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HOT GAS FILTRATION USING SINTERED METAL FIBER MEDIA

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ABSTRACT
Sintered metal fiber filters have been utilized for gas/solid separation in numerous industrial gas filtration applications in the chemical process, petrochemical and power generation industries. Applications require particulate removal to protect downstream equipment, for product separation, or to meet environmental regulations. These filters can provide particulate capture efficiencies of 99.9% or better using either surface or depth media. Operating temperature can be as high as 1000^o C, depending on the selection of metal alloy. Along with the filtration efficiency consideration, equally important criteria include corrosion resistance, mechanical strength at service temperature, cake release (blowback cleanability), and long on-stream service life. These issues are critical to achieving successful, cost effective operations.

INTRODUCTION
Gas filtration is the process of removing solid particles from a gaseous fluid using a porous media with the ultimate objective to achieve a pre-determined level of fluid purity. Sintered metal fiber media combine many different properties, ranging from its outstanding filtration and cleaning characteristics and its excellent chemical and thermal resistance to its mechanical strength.

Two main filtration techniques can be considered, i.e., depth filtration and surface filtration. In the case of depth filtration, the particles are captured inside the media, while in surface filtration they are retained, as the terms explains, at the surface where subsequently a cake of particles is formed.

METAL FIBER MEDIA
Sintered stainless steel fiber candles have been successfully used in hot-gas systems for more than 15 years. The filter media Bekiflow® HG is based on stainless steel sintered fibers, varying in diameter from 1.5 to 80 µm. A scanning electron photomicrograph of a typical metal fiber media is shown in Figure 1. The metal fiber fleece can be composed of different layers of fibers. The final filter rating is determined by the weight per used layer, the fiber composition of

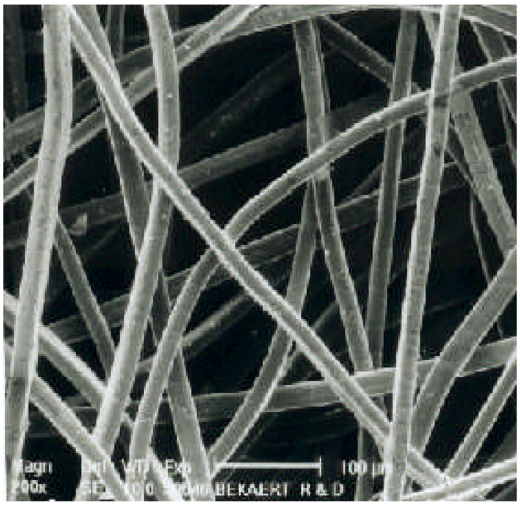

Figure 1. Scanning electron photomicrograph of a metal fiber media.

the layer and the combination of several layers. The mat is compressed to a pre-determined thickness and a sintering process, under an inert gas atmosphere or under vacuum conditions, fuses the respective single fibers to each other. The availability of a high porous structure (up to 85%) offers a very higher permeability and hence a low pressure drop. The development of the non-compressible media contributes to an increased quality level through a finer filter rating and an extended on-stream life. The superiority of these media is enhanced through the excellent thermal-mechanical characteristics for sintered metal fibre media in comparison with ceramics.

The properties of metal fiber filters, fabricated from various metal alloys, for gas filtration applications allow the use in extreme conditions: high temperature, high pressure and corrosive atmospheres. The primary benefits of sintered metal filters are: strength and fracture toughness, high pressure and temperature capabilities, high thermal shock resistance, corrosion resistance, cleanability, all-welded assembly, and long service life.

The inherent toughness of the metal filters provides for continuous, back pulsed operation for extended periods. For high temperature applications, additional criteria such as creep-fatigue interactions, and high temperature corrosion mechanisms need to be addressed.

Filters with semi-permanent media are cost effective, since such units lend themselves to minimal downtime, closed and automatic operation with minimal operator intervention, and infrequent maintenance. The proper selection of filter media with appropriate pore size, strength and corrosion resistance enables long-term filter operation with high efficiency particle retention.

