



**MOLECULAR
CORROSION CONTROL**



Clean Air Solutions

CORROSION CONTROL

SENSITIVE ELECTRONICS

Automation is used in manufacturing businesses around the world. Many industries are completely reliant on electronic and electrical control equipment for the safe and efficient operation of complex and valuable manufacturing processes. In certain heavy industries, the external air around the facility is likely to be contaminated with acidic gases.

These gases originate from the raw materials used in the process or chemicals added to the process. The industries where these gases are most prevalent are oil and gas, pulp and paper, mining and metal refining, and wastewater treatment.

At oil and gas facilities, the acidic gases arise from sulfur and sulfide impurities present in crude oil. At pulp and paper facilities, the contaminants arise from chemicals used to digest and bleach wood and other cellulose based materials for the pulp making process.

Examples of acidic gases include hydrogen sulfide (H₂S), sulfur dioxide and trioxide (SO₂, SO₃), chlorine (Cl₂), nitrogen dioxide (NO₂) and hydrogen fluoride (HF). All of these gases can corrode electronic and electrical control equipment.

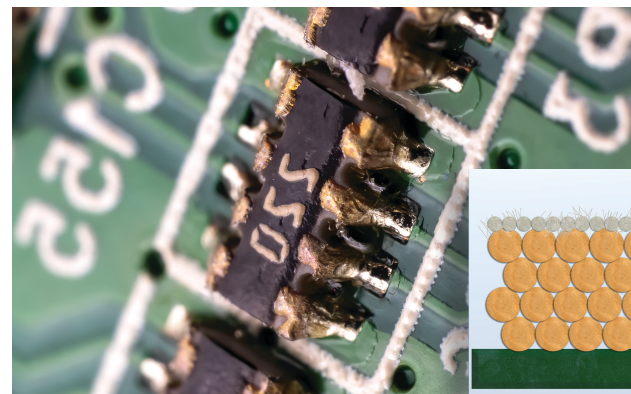
If steps are not taken to protect the control assets then the likely consequence will be unscheduled breakdown caused by equipment failure. Process downtime is expensive and erodes profits and maintenance budgets.

The degradation of electrical control equipment by corrosive gases is a well-known effect. In fact, virtually all manufacturers of sensitive electronic and electrical equipment specify the required environmental conditions for their equipment as part of the warranty conditions. These specifications set limits for temperature, relative humidity and chemical contaminants, as they all influence the rate of corrosion.

Many individual electronic components are afforded some protection from corrosive agents because they are encapsulated inside an airtight plastic or resin body. The components that are most susceptible to damage are printed circuit boards (PCBs), exposed contacts and conductors.

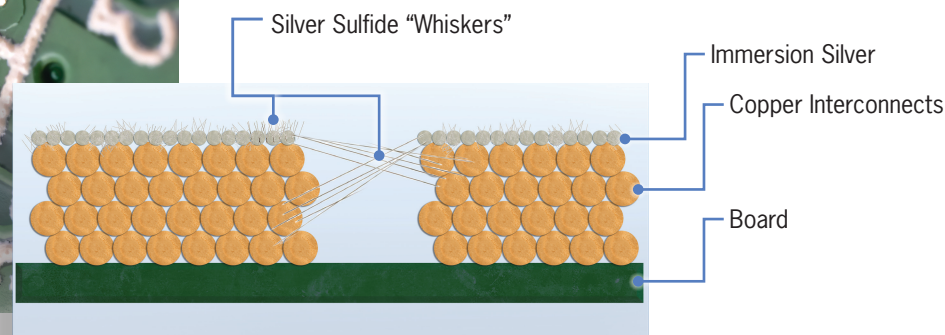
There are several established techniques for PCB production. They differ in terms of cost, surface flatness, shelf life and corrosion resistance. The method that is gaining most popularity following the introduction of RoHS legislation (Restriction of Hazardous Substances), which required the elimination of lead from solder, is "Immersion Silver" (iAg or IM Ag). In this method, the copper tracks on exposed edges of the copper sub-track and the silver coating are susceptible to corrosion.

Molecular filtration using adsorption technology is the industry accepted method to remove the corrosive agents from the air.



Printed Circuit Boards (PCBs) are Susceptible

- Elimination of lead in 2006 has reduced PCB resistance to corrosion
- Immersion Silver (ImAg) is the most common technology
- Copper tracks or "interconnects" are covered, but not encapsulated, with a thin layer of silver (0.07-0.25µ)
- In high sulfur atmosphere, silver sulfide "whiskers" form and short-circuit the device



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 ₂ S)	< 3	< 10	< 50	50
	Sulfur dioxide (SO ₂)	< 10	< 100	< 300	300
	Sulfur trioxide (SO ₃)				
	Chlorine (Cl ₂)				
	Nitrogen oxides (NO _x)	< 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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APPLICABLE STANDARDS FOR CORROSION CONTROL

There are two commonly referenced standards that categorize environmental conditions in relation to the deployment and reliability of electronic equipment:

1. ANSI/ISA -71.04-2013.
2. IEC 60721-3-3

ANSI/ISA-71.04-2013 is the most popular and focuses on airborne contaminants and observed rates of corrosion for copper and silver metals. IEC 60721-3-3 categorizes environmental conditions based on several parameters such as climatic conditions, biological and chemical contaminants and mechanical effects.

