**Publication Series Viledon**

# Expanded Application Options for a Test Rig to VDI 3926, Type 1

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**Published in VDI Publication Series,**
**Volume 29, January 2000**
**Kommission Reinhaltung der Luft (KRdL)**
**im VDI und DIN Normenausschuß**

Freudenberg
Filtration Technologies

## Abstract

**VDI Guideline 3926 describes a test procedure for comparative examination of cleanable filter media, which includes pulsejet cleaning. Assessment covers the long-time filtration characteristics of filter media in terms of residual pressure drop, cycle times between the cleaning pulses, dust deposits in the filter medium, as well as clean-gas concentration.**

**There is a brief description of the test rig used, which conforms very largely to the Type 1 described in VDI Guideline 3926. Above and beyond the concept of the VDI Guideline, however, the test rig was fitted with a high-quality optical particle measuring instrument and a dust feeder for small mass flows. This additional test rig equipment offers utilization options extending beyond VDI Guideline 3926, which are particularly useful for filter media development work (research).**

**VDI Guideline 3926 offers an option for testing with three different types of dust. The influence of the test dust on the test results for high-quality filter media is described in terms of two of these specified test dusts, titanium dioxide and Micro-Calcilin (limestone). The expanded additional options for the test rig compared to the VDI Guideline are then described. These are time-dependent measurements of the fractional collection efficiency and the particle penetration. Using two comparable filter media, the influence of the weight per unit area on the fractional collection efficiency and the particle emissions are plotted as a function of time.**

**In practice, the question is frequently raised whether a high-pressure drop in a filter system is being caused by inadequate cleaning or by an irreversible pressure rise in the filter medium due to particle deposits. This question is very difficult to answer without an appropriate testing option. Another advantageous option for using the test rig is accordingly to examine dust-laden filter media for irreversible blockage and inadequate cleaning efficiency.**

**The type testing of filter media conducted by the BIA (German Employers Liability Associations' Institute for Workplace Safety) in conformity with ZH 1/487 is, for historical reasons, established practice on the market. However, in comparison to VDI 3926 this test does not cover the effect of particle penetration through the filter medium during cleaning. To enable the classification under ZH 1/487 to be estimated in advance for newly developed types as well, the test rig in conformity with VDI 3926 was utilized for a simulation study. The procedure involved, and the initial results of this study, are presented here.**

## Construction of the test rig

The test rig in conformity with VDI 3926 Type 1 used for the studies is shown below in diagrammatic form: it has been upgraded by incorporating a dust feeder for small mass flows and an optical particle counter. These extra metrological options enable the test rig to be used for further studies like fractional efficiency measurements and particle penetration measurements during the cleaning procedure.

Besides the technical filter studies in conformity with VDI 3926, these extended studies provide important information for filter media development work.