FILTRATION FUNDAMENTALS

Understanding of the ability of a filter to remove particles from a gas stream passing through it is key to successful filter design and operation. For gases with low levels of particulate contamination, filtration by capturing the particles within the depth of a porous media is key to achieving high levels of particle efficiency. The structure of sintered metal provides a tortuous path in which particles are captured. Particles capture continues as a cake of deposited particles is formed on the media surface; however, particles are now captured on previously deposited particles. The life of such filters will depend on its dirt holding capacity and corresponding pressure drop. For gases with high dust loading, the operative filtration mechanism becomes cake filtration. A particle cake is developed over the filter element, which becomes the filtration layer and causes additional pressure drop. The pressure drop increases as the particle loading increases. Once a terminal pressure is reached during the filtration cycle, the filter element is blown back with clean gas and/or washed to dislodge the filter cake. If the pore size in the filter media is chosen correctly, the pressure drop of the media can be recovered to the initial pressure drop. However, if particles become lodged within the porous media during forward flow, and progressively load the media, the pressure drop may not be completely recovered after the cleaning cycle.

The effectiveness of the cleaning cycle and the pressure drop recovery is a critical function of the properties of the cake. The cake strength depends upon the dust particle morphology and size distribution, electrostatic and chemical interactions, and cake moisture levels.

Particle capture is dependent on particle size and gas velocity. For particles in the vicinity of the most penetrating particle size (MPPS), the dominant particle collection mechanisms are diffusion and inception. The combination of these two mechanisms leads to an overall particle penetration curve that first increases with increasing particle, then decreases with further increases in the particle size. Of particular importance is maximum penetration point, which is also the point of minimum particle capture efficiency. The corresponding particle is referred to as the MPPS. Still larger particles are captured via the mechanisms of inception and inertial impaction. The particle penetration for all filter materials exhibit the same basic shape, with the level of penetration and the location of the MPPS dependent on the filter media and its usage. In general the location of the MPPS is typically in the range of 0.1 to 0.3 μm; thus leading to the use of the traditional 0.3 μm DOP test for filter efficiency.

DEPTH FILTRATION

Depth filtration is mainly used in applications where small dust loads have to be separated such as in the protection of downstream equipment against fouling or erosion, protection of catalysts from poisoning and in product purification. The particles penetrate into the media and are subsequently captured within its multiple layer structure. This multiple layer structure prevents premature blocking of the media and increases the capacity to hold dirt and on-stream lifetime. Because the particles are captured within the depth of the media, off-line cleaning will be required. This off-line cleaning can be accomplished with solvents, ultrasonic vibration, pyrolysis, steam cleaning or water back flushing. In addition, the media may be pleated, a configuration that minimizes housing size and cost.

Experimental Tests

The basic principles of efficiency testing, utilizing either polydisperse or mono-sized particles, are adapted according to the nature of the fluid (liquid or gas) and the relevant filtration mechanisms (e.g., depth filtration) associated with the structure of media. Figure 2 illustrates such efficiency curves of three different Bekiflow® HD filter elements, made of multi-layer sintered metal fiber media with respectively increasing filter rating. The experiments are performed at a filtration velocity of 15 m/min (approx. 50 ft/min) at ambient temperature. The finer the filter rating, the more efficient the particles are separated. However, as can seen in Figure 3, the finer the filter rating, the higher the clean pressure drop and the smaller the on-stream life time between two successive cleaning actions, with consequently higher operating costs. Therefore, for each specific application, priorities regarding capital expenditure, filtering rating and operating costs have to be determined by the customer.