ANSI/ISA-71.04-2013 defines four classes of air quality that relate to different rates of reactivity or corrosion of copper and silver. These are: G1 Mild, G2 Moderate, G3 Harsh and GX Severe. Most original equipment manufacturers (OEMs) require provision

of G1 Mild conditions as part of their warranty conditions since the standard states for class G1 that "Corrosion is not a factor in determining equipment reliability." The external ambient air at some heavy process industries will routinely be classified as GX Severe.

For reference, the standard tabulates concentrations of different gases that approximately correspond to the four categories of copper reactivity. It is worth noting that extremely low concentrations of some agents are required to achieve G1 Mild conditions. For example, at relative humidity ≤ 50%, the concentration of hydrogen sulfide should be < 3 parts per billion (ppb) to achieve G1 conditions, and the concentration only needs to rise to > 50 ppb to reach GX conditions.

External ambient levels of hydrogen sulfide in the air at some industrial facilities can exceed 1 part per million (ppm). Although the standard indicates concentrations of individual gases that loosely correspond to the four classes of corrosivity, these should be treated with caution. If multiple gases are present in the air, then there may be a synergistic effect on the observed rate of corrosion that is difficult to quantify. Consequently, on-site monitoring for a single or multiple gases may not in itself predict or explain corrosion of silver and copper.

The information above defines the requirement for effective molecular filtration. Reducing gas concentrations from ppm levels down to very low ppb levels requires very high efficiency molecular filtration and devices that are not compromised by internal leaks or bypass.

MOLECULAR FILTRATION SOLUTIONS

Rooms where electrical and electronic control equipment are installed are ventilated with temperature and humidity conditioned air to achieve the environment required under the OEM's warranty.

The supply (also called make-up) air will be taken from an external location and, in certain process industries, that air may be heavily contaminated with harmful corrosive agents, such as acidic gases. If these gases are not removed before the air enters the room, the control equipment will be susceptible to damage and ultimately failure due to corrosion.

The gas concentrations may be as high as tens of parts per million (ppm), but the manufacturer's warranty require in-room concentrations in the very low parts per billion (ppb) range. This can be achieved by utilizing a molecular filtration system with a very high single-pass removal efficiency.

Camfil's ProCarb Vertical Deep Bed (VDBs) filter is specifically designed for this purpose. The make-up air, which may account for up to 40% of the total room ventilation rate, is used to positively pressurize the control room to prevent the ingress of fugitive gases.

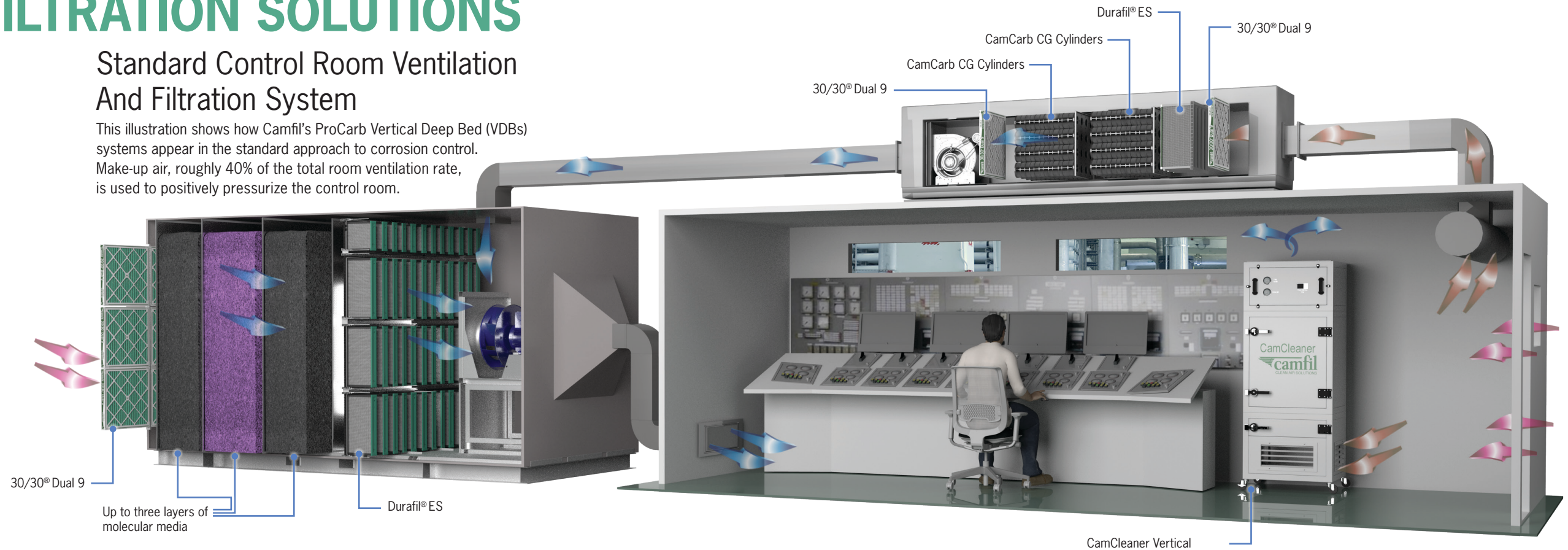
The level of pressurization can be compromised by unnecessary opening of doors, windows and leaks due to construction defects and leaks at service entry points. To provide additional protection from fugitive gases, additional molecular filtration can be installed in the return/recirculation air system and with the use of a standalone air purifier, such as Camfil's CamCleaner Vertical.

