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Assessment of a High-velocity Fabric Filtration System Used to Control Fly Ash Emissions

Interagency Energy/Environment R&D Program Report

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EPA REVIEW NOTICE

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Assessment of a High-velocity Fabric Filtration System Used to Control Fly Ash Emissions

by

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CONTENTS

ABSTRACT

As a follow-up to a pilot plant study, a full scale investigation of applying high velocity fabric filtration to coal-fired boiler fly ash control was conducted. Two filter systems were separately applied to two 60,000 lb./hr. coal fired boilers. Performance evaluations conducted over the course of a year included total mass removal efficiency and fractional efficiencies. One filtration system employed Teflon felt as the filter medium while the second system employed Gore-Tex, a PTFE laminate on PTFE woven backing. During the course of the year a limited number of glass felt and woven glass bags were introduced into the house containing Gore-Tex.

Installed, operating and annualized costs have been computed for five filter media (Teflon felt, Gore-Tex PTFE laminate, 2 weights of woven glass and a felted glass fabric) in a fabric filter system capable of handling 70,000 ACFM. The lighter weight woven glass fabric is the least expensive filter medium overall and (assuming a four-year bag life is feasible) this makes fabric filtration an economically attractive alternative to electrostatic precipitation.

LIST OF FIGURES

LIST OF FIGURES
(continued)

LIST OF TABLES

ACKNOWLEDGEMENTS

This program was funded by the Environmental Protection Agency (EPA Grant Number 68-02-2148) with FabricsAmerica as the prime contractor and Enviro-Systems & Research, Inc. as the major sub-contractor.

The authors wish to express their deep appreciation for installation of Gore's fabric filters and for their subsequent technical assistance to:

W. L. Gore & Associates, Inc.

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Operation during 1977 of the baghouses at Kerr Industries was not ideal. Mechanical failures were the greatest problem, resulting in one or the other baghouse going off-stream, sometimes for days at a time. Difficulties at the Kerr boiler house sometimes caused shutdown of the baghouses and resulted in the almost daily occurrence of cold start-ups. Both baghouses experienced dew point excursions during 1977 as a result of the mechanical and boiler house problems mentioned above. The 1977 coal miners' strike necessitated the use, for part of the year, of poor quality coal at Kerr.

The net result of these difficulties is illustrated by the higher than anticipated system pressure losses.

Another illustration of the impact of these difficulties, particularly the burning of poor quality coal, is evidenced in part by the lower than normal filtration efficiencies. However, when reviewing these data, one must take into account the inlet grain loadings, which seemed both lower and finer than one would normally expect.

INTRODUCTION

In 1973 Enviro-Systems & Research, Inc. was awarded an EPA contract for the purpose of determining the technical and economic feasibility of employing fabric filter dust collectors for fly-ash emission control, particularly as applied to industrial boilers. Initially, the program was jointly funded by EPA, Kerr Finishing Division of FabricsAmerica and Enviro-Systems & Research, Inc. (ES&R). The plant, located in Concord, North Carolina, served as the host site for the program, and ES&R manufactured and installed the pilot facility. The pilot plant, installed on a slip stream of Kerr's No. 2 boiler, was sized to handle 11,000 ACFM when operating at a gas-to-cloth ratio (apparent filtering velocity) of 6/1. This prototype facility was actually a two module commercial size unit (Enviro-Clean Model RAC-3) selected in order to minimize future scale-up problems. It is shown in Figure 1.

In order to evaluate fabric filtration as an acceptable means of dust collection with respect to coal-fired stoker boilers, the following had to be examined:

1. Pressure drop vs. gas-to-cloth ratios for the various levels of cleaning-air volumes and bag material types.
2. Outlet loadings by size vs. gas-to-cloth ratios for the various levels of cleaning air volumes and bag material types.
3. SO_2, SO_3, inlet loadings and particle size distributions.
4. Capital and operating cost comparisons for the different bag materials vs. an electrostatic precipitator.
5. The boiler load for the various tests performed.

The filter media evaluated were Nomex(R) felt, Teflon(R) felt (2 styles), Gore-Tex(R) and Dralon-T(R). Fractional efficiencies were determined using an Andersen inertial impactor for the four filter media at three gas-to-cloth levels. The effect of cleaning gas volume on outlet loading and on pressure drop across the bags was evaluated.

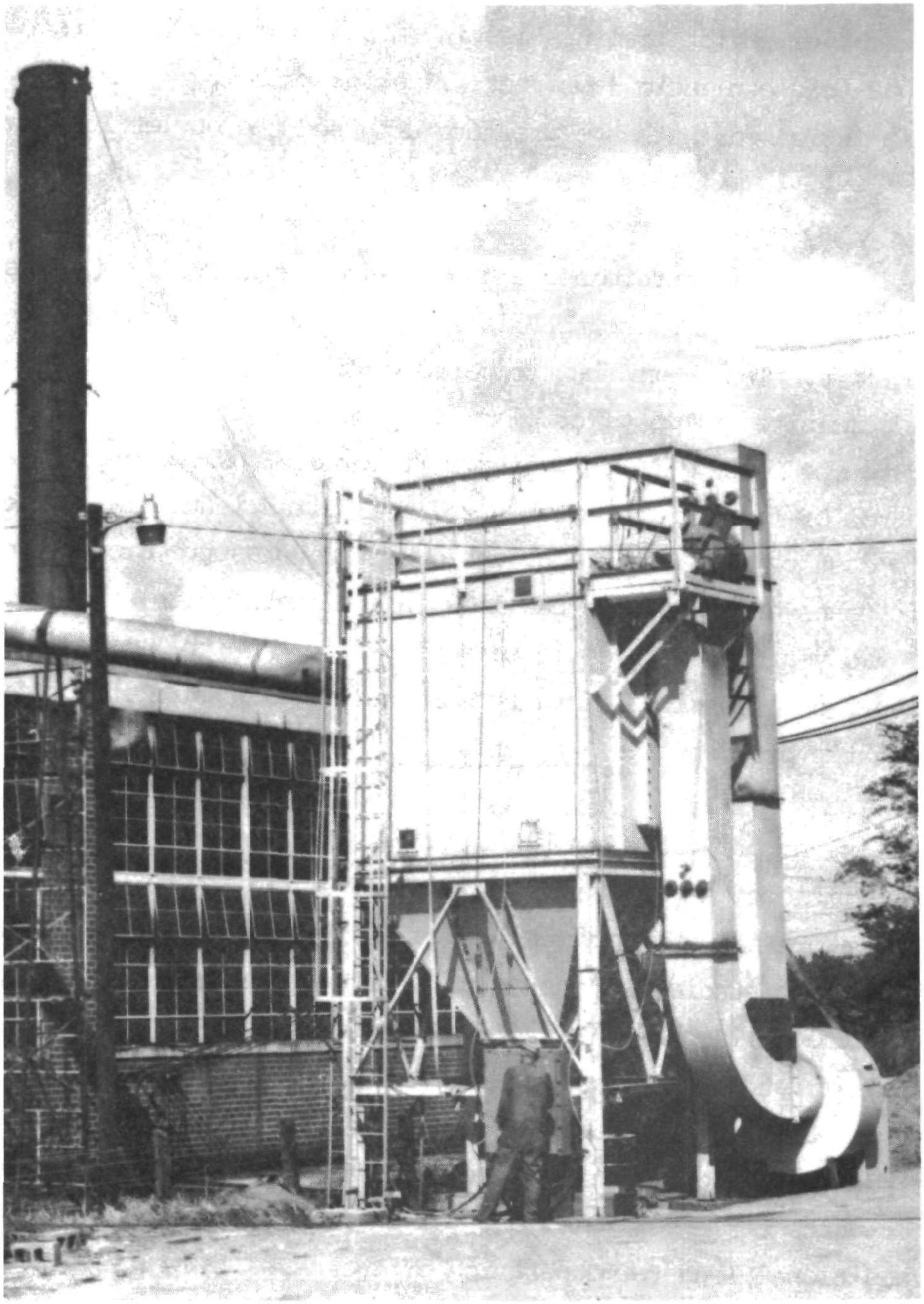


Figure 1

Kerr Pilot Plant

In addition, studies of the effect of cleaning frequency and duration were conducted. The overall technical conclusion was that all four media tested could achieve outlet loadings meeting state code requirements regardless of the gas-to-cloth ratio (apparent filtering velocity). As the gas-to-cloth ratio increased, both the pressure drop and the outlet loadings increased.

Installed costs were determined and operating and annualized costs were developed from the operating characteristics obtained plus assumptions regarding bag life. They were then compared with precipitator costs developed for the same site. This pilot plant program and subsequent economic analysis led to the conclusion that fabric filter dust collectors are suitable for control of fly-ash from stoker fed coal-fired industrial boilers in terms of both dust removal efficiency and operating pressure drop. The main question left unanswered was what bag life is achievable with continuous service. If two year bag life could be achieved, even with Teflon felt (the most expensive bags), fabric filters appear economically more attractive than electrostatic precipitators for industrial coal-fired boiler applications.

The pilot plant program provided short term performance data including dust removal efficiencies and pressure drops for a number of filter media. These data and a preliminary economic analysis indicated that long term bag life and performance studies were warranted. The EPA thus decided to award a contract for the full scale assessment of this approach to fly-ash control. Figure 2 is an artist's rendition of the assessment project. The initial contract awarded to FabricsAmerica, with ES&R as the major sub-contractor, called for ES&R to design, fabricate, install and then operate the two fabric filter units for a period of one year. Contract options called for subsequent additional long term operation of the units in order to test other filter media and also to evaluate the device as a sulfur dioxide removal system.

The purpose of the assessment program is the testing of a full scale fabric filter system installed on an industrial size coal-fired stoker boiler. The baghouse system will be operated and tested over the duration of the pro-

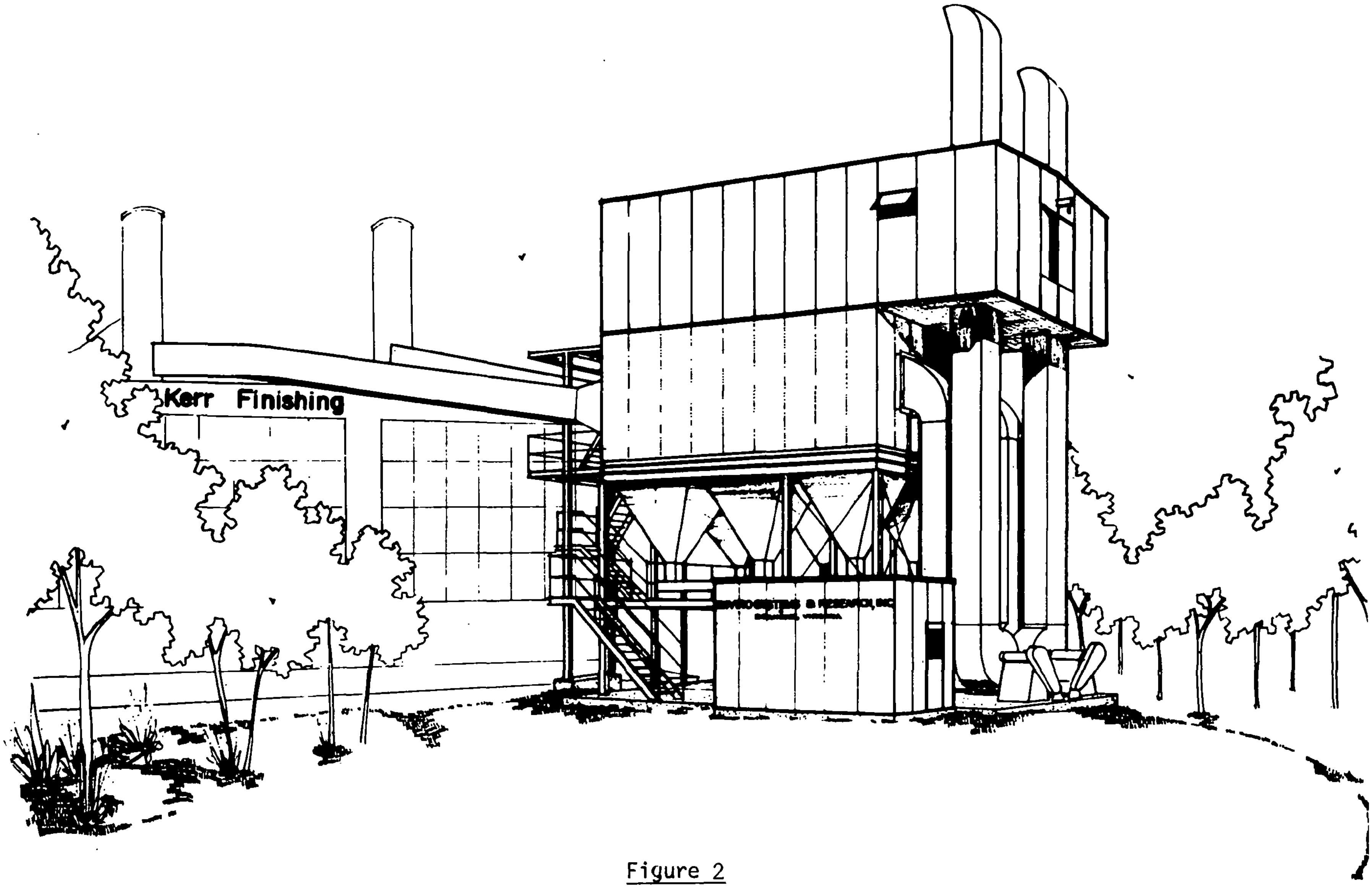


Figure 2

EPA DEMONSTRATION OF THE ENVIRO-SYSTEMS FABRIC FILTER SYSTEM AT KERR FINISHING DIV. FABRICSAMERICA, CONCORD, NORTH CAROLINA

gram to determine general operating parameters, bag life data and economic factors necessary for making techno-economic evaluations.

The objectives of the program are to demonstrate the feasibility of applying fabric filtration to industrial size coal-fired stoker boilers and to obtain the following data:

1. Comparisons of system performance (size efficiency and pressure drop) for Nomex, Gore-Tex, Teflon and Dralon-T fabrics.
2. Determination or prediction of fabric changes and fabric life for each fabric.
3. Capital, operating and annualized costs for the filter system for each fabric tested, and comparison with equivalent electrostatic precipitators.
4. A record of all pertinent boiler and filter system operating parameters.
5. Scale-up factors or deviations from the original work performed under Contract 68-02-1093.
6. Characterization of the flue gas stream.
7. Characterization of the boiler fly-ash.

CONCLUSIONS

"Average" outlet particle size distribution curves are roughly parallel for the pilot plant and the full scale unit; however, the full scale unit yielded a smaller percentage of sub-micron particles.

The outlet transmissometer on Baghouse No. 2 recorded little change in opacity between normal operation and grate cleaning.

Bag failure rate in the first year indicates that bag life for both Teflon felt and the Gore-Tex PTFE laminate could exceed the estimated four years if the failure rate is not accelerated by on-stream time.

Of the media tested, Teflon felt is the most resistant to wear by abrasion and acid attack. Nomex felt is the least resistant to acid attack. The least expensive filter medium to install and operate with (assuming a four-year bag life) is the 15 oz./yd.^{2} woven glass.

The Teflon felt medium is the most expensive to install. At gas-to-cloth ratios of 3.5/1 and lower, Teflon felt is also the most expensive with which to operate; however, at higher gas-to-cloth ratios, the PTFE laminate is the most expensive to operate, because of higher pressure drops for this medium.

RECOMMENDATIONS

Impactor data should be collected to prove or disprove the theory that the multicyclone in use during the pilot plant project did indeed cause the shift in the "average" particle size distribution curves.

In order to corroborate predicted bag life the Teflon felt medium needs to remain on stream so that actual bag life can be determined. During this time pressure drop versus gas-to-cloth data should be expanded and correlated with on-stream time.

Finally, the lime injection system needs to be evaluated as an SO_2 pollutant removal system as well as an aid in reducing acid attack on filter media.

THE KERR BOILERS

The Kerr Finishing Division of FabricsAmerica is a textile dye and finishing plant located in the textile belt of central North Carolina.

Kerr's normal production schedule is three shifts per day, five days per week (although they sometimes operate six days per week) with 450-500 employees. Plant capabilities include processes to bleach, mercerize, dye, nap, finish and Sanforize both cotton and synthetic fabrics, as well as cutting and preparing corduroy.

Two Babcock and Wilcox Type FF integral furnace, water tube boilers are in operation at the Kerr facilities. During the test period they have been in use 146 hours per week and are shut down only between 11:00 PM Saturday and 9:00 PM Sunday each weekend. The annual plant shutdowns occur one week in July to encompass July 4th as well as three or four days surrounding Christmas.

The boilers burn bituminous 1¼" X ¼" modified stoker coal. The average combined coal consumption of these boilers is approximately 75 tons per day; however, during winter months nearly 100 tons of coal are burned per day since the plant is also heated by steam. At this time the average heat input per boiler is 50 million BTU per hour, although its design parameter is 73.2 million BTU per hour.

Last winter's coal strike had some effect on boiler operation at Kerr. The company was able to purchase coal from a nearby plant that had converted to oil burners. Although this coal was readily accessible, it was poorer in quality than the coal ordinarily used and much of it was frozen or wet. With the higher moisture content it is difficult to keep up the boiler load since the excess water tends to put the fire out.

Based on specific performance conditions, the Babcock and Wilcox Company guarantees a two-hour peaking capacity of seventy thousand pounds of steam per hour for each boiler. The design capacity for each boiler is sixty thousand pounds of steam per hour although the load range is actually twenty-five thousand to sixty thousand pounds per hour each. The boilers operate at approximately forty-five thousand pounds of steam per hour each about fifty percent of the time. They operate at the high load thirty percent of the time and the low load twenty percent of the time. Usually when one boiler is running high the other is running low. At the design capacity of sixty thousand pounds of steam per hour each, the boilers should have a combined efficiency of 82% or greater, with a draft loss of less than 5.4 inches (W.G.) through the unit and with less than three parts per million of solids in the steam leaving the boiler. However, the operating efficiency is approximately 77%.

In this type of boiler the furnace gases enter one side of the boiler, travel up the full height, make three horizontal passes and then exit through the opposite side of the boiler. Baffles between the tube sections keep the flow across the tubes rather than along them. "The interior of the steam drum is so arranged that the boiler water circulates down to the lower drum through a section of boiler tubes in the third or last gas pass of the boiler. The water from the lower drum then circulates up through the remainer of the boiler tubes and the tubes in the furnace walls. An additional water-cooled wall in the furnace of the FF boiler provides an "open-pass" through which the gases flow after leaving the furnace." (Steam, The Babcock & Wilcox Company, 1955; pp. 11-5, 11-6)

Both boilers are right hand with heating surfaces of 7,900 sq. ft. and design pressures of 250 psi. The tubes are two inches in diameter (except in the furnace walls where they are two and one-half inches) -- the insides of which are cleaned by a standard turbine tube cleaner and the outsides by soot blowers. Boiler and furnace casings were constructed of #12 gauge steel.

Each boiler is equipped with a Detroit Rotostoker consisting of a stoker proper, which includes a four-section dumping grate having a total active grate area of 186.1 square feet; a steam cylinder operated by a three-way control valve; two one-horsepower motors each running two stoker coal feeders; four hand controlled blast gates for controlling forced draft air to each grate section; and a sectionalized front assembly with ashpit and firing doors. The grates are cleaned at four-hour intervals

(1:00, 5:00 and 9:00 AM; 1:00, 5:00 and 9:00 PM) and the cleaning lasts approximately 20 minutes per boiler, or about 5 minutes per grate. Included also is an extension coal hopper assembly to increase coal storage to 2,200 pounds. Each boiler is also equipped with a cinder return system for returning the heavy particulate collected by the multi-cyclones for reburning. This system is no longer in operation since the multi-cyclones have been gutted.

Fly ash collected in the pilot study as well as early in the full scale operation had a high carbon content. In December, 1976, an evaluation of the possibility of re-injecting this fly ash was made. Re-injection would yield a dual problem of increased dust loading and increased abrasion on this type of baffle design boiler. It was estimated that a 70% re-injection was possible when a baghouse was used, but it would give an efficiency improvement of only 3 or 4 percent. It is believed that this measure would be more feasible on a modern boiler where steps could be taken to reduce abrasion and slag build-up.

