United States
Environmental Protection
Agency

Air and Energy Engineering
Research Laboratory
Research Triangle Park NC 27711

Research and Development

EPA/600/S7-85/049 Jan. 1986

EPA

Project Summary

Development of Advanced ESFF Technology

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This report summarizes work done to explore ways to magnify the effects and broaden the scope of electrical stimulation of fabric filtration (ESFF). The importance of these effects was established in earlier work, both in the laboratory and in pilot plant trials. The present work covered a number of separate topics: a) effects of particle charge levels, b) mechanisms of pressure drop reduction, c) programming applied electric fields with respect to time, d) cleaning fabric filters, and e) printed electrodes.

The results showed that particle charge has a strong effect on the response of filtration performance to ESFF and that some form of precharging would be cost-effective in many cases. Measurements of dust deposition patterns showed that electrical effects cause shifts in the dust deposits: a) toward the entrance of the bag, b) to the electrodes, and c) toward the surface of the fabric. Results of modeling studies agree quantitatively with the observed effects. Studies of programmed voltages examined the possibility of using sudden changes in electric field to aid bag cleaning and also the effects of using ac rather than dc fields, but neither approach held out promise of significantly improved performance. When pulse-cleaned bags were run at higher than conventional velocities, penetration rose to unacceptable levels; whereas, with bags cleaned with reverse air, pressure drop reached large values. The difference appears to be related to the energy levels of the two cleaning methods. "Printed" electrodes (PEs) are stripes of conducting material replacing metal wire electrodes and having the advantages of lower cost and the possibility of applying electrodes of complicated design; they appear to be as effective as wire electrodes.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Background

The cost of emissions control can be a substantial fraction of the total capital and running costs of electric utilities. Where the chosen means of particulate removal is a baghouse, some cost reduction could be achieved by increasing face velocities, allowing the use of fewer bags and a smaller baghouse. It has already been shown that with electrostatic augmentation, a baghouse can operate continuously at about double the conventional face velocity. Reduction in cost has been estimated at 30 percent for a pulse-jet baghouse if, by means of ESFF, face velocity is increased from 2 to 3 cm/s. Similar pilot plant results have been obtained for reverse-air baghouses.

The promsing results of the two pilot plant tests were obtained with a rather simple modification of conventional bags. It is reasonable to suppose that this did not represent the best possible design and that additional research might indicate ways of further improving the response to ESFF. The work discussed in this report consisted of a number of studies, outlined in the abstract. Some were experimental; others sought a better understanding of ESFF mechanisms through modeling. The several studies addressed the following problems:

1. The charge level on the aerosol has received limited attention in the past. In the Apitron process, charging is known to produce great improvement in performance, but little is known about the effects of charge when an externally applied parallel field is applied to the fabric. In the pilot plant tests of ESFF, the charge level was neither controlled nor measured.

2. The reason that ESFF brings about lower pressure drop (Δp) has usually been given, qualitatively, as a "more porous dust cake." In this study, a more precise quantitative treatment of the mechanism involving a shift of the dust cake upstream into the fluffy layer of the filter was undertaken. Other mechanisms were also considered (i.e., displacement of the dust mass in axial and tangential directions in the bag. This was experimentally verified.

3. Most ESFF work to date has employed dc voltages. Part of this study examined reversals of voltage polarity as an aid to cleaning and use of ac voltages, since in some cases this might bring some cost advantages.

4. The purpose of using ESFF is operation at higher face velocities. Even with ESFF, however, an upper limit to velocity is imposed by uncontrolled rise in Δp. This limit can be assumed to reflect the point at which the cleaning removes less dust than was collected in the cycle. Thus, improvement in cleaning should allow greater increases in velocity than are possible with ESFF alone.

5. To control buildup of static electricity, a technique for applying conductive bands or stripes to fabrics has been developed commercially. Part of this project examined the possible use of such "printed" electrodes as substitutes for wire electrodes.

Results

With the exception of measurements for the modeling of pressure drop mechanisms, all experimental work was carried out with a single-bag laboratory baghouse. The bag length and diameter were 122 and 11.4 cm, respectively. The aerosol was redispersed coal fly ash.

1. The initial object of altering aerosol charge levels was to explain why, with the TRI baghouse, the improved performance due to ESFF would diminish or "fade" with time. The results of charge measurements showed that the redispersed fly ash aerosol carried such a small charge that it was not measureable. It is assumed that some charging occurred from corona from the bag electrodes, but this was suppressed in time by dust buildup. Precharging the aerosol eliminated fading, but this particular result is of interest only in explaining laboratory results, since (in the field) fly ash from a boiler carries considerable charge and fading is unlikely to occur. Figure 1, for a bag cleaned with reverse air, however, shows that there is a definite dependence of the response to ESFF on charge levels, which were approximately 2.5 and 5 μC/g at 9 and 15 kV precharger potentials, respectively. Weighing the bag showed that the mass of dust collected was the same no matter what the charge level, so that the reductions in Δp were not due to loss of dust in the precharger. The same dependence on particle charge was observed with a pulse-jet cleaned bag.