Concentrations of gases are much lower in the return air, and a filter will operate on a multi-pass basis; therefore, a lighter duty filtration solution is appropriate. Camfil's CamCarb CG cylindrical filter system is intended for this specific application.

In all cases, to handle multiple gases or to extend filter lifetime, more than one media bed (VDBs) or stage (CamCarb) can be employed.

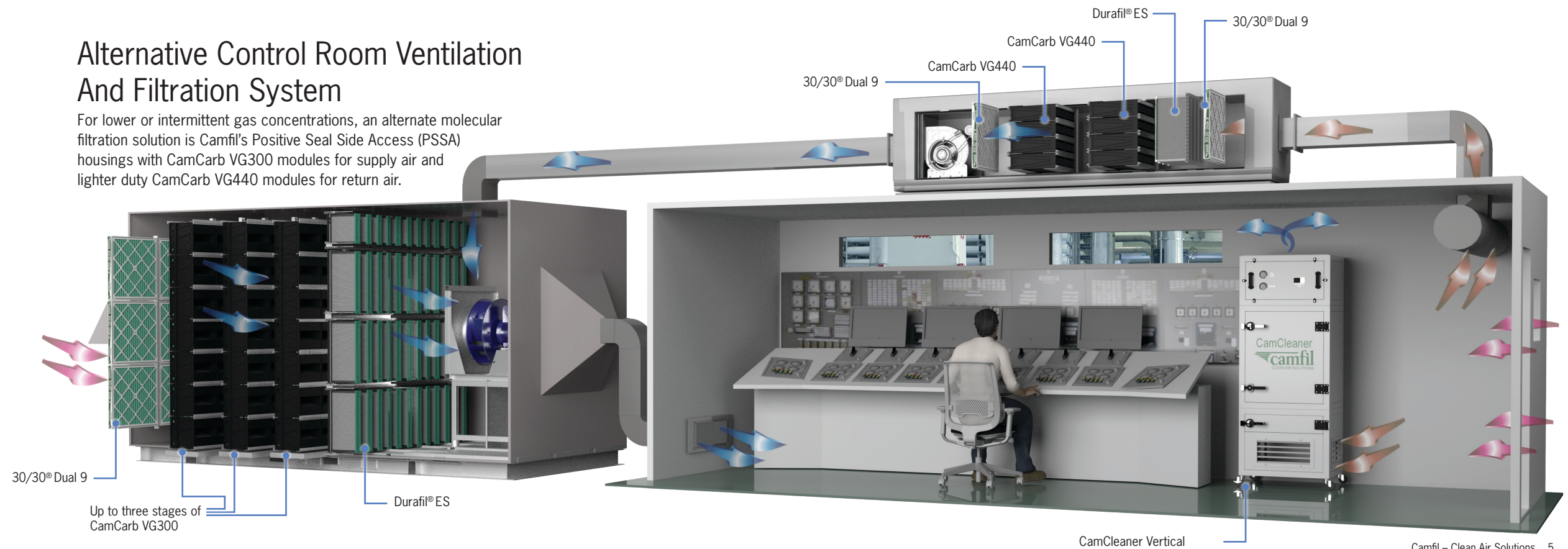
Standard Control Room Ventilation And Filtration System

This illustration shows how Camfil's ProCarb Vertical Deep Bed (VDBs) systems appear in the standard approach to corrosion control. Make-up air, roughly 40% of the total room ventilation rate, is used to positively pressurize the control room.



Alternative Control Room Ventilation And Filtration System

For lower or intermittent gas concentrations, an alternate molecular filtration solution is Camfil's Positive Seal Side Access (PSSA) housings with CamCarb VG300 modules for supply air and lighter duty CamCarb VG440 modules for return air.



PROCARB MOLECULAR FILTRATION

Camfil ProCarb deep bed molecular filters are designed for industrial applications. They provide the highest levels of performance where plant reliability and elimination of corrosive gases, toxic gases and odors are essential for operational security and/or regulatory compliance.