Both boilers are similarly equipped. The only difference between them is that Unit #2 is equipped with overfire steam injection to achieve better combustion control. The coal is put in three feet above the boiler bed, thus there is a certain amount of suspended coal dust. The steam injection system is merely a perforated steam pipe, through the boiler wall, which blows the suspended coal down to the boiler bed to be burned.

The air heaters have 4,700 square feet of heating surface composed of two-inch elements of 15 gauge steel with steel plate baffles to produce proper heat transfer. The steam and bottom drums are 54 inches and 36 inches in diameter, respectively, and the drum plate has a tensile strength of 70,000 psi. The multi-cyclones were Model 9VG12 manufactured by the Western Precipitation Corporation. They were sized to handle 35,000 CFM at 400° F with a pressure drop across each multicyclone of 2.4 inches (water column). The multi-cyclones were gutted before beginning the assessment project. Each boiler was also provided with ports for three Babcock and Wilcox register type burners to ease a fuel transition to oil or natural gas, should there be a need.

The forced draft fan is a Sturtevant #95 Turbovane, Design 9, with a 40 horsepower general purpose induction motor with special insulation to resist abrasive dust and with a magnetic across-the-line starter. The forced draft fan was sized to handle 17,000 CFM at 80° F. The induced draft fan is a Sturtevant #1002 TVID, Design 2, with a 100 horsepower general purpose induction motor, also with the dust-resistant insulation and with an auto-transformer reduced voltage magnetic starter. This fan was sized to handle 33,000 CFM at 400° F.

The soot blowers are Automatic Valv-in-Head Model G-9B, manufactured by the Diamond Power Specialty Corporation. Each boiler has two soot blowers with two-inch revolving elements made of steel and "calorized" (i.e., heavy seamless steel "calorized" inside and out by impregnating the steel surface with aluminum, thus making it very refractory to high gas temperatures). The air heaters each have one straight line unit. Soot blower operating pressure is 150 pounds. The furnace draft is increased for soot blowing and the air and fuel are manually controlled.

Each boiler is equipped with Bailey meters. The boiler meter (Type D36) indicates and records steam flow and records air flow supplied to the furnace for combustion. The temperature recorder (Type K35, Class 5H5H5H) indicates and records gas temperature entering and leaving the air heater as well as air leaving the air heater. The boiler drum water level recorder Type LU35, Class 1) has high and low water level alarm and indicating lights.

According to the Babcock and Wilcox Company's proposal, the control equipment was arranged "....to control the fuel supply and the position of the induced draft damper simultaneously and in parallel as required to meet the demand for steam as indicated by changes in steam pressure at the boiler outlet. Optimum combustion conditions will be automatically maintained at all times by readjusting the position of the induced draft damper as required to maintain the steam flow and air flow records of the boiler in coincidence. Furnace draft will be maintained automatically by positioning the forced draft damper."

The feedwater control is "two-element and air-actuated, receiving a primary load change impulse from the boiler steam flow recorded with final repositioning impulse from the boiler drum level".

The air compressor is a "two stage, air cooled, motor drive, horizontal receiver mounted design".

Each stack is 75 feet from floor level and 48 inches in diameter. The steel stacks were supplied as seven stages plus a flare and with an expansion joint between the induced draft fan and the stack.

SYSTEM DESIGN AND MANUFACTURE

Before the full scale system could be completely designed, the location for the collectors had to be determined. The objectives were to maximize the use of the space available and to determine the length of duct to the collectors. The final decision was to parallel the baghouses at the end of the property near the boiler house. This location isolated the units from plant traffic and minimized the loss of parking space. The control room was then placed adjacent to the baghouses for easy access. Also considered in this orientation was the possible future location of lime injection equipment for sulfur dioxide removal.

The baghouse foundations were designed as spread footings at the original grade. The structural support system was designed as column and beam construction with a cantilever section to support the testing platform at the collector discharge end. A "penthouse" over both baghouses was built to protect workers during bag changes and testing. The penthouse has solid metal sides with several translucent roof panels for light and fans for ventilation. All levels have stair access for testing and maintenance.

Prior to operation of the baghouses certain measures had to be taken to insure its success. The existing multi-cyclones were gutted because they provided little ash removal and because the tubes were in poor condition. Also a boiler stack damper had to be designed since the baghouse inlet ductwork opened into the existing stacks. The stacks could not support heavy top caps, so a butterfly-type was designed and positioned above the duct take-off to the collector. This location of the cap facilitates servicing and cap position monitoring from the roof of the boiler house. An interlock was built into the boiler start-up circuits to prevent starting if the stack dampers are closed.

The baghouses are identical to facilitate interchangeability of parts. The air compressors are interconnected to provide back-up capability. The inlet duct lengths were designed so that test ports could be located 8 duct diameters downstream and 2 duct diameters upstream from any flow disturbance, and the inlet ducts measure 36" X 36". This facilitates testing by requiring only 12 traverse points in the duct according to the Code of Federal Regulations (Title 40, Part 60, Appendix A). The testing platform at the inlet ducts was extended to the boiler house roof to provide easy access. Adjustable inlet distribution dampers have been provided as a means to equalize distribution of the dust loading to all hoppers and chambers.

Pyramid hoppers with double dump valves were selected over trough hoppers with screw conveyors. This choice was made in order to eliminate the potential abrasion and wear problems that fly ash conveying via screw conveyors pose. During manufacture of the hoppers and double dump valves, provisions were made for capacitance type hopper level indicators. The ash is currently delivered from the double dump valves through elephant trunk tubes to bins supplied by Kerr Finishing.

The fan stacks were set at a height equal to the existing boiler stacks in order to provide the same 12 point sampling traverse criteria as outlined for the inlet ductwork. The outlet duct inside area is 11.396 square feet. The stacks are set for vertical discharge and have a rain lip at the top for drawing off water. The stacks have expansion-isolator joints and are supported by the penthouse floor.

Figures 3 through 6 show steps in the erection of the baghouses and the completed structure.

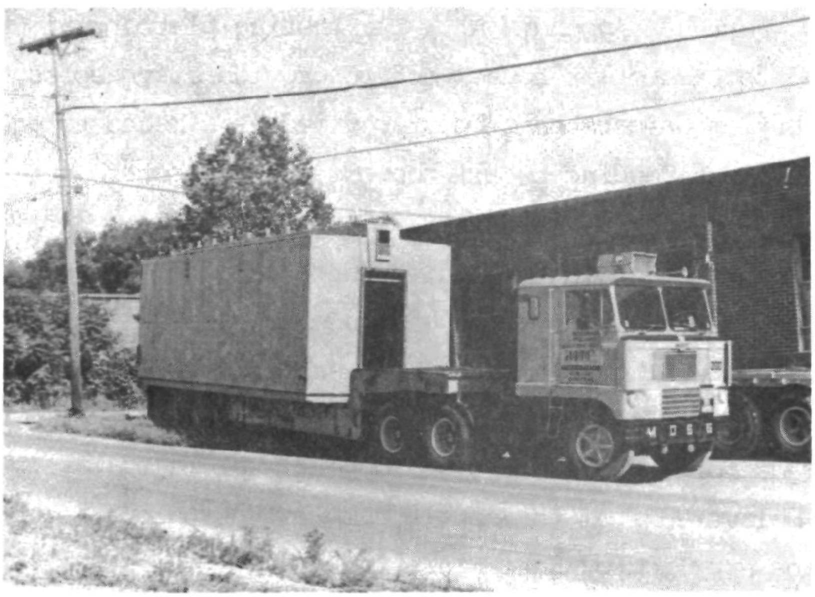


Figure 3

House on Truck Leaving Factory

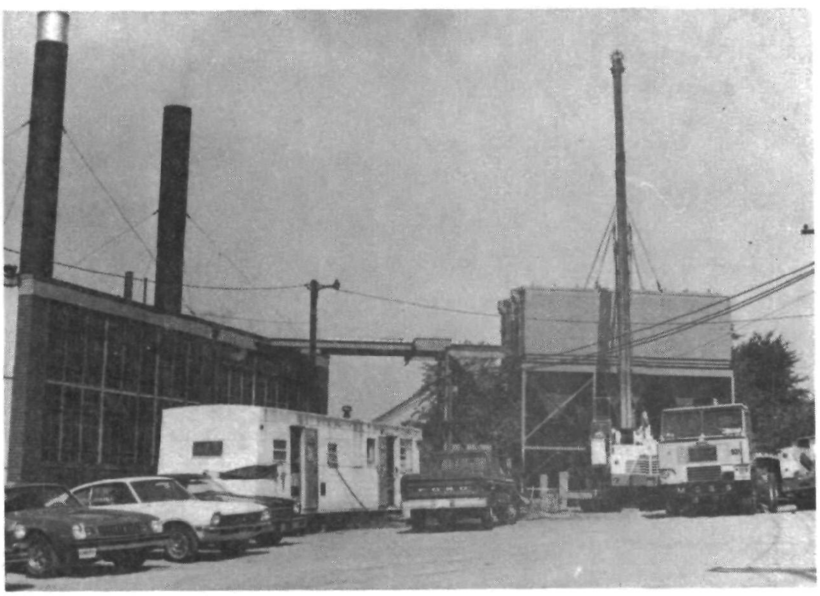


Figure 4

House Being Lifted onto Hopper - Far View

Figure 5

House Being Lifted onto Hopper - Near View

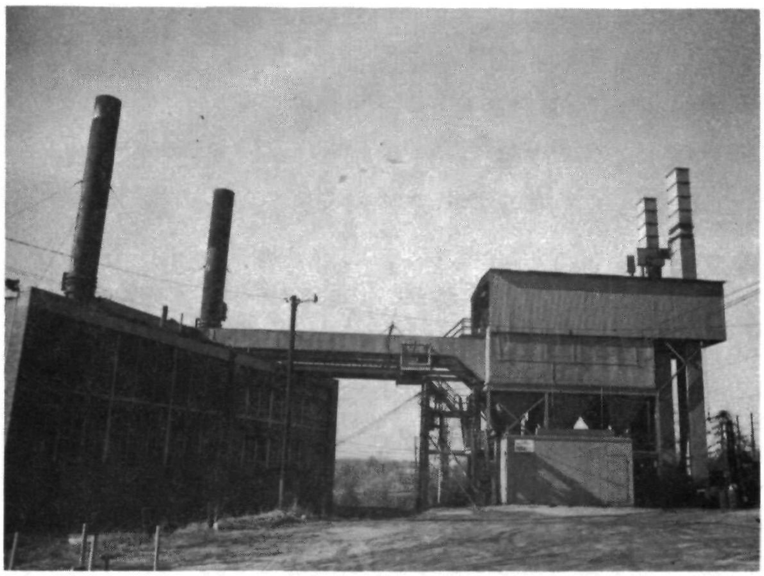


Figure 6

Completed System

DESCRIPTION OF BAGHOUSE DETAILS

Before the dust collector design could be finalized, certain criteria had to be examined. The collector would have to remove fly ash at a concentration of 0.6 grains/cubic foot (80% of which was smaller than 10 microns in diameter). The total flue gas design volume to be handled was 70,000 ACFM at 400° F with a moisture content of 8% by volume. The baghouse system would be in continuous operation outdoors at an elevation of 700 feet above sea level. Maximum design pressure drop across the total system was 12 inches of water.

Two Enviro-Clean Model 648-RAC3-5-104 fabric filter dust collectors were selected for the assessment project -- each to handle the flue gas from one boiler. The operating pressure drop should range from 2-7" W.G. and the maximum operating temperature is 450° F. Figures for the SD-10 general arrangement and for the baghouse gas flow can be found in Appendix A-2.

Each single chamber baghouse consists of 18 cells with thirty-six bags per cell, or 648 bags per house. The bags are five inches in diameter and eight feet - eight inches in length, yielding a total fabric area of 7,440 square feet per baghouse. This produces a gas-to-cloth ratio of 4.71 to 1 with all cells active, or 4.98 to 1 with one cell cleaning. Cleaning cycles are automatically set by a timer but are adjustable.

The bags are set into a tube sheet (as seen in Figure 7), located 6 3/4" to 4 3/4" from the sloped top of the house. Two snap rings are incorporated into the open end of each bag and when the bag is in place one ring is above and one below the tube sheet. Each bag also slips into a grid of metal prongs at the bottom of each cell to prevent bag-bag and wall-bag abrasion. On a horizontal plane, spacing between the bags at the tube sheet is 6 3/8 inches from the center of one bag to the center of the next in one direction and 6½ inches perpendicular to the first direction.

Rigid cages 5 inches in diameter with 10 vertical supports are set inside the bags to prevent them from collapsing. The cages were constructed of 9 gauge mild steel and were electrolytically plated with nickel to a thickness of 3 mils, the nickel plating was then coated by a chrome flashing

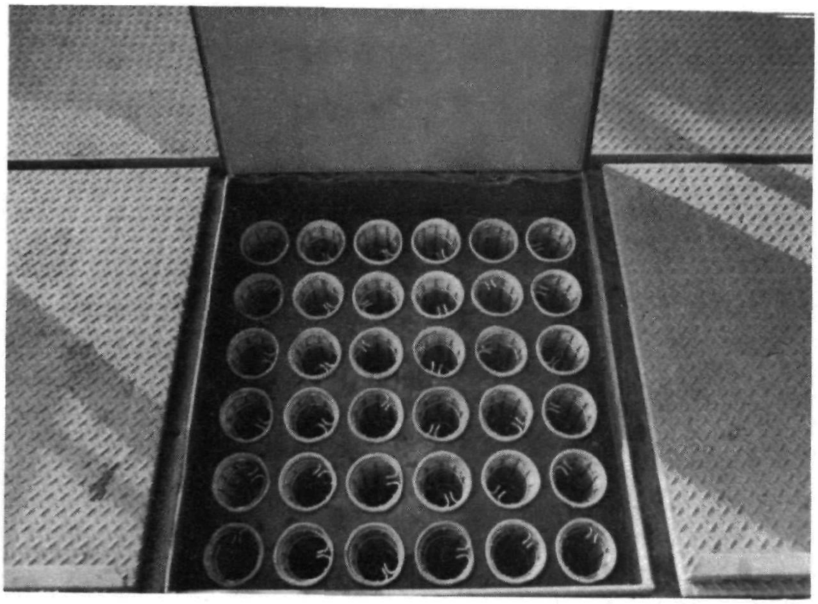


Figure 7

Top View of Module Showing Cell and Bag Arrangement to a thickness of 1 mil. Before this type of cage was chosen, both a wire mesh and a spiral cage were considered. The spiral cage was eliminated because of its potential for creating abrasion between the bags and the house walls. The wire mesh was eliminated because it was unproven. The nickel-chrome coating over mild steel was used in an attempt to reduce corrosion.

The baghouses are constructed of 10 gauge mild steel with 3' 1" by 3' 4" hatch covers over each cell. The hatch covers are hinged to provide easy access for checking and replacing bags. Each baghouse has three pyramid hoppers with side-wall slopes of 60°. The hoppers are made of 3/16" mild steel and have a capacity of approximately 363 $ft.^3$ each, or 1,089 $ft.^3$ per house. The hoppers can be emptied either automatically or manually through the "double-dump" valve at the bottom of each hopper. The double-dump valve consists of two chambers, each with a volume of approximately 1 $ft.^3$, with a gate opening from the hopper into the upper chamber and a gate opening between the chambers. The purpose of the valve is to eliminate a back-draft into the hopper because of its negative pressure. The upper chamber is filled, closed off and then the ash dropped into the lower chamber where it exits via elephant trunk tube into a barrel. The long straight ductwork between boilers and baghouses is constructed of 3/16" mild steel plate. Ductwork, baghouses and hoppers are covered by three inches of high temperature Fiberglas insulation which in turn is covered by a 20 gauge aluminum skin.

Other components for each baghouse (a list of system components follows this section) include a standard cleaning timer panel, high temperature cutoff switch, a cleaning assembly (blower) and manual slide gates, as well as platforms, handrails and caged ladders. Auxiliary components include:

1. A fan with V-belt drive and motor rated at 150 H.P. for 35,000 ACFM at 440° F and 12" S.P. for each house.

2. A system drives panel containing cleaning fan motor starters (reduced voltage automatic type) and a 3 KVA transformer.

3. Dampers that are remotely operated to open on a temperature set-point or upon shutdown of baghouse. Slide dampers were provided in each stack duct take-off to isolate the baghouses. A signal sent by a Numatics Series 11SAD4 single solenoid (spring return) activates an Advance Automation Company Triple A cylinder (with two Nuflo valves each) to slowly open or close the damper in question.

4. A temperature control system in which inlet temperature probes are set at 440° F. If this point is reached, the sensor will be interlocked to open the relief cap first, followed in order by the system fan motor shutdown and then the cleaning fan motor shutdown.

The two baghouses were covered by a "penthouse" to enable testing in inclement weather. A system control console located under the penthouse houses individual cleaning fan motor ampere read-outs, system fan motor readouts, inlet duct gas temperature read-outs and individual collector pressure drop read-outs.

List of System Components

1. Garden City #AART-18-6 Fan with upblast discharge, maximum recommended speed of 1800 rpm at 600° F.

2. Garden City Vortex Damper. A pressure transmitter (P1) in the boiler stack sends an electric signal to a control unit on the control console. This control unit maintains a constant pressure by supplying a modulated air supply to the vortex damper control.

3. Lincoln Motor, 150 H.P., full load speed 1780 rpm, full load current 342 amps.

4. Ingersoll-Rand Type 30 Air Compressor, Model T305TM. The Model T305TM is a 5 horsepower compressor with a receiver capacity of 60 gallon with maximum receiver and discharge pressure of 200 psig.

5. Eclipse Burner No. 300 H.P. This burner provides a heat capacity of 3,000,000 BTU/Hr. and requires a 1/3 horsepower blower.

6. Advance Automation Air/Hydraulic-Low Pressure Cylinder

Model B960	3.5 Inch Bore	12 Inch Stroke
Model BS2121P1	2.5 Inch Bore	4 Inch Stroke
Model BS2123P1	1.25 Inch Bore	4 Inch Stroke

7. Lincoln Motor, 15 H.P., full load speed 1175 rpm, full load current A7 amps.

8. Advance Automation Actuator/Positioner Air Cylinder, Model B960, 3.5 inch bore, 16 inch stroke.

9. Arrow Model A-30 Non-Cycling Refrigerated Air Dryer.

10. Arrow Model 3104 Air Filter.

11. Arrow Model 1584 Air Regulator.

12. Arrow "Oilescer" Filter, Model 3304P with automatic drain.

13. Stack Cap, single blade, butterfly type, 48 3/8" inside flange diameter.

14. Purge Damper, single blade, butterfly type, 20" X 7" inside flange.

15. Clean Air Stack Damper, louvered type, parallel blade, 6 blades, 2' 6.75" X 4' 6.75" inside flange.

16. Bleed-In Damper, single blade, butterfly type, 6" X 36" inside flange.

17. Isolation Damper, louvered type, parallel blades, 4 blades, 36.5" X 36.5" inside flange.

BAG CANDIDATES

The fabrics initially considered for use in the demonstration project were those used in the pilot project - Teflon(R) felt Style 2663, a tetrafluoroethylene (TFC) fluoro-carbon; Gore-Tex(R), an expanded Teflon (Polytetrafluoroethylene - PTFE) with interfacing air filled pores; Dralon(R)-T felt, a homopolymer of 100% acrylonitrile; and Nomex(R) felt, a high temperature resistant nylon fiber (polyamide). Of these media, the Teflon felt and the Gore-Tex PTFE laminate were selected as the first to be tested for bag life studies.

Dralon-T was not included initially because of the maximum temperature limitation of approximately 280° F. It is, however, still under consideration. Modification of the system to cool the flue gas at the baghouse inlet could bring satisfactory results with Dralon-T.

Nomex felt was also omitted from the first testing due to fabric degradation resulting from acid attack observed during the pilot program. However, it is still under consideration since a lime coating on the fabric might decrease the intensity of acid attack. Therefore, a useful study could be made of treated and untreated bags with respect to on-stream time.

