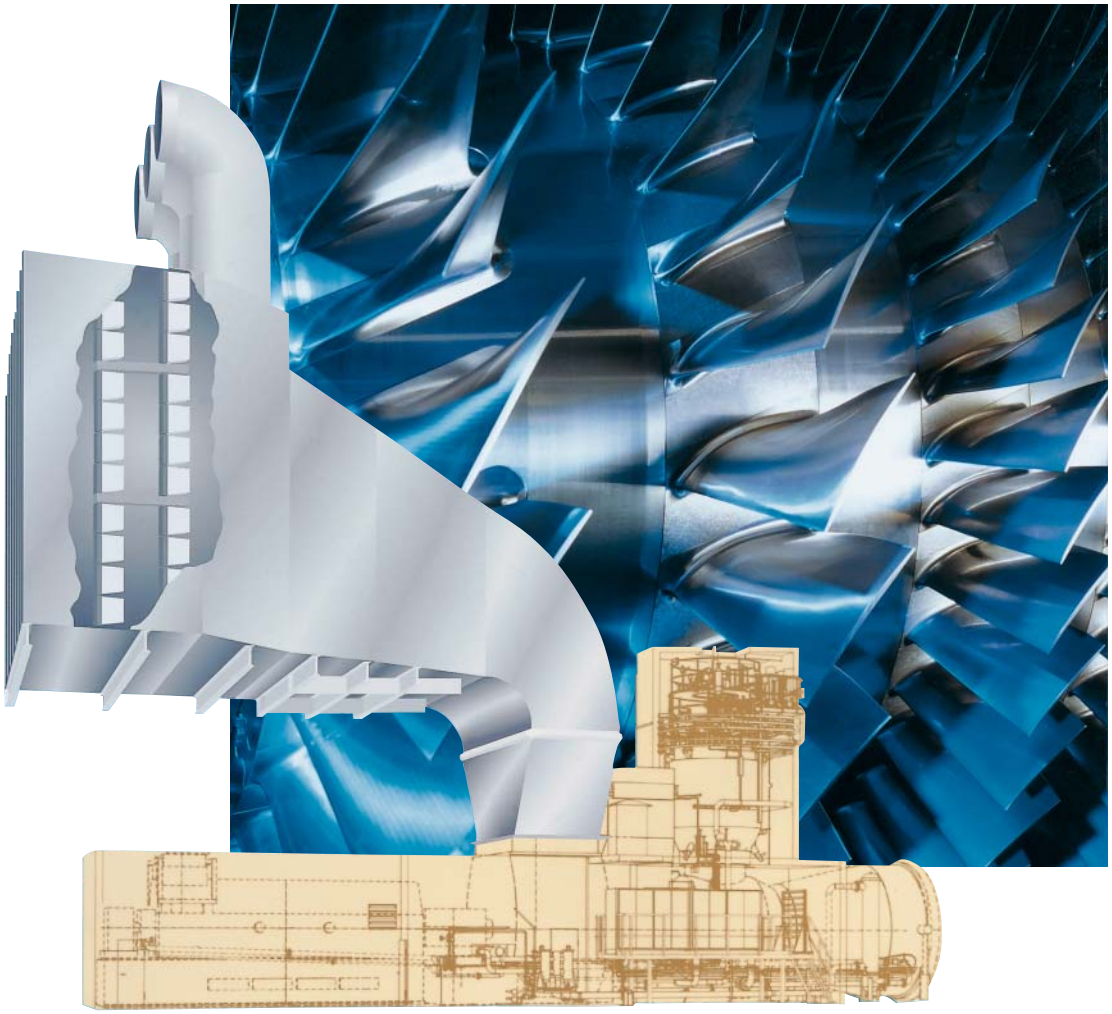
Viledon Air Intake Systems for Turbomachinery: Proactive Performance from Plan to Plant



viledon®

Freudenberg
Filtration Technologies

Freudenberg

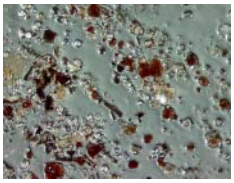
The air

The outside air is always polluted with particles to a greater or lesser extent, depending on the location and the time of year involved. A basic distinction is made here between two particle categories:

- natural particles, predominantly due to soil erosion, and
- anthropogenic particles, emitted from industrial processes, furnaces, traffic and the like.

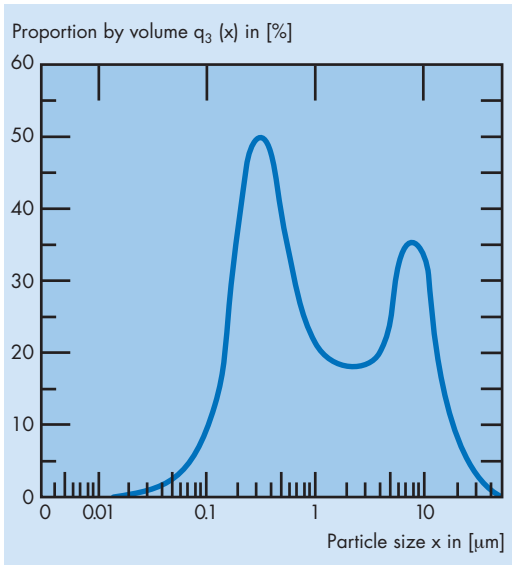
The most important parameters for characterizing polluted air are particle size distribution and dust concentration. The graph exemplifies the particle size distribution in normally polluted urban air:

- In the >1 µm range, the particles found are mostly natural ones.
- The <1 µm range covers the anthropogenic particles.



LIM picture: sand

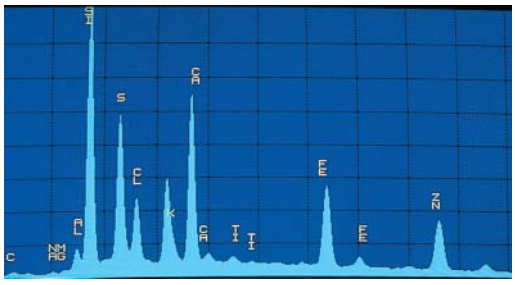
The actual proportions inside these ranges of course vary from place to place. Meteorological factors, in particular, like fog, rain or snow, or other local conditions, may affect the particle size distribution. The air in coastal regions, for example, contains more salt, some of it in crystalline form (particle size range <2 µm) or dissolved in water (droplets of approx. 10 µm in size). EDX analyses of deposits show the chemical composition of the local airborne particles, e.g. silicium/calcium from sand, iron from rust, titanium from coated surfaces, and chlorides from coastal areas.



Particle size distribution in normally polluted urban air

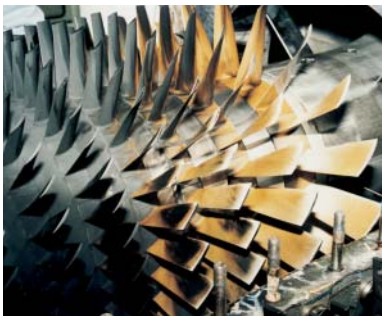
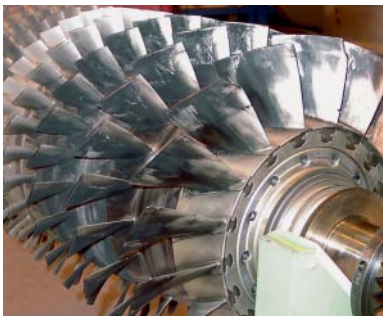
To determine the dust concentration, the dust content per cubic meter of air is measured. The dust concentration is subject to significant geographical and temporal fluctuations. The table shows typical mean values for various regions. In desert areas, the dust concentration may reach such high levels that special inertial separators, for example, are required before the actual filters.

Region	Particle concentration	Particle size range
Residential areas	0.01 - 0.1 mg/m³	0.01 - 5 µm
Country areas	0.01 - 0.2 mg/m³	0.01 - 10 µm
Light-industry areas	0.05 - 0.3 mg/m³	0.01 - 5 µm
Heavy-industry areas	0.1 - 1 mg/m³	0.01 - 30 µm
Coastal regions and offshore	0.01 - 0.5 mg/m³	0.01 - 10 µm
Desert areas	0.01 - 500 mg/m³	0.1 - 100 µm
Arctic areas	0.01 - 0.5 mg/m³	0.01 - 5 µm
Tropical areas	0.01 - 0.5 mg/m³	0.01 - 10 µm

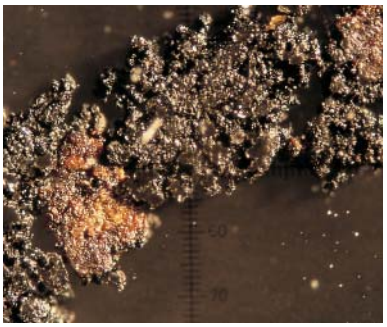


EDX analysis: fouling sample from rotor blades

The damage





LIM picture: Fouling sample 200 µm

Damage category	Particle size range	Gas turbine	Turbo-compressor
Erosion	> 5 - 10 µm	•	•
Fouling and resultant unbalances	appr. 0.1 - 5 µm	•	•
Fouling of the intercoolers and downstream system components	appr. 0.1 - 5 µm		•
Wet corrosion	appr. 0.1 - 5 µm	•	•
High-temperature corrosion	appr. 0.1 - 5 µm	•	
Clogging of the cooling air slits	from 0.1 µm	•	

Filter systems are used to remove particles from the supply air for turbomachinery. The harmful effects of polluted air are minimized by selecting appropriate filters, thus helping to enhance the cost-efficiency of the systems concerned.
The pictures on the left show good examples of how inadequate filtration can result in fouling and dust encrustations; here on the compressor blades and guide vanes of industrial gas turbines.

