camfil

CULTURAL HERITAGE

Clean air solutions

The art of artefact preservation

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

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.

DISPLAY AND STORAGE CONDITIONS IN MUSEUM, GALLERY AND ARCHIVE BUILDINGS

Inappropriate environmental conditions may cause irreversible damage to vulnerable artefacts. 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.

It is known that a synergistic relationship exists between increased temperature, increased humidity, molecular pollutants and observed rate of deterioration. Different categories of artefact e.g. paper, paintings, metals and wood 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 artefacts. Interestingly, in most collections only a small proportion of the artefacts are on the display, the bulk of the items are in storage.

If different classes of artefact are present, it is normal to provide a cell or compartmentalised construction within the building, in which it is possible to provide different 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 pollutants 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 artefacts. These include; materials used in building construction and finish, cleaning agents, humans and perhaps surprisingly, the artefacts themselves. The collection objects responsible for hazardous pollutants are made from cellulosic materials e.g. 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 transport, power generation and other combustion processes.

High concentrations of molecular pollutants are normally associated with high population density, e.g. cities. In terms of damage to artefacts, molecular pollutants fall into two broad categories:

- those with acidic chemical properties
- those with oxidising chemical properties

The principal acidic precursor gases are sulphur dioxide and nitrogen dioxide. These may react with atmospheric humidity to form the sulphurous 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 oxidising gases are ozone, nitric acid and other oxygen/nitrogen compounds.

Particulate pollutants

PARTICULATE POLLUTANTS

Particulate pollutants arise from multiple sources including combustion processes (industrial, power generation, vehicle exhausts, cigarette smoke), vehicle tyres 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 remotest corners in rooms and display cabinets. Here surface deposition will lead to soiling or discolouration.

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 arising from building works (concrete) are alkaline and abrasive and harmful to artefacts such as paintings and textile fibres. Particles are specified according to their size and frequency, i.e. number per cubic metre. 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 ATREFACTS	TYPE OF DAMAGE
Sulphur 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 sulphide formation
Oxides of nitrogen, particularly nitrogen dioxide	(NOX), NO_2	External, traffic fumes	Metals, marble/limestone	Acidic corrosion
Ozone	(O_3)	External, atmospheric	Paper, fabrics	Oxidation (ageing)
Hydrogen sulphide	H_2S	External – industry, wastewater treatment Internal – leather items	Old paintings, particularly the natural pigments (inorganic and organic)	Blackening due to sulphide formation
Organic acids – formic or methanoic acid, acetic or ethanoic acid	HCOOH CH_3COOH	Internal – wooden fixtures, wooden and paper artefacts, old film stocks	Metals and organic based materials	
Organics e.g. phenol, formaldehyde	C_6H_5OH	Internal, construction and furnishing materials	Various	Ageing

Safe concentrations of molecular pollutants

Since each individual molecule is capable of causing change in an artefact, 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 artefacts is dose-based behaviour. 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 reasonably long-time scales (hundreds to tens of hundreds of years). There are no absolute definitions of acceptable concentrations of molecular pollutants, because the sensitivity of different artefacts varies, and the harmful effects are influenced by other factors such as temperature and humidity.

Nevertheless, guidelines do exist for critical gas concentrations that support an environment that is acceptable for long term storage, see Table.

APPROXIMATE THRESHOLD CONCENTRATIONS IN PPB(V) FOR CERTAIN POLLUTANT-MATERIAL INTERACTIONS ACCORDING TO BRITISH STANDARD PAS 198:2012

Material	Pollutant and associated approximate threshold concentrations parts per billion by volume						
	Acetic add (ethanoic acid)	Formic add (methanoic add)	Formaldehyde (methanal)	Reduced sulfides	Sulfur dioxide	Nitrous oxide	Ozone
Historic soda silicate glass	-	500	300	-	-	-	-
Limestone, ceramics, fossils, pottery	1 000	-	-	-	-	-	-
Shells, eggs	1 000	500	-	-	-	-	-
Lead	100	-	-	10	-	-	-
Copper							
Silver	-	-	-	10	-	-	-
Zinc	-	-	-	10	-	-	-
Lead-based pigments	100	-	-	10	-	-	-
Paper	100	-	-	-	1	10	10

Pollutant	Acceptable concentration
Sulphur dioxide	< 10 µg/m³
Nitrogen dioxide	< 10 µg/m³
Ozone	< 2 µg/m³

PERMISSIBLE "IN-GALLERY" CONCENTRATIONS ACCORDING TO BRITISH STANDARD PD 5454:2012 AND THE INTERNATIONAL CENTRE FOR THE STUDY FOR PRESERVATION AND RESTORATION OF CULTURAL PROPERTY.