Currently, Baghouse No. 2 contains one full cell of Huyck experimental felted glass bags and one cell each of Globe Albany 22½ oz. woven glass bags and Globe Albany 15 oz. woven glass bags (both with the Q-78 finish). Also, there are three Nomex bags in Baghouse No. 2. Locations of these bags can be seen in Figure 8. These bags are being screened as possible alternatives to the Gore-Tex bags in Baghouse No. 2. Specifications for these fabrics are listed in Table 1.

Figure 8

Schematic of Bag Arrangement

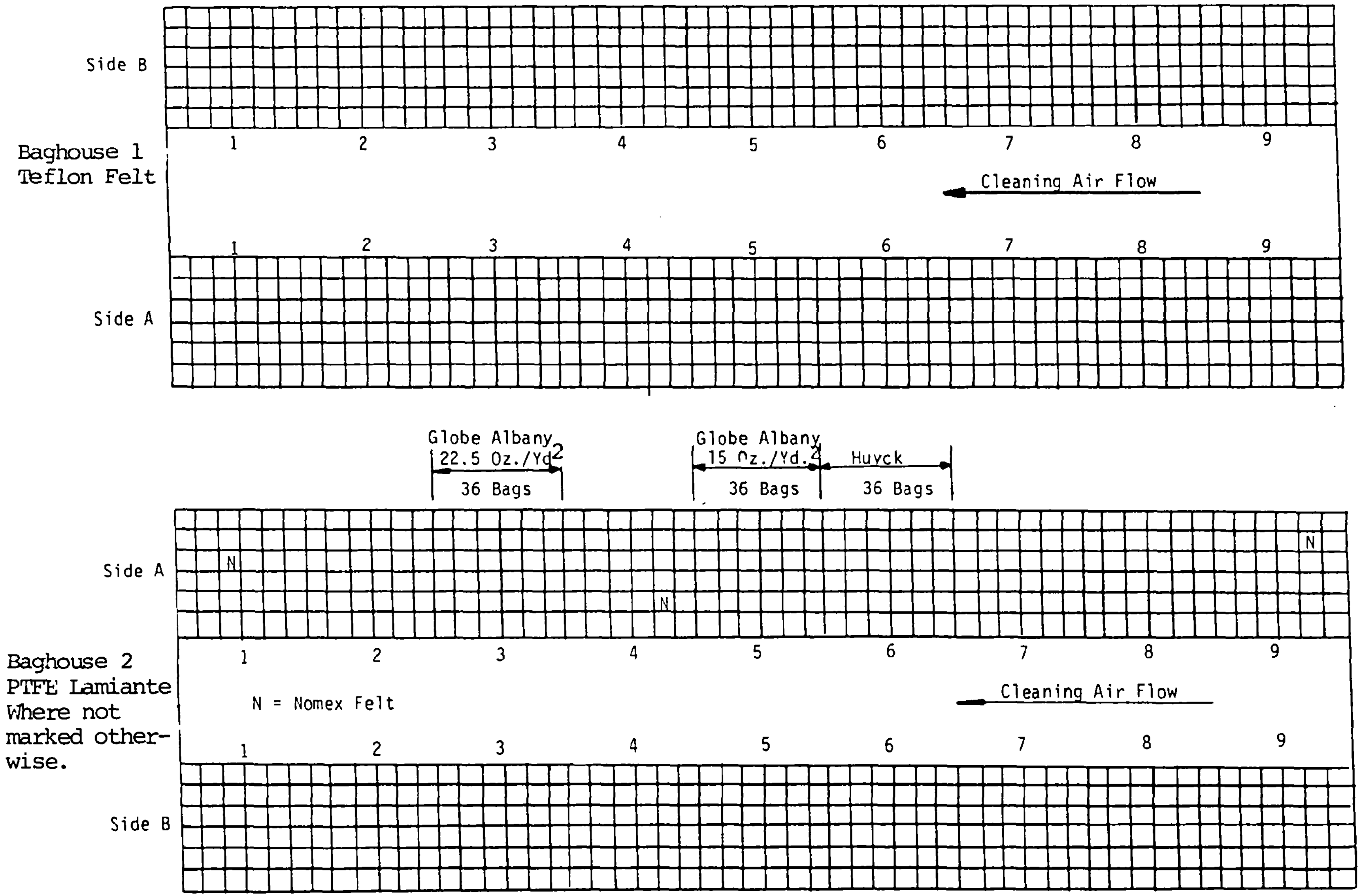


Table 1

Filter Media Characteristics

Filter Media	Weight Ozs./Yd.^{2}	Permeability CFM/Sq. Ft.	Mullen Burst psi	Tensile Strength Lb./Inc. Min.	Cost Per Bag (12/77)
Teflon(R) Felt Style 2663	21-29	15-45	250	180 X 150	$ 53
Gore-Tex(R) PTFE Laminate	4-5 +	8-15	239-400	-	45
Globe Albany(R) Woven Glass Type Q78-S1611	15	42	700	630 X 360	14.61
Globe Albany(R) Woven Glass Q78 Finish	22.5	25	800 +	-	18.65
Huyck - Experimental Needled Fabric	29 $\pm$ 2	40 $\pm$ 10	850	500 X 300	21.50*
Dralon(R)-T	13-15	20-30	250	-	-
Nomex(R) Felt	14	25-35	450	131 X 100	-

*Based on Quote of $14.25/Yd.^{2}

DESCRIPTION OF THE CONTROLS

The elaborate control system at Kerr was designed to facilitate testing and to facilitate the solution of any problem that might arise. The system is arranged so that the entire operation of both baghouses is controlled from the console located in the control house adjacent to the baghouses. When set-up for automatic operation, either baghouse can be started and stopped from controls located in the boiler house; however, provision is made on the control house console to lock-out the boiler house start function.

Also located in the control house are the circuit breakers and starters for the various motors, the main power disconnects, the system logic control panels, and the distribution circuit breaker panel for 110 and 220 volt utility circuits (lighting and convenience outlets are located in the baghouse area).

Located at required locations external to the control house are position indicating limit switches, pressure and temperature transducers, thermocouples, burner controls for heating flue gas and air entering the baghouse, and sequence controllers for the bag-cleaning function. A power safety switch disconnect is located adjacent to each drive motor.

The console (Figure 9) is arranged in three parts with test instrumentation located in the center and the baghouse controls at the left and right. Each baghouse console is arranged with a system diagram with status lights located in the middle (vertical section), and all operating controls (push buttons, indicating lights, and selector switches) on the lower or desk section.

The control console selector switch allows baghouse operation to be fully automatic, manual, or in testing mode. When switched to the "off" position all control power will be disconnected leaving only the "power available" indicating lights "on".

In the automatic mode the system is started or stopped by pressing one "start" or one "stop" pushbutton. Damper and thermostat locations

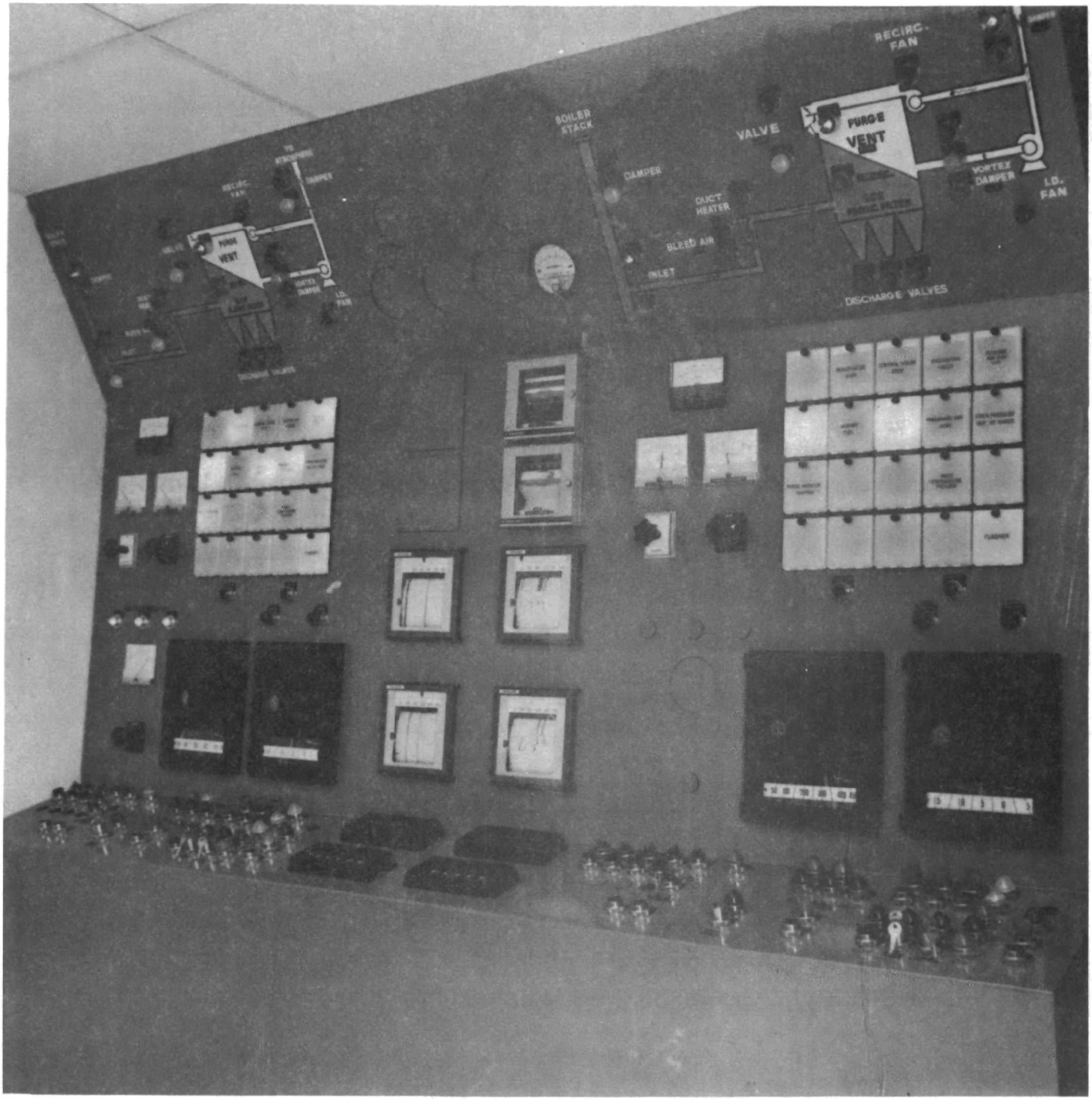


Figure 9

Control Panel

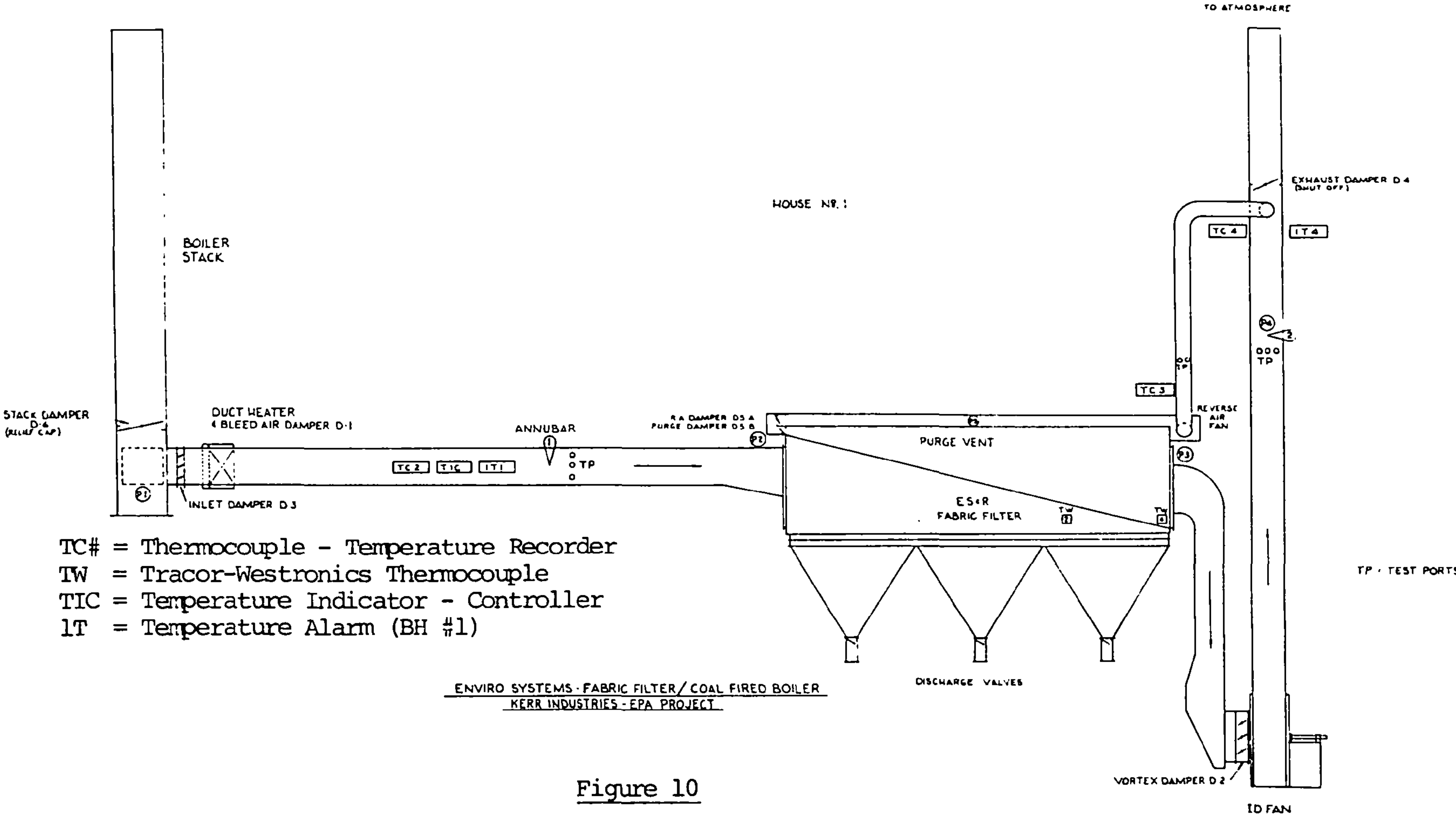
can be found in Figures 10 and 11. A plan view (Figure 12) is also included for reference. Upon starting the system, the preheat operation is initiated. At this time the baghouse is isolated from the stack by closing D3 and opening relief cap D6 to allow escape of the flue gas through the stack. Dampers D1 (the bleed air damper) and D2 (the vortex damper) are fully opened and the exhaust damper D4 is closed. This allows ambient air to enter and be heated by the flame heater before passing through the baghouse and the vortex damper to the cleaning fan and then exhausted to the atmosphere through purge dampers D5A and D5B.

During the preheat mode only, the cleaning fan and the heater will be in operation. The temperature of the air is controlled by means of a thermostat at T2 (baghouse inlet) which controls the heater flame by controlling the heater gas valve. When the desired preheat temperature of 250° is reached, or when the temperature T4 at the exhaust stack reaches 180° F, the control system automatically will initiate the normal operating condition.

The equipment will operate in the following sequence when changing from preheat to normal operation.

A. Open D4 (Exhaust Stack Damper)
B. Close D5A, Open D5B (Adapt-A-Clean and Purge Outlet Dampers)
C. Start Bag Cleaning System
D. Open D3 (Baghouse Isolation Damper at Kerr Stack)
E. Close D1 (Ambient Air Inlet Damper)
F. Set D2 Control on Automatic
G. Start System Fan
H. Close Relief Cap D6

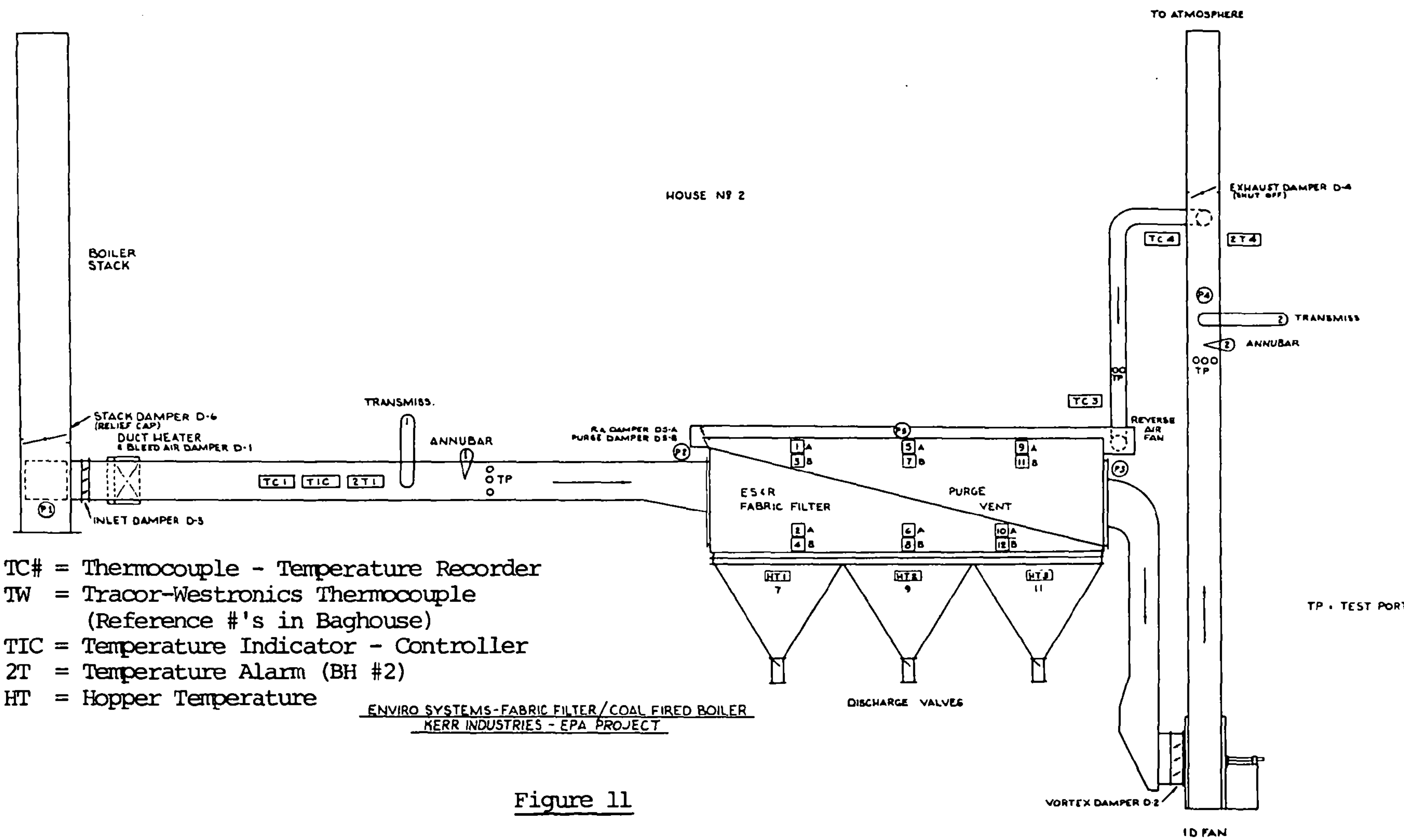
During normal operation the flue gas will be passed through the baghouse by opening dampers D3 (baghouse inlet), D2 (vortex), D4 (baghouse exhaust), running the system and cleaning fans, and closing purge outlet damper D5A and D5B and stack relief cap D6. A pneumatic pressure controller located on the console maintains a set static pressure at the stack inlet by controlling the position of the vortex damper (D2); thus, air volume through the house is controlled. Air temperature through the baghouse is controlled by the inlet temperature thermostat at T2 at 250° $\pm$ 10° F. If the temperature



TC# = Thermocouple - Temperature Recorder
TW = Tracor-Westronics Thermocouple
TIC = Temperature Indicator - Controller
1T = Temperature Alarm (BH #1)

Figure 10

System Schematic



TC# = Thermocouple - Temperature Recorder
TW = Tracor-Westronics Thermocouple (Reference #'s in Baghouse)
TIC = Temperature Indicator - Controller
2T = Temperature Alarm (BH #2)
HT = Hopper Temperature