The table below shows typical categories of damage, and the various particle sizes which cause them.

▶ Abrasive dusts attack the rotating parts, resulting in material erosion.

▶ Fouling of the compressor blades due to caked-on dust causes significant alterations in profile, resulting in substantial losses in efficiency. In addition, if the caked dust breaks off this may produce imbalances, resulting in impermissible stresses on the bearings.

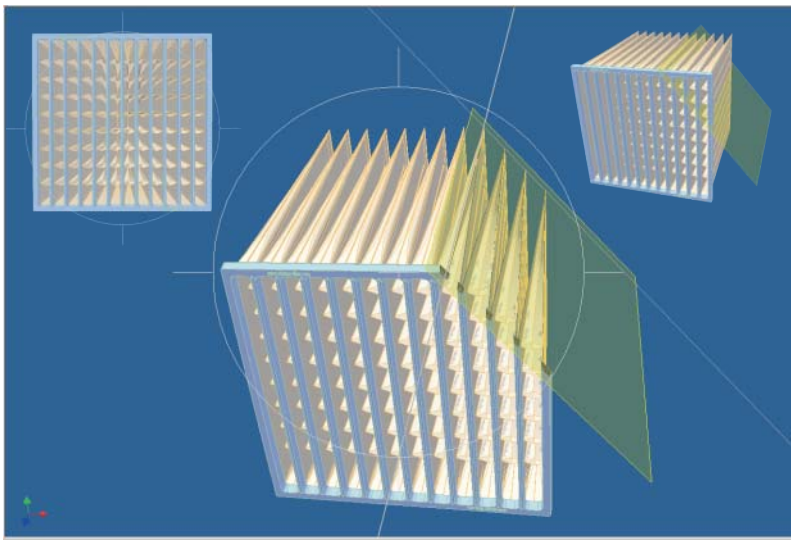
▶ Fouling in the intercoolers reduces the compression heat removal, reducing overall efficiency.

▶ Wet corrosion, caused by the interaction of atmospheric moisture with acid anhydrides, salts and other corrosive substances, may lead to damage, especially at the first compressor stages.

▶ High-temperature corrosion is primarily caused by contamination in the fuel. But air pollution, too, like sulphates from flue-gas desulfurization systems, or metallic oxides at industrial locations, is responsible for corrosion damage.

▶ Clogging up of the cooling air slits in the turbine blades is primarily caused by ultrafine particles with a high specific surface area. The consequence is accelerated material fatigue due to overheating.

The conclusion



Inhouse filter design and engineering with state-of-the-art CAD software

The causal connections between air pollution on the one hand and damage to turbomachinery on the other entail very specific requirements for the filtration system:

- Efficient arrestance of potentially harmful particles.
- Low pressure drops for a given air flow, in order to minimize power losses. For example, 50 Pa less operating pressure drop at the intake system's filters will increase the gas turbine's output by approximately 0.1 %.
- Long useful lifetimes with reliable particle arrestance.

In addition, the tough service conditions encountered demand stringent requirements for operational reliability:

- Even in humid and aggressive atmospheric conditions, the filters must neither lose their mechanical stability, nor corrode.
- The filters must also ensure reliable operation even if the pressure drop rises briefly beyond the design figure.
- The filters, and the assembly as a whole, must stand up to severe mechanical stresses during non-stationary flow conditions (surge) without suffering damage.
- Even after a lengthy period of service, the arrestance characteristics of the filtration system must not deteriorate.

The filters' long-time behaviour can also be tested on site by our specialists. And to supplement the figures thus determined, Freudenberg's metrological laboratory has a wide range of measuring equipment and test rigs available: filter test channel to EN 779, scanning electron microscope (SEM), light microscope, energy-dispersive X-ray spectroscope etc.
A modern quality management system to ISO 9001 monitors each and every operation, from the very beginning of development work and application engineering consultancy all the way through to delivery and after-sales service.

CERTIFIED DIN EN ISO 9001 QUALITY SYSTEM
Reg. No. 1420

Freudenberg
Filtration Technologies
Weinheim/Germany

EUROVENT CERTIFIED PERFORMANCE
AIR FILTERS
CLASS F5-F9

Filter test channel to EN 779 in Freudenberg's metrological laboratory

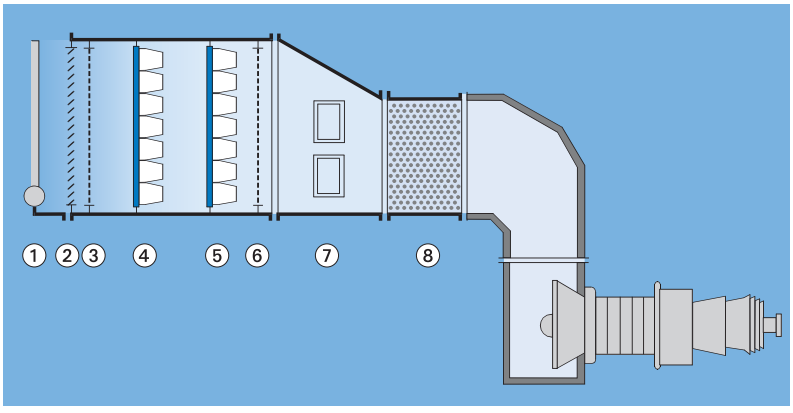
The concept

Selecting a cost-efficient combination of prefilters and final filters is always a project-specific solution, which will be tailored to local factors like the ambient air, the space available, and the turbomachine's specifications.

Our prefilter range is based on the Compact pocket filters in Filter Classes G3 to F6. If the air involved is severely polluted and a high-class final filter is to be used in combination, it is advisable to choose the T60 (F6), with its particularly high dust holding capacity, as prefilter. For single-stage filter systems with limited space we also offer prefilter panels in Classes G3 to F5.
The efficiency of further filter stages is matched to the clean-air requirements of the turbomachinery involved. For these filter stages, we recommend the cassette filters of the MaxiPleat range (F6 to H12) or the pocket filters T 60 (F6) and T 90 (F7).

In air intake systems designed for filter cartridges, both our surface-loading GTC cartridges (for pulse-jet cleaning) and our depth-loading TFP cartridges (no cleaning) have given excellent results.

Besides the selection of filters, the overall design of the air intake system is particularly important. Freudenberg work closely together with manufacturers and users of turbomachinery to work out technical specifications both for the filters and for the specific system involved.



As an example, the picture below shows module options for air intake systems with pocket or cassette filters:

- At locations with low ambient temperatures and high relative humidity during part of the year an anti-icing unit (1) should be provided in order to prevent the filters being blocked by icing up.

- In order to prevent driving rain and mist being sucked into the air intake system, a weather-hood/louver or mist eliminator (2) are installed after the anti-icing unit.

- A close-meshed protective screen (3) makes it impossible for birds and other small animals to penetrate into the space before the filters.

- The first stage filter wall (4) is made of frames either bolted or welded together in an integrated support structure. The prefilters concerned are then mostly installed from the downstream side. Depending on the site conditions involved, inertial separators and/or coalescers can additionally be incorporated.

- The 2nd or 3rd stage filter walls (5) are constructed as the first stage, however, the final stage filter wall is usually welded and final filters are always installed from the upstream side to avoid leaks.

- For enhanced security, an additional protective screen (6) for the air intake duct can be located after the final filters.

- The adjoining transition piece (7) reduces the housing size to fit the turbomachine. By-pass flaps can be fitted to this section.

- These modules are supplemented by a silencer (8) and the air intake duct leading to the turbomachine.