2. To study the mechanisms responsible for Δp reductions, a modified bag was made that could easily be opened to examine the dust deposit. This was done after operation with various combinations of precharger and bag potentials. Visual observation (Figure 2) and measurement of dust mass distribution showed that, with precharging, dust settled closer to the bag entrance and preferentially on the electrodes. Calculations of Δp based on measured skewed dust distributions gave good agreement with the observed Δp. Calculations of the trajectories of charged particles in the electric field generated by charged electrodes in the bag also indicated concentrations of dust on the electrodes, in agreement with the observed patterns. The same calculations also showed the presence of a cylindrical zone in the center of the bag where the electric field was essentially zero.

A separate study examined the change in Δp due to shifting of the dust deposit upstream to a low solidity surface layer of the filter fabric. Measurements with layered filters showed an increasing shift to the upstream layer as the electric field increased. Calculations of the reduction in Δp expected to result from these shifts were made based on the Happel cell model. It was found that the calculated Δp depended on the assumed form of the collected dust; that is, agreement between theory and experimental values required an arbitrary "dendrite fraction" of 0.25; i.e., it was assumed that one quarter of the dust settled on the fibers in the form of dendrites. The actual value of the dendrite fraction was not determined experimentally.

3. Sudden large electrical potentials of reversed sign were applied to the electrodes on the dust-laden bag during the cleaning cycle. Initially, results seemed encouraging, since there was a sharp drop, as much as 30 percent, in the residual Δp. However, this drop was quickly reversed when filtration was resumed, leading to the assumption that

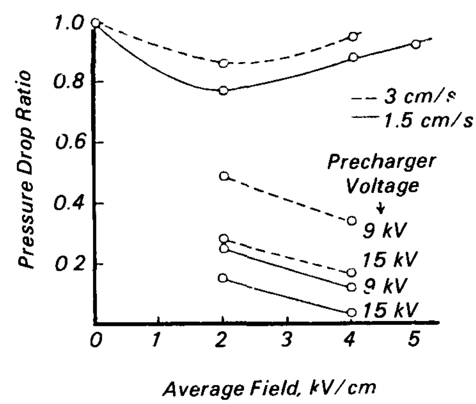

Figure 1. *Dependence of pressure drop ratio (PDR) on bag field after extended run for a woven-glass reverse-air bag. (Top curves: no precharger.)*

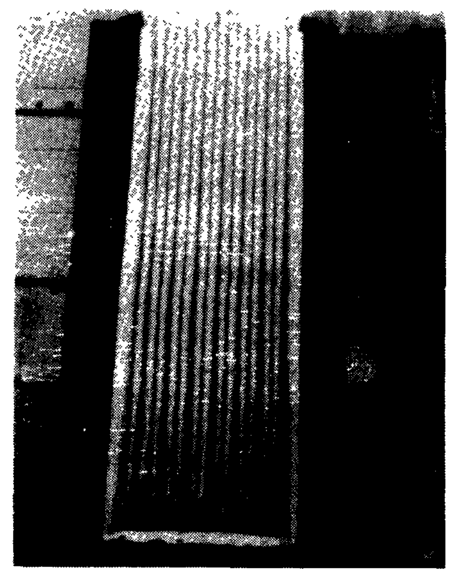

Figure 2. *Dust deposition pattern with 4 kV/cm field and −15 kV precharger potential.*

only a small area of the dust cake near the electrodes was affected, the dust cake in this area quickly becoming restored, so that practically no overall improvement was obtained. The drop in residual Δp was even smaller when a large potential was applied to the electrodes during the filtration part of the cycle. When ac was used in either the bag or the precharging electrodes, the improvement in performance was somewhat smaller than with dc potentials equal to the RMS ac. Thus little advantage can be derived from use of ac potentials.

4. Bag cleaning studies were made with a Teflon® felt bag cleaned by pulse-jet (T-PJ), a woven glass bag cleaned by pulse-jet (G-PJ), and a Teflon felt bag cleaned by reverse air with shaking (T-RA). It was found that with T-PJ, Δp remained within acceptable levels (~ 1.0 kPa) even at face velocities of 7.5 cm/s. However, penetration slowly rose to the order of 0.1 and did not return to acceptable levels even when the velocity was lowered. With G-PJ, penetration was almost 0.1 even at low velocity. As with T-PJ, however, Δp remained low. With T-RA, penetration remained very low throughout, never rising above 10^{-2} with no ESFF potential or above 10^{-3} with 4 kV on the bag electrodes and 15 kV on the precharger. Even with these potentials, however, Δp rose out of control at 4.5 and 6 cm/s. The different behavior is explained by the large difference in the energy input for the two methods. The shaker used released about 1 J/m^2 of fabric per shake. The 30 psi (207 kP) pulse released 350 J/m^2. Future research should examine performance at intermediate energy levels.