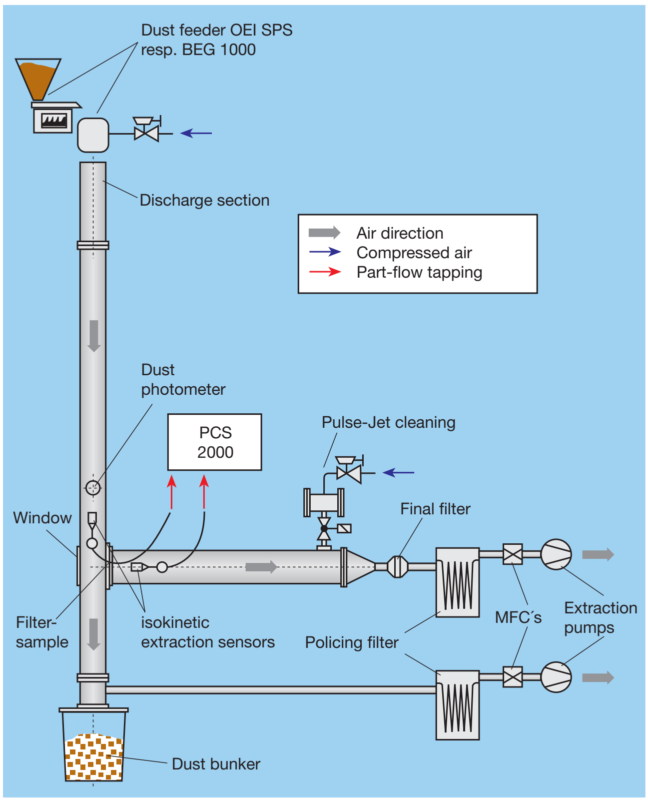


*Fig. 1 Test rig in conformity with VDI 3926, Type 1*

## Influence of the test dust in filter testing to VDI 3926

VDI 3926 specifies three different test dusts for testing filter media. The choice of the test dust has a major influence on the result of the study. Two of the test dusts described are Micro-Calcilin and titanium dioxide. The results presented below are based on studies conducted using these two dusts.

In comparison to Micro-Calcilin, titanium dioxide is a test dust which due to its fine particles and its tendency to agglomeration shows up even very tiny differences in the filtration characteristics of filter media. In the case of simple, uncoated filter media, the cycle times can be very short when using titanium dioxide, so that it is difficult to analyze the results. Micro-Calcilin, by contrast, is a test dust, which supplies very good results with simple filter media. In the case of high-quality filter media, however, it may happen that differences in the filtration characteristics do not become apparent.

The influence of the test dust on residual pressure drop, dust deposition and cycle duration is presented as exemplified by three high-quality PTFE-coated filter media.

In the test featuring Micro-Calcilin (Figure 2) no major differences emerge between the three filter media in terms of residual pressure drop. When dust deposition and cycle duration are examined, two of the media exhibit very similar characteristics, whereas there are manifest differences with one medium.

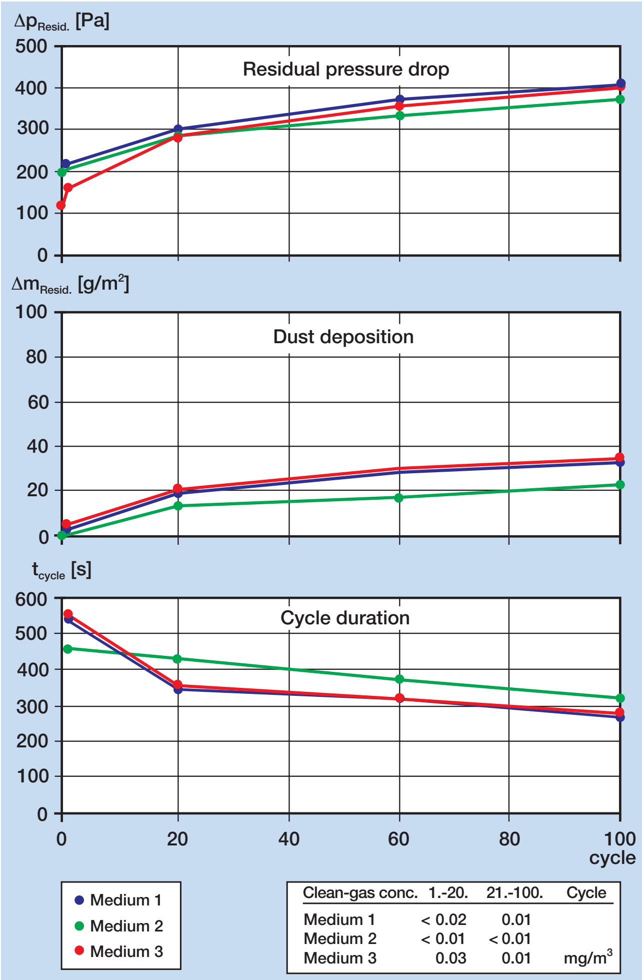


*Fig.2 Testing three filter media with Micro-Calcilin in conformity with VDI 3926*