The solution: Viledon Compact pocket filters

F45S Compact pocket filter

T60 Compact pocket filter

T90 Compact pocket filter

Viledon Compact pocket filters are depth-loading filters. The particles are arrested in the filter medium at the fiber surface.
The Compact pocket filters have given cost-efficient, dependable service in a wide range of different applications. Their particular design features offer numerous advantages for turbomachinery operators:

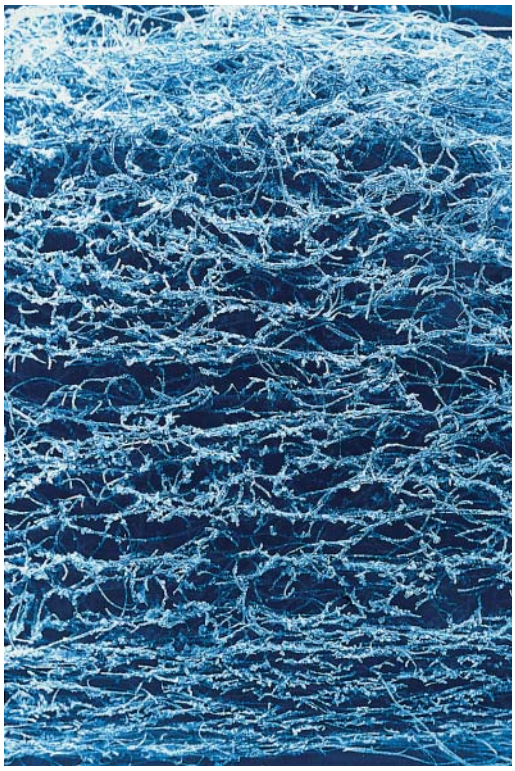
- The filter media of synthetic-organic fibers have a progressive (up to Class F6) or triple-layered progressive structure and provide high dust holding capacity in conjunction with a slow rise in pressure drop and thus long lifetimes.

- The self-supporting design of the filter pockets ensures uniform dust storage. The pockets will neither sag nor collapse, offering maximized security against dust penetration, also at shutdowns or load changes. Even with high dust loads and damp or wet conditions the inherent stability is maintained and offers excellent coalescing properties.

- The filter pockets are edge-welded to prevent leaks and securely foamed into the PU front frame; dust penetration is thus reliably precluded even at high pressure drops.

- The welded-in spacers ensure optimum shaping of the filter pockets during operation, preventing any loss of active filtering area due to pocket surface contact.

- The sturdy polyurethane front frame is corrosion-proof and reinforced by a foamed-in profile for maximum mechanical strength.



Progressively structured nonwoven filter medium *500 µm*

- The filter elements are moisture-resistant up to 100% rel. humidity, thermally stable up to 70°C, stand up well to most chemicals, and can be incinerated.

- Very dependable, maintenance-free and longlife performance.

- High resistance to pressure surges (burst pressure >3000 Pa).

Viledon Compact pocket filters – the design assets

The solution: Viledon MaxiPleat cassette filters

MaxiPleat cassette filter

MaxiPleat Modular System

Viledon MaxiPleat filters constitute a technological milestone in the field of rigid/cassette filters. Their innovative design ensures a performance profile that particularly pays off in turbomachinery operation on- and offshore:

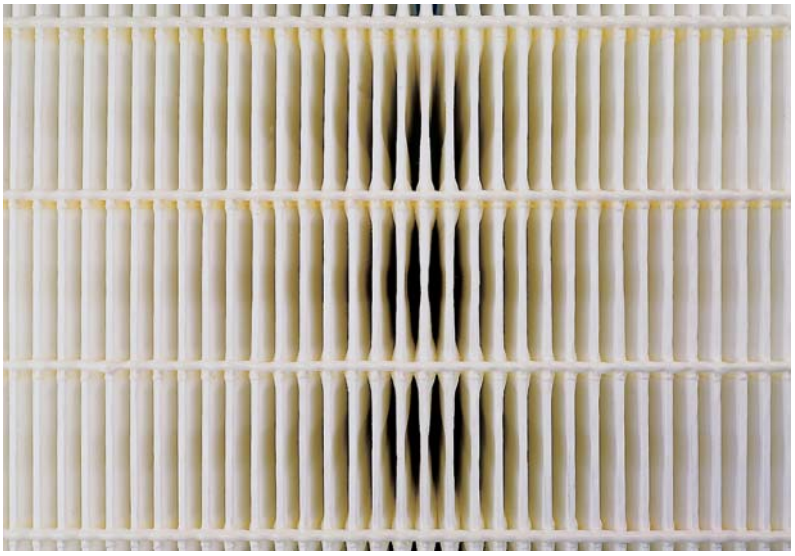
- High-strength glassfiber papers with a special thermoplastic bonding system and a water-resistant coating are used as filter media.

- Our patented thermal embossing process provides optimum pleat geometry with equidistant spacing, as well as homogeneous air flow at a low pressure drop.

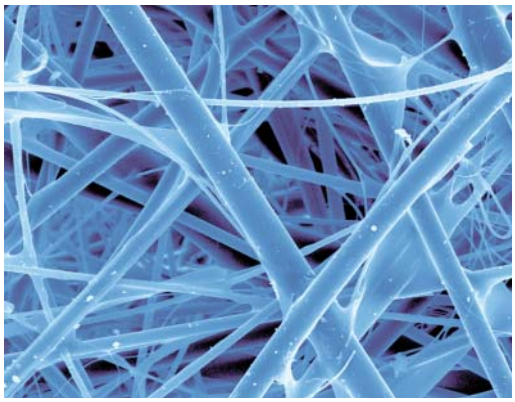
- The V-shaped pleat configuration allows full utilization of the filter area with uniform dust deposition. This in turn means long useful lifetimes and cost-efficient, reliable operation.

- The leak-proof casting of the dimensionally stable pleat pack in the distortion-resistant plastic frame results in outstanding bursting strength and high security against dust penetration.

- Gripping lugs facilitate mounting and removal, and protection grids minimize the risk of damage to the filter medium. An optional water barrier prevents intaken water from reaching the clean-air side. A foamed-on PU gasket is available upon request.



Optimum pleat geometry and equidistance due to patented embossing process



High-strength glassfiber filter medium with a special thermoplastic bonding system *20 µm*

- With the MaxiPleat Modular Filter System, MaxiPleat filters of different filter classes and depths can be combined in a positive fit by simple plug-on. This allows an additional filter stage to be inserted without any rebuilding.

- The filter elements are non-corroding, fully incinerable and light in weight, as they are without any metal parts. Frames and protection grids are made of halogen-free plastic.

- Viledon MaxiPleat filters are moisture-resistant up to 100% rel. humidity and thermally stable up to 70 resp. 80°C.

- The frames and filter media are self-extinguishing to DIN 53438 (Fire Class F1).

- High resistance to pressure surges (burst pressure >6000 Pa).

- The MaxiPleat cassette filters can be operated at velocities from 2.5 up to 4.25 m/s, meaning air intake housings can be downsized, e.g. offshore.

The solution: Viledon surface-loading filter cartridges

GTC 445

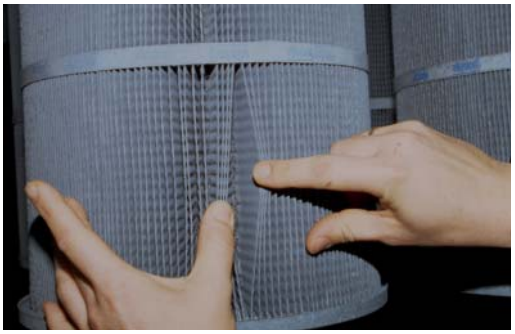
GTC 327

Practical experience with pulse-jet systems has shown that surface-loading filter cartridges with conventional filter media often can not be effectively cleaned, resulting in very high operational pressure drops and frequent pulsing, which leads to severe mechanical stresses on the filter media and high clean-gas concentrations. The useful lifetime of these pulse-jet filters is therefore often shorter than anticipated.

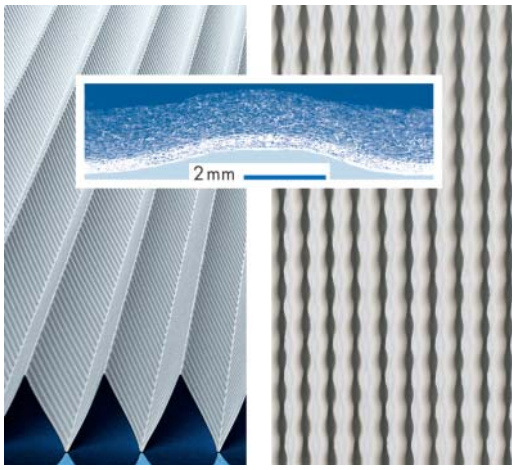
Viledon surface-loading filter cartridges with a patented, corrugated high-performance filter medium are an ideal solution for pulse-jet systems which have to cope with very high dust concentrations and/or fine, pourable dusts, entailing stringent requirements for cleanability. Thanks to their unique corrugated filter medium, the Viledon surface-loading cartridges have won the INDEX 05 Award (Category 4), the highest accolade for achievement in nonwovens, and it renders them unbeatable, particularly in challenging applications:

- The corrugated polyester filter medium with microfibers and a sinusoidal cross-section achieves very high collection efficiency and uniform dust loading in the cartridge even for fine dusts, thanks to its homogeneous fiber structure, and it offers a larger effective filter area than flat media. By reason of its all-over thermal bonding, it also exhibits a smooth surface, and is thus particularly easy to clean.

