Reduction of operating costs by up to 40% through state-of-the-art dust removal technology

Industrial bag filters provide a fundamental technological edge by easily meeting applicable limit values in a single-step process even at high volumetric flows and dust loads. Reducing energy consumption of the filtering installation – today in the majority of cases jet pulse bag filters - is very important in this context. The article presents innovations with regard to design, control and filtration technology, reducing the specific energy consumption of dust removal systems using jet pulse bag filters.

Dr.-Ing. Gunnar-Marcel Klein, Dipl.-Ing. (FH) Tim Neuhaus, Dipl.-Ing. (FH) Tobias Daniel, Astrid Kögel, **Intensiv-Filter GmbH & Co. KG**, Velbert-Langenberg, Germany

Contact: www.intensiv-filter.com
E-mail: astrid.koegel@intensiv-filter.com

Figure 1. **Waste gas treatment plant**

Plant operators are installing waste gas treatment systems to comply with legal regulations and to increase product recovery (figure 1). If particulate emissions are concerned, separator types as cyclones, wet scrubbers, electrostatic precipitators and bagfilters are used. Industrial bag filters provide a fundamental technological edge as they easily meet applicable limit values in a single-step process even at high volumetric flows and dust loads. These advantages are the reasons why scrubbers, centrifugal and electrostatic precipitators are increasingly replaced with filtering separators, in particular bag filters.

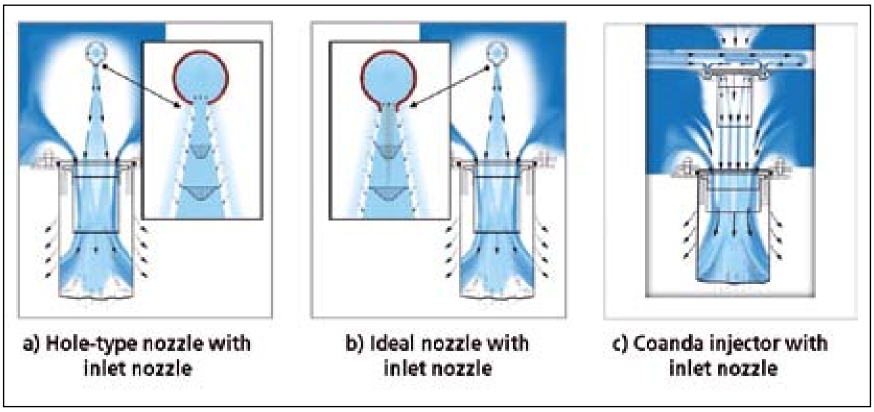
At the same time, the trend towards further reduction of energy consumption in all sectors of the producing industry is unbroken. Dust removal installations used for product recovery from gas streams and in waste gas purification are particularly affected by this trend. These installations handle volumetric flows ranging from a few thousand to 2 million m^3/h and are often in continuous operation. In this context, reducing energy consumption of the filtering installation, today mainly jet pulse bag filters, is a very important factor.

Increasing energy efficiency of jet pulse bag filters

Filtering separators of Intensiv-Filter design feature a cross-flow raw gas infeed. The dust-laden gas enters the housing through the raw gas pipe, impacting on the distribution plate. Here a separation takes place, reducing the speed of the flow. The raw gas flow is homogenized and channelled in cross flow to the filter bags. The particles deposit on the surface of the filter medium and subsequently on the surface of the filter cake forming on the filter medium. In order to achieve stationary operation, i.e. a stable pressure drop (Δp_F) of the filter, the bag filter is cleaned at regular or variable intervals. The flow resistance of the filter is a result of the pressure drop of the filter cake (Δp_{FC}) and the filter medium directly after jet pulse cleaning (residual pressure drop Δp_0). All further flow resistances (from raw gas inlet to filter cake surface, flow pressure drop of the internal bag flow, clean gas flow from bag outlet to clean gas channel outlet) are combined in the housing pressure drop (Δp_G).

