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CONTROL OF FINE PARTICULATE MATTER BY MEANS OF HIGH EFFICIENCY ePTFE MEMBRANE FILTER LAMINATES

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Abstract:

The COUNCIL OF THE EUROPEAN UNION has enacted laws to improve the quality of the ambient air: The "COUNCIL DIRECTIVE 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air" and the "DIRECTIVE 2008/50/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 May 2008 on ambient air quality and cleaner air for Europe".

The Member States had to bring into force the laws, regulations and administrative provisions necessary to comply with these Directives.

These Directives are raising the expectations on the reduction of fine particulate matter on the potential emitters, mainly public traffic, industry and waste-to-energy (WtE) plants.

Although there is currently no European regulation on stack emissions of fine particulate matter, local regulatory authorities have tightened the emission limits of total particulate matter.

For example, quite a number of Italian WtE plants are expected to meet dust emission levels of less than 2 mg/m³.

In order to assure compliance strong efforts and large investments have been made to optimize the efficiency of their APC system.

Different dust filtration technologies will be compared and the filtration principles of depth filtration and surface filtration will be detailed.

A comparison of an experimental study and the practical performance of the different technologies are discussed.

Special focus will be given to the development and application of High Efficiency Membrane Filter Laminates for retention of fine particulate matter.

These filter materials consist of micro-porous expanded PolyTetraFluoroEthylene (ePTFE) membranes laminated onto suitable backing materials, retention rates of > 99.99 % of PM_{2.5} have been achieved.

A number of large European WtE plants have already completed their APC upgrades by using the High Efficiency Membrane Filter Laminates.

Some of them are on operation for a couple of years, performance reviews will be detailed.

Introduction:

Long-term observation and academic and industry based studies such as the “Harvard Six-Cities Study” and the “National Morbidity, Mortality and Air Pollution Study” (NNMAPS), confirm the correlation between the concentration of fine particulate matter in ambient air and serious health problems.

The European legislative authorities have responded to this issue. Currently there is no regulation for the emission of PM₁₀ or PM_{2.5}, but the Directive 2008/50/EC of the Council [1] is setting limit values for ambient air quality.

Limit values for the protection of human health:

A 24-hour limit value of 50 µg/m³ PM₁₀, not to be exceeded more than 35 times a calendar year (Already in force since 1 January 2005).

Potential reduction measures:

In 2005 in a study of the German Federal Environmental Agency (UBA) the emission inventory on TSP (Total suspended particulate matter) and the fine fractions (PM₁₀ and PM_{2.5}) was updated. On this basis a reference scenario was developed for anthropogenic emissions of particulate matter up to the years 2010, 2015 and 2020. In addition potential emission reduction measures were systematically collected and quantified [3]. Figure 1 shows a selection of Industries, were fabric filters contributed significantly to the reduction of fine particulate matter emissions or may have the potential for future emission reduction measures.

Comparison of fabric filtration technologies

In the past there used to be a differentiation between surface filtration and depth filtration, nowadays fabric filter media are mainly classified in differently surface-treated filter media and ePTFE membrane filter media.

Surface treated filter media require the build-up of a protective filter layer of dust to collect fine particulate matter. As long as the filter layer is in place the collection efficiency is high. Increasing differential pressure across the filter media requires periodical cleaning with compressed air. The cleaning pulse removes the filter layer and time is required to build up a new layer.

This phase allows fine particulates to migrate in and across the filter fabric.

This periodic sequence of cleaning results in a number of small emission peaks. As long as the differential pressure and the cleaning frequency are low the total of

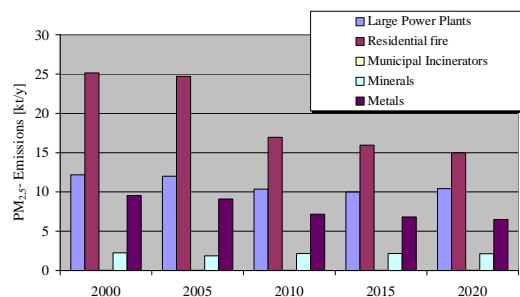
National limit values for PM_{2.5}:

Stage 1: A limit value of 25 µg/m³ to be met by 1 January 2015.

Stage 2: A limit value of 20 µg/m³ to be met by 1 January 2020.

The Directive 2008/50/EC defines PM₁₀ respectively PM_{2.5} as “particulate matter which passes through a size-selective inlet as defined in the reference methods for the sampling and measurement of PM₁₀, EN 12341, and PM_{2.5}, EN 14907 with a 50 % efficiency cut-off at 10/ 2.5µm aerodynamic diameter”.

In American literature particulate matter is also differentiated in fine (< 2.5 µm) and coarse modes, depending on source, size, chemical composition and atmospheric behavior [2].