- The low pressure drop of the corrugated filter medium enables cycle times to be prolonged and cleaning intervals extended, with resultant gains in operational cost-efficiency.



Full utilization of the filtering area, no pleats collapsing



Corrugated high-performance filter medium

- The corrugation keeps the pleats exceptionally stable, preventing them from collapsing even under high volume flows and alternating loads in the cleaning phases. This outstanding mechanical stability renders an external support cage superfluous, which in turn facilitates cleaning and significantly reduces the risk of icing up.

- The excellent cleanability over long periods, using pulse-jet routines and, if desired, even additional appropriate washing, plus the high functional dependability maintain favourable operating conditions coupled with low energy and servicing costs.

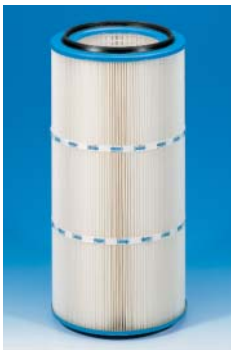
- For a leak-free configuration, the pleated filter medium and the powder-coated support cage are cast into the cover and base of the filter cartridge, both made of galvanized or powder-coated steel. The foamed-on polyurethane gasket ensures optimized sealing with the mounting plate.

- The filter cartridges are thermally stable up to 80°C, largely resistant to chemicals, and 100% moisture-proof, i.e. they stay in shape even when pulse-cleaned in moist condition.

- The filter medium has been tested by an independent institute to EN 60335-2-69 Annex AA (Testing of cleanable filter media), and meets the requirements of Dust Class M.

The solution: Viledon depth-loading filter cartridges

TFP60



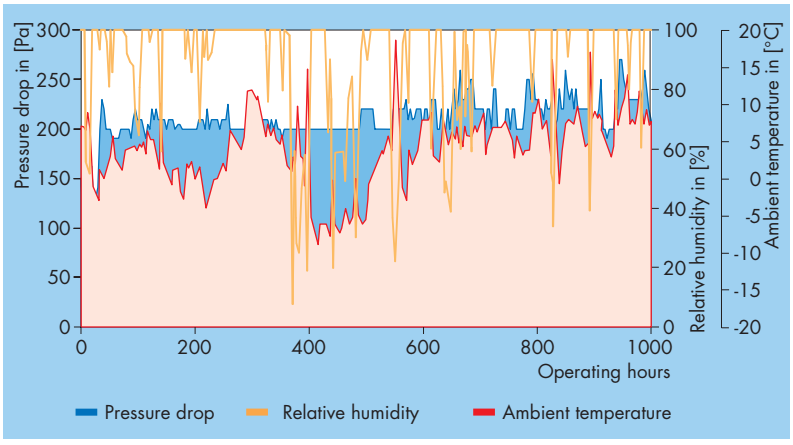
TFP95

TFP98

In applications, in which the cleaning of surface-loading filter cartridges does not produce any effective reduction in pressure drop, because the dust concentrations are too low and/or the dusts concerned are too sticky, the patented Viledon depth-loading filter cartridges are particularly successful. They are dust-storing filters and their exceptional operating characteristics both on and offshore are based on their special design features:

- The nonwoven filter media are progressive (TFP60) and 3-layer progressive (TFP95) in structure, and the TFP98 cartridges feature our innovative hybrid-synthetic nanofiber (HSN) media. They offer optimized filtration performance, as the dust is stored in the depths of the media, combined with a low pressure drop and high dust holding capacity. With their high-efficiency filter media, the TFP95 and TFP98 types are specially suited for locations with a high proportion of fine dust in the ambient air.

- High operational reliability also in foggy and rainy conditions, as the synthetic-organic filter media are 100% resistant to moisture. Empirical feedback from actual installations has shown that even at low temperatures and simultaneous high humidity there are only temporary moderate increases in pressure drop, but no ice blocking (see graph).



Installation near the coast: pressure drop of Viledon TFP60 depth-loading filter cartridges

3-layer nonwoven filter medium, 500 µm inner layer electrostatically spun microfibers (TFP95)

- The pleats will not collapse, even when subjected to higher volume flows.

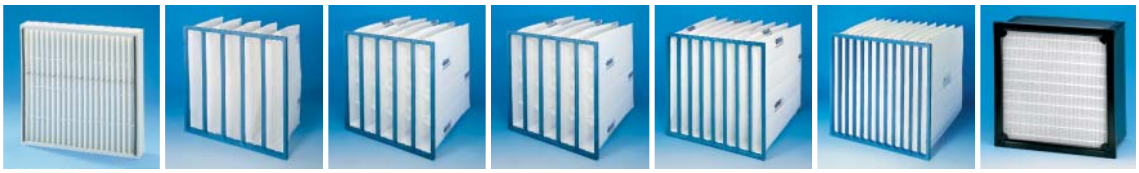
- The pleated medium and the plastic support cage are cast into polystyrene covers and bases to prevent leaks. Cover/base and support cage are also available in surface-finished steel versions and in conical shape on request. A foamed-on PU gasket ensures optimum sealing against the mounting plate.

- Since the cartridges are not supposed to be pulse-cleaned, the compressed-air supply can be dispensed with.

- The cartridges in the metal-free versions are easily disposable.

TFP95 cartridges functioning under icy conditions

The filter survey



	MP 45 KTC	G 35 S F 45 S	G 35 SL F 40	F 50	T 60	T 90	MX 75 MX 85
Filter Class to EN 779	G 4	G 3 G 4	G 3 G 4	F 5	F 6	F 7	F 6 F 7
Nominal air flow rate	3400 m^3/h	3400 m^3/h	4250 m^3/h	4250 m^3/h	4250 m^3/h	4250 m^3/h	4250 m^3/h
Maximum air flow rate	4500 m^3/h	4500 m^3/h	5500 m^3/h	5500 m^3/h	5500 m^3/h	5500 m^3/h	5500 m^3/h
Initial pressure drop at nominal air flow rate	50 Pa	20 Pa 40 Pa	20 Pa 30 Pa	45 Pa	65 Pa	80 Pa	135 Pa 140 Pa
Recommended final pressure drop *	250 Pa	250 Pa	250 Pa	450 Pa	450 Pa	650 Pa	650 Pa
Bursting strength	---	>3000 Pa	>3000 Pa	>3000 Pa	>3000 Pa	>3000 Pa	>6000 Pa
Average arrestance/ ASHRAE dust	91%	86% 95%	87% 95%	97%	99%	>99%	99% >99%
Average efficiency/ ASHRAE dust	n.a.	n.a.	n.a.	51%	63%	85%	75% 86%
Dust holding capacity/ AC Fine/800 Pa	n.a.	n.a.	n.a.	4800 g	5000 g	3500 g	2300 g 1900 g
Moisture resistance/ rel. humidity	100%	100%	100%	100%	100%	100%	100%
Thermal stability/ temporary peaks	70°C 80°C	70°C 80°C	70°C 80°C	70°C 80°C	70°C 80°C	70°C 80°C	70°C 80°C

* For cost-efficiency or system-specific reasons it may be appropriate to change the filters before reaching the stated final pressure drop. It can also be exceeded in certain applications.

Conversion of existing installations is no problem, as the Viledon filter frame dimensions correspond to the standard figures. Further technical data for Viledon filters can be found in the corresponding data sheets.