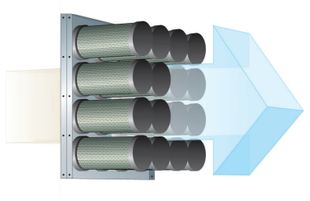
There are no obvious standards or guidelines for the pollutants from internal sources. However, there are many studies that describe damage to various types of artefacts (copper, lead, glass, paper etc.) caused by extremely low concentration of organic acids (formic and acetic) and formaldehyde. Damage will be dose related, i.e. a combination of concentration and exposure time. This may lead to different environmental solutions, including air quality for for long term storage and short term exhibitions.

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 artefact to be protected and the configuration of the ventilation system.

Molecular filtration may be applied in either the outdoor air system or recirculation air units to control either outdoor pollutants and / or pollutants from indoor sources. Solutions for make-up air applications need to reflect high external concentrations and one-pass operation. Solutions for recirculation applications reflect lower ambient concentrations and multi-pass operation.

Proven products from Camfil: **Molecular Filtration**



1. 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 of the adsorbents. This product provides extremely high efficiency and long lifetime, which minimises total cost of ownership.

2. CAMCARB VG 300/CAMCARB VG 440

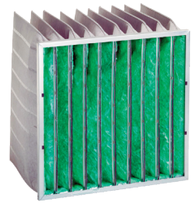
CamCarb VG modules are also robust, loose-fill solutions but with "Vee-cell" configuration. VG 300 is particularly suited to make-up air applications (outside AHU) and VG440 is appropriate for recirculation applications.

3. CITYSORB

CitySorb is a compact and practical solution aimed at low concentration (predominantly recirculation air applications). Citysorb uses a very finely divided adsorbent and provides Rapid Adsorption Dynamics (RAD). Two versions are available, one with very high quality Broad Spectrum adsorbent and one with impregnated activated carbon to target acidic gases.

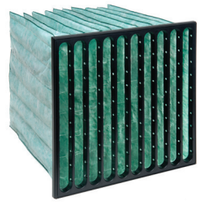
4. CITYCARB I & CITYCARB CH

CityCarb is a group of very compact solution that feature both particulate and molecular filtration in a single device (combination filter). Two versions are available, one with very high quality Broad Spectrum adsorbent and one with impregnated activated carbon to target organic acidic gases. CityCarb I is recommended for outdoor air applications (subject to pollutant concentrations) and CityCarb CH is recommended when organic acids (formic and acetic) are known to be released from internal sources.



5. CITY-FLO

City-Flo is a member of the Hi-Flo bag filter family that also includes a layer of very high performance Broad Spectrum activated carbon. This combination filter will provide good control of particles and molecular contaminants, especially ozone, polyaromatic hydrocarbons and VOCs.



6. HI-FLO

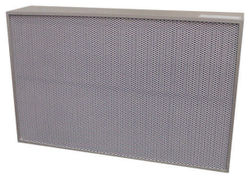
A high efficiency bag filter in filter classes from ISO ePM10 60% to ISO ePM1 85% acc. ISO 16890. With an optimised filter design and the use of superior material it is the ideal choice for very high levels of indoor air quality (IAQ). The Hi-Flo filter is the ideal first stage particle filter for an optimised low pressure drop and protection of the second step filters.

7. OPAKFIL ES

A high efficiency compact filter in filter classes from ISO ePM10 70% to ISO ePM1 80% acc ISO 16890. Opakfil ES provides the highest level of particle removal in a compact format. The ideal second stage filter, to control fine particles.

8. ECOPLEAT

This new generation of fine compact filters is the ideal filtration solution for applications with restricted space. Available in fully incinerable versions.