The inherently leak-free construction and extended contact time provided by ProCarb scrubbers ensure the highest levels of removal efficiency and longest possible lifetime against high concentrations of gases even in single-pass operation.

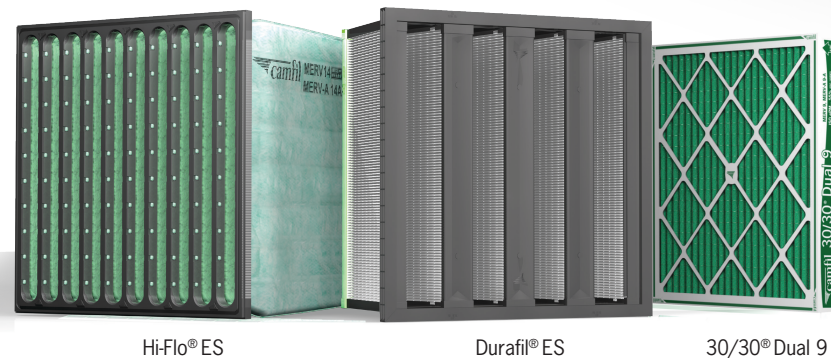
ProCarb Vertical Deep Bed Filter (VDBs)

The VDBs filter is a robust solution for removing corrosive gases from supply (make-up) air systems with very high efficiency in a single pass. Also called a dry scrubber, it houses vertical beds of filtration media that are contained in perforated screens.

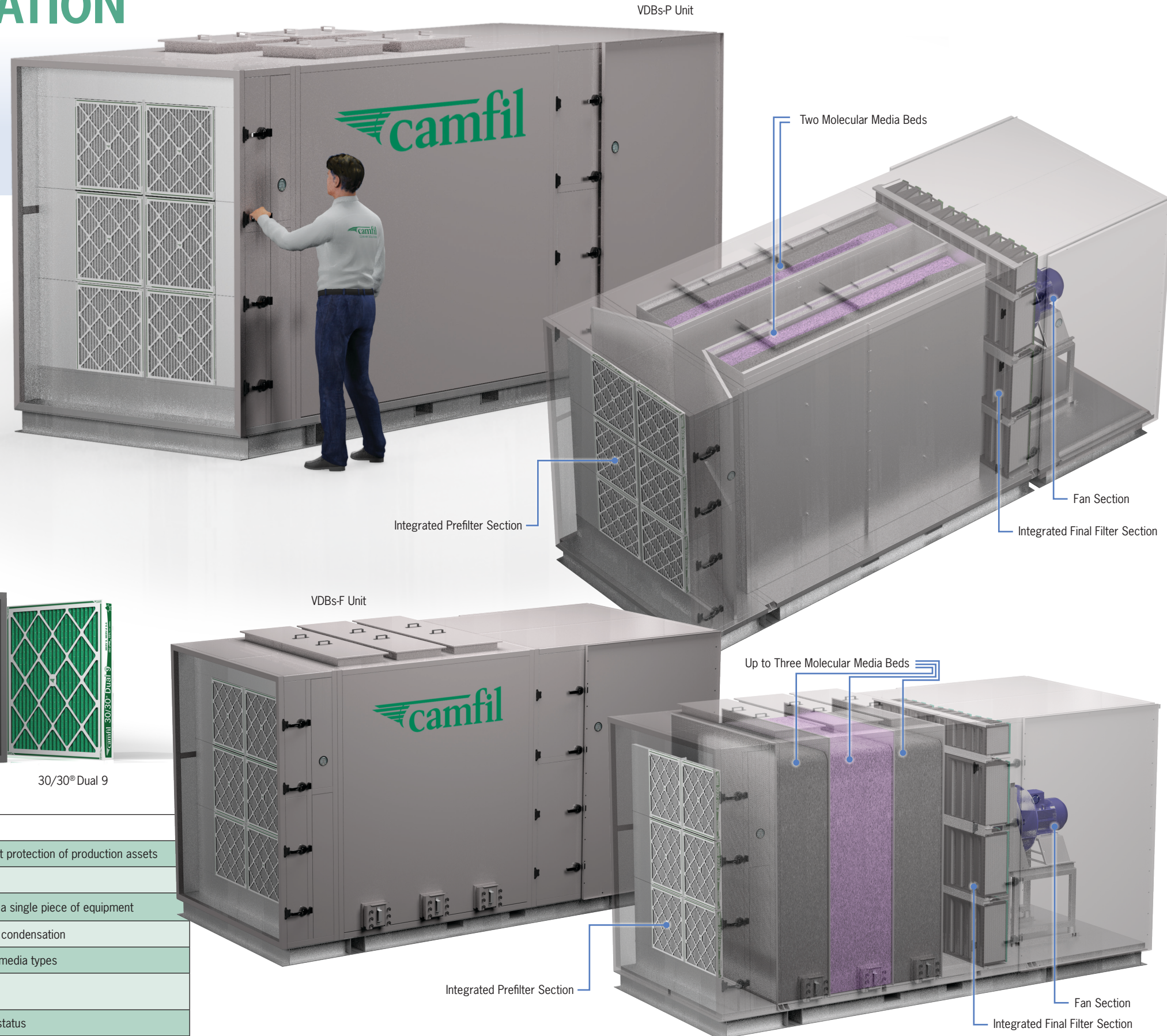
There are two styles of VDBs, which are selected based on airflow, gas concentrations and available space:

- In a VDBs-P style scrubber, the air travels parallel to the beds down the center of the unit, horizontally outward across the media, then along the sides toward the exhaust. This design is used for higher air flows.
- In a VDBs-F style scrubber, the air travels perpendicular to and across the face of the media beds. This design is used for lower air flows.