	MX 95 MX 98	MX 100 MX 120	TFP 60	TFP 95	TFP 98	GTC 327 + GTC 445 (pair)
Filter Class to EN 779	F 8 F 9	H 11 ① H 12 ①	F 6 ②	F 8 ②	F 9 ②	F 9 ②③
Nominal air flow rate	4250 m^3/h	3400 m^3/h	1000 m^3/h	1000 m^3/h	1000 m^3/h	2500 m^3/h
Maximum air flow rate	5500 m^3/h	4250 m^3/h	1500 m^3/h	1500 m^3/h	1500 m^3/h	3500 m^3/h
Initial pressure drop at nominal air flow rate	150 Pa 175 Pa	195 Pa 320 Pa	110 Pa	110 Pa	100 Pa	160 Pa
Recommended final pressure drop *	650 Pa	650 Pa	800 Pa	800 Pa	800 Pa	800 Pa
Bursting strength	>6000 Pa	>6000 Pa	>3000 Pa	>3000 Pa	>3000 Pa	>3000 Pa
Average arrestance/ ASHRAE dust	>99%	n.a.	99%	>99%	>99%	>99%
Average efficiency/ ASHRAE dust	92% 96%	>99%	65%	92%	95%	96%
Dust holding capacity/ AC Fine/800 Pa	1700 g 1500 g	1450 g 1000 g	1200 g	1300 g	2200 g	n.a.
Moisture resistance/ rel. humidity	100%	100%	100%	100%	100%	100%
Thermal stability/ temporary peaks	70°C 80°C	70°C 80°C	70°C 80°C	70°C 80°C	70°C 80°C	70°C 80°C

① Filter class to EN 1822

② Filter class in broad conformity with EN 779

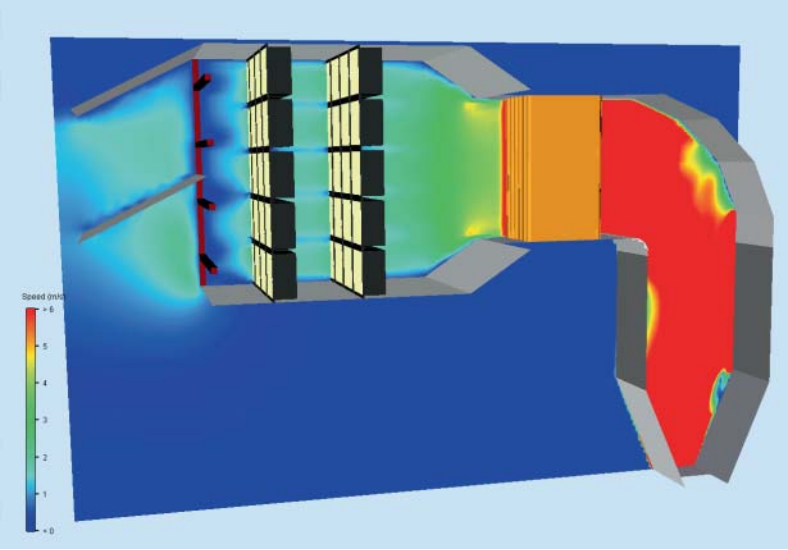
③ tested up to a final pressure drop of 800 Pa

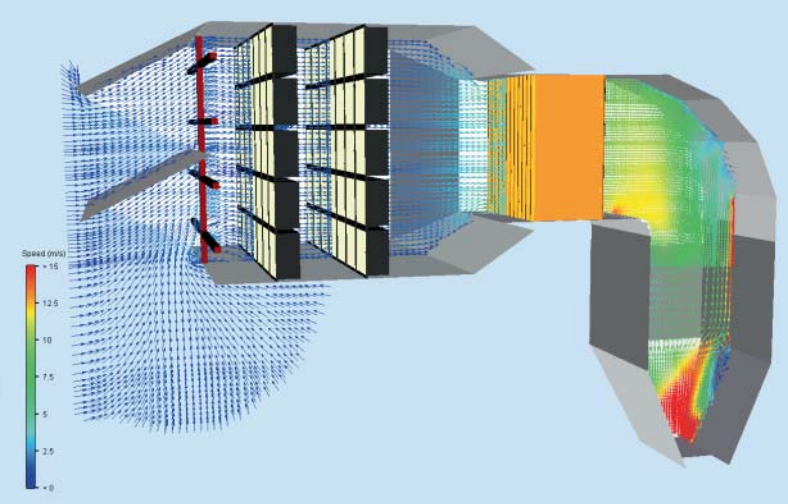
The figures given are mean values subject to tolerances due to the normal production fluctuations. Our explicit written confirmation is always required for the correctness and applicability of the information involved in any particular case. Subject to technical alterations.

You will find instructions on how to handle and dispose of loaded filters in our information on product safety and eco-compatibility.

The services

The Viledon filterCair filter management system is a package assembled from our top-quality filter products and services, tailored to the needs and specifications of our customers. Our long years of practical experience and our broadly diversified product portfolio are your guarantees for the high efficiency and output of your turbomachinery, thanks to innovative, efficient, affordable and eco-friendly solutions.
You receive a flexibly customizable system featuring the individually required mix of Viledon air filters, competent service support and warranties … all of it at fixed, plannable costs.

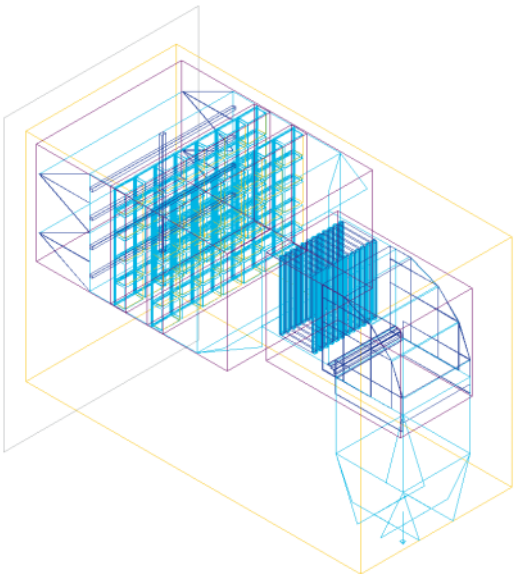




Visualization of flow conditions using computer-aided flow simulation for dimensioning in the run-up to system design work

The filterCair filter management package for gas turbines and compressors offers you the following options to choose from:

- Visualization of the flow conditions using computer-aided flow simulation for dimensioning in the run-up to system design work
- System / location-specific measurements and analyses for determining the location-relevant dust loading, with the aim of optimizing the filtration function
- Dirt and damage analyses using SEM (Scanning Electron Microscopy), EDX (Energy-Dispersive X-Ray Spectroscopy), Light Microscopy as well as Infrared and Raman Spectroscopy
- Supply chain management, correct filter installation, filter replacement and system cleaning
- Monitoring of the air quality and the filters
- Video-endoscopic inspections and damage analysis in the air intake system, compressor stages, combustion chambers, turbine components, gear units



Designing an intake air housing by means of CAD

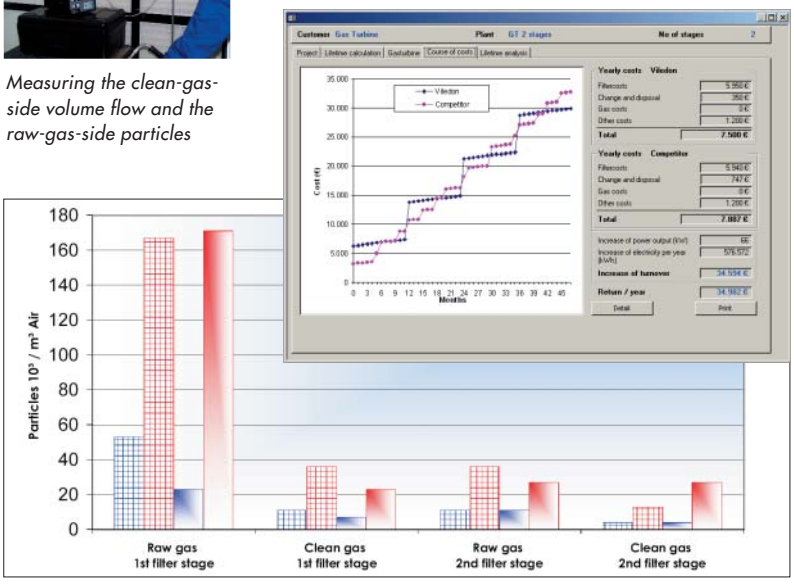
Measuring the clean-gas-side volume flow and the raw-gas-side particles

- Operating cost analyses, covering filter costs, useful lifetime, performance loss, down-times, etc. (cost-efficiency studies)
- Service technicians.

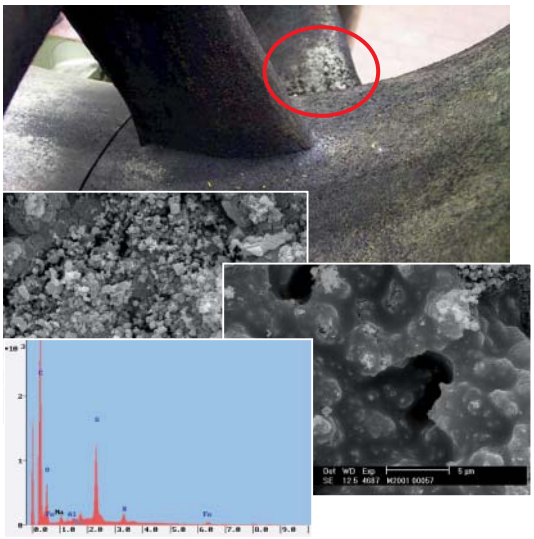
A Viledon filterCair filter management package offers you commercial advantages, thanks to:

- reduced filter, replacement, maintenance and disposal costs
- lower energy costs and enhanced power output
- useful-lifetime risk transferred
- reduced number of washing cycles
- reduced downtimes.