Figure 11

System Schematic

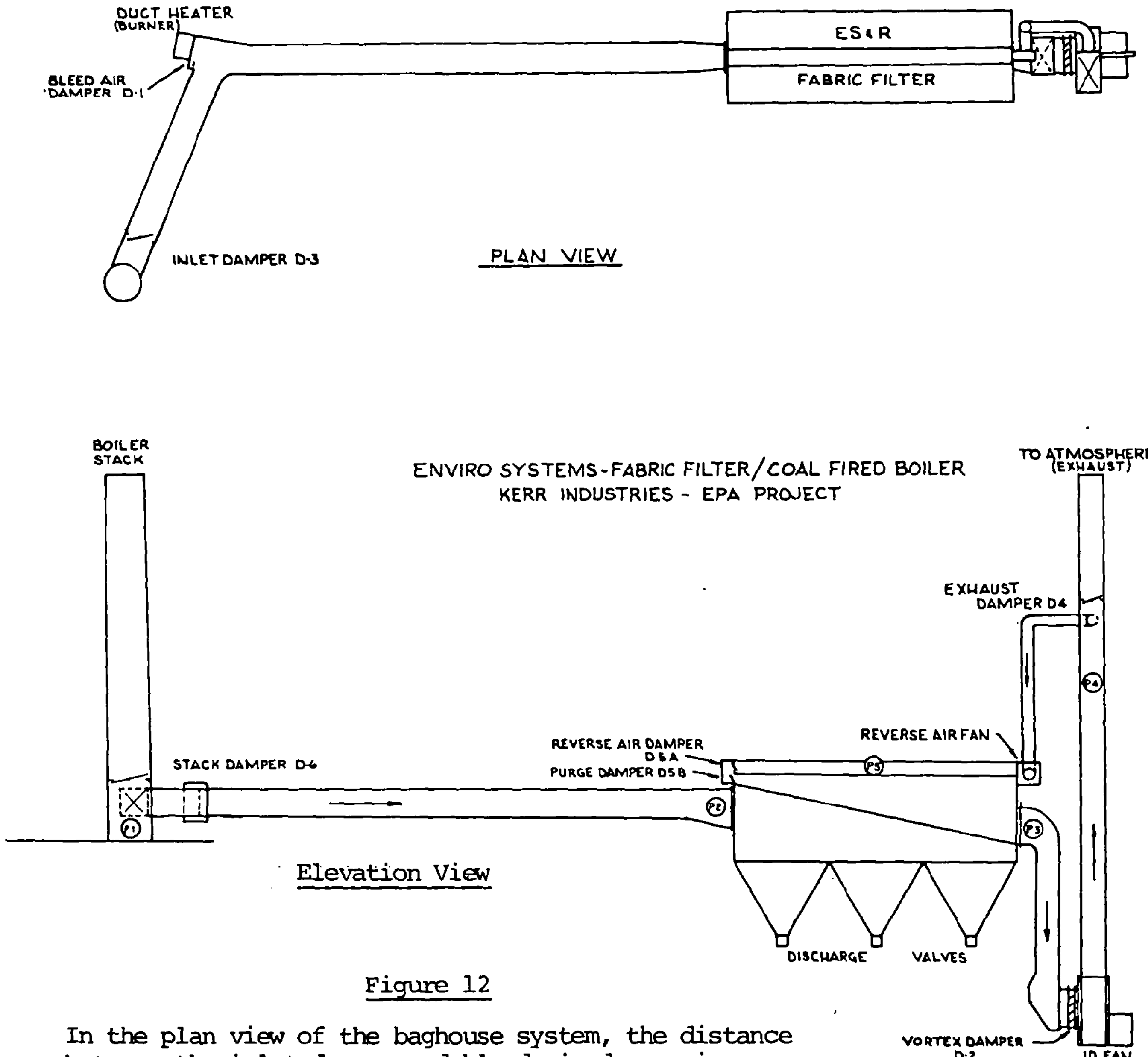


Figure 12

In the plan view of the baghouse system, the distance between the inlet damper and bleed-air damper is different on the two houses.

drops below 250° F, the heater system is activated, if the temperature rises above 380° F, ambient air is admitted to the system by opening damper D1 and shutting off the heater.

System shutdown will be initiated by any of the following conditions:

A. Pressing any "stop" pushbutton
B. Temperature at T2 (Baghouse Inlet) exceeds 425° F
C. Boiler shutdown (initiated by "stop" pushbutton in boiler house)
D. Failure of either fan
E. Power failure
F. Control power failure

For any of the above conditions the relief cap D6 will be tripped and thus will open automatically. As soon as D6 is fully opened (limit switch check) and provided E or F has not occurred, the following shutdown sequence will be started:

A. Open D1
B. Activate heater control
C. Open vortex D2 fully
D. Close D3
E. Open D5
F. Close D4
G. Stop system air fan - drop out normal operation relay NR
H. Start purge and purge timer; the purge cycle has the same system set-up as "preheat" except that the heater will not come on unless temperature drops below 250° F during the 1½ hour purge cycle.
I. After set time - stop purge
J. Drop out automatic system, start-up relay "AR"
K. Stop cleaning fan

During shutdown sequence a light will flash on trouble annunciator panel and an alarm will sound. The alarm panel will also indicate the reason for the shutdown. Note: Alarm may be shut-off by pressing "silence" pushbutton but light will remain on until circuit causing the alarm is reset.

By switching the selector to "man" each separate operating mode will be started and stopped manually. Interlocking will be provided, however, to prevent a wrong starting or shutdown sequence and all protective devices and circuits will be functioning. Once started, the particular mode will operate automatically as previously described under automatic operation.

Three different sets of "start-stop" pushbuttons will be activated by the "man" position of the selector switch and indicating lights will give the status. The following modes can be thus started:

A. Preheat
B. Normal
C. Purge

Operation will be as follows:

Pressing the preheat "start" pushbutton will initiate the previously described preheat mode. When the set temperature of 250° F is reached an indicating light will light and a permissive interlock will close enabling the normal "start" pushbutton. The operator may then press the normal "start" pushbutton and the previously described normal mode will proceed. If any of the system shutdown signals occur the automatic shutdown sequence will occur automatically. However, since both the preheat and normal modes may be stopped at any time by the operator, he may also start and stop the purge mode at any time normal operation has ceased. The purge mode will continue until the operator shuts down except where automatic shutdown may occur.

With the selector switch in "test" position each electric drive motor and each damper for all system components may be operated by a spring return selector switch. This feature provides for checking out all equipment before starting the baghouse or after emergency shutdowns, etc. No system interlocking will be active; however, protective functions such as overloads, heater protective devices, circuit breakers and excessive temperature functions will be active.

The following equipment operates regardless of the various operations previously described.

A. Air compressors operate to maintain control air pressure but can be started and stopped at the console. However, the entire system cannot function if control air pressure is too low. The air dryer must be started before either air compressor can be started.

B. The trouble annunciators will be energized at all times.

C. By means of a "man-auto" selector switch, the bag cleaning sequencing control may be operated manually (selector in "man") even though the rest of the system is not operating. When in the "auto" position, it will be started during the automatic sequences previously described.

D. By opening the control circuit breaker (in the enclosed control house area), all equipment will be de-energized (except the burner blower motor).

The inlet gas heating control consists of an RTD element located at T2 and a control unit (on the control house console) with read-out, temperature setting, high-low alarm contacts and a pneumatic output, as well as a pneumatically operated gas volume at the heater. The gas will shut off at the desired temperature setting (or above) and is modulated by a controller to maintain set temperature.

A constant set pressure at P1 is maintained by controlling the vortex damper D2 on the system fan. A pressure transmitter P1 supplies an electric signal (4-20 mA) to a control unit located on the control console in the control house. The control unit maintains a set pressure at P1 by supplying a modulated air supply to the D2 (vortex) pneumatic damper control. Excessive pressure at P1 will be alarmed and will cause system shutdown.

INSTRUMENTATION

Many parameters related to the operation of the baghouses are monitored and/or recorded. These include boiler stack pressure, baghouse flow rates, pressure drops and temperatures as well as fan current, speed, etc. Table 2 is a listing of these parameters. Note that only Baghouse No. 2 is equipped with transmissometers to record inlet and outlet opacities.

Certain functions are alarmed on the annunciator. Alarm conditions will cause horns (located in penthouse and boiler house) and a buzzer in the control house to sound and the particular alarm light to flash. Pressing the "acknowledge" pushbutton will silence horns and buzzer and stop flashing of the light; however, the light will remain on until the alarm condition has been corrected or reset. Some alarm functions will also cause a system shutdown. The alarmed functions are listed in Table 3. A key operated selector switch is provided so that audible alarms may be turned off when the equipment is being checked or adjusted.

A listing of the instrumentation at the facility is located at the end of this section. Also, location of all pressure and temperature sensors can be found in Figures 10 and 11 for Baghouses 1 and 2, respectively.

Table 2

Parameters Monitored

Parameter	Measured	Recorded
Boiler Stack Pressure	X	X
Baghouse Inlet Flow		X
Baghouse Pressure Drop		X
Baghouse Main Fan Pressure Drop		X
Baghouse Outlet Flow		X
Boiler Stack Temperature		X
Baghouse Inlet Temperature	X	X
Baghouse Outlet Temperature		X
Baghouse Cleaning Air Temperature		X
Baghouse Inlet Opacity*		X
Baghouse Outlet Opacity*		X
Cleaning Air Fan Static Pressure	X	
Cleaning Air Fan Current	X	
Main Fan Speed	X	
Main Fan Current	X	
System Voltage	X	
Baghouse Temperatures	X	

*Baghouse No. 2 Only

Table 3

Alarms and Shut-Down Functions

Function	Alarm Only	Alarm & Shut-Down
Bag Cleaning on Manual	X	
Boiler House Stop		X
Control House Stop		X
System Fan Below 1400 RPM		X
Cleaning Air Fan Off	X	
Hopper Full	X	
Heater Off	X	
Pneumatic Air Low	X	
Stack Pressure Out of Range		X
Phase Monitor Tripped	X	
Inlet or Outlet Temperature High		X
Dryer Off	X	
Alarm Horns Off	X	

List Of Instrumentation

1. Taylor Electronic Differential Pressure Transmitter No. 1301T

   This is a force balance instrument transmitting 4-20 mA signals proportioned to the differential produced by the primary element. The transmitter provides capability for measuring differential spans from 1 to 10 inches of water at operating pressures as high as 50 PSIG.

2. Taylor Electronic Differential Pressure Transmitter No. 1302T

   This instrument is identical to the 1301T except it is adjustable from 5 to 50 inches of water and has a maximum working pressure of 500 PSIG.

3. Taylor Pneumatic Indicating Controller No. 441R

   The Taylor 441R controller is a single duty pneumatic indicating controller with proportional response and differential gas feature. The instrument requires an air supply pressure between 18 & 30 PSIG with 20 PSIG being recommended. The output is a nominal 3 to 15 PSIG signal.

4. Taylor Alarm No. 1016N

   The 1016N alarm is a solid state instrument which accepts a current or voltage input signal and provide relay contacts for operating external devices.

5. Taylor Alarm No. 1019N

   The 1019N alarm is a solid state instrument which accepts a thermocouple or millivolt input signal and provides relay contacts for operating external devices. The relay within the alarm is de-energized when an alarm condition exists or when power fails.

6. Taylor 2140J Series Multi-Scan Recorder

   This is a potentiometric instrument which applies the principle of measuring by opposition. It is basically a D.C. voltage meter which operates as well with current and resistance, depending on voltage. The unit can accept up to six different functions.

7. Model 400-0000 High Performance Transmissometer manufactured by Contraves Goerz Corporation.

8. Model 401-0000 Process Control Transmissometer manufactured by Contraves Goerz Corporation.

9. Model ES-MS401C Recorder with felt tip cartridge pen and chart speed of 3 cm/hr. manufactured by Esterline Angus Instrument Corporation.

10. Taylor Industrial Thermocouple No. 81CT14 iron-constantan type.

11. Taylor Resistance Thermocouple device with 100 ohm platinum bulb.

12. Annubar No. 741-316

    The annubar is an annular averaging velocity head sensor for the natural measurement of flow through a duct. It produces a differential pressure proportional to the square of the fluid velocity. Manufactured by Dieterich Standard Corporation.

ECONOMIC CONSIDERATIONS

Installed, annual operating and annualized costs have been computed for the Teflon felt and PTFE laminate filter media already in use at Kerr, and also for an experimental felted glass fabric and two weights (15 oz./yd.^{2} and 22.5 oz./yd.^{2}) of woven glass fabric that are being considered. Table 4 lists these costs.

Installed costs and total cost of flange-to-flange hardware plus bags plus installation (installation costs are based on in-house estimates), were determined for a fabric filter dust collector sized to handle 70,000 ACFM at 350° F. The bag costs are based on January, 1978 quotes. The hardware and installation are 1975 prices for RAC-3 model collectors similar (although different in size) to those at Kerr. A listing of equipment included in these prices as well as a bill of materials listing actual costs can be found in Appendix A-3. ES&R no longer manufactures the RAC collectors but 1978 costs for the comparable SD-10 units can be obtained by applying a multiplier of 1.7 to 1975 RAC costs. Electrostatic precipitator costs for 1978 are also located in Appendix A-3.

Since the conclusion of the pilot study the price of the Teflon felt bags has been reduced from $75/bag to $53/bag. This price lowering has increased competition among fabric types. For gas-to-cloth ratios of 2.9/1, 5.8/1, 8.9/1 and 11.3/1, the installed costs for Teflon felt are $4.07, $3.79, $1.72 and $1.53 per ACFM. This cost is still somewhat higher than that of the PTFFE lamiante, but the Teflon felt has been proven to damage less easily and, thus, may last longer. The experimental felted glass and both fabric weights of the woven glass are similar with respect to installed costs, and the 15 oz./yd.^{2} woven glass has an installed cost of $2.89, $1.60, $1.33 and $1.22 for gas-to-cloth ratios of 2.9/1, 5.8/1, 8.9/1 and 11.3/1 respectively. The difference in installed costs between the most expensive and least expensive fabrics decreases markedly as the gas-to-cloth ratio increases (see Figure 13). This is due to the decreasing percentage of capital costs attributable to the fabric filters.

Figure 14 is a comparison of the five filter media for annual operating costs. A sample calculation of operating and annualized costs is located in

Table 4

Installed, Operating and Annualized Costs[1]

Filter Media	G/C Ratio	Δp[2] (" W.G.)	1975 Installed Costs[3]	1977 Operating Costs	1977 Annualized Costs
Teflon Felt	2.9/1	2.5	$ 285,080	$ 33,100	$ 71,016
($53/Bag)	5.8	3.4	153,700	20,410	40,852
	8.9	5.9	120,570	20,120	36,156
	11.3	9.2	107,318	24,130	38,403
	6 (Approx.)[4]	7.1[4]	153,700	27,050	47,492
Gore-Tex/Gore-Tex	2.9	4.2	267,800	31,833	67,450
($45/Bag)	5.8	5.3	145,060	21,656	40,949
	8.9	8.9	114,810	24,063	39,333
	11.3	11.4	102,710	26,210	39,870
	6 (Approx.)[4]	12.2[4]	145,060	34,030	53,323
Globe Albany[5]	2.9	2.5	202,158	12,273	39,260
Woven Glass - 15 Oz./Yd.[2]	5.8	3.4	112,239	10,042	24,970
($14.61/Bag)	8.9	5.9	92,929	13,212	25,572
	11.3	9.2	85,205	18,605	29,937
Globe Albany	2.9	2.5	210,884	14,555	42,603
Woven Glass - 22.5 Oz./Yd.[2]	5.8	3.4	116,602	11,134	26,642
($18,65/Bag)	8.9	5.9	95,838	13,940	26,686
	11.3	9.2	87,532	19,187	30,829
Huyck Felted Glass	2.9	2.5	217,040	16,094	44,960
($21.50/Bag)	5.8	3.4	119,680	11,903	27,820
	8.9	5.9	97,890	14,453	27,472
	11.3	9.2	89,174	19,597	31,457

[1]Flange-to-flange costs are based on cost of ES&R's RAC collectors installed at Kerr in 1975, plus 1975 engineering installation estimates; bag prices and operating costs are based on prices effective 1/78.

[2]Pressure drops are actuals obtained in the pilot study (plus 2" for the drop across the inlet duct) and were used in the pilot study calculations.

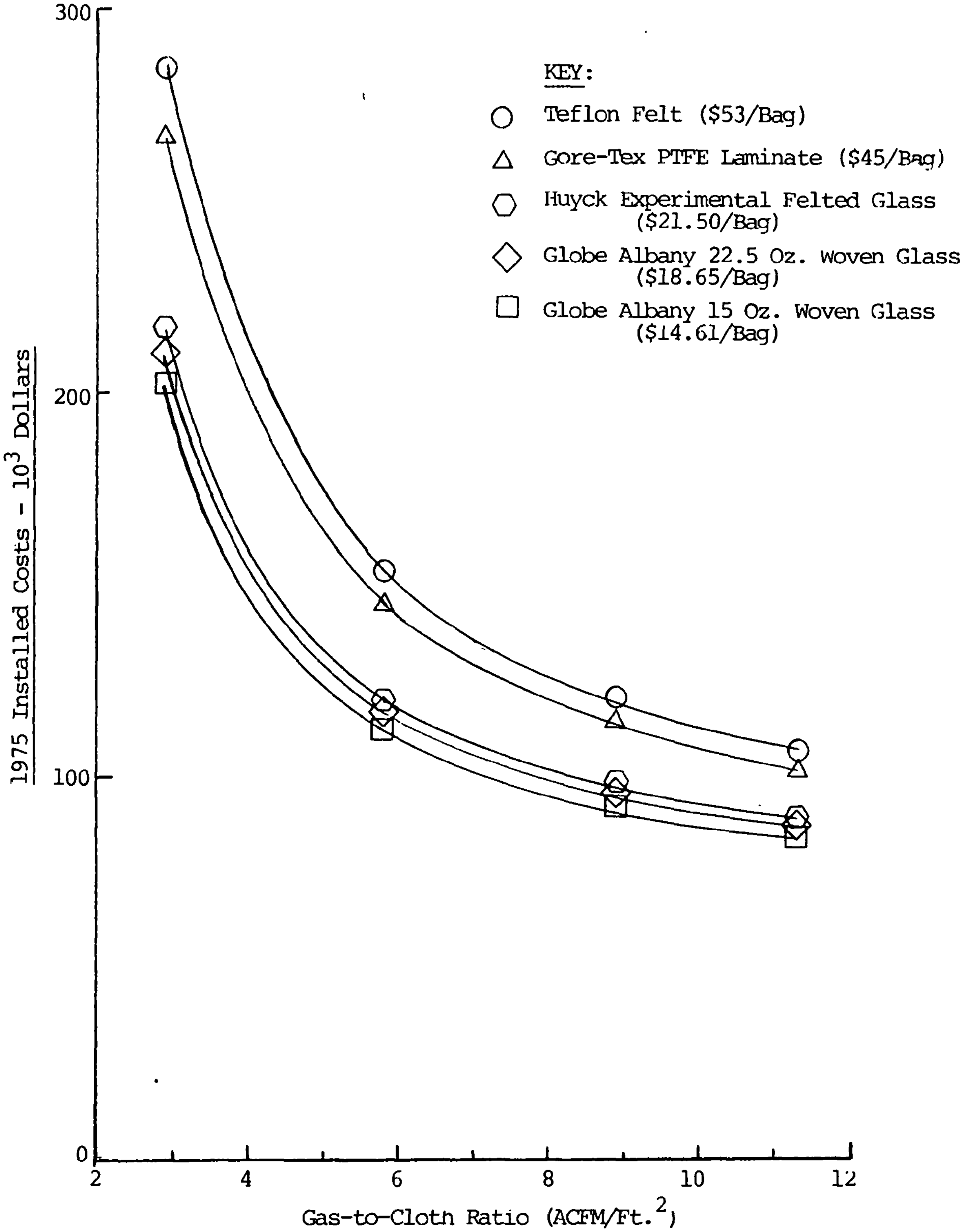
[3]A multiplier of 1.7 applied to 1975 installed costs will give 1978 installed costs.

[4]1977 mean G/C ratios and Δp's obtained in the assessment project at Kerr for Teflon felt and Gore-Tex houses.

[5]Pressure drops are assumed to be equal to those of Teflon felt.