9. GIGAPLEAT NXPP/GIGALAM

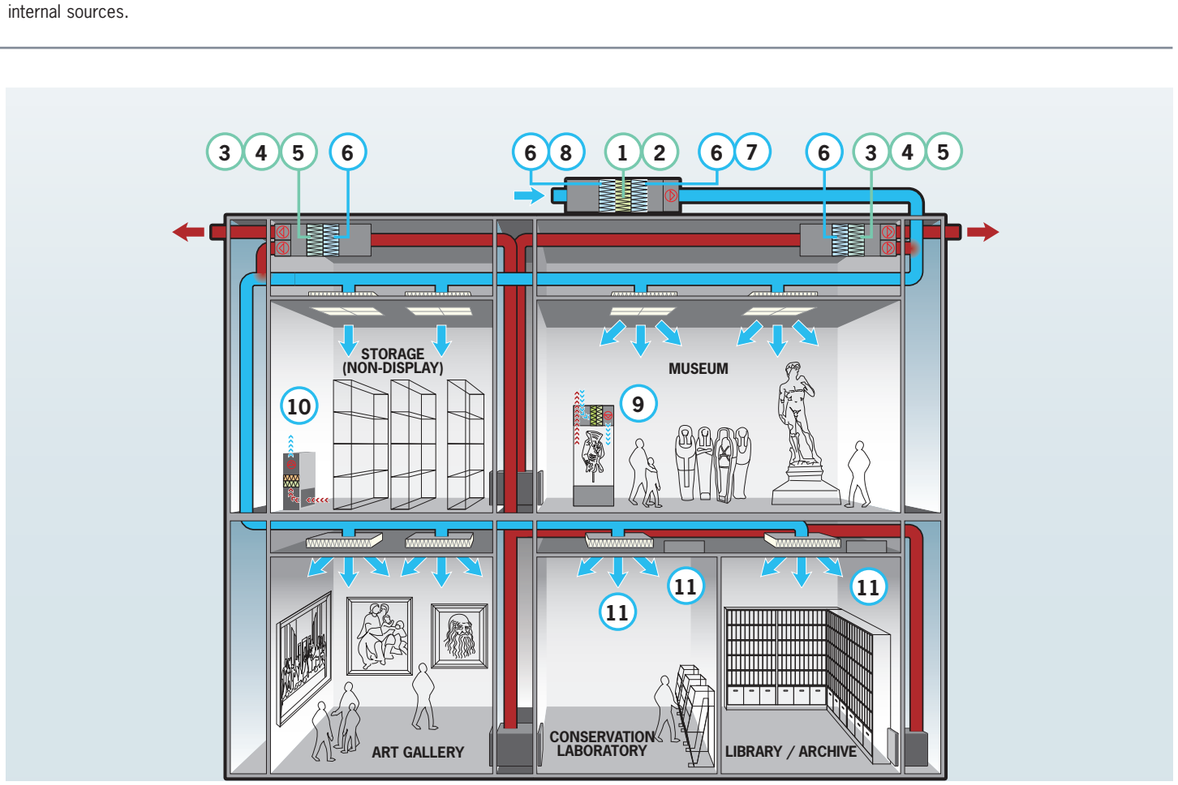
A high efficiency / low energy consumption molecular filter with extreme cleanliness (up to ISO Class 4) to avoid particle contamination or outgassing from filter components in closed vitrines. A combination (2 in 1) particulate and molecular filtration device also exists; Gigalam.

10. AIR CLEANER CC1700

CC1700 is a versatile Air Cleaner specialized for elimination of acids, corrosive gases, VOC's, ozone, formaldehyde and particulate matter. Inside, you will find the well-known CamCarb, City or Gigapleat molecular products and EN, ASHRAE or ISO certified Particle filters.

11. AIR CLEANER CC 400 CONCEALED

This new generation of fine compact filters is the ideal filtration solution for applications with restricted space. Available in fully incinerable versions.



Solid pollutants (particle filtration)

Artefacts must be protected from particulate matter (PM) or dust. PM varies widely in size from very large visible entities (hair, fibres, 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. Depositied 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 mould outbreaks. Staining and discolouration of collection items can occur if dusty items become damp. To provide the appropriate environment inside a cultural heritage building may require a combination of high efficiency particulate and effective molecular filters.

On-site testing – air quality measurement

The use of molecular filtration for the protection of cultural heritage artefacts 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 provide customers with support services to monitor the on-going effectiveness of their filters.

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

GIGACHECK ACTIVE: Advanced techniques for detailed measurement of VOCs or ionic species. Indoor air is sampled for 4 to 8 hours then analysed in the laboratory using various chromatography and spectroscopic techniques.

CORROSION COUPON: A low cost passive technique for measuring the corrosivity of indoor air according to ISA71.04:2013. 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 analysed in the laboratory.

ISA-CHECK: On-line corrosivity monitor. A continuously reading air corrosivity monitor. The monitor uses thin film copper and silver sensors and displays rate of corrosion and corrosivity classification according to ISA71.04:2013.

CAMPURE COUPON

ISA-CHECK II UNIT WITH
COPPER AND SILVER SENSORS

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, normalized to a 30-day exposure.*

COPPER REACTIVITY LEVELS (Å/month)		DESIRED CONDITION 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

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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 to those during summer in Florence.