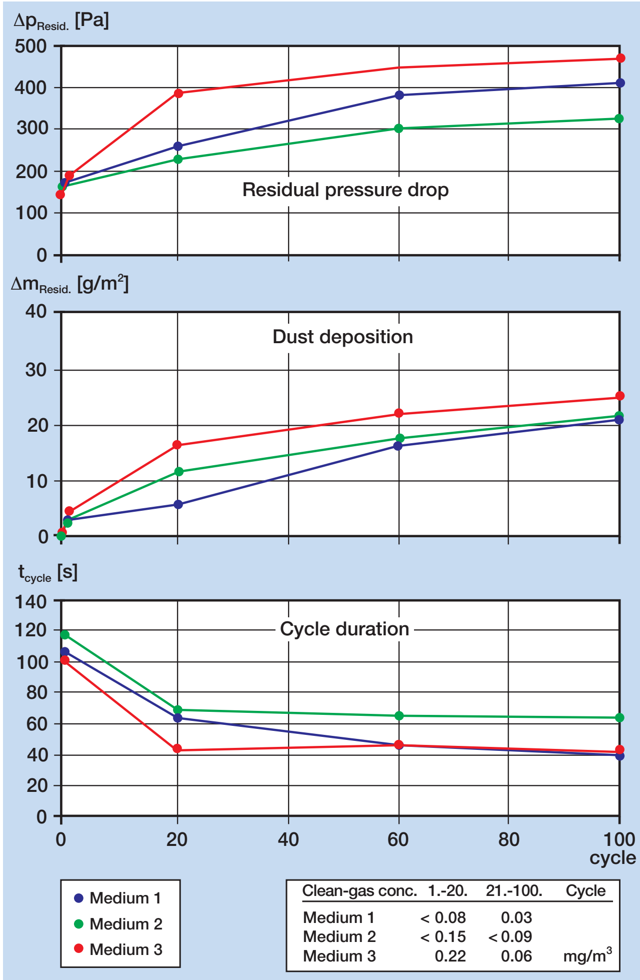


*Fig.3 Testing three filter media with titanium dioxide in conformity with VDI 3926*

These results admit of differing interpretation:

1. the differences between the filter media tested are very slight

2. the test conditions are not suitable for detecting differences

In order to substantiate the statements concerned, the filter media were tested using titanium dioxide. The results are depicted in Figure 3.

When these results are examined, definite differences emerge between the three filter media concerned. The slight tendencies detectable when testing with Micro-Calcilin are amplified when titanium dioxide is used. The assumption possible after the test featuring Micro-Calcilin, that the differences between the filter media tested are very slight, cannot be confirmed following the test with titanium dioxide.

The test conditions can be tightened up by a variety of means. One of them, as described above, is to change the test dust while retaining all the other filtration conditions involved. Another option is to increase the air-to-cloth ratio while using the same test dust.
From the results depicted, it can be concluded that direct comparisons between different measurements are possible only when all test parameters are the same.

## Measuring the fractional collection efficiency

The test rig depicted in Figure 1 enables filter media studies to be conducted above and beyond the measurements specified in VDI 3926. One of these studies involves measuring the fractional collection efficiency of filter media. This is made possible by using an appropriate optical particle counter and an adapted dust feeder for small mass flows. This means the test rig can be used not only for cleanable filter media, but also for studying storage filter media as well.

A filter medium's fractional collection efficiency influences the resultant clean-gas concentration. This applies both for surface filter media and for depth-loading filter media. In the case of surface filters, however the filter cake that forms influences the collection efficiency very significantly.

Figure 4 shows the fractional collection efficiency as a function of time for two filter media which are very similar in structure but differ essentially in terms of thickness and weight per unit area.

| | |
|---|---|
| **Medium A** | **PES stable-fiber nonwoven, thermally bonded, 300 g/m², thickness 0.55 mm** |
| **Medium B** | **PES stable-fiber nonwoven, thermally bonded, 125 g/m², thickness 0.22 mm** |

The diagrams show very impressively the influence of the dust cake and of the weight per unit area on the fractional collection efficiency.