A range of standard sizes accommodates airflows from 600 to 18,000 cfm (1,000 to 25,000 m³/hr.) Depending on the airflow, the unit can be configured with up to three separate media beds in series. This allows different media to be combined in a layered configuration to handle complex contaminant mixtures in the most cost-effective manner. Camfil does not recommend using blends as this results in unspent media being prematurely replaced. Prefilters and final filters can be integrated in the housing to provide a total filtration solution in a single unit. VDBs filters are safe and simple to install. They are completely passive in operation and require no routine maintenance beyond changing the filters and media.



FEATURES	CUSTOMER BENEFITS
Long contact time to ensure optimum media usage and lifetime	Lowest possible life cycle cost (LCC) and highest protection of production assets
Inherently leak-free design	Extremely high removal efficiency
Integrated prefilters and final filters	Compact footprint and convenient installation of a single piece of equipment
Double skin with insulation	Internal temperature control and reduced risk of condensation
Multiple media bed arrangement	Ability to target multiple gases utilizing different media types
Media contact parts from 316 quality stainless steel or other materials, depending on application	Corrosion resistant and durable installation
Magnahelic pressure loss gauges for all particulate filter stages	Real-time assessment of prefilter and final filter status

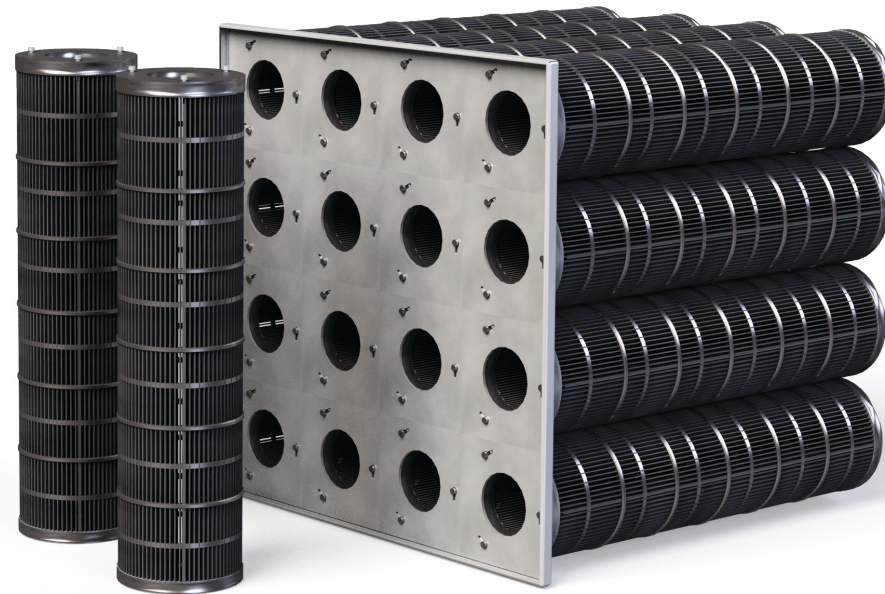


MOLECULAR CYLINDERS

CamCarb CG Cylinders

The CamCarb CG cylindrical filter is Camfil's flagship molecular filter for moderate duty applications in process and industrial environments. When mounted on its dedicated holding frame, all internal leaks are eliminated and very high efficiency values are achieved. CamCarb CG is ideally suited to use in recirculation/return air systems in corrosion control applications. It can also be used in make-up air systems in applications where low or moderate gas concentrations are expected.

CamCarb CG is manufactured from plastic and is extremely corrosion resistance. The endcap features a radiused profile to reduce pressure drop and a pair of co-molded TEP thermo-elastic gaskets to eliminate air bypass. Each cylinder is filled using a vibratory technique to ensure perfect packing density of the filtration media. The cylinders are easily mounted and unmounted from the base plate using a standard 24 mm wrench.



Leak-free installation of CamCarb CG cylinders on base plate via three bayonet mounting pins and co-molded rubber gasket.

GlidePack CamCarb Cylinder Housing

GlidePack Cylinder Housing with 30/30 D9 prefilter and CamCarb CG3500 cylindrical filters



These side-access housings for cylindrical filters are recommended in recirculation systems where concentrations of corrosive gases are high.