Source: Umweltbundesamt, Emissions- und Maßnahmenanalyse Feinstaub 2000 - 2020

Figure 1: Reference emissions scenario for PM_{2.5} - Emissions in Germany [kt/y]

the emission spikes is well below regulations for fine dust.

Thus using surface-treated filters the emission of particulate matter is a function of the overall condition of the filter media; once the differential pressure increases over time, faster cleaning is required and the dust emission is growing.

ePTFE Membrane Filters do not depend on a protective dust layer, the filtration is always performed by the ePTFE membrane. The emission of particulate matter remains constantly low independently from service life of the filter material or cleaning frequency.

The specific appearance and the functions of surface-treated filter media and ePTFE membrane filters are depicted in the figures 2 and 3.

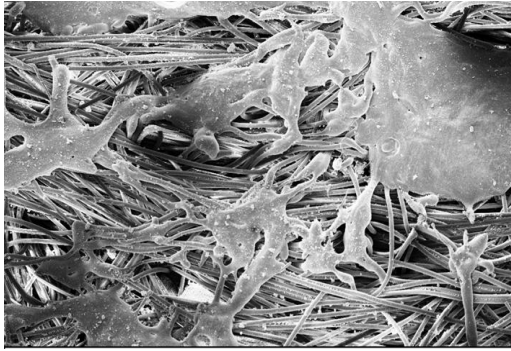


Fig. 2: Surface-treated Filter media, 50x magnification

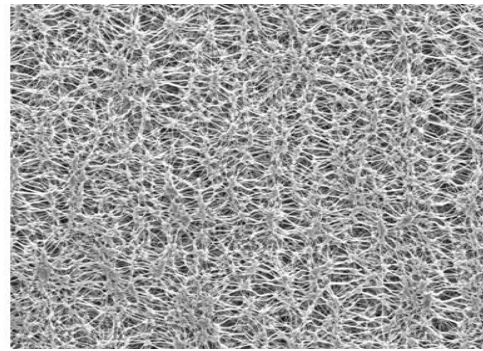


Fig. 3: ePTFE filter membrane, 1500 magnification

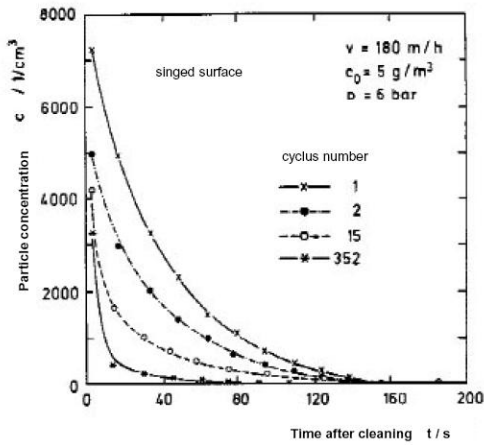


Figure 4: Surface-treated filter media, Pilot measurements [4]
Development of particle concentration after cleaning

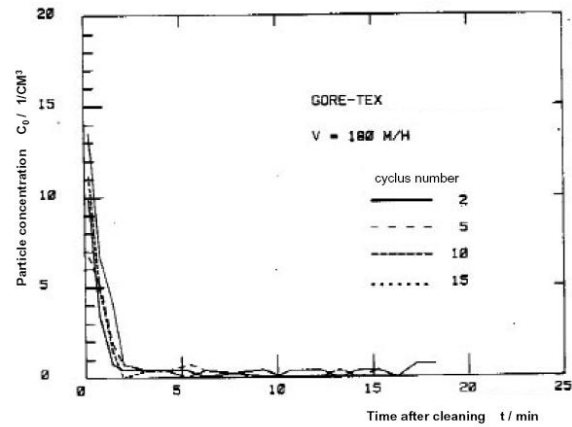


Figure 5: ePTFE membrane filter, Pilot measurements [4]
Development of particle concentration after cleaning

Pilot tests at the University of Karlsruhe [4] show the significant difference between the two technologies. The surface treated media shows clear emission spikes after the cleaning pulse (fig. 4),

the particulate emission of the ePTFE membrane filter is in the range of the detection limit (fig. 5).