The grade efficiencies and filter resistances of the two filter media differ quite significantly at the beginning of the filtration phase. For a particle size of 1 µm, Medium A possesses a collection efficiency of about 85 % at 75 Pa, while Medium B lies at around 50 % and 28 Pa.

During the course of filtration, both the arrestance and the filter resistance rise. After 1 hour, arrestance and filter resistance of the two filter media are at about the same level. This means that the arrestance is no longer being influenced by the filter medium, but essentially by the filter cake which has been built up.

Measuring the fractional efficiency as a function of time enables conclusions to be drawn on the filter cake build-up and the clean-gas concentration, and is thus also an important measured variable for the development of surface filters.

## Measuring of particle penetration during the cleaning procedure

Using the test rig in conformity with VDI 3926, the clean-gas concentration is determined gravimetrically. For this purpose, the clean-gas flow is passed through an absolute filter, and the weight change in the absolute filter is determined over the test period. The value measured for the clean-gas concentration is an integral measured value, which hardly permits any conclusions to be drawn on the temporal behavior of the clean-gas concentration.

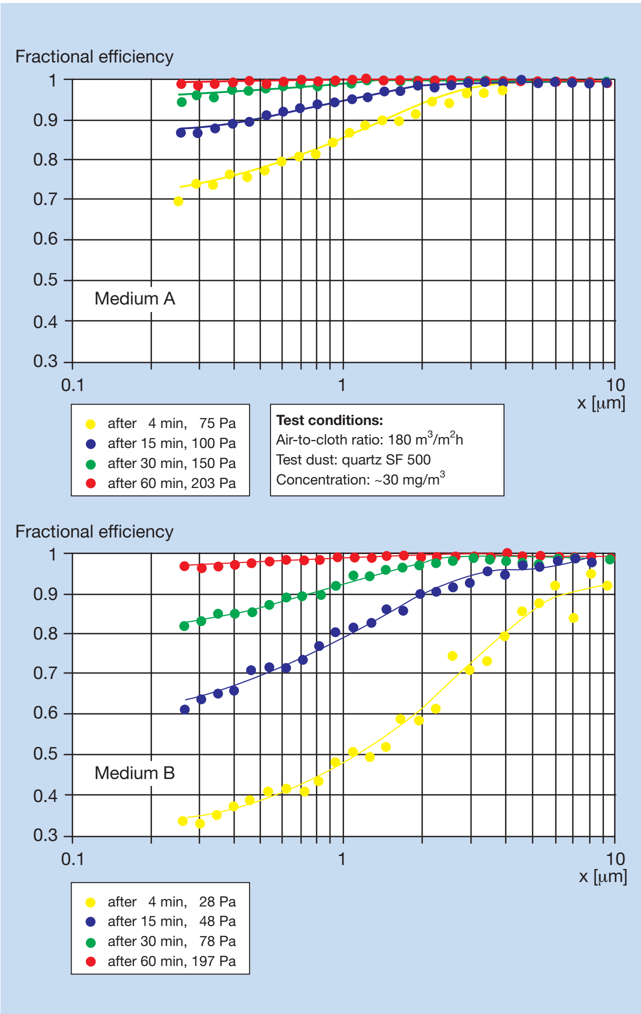


*Fig.4 Measuring the fractional efficiency of filter media as a function of time*

In the case of filters cleaned by pulse jetting, the clean-gas concentration is known to show a significant rise immediately after the cleaning pulse. These sudden increases in clean-gas concentration can be measured only with on-line measuring instruments.

Figure 5 shows the temporal behavior of particle penetration through two different filter media. The media concerned have already been described in the preceding section. The measuring instrument used was an optical particle counter, which determined the particle numbers and particle sizes in the clean gas over a series of measurements.

The blue curve shows the particle counting rate measured at 5-second intervals, while the points marked with the green trend line represent the integral of the particle counting rate, i.e. the total number of particles per cleaning pulse. This depiction does not cover the particle size distribution as a function of time.

