10 | < 100 | < 300 | 300 |
| | Sulfur trioxide ($SO_3$) | | | | |
| | Chlorine ($Cl_2$) | < 1 | < 2 | < 10 | 10 |
| | Nitrogen oxides (NOx) | < 50 | < 125 | < 1,250 | 1,250 |
| B | Hydrogen fluoride (HF) | < 1 | < 2 | < 10 | 10 |
| | Ammonia ($NH_3$) | < 500 | < 10,000 | < 25,000 | 25,000 |
| | Ozone ($O_3$) | < 2 | < 25 | < 100 | 100 |

## Camfil – a global leader in air filters and clean air solutions.

For more than half a century, Camfil has been helping people breathe cleaner air. As a leading manufacturer of premium clean air solutions, we provide commercial and industrial systems for air filtration and air pollution control that improve worker and equipment productivity, minimize energy use, and benefit human health and the environment.

We firmly believe that the best solutions for our customers are the best solutions for our planet, too. That's why every step of the way – from design to delivery and across the product life cycle – we consider the impact of what we do on people and on the world around us. Through a fresh approach to problem-solving, innovative design, precise process control and a strong customer focus we aim to conserve more, use less and find better ways – so we can all breathe easier.

The Camfil Group is headquartered in Stockholm, Sweden, and has 33 manufacturing sites, six R&D centers, local sales offices in 30 countries, and about 4,800 employees and growing. We proudly serve and support customers in a wide variety of industries and in communities across the world. To discover how Camfil can help you to protect people, processes and the environment, visit us at www.camfil.com.



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