The cyclic cleaning of the filter is carried out during filtering operation by means of compressed air pulses blasted by injectors into the open filter bags. In this operating mode, i.e. online mode, the raw gas volume flow is constantly filtered. Immediately after jet pulse cleaning, the particle concentration in the proximity of the filter bag is very high. In this condition, and especially with fine-particle dust and low agglomeration tendency, the already removed particles are refiltered. This "internal" dust circulation may constitute a significant portion of the filter cake mass and contributes to the pressure drop (Δp_{FC}). As a basic technical measure to enhance energy efficiency, shut-off valves (butterfly, gate or other valves) in the raw and/or clean gas ducts are used to put the filter modules of the filtering installation into a flow-free state during cleaning. This is termed "offline" operation mode, or "semi-offline" (only the clean gas side is shut off). This measure effectively prevents any repeating depositing of dust layers. At the same time, in the offline mode impulse cleaning can be performed at low compressed air intensity (reservoir pressure of the compressed air tank 0.1 to 0.3 MPa). In addition to the main effect of decreasing the pressure drop of the filter cake, compressed air consumption is significantly reduced.

CFD (Computational Fluid Dynamics) simulation makes it possible to predict the flow, temperature and pressure drop distribution of bag filters having a complex geometry. CFD-based design optimisation has led to improved baffle plates and wall-mounted raw gas butterfly valves. These measures contribute to the reduction of the housing pressure drop Δp_H by more than 20%.