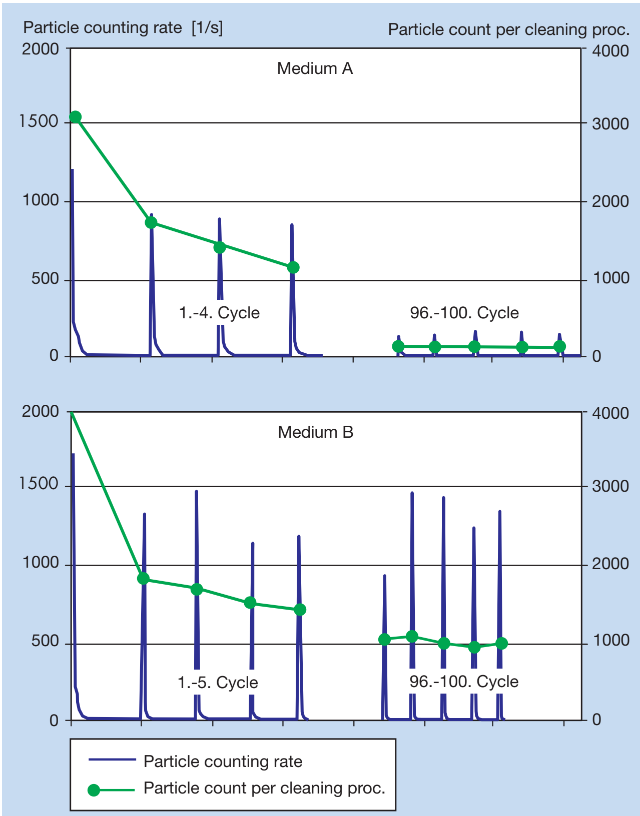


*Fig.5 Particle penetration during the cleaning procedure*

With both filter media, it is evident that particle penetration is triggered by the cleaning pulse, with particle penetration being essentially caused by two time-offset effects. First, the mechanical stress on the filter medium results in particle penetration. The cleaning pulse removes either part or all of the filter cake. After this, the effect described in Figures 3 and 4 occurs that particles, due to the absence of the filter cake, penetrate the filter medium until a protective filter cake once again prevents particle penetration.

It is also noticeable that the peak value of the particle number at the second pulse is significantly below the first value; in the case of Medium B, less than 50 % of it. The peak value for particle penetration then decreases more slowly, and in the two media examined has stabilized at a constant level after 100 cleaning cycles. The development of the quite disparate long-time behavior of the two media cannot be foreseen simply by considering the initial peak values. The clean-gas concentration to be anticipated over long periods of operation is thus primarily a function of the peak value per cleaning pulse and the pulse frequency. The size of the peak value depends, as shown, on the filter medium concerned, but certainly also on the intensity of the cleaning pulse and the dust properties involved.

For filter system operators, this means that the resultant clean-gas concentration, given constant cleaning conditions, can be very simply reduced by extending the intervals between the cleaning pulses. Another helpful measure is to change over from time-controlled cleaning to differential-pressure control, since unnecessary cleaning pulses can thus be avoided.

## Testing filter media for irreversible blockage

As described in the previous section, the cleaning pulse results in higher particle penetration through the medium, and thus also to deposition of particles in the filter material.

This effect can be very clearly seen in Diagram 5. The significant reduction in particle penetration between the first and second cleaning pulse is attributable to particle deposition on and in the fiber layer of the filter medium near its surface.

Even when in the case of filter media for surface filtration the particles are to be arrested at the surface of the filter medium, particle deposition inside the medium can never be entirely prevented. The extent of particle deposition in the filter medium will depend on a variety of factors, e.g. dust properties, surface quality and structure of the filter medium (fiber structure, pore radius distribution), intensity and frequency of cleaning, cleaning control mode (time-controlled or pressure-differential-controlled).

Particle deposits in the filter material will, due to the resultant increase in throughflow resistance, lead in the long term to a rise in the filter resistance involved. Not every increased filter resistance in a filter system, however, is attributable to an irreversible blockage of the filter medium due to dust deposits in the filter medium.

