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Project Summary

Electrostatic Augmentation of Fabric Filtration: Pulse-Jet Pilot Unit Experience

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This report summarizes the development of the parallel-field electrostatically augmented fabric filter (ESFF) on a pilot-scale pulse-cleaned baghouse. The pilot unit consisted of parallel conventional and ESFF baghouses installed on a slipstream from a pulverized coal boiler. Teflon and fiberglass fabrics were investigated under a wide variety of operating conditions. The major parameters studied were particulate collection (total mass and size dependent), baghouse pressure drop, and electrical characteristics.

The results of this research show that the ESFF baghouse has significant advantages over conventional baghouses. The flow resistance of the collected dust is substantially reduced. Under the same operating conditions, an ESFF baghouse has about half the pressure drop of a conventional baghouse. Alternatively, the flow through a given area of fabric (face velocity) can be increased at constant pressure drop in the ESFF baghouse. Experience at the ESFF pilot unit suggests that face velocity can be doubled. An economic projection based on these results indicates that the ESFF would reduce the annualized cost of the filter by 30 percent. Particulate control capabilities of the ESFF baghouse were about the same as for the conventional baghouse: outlet loadings averaged less than 0.017 g/std m^3.

This Project Summary was developed by EPA's Industrial Environmental 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 use of fabric filters to remove particles from gas streams, well established in industrial practice, is of growing importance in electrical utility applications. Fabric filters boast high particulate collection efficiencies and are competitive in price with other control technologies. Their major drawback in coal-fired applications has been unexpectedly high pressure drops at some installations. Reduction of the pressure drop for fabric filters is, thus, important and capable of significantly influencing the choice of equipment for control of particulate emissions.

The deliberate use of electrical effects to improve the performance of conventional fabric filters has only recently received commercial consideration, although research has been underway for some time. Conventional design practice does not consider the electrical properties of either the dust or the fabric. Research has shown, however, that electrostatic forces on particles in a fabric filter can be important, and that their importance can be increased by charging the particles or by applying an electric field. The electrostatic forces influence the ways the particles interact with the fabric and other particles. If the interaction with the fabric results in increased particle collection at the fabric surface (reduced filtration in depth), cleaning could be expected to be more efficient and the residual pressure drop of the filter to be reduced. If the electrically influenced particle-to-particle interactions result in a dust cake that is more porous than normal, the flow resistance of the collected dust is reduced. Research indicates that both reduced residual pressure drop and reduced dust cake flow resistance can be achieved in electrostatically enhanced fabric filtration (ESFF).

The many ways to take advantage of electrostatic forces in fabric filters can be grouped into three broad categories: (1) allow the natural particle charges to accumulate on the fabric filter, (2) charge the incoming particles, then allow charge accumulation on the fabric, and (3) apply an electric field at the fabric surface. The first category describes many existing fabric filters; it is the natural result of the use of nonconductive fabrics. The commercially available Apitron filter utilizes the second approach (1). A corona precharger is placed at the inlet of a filter bag. The incoming particles are charged (and a significant fraction collected) within the precharger. The remaining dust is collected by the fabric filter. Charge accumulation by the fabric and collected dust causes an electric field to develop, which further enhances collection. The work discussed in this report utilizes the third approach, an externally applied electric field at the fabric surface. Electric fields can be applied either parallel or perpendicular to the fabric surface. Laboratory and theoretical work have shown that the use of an electric field parallel to the fabric surface results in improved fabric-filter performance (2). An external harness, similar to that shown in Figure 1, was tested in a small laboratory fabric filter (3). The flow resistance of the dust cake was significantly reduced at relatively low power levels. Several fabrics were tested in a range of electrical conditions: the results, in general, were encouraging.

Purpose of Program

The main purpose of this research program was to evaluate the concept of ESFF, as developed in the laboratory, on particulate in a slipstream from an operating coal-fired boiler. It was recognized that the laboratory work, although very encouraging, had been done under carefully controlled conditions, which were not similar to the flue-gas environment. The laboratory-test dust was reentrained fly ash, but in air at room temperature. Relatively low fabric dust loadings had been used. There were many questions concerning the operability of the ESFF system in the field other than the straightforward problems of design and materials selection. The approach taken was to attempt to use the laboratory design at field conditions. The relative merit of the ESFF system compared to the conventional fabric filter could then be evaluated.