A unique frame bayonet mounting system and two extruded aluminum filter slide tracks with polypropylene fin seals limit internal air bypass. One track allows for the installation of a universal holding frame for a 2" deep particulate prefilter or a downstream carbon dusting filter. The main track is designed to accommodate the installation of a frame with CamCarb CG Cylinders.

Housings are available in stainless steel or 16-gauge aluminum. Pre-drilled standing flanges provide convenient mating to existing housings (multi-stage filtration) or directly to HVAC equipment. All components are weatherproof without modification for interior or exterior installation.

Dual-access doors with high-memory sponge neoprene gaskets ensure door-to-filter seal and allow filter service from either side of the unit. Doors swing open and are engineered to be square to the housing flange. UV resistant 'starstyle' knobs ensure a renewed tight seal each time the access doors are opened and closed.

When matched with Camfil CamCarb cylinders, sound attenuation is comparable to conventional silencers and sound absorbing dampers.



CamCleaner Vertical with molecular filters in a control room.



CAMCLEANER

Air Cleaner & Positive Pressurization Unit

The CamCleaner Vertical is a free-standing air cleaner that is effective in removing corrosive gases within control rooms at industrial sites.

The device is completely self-contained and includes pre-filtration, molecular filtration using CamCarb CG cylinders, final filtration, a fan and controls. Contaminated air enters at low level and passes upwards through the unit. Clean air is discharged at the top. Dampers at the bottom allow the unit to be used in 100% fresh air mode (with duct connection to external source), 100% recirculation mode, or in a combination of the two modes.

The CamCleaner Vertical is particularly useful if there is no external recirculation system and additional filtration is required to overcome the effect of ingress of fugitive gases. It can also be configured to positively pressurize the control room.

The unit is quiet and has a high aesthetic finish. It is, therefore, ideally suited for process control rooms with a high level of human occupancy. Nominal flow capacity is 1,000 cfm (1,700 m3/h).

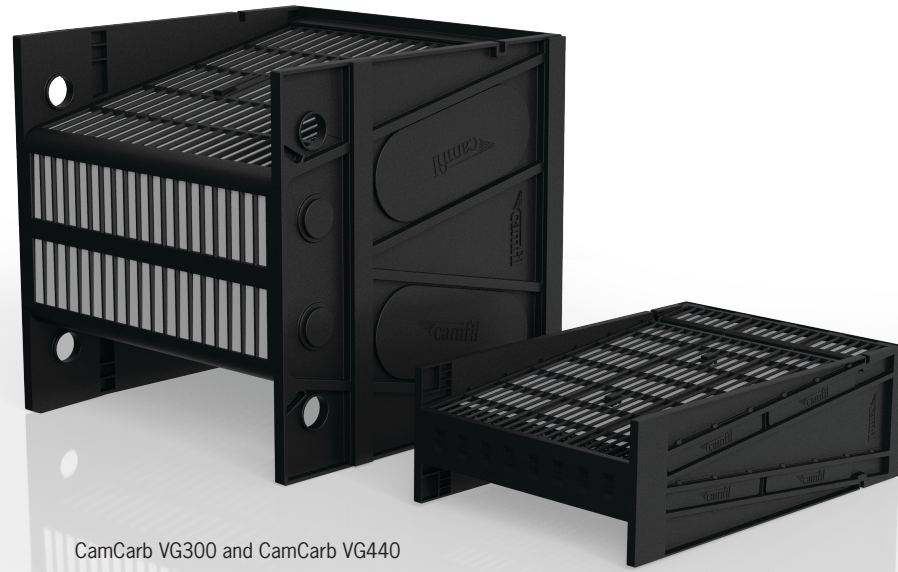
CAMCARB VG MODULES

CamCarb VG modules are V-cell style filters available in two configurations:

- CamCarb VG300 is best suited for moderate duty (normally make-up air) applications
- CamCarb VG440 is best suited for light duty (recirculation air) applications

CamCarb VG modules may be filled with a variety of molecular filtration media to address different gas challenges. When multiple types of media are required, Camfil recommends separate stages of individual media instead of using blends. This ensures the lowest possible total cost of ownership since each individual media can be changed when it reaches the end of its useful life. With a blend, all of the media will be replaced when only one of the components has been depleted.

CamCarb VG modules are the only V-cell filters on the market constructed with a molded mesh that enables the use of smaller, granular media. The large total surface area of this media translates to higher removal efficiency and longer filter lifetime.



CamCarb VG300 and CamCarb VG440

GlidePack® CamCarb VG440 Housing



Part of Camfil's GlidePack family, this housing is suited for recirculation systems for moderate concentrations of corrosive gases. CamCarb VG440 modules (also called cassettes) are loaded from either side by simply sliding them along the channeled tracks.

Housings are available in 16-gauge galvanized steel, aluminum or stainless steel. Pre-drilled, out-turned standing flanges provide convenient mating to existing housings (multi-stage filtration), or directly to HVAC equipment. All components are weatherproof without modification for interior or exterior installation.