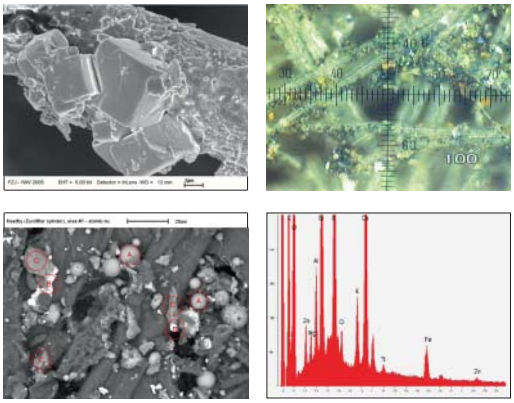
The Viledon filterCair filter management package also leads to improved, monitored air quality and less dirt in the system. Talk to us, we'll be pleased to advise you.



System-specific measurements and cost-efficiency calculations for optimizing the filtration function



Fouling analysis using SEM and EDX



Pictures from various analytical procedures (SEM, LIM and EDX) for the categorization of dust in filters

Material analysis with our ESEM (Environmental Scanning Electron Microscope)

The implementation

4 of 12 air intake systems (278,000 m³/h each) on their way to assembly on an offshore platform (Brazil)

Large filter house module

From plan to plant
Freudenberg deliver complete turnkey air intake systems, constructed on the basis of the jointly defined specifications. The scope of services provided covers consultancy and engineering, manufacture and commissioning, and of course documentation and after-sales service.

Modular design
The special feature of Freudenberg air intake systems is their modular design, permitting customized solutions and offering significant advantages:

Pre-mounted module of a filter housing after arrival on-site (Germany)

- The design can be flexibly adapted to match the local and system-specific considerations involved.

- The modules are assembled completely beforehand, and need only be bolted or welded together, thus facilitating erection and cutting the installation costs.

- This concept also allows the development of standardized air intake systems to suit a particular range of turbomachinery.

The housing for accommodating the filter walls is made of steel or stainless steel sheeting/plate, and is bolted and welded together from separate elements. All other modules of the air intake system are added on to this basic housing. The individual modules can also be installed in already-existing buildings. The size of the individual elements depends on the erection and transportation options available.

Modernization
Freudenberg provides an analysis service for checking out the cost-efficiency of existing filter systems. Those which are found to no longer satisfy the requirements of cost-efficient operation can be modified for Viledon filters.

When modernizing existing systems, individual assemblies can be quickly and therefore inexpensively replaced, e.g. during brief standstills.

Air intake system being installed at a new compressor station

From the field: cleanroom technology adopted for a gas turbine's intake air system

Paper and cardboard factory, on the North German coast

Location	Germany, North Sea coast
Gas turbine	Siemens Tempest / 1 unit
Power output	7.6 MW
Intake air flow rate	approx. 90,000 m^3/h
Intake air system / filters fitted	3-stage filter system, each stage with 36 Viledon filters, size 1/1: 1st stage T60 pocket filters, Filter Class F6 2nd stage MX98 cassette filters, Filter Class F9 3rd stage MX100 cassette filters, Filter Class H11

View into the 3rd filter stage

At this paper and cardboard factory, electricity, steam and heat for operating the paper machines are generated in the firm's own power plant, featuring two gas turbines. The description below relates to the new gas turbine plant, installed in 2002.

The basic design stipulation for the intake air filter system of this new gas turbine plant was the client's wish to dispense with any washing routines for the compressor blades (online and offline), i.e. to ensure optimum protection for the gas turbine, so as to increase the machine's efficiency and availability.

An innovative 3-stage filter system was accordingly chosen, with MX 100 cassette filters of Filter Class H11 in the third stage.
In the first stage, T60 pocket filters of Filter Class F6 can be relied on to arrest the main particle loading even under difficult weather conditions. The second stage incorporates MX 98 cassette filters of Filter Class F9, to provide optimum protection for the high arrestance filters of the third stage.
To counteract what would normally be an increased pressure drop over the third stage, the filter housing has been made correspondingly larger.

Infrared anti-icing unit

- The gas turbine has been operating at 100% output since the trial runs, without any washing required.
- After more than 4000 h, the blades exhibit no fouling (dust caking) whatsoever. The pressure drop over the three filter stages has not increased during this period, and still corresponds to the initial pressure drop (230 Pa).
- Another special feature of the Viledon intake air system is the innovative infrared anti-icing unit, designed to prevent the first filter stage from icing up in winter. It has been integrated into the filter housing for maximized space savings, is easy to handle, with the additional advantage that despite the radiant heat the intake temperature shows practically no rise. The resultant higher fill factor leads in turn to an increased turbine output.
- The entire cleanroom section has been made from V4A stainless steel (1.4571) and designed to accommodate a FOG evaporate cooling system as a retrofit option. This enables the intake temperature to be lowered in summer, so as to increase the fill factor again.

This installation demonstrates that it's worth while investing in sophisticated technology even when the purchase price for certain components appears somewhat higher at first glance. In the long run, however, this kind of investment pays off in terms of increased availability, dependable plant operation and enhanced overall cost-efficiency.

From the field: retrofitting of an original equipment air intake system to improve performance

1st and 2nd filter stages

This GE Frame 9FA power station produces electricity for the national grid system. The study relates to a retrofitting project implemented by Freudenberg to improve the original equipment air filtration system. The primary design specification was to extend the lifetimes of the air filters, allowing the gas turbines to operate non-stop except for the annual maintenance shut-downs (after approx. 12 months or 8000 operating hours).

The customer was experiencing high and unstable pressure drop, with the original equipment prefilter pads requiring frequent changes (< 2000 hours) due to their low dust holding capacity. Also, the poor fastening arrangement of the prefilter pads allowed bypass of the dirty air, which caused short lifetime of the final filters (< 8000 hours).

Therefore, customized 2-stage Viledon filter systems were designed and installed, with T60 pocket filters of Filter Class F6 fitted in a stainless steel prefilter wall. The 2nd stage incorporates MX95 cassette filters of Filter Class F8 to provide high dust holding capacity combined with optimized protection in accordance with the gas turbines' specification.

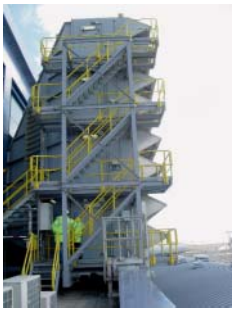
- The customer now reaches filter lifetimes of 16,000 h in the 1st stage and 24,000 h in the 2nd stage. The prefilters are operated at a higher air flow rate, as the 250 T60 pocket filters offer a 10x larger filtering area and corresponding dust holding capacity than the previous 440 prefilter pads. Also the MX95 final filters exhibit an approx. 20% higher dust holding capacity than the previous final filters.
- A consistent, lower pressure drop is achieved, so the gas turbines' performance and output is optimized.
- Safety risks for the personnel are avoided, as the filters no longer need to be changed on-line, but only at the scheduled maintenance shutdowns.

Location	UK, rural / near motorway
Gas turbines	GE Frame 9FA / 2 units
Power output	220 MW each
Intake air flow rate	1,764,000 m^3/h each
Intake air systems / filters fitted	2-stage filter systems, 2nd stage chevron-shaped / 1st stage: 250 Viledon T60 pocket filters, Class F6 2nd stage: 440 Viledon MX95 cassette filters, Class F8

Stainless steel prefilter wall

From the field: Viledon filters operating in a large coastal power station

Large power station, located approx. 100 m from the coast



This 400 MW combined-cycle power station is located at a harbour on the South Coast of England and supplies electricity to the national grid. The 300 million Euro facility comprises a 260 MW advanced technology gas turbine and a 140 MW steam turbine, and was commissioned in December 2000.
The air intake system was constructed by a partner company, who have worked in co-operation with Freudenberg for 30 years.

Due to the coastal location several key environmental aspects had to be considered: the seawater effect, airborne emmissions, visual impact and noise.