Secondary objectives of the program were to: evaluate performance with respect to particle size, estimate the effects of different coal types, and evaluate the economics of the ESFF system.

Pilot Unit and Operating Experience

The basis of the ESFF pilot-unit test program was parallel operation of

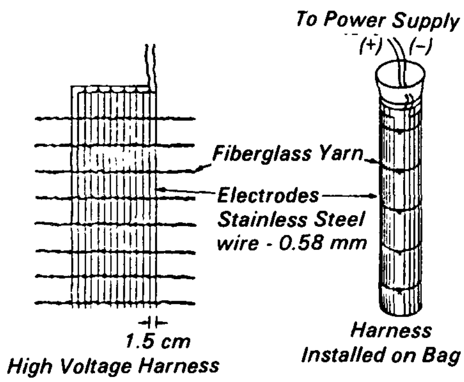

Figure 1. *Harness for applying electric field parallel to the surface of a fabric filter bag.*

identical conventional and ESFF baghouses. Boiler and coal variations were expected to be too large for successful testing to be done consecutively in time. The pilot unit was operated on a slipstream from an industrial pulverized-coal boiler house. The coal fed to the boilers was highly variable: sulfur content ranged from 0.6 to 2.9 percent (average about 1.3 percent), and ash content from 6 to 27 percent (average about 13 percent).

Figure 2 is a schematic of the pilot-unit installation. The pilot-plant capacity was about 9 m^3/min (300 ft^3/min) in each baghouse; average inlet mass loading was about 0.7 g/m^3 (0.3 gr/scf). The inlet temperature was around 150° C (300° F). Each baghouse was operated with up to five bags, 11.5 cm (4.5 in.) in diameter, and 2.44 m (8 ft) long. The electrical hardware consisted of high-voltage DC power supplies, current and voltage instrumentation, and the ESFF electrodes. Operation was 24 hours each day while a test was in progress.

The initial electrode design was a high-temperature version of the electrode harness shown in Figure 1. Material problems and inherent design weaknesses led to rapid deterioration of the outside harness. An improved electrode design was developed and mounted

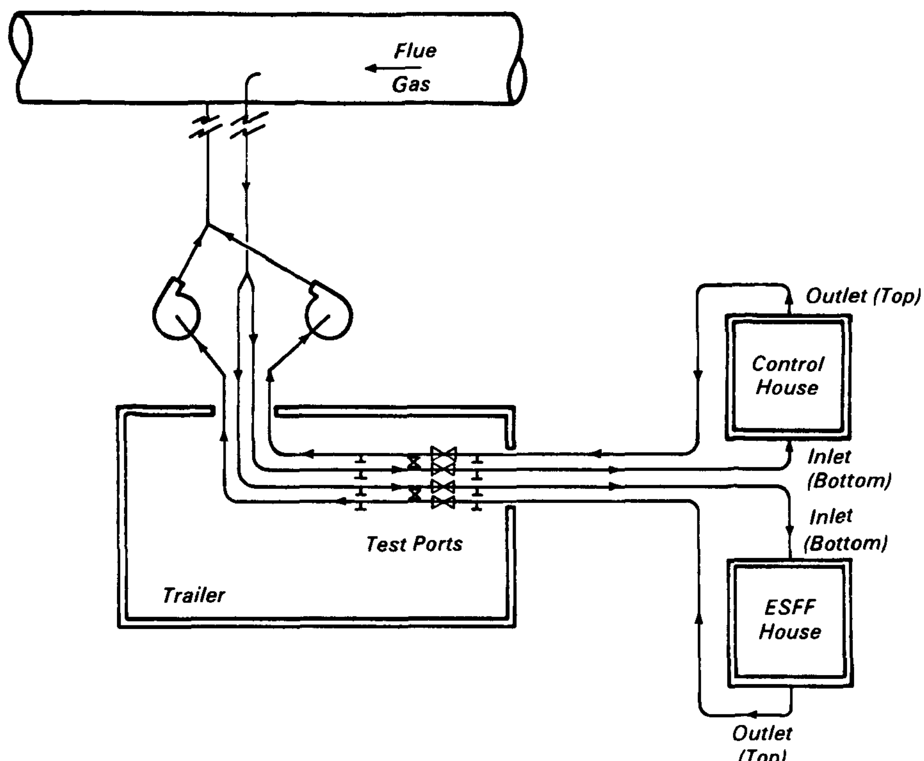

Figure 2. *Schematic of ESFF pulse-jet pilot unit.*

inside the bag, replacing the normal pulse-jet cage. The electrodes remained vertical but were supported by and insulated from the horizontal cage wires. This new design was an important improvement, greatly increasing the reliability of the ESFF baghouse.