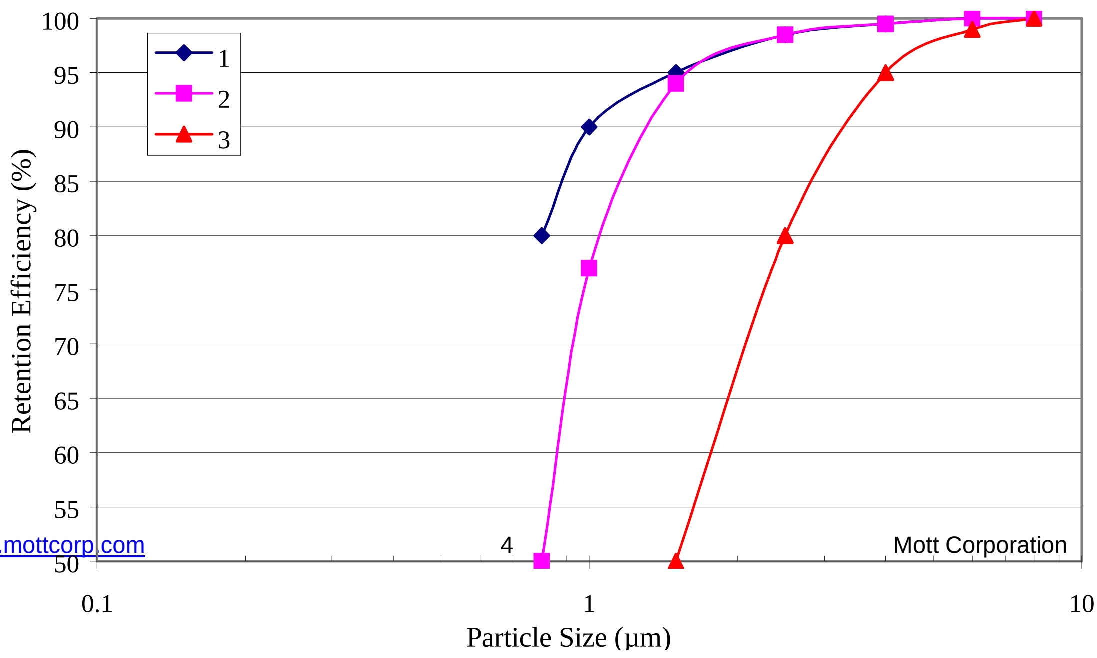

Figure 2. Retention efficiency curves at filtration velocity of 15 m/min for three different Bekiflow® HD filter elements with respectively increasing filter rating.

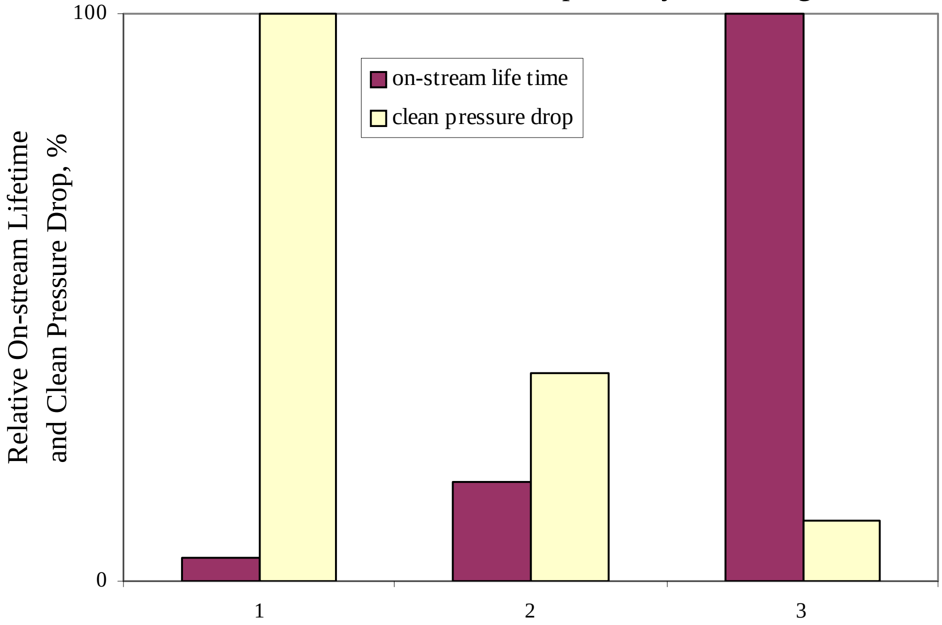

Figure 3. Relative on-stream lifetime and clean pressure drop of three different Bekiflow® HD filter elements with respectively increasing filter rating.

SURFACE FILTRATION

Surface filtration is mainly used in applications where large dust loads have to be separated from a gas stream such as catalyst and product recovery in chemical and calcination processes, as well as the cleaning of off-gases in the refinery and (petro)chemical industry. A dust cake accumulates at the surface of the filter medium (Bekiflow® HC), since the particles are unable to effectively penetrate into the media due to its multiple layer structure using the finest fibers available on the market today. The cake formation increases the filtration efficiency as finer particles are additionally retained in the dense cake layer. The cake is removed at certain time intervals or when a predetermined pressure is achieved using a short pulse of compressed air against the hot gas flow.