Other possible causes are:

- Inadequate intensity of the cleaning procedure and thus a filter cake not removed
- Refiltration of the dust at online cleaning due to excessively high uplift velocity or a very pourable dust

For analyzing the cause of high filter resistances in filtration systems, it is accordingly important to know whether the filter resistance is being caused by irreversible blockage of the filter medium or whether other factors are operative.

The test rig in conformity with VDI 3926 can be used for examining dust-loaded filter media for irreversible blockage. For this purpose, the filter medium under test is clamped in position, and the pressure differential curve is recorded as a function of the air-to-cloth ratio. The medium is then cleaned in a defined procedure at high intensity, and the pressure differential curve repeated. The difference between the two pressure curves in comparison to the pressure differential curve for the new filter medium supplies information on the throughflow resistance of the filter medium concerned. This fast examination method thus helps to find out the reasons for high filter resistance inside filter systems.

The upper part of Figure 6 depicts a case where the filter material has been blocked. The pressure drop can be reduced only to an insignificant extent even by five-fold offline cleaning. By contrast, the lower diagram depicts a case where the pressure drop is significantly reduced by a defined cleaning procedure. The filter medium is not blocked irreversibly; the high filter resistance in the filter system thus has different causes.

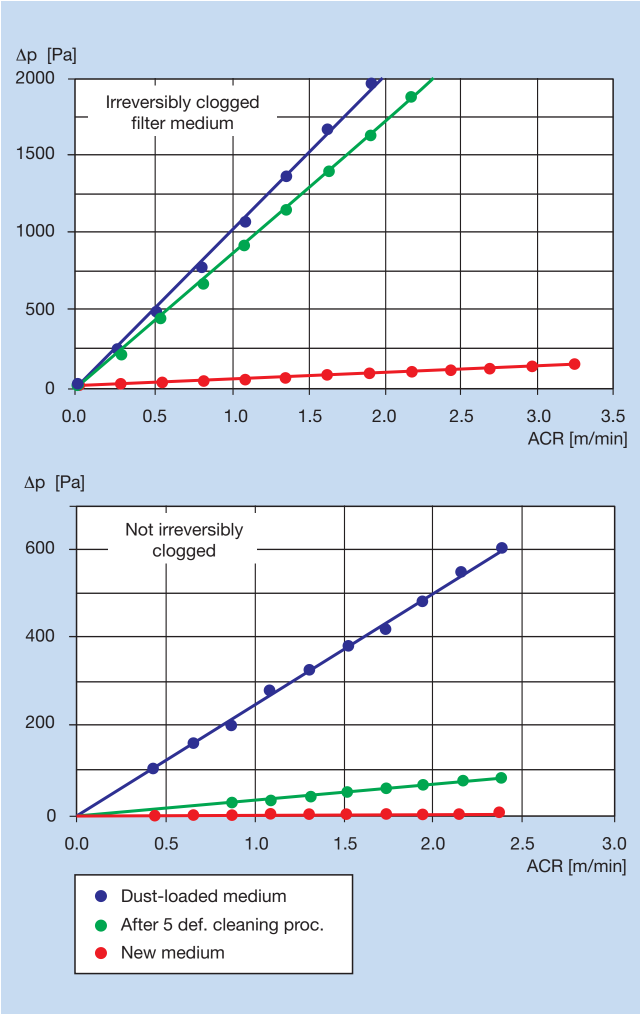


*Fig.6 Testing filter media for irreversible blockage*

Figure 7 shows pressure differential curves for filter media taken from a filter system at different periods in the operating cycle. The reduction in pressure drop due to cleaning is approximately the same in both tests. The rise in pressure differential at the filter system is in this case caused by a rise in the pressure differential at the filter medium itself, due, for example, to excessively frequent cleaning pulses.