- The complete air intake housing and filter frame matrix was manufactured from stainless steel to avoid salt corrosion.
- A weather hood was fitted to handle heavy rains and a high-efficiency mist eliminator was installed to remove fine water droplets which can carry salt particles.
- The two separate filter stages were built with maximized filter wall distance to allow coalesced water droplets to fall out under gravity. Mesh flooring was used to allow drainage to occur at all filter levels.
- Viledon air filters were chosen as they met the stringent OEM specification and the arduous climatic and site conditions. In the 1st stage, T60 pocket filters (Class F6) are used to arrest the main airborne particles and coalesce any remaining droplets not removed by the mist eliminator. In the 2nd stage, MX95 cassette filters (Class F8) give excellent service thanks to their high-efficiency filter media with water-resistant coating.
- Filter lifetime of 20,000 h / 33 months was achieved, which exceeded the operator's and the OEM's expectations of 17,000 h or 24 months. The pressure drop was slowly increasing at a comparatively low level over the total filter lifetime. It was noted that other plants with similar climatic conditions required filter change every 12-18 months.

Location	UK, South coast, harbour
Gas turbine	Alstom GT26 / 1 unit
Power output	400 MW
Intake air flow rate	1,700,000 m^3/h
Intake air system / filters fitted	2-stage filter system, with weather hood, mist eliminator 1st stage: 384 Viledon T60 pocket filters, Class F6 2nd stage: 384 Viledon MX95 cassette filters, Class F8

From the field: Viledon filters pass the trial for performance and cost-efficiency

3-sided air intake filter system of the combined-cycle power plant (Philippines, SEA)

This combined-cycle power plant delivers electricity to the national grid, which is distributed to the end users by the local utilities.
A new air intake filter design from Freudenberg was installed and put on trial during the major outage. The original design incorporated a 3-stage filtration system – one wall with coalescer mats and one wall with pre-filters and fine filters (Classes G4 / F8) combined. The new Viledon system is a 2-stage filtration design, with T60 pocket filters of Class F6 as pre-filters with coalescing properties, and MX95 cassette filters of Class F8 as final filters, in two separate walls.
Based upon the information retrieved after 12 months of operation, the major benefits of this two stage Viledon filtration system are:

- A higher gas turbine power output is experienced, due to a reduced pressure drop across the two filter stages.
- Extended time period between filter replacement – the projected lifetime of the new filters is more than twice that of the originally installed filters. The main reason for the extended lifetime is the larger surface area, and thus higher dust holding capacity, of the new T60 pre-filters.
- Reduced outage time and manpower required for replacement due to the new frame design with two individual filter walls, resulting in quick fit installation.
- The higher filtration class of the new pre-filters traps more small hydrocarbons, particles, and humidity and thus increases protection of the fine filters.

The installation involved modification to the filter houses, including construction of pre-filter holding framework, changes to fine filter frames and impulse lines for pressure drop measurement. Based upon the good operation results and low maintenance costs in this trial unit, Viledon filter systems were also installed in the other 5 gas turbine units of the site.

Location	Philippines, South East Asia
Gas turbines	V.84.3A2 / 6 units
Power output	250 MW each
Intake air flow rate	1,640,000 m^3/h each
Intake air systems / filters fitted	2-stage filter systems, 1st stage: 400 Viledon T60 pocket filters, Class F6 2nd stage: 357 Viledon MX95 cassette filters, Class F8

From the field: 12 complete air intake systems for 3 offshore platforms

One of the offshore platforms, with 8 air filter systems (4 for combustion, 4 for ventilation)

Generation modules before and on leaving to the platforms

Construction phases

Intake air filter housing for ventilation, 2-sided

These large new offshore platforms, owned and operated by the Brazilian state oil company, will extract oil and gas at a water depth of approx. 2000 m. Each of the 3 platforms has 4 gas turbines and is expected to produce approx. 180,000 barrels of oil per day, or 10% of the total national production, plus 6 million standard cubic meters per day of associated gas.

Working with the customer for many years, which included filter supply and retrofit work, Freudenberg was awarded the contract to build 12 intake air filter systems for combustion and the corresponding ones for ventilation of the gas turbines. The scope of supply included engineering, manufacturing, construction and assembly at our Brazilian facilities in Rio de Janeiro. The filter systems were tailored to withstand the special climatic conditions, e.g. the effect of salt, to be encountered offshore:

- The complete air intake housings were manufactured from stainless steel and painted to avoid corrosion.
- Weather hoods were fitted to handle heavy rains, together with droplet separator vanes that remove water droplets which can carry salt particles.
- The 2nd stage prefilters arrest the main airborne particles at a low pressure drop and coalesce remaining fine droplets and mist after the 1st stage droplet separator vanes.
- Wider stage distances with mesh flooring allow drainage of the coalesced water droplets.
- The high-performance pocket filters offer long lifetimes, an important request in offshore platforms due to the expensive disposal.

Location	Brazil / offshore
Gas turbine / units	Rolls Royce RB211 / 12 (3x4)
Power output	25 MW each
Intake air flow rate per unit	278,000 m^3/h for combustion 50,000 m^3/h for ventilation
Intake air systems / filters fitted	4-stage filter systems for combustion intake air: 1st stage: Weather hoods + droplet separator vanes 2nd stage: 56 Viledon G35SL pocket filters, Class G3 3rd stage: Mist eliminator 4th stage: 56 Viledon T90 pocket filters, Class F7 3-stage ventilation systems: 1st stage: Weather hoods 2nd stage: Droplet separators 3rd stage: 12 Viledon G35SL pocket filters, Class G3

From the field: lifetime improvement of a pulse-jet cartridge air filtration system

The filter housing

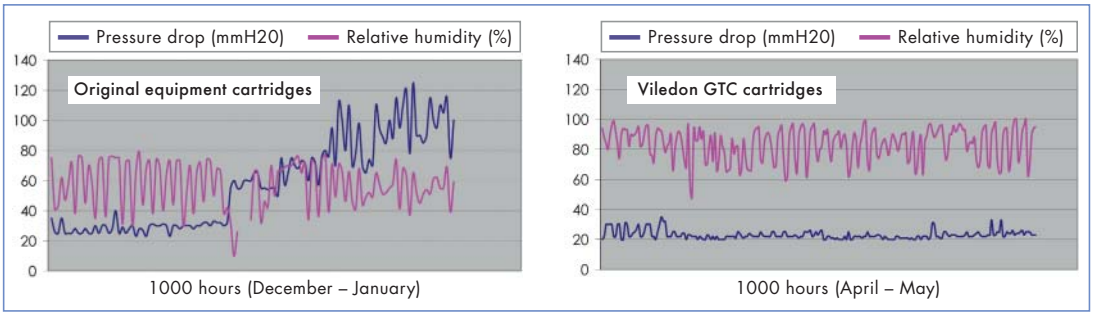
Viledon cartridges GTC 327+445 after 1000 h

This site near the sea operates two gas turbines for cogeneration for a paper mill. The case study relates to retrofitting of the original equipment pulse jet cartridges to the current Viledon GTC cartridges, in order to improve cost-efficiency and performance. The operator was experiencing rapidly increasing pressure drops due to the oily environment, pollen and high relative humidity, occuring especially in the spring months.
The primary specification was a long lifetime of the air filters to avoid unnecessary shutdowns between the maintenance periods of approx. 4000 h. The operator decided to fit the Viledon GTC cartridges in a conical/cylindrical combination, mounted horizontally onto the existing filter frame system. Their synthetic corrugated media proved impervious to the humidity and excelled in filtering performance, cleanability and reliability:

Location	Spain, Industrial area
Gas turbines	LM6000 PC / 2 units
Power output	43 MW each
Intake air flow rate	468,000 m^3/h each
Intake air systems / filters fitted	1-stage filter systems, with 168 sets of Viledon surface-loading filter cartridges GTC 327 (cylindrical) + GTC 445 (conical), Class F9 mounted horizontally

- Lifetime of the Viledon cartridges is now > 8000 hours, where previously only 1000~ 2000 hours were achieved.
- The filter pressure drop is slowly increasing at a low level (230 Pa after 1000 h, 300 Pa after 5700 h, 420 Pa after 8000 h) even with high relative humidity, so the operator can maximise power output.

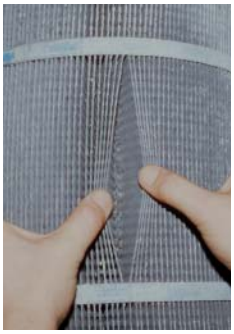
The graphics show the pressure drops of the two types of cartridges over a period of 1000 operating hours and the relative humidity on site.



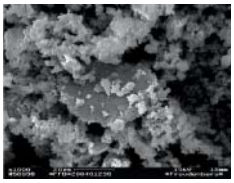
From the field: GTC surface-loading filter cartridges successfully handle marathon duty in a chemical plant

GTC surface-loading filter cartridges at a chemical plant in Germany

Location	Germany, near the Rhine
Gas turbines	Ruston Tornado / 2 units
Power output	6.2 MW each
Intake air flow rate	approx. 82,000 m^3/h each
Intake air systems / filters fitted	1-stage filter systems, with 80 Viledon GTC 327 S12 S5 surface-loading filter cartridges Filter housings mushroom type, with intake air cooling system on the evaporation principle and pressure drop monitoring (alarm level at 900 Pa)



Stable pleats, full utilization of the filtering area



SEM picture: dust sample from a GTC cartridge

The customer is a producer of additives and catalysts for paints, varnishes, plastics and refineries, and at his plant in Germany operates two cogeneration systems featuring two Ruston Tornado gas turbines for generating heat and power.