Figure 13

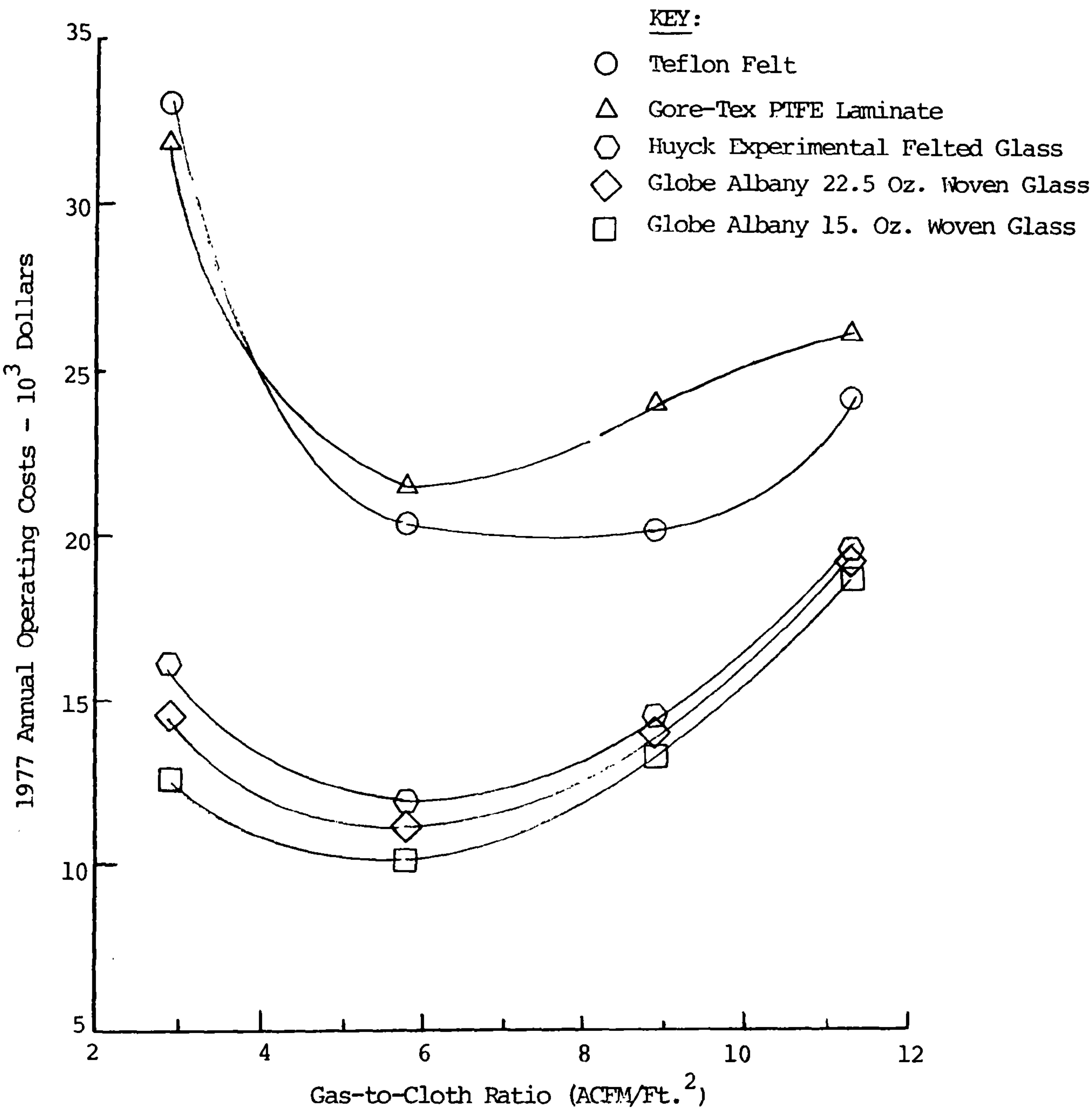
Comparison of Five Filter Media for Installed Costs[1]
vs.
Gas-to-Cloth Ratio



[1]A multiplier of 1.7 applied to these 1975 installation costs will give 1978 installation costs.

Figure 14

Comparison of Five Filter Media for Annual Operating Costs
vs.
Gas-to-Cloth Ratio



Appendix A-3. The following assumptions were made in order to compute these values:

1. Bag replacement would be 25% per year.
2. Operating pressure drops would be the same as those determined in the pilot study for Teflon felt and PTFE laminate, since the pilot study dealt with a wider range of gas-to-cloth ratios than the assessment project has thus far. (However, for comparison, Table 4 shows actual 1977 mean operating G/C ratios and Δp's for both baghouses, and their effect on operating and annualized costs.)
3. The pressure drops for woven glass bags and felted glass bags would be the same as those for Teflon felt.
4. Current average electrical rates were $0.021/KWH.
5. Based on operation of 6,240 hours/year.

From the graph it is obvious that the 15 oz./yd.^{2} woven glass bags have the lowest operating cost -- assuming that the pressure drops used in the computations are nearly correct. Operating costs for these bags are $0.18, $0.14, $0.19 and $0.27 per ACFM for gas-to-cloth ratios of 2.9/1, 5.8/1, 8.9/1 and 11.3/1. With the lowered Teflon felt bag price, Teflon felt has a lower operating cost than the PTFE laminate for gas-to-cloth ratios higher than 4/1. This is due to the high operating pressure drops attributable to the PTFE laminated fabric. Figures 15 through 19 show the increasing cost of each fabric filter system by increasing pressure drops in one inch (W.G.) increments. If the pressure drop is as much as 4" W.G. greater than found in the pilot study, it would increase the annual operating costs by as much as $8,000 per year for each filter medium.

It should be noted that these values do not include the operating costs for the cleaning-air fan. A 4,000 ACFM fan operating at a 2" W.G. pressure drop would cost approximately $205/year to run, based on the 6,240 hour work year and current electrical costs. This value would double if the operating pressure drop were 4" W.G. Even though this cost should be considered in total operating costs, it is fairly insignificant with respect to the rest of the baghouse operating costs.

Figure 15

The Impact of Varying Pressure Drop on Operating Costs
Teflon Felt Operating Costs vs. Gas-to-Cloth Ratio

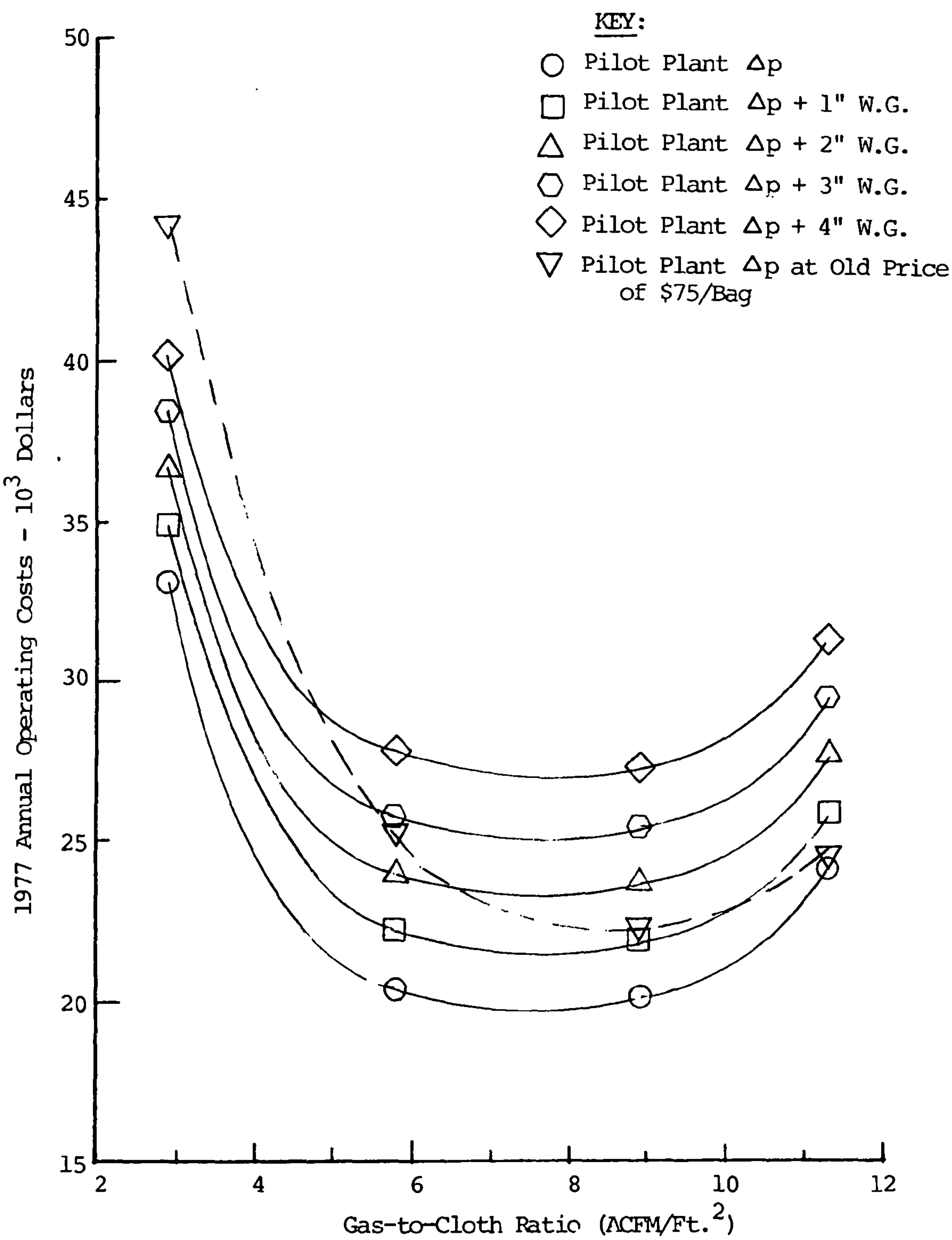


Figure 16

The Impact of Varying Pressure Drop on Operating Costs
PTFE Laminate Operating Costs vs. Gas-to-Cloth Ratio

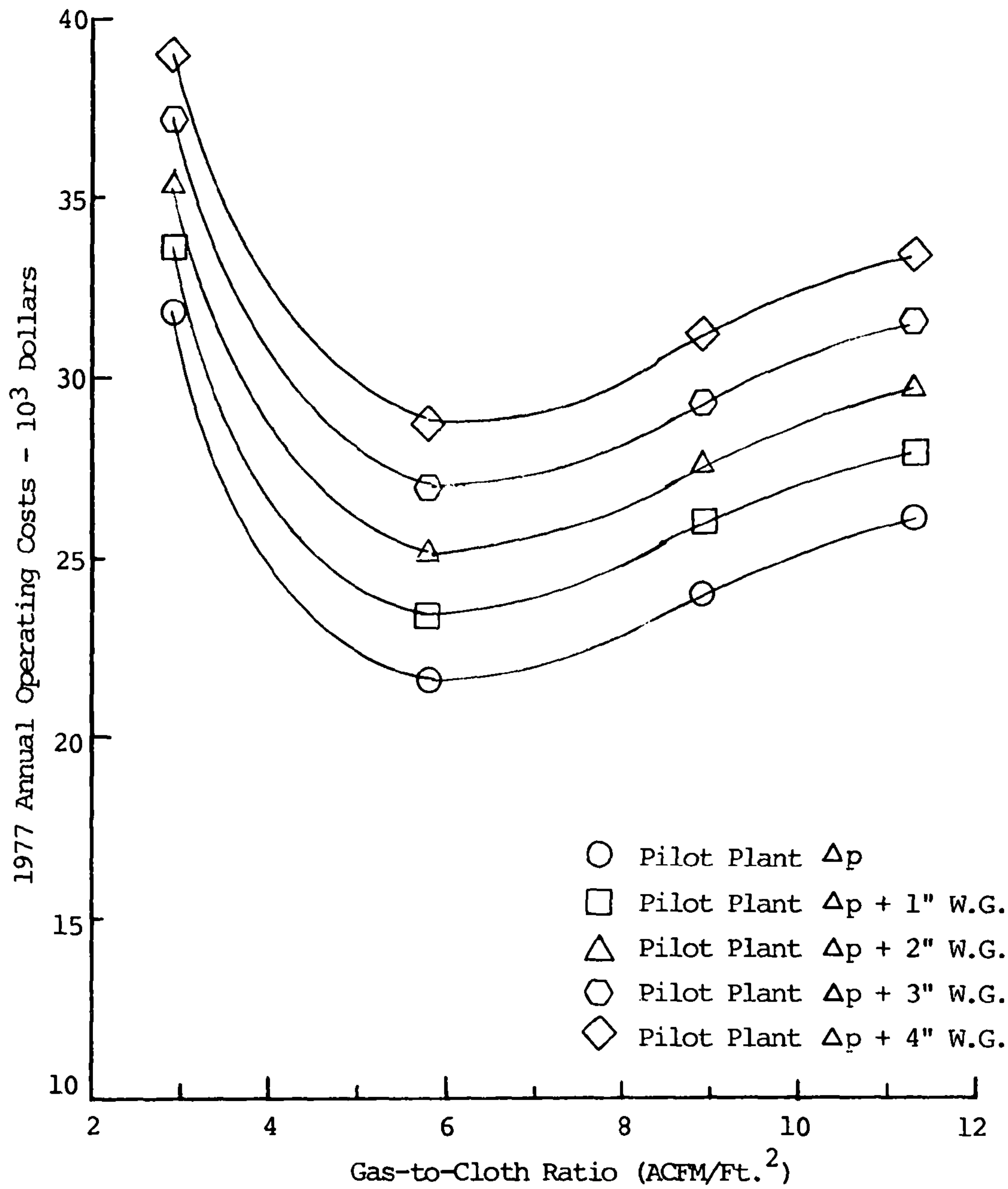


Figure 17

The Impact of Varying Pressure Drop on Operating Costs
Felted Glass Operating Costs vs. Gas-to-Cloth Ratio

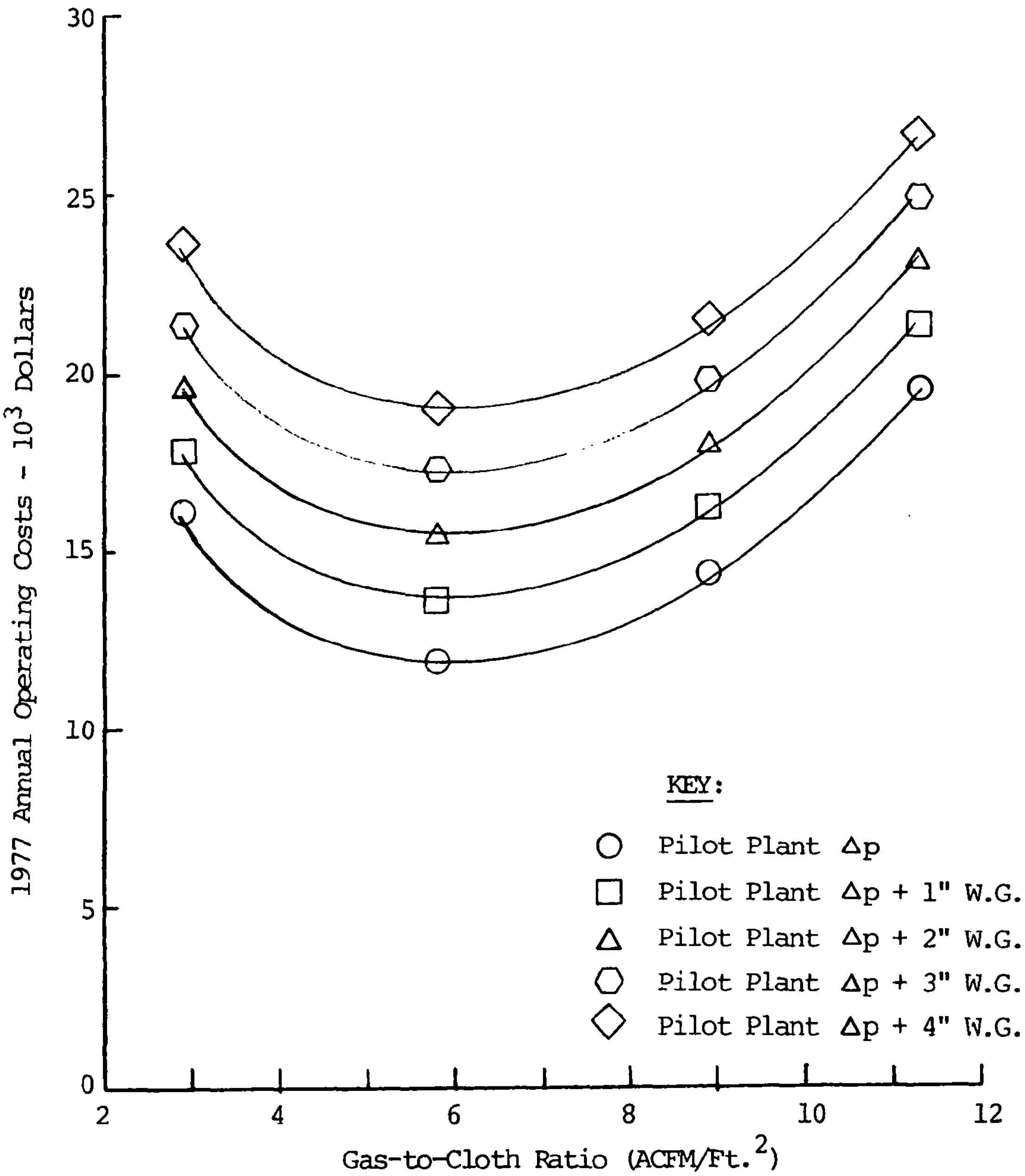


Figure 18

The Impact of Varying Pressure Drop on Operating Costs
Woven Glass (15 Oz.) Operating Cost vs. Gas-to-Cloth Ratio