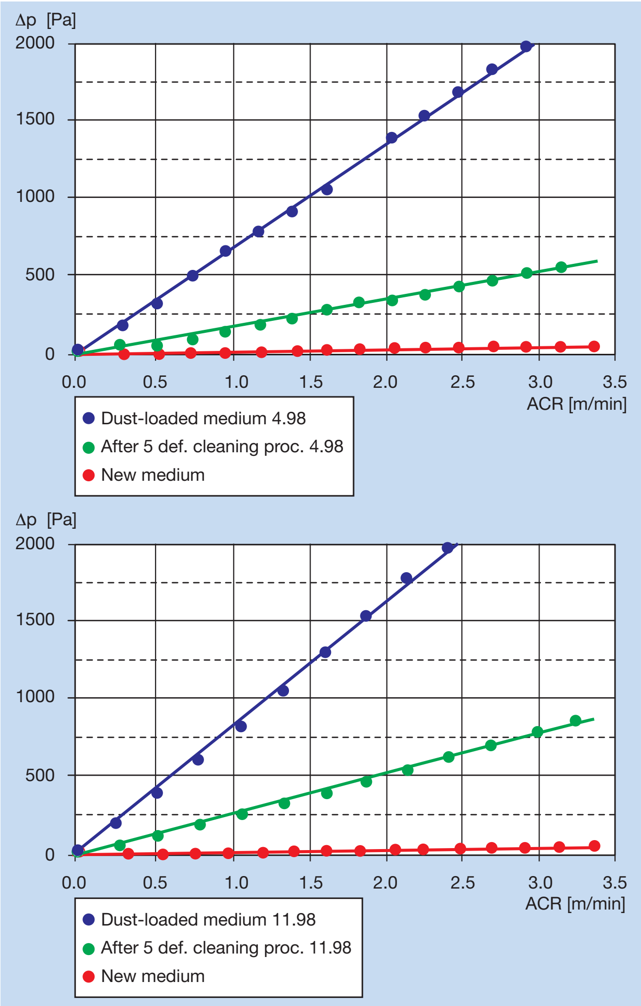


*Fig.7 Testing filter media for irreversible blockage*

## Simulation test for BIA type test to ZH 1/487

In filter systems intended for operation within the territory covered by the currently valid German Federal Immission Protection Ordinance (Bundes-Immissionsschutz-Verordnung or BImSchV), the filter media used will usually have been tested by the German Employers' Liability Associations' Institute for Workplace Safety (Berufsgenossenschaftliches Institut für Arbeitsschutz or BIA) in conformity with ZH 1/487, and will thus have been classified in the appropriate utilization category.

For historical reasons, filter media testing in conformity with ZH 1/487 has attained major importance on the market, since it was the first standardized test for evaluating particle penetration through filter media. Even in cases where filter systems are being operated in emission mode and the BImSchV thus does not apply, operators and manufacturers of filter systems very often demand the type test conducted by the BIA (ZH 1/487).

Since the type test performed by the BIA is a very frequently voiced requirement, Freudenberg Vliesstoffe KG sought an option for estimating the classification into Utilization Categories to ZH 1/487 by means of a fast simulation test, thus shortening the development time needed for new filter media.
The simulation test is conducted on the test rig described in Figure 1, with the additional dust feeder for small mass flows being used for dust dosing. Figure 8 provides a tabulated overview of the test conditions applying in the BIA type test and the simulation on the VDI test rig.
Filter media testing in conformity with ZH 1/487 is conducted on new filter media. The effects of cleaning procedures on particle penetration are **not** covered here. Particle penetration thus conforms to the behavior depicted in Figure 4. As the filter cake grows, particle size distribution and concentration in the clean gas will alter. The measuring instrument used by the BIA is an extinction photometer, whose measurement signal delivers an unambiguous relation to the concentration given a **constant** particle size distribution.