The globally applicable ISO10121[1)] standard for testing the performance of molecular filters fulfils this purpose. This test is a laboratory procedure and allows adsorbents and complete filters to be challenged with application-real concentrations of gases and the efficiency and capacity (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.*

Performance testing of particulate filters

ISO16890 is the globally applicable standard for testing and classifying the performance of particle filters used in general ventilation systems. Specifiers, purchasers and users of air filters can select filters from 49 individual classifications spread across 4 categories of efficiency; ePM1, ePM2.5, ePM10 and Coarse.

Using ISO 16890 it is simple to understand how efficient a filter will be against 4 different particle sizes. This is a big advantage over the previous EN779:2012 and ASHRAE 52.2 standards where the classifications often meant very little to customers e.g. F7, Merv 8 and Merv 13. All Camfil particle filters are rated acording to ISO16890.

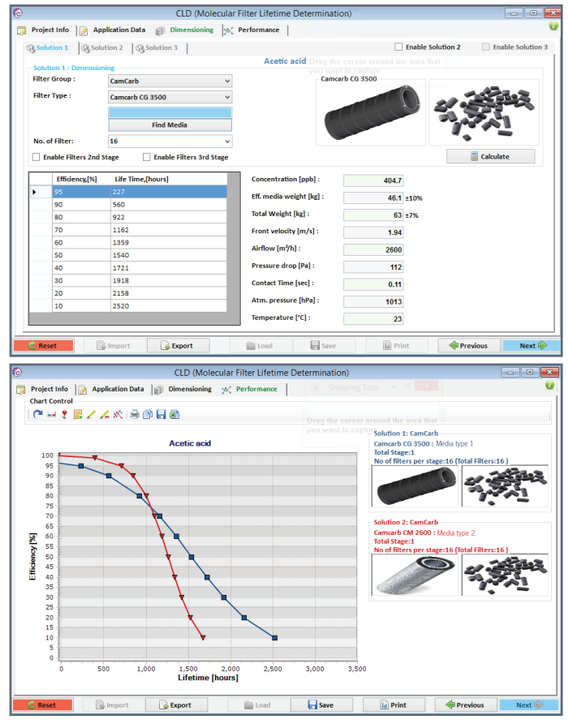
Lifetime simulation software for molecular filtration solutions

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 in which we model the customer application and the selected filter solution.

The outputs from the software are a table and a curve showing filter efficiency against lifetime. Importantly the software model simulates real-world conditions and filter behaviour in the real-world.

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

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



CLD SOFTWARE FOR MOLECULAR FILTRATION

Camfil real-time corrosivity monitor
ISA-check II

ISA-CHECK II UNIT WITH
COPPER AND SILVER SENSORS

ISA-CHECK II UNIT WITH COPPER AND
SILVER SENSORS, WITH DATA PENCIL

Camfil offer the latest advanced technology real-time corrosion sensor: **ISA-Check II**.

This entirely new product has been developed specifically for use in heavy process industries and offers some unique customer benefits.

Real-time information on the air corrosivity is crucial for effective corrosion protection of valuable control assets. ISA-Check II measures and registers the change over time in the electrical resistance (ER) of a thin metal track applied on an insulating substrate.

If the metal corrodes, the cross-sectional area of the track decreases and the ER increases. The changes in ER can be directly translated into corrosion depth and corrosion rate.

The ISA-Check II monitoring system is comprised of four principal parts:

- Electronic logger for measuring and recording ER
- Sensitive thin-film metal corrosion sensors
- Non-contact communication interface between the logger and computer, the “data pencil”
- User-friendly software programme, WINISACHECK

FEATURES	CUSTOMER BENEFITS
Battery powered. Lifetime > 3 years	No need to hardwire or have skilled technician for installation
3 colour LED indicates copper reactivity class according to ISA 71.04-2013. (G1, G2, G3/GX)	Instant indication of air classification according to the most commonly adopted standard
Single button operation to scroll through menu and display commands	Simple to operate
Utilises 2 different metal sensors, usually copper and silver	Results are compliant with ISA 71.04.-2013
Measures temperature and relative humidity	Allows customer to monitor important parameters that influence rate of corrosion
Measures atmospheric pressure	Indicates control room pressurization
Non-contact data reading allows the logger to remain in place when data is downloaded to laptop	Very convenient to upload data to a laptop
User-friendly WINISA-Check II software provides rapid interpretation of results in terms of corrosion depth and corrosion rate and classifies the air quality and corrosivity according to three standards	Very convenient to process, manipulate and display data

ISA-CHECK II UNIT WITH DATA PENCIL AND LAPTOP BASED SOFTWARE

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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