Dual-access doors with high-memory sponge neoprene gaskets ensure door-to-filter seal and allow filter service from either side of the unit. Doors swing open and are engineered to be square to the housing flange. UV resistant star-style handles ensure a tight seal each time the access doors are opened and closed.

POSITIVE SEAL SIDE ACCESS (PSSA) HOUSING

CamCarb VG300 and PSSA Housing



GlidePack® MultiTrack with 30/30 Dual 9® Prefilter

In other manufacturers' supply air housings, V-cell filters are known to have mechanical leaks that will compromise the claimed efficiency.

Camfil's PSSA housings provide a high-integrity, minimum leakage installation for CamCarb VG300 filter modules in supply air applications where the protection of sensitive control equipment from corrosion caused by moderate concentrations of acidic gases is essential for the reliable operation of critical industrial processes.

The unique positive clamping mechanism is a first in the industry. Not only does it eliminate leakage between the modules and the internal sealing, but it is also designed to ensure ease of installation and simple servicing procedures.

Depending on the contaminant(s) to be controlled, any molecular filtration media can be used in a series to handle mixed gases or to extend filter lifetime. VG300 filters and PSSA housings are passive in operation and require minimal routine maintenance.

A range of standard size PSSA housings are available to provide airflow capacities ranging from 500 to 6,000 cfm (800 m³/h to 10,500 m³/h).

The PSSA housing can be configured with Camfil's GlidePack UniTrack or MultiTrack housings with particulate filters for a complete filtration solution.

FEATURES	CUSTOMER BENEFITS
Positive filter clamping mechanism. No special tools required	Minimal leakage. Quick and easy filter changes
Aluminium coated steel construction	Offers robust protection against environmental conditions
Double skin with insulation	Internal temperature control and reduced risk of condensation
May be used in multiple stages	Ability to target multiple gases utilizing different media
Minimal maintenance and service time	Reduced maintenance cost and equipment downtime
No requirement to handle filter media	Reduced Personal Protection Equipment (PPE) requirement for installation and maintenance
Leakage tested housing	Ensures high efficiency of contaminant removal

CAMPURE MOLECULAR FILTRATION MEDIA

Achieving a cost-effective molecular filtration solution is very dependent on selecting the most appropriate media for the application. It is necessary to take into account the target gas(es), temperature and relative humidity. It is equally important to ensure that sufficient media is deployed in the filter to ensure that a high efficiency value is maintained over an extended period and low life cycle cost (LCC) or total cost of ownership (TCO) is obtained.

There are many commercial adsorbents available to filter manufacturers, contractors, service companies and end users. Even to the trained eye many are visually indistinguishable.

The reality is that, depending on the manufacturing method, quality assurance procedures and, most importantly, performance testing, the value provided in a real-world installation can be highly variable.

Camfil manufactures all of its CamPure media for corrosion control applications in-house according to stringent quality control procedures in an ultra-modern, purpose-designed facility that uses the latest process control technologies.

CamPure 15



ON-SITE PERFORMANCE MONITORING

The use of molecular filtration for the prevention of corrosion in electrical or electronic equipment is a critical application. The safe and reliable operation of end-user assets and processes are dependent on the performance of the molecular filters.

Camfil provides customers with support services to monitor the air quality in the enclosed space and to measure the condition and predict the lifetime of the media in the filter.

Air quality can be assessed by measuring the rate of corrosion on copper and silver foil sensors. This can be done by both passive and continuous real-time techniques.

The passive method involves mounting copper and silver CamPure Corrosion Coupons inside the enclosed space for 30 days. The coupons are then returned to Camfil's laboratory to measure the thickness of the corrosion layer. The results are reported according to the four ISA 71.04-2013 categories. This technique is simple to execute; however, the results only show the average and not short-term high or low values.

Real-time monitoring involves a similar technique. Very sensitive thin-film copper and silver sensors are exposed to the enclosed space, but in this case they are integrated into a self-contained analyzer and data logger called ISA-Check II. The device continuously assesses the rate of corrosion growth on the foils and displays the current ISA 71.04-2013 classification. Variations in air quality are captured, and all data is readily downloaded to a Windows-based application for visualization and review.

Media Life Analysis is a powerful tool for determining the condition of a filter and estimating its residual life. This technique involves removing samples of media from a filter and returning them to Camfil's laboratory for analysis. A series of tests are performed to measure the amount of adsorbent capacity, and when plotted over time, Camfil can extrapolate and recommend when the filters should be changed out to ensure system performance.