a) Hole-type nozzle with inlet nozzle

b) Ideal nozzle with inlet nozzle

c) Coanda injector with inlet nozzle

Figure 2. Comparison of different injector systems

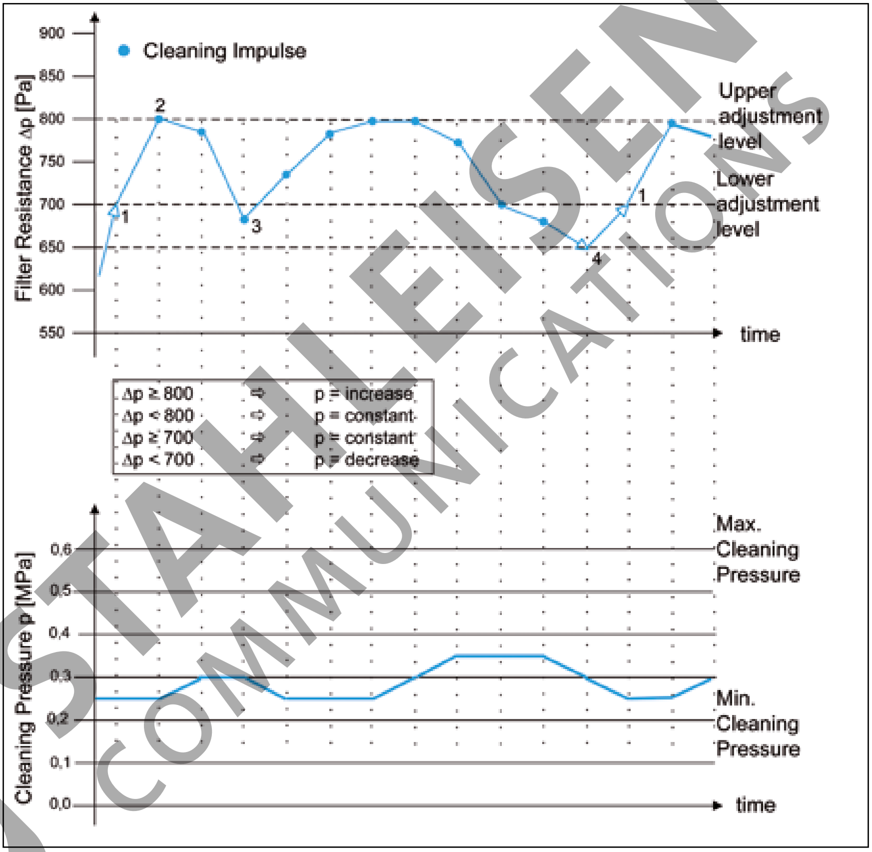


Figure 3. Characteristics of cleaning mode based on control of supply pressure

The Coanda injector cleaning system

One of the decisive factors for energy-efficient operation of a jet pulse bag filter is the injector system. The cleaning process must completely remove the filter cake along the entire bag length. At the same time, the "rug-beater effect" of the filter medium repulsing back against its supporting cage must be minimized by appropriately modifying the pressure profile. Many injector systems consist of a blast pipe with simple boreholes as hole-type nozzles (known as a nozzle injector, figure 2a). This can be significantly improved by optimizing the nozzle geometry, thus converting the static energy in the blast pipe into a directed flow of compressed air (figure 2b). The cleaning system developed by Intensiv-Filter under the name "Coanda injector" exploits the Coanda effect, whereby the compressed air escaping via an annular gap is directed over a curved surface. The primary air thus follows the boundary layer, which does not separate from the wall due to the geometry of the Coanda injector. Within the first injector step, an extremely high negative pressure is created. With that, secondary air is sucked into the injector creating a propulsion jet which, compared to the other variants mentioned, shows a greatly increased amount of air (figure 2c). This air jet enters the inlet nozzle, constituting the second injector step, during which more secondary air is sucked in. Compared to other injectors, these systems set a benchmark in that the Coanda injector achieves the maximum pressure impulse independent of the tank pressures.

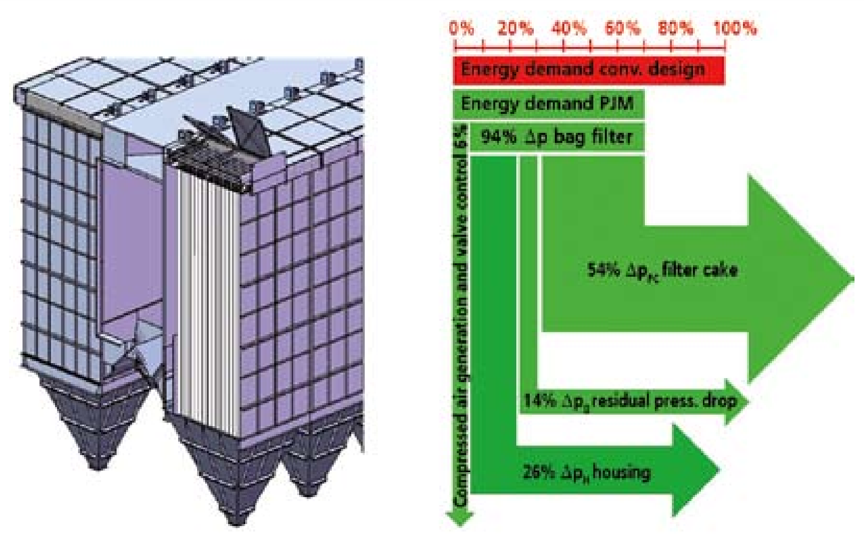


Figure 4. **Design and energy flow diagram for ProJet mega®, offline operating mode**

JetBus cleaning control system

Today, cleaning is controlled by microprocessor technology and fieldbus systems. The JetBus Controller® filter control system developed by Intensiv-Filter is a decentralized, modular control system. In addition to controlling the diaphragm valves, it also controls the pneumatically or electrically actuated raw and clean gas flaps and processes signals from field sensors, such as “broken bag detectors”. When cycling the pressure pulses, it differentiates between operation with fixed cycles and differential pressure control with variable cycle times. The JetBus Controller® offers a further control parameter which allows cleaning to be carried out when needed. By continually adjusting the cleaning pressure, the compressed air requirement can be adapted to suit the current operating conditions. The filter differential pressure serves as control variable for pressure-controlled cleaning.