Because of the plant's proximity to the Rhine, there are often periods of high humidity during gas turbine operation. The cellulose cartridges originally used reacted to the moisture with high pressure drop peaks. After only 3000 h, a pressure drop of 700 Pa had been reached, at which the cartridges were cleaned by pulse jet. After approx. 7000 h, the cartridges had to be replaced by reason of the high pressure drop.

▶ In December 2001, Viledon GTC 327 S12 S5 surface-loading filter cartridges were installed, which were operated until April 2005 without cleaning at a low pressure loss level. The intake air cooling system was activated every year from approx. May to September, and not only increased the efficiency of the gas turbines but also the moisture loading on the filters. Nonetheless, the pressure drop in December 2004, after three years of operation (approx. 8600 hours p.a.), was just 600 Pa. After this, the pressure drop rose merely in humid periods to briefly approach the alarm value of 900 Pa. For this reason, in April 2005 the customer decided to change the filters, and replace them by new GTC cartridges of the same type. After all, the Viledon GTC cartridges had achieved more than triple the lifetime, and also a far higher efficiency than the cellulose cartridges previously used.

▶ Whereas when the cellulose cartridges were installed two online washing procedures were required for the turbines each week and one offline washing procedure a month, with the Viledon GTC cartridges no online washing procedures are now needed, and one offline washing procedure every three months suffices to maintain the turbines' output.

▶ By using the GTC cartridges, the operator has substantially reduced the costs for washing procedures. In addition, during periods of high humidity reliable operation can be observed without any lasting severe pressure drop peaks. The average pressure drop lies far below that of the cellulose cartridges previously used, which means the power output of the gas turbines is maintained at a consistently higher level.

▶ Since the new GTC cartridges were installed in April 2005, the average pressure drop in the air intake system, from its initial 380 Pa, has currently reached 450 Pa – a rise of only 70 Pa after more than 23,000 operating hours so far.

From the field: depth-loading filter cartridges keep fine, sticky dusts under control

Depth-loading filter cartridges TFP 95 in the filter housing

This cogeneration plant is located in an industrial area and produces steam for the processes and warm water for the buildings' heating. Cogeneration plants in France operate under the EDF cogeneration contract, under which they have to supply power between November 1 and March 31, corresponding to 3624 up to 4500 h/annum.

The intake air system for the gas turbine was previously equipped with paper media cartridges of Ø 410 mm, but the operator on site was very dissatisfied with their pressure drops and lifetimes.

Freudenberg then were asked by the client for support and technical expertise in order to define the appropriate cartridge design for the site conditions concerned. As fine, sticky industrial dusts predominate on this site, it was decided to install the Viledon depth-loading filter cartridges TFP 95 with Ø 410 mm, in 156 sets of 2 cartridges. And in practice this proved to be the right choice:

- Our TFP 95 depth-loading filter cartridges were installed from October 2001 until October 2007 and were operated for almost 22,000 h (6 seasons at 3624 h per season).
- To optimize operation, the customer performed one offline washing every 10 weeks, but not any online washing, following our recommendations.
- As part of the support for the operator, annual analyses of the filters were carried out in the Freudenberg Laboratory. The analysis after the 4th season showed that the filters were still working in accordance with the specification and could start into a new season.
- After the 6th season, finally, at an operating pressure drop of approx. 270 Pa, new sets of TFP 95s were installed. With optimized life-cycle and maintenance costs under safer operating conditions, we have matched all the operator's expectations, as he himself stated.

Location	France, industrial area
Gas turbine	GE PG6551 / 1 unit
Power output	43 MW
Intake air flow rate	approx. 400,000 m^3/h
Intake air system / filters fitted	1-stage filter system, with 312 Viledon depth-loading filter cartridges TFP 95, Filter Class F8 mounted as 156 sets of 2 cartridges

From the field: depth-loading filter cartridges stand up to arctic weather conditions

TFP 95 depth-loading filter cartridges function reliably at temperatures of down to –35°C thanks to porous ice layers

Sideview of the outdoor intake air filter housing

Porous ice layers on the TFP 95s at –21°C

Blocking, non-pulsable ice layers on the competitor's cartridges previously used at –15 to –20°C

The customer operates an air separation plant in the north of Scandinavia, where he supplies a steelworks with liquid oxygen. Extremely high standstill and start-up costs in steel production mean that supplies of liquid gas must never be interrupted.

The compressor's intake air was originally purified using cleanable filter cartridges. Any ice layers forming during the winter months were supposed to be detached from the filter cartridges using a pulse-jet system, thus ensuring continuous operation. In actual practice, however, the cleaning behavior was unsatisfactory, since the ice that formed was too firmly attached to the outer metal support cages of the cartridges, rendering it impossible to detach the ice, which accordingly blocked the air intake, requiring the compressor to be shut down when the pressure drop reached 1000 Pa. This resulted in unscheduled downtimes, in which no liquid gas could be produced.

▶ In the summer of 2006, the air intake was re-equipped to feature fully synthetic Viledon TFP 95 depth-loading filter cartridges. The initial pressure drop of the TFP 95s was a mere 180 Pa, compared to the 270 Pa of the previous cartridges.

Location	North Scandinavia
Compressor	Siemens / 1 unit
Intake air flow rate	approx. 170,000 m^3/h
Intake air system / filters fitted	1-stage filter system, with 128 Viledon depth-loading filter cartridges TFP 95 W12 S5, Filter Class F8

▶ The crucial advantage of the TFP 95s then emerged during wintertime. During heavy snowfall and at temperatures of down to approx. –20°C, the pressure drop remained stable at approx. 320 Pa. Even under the nastiest of weather conditions, at –35°C and in a snowstorm, the pressure drop rose to a maximum of 800 Pa, and the compressor could be operated continuously. The layer of ice forming remained sufficiently porous to permit enough air to flow in. Pulse-jet cleaning was dispensed with.

▶ The extreme sturdiness and the special media characteristics of the Viledon depth-loading filter cartridges thus, to the customer's great satisfaction, enable the system to be operated without any interruptions even under conditions of extreme cold.

From the field: the T60 Compact pocket filters also in their element on the high seas

A view of the ship's funnel with filter modules mounted at the sides

The cruise liner "Serenade of the Seas"

An assembled intake air filter housing, with an upstream water separator

Early in 2002, staff from one of Germany's biggest shipyards contacted us and asked for advice regarding the gas turbine air intake systems for the turbine-driven ships of the Royal Caribbean Cruise Line (RCCL).
There are 4 ships involved, launched in 2002: Radiance of the Seas, Brilliance of the Seas, Jewel of the Seas and Serenade of the Seas.
Each of them features two LM 2500+ units for power generation, each rated at 26 MW. This electricity is utilized mainly by two 19-MW electric motors, installed in what are called POD drives, which power the ship's propellers. These drives serve simultaneously as rudders, since they are swivel-mounted.

The gas turbines used require intake filters in order to prevent any soiling on the compressor blades. The filters previously installed were providing inadequate arrestance and exhibiting an excessive pressure drop. The load on each filter was more than 6000 m^3/h, since the 226,000 m^3/h of intake air, plus the cooling air for the turbines' sound-proofing hoods, all flow through these filters.

Location	4 cruise liners
Gas turbines	2 LM 2500+ each per ship
Power output	2 x 26 MW per ship
Intake air flow rate	226,000 m^3/h each
Intake air systems / filters fitted	1-stage filter systems, with Viledon T60 pocket filters, Filter Class F6, 36 filters in size 1/1 + 12 filters in size 5/6 each

▶ Because of the restricted space available in the ships, only 36 T60 1/1 and 12 T60 5/6 units could be provided for each turbine: we installed the filters together with the support frames in the intake system designed by the shipyard.

▶ Actual operation confirmed, that despite the loading, high arrestance and long lifetimes were being achieved. The filters are mounted at the sides and front of the ships' funnels. The cleaned air then flows through 50-m-long ducts down to the power plant directly into the turbines' intake apertures.

Freudenberg Filtration Technologies KG
69465 Weinheim/Germany
Tel. +49 (0) 6201/80-6264 | Fax +49 (0) 6201/88-6299
viledon@freudenberg-filter.com | www.viledon-filter.com

LMP 046 June 2008 GK • Replaces all previous issues of this brochure.