Results

The most important results obtained at the ESFF pilot unit concerned improvements in the pressure drop characteristics of the fabric filter. Three aspects of this phenomenon are discussed below.

The effect of ESFF on dust-cake flow resistance can be readily observed in a plot of pilot-unit pressure drops as a function of time, shown in Figure 3. The pressure drop of the ESFF baghouse does not increase as rapidly as that of the conventional baghouse. Because the same amount of dust is being deposited on the bags in both baghouses, the difference must be in the resistance of the dust cake to flow. This reduction in dust-cake flow resistance has been quantified as pressure drop ratio (PDR), defined as:

$$PDR = \frac{(\Delta P_f - \Delta P_i)\ ESFF}{(\Delta P_f - \Delta P_i)\ Conventional}$$

where ΔP_f = pressure drop just prior to cleaning,

ΔP_i = pressure drop just after cleaning,

ESFF refers to the ESFF baghouse, and

Conventional refers to the conventional baghouse.

Figure 4 shows the relationship between PDR and electric-field strength at the bag surface for fiberglass and Teflon fabrics for a range of face velocities. At 3 kV/cm the increase in pressure drop over a cleaning cycle for the ESFF baghouse was a little less than half that for the conventional baghouse. PDR at the pilot unit was not a strong function of field strength for either fiberglass or felted Teflon fabrics. The Teflon results are in general agreement with the laboratory work.

Figure 5 shows another advantage of the ESFF baghouse over conventional technology--a reduced residual pressure drop. The ESFF baghouse had achieved stable operation at a residual pressure drop of 0.5 kPa (2 in. H_2O), while the conventional baghouse under identical conditions had a residual pressure drop of more than 1.5 kPa (6 in. H_2O). The ESFF residual pressure drop averaged about 60 percent of that for the conventional baghouse. It was possible, through repeated off-line cleanings, to return both baghouses to about the same pressure drop. The difference in residual pressure drop developed again soon after normal operations resumed.

From the standpoint of process economics, the most useful manifestation of the reduced flow resistance of the dust cake collected under ESFF conditions is the ability of an ESFF baghouse to operate at high face velocities. Experience at the pilot unit showed that the conventional baghouse could not be operated in a stable fashion above about 2 cm/s (4 ft/min). The ESFF baghouse was operated for nearly a month at greater than 2 cm/s, and it was possible to stabilize the operation at up to 5 cm/s (10 ft/min) by increasing the cleaning frequency.