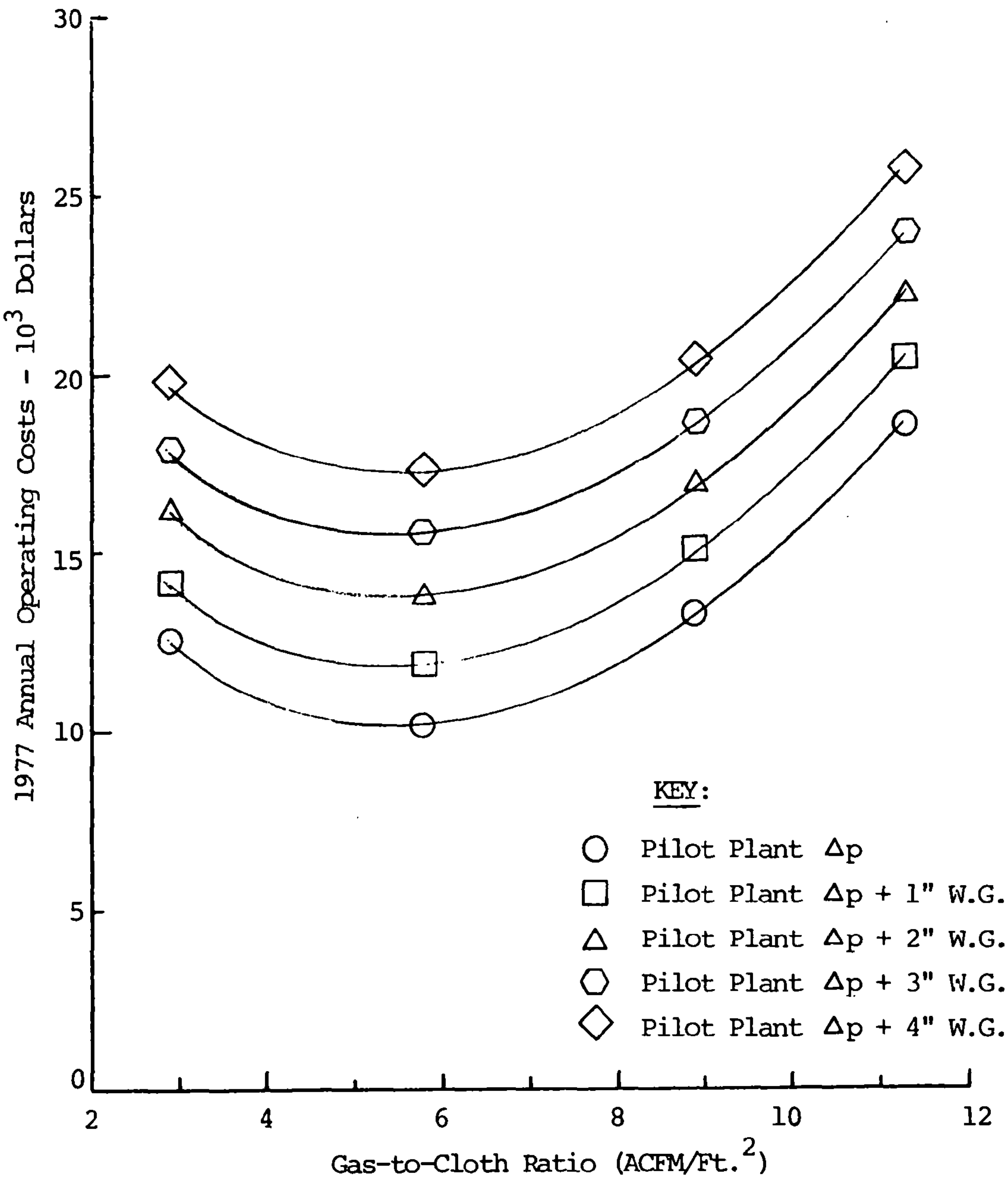
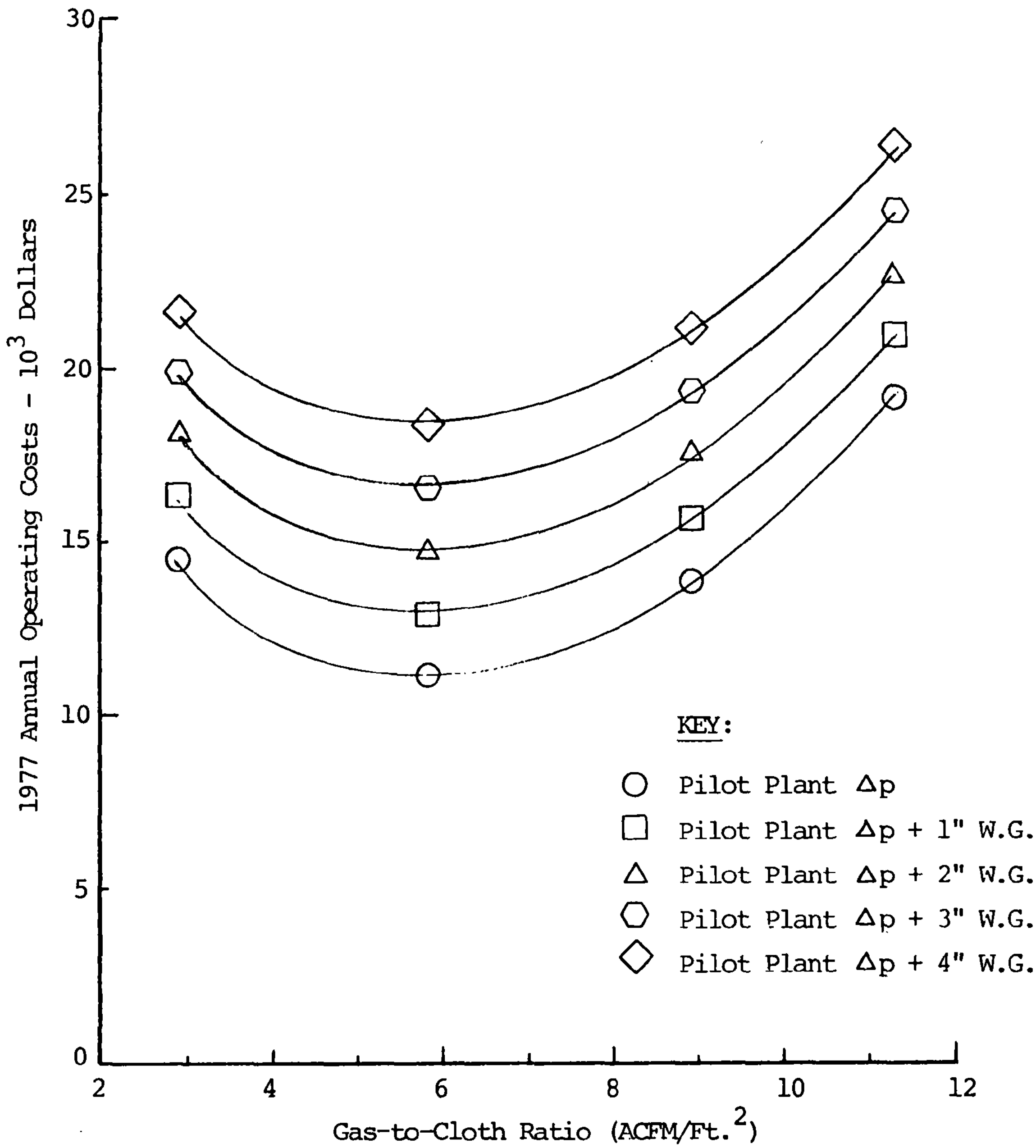


Figure 19

The Impact of Varying Pressure Drop on Operating Costs
Woven Glass (22.5 Oz.) Operating Costs vs. Gas-to-Cloth Ratio



Annualized costs for baghouses with these filter media are graphed in Figure 20. These values are based on the straight line method of depreciation over 15 years (6 2/3% per year). Capital costs are assumed to be equal to the amount of depreciation; therefore, depreciation plus other capital charges amount to 13 1/3 percent of the initial capital costs of the equipment. Annualized costs would then equal the annual operating costs plus 13 1/3 percent of the installed cost.

The 15 oz. woven glass fabric is the least expensive with respect to annualized costs ($0.56, $0.36, $0.37 and $0.43 per ACFM for gas-to-cloth ratios of 2.9/1, 5.8/1, 8.9/1 and 11.3/1) with the 22.5 oz. woven glass and the experimental felted glass close behind. The new Teflon felt bag price makes it very competitive with the PTFE laminate at low gas-to-cloth ratios, and makes it less expensive (again due to the higher operating pressure drop of the PTFE laminate fabric) at gas-to-cloth ratios higher than 5.8/1. Figure 21 shows the amount of the decrease in Teflon felt annualized costs due to the lowered bag price.

Figure 20

Comparison of Five Filter Media for Annualized Cost
vs.
Gas-to-Cloth Ratio

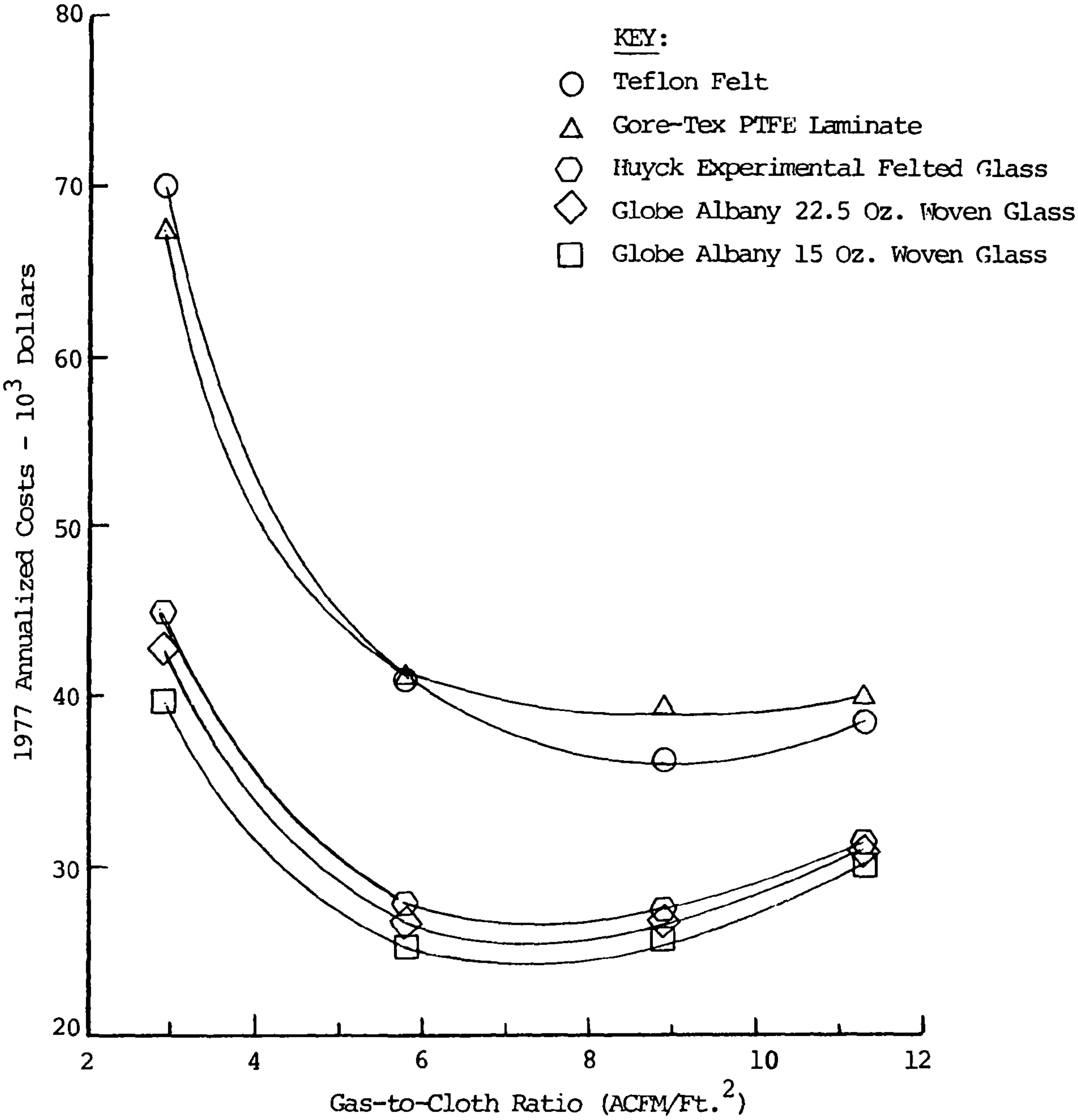
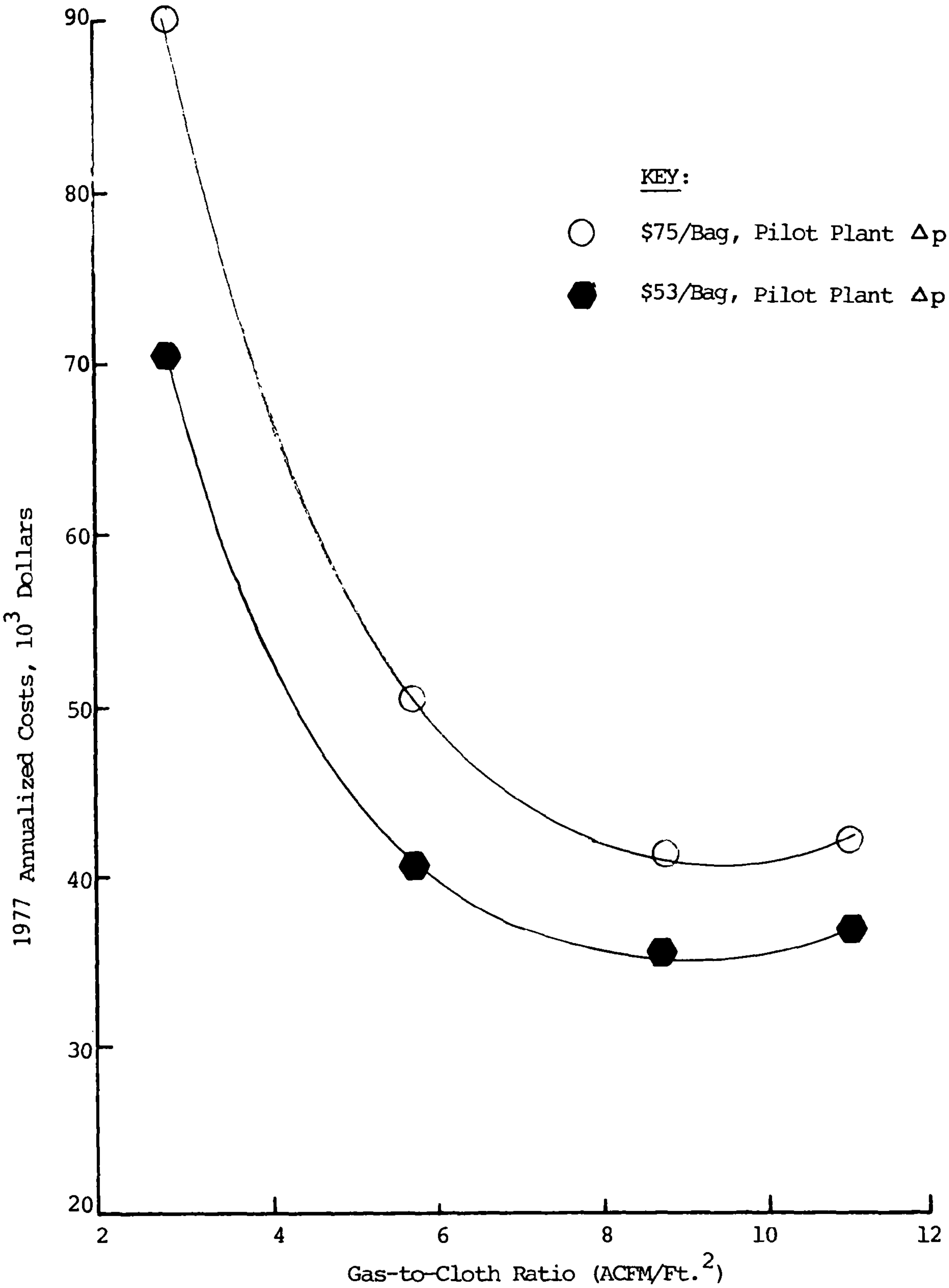


Figure 21

The Effects of Bag Price Reduction on Annualized Costs
vs.
Gas-to-Cloth Ratio for Teflon Felt



OPERATION

Baghouse No. 1 (the Teflon house) was initially brought on line on November 7, 1976 for debugging and brought on line again on December 15 through 17. The Gore-Tex house was brought on line on December 29, 1976. Current start-up and operating procedures are listed following this section. After four months of operation, two additional procedures were added: the boilers would be brought up to load before the baghouses would be brought on line and the baghouses would be shut down one hour before the boilers. Flue gases would be vented through the boiler stack during these times.

The first problem encountered when Baghouse No. 1 was brought on line was that the instrumentation system controller failed to maintain stable conditions. This poor response caused the duct gas heater to malfunction -- shorting out the system. One measure taken to solve this problem was the redesign of the burner area. In the December start-up the system controller began to over-respond to the stack cap closure, creating a pressure surge. A representative of Taylor Instruments recommended a dampering valve to decrease the sensitivity of the primary signal to the system controller. This was installed in February, 1977.

The cleaning-air fan in Baghouse No. 2 was found to be cracked, causing an outage of that unit until it could be replaced. The severely cold weather during February, 1977, created other problems. The damper operator in Baghouse No. 2 was damaged and had to be totally replaced. Also, freezing occurred in the control system air lines. The revamping of the compressed air system included the installation of after-coolers on each compressor and a larger capacity air dryer for the system.

Maintenance activities through the year were varied. Standard maintenance procedures are located in Appendix A-4. A continuously running pneumatic purge was installed on Baghouse No. 1's stack to clear the pressure tap of moisture and dust in June, 1977. An access hatch was also installed on the stack so that cleaning and maintenance of the stack damper could be more easily performed. In August, maintenance activities included recalibration of the inlet differential pressure transmitter by shifting the zero to make it read properly, replacement of a vortex damper positioner that had been misadjusted, replacement of wires between the control house and compressor No. 2 because of a short in the wiring, and replacement of a flame rod in the heater since it would not come on during "pre-heat". Other maintenance activities were tightening of the belts on the fan, which solved the problem of system fan failure shutting down the system; adjusting the stack pressure alarm setting from 1.0" to 1.5" on each side of zero so that the damper control arm would not set off the alarm and shut down sequence when the cap started closing; installing an air scoop on Unit No. 1 at the junction of the exhaust stack and the inlet to the cleaning air fan duct since no dead head pressure was registering and the system did not appear to be cleaning properly; and finally, replacing gasketing on D5B and adjusting the rest of the dampers for a tighter fit.

Again in September the main fan control system began to malfunction, shutting down the system, and the cleaning damper leaks were still causing loss of cleaning pressure and, therefore, cleaning effectiveness. November brought a heater malfunction and an induced draft fan failure for Boiler No. 1. Both were repaired. In December, the purge damper was sealed to improve cleaning air pressure and cleaning-air fan belts and sheaves were replaced. Also, the line between the cleaning-air plenum and the control room gauge was obstructed and had to be replaced.

Maintenance problems of Baghouse No. 2 during 1977 have included the repair of its gas burner because of a surface overheat in May and the repair of the differential pressure transmitter for the controller in August. While the transmitter was out of commission the system was operated manually with the wire from relay No. 45 removed so that the alarm would not shut it down. The heater wires had to be replaced again in August and one cell was not operating because the clevis had separated from the damper cylinder and the cylinder was jammed in the "up" position — this was repaired.

Back pressure into the boiler became a problem in Unit No. 2, so the boiler stack damper was held open during operation. The stack cap was open all of September with no problems, so this became standard for operation of Baghouse No. 2. Other problems encountered were low cleaning air pressure (improved by welding the purge damper closed), obstruction of the line between the cleaning-air plenum and the control room gauge, and a burner short circuit (rewired with asbestos wire).

Another problem encountered was the deterioration of the silicone gasketing material around the hatch covers and dampers in January, 1977. The problem was attributed to the high temperature and the SO_2 concentrations in the flue gas. The replacement was asbestos tad-pole style gasketing, but in November, 1977, a damper sealing problem became apparent - caused by the hardening of the asbestos into a compressed state. At this time an asbestos tad-pole design gasket with a Teflon coating and with a spring-wire mesh center is being tested in the purge vent damper (D5A) in Baghouse No. 1. This appears to solve the problems of compression and hardening.

By April, 1977, it was evident that too heavy a filter "cake" was on the bags and that they would have to be cleaned. An industrial cleaning contractor was hired in May to raise each bag above the tube sheet and to manually vacuum each bag. During the month following bag cleaning the average pressure drop across the Teflon house was 7" W.G. The Teflon felt bags were vacuumed in July and again in November -- the latter time because the pressure drop became too high for effective cleaning and visual inspection of the bags showed heavy pearling (an indication of sub-dew point excursions).

Although Baghouse No. 2, outfitted with Gore-Tex bags of PTFE laminate, had only started up December 29, 1976, by April eight bags had been replaced; four due to material failure and four due to shrinkage which forced the cages above the tube sheets. Twenty-five more were seriously damaged during vacuum cleaning in May. An inspection in July found thirty more bags to have holes or tears in them, apparently due to some maintenance activity. Since there were no more spare Gore-Tex bags, one complete cell of House No. 2 was filled with Globe Albany woven glass bags (these were 22.5 oz./ $yd.^2$ bags taken from the pilot facility at Nashville Thermal Transfer

Corporation) on July 27. A representative of Gore Associates suggested that the Gore-Tex bags could be repaired and suggested that the bags be steam cleaned instead of vacuumed to lower the risk of damage. In October, three more bags were lost; one was shredded and two had one-inch diameter holes. In November, fourteen bags were discovered to have one and a half inch holes in the upper two feet of the bag, primarily where the bags made contact with cage ribs.

List of Bag Replacements

Baghouse No. 2

Gore-Tex Bag Loss

•

Date	No. of Bags Replaced	Comments
4/77	8	4 Shrank (Forced Cage Up) 4 Material Failure
		First Cleaning Was During May
5/77	25	Serious Damage During Cleaning
7/77	30	Holes or tears apparently due to maintenance. Gore said bags should be steam cleaned in place; can repair these.
10/77	3	1 Shredded, 2 w/Small Holes
11/77	14	Holes 1-1½" long in upper 2 feet of bag where contact rib of cage.

Thirty-six (36) Huyck experimental glass bags put in House No. 2, Cell 6A, 3/28/77.