Figure 3 shows the control characteristics of the cleaning mode based on supply pressure control. Here, the necessary pressure of the compressed air tank is determined by the operating behaviour of the filter. The top diagram shows the filter differential pressure. The bottom graph shows the tank pressure (=cleaning pressure). At position 1, the cleaning system is switched on. As the sequence progresses, the differential pressure may, for example, increase. When the upper differential pressure limit (800 Pa) is reached or exceeded, the cleaning pressure is increased (position 2). As a result, the differential pressure drops within the permissible range, and the cleaning pressure is kept constant at 0.3 MPa. With this setting, the differential pressure drops below the lower limit (700 Pa), at which point the cleaning pressure is reduced once more (position 3). If the filter differential pressure falls below the lower maximum permitted limit and continues to fall (position 4), the system switches off the cleaning process. Only when the lower maximum permitted limit has been reached (700 Pa line), does the cleaning operation resume. If the cleaning system remains switched off due to low differential filter pressure, forced cleaning can be carried out if necessary to avoid large accumulation of dust. The operating data of the bag filter is thus permanently maintained at the desired operating point ensuring minimum compressed air consumption.

Combining the measures in a new filter series

By combining the offline operation mode described above with the highly effective Coanda injectors and the JetBus Controller® controller, the specific energy requirements of a filter installation can be reduced by up to 30 %. The newly developed ProJet mega® series includes all the measures for energy efficiency increase described in this section. These filtering installations have a modular design, consisting of standardized components and covering a wide volumetric flow range from auxiliary dust removal installations to large process filter plants. Figure 4 shows a partial view of a ProJet mega® process filter, including an energy flow diagram which compares the energy requirements with those of conventional jet pulse bag filter design.

Energy-efficient technology for filtering installations in online mode

After perfecting the injector system, the cleaning control system and the offline operation mode, Intensiv-Filter has recently turned its attention to developing its own filter media. The main