| | **BIA type test (ZH 1/487)** | **Simulation on VDI test rig** |
|---|---|---|
| **Air-to-cloth ratio** | 200 $m^3/m^2h$ | 200 $m^3/m^2h$ |
| **Test dust** | Quartz | Quartz SF 500 |
| **Aerosol generation** | 90% of particles with 0.2 μm < x < 2 μm | 90% of particles with 0.2 μm < x < 1.5 μm $x_{50.0} \approx 0.4$ μm |
| **Dust concentration** | (200 ± 20) $mg/m^3$ | (200 ± 20) $mg/m^3$ |
| **Sample area and shape** | 100 $cm^2$, circle | 154 $cm^2$, circle |
| **Dusting duration** | 1h | 1h |
| **Evaluation procedure** | Extinction photometer | Gravimetric |
| **Result** | **Category U, S, G, or C** | **Prognosis for category** |

*Fig.8 Simulation of BIA type testing at the VDI-3926 test rig (parameters)*

Figure 9 shows a comparison of the results between the BIA type test to ZH 1/487 and the simulation procedure on the VDI test rig. The non-linear correlation curve is certainly attributable both to the different measuring technologies involved and to the above-described dependence of a photometer on particle size distribution and concentration.

Since the test as specified by ZH 1/487 does not include any cleaning procedure, only the initial filtration characteristics are adduced for assessing the filter media concerned. The effects of the cleaning pulse depicted in Figure 5 on particle penetration through the filter medium, and thus on the clean-gas concentration, are not covered.

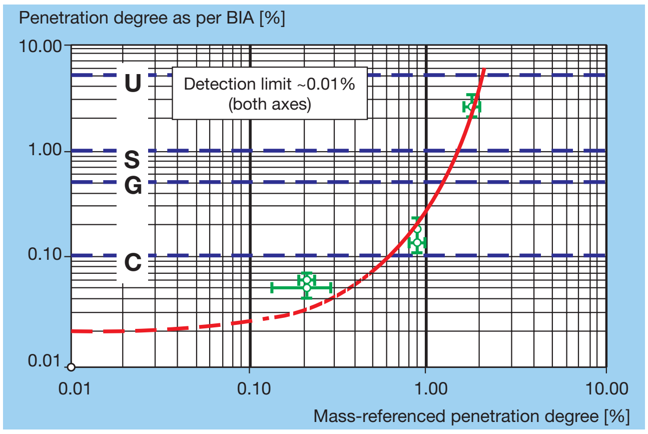


*Fig.9 Correlation between the penetration degree to BIA and the mass-referenced penetration degree*

## Summary


The testing of cleanable filter media in conformity with VDI Guideline 3926 provides important comparative data regarding long-time filtration characteristics under cleaning conditions, determining the behavior against time of pressure drop, cycle times, the gravimetrically ascertained values for dust deposition in the filter media, and the clean-gas concentration.

The higher the quality of the filter media under test, the more stringent the test conditions have to be in order to detect differences between the filter media concerned. More stringent test conditions can be achieved by using a test dust more difficult to filter out, and also by tightening up the test conditions themselves, e.g. by increasing the air-to-cloth ratio.

For the user of a test rig in conformity with VDI 3926, the multiplicity of variation options is important, since this enables cleanable filter media to be quickly assessed in terms of applications engineering.

Expanding the test rig to incorporate adapted particle-measuring equipment and an adapted dust feeder provides some further utilization options, of particular significance for filter media development work:

- Measuring the particle size distribution of dusts
- Fractional collection efficiency as a function of loading
- Particle penetration measurements as a function of time (numerical and size distributions)
- Simulation test for the BIA type test (ZH 1/487)

Besides the utilization options described above, the test rig to VDI 3926 can be very easily employed to test filter media for irreversible blockage. This test is of great assistance in ascertaining whether a high filter resistance is being caused by blockage of the filter medium concerned or whether other reasons are involved. This is of particular interest when filter element replacement entails high changeover costs.

For the user of an expanded test rig as depicted in Figure 1, there are some significant advantages:

- fast and accurate application-engineering assessment of filter media
- fast determination of measured data relevant to filter design
- fast development of filter media on a sound applications-engineering basis

The options provided by the expanded test rig to VDI 3926 as described above, plus the knowledge that can thus be obtained of filtering and applications-engineering interrelationships, offer a foundation for continuing success in a fiercely contested market.



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