Cleaning by bag shearing was explored. The upper bag support is rotated about the bag axis so that the fabric is sheared. This mechanical action was found to be as effective as shaking in lowering Δp when the shear strain was about 6°. This short program did not examine the effects on penetration.

5. Measurements with commercially produced filter felts fitted with printed electrodes (PEs) showed improvement in performance very similar to that obtained with wire electrodes (Figure 3). Measurements with woven fabrics likewise gave similar results with PEs or wires, but a separate problem was the fragility of PEs when applied to woven fabrics, which have a high in-plane shear compliance so that the PEs were too easily strained to the breaking point. Electrical continuity was then destroyed. This problem was overcome by making PEs of mixtures of carbon black and rubber cement. However, this rubber degrades at utility baghouse temperatures: a temperature-resistant formulation does not exist.

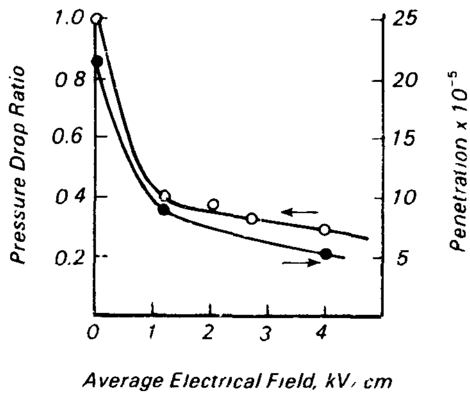

Figure 3. Performance of polyester felt bag fitted with printed electrodes

Conclusions

The electric stimulation of fabric filters is strongly dependent on the level of charge on the incoming particles. If the electrode wires can be kept clear of dust cake, charging the dust by corona from the electrodes is sufficient to reduce pressure drop by an order of magnitude. Failing that, the charge level can be maintained by a separate charging device, and significant improvement in performance can be obtained.

When a precharger is used, the paths of the dust particles as they approach the fabric are altered so that dust collection occurs preferentially on the electrodes and near the bag entrance. Measurements show that the dust mass redistribution over the surface of a bag accounts for a large part of the reduction in Δp. Calculated particle trajectories are consistent with the observed pattern of dust deposition on the bag wall, but also indicate a region with radius equal to half the bag radius in which the electric field strength is almost zero and in which particles respond only to the flow field.

Besides responding to changes in dust mass distribution, Δp is also reduced because of the higher permeability of a dust cake formed in a strong electric field. The relative importance of the two effects varies as the dust is more or less uniformly distributed over the bag surface. The increased permeability is largely due to a shift upstream into a region of the fabric having lower solidity. This has been demonstrated experimentally, and mathematical modeling shows that the Δp is also sensitive to whether the dust collects as dendrites or as compact coatings on the fibers. Agreement between models and experimental results requires assumption of an intermediate mode, expressed as the dendrite fraction, which has not yet been determined experimentally.

There is no benefit to be derived from programmed variations of the voltage applied either to the bag electrodes or to the precharger. Sudden reversal of the voltage polarity when the bag is cleaned gives negligible improvements in cleaning. Use of ac rather than dc potentials resulted in slightly higher Δps, higher penetrations, and large electrode currents. However, although improvements in performance with ac were smaller than with dc, it is worth noting that use of ac in ESFF need not be ruled out.

As face velocity is increased, performance depends increasingly on cleaning energy. High cleaning energy, as in pulse-jet cleaning, leads to large penetration, while Δp remains within a commercially acceptable range. Low cleaning energy, as in reverse air with shaking, leads to large Δp, with penetration remaining low. Shear cleaning, a method which uses in-plane shear deformation of the fabric to aid reverse air cleaning, appears to have some potential as a nontraumatic substitute for shaking.

"Printed" electrodes (i.e., bands of conducting material deposited on the filter fabric) are as effective as wires in producing ESFF. Their use by utilities depends on finding a formulation for the material that will resist the temperature and chemical environment of baghouses.

Recommendations

Designing electrode systems to maximize field intensities and particle charge levels would be desirable. Replacing the lightning rod with an axial wire for corona charging should achieve both ends. For pulse-jet baghouses, the wires would be suspended between the bags.

Using the highest voltages would maximize electric effects. This, however, may lead to problems analgous to the back corona experienced with electrostatic precipitators. Studying the possible occurrence of this phenomenon, as well as means for preventing it, would also be desirable.

Another benefit would be the development of fabrics, having an upstream region of low solidity, that are suitable for commercial fabrication of bags, tested to determine long-term performance.

Formulating and pilot-plant testing of conducting substances, to be used for printed electrodes that can withstand baghouse conditions, would solve a serious problem in this area.

Other problems would be solved by investigating the potential usefulness of shear cleaning, including its effects on penetration and bag life.

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The complete report, entitled "Development of Advanced ESFF Technology," (Order No. PB 86-122 595/AS; Cost: $11.95, subject to change) will be available only from:

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