Thirty-six (36) Globe Albany 22½ oz./yd.^{2} woven bags put in House No. 2, Cell 3, 5/27/77.

Thirty-six (36) Globe Albany 15 oz./yd.^{2} bags installed in House No. 2, Cell 5, 2/21/78.

Three (3) Nomex felt bags installed in House No. 2, Cells No. 1, 4 and 9, 2/21/78.

START-UP AND OPERATING PROCEDURES

I Start-Up -- Preliminary Procedures

A. These devices must be closed:

1. Main Disconnect Switch

2. All Motor Starter Doors

3. All Motor Starter Circuit Breakers

4. All Motor Disconnects

5. Control Circuit Breakers

B. Fuses must be in place and of recommended rating.

C. Air dryer switch must be on before air compressor is started.

D. Press air compressor "start" button and "air compressor on" indicating light must be lighted.

E. All trouble annunciator lights must be out after pressing silence button.

F. Turn mode selector from "off" to "test" to check operation of all drives and dampers (except stack cap).

G. Turn mode selector to "off".

II Automatic Operating Procedures

A. Turn mode selector to "automatic".

B. Wait about 10 seconds until all relays have reset.

C. Press "auto start" pushbutton.

D. System will start-up and operate as described.

III Manual Operating Procedures:

A. Turn selector switch to "manual".

B. Wait about 10 seconds until all relays have reset.

C. Start preheat cycle.

D. Wait until baghouse is up to 250° F (on digital read out) and exhaust stack is up to 180° F (on temperature recorder).

E. Press normal start pushbutton.

DATA OBTAINED

Inlets to both baghouses were characterized by both EPA Methods 1 - 5 testing (substituting a medium porosity alundum thimble for a heated glass filter) and by continuous recording monitors. The ranges of various parameters as well as average values can be found in Table 5. These averages are based on six tests for the inlet to Baghouse No. 1 and three for the inlet to Baghouse No. 2. The data vary only slightly between houses.

In January, 1973, (prior to the pilot study) the North Carolina Air Quality Division performed testing on two consecutive days to determine the quantity of particulate emissions from the stack for Kerr's Boiler No. 2. The Orsat analysis of the stack gas showed the oxygen content to be 10% and the carbon dioxide content to be 9.5% with no carbon monoxide. An emission factor of 0.36 lb./million BTU was assigned to each Kerr boiler, based upon design BTU input. This factor multiplied by the actual BTU input (a computation based on the actual steam production rate and the generating efficiency of 77%) yielded the allowable emission rates of 25.1 lb./hr. and 27.8 lb./hr. for the two tests which had actual emission rates of 131.4 lb./hr. and 135.6 lb./hr., respectively.

Outlet emissions testing during the first year of the assessment project's operation proved that the baghouse emissions would be in compliance with air pollution regulations under most conditions. The high oxygen content in the gas results in higher excess air and higher emission rates. Better results could be obtained by eliminating some of this oxygen. Table 6 lists a summary of outlet data acquired by EPA Methods 1 through 5 sampling as well as the data recorded on baghouse monitors. Table 7 lists the parameters used in computing the emission rates for specific tests.

Since the gas-to-cloth ratio did not vary much in 1977 (4.5/1 to 5.8/1) it is assumed that this had very little effect on outlet grain load. However, coal variablity, bag on-stream time, across-house pressure drop and boiler load are interrelated in affecting each other and, possibly, outlet loading. From Table 7 it does not appear that boiler load has any effect upon the outlet loading. Nor does it appear to influence any other parameter.

Table 5

Inlet Characterization
1977

	Baghouse #1 Teflon Felt	Baghouse #2 Largely Gore-Tex
	Source Testing (EPA Method 5)	
CO_2 (%)	4.5 (Range 3.9-5)	4.4 (Range 3.9-4.7)
CO (%)	0	0
O_2 (%)	15.2 (Range 14.5-16.8)	14.6 (Range 13.7-15.5)
Moisture (%)	5.1 (Range 3.0-8.3)	3.1 (Range 2.7-3.3)
T (° F)	322 (Range 310-350)	317 (Range 310-330)
Gas Volume (ACFM)	37,700 (Range 34,900-40,700)	35,300 (Range 33,100-38,100)
Grain Loading (Grains/DSCF)	0.5356 (Range 0.3846-0.7878)	0.4272 (Range 0.3999-0.4593)
	Continuous Monitoring	
Boiler Stack Temperature	300° F (Range 270-330° F)	95° F (Range 50-120° F)*
Inlet Temperature	270° F (Range 100 -320° F)	310° F (Range 240-335° F)
Inlet Flow Rate	76.7 Ft./Sec. (Range 59.44-88 Ft./Sec.)**	61.1 Ft./Sec. (Range 24-74 Ft./Sec.)**
Inlet Opacity	-	40% (Range 18-80%)

*The stack cap is always open on #2.

**Computed with the average inlet temperature, the values were then adjusted by dividing the flow rate derived by 1.25 and 1.5 for baghouses 1 and 2, respectively, to correspond to values obtained via pitot tube.

Table 6

Outlet Characterization 1977

	Baghouse #1 Teflon Felt	Baghouse #2 Largely Gore-Tex
	Source Testing (EPA Method 5)	
CO_2 (%)	4.0 (Range 3.7-4.3)	4.2 (Range 3.8-4.9)
CO (%)	0	0
O_2 (%)	14.9 (Range 14.2-15.3)	14.6 (Range 13.8-15.8)
Moisture (%)	4.0 (Range 2.8-4.8)	3.5 (Range 2.7-5.0)
T (° F)	291 (Range 272-320)	292 (Range 260-307)
Gas Volume (ACFM)	46,700 (Range 44,500-49,000)	45,600 (Range 44,200-46,800)
Grain Loading (Grains/DSCF)	0.0367 (Range 0.0175-0.0912)	0.0605 (Range 0.0263-0.1230)
Emission Factor (Lb./10^6 BTU)	0.16778 (Range 0.06299-0.41764)	0.36963 (Range 0.11846-0.72096)
	Continuous Monitoring	
Outlet Temperature (° F)	280 (Range 230-305)	290 (Range 210-310)
Outlet Flow Rate (ft./s)	64 (Range 43.2-74.8)*	69.3 (Range 39.7-77.4)*
Δp House ("H_2O)	7.1 (Range 2.7-13.8)	12.2 (Range 8.7- >15)
Δp Main Fan ("H_2O)	10.8 (Range 3.6- >15)	13.2 (Range 9.6- > 15)
Reverse-Air Fan Temperature (° F)	275 (Range 230-300)	300 (Range 230-315)
Outlet Opacity (%)	-	7 (Range 4-20)

*Based on Average Outlet Temperature

Table 7

Summary of EPA Method 5 Outlet Data
1977

Baghouse No. 1

Run #	Date	Approximate Gas-to-Cloth Ratio	DSCFM	% O_2	Outlet Loading Lb./Hr.	Emission Factor Lb./10^6 BTU	Average Boiler Load Lb./Hr.
1	12/16/76	5.5	30,640	6.7	8.85	0.14746	41,250
2	12/17/76	5.4	29,088	7.1	8.21	0.13598	45,250
9	4/26/77	5.1	31,635	6.4	24.72	0.41764	38,000
30	9/1/77	5.8	31,106	5.6	4.67	0.09170	32,000
31	9/1/77	5.7	30,714	5.7	3.48	0.06799	37,600
32	9/1/77	5.8	31,186	5.6	7.45	0.14592	32,600

Baghouse No. 2

Run #	Date	Approximate Gas-to-Cloth Ratio	DSCFM	% O_2	Outlet Loading Lb./Hr.	Emission Factor Lb./10^6 BTU	Average Boiler Load Lb./Hr.
7	1/20/77	5.8	32,747	5.1	34.51	0.72096	44,000
11	4/27/77	5.4	30,431	6.5	6.85	0.11846	40,500
12	4/28/78	5.8	26,949	6.5	13.80	0.26948	50,600

Coal variability does appear to be the major influence in baghouse operation and outlet loading. During 1977 a poorer quality of coal was used in April, August and December due to heavy rains and flooding, and the coal miner's strike. The coal used during these months had a higher volume of water decreasing the ability to get the boilers up to load and was generally of poorer quality. When used, this coal caused an increase in across-house pressure drop to 12" W.G. and above. In April the pressure drop increases kept causing the baghouses to shut down. The primary causes of the pressure drop increases were the increase in water content and the increase in inlet loading - both causing the bags to "plug" up.

A coal analysis was performed on the standard coal used early in December 1977 and can be found in Table 8. Ash taken from Baghouse No. 2 at this time was found to have an unburned carbon content of 25.21%. Still using the poorer quality coal in February 1978 showed the unburned carbon content in the ash to be 33.81% and 34.39% for Baghouses 1 and 2 respectively.

Since on-stream time affects the filter media, it also affects baghouse operation. The Gore-Tex filters underwent a great deal of abrasion in contact with the metal ribs of the cages. There were instances of holes at other locations which could be due to the flexing or acid attack. The permeability of the new Gore-Tex bags ranged from 8.13 to 12.9 $ft.^3/ft.^2/min.$ with the average being 10.22 $ft.^3/ft.^2/min.$ After one month on-stream these bags had permeabilities of about 2.5 $ft.^3/ft,^2/min.$ and the perms were not improved by vacuuming the bags. Throughout the year bags were removed periodically for perms. The highest found was 4.05 $ft.^3/ft.^2/min.$ after vacuuming. The bag had been on-stream less than three months. By November 1977 the average permeability (after vacuuming) was only 1.25 $ft.^3/ft.^2/min.$ It should be noted that manual industrial vacuuming can and did damage bags in place. at Kerr. The vacuuming did not improve the pressure drop across Baghouse No. 2.

The Teflon felt bags have responded somewhat better. New bags had a perm range of 27.5 to 41.73 $ft.^3/ft.^2/min.$ with an average of 33.12 $ft.^3/ft.^2/min.$ After two months on stream the bags had an average perm of 10.45 $ft.^3/ft.^2/min.$ but were vacuumed to an average of 15.53 $ft.^3/ft.^2/min.$ By

Table 8

Coal Analysis

December 1977

	As Received	Dry
Moisture	6.87 %	
Ash	14.35 %	15.41 %
Volatile	30.12 %	32.34 %
Fixed Carbon	48.66 %	52.25 %
Sulfur	0.67 %	0.72 %
Carbon	65.49 %	70.32 %
Hydrogen	4.21 %	4.52 %
Oxygen & Nitrogen	8.41 %	9.03 %

Heat Value	As Received	Dry	MAF
BTU/lb.	11560	12412	14674

April of 1977, some bags could still be cleaned to 20.8 $ft.^3/ft.^2/min$. Industrial vacuuming did not harm the fabric and lowered the across-house pressure drop 5-8" W.G. each time it was done.

The across-house pressure drops have been found to be approximately four inches higher in the Teflon house during the full scale demonstration than in the pilot program. This could be attributable to the removal of the multicyclones or to the longer on-stream time of the bags.

Also directly attributable to the removal of the multicyclones at the beginning of the demonstration project is the outlet particle sizing. Tables 9 through 11 show inertial impactor characterizations of inlet and outlet, mass emissions removal efficiencies, and particle size removal efficiencies. (Tables A-2 through A-6 in Appendix A-5 show results of individual Andersen tests on outlets.) Figure 22 shows the relationship of the average curve for the pilot plant using Teflon felt (no nozzle wash was collected) and the average curves for the demo unit with and without the nozzle washes. Without the nozzle wash, the curves approximate each other in shape, but the demo is shifted up and to the left due to larger particles entering the baghouse than during the pilot study when the multicyclone was in use.

Table 9

Inlet Characterization
(Particle Sizing)

Mean of Andersen tests from Pilot Study.[1]

Stage	Particle Diameter, μ		Loading Grains/dscf
1	>8.72		.14546[2]
2	5.45		.03850
3	4.02		.02643
4	2.47		.01287
5	1.55		.01276
6	0.86		.00492
7	0.51		.00270
8	0.35		.00297
Back-Up Filter	<0.35		.00429
		Total	.25090

Brink test on inlet of Teflon felt house, 11/15/78.

Stage	Particle Diameter, μ		Loading Grains/dscf	
1	>1.59		.05831[2]	.26415[3]
2	0.92		.12987	.12987
3	0.61		.03973	.03973
4	0.30		.01882	.01882
5	0.17		.00767	.00767
6	0.09		.00465	.00465
		Total	.25904	.46488

[1]McKenna, J.D., Mycock, J.C. and Lipscomb, W.O. Applying Fabric Filtration to Coal Fired Industrial Boilers: A Pilot Scale Investigation. EPA-650/2-74-058a, U.S. Environmental Protection Agency, Washington, D.C. August, 1975. 191 pp.

[2]Probe + nozzle washes omitted from Stage 1

[3]Probe + nozzle washes included in Stage 1

Table 10

Outlet Characterization by Andersen Impactor
(Particle Sizing)

Mean values of 13 tests during 1977 on Teflon felt house, gas-to-cloth ratio 4.5-6/1.

Stage	Particle Diameter, μ	Cumulative % Less Than Size Indicated			Loading Grains/dscf	
1	>9.41	77.92[1]	5.48[2]		.00102[1]	.04229[2]
2	6.60	64.50	4.63		.00062	.00038
3	4.06	48.27	3.46		.00075	.00052
4	2.85	34.85	2.41		.00062	.00047
5	1.85	22.29	1.65		.00058	.00034
6	0.85	13.42	1.01		.00041	.00029
7	0.51	8.44	.63		.00023	.00017
8	0.36	5.63	.36		.00013	.00012
Back-Up Filter	< 0.36	-	-		.00026	.00016
				Total	.00462	.04474

Mean values of 3 tests during 1977 on (largely) Gore-Tex house, gas-to-cloth ratio 4.5-6/1.

Stage	Particle Diameter, μ	Cumulative % Less Than Size Indicated		Loading Grains/dscf
1	>10.43	66.41[1]		.00304[1]
2	7.32	55.14		.00102
3	4.51	42.32		.00116
4	3.17	35.36		.00063
5	2.06	27.07		.00075
6	0.95	17.68		.00085
7	0.57	10.06		.00069
8	0.41	6.19		.00035
Back-Up Filter	< 0.41	-		.00056
			Total	.00905

[1]Probe + nozzle washes omitted from Stage 1

[2]Probe + nozzle washes included in Stage 1

Table 11

Mass Emissions and Particle Size Removal Efficiencies

Mass Emissions Removal Efficiencies[1]

	Teflon Felt House	(Largely) Gore-Tex House
Best Case	95.45% @ .0175 gr/dscf outlet loading	93.42% @ .0263 gr/dscf
Mean	93.15 @ .0367	85.84 @ .0605
Worst Case	88.42 @ .0912	73.22 @ .1230

Particle Size Removal Efficiencies[2] at G/C ratio of approx. 6/1 for both media.

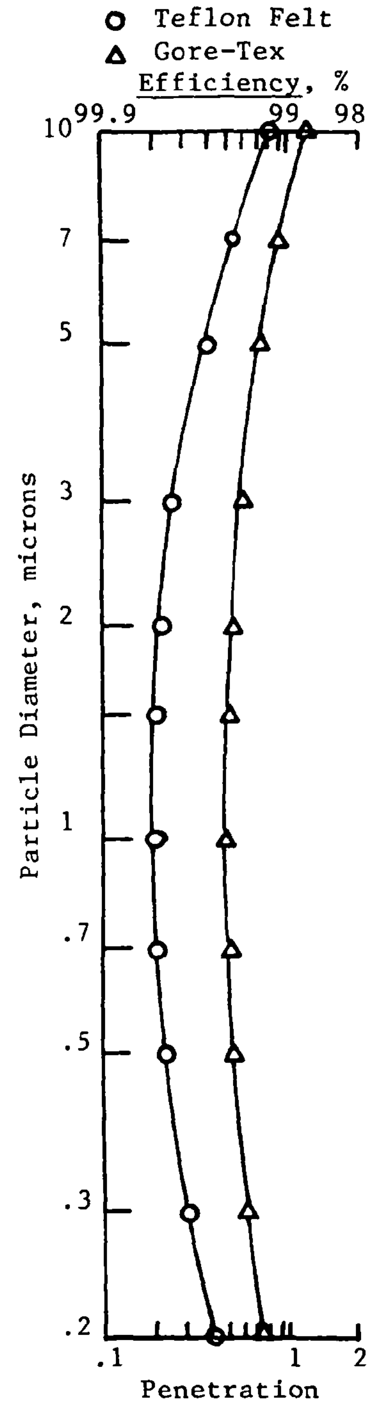
Particle Diameter, μ	Teflon Felt House Penetration	Teflon Felt House Efficiency	(Largely) Gore-Tex House* Penetration	(Largely) Gore-Tex House* Efficiency
.2	.0042	99.58%	.0075	99.25%
.3	.0031	99.69	.0063	99.37
.5	.0024	99.76	.0054	99.46
.7	.0021	99.79	.0051	99.49
1.0	.0021	99.79	.0050	99.50
1.5	.0021	99.79	.0051	99.49
2.0	.0023	99.77	.0054	99.46
3.0	.0028	99.72	.0061	99.39
5.0	.0040	99.60	.0077	99.23
7.0	.0055	99.45	.0094	99.06
10	.0083	99.17	.0122	98.78
20	.0219	97.81	.0223	97.77
Overall		98.02		98.99

Particle size removal efficiencies are shown in the graph to the right.

[1] Based on 1977 source (EPA Method 5) tests.

[2] Based on 1977 Andersen tests on outlets of both houses, and 1978 Brink test on inlet to Gore-Tex house (linear least squares data fit).

* No probe and nozzle washes were collected.



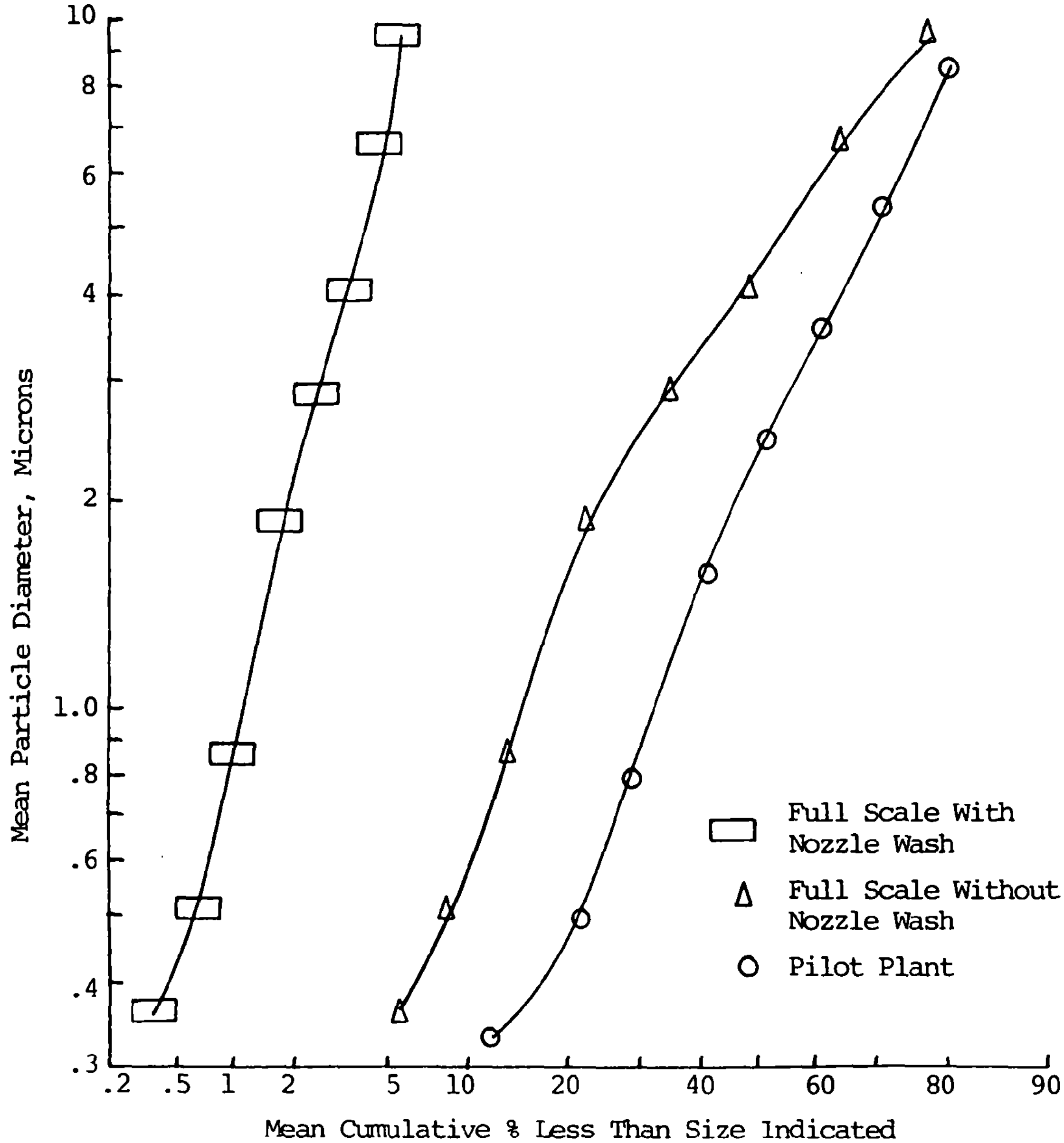


Figure 22

Comparison of Pilot Plant with Full Scale Assessment Project in Terms of Outlet Particle Size Distribution

(Teflon Felt - Gas-to-Cloth Ratio 4.5-6/1)

FUTURE PLANS

The EPA has elected to exercise all contract options, thus the two demonstration units will continue to be operated and tested throughout 1978 and 1979. House No. 1 will continue to be operated with Teflon felt as the filter media. The program plan calls for replacement of the Gore-Tex with a series of other filter media, thus obtaining cost, life and performance data on a variety of candidate media considered potentially suitable for fly ash control applications. The initial candidate materials include both a woven glass and an experimental felted glass.