Regeneration by Pulse Jet Cleaning

The pulse generating system consisting of a pressure vessel, connecting pipe-work, a fast-acting valve and a nozzle, should yield a maximum jet momentum while operating at the lowest possible pressure to reduce the consumption of pulse air. A successful pulse cleaning of the filter is essential to reach a low and stable conditioned pressure drop during filtration and to operate the filter over long periods of time. The cleaning intensity is commonly related to the magnitude of the internal pressure generated during pulse jet cleaning and measured by fast pressure transducers as schematically presented in Figure 4.

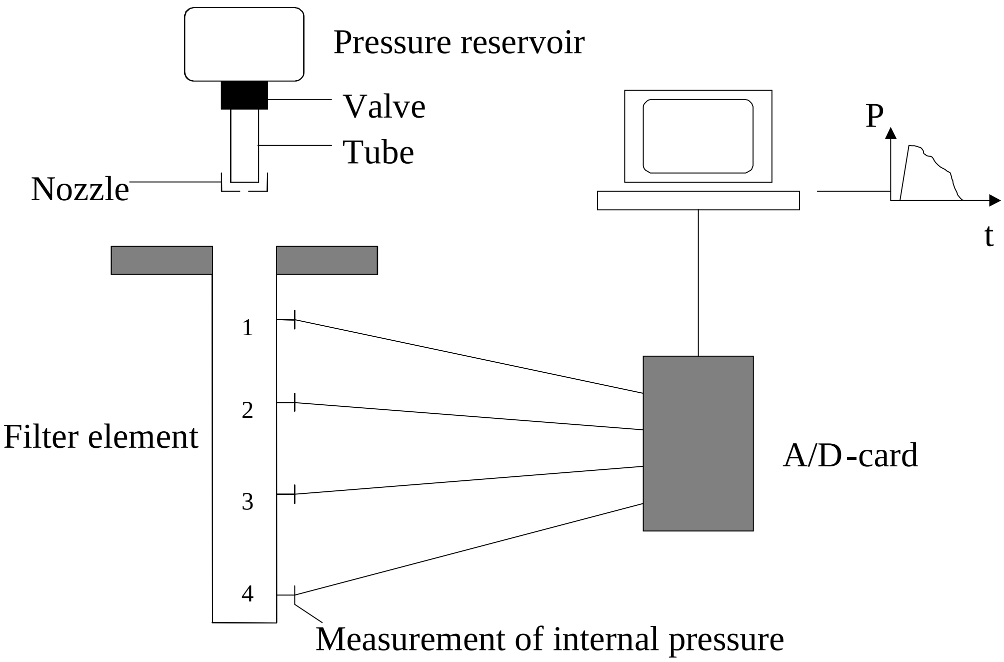

Figure 4. Schematic presentation of the measurement of the internal pressure during pulse jet cleaning.

Pilot Test Cases

Low Pressure Drop Systems

In most applications, for example, when a fan or pre-separating cyclones are used where the performances are greatly affected by flow rate changes and upsets, a small fluctuation in pressure drop across the filter is required.

Results of pilot tests with 4 Bekiflow® HC filter elements, covering a total surface area of 0.226 m² (2.4 ft²), are illustrated in Figure 5. These tests, carried out at a filtration velocity of 4 cm/s (8 ft/min) with a cycle time of 480 s and a dust load of 3 g/Nm³ with a mean particle diameter of 5.5 µm, show stable filtration conditions with a maximum dirty pressure drop of 12 mbar and a recovery pressure drop of 4 mbar after cleaning. A typical emission profile for the first 20 cycles is illustrated in Figure 6. During the first cycles, a peak in the emission profile is noticed after every cleaning pulse. However, after 20 cycles, the filtration efficiency increases as finer particles are additionally retained in the residual dense layer and consequently, the peaks fade away.