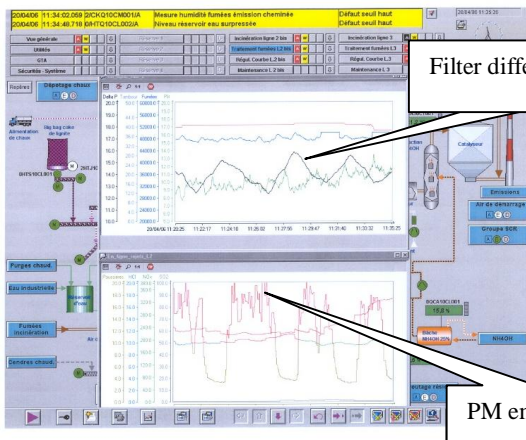


Figure 6: MSWI, Surface treated filter
Particulate emission 3 – 20 mg/m³

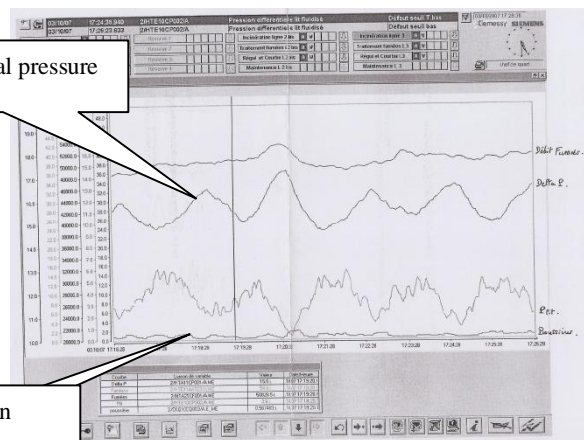


Figure 7: MSWI, ePTFE membrane filter
Particulate emission 0 – 2 mg/m³

This behavior can also be seen from the example of a municipal waste incinerator plant, where the strong dependence of the dust emission from filter cleaning caused periodically heavy emission of particulate matter.

When the pulse-jet system started to clean the surface-treated filters, the dust emission grew to spikes of 20 mg/m^3 until the differential pressure

across the fabric filter reached the lower threshold. Once a cleaning cycle stopped the emission decreased to 3 mg/m^3 (fig. 6).

After replacement of the surface-treated filters by ePTFE membrane filters the dust emission remained always below the detection limit (fig. 7).

Methods of testing Filter Media:

Increased environmental demands require higher quality of industrial filter media. The filter media suppliers are continuously improving existing products and are developing new concepts.

For the technology buyer it is not easy to decide for the most efficient and most cost effective product of the large portfolio of filter media available on the market.

There are multiple methods of testing industrial filter media, but usually the results are not accessible for the technology buyers and permittees. An exception is the ETV testing program of the American EPA.

ETV Tests

The "Environmental Technology Verification Program" (ETV) [5] supplies technology buyers and developers, consulting engineers, states, and permittees with high quality objective

data on the performance of new or improved technologies. Availability of these data encourages more rapid protection of the environment with better and less expensive approaches.

The goal of the ETV Program is to verify the environmental performance characteristics of commercially ready technologies through the evaluation of objective and quality-assured data that the potential purchasers and permittees are provided with an independent and credible assessment of what they are buying and permitting.

As part of the ETV Program the „Air Pollution Control Technology (APCT) Center" has tested the efficiency of 17 fabric filter technologies on the retention efficiency of $\text{PM}_{2.5}$.

Testing procedure:

Filter probes: 150 mm Ø

Testing aerosol: Al_2O_3

Particle size distribution: $1,5 \pm 1 \mu\text{m}$

Dust load: $18,4 \pm 3,6 \text{ g/Nm}^2$

Specific air-to-cloth ratio: $120 \pm 6 \text{ m}^3/\text{m}^2\text{h}$

To simulate long-term operation the test filter is first subjected to a **conditioning period**, which consists of 10,000 rapid pulse cleaning cycles under continuous dust loading.

During this period the time between cleaning pulses is maintained at 3 seconds. No filter performance parameters are measured at this period.

The conditioning period is immediately followed by a **recovery period** which allows the test filter to recover from rapid pulsing. The recovery period consists of 30 normal filtration cycles under continuous dust loading. During a normal filtration cycle the dust cake is allowed to form on the test filter until the differential pressure of

1,000 Pa (4" WG) is reached. At this point the test filter is cleaned by a pulse of compressed air from the clean gas side.

Performance testing occurs for a 6 hour period immediately following the recovery period. During the performance test period normal filtration cycles are maintained and, as in the case of the conditioning and recovery periods the test filter is subjected to continuous dust loading. Outlet mass and $\text{PM}_{2.5}$ dust concentrations are measured using an inertial impactor located downstream of the test filter.

Performance testing includes the measurement of emission, number of required cleaning cycles and residual pressure loss after cleaning.

Results of these tests are depicted in figures 8 and 9.