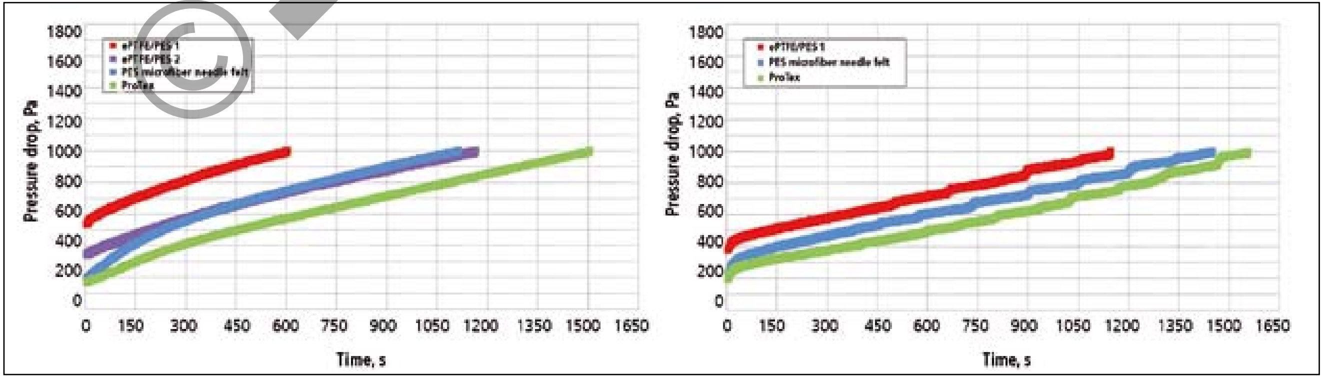


Figure 5. **Pressure drop curves for various filter media and cycle times**

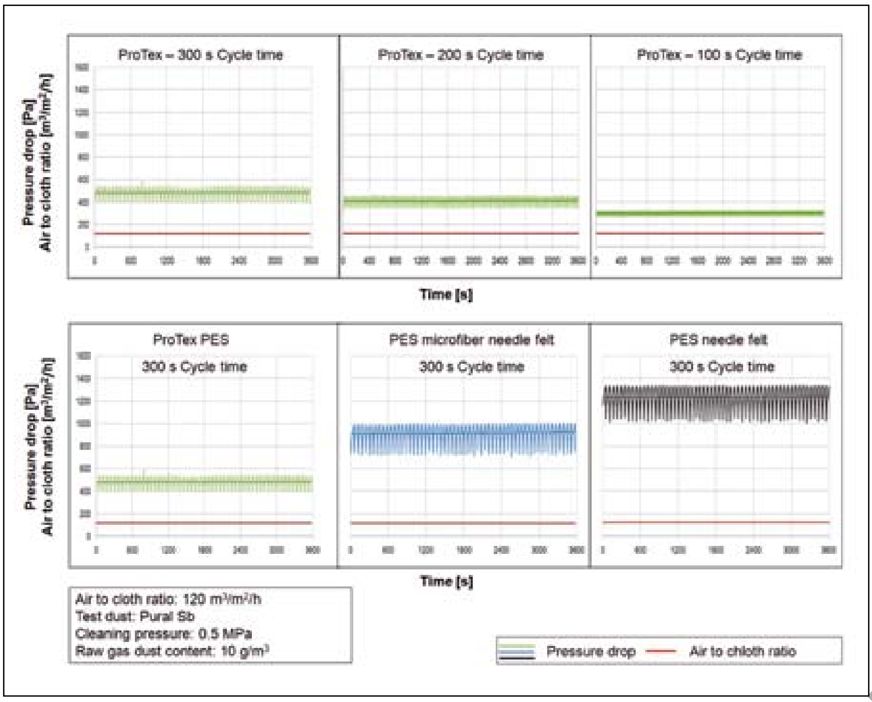


Figure 6. Pressure drops measured on a real filter

challenge in designing a filtering plant is always to combine high particulate retention efficiency with low maintenance demands and operating costs. Here the filter media play an important role. The pressure drop caused by the filter medium and the deposited filter cake makes by far the greatest contribution to the energy costs. The development work therefore focused on reducing the pressure drop. The new ProTex filter media generation is the result of this development.

Unlike conventional filter media, ProTex filter media feature microfibers with a titre of ≤ 1.5 dtex on the upstream side (between the raw gas side and the backing fabric). These are arranged so as to produce a significantly smaller gradient on the pressure drop curve in the first filtration phase after jet pulse cleaning **(figure 5)**. This effective measure alone significantly reduces the differential pressure within the filtration cycle.

The characteristics of ProTex were compared with those of materials currently available on the market using the test specifications of VDI 3926. The tested materials included a needle felt with a laminated ePTFE membrane, a conventional microfiber needle felt and the new ProTex PES filter medium. Pural SB and cement were used as test dusts. Particular attention was paid to the differential pressure curve, residual pressure drop and clean gas concentration.

Figure 5 shows the differential pressure profiles of the filter media over one filtration cycle (criterion for aborting = differential pressure of 1,000 Pa) in a quasi-stationary operating state, i.e. once the medium had been aged by being subjected to pressure impulses of 10,000 cleaning cycles. The filter medium with laminated ePTFE membrane showed a minimal pressure gradient in the pressure drop curve directly after cleaning, but a very high residual pressure drop attributable to the irreversible deposition of dust in the pores of the membrane. The conventional microfiber medium exhibited a relatively low residual pressure drop but a high rise in the pressure drop curve directly after cleaning so that the pressure drop level reached at the end of the cycle was approximately the same as that for the ePTFE membrane media. The newly developed ProTex filter medium showed both a small gradient on the pressure drop curve and a low residual pressure drop for both test dusts. The irregularities in the linear progression of the curve during the tests with cement dust, which increased as the filter cake became thicker, can be attributed to compression processes in the dust cake.