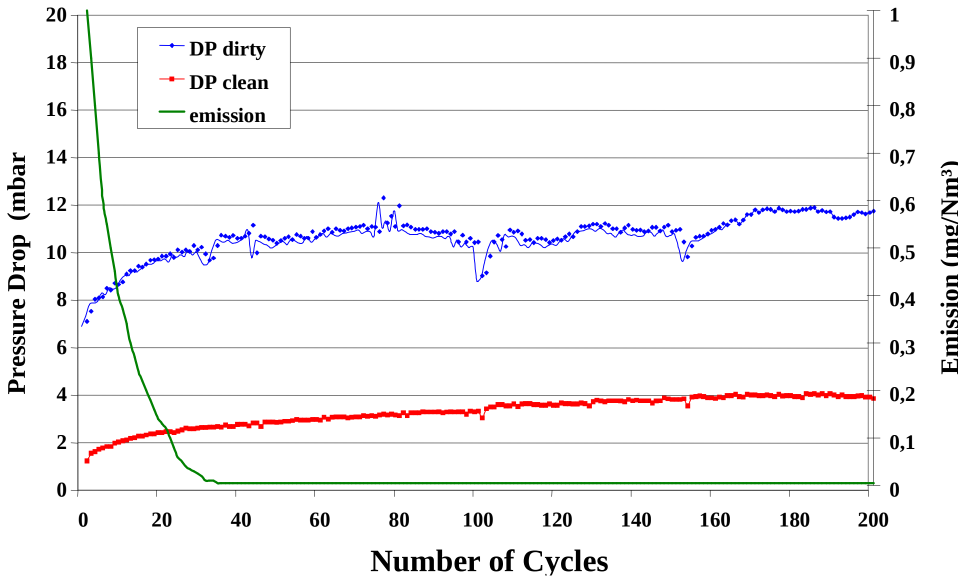

Figure 5. Evolution of dirty pressure drop, pressure drop after cleaning and emission level.

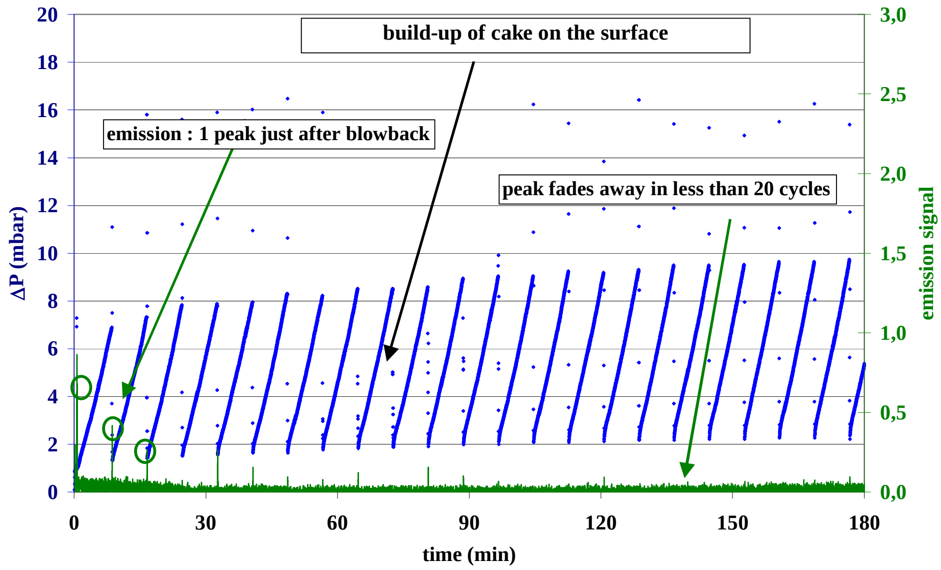

Figure 6. Typical pressure drop and emission profile during cake formation and periodic removal by pulse jet cleaning.