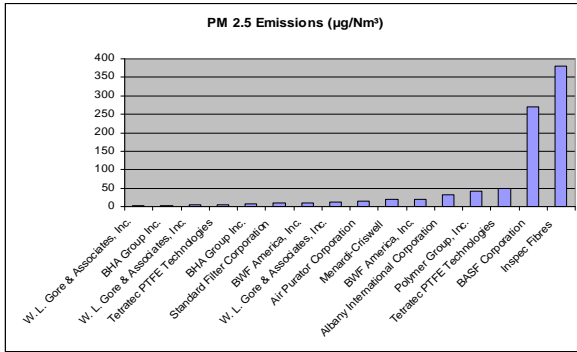


Figure 8: ETV- Tests; PM_{2.5} Emissions

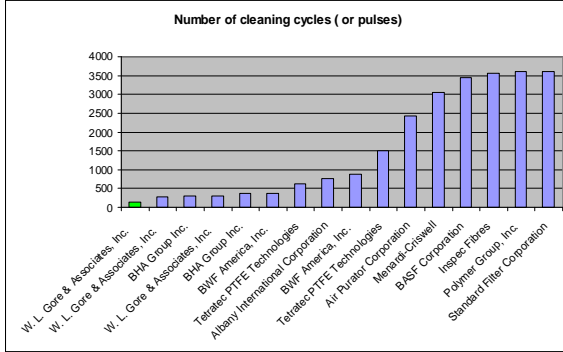


Figure 9: Number of required cleaning cycles

Control of Fine Particulate Matter in Air Pollution Control Systems

The test results are providing a reliable indication for the quality of the filter material. The practical long-term performance is strongly influenced by additional parameters, e.g. the condition of the filter collector and bypass systems, filter bag manufacturing and installation and maintenance.

Gore® ePTFE Membrane Filters achieve dust retention efficiency larger than 99,99% not only in tests but also in full size flue gas cleaning systems. Although in Europe there are no regulatory limits for the emission of PM₁₀ or PM_{2,5}, local regulatory authorities have started to significantly reduce the limits for total suspended matter and thus reducing the emission of fine PM.

In North Italian MSWIs sometimes the dust emissions to be guaranteed by the filter suppliers are < 2 mg/m³. Even those plants that are not

exposed to the stringent emission limits are making strong efforts to achieve emissions as low as possible.

Figure 10 shows the progression of the weekly average dust emissions of the MSWI Silla 2, Milano, Italy for the current year 2008. (Incineration capacity 3 x 20 t/h).

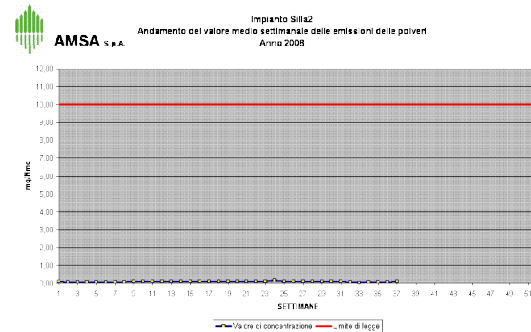


Figure 10: Dust emissions (weekly averages) of the MSWI Silla 2, Milano

The example depicted in Figure 11 shows simultaneous raw- and clean gas sampling of particulate matter downstream of an industrial boiler of a paper mill (2500 m² filter area)

The sampling was performed by means of a cascade impactor, the emitted TSP was approx. 100µg/m³

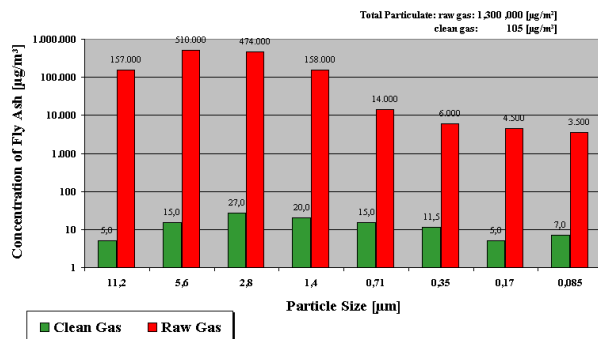


Figure 11: Efficiency of particulate matter retention with GORE® ePTFE Membrane Filters

Summary

- The Directive 2008/50/EC of the Council of 21. May 2008 defines limits for sulphur dioxide, nitrogen dioxide and nitrogen oxide, particulate matter (PM₁₀ and PM_{2.5}) lead, benzene and carbon monoxide in ambient air. Although in Europe there are no regulatory limits for the emission of PM₁₀ or PM_{2.5}, local authorities have started to significantly lower the emission of total suspended matter and thus reducing the emission of fine PM.
- For the control of fine particulate matter various technologies are available. ePTFE- Membrane Filters have proven to be the most effective and most reliable technology.
- Filter tests have shown that a retention efficiency of > 99,99% for PM_{2.5} is achievable for GORE® ePTFE- Membrane filters.
- Also at large-scale flue gas cleaning systems of power plants and municipal waste-to-energy plants clean gas dust concentrations below 2 mg/m³ can be achieved and can be guaranteed.

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