CamPure Corrosion Coupon



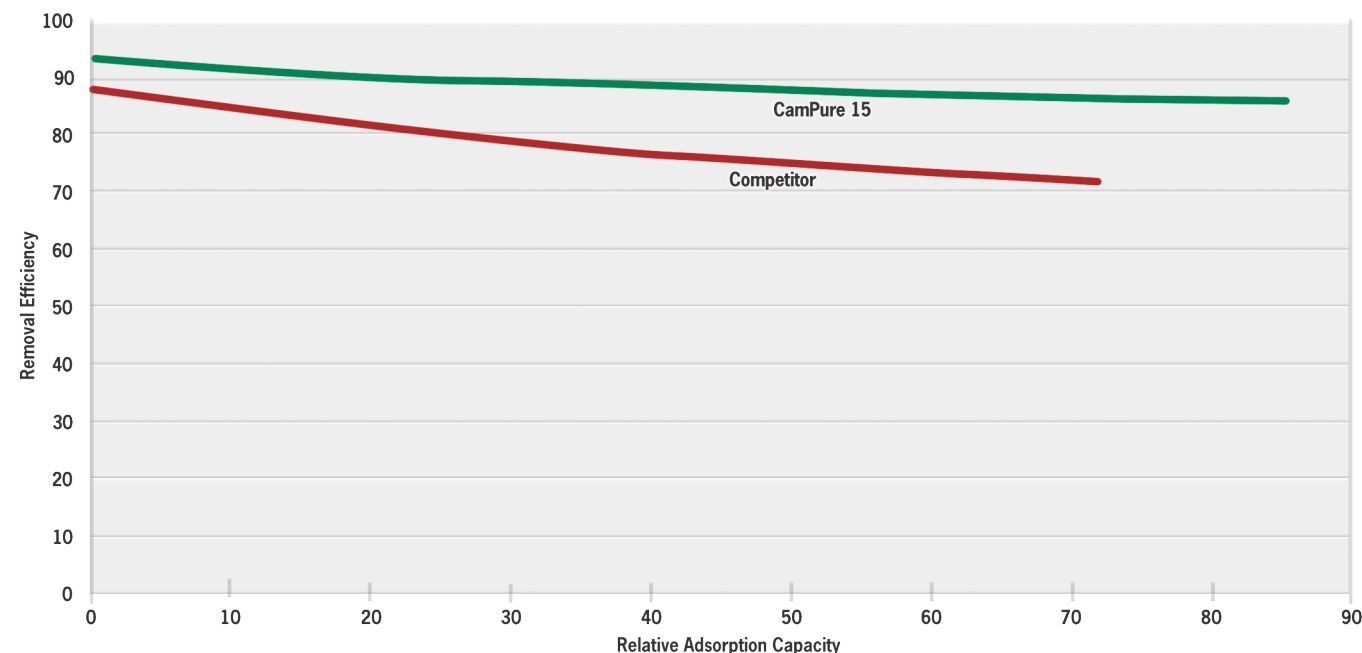
CamPure 8

Performance Validation

Performance testing is done in Camfil's unique molecular filtration test laboratory in accordance with standards ISO 10121-1/10121-2 and ASHRAE 145.1/145.2, which require testing under real-world conditions with actual process gases. Results from these tests enable Camfil to recommend the most cost-effective filtration solution.

CamPure 15 is Camfil's flagship media to capture hydrogen sulfide, the most common corrosive gas. Performance testing under actual operating conditions shows its superior performance to competitor media.

Efficiencies vs Adsorption



H2S removal efficiency - CamPure 15 vs. Competitor Media for Corrosion Control
Tested per ISO 10121 method for assessing the performance of gas-phase air cleaning media and devices for general ventilation.

SPECIALIZED SOFTWARE

The lifetime of a Camfil filter can be simulated using the proprietary Molecular Contamination Control Lifetime Determination (MCCLD) program. Its purpose is to provide accurate estimates of the performance of molecular filtration products under selectable conditions that closely approximate actual applications.

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

The key inputs are system airflow, gases/vapors to be controlled, concentrations, type of adsorbent, amount of adsorbent, contact time, relative humidity and temperature.

Camfil offers customized simulations and reports that can be used as part of the design and specification process.



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

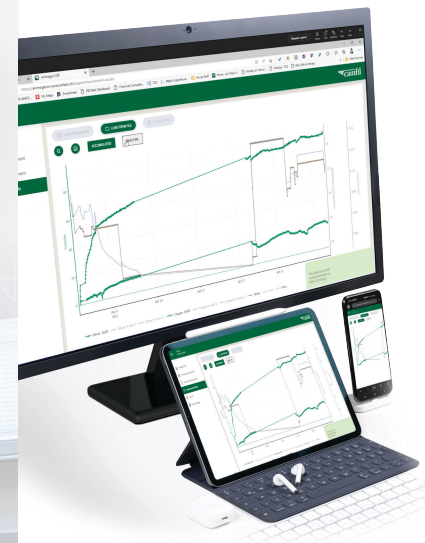


Making the Invisible ... Visible Know exactly when to change your air filters

View Data Remotely on Any Desktop or Mobile Device

5" Touchscreen Display

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

Most Accurate Sensors Engineered for Real-Time Corrosion Monitoring

The Most User-Friendly Corrosive Gas Monitor



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.

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

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	Sulfur dioxide (SO ₂)	< 10	< 100	< 300	300
	Sulfur trioxide (SO ₃)	< 1	< 2	< 10	10
	Nitrogen oxides (NO _x)	< 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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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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