Particulate control by the two baghouses appeared to be essentially the

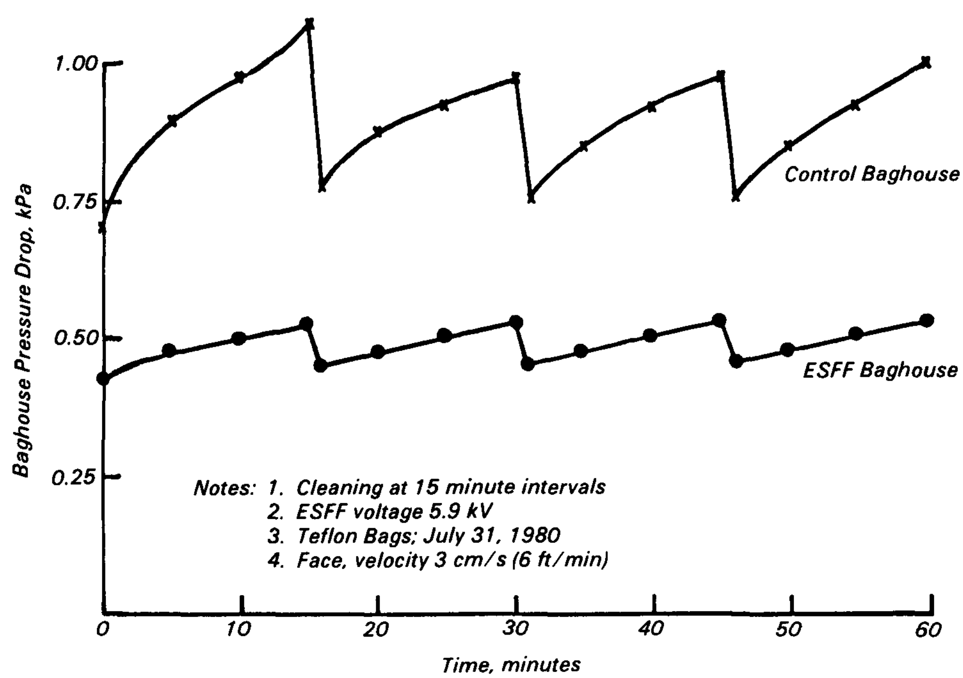

Figure 3. *Pressure drop plot for pilot baghouse.*

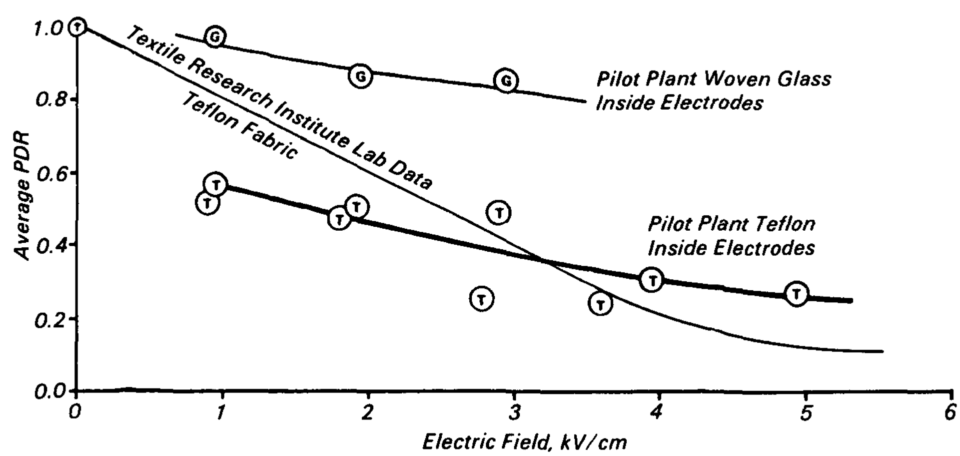

Figure 4. *PDR-field strength relationship for Teflon and glass fabrics.*

same. The average outlet loading from the ESFF baghouse was 0.017 g/std m³, and that from the conventional baghouse was 0.016 g/std m³. Impactor measurements of the size-dependent particulate removal efficiency indicated that the ESFF baghouse was more efficient than the conventional baghouse. However, the conventional baghouse was cleaning much more frequently than the ESFF baghouse, and the increased penetration might well be due to seepage. The electrical requirements of the ESFF baghouse were modest. The outside harness electrodes, imbedded in the dust cake, averaged about 50 μA of current per bag. Current was roughly proportional to voltage for the outside electrodes. The inside cage/electrode combination drew only about 10 to 20 μA per bag, and the current was not affected by voltage within the normal operating range. The current was fairly stable, but some drift did occur over periods of hours. Power requirements at the field strengths and currents described above amount to 0.5 to 1 W/m² (0.05 to 0.1 W/ft²).

The results of the economic analysis are shown in Figure 6. An ESFF baghouse operated at 3 cm/s (6 ft/min) was estimated to have a total annual cost about 30 percent below that of a conventional baghouse operated at 2 cm/s (4 ft/min). Still higher face velocities would allow even greater savings.

Conclusions

Electrostatic augmentation of fabric filtration (ESFF), utilizing an electric field parallel to the fabric surface (with no particle charging), has been successfully applied at pilot scale on a pulse-jet baghouse.

The electrode configuration developed in the course of this study consists of a combination cage/electrode assembly, modified from a conventional pulse-jet cage, and appears to be a design with potential for commercial use.

At any given face velocity, the pilot ESFF baghouse had a reduced residual pressure drop and a reduced rate of pressure drop increase when compared to the pilot conventional baghouse.

The pilot ESFF baghouse could be operated in a stable fashion at face velocities up to about twice the stable operating conditions possible for the pilot conventional baghouse.