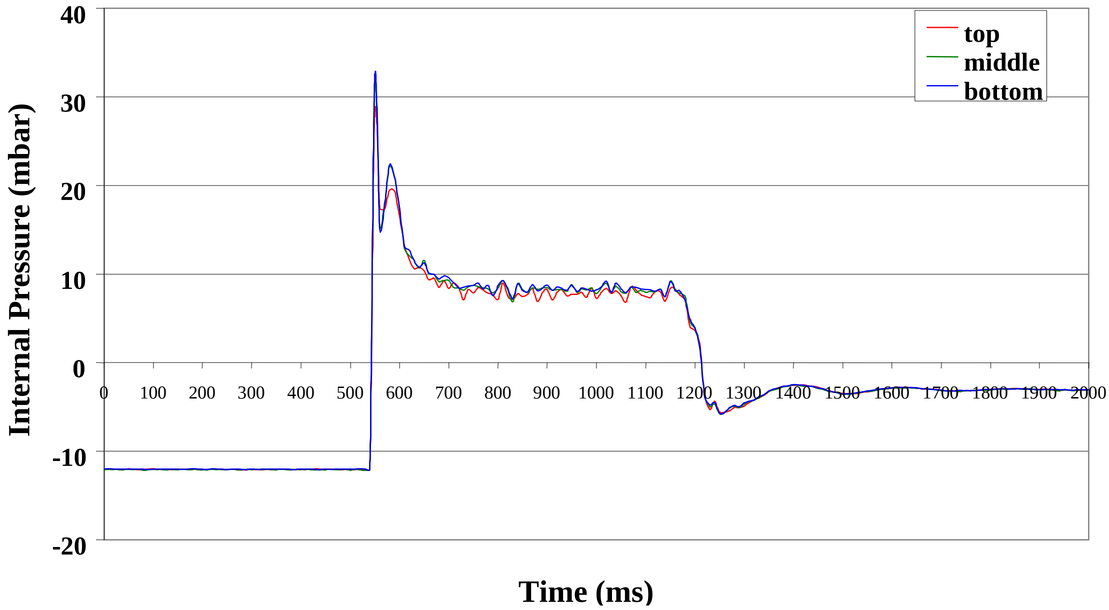

Figure 7. Internal pressure profile during pulse jet cleaning.

After each 480 s loading period, the filter elements are cleaned with a short pulse (500 ms) of compressed air at 6 bar (87 psig) through a 5 mm-nozzle (0.196 inch) against the forward gas flow. Cleaning intensity is characterised by the evolution of the internal pressure at the clean gas side of the element. As seen in Figure 7, the element is uniformly cleaned along its total length.

High Pressure Drop Systems

In many applications, the magnitude of the pressure drop fluctuations is of no significant concern. Consequently, cycle time can be increased and cleaning frequency can be decreased resulting in a lower consumption of compressed cleaning gas and thus lower operating costs. Results of pilot tests with Bekiflow® HC filter elements, covering a total surface area of 0.113 m^2 (1.2 ft^2), are illustrated in Figure 8. Pertinent test data are presented in Table 1. During cake filtration a maximum pressure drop of 100 mbar (1.45 psi) was reached, while maintaining a stable and low pressure drop after cleaning of 19 mbar (0.28 psi).

Table 1
Data generated during pilot tests with Bekiflow® HC filter elements

Dust load	6 g/Nm^3 (0.17 g/scf)
Mean particle diameter of test dust	5.5 µm
Filtration velocity	1.8 m/min (5.9 ft/min)
Maximum pressure drop before cleaning	100 mbar (1.45 psi)
Recovery pressure drop after cleaning	19 mbar (0.28 psi)
Blowback pressure	6 bar (87 psig)
Nozzle diameter	5 mm (0.196 inch)
Duration of blowback valve opening time	500 ms