Tests with a 10-bag pilot plant confirm the great potential of the ProTex filter media for reducing differential pressure **(figure 6)**. The first series of diagrams shows the differential pressure curve over the measuring period when using ProTex PES, a conventional microfiber needle felt and a standard needle felt at a cycle time of 300 s. When using the ProTex filter medium, the average differential pressure (measuring points on the raw and clean gas sides) can be

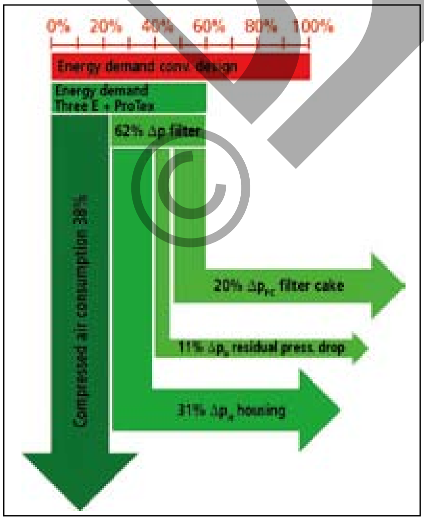


Figure 7. Energy flow diagram

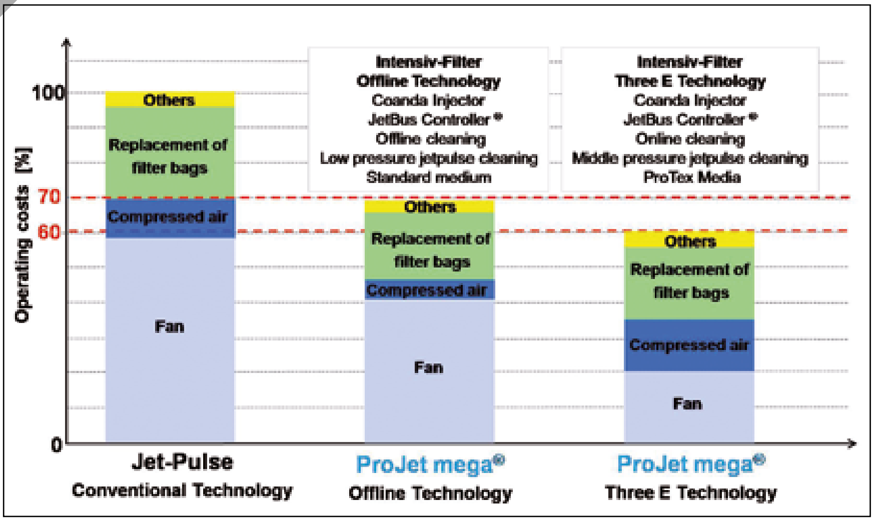


Figure 8. Comparison of operating costs and savings potential

reduced by more than 40% compared to that of a conventional microfiber medium. Compared to the results with a conventional PES needle felt filter medium (without microfibers), the differential pressure level dropped by 60%.

The second series of charts in **figure 6** shows the differential pressure characteristics when using the ProTex filter medium with reduced cycle times (100 s and 200 s). When the cycle time is reduced to 100 s, the ProTex filter medium attains a mean differential pressure which is less than that of the benchmark by a factor of 4 (needle felt medium and operation at a cycle time of 300 s).

The conventional needle felt demonstrated emissions between 10 and 20 mg/m³, which is a sign of strong penetration of the particles into the filter medium and an open pore structure. The total dust concentration detected in the clean gas was even lower regarding the use of the conventional microfiber medium and the ProTex filter medium in the pilot plant. Both filter media will therefore easily reach the limits imposed by TA Luft (German Clean Air Act). These low limits were still achieved when the cycle time was further reduced to 100 s.

Results

Figure 7 shows the energy flow diagram of a ProJet mega® filter with ProTex filter media using the Three E technology (optimum cleaning control system) in online mode. A comparison of the operating costs of conventional filtering installations with the new developments described in this article, i.e. ProJet mega® in offline mode and ProJet mega® with ProTex filter media using Three E in online mode **(figure 8)**, highlights the economic relevance of the new technology. The new filter technology is currently being rolled out for series applications. At the same time, we are working on expanding the Intensiv-Filter ProTex filter media portfolio to high temperature applications. ■