A reduction in total annualized cost of 30 percent or more was estimated for a typical industrial boiler installation, controlled by an ESFF pulse-jet baghouse at 3 cm/s rather than a conventional pulse-jet baghouse at 2 cm/s. For a 27,200-kg-steam/hr (60,000 lb/hr) boiler using electricity at $0.05/kWh, the estimated annualized cost of the ESFF baghouse was about $107,000 at 3 cm/s, while the cost of a conventional baghouse at 2 cm/s was estimated at $146,000/yr.

Particulate mass emissions from the two pilot baghouses were not significantly different. The average efficiency for the pilot ESFF baghouse was 98 percent, with an average outlet loading of 0.017 g/std m³. The average efficiency of the pilot conventional baghouse was 98.9 percent, with an average outlet loading of 0.016 g/std m³.

Recommendations

To install a pulse-jet ESFF at essentially full commercial scale, the retrofit of a single compartment of an existing pulse-jet baghouse with ESFF or the modification of a new design would be sufficient. This program could be directed toward investigating system scale-up parameters and an extended (months-long) period of routine testing.

The use of ESFF with fabrics other than the felted Teflon and woven fiberglass tested in this program needs to be investigated. Laboratory work indicates that other fabrics can be used as ESFF fabrics; in some applications these might be desirable.

Investigation of the use of ESFF on dust sources other than pulverized coal-fired boilers would be valuable. The advantages of ESFF should be applicable to other sources, but little data is available.

Important fabric-dust interactions and properties that require investigation include the electrical properties of both