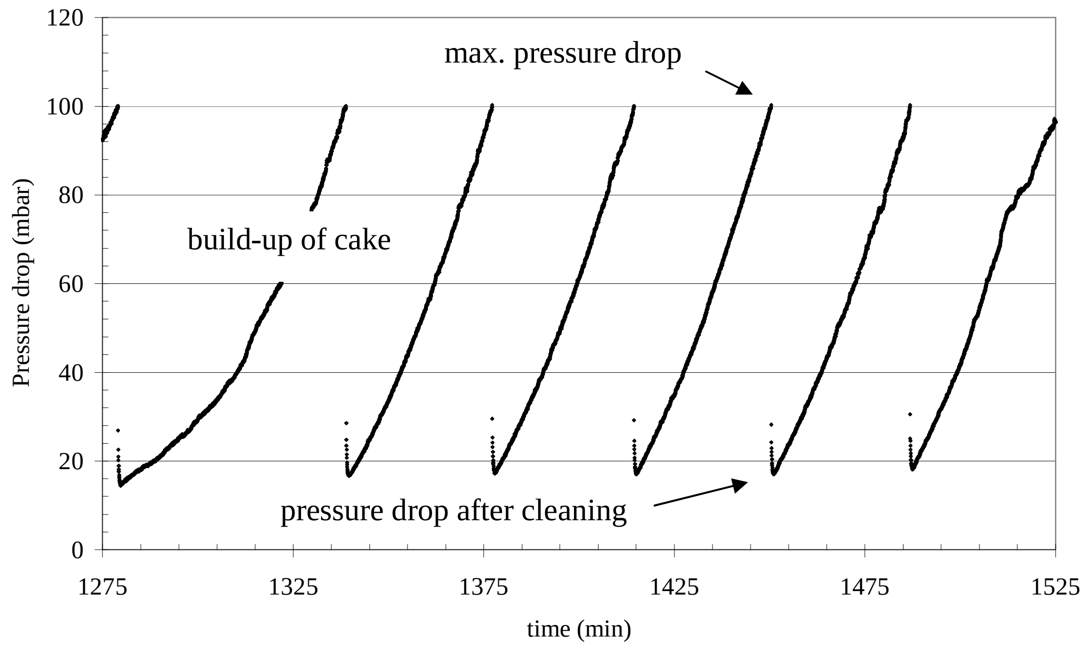

Figure 8. Evolution of pressure drop during cake filtration, ranging from 19 mbar to 100 mbar.

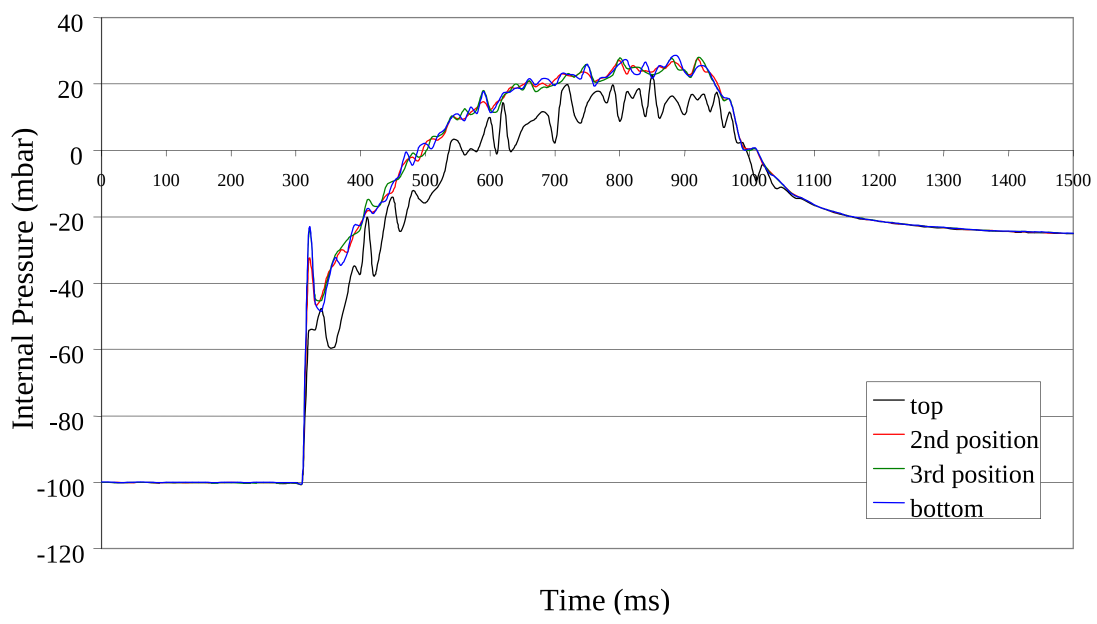

Figure 9. Measurement of the cleaning intensity along the total length of one filter element.

At regular time intervals, the cleaning intensity was measured as illustrated in Figure 9, showing that the pulse generating system maintained a successful cleaning of the filter elements during the total duration of the pilot tests (35 cycles of approximately 50 min).

CONCLUSIONS

The success of stable, long-term filtration of hot gases depends on both the conditions under which the dust to be abated has been deposited on or within the filter media (in case of respectively surface or depth filtration) and on the cleaning action applied. The superiority of the Bekiflow® HD filter elements is enhanced by its multiple layer structure which prevents premature blocking of the media and increases the capacity to hold dirt and on-stream lifetime. Bekiflow® HC filter elements offer a good solution for those surface filtration applications where pressure drop fluctuations are an issue, because of the benefits of the highly porous structure combined with the ease of cleaning. Even in high pressure drop applications (up to 100 mbar pressure drop), stable filtration can be achieved while maintaining a low recovery pressure drop after cleaning. In such a way, cycle time can be increased and less frequent cleaning interventions are necessary, resulting in lower consumption of cleaning gas.