Estimates for a new multi-cyclone and for refurbishing the interior of one of the existing multi-cyclones are being collected. If economically feasible, a multi-cyclone will be used as a particulate pre-collector for House No. 1 (the Teflon house) for comparison with results obtained by baghouse use alone.

Operation of the fabric filter as an SO_2 removal system by the use of two (2) injected sorbents will begin in 1979.

APPENDIX

Section	Contents	Page
A-1	Units of Measure - Conversions	74
	Glossary of Terms	75
A-2	SD-10 General Arrangement	80
	Shock-Drag Bag Cleaning System	81
A-3	List of Equipment Included in Installed Costs	83
	Bill of Materials for Actual Kerr Installation	84
	List of Components Included in the Flange-to-Flange 1978 Collector Costs	
	Installed, Operating and Annualized Costs for Electrostatic Precipitators - 1978	
	Sample Calculations of Operating and Annualized Costs for Fabric Filtration	
	Sample Calculations of Operating and Annualized Costs for Electrostatic Precipitation	
A-4	Baghouse Maintenance Procedures	
	Baghouse Maintenance Schedule	
	Spare Parts List	
A-5	Results of Andersen Impactor Tests on Outlets	

APPENDIX A-1

Units of Measure - Conversions

Glossary of Terms

UNITS OF MEASURE - CONVERSIONS

Environemntal Protection Agency policy is to express all measurements in Agency documents in metric units. When implementing this practice will result in undue costs or lack of clarity, conversion factors are provided for the non-metric units used in a report. Generally, this report uses British units of measure. For conversion to the metric system, use the following conversions:

TO CONVERT FROM	TO	MULTIPLY BY
°F	°C	$\frac{5}{9}$ (°F-32)
ft.	meters	0.304
ft.^{2}	meters^2	0.0929
ft.^{3}	meters^3	0.0283
ft/min (fpm)	centimeters/sec	0.508
ft.^{3}/min	centimeters^3/sec	471.9
in	centimeters	2.54
in^2	centimeters^2	6.45
oz	grams	28.34
oz/yd^2	grams/meter^2	33.89
grains	grams	0.0647
grains/ft^3	grams/meter^3	2.288
lb force	dynes	4.44×10^5
lb mass	kilograms	0.453
lb/ft^2	grams/centimeter^2	0.488
in H_2O/ft/min	cm H_2O/cm/sec	5.00
$\frac{\text{in } H_2O\text{/ft/min}}{\text{lb/ft}^2}$	$\frac{\text{cm } H_2O\text{/cm/sec}}{\text{gm/cm}^2}$	10.24

GLOSSARY OF TERMS

ACID DEW-POINT - The temperature at which the condensation of the acid vapors initiates for a given state of humidity and pressure.

AIR-TO-CLOTH RATIO - The volumetric rate of capacity of a fabric filter; the volume of air (gas), cubic feet per minute, per square foot of filter media (fabric).*

BAG- The customary form of filter element. Also known as tube, stocking, etc. Can be unsupported (dust on inside) or used on the outside of a grid support (dust on the outside).

BLINDING (BLINDED)- The loading, or accumulation, of filter cake to the point where capacity rate is diminished. Also termed "plugged".

CLOTH - In general, a pliant fabric; - woven, knitted, felted, or otherwise formed of any textile fiber, wire, or other suitable material.

CLOTH WEIGHT - Is usually expressed in ounces per square yard or ounces per square foot. However, cotton sateen is often specified at a certain number of linear yards per pound of designated width. For example, a 54" - 1.05 sateen measures 1.05 linear yards per pound in a 54" width.

DAMPER - An adjustable plate installed in a duct for the purpose of regulating air flow.

DIMENSIONAL STABILITY - Ability of the fabric to retain finished length and width, under stress, in hot or moist atmosphere.

DUST LOADING - The weight of solid particulate suspended in an air (gas) stream, usually expressed in terms of grains per cubic foot, grams per cubic meter or pounds per thousand pounds of gas.

*Although it is EPA's policy to use the metric system for quantative descriptions, the British system is used in this report because not to do so would tend to confuse some readers from industry. Readers who are more accustomed to metric units may use the table of conversions in the appendix to facilitate the translation.

GLOSSARY OF TERMS

FABRIC - A planar structure produced by interlacing yarns, fibers or filaments.

KNITTED fabrics are produced by interlooping strands of yarn, etc.

WOVEN fabrics are produced by interlacing strands at more or less right angles.

BONDED fabrics are structures built up by the interlocking action of the fibers themselves, without spinning, weaving or knitting.

FELTED fabrics are structures built up by the interlocking action of the fibers themselves, without spinning, weaving or knitting.

FILTER MEDIA - The substrate support for the filter cake; the fabric upon which the filter cake is built.

FILTER VELOCITY - The velocity, feet per minute, at which the air (gas) passes through the filter media, or rather the velocity of approach to the media. The filter capacity rate.

FILTRATION RATE - The volume of air (gas), cubic feet per minute, passing through one square foot of filter media.

FRACTIONAL EFFICIENCY - The determination of collection efficiency for any specific size or size range of particles.

GRAIN - 1/7000 pound or approximately 65 milligrams.

INCH OF WATER - A unit of pressure equal to the pressure exerted by a column of liquid water one inch high at a standard temperature. The standard temperature is ordinarily taken as 70^{o} F. One inch of water at 70^{o} F. = 5.196 lb per sq. ft.

MASS MEAN PARTICLE DIAMETER - Refers to the point of a curve plotting particle diameter versus cumulative mass percent that shows 50% of the material is less than and 50% of the material is greater than the indicated particle diameter.

MICRON (um) - A unit of length, the thousandth part of 1 mm or the millionth of a meter, (approximately 1/25,000 of an inch).

MULLEN BURST - The pressure necessary to rupture a secured fabric specimen, usually expressed in pounds per square inch.

GLOSSARY OF TERMS

NEEDLED FELT - A felt made by the placement of loose fiber in a systematic alignment, with barbed needles moving up and down, pushing and pulling the fibers to form an interlocking of adjacent fibers.

NON-WOVEN FELT - A felt made either by needling, matting of fibers or compressing with a bonding agent for permanency.

NYLON - A manufactured fiber in which the fiber forming substance is any long-chain synthetic polyamide having recurring amide groups.

PEARLING - Refers to a condition of the dust cake on the fabric which appears as nodular structures of agglomerated dust.

PERMEABILITY, FABRIC - Measured on Frazier porosity meter, or Gurley permeometer, etc. Not to be confused with dust permeability. The ability of air (gas) to pass through the fabric, expressed in cubic feet of air per minute per square foot of fabric with a 0.5" H_2O pressure differential.

PITOT TUBE - A means of measuring velocity pressure. A device consisting of two tubes - one serving to measure the total or impact pressure existing in an air stream, the other to measure the static pressure only. When both tubes are connected across a differential pressure measuring device, the static pressure is compensated automatically and the velocity pressure only is registered.

POROSITY, FABRIC - Term often used interchangeably with permeability. Actually percentage of voids per unit volume - therefore, the term is improperly used where permeability is intended.

PRESSURE, STATIC - The potential pressure exerted in all direction by a fluid at rest. For a fluid in motion, it is measured in a direction normal to the direction of flow. Usually expressed in inches water gage, when dealing with air.

PRESSURE, TOTAL - The algebraic sum of the velocity pressure and the static pressure (with due regard to sign). In gas-handling systems these pressures are usually expressed in inches water gage. The sum of the static pressure and the velocity pressure.

GLOSSARY OF TERMS

TEMPERATURE, DEW-POINT - The temperature at which the condensation of water vapor in a space begins for a given state of humidity and pressure as the temperature of the vapor is reduced. The temperature corresponding to saturation (100 per cent relative humidity) for a given absolute humidity at constant pressure.

TWILL WEAVE - Warp yarns floating over or under at least two consecutive picks from lower left to upper right, with the point of intersection moving one yarn outward and upward or downward on succeeding picks, causing diagonal lines in the cloth.

VELOCITY HEAD - Same as velocity pressure. (See Pressure, Velocity).

VELOCITY OF APPROACH - The velocity of air (gas), feet per minute, normal to the face of the filter media.

VELOCITY TRAVERSE - A method of determining the average air velocity in a duct. A duct, round or rectangular, is divided into numerous sections of equal area. The velocity is determined in each area and the mean is taken of the sum.

APPENDIX A-2

SD-10 General Arrangement
Shock-Drag Bag Cleaning System

General Arrangement SD-10

Pyramid Hopper

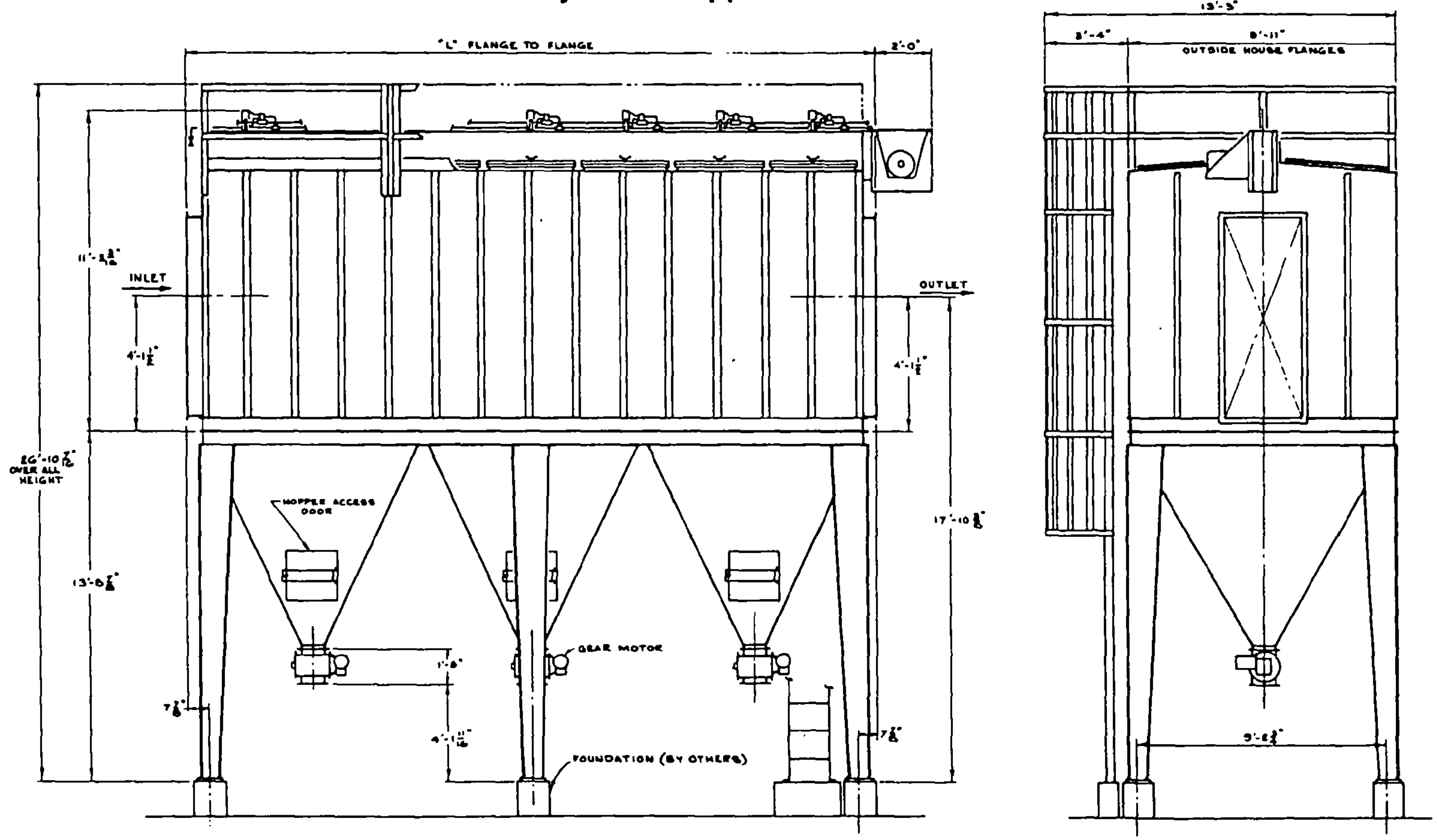


Figure A-1

SD-10 General Arrangement with Pyramid Hoppers

The arrangement of the SD-10 is very similar to that of the RAC-3's in use at Kerr.

Figure A-2

Baghouse Pictorial Showing Gas Flow

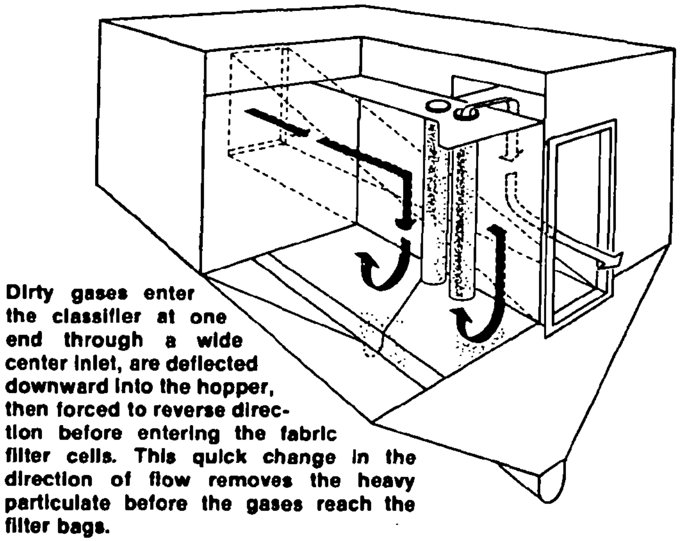
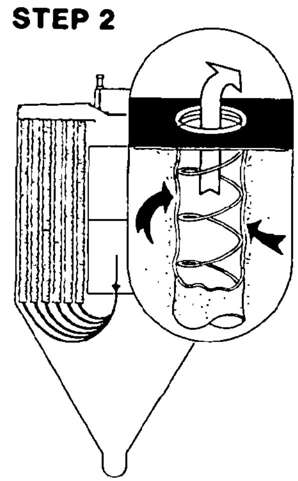


Figure A-3

Baghouse Pictorial Showing Gas Flow



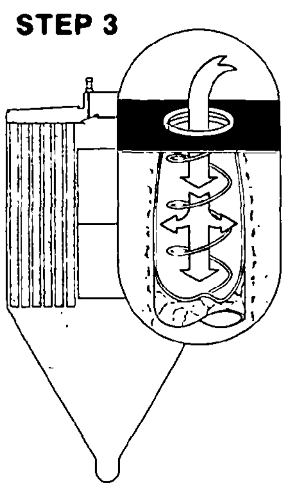


Figure A-4

Baghouse Pictorial Showing Gas Flow - Shock

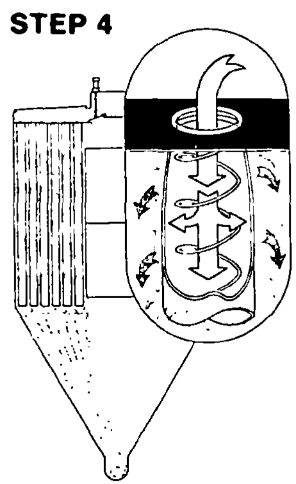


Figure A-5

Baghouse Pictorial Showing Gas Flow - Drag

APPENDIX A-3

List of Equipment Included in Installed Costs

Bill of Materials for Actual Kerr Installation

List of Components Included in the Flange-to-Flange 1978 Collector Costs

Installed, Operating and Annualized Costs for Electrostatic Precipitators - 1978

Sample Calculations of Operating and Annualized Costs for Fabric Filtration

Sample Calculations of Operating and Annualized Costs for Electrostatic Precipitation

List of Equipment Included in "Installed Cost"

COLLECTOR

Standard Collector Components
Bags

COLLECTOR AUXILIARY COMPONENTS

Support Structure
Cleaning Control Panel (Standard)
Reverse-Air Blower
Reverse-Air Service Platform and Railing
High-Pressure Switch
High-Temperature Switch
Rotary Air Lock
Handrails
Ladder
Paint
Insulation

SYSTEM AUXILIARIES

Control Panel
Cross Screw
Ductwork
System Fan
Relief Cap
Installation

ENGINEERING SERVICES

Site Survey
Design & Engineering
Drawings
Start-Up and Instruct

BILL OF MATERIALS

Job No. 76-100

Item	Qty.	Part No.	Material	Actual Costs
1	2	S-9101P9	648-RAC3-5-104 Baghouse with Insulation	$ 120,700
2	2	S-9097	ES16, Arrg. 9, Reverse-Air Fan Assembly	3,800
3	1296	S-2096	Rigid Cage Assemblies (Included in 1)	--
4	1		Compressor System	8,000
5	2	S-9102P9	9 Module Pyramid Hoppers With Insulation (Included in 1)	--
6	1 Lot	76-100-	Structure and Walkways	19,810
7	1	76-100-	Pent House Assembly	7,977
8	1	76-100-	System Motor Control Center	45,406
9	1 Lot	76-100-	Ductwork With Relief Caps and Dampers	64,498
10	1	76-100-	Control House	39,648
11	2	76-100-	System Fan Assemblies	27,585
12	6	S-9144	Double Dump Valves	9,000
13	1	76-100-	Motor Speed Control Center (Included in 8)	--
14	1	76-100-	System Control Console (Included in 8)	--
15	1		Heat Control System (Included in 8)	--

List of Components Included in the Flange-to-Flange
1978 Collector Costs
(Coal-Fired Boiler Applications)

Collector

Supports

Timer

Reverse-Air Fan

Reverse-Air Fan Platform

High Pressure

High Temperature

Double Dump Valves

Heater

Ladder

Paint

Insulation (2 Inches Thick)

Electrostatic Precipitator - 1978
Installed, Operating and Annualized Costs

Efficiency	SCA	Installed Costs	Operating Costs	Annualized Costs
90%	247	$250,750 ($3.58/ACFM)	$26,832 ($0.38/ACFM)	$60,182 ($0.86/ACFM)
95%	309	274,550 ($3.92/ACFM)	27,252 ($0.39/ACFM)	63,767 ($0.91/ACFM)
99%	463	366,520 ($5.24/ACFM)	36,869 ($0.53/ACFM)	85,616 ($1.22/ACFM)

Fabric Filter

Operating and Annualized Costs

Sample Calculations

Formulae for calculating theoretical operating and annualized cost of