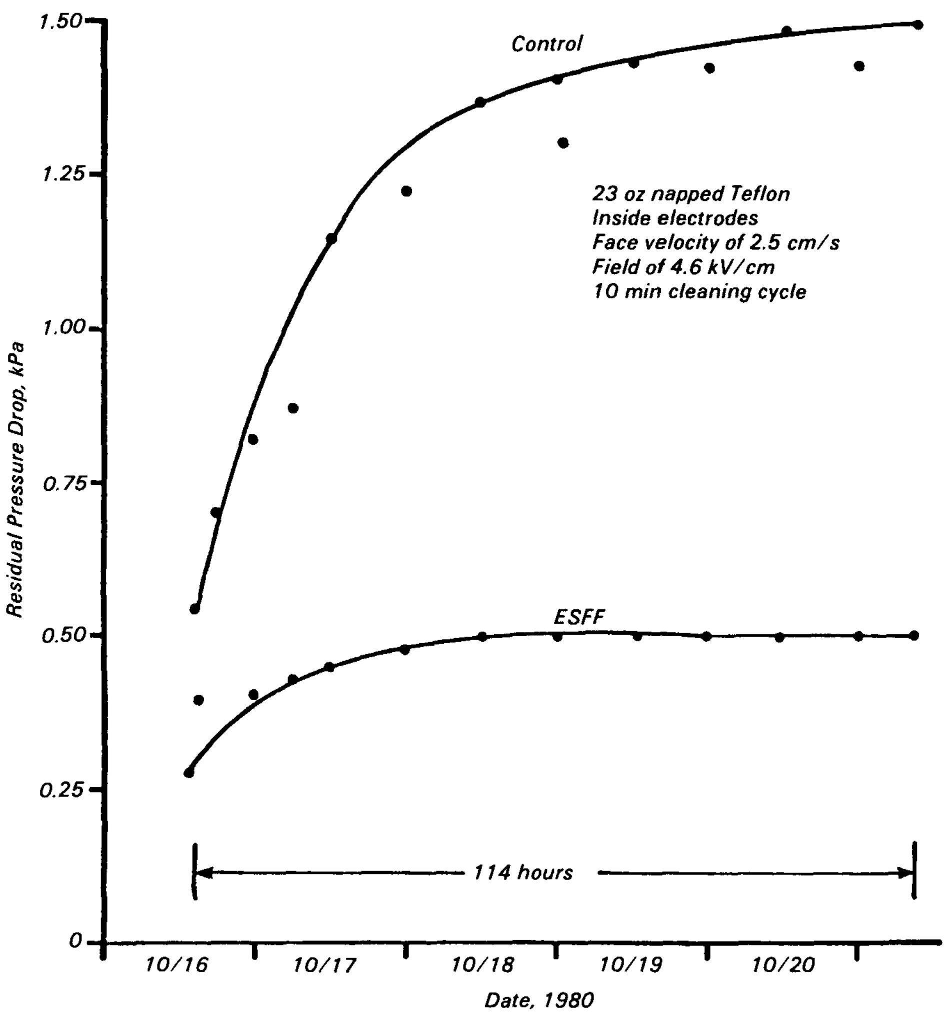

Figure 5. *Residual pressure drop for ESFF and control baghouses.*

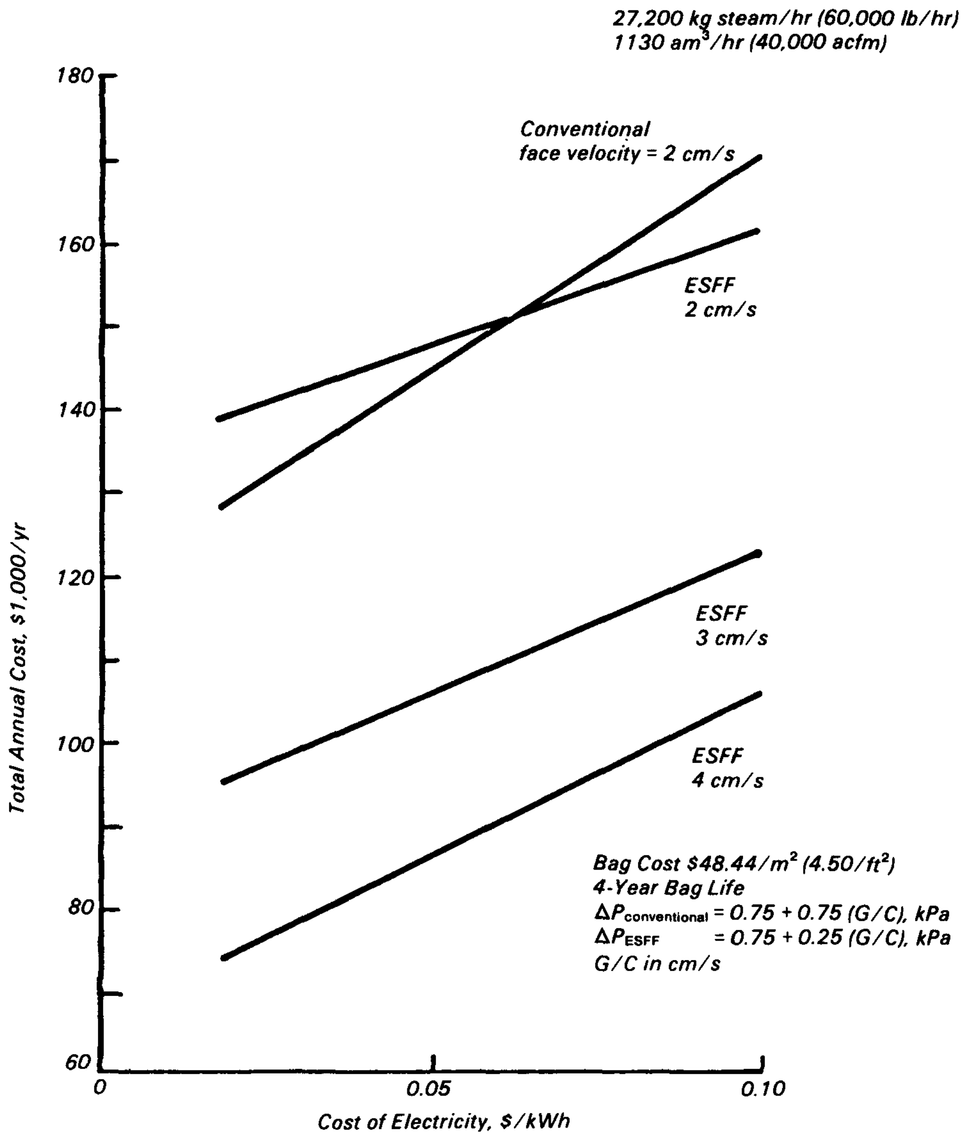

Figure 6. *Pulse-jet baghouse cost: pulverized-coal industrial boiler.*

the fabric and the dust, particle size, natural charge of the dust, gas conditions, and similar parameters.

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The complete report, entitled "Electrostatic Augmentation of Fabric Filtration: Pulse-Jet Pilot Unit Experience," (Order No. PB 83-168 625; Cost: $11.50, subject to change) will be available only from:

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