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Project Summary

Pilot-Scale Evaluation of Top-Inlet and Advanced Electrostatic Filtration

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Advanced Electrostatic Augmentation of Fabric Filtration (ESFF) was evaluated on a slipstream from a stoker-fired boiler. Advanced ESFF, with its characteristic high-voltage center-wire electrode, was compared with conventional filter bags in the same baghouse using calibrated flow orifices. The advantage of advanced ESFF was demonstrated by consistently higher gas flow rates in the bags with the corona producing electrodes. Analysis of the data showed that the specific resistance of an electrostatically enhanced filter was 70% less than that of a conventional bag. An economic analysis showed a capital cost savings of 26% with advanced ESFF, based on doubling the air-to-cloth ratio for advanced ESFF. In a second test, the feasibility of using top-inlet filtration on stoker fly ash was established. No definitive comparison with conventional bottom-inlet filtration could be made in the allotted test period.

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).

Introduction

Under a program funded by the U.S. Navy, and with support from the U.S. Environmental Protection Agency, personnel from Research Triangle Institute and ETS, Inc., conducted a pilot plant evaluation of fabric filtration at a baghouse. The study focused on two different approaches to fly ash filtration: top-inlet filtration and advanced electrostatic stimulation of fabric filtration (ESFF). In designing a baghouse, several variables must be considered: the cost of the fan(s); the rate of the pressure loss (amount of energy required to pull air through the dust-laden fabric); and the ratio of the air flow rate to the filter area (air-to-cloth ratio). Generally, it is better to have a low rate of pressure loss or drop. Attaining a low pressure drop means ensuring a slow rate of dust deposition which, in turn, is related to the amount of fabric area available for dust deposition. This all points to the importance of air-to-cloth ratio. The design of a baghouse poses the problem of specifying the highest possible air-to-cloth ratio (to minimize the overall size of the baghouse and subsequently its cost) while ensuring that the pressure loss limitations (influenced by fan cost considerations) are not exceeded.

One form of ESFF involves placing electrodes of opposite polarity on the surface of the fabric and then generating an electric field parallel to the fabric. The most recent version of ESFF (also called advanced ESFF) calls for placing the electrode in the center of the filter bag (Figure 1). Experiments conducted by the U.S. EPA showed that the electric field alters the dust deposition pattern and the structure of the dust cake. The overall result was a reduction in the pressure drop across the bag. The advanced form of ESFF was tested during this project.

The top-inlet design of a baghouse was the other form of filtration tested at the pilot scale. The standard, bottom-inlet design allows dirty gas to enter and flow up the bag. Because of this upward flow,

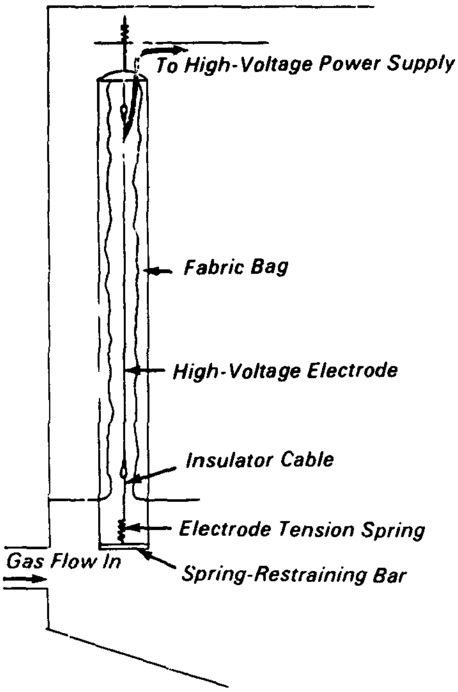

Figure 1. *The center-wire configuration for advanced ESFF.*

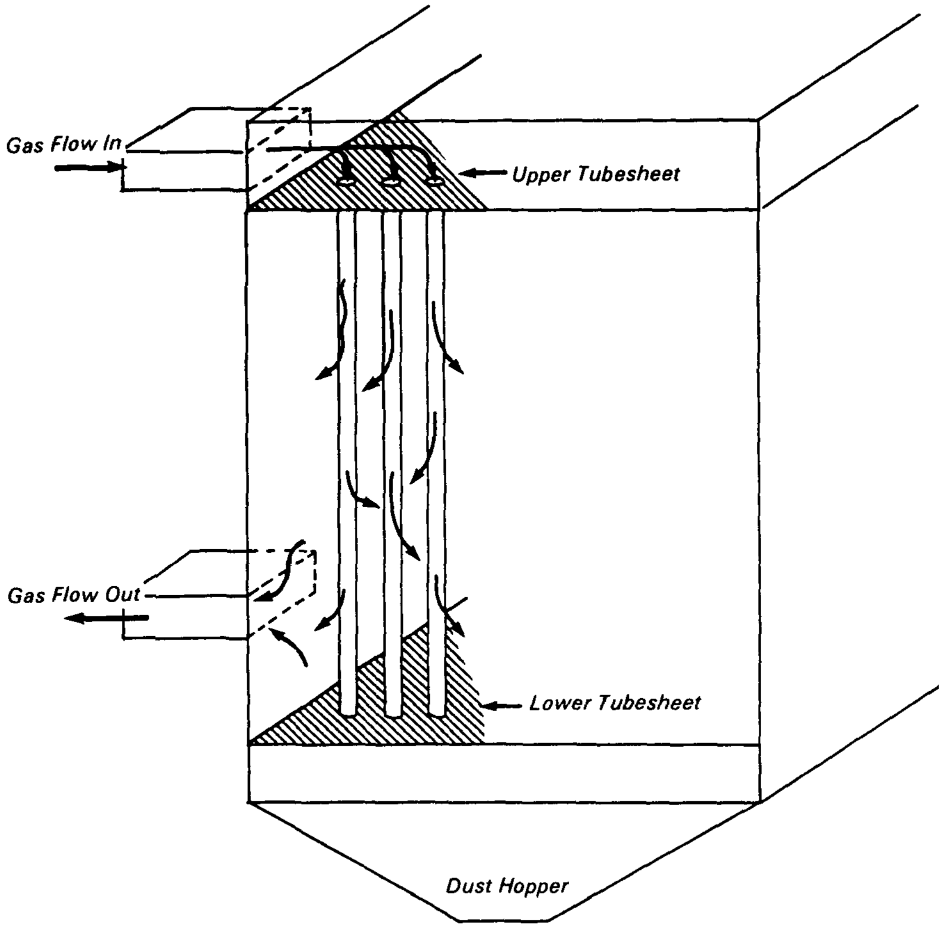

Figure 2. *Conceptual design of a top-inlet baghouse.*

large particles either fall from the gas into the hopper below or are deposited on the lower portion of the bag. An elutriation effect may occur whereby the average particle size deposited on the bag decreases as the distance from the bottom inlet increases. The resistance of the dust cake may increase as the mean particle size decreases, producing an increase in flow resistance as the distance up the bag increases. Based on this theory, it has been recommended that the dust-laden gas be introduced from the top, into a bag with openings at both the top and the bottom (Figure 2). In this way, the large particles would be retained in the gas and be distributed more evenly along the entire length of the bag. This may both lower the resistance of the dust cake and make it more uniform.

Pilot Plant Design

Located at Cherry Point Marine Corps Air Station in Havelock, NC, the pilot plant (Figure 3) filtered coal fly ash from a slipstream from two spreader-stoker-fired boilers. The boilers are rated at a maximum of 77,500 lb steam/hr (9.77 kg/sec). Only one boiler was online at any given time during the test period. The fuel was an eastern coal of 1% sulfur and 5% water and had a heat content of 31,600 kJ/kg (13,600 Btu/lb). The ash's electrical conductivity (relatively high for a coal ash) resulted from a high, unburned carbon content. Identical baghouse compartments were located next to each other, with each fed by a separate fan with a capacity of 19.82 m³/min (700 ft³/min) of air drawn from a common duct. This common duct pulled gas from the inlet of the electrostatic precipitators (ESPs) downstream of each boiler. A single reverse-air fan provided ambient air for cleaning each compartment.

Because of the project's focus on the feasibility of advanced ESFF, the only tests performed were those which demonstrated the effect and, to a small degree, the operating range of advanced ESFF. Time constraints dictated completion within 1 year (February 1985 to February 1986). This requirement affected the experimental design. The central problem in designing the plant consisted of making it possible to test three kinds of filtration — advanced ESFF, top-inlet, an(conventional bottom-inlet — in only tw(compartments as efficiently as possible The engineers decided to use individua bag flow monitors (IBFM™), thereby al lowing for the simultaneous operation c advanced ESFF and conventional filtratio in the same compartment. This left th second compartment free for testing th top-inlet design.

The IBFM™ has a calibrated orific plate at the inlet of the bag on top of th compartment tubesheet. Pressure tap on the upstream and downstream side of each orifice plate make it possible t measure the orifice pressure drop. Th flow into each bag is calculated from dat on the pressure drop and the temperatu of the gas. This information, along wi the tubesheet pressure drop and inl dust concentration, can then be used calculate the dust cake's specific resi tance and residual drag. A comparison these parameters produces a figure

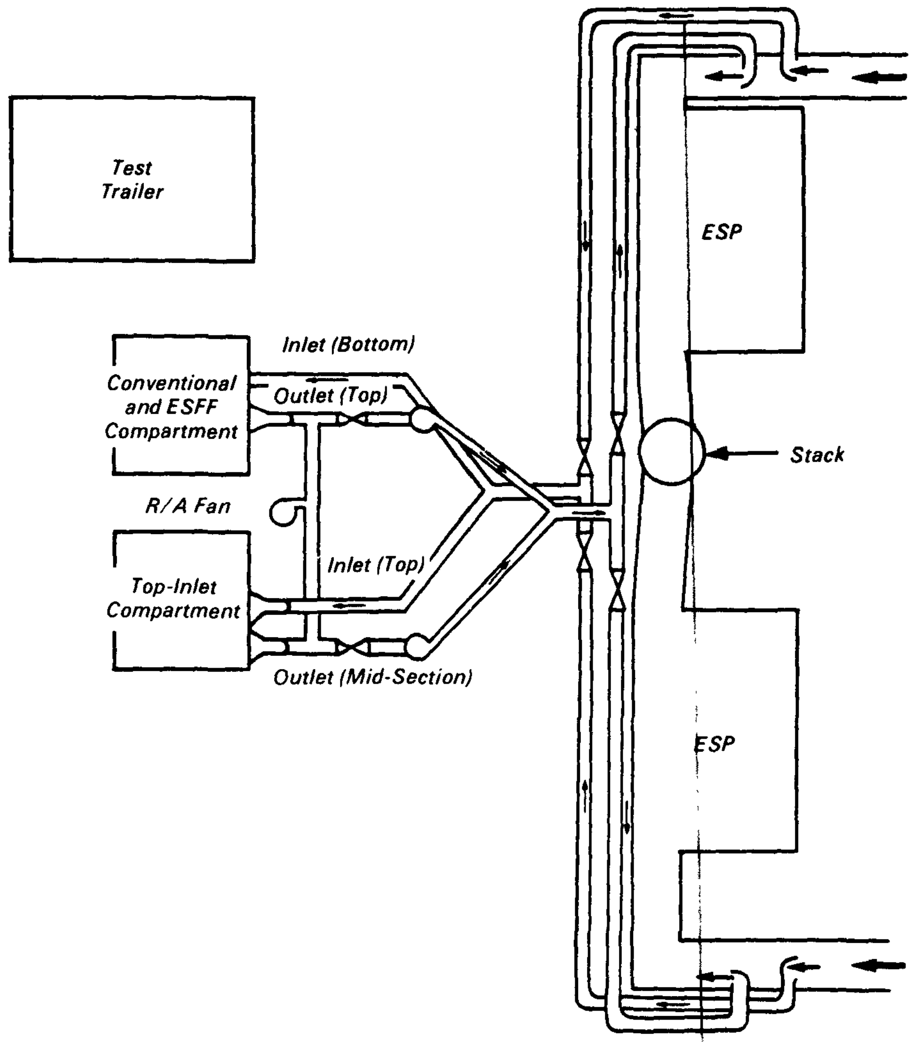

Figure 3. *Schematic of the Cherry Point pilot plant.*

merit for evaluating the ESFF design. The data obtained from the top-inlet compartment resulted in a similar comparison. Testing the ESFF and conventional bags in the same compartment meant that the bags were exposed to identical conditions, thereby increasing the confidence in the results.

Data Acquisition System

As mentioned earlier, the project had a time constraint of 1 year. Also, cost considerations precluded payments for an on-site operator. Thus, the engineers designed an automated system for collecting, retrieving, and analyzing the data. This system offered a number of advantages, the most important of which were: elimination of labor costs for data collection and computer entry; and long-distance data retrieval. The second advantage meant that the data could be monitored and analyzed daily.

It was necessary to measure the temperatures, tubesheet and orifice pressure drops, electrical conditions, and dust-inlet loadings. All were automated except for the dust-inlet loadings (measured according to standard EPA Method 5 procedures). The signals from the various thermocouples and pressure transducers fed into a Molytek Model 2702 Programmable Datalogger. The datalogger, in turn, interfaced with a Tandy 1200 microcomputer. At 10-minute intervals, the datalogger transmitted instantaneous readings to the computer which then stored the data (with custom-developed software). The concurrent PC-DOS operation allowed for simultaneous operation of the data collection/storage program and remote communication. Thus, the engineers could use a high-speed modem to call the on-site computer and read data files over the phone lines into their own microcomputers. Once the data files were retrieved in this fashion, they were read into a Lotus 1-2-3 (C) worksheet for analysis. The one disadvantage in testing two kinds of filtration in the same compartment was that it precluded on-site evaluation of performance based on the tubesheet pressure drop. Thus, it was necessary to analyze the data before the results were known. However, the advantages certainly outweighed this one disadvantage.

Results

During February and March 1985, the pilot plant was installed. The plant was brought online in April, with hardware debugged in April and May. The collection of data began in June. The plant operated continuously until the end of September, except for brief periods due to coal elevator repair, a switch from boiler No. 1 to No. 2, and electrical failure. At all other times, the plant required a minimum amount of intervention and collected data automatically.

Bottom-Inlet/ESFF Compartment

The feasibility of advanced ESFF and, to a lesser degree, of top-inlet filtration is determined by the ability to operate at higher face velocities. Therefore, the focus was on determining if ESFF and top-inlet filtration could be used for prolonged periods of time at face velocities that were substantially higher than those of a conventional filter. Thus, the test plan called for one long experiment with the filtration velocity increased gradually. This experiment was particularly important since it was impossible to explicitly set the flow rate through the bottom-inlet and ESFF bags. Instead, it was possible only to set the overall flow rate to the entire compartment. The engineers determined the distribution of flow between the bottom-inlet and the ESFF bags by calculating the drag differential between the two sets of bags.

Figure 4 plots the average air-to-cloth ratio (for each bag) against the cycle number. One cycle represents a 12-hour period (11 hours and 50 minutes of filtration, and 10 minutes of cleaning). The curves are separated into two distinct groups, with the exception of the data from cycle 50 through 70. The upper set of curves corresponds to the advanced ESFF bags, and the lower set corresponds

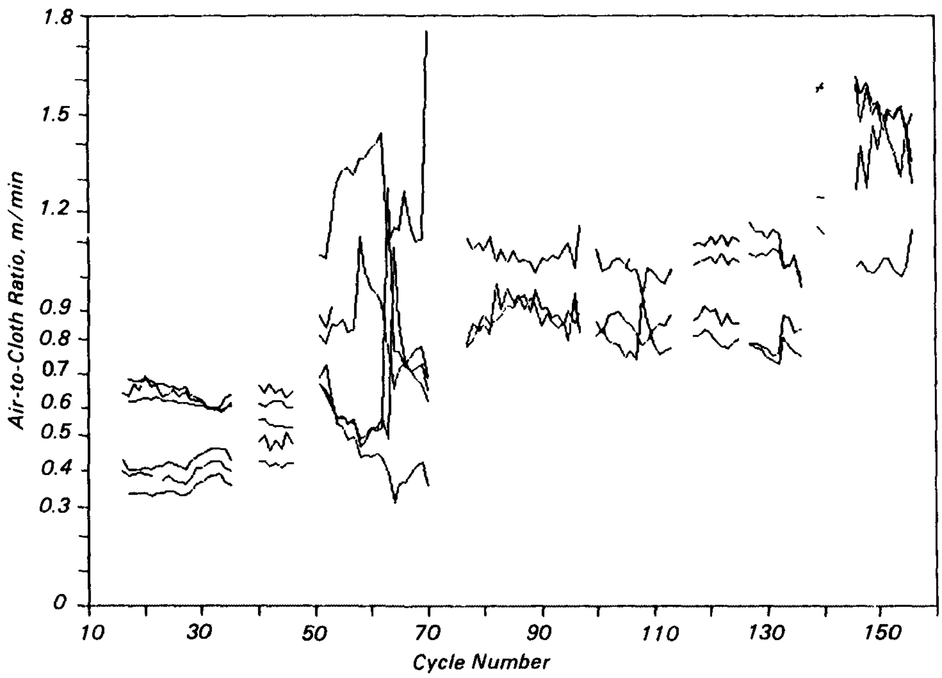

Figure 4. *Average air-to-cloth ratio for conventional and ESFF bags in bottom-inlet compartment.*

to the conventional bags. The overall air-to-cloth ratio (compartment inlet flow/total compartment bag area) increases from an initial value of 0.55 to 0.79 m/min (1.8 to 2.6 ft/min) at cycle 50. Then, the reverse air fan failed, resulting in erratic data. The tubesheet pressure drop ranged from 0.1 kPa (0.4 in. H_2O) at an air-to-cloth ratio of 0.55 m/min to 0.87 kPa (3.5 in. H_2O) at an air-to-cloth ratio of 1.26 m/min.

It was possible to convert the data into flow rates and then use those rates and the dust concentration information to compute the variation of dust load (kg/m^2) on each bag as a function of time. The ratio of pressure drop to bag flow velocity gives the bag drag. Figures 5 and 6 plot the bag drag as a function of dust load for the ESFF and conventional bags, respectively. The straight line in each figure represents the regression fit to the data. Note the two important features in these figures: (1) the straight lines show a good fit to the data, indicating that it is reasonable to assume a linear relationship between drag and dust load; and (2) the slopes (i.e., specific resistance) of the two lines are quite different. The value of drag for the ESFF bag rises much more slowly than the conventional bag's value. Thus, by using an appropriate model of pressure drop behavior and measuring the individual bag flows, the values for the specific resistance and residual drag can be determined fairly easily.

Top-Inlet Compartment

In making these measurements, a single value for specific resistance was assumed as characterizing all the bags in the compartment at a given time. The value for residual drag also was assumed to be the same for all the bags. Values for the compartment drag and dust load were calculated from measurements of the compartment inlet flow and the tubesheet pressure drop. The test plan for this compartment was very similar to the plan for the other compartment, with the face velocity increasing from 0.55 to 0.79 m/min. The results, however, were marred by two problems: the breakdown of the cleaning fan (mentioned earlier) and the loss of control over a flow-control valve. Because of the small amount of reliable data, it is doubtful that any accurate conclusions can be drawn about the operation of the top-inlet compartment.

Economic Analysis of Advanced ESFF

This project showed that advanced ESFF can greatly reduce the rate of pressure rise of a baghouse. This can translate into an economic savings in that, for a fixed average pressure drop, a baghouse which uses ESFF will be smaller than a conventional baghouse. Also to be considered is whether or not this smaller size will offset the cost of the additional hardware. The pressure drop depends on both the residual drag and the specific resistance of the dust cake. Test results indicated that an ESFF baghouse can be expected to have a specific resistance equal to 30% of that of a conventional baghouse. This value was used to estimate pressure drop. Two values were considered for residual drag: case I made the ESFF's residual drag equal to a conventional baghouse's, while case II

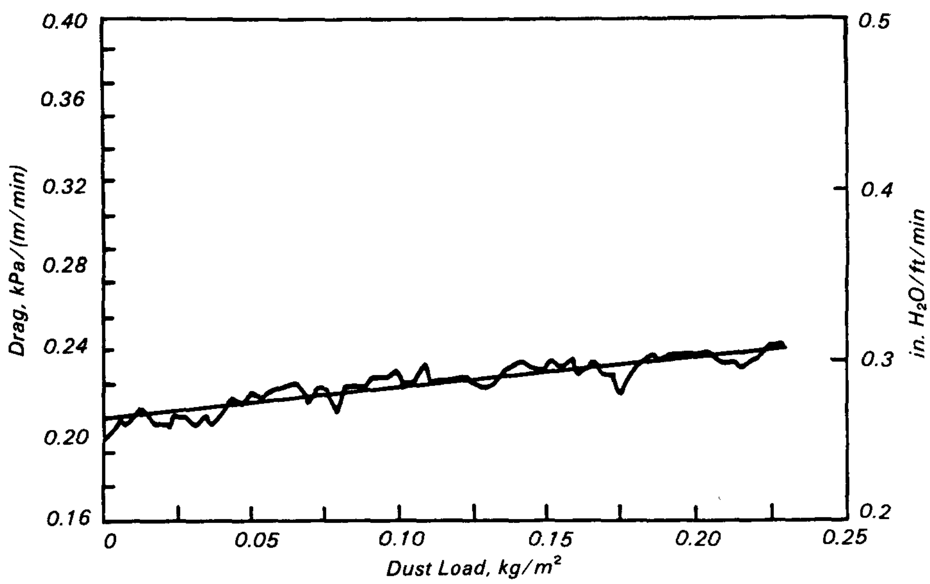

Figure 5. *Drag correlation for the ESFF bag.*

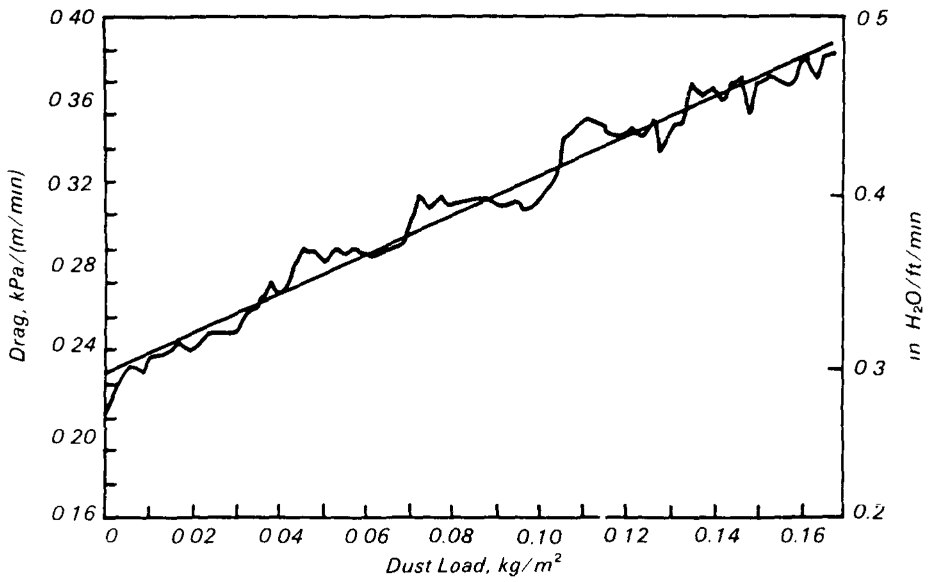

Figure 6. *Drag correlation for the conventional bag*

assumed the ESFF value to be half of that of the conventional baghouse Although the results from this study present little evidence to support this assumption, laboratory and pilot-plant studies of other ESFF geometries have indicated a large difference in residual drag Based on these assumptions about the air-to-cloth ratio, bag life, specific resistance, and residual drag, the annual operating and maintenance costs were computed. Figure 7 plots the annual savings (in the form of the percent difference in cost between an ESFF and a conventional baghouse)

Conclusions and Recommendations

On an average, the specific resistance of the ESFF bags was 70% less than that of conventional bags. The IBFM^{tm} system worked well, proving invaluable to the success of this program The automated data acquisition/analysis system also worked well and allowed the pilot plant to operate unattended for days at a time. Problems with the cleaning hardware in the top-inlet compartment significantly affected the conditions and produced unreliable results. Finally, the additional cost of the ESFF hardware is more than offset by the savings resulting from the smaller size of the baghouse. The capital cost of an ESFF baghouse which was operated at air-to-cloth ratio of 1.22 m/min would be 26% less than that of a conventional baghouse with an air-to-cloth ratio of 0.61 m/min.

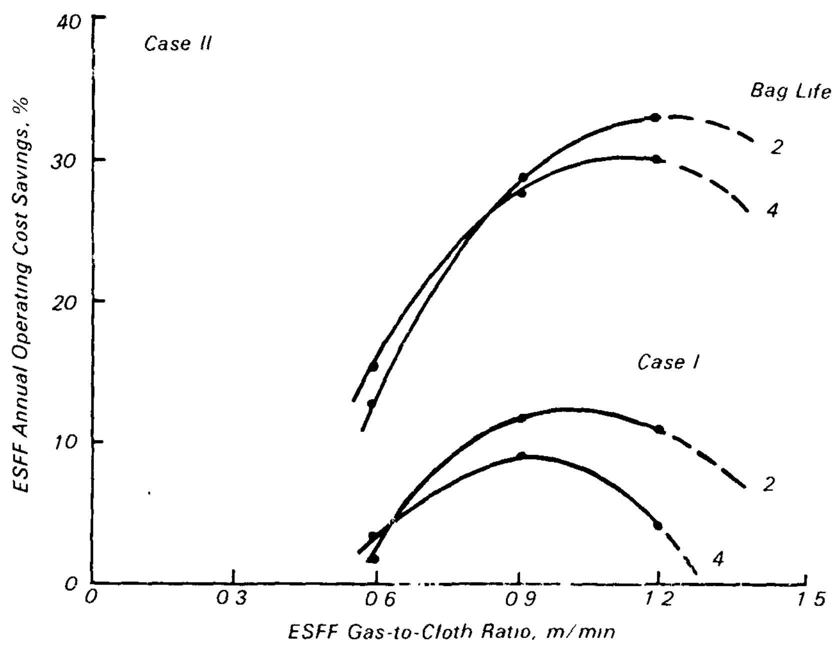

Figure 7. *Annual ESFF savings in operating and maintenance costs*

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The complete report, entitled "Pilot-Scale Evaluation of Top-Inlet and Advanced Electrostatic Filtration," (Order No. PB 87-133 096/AS; Cost: $13.95, subject to change) will be available only from:

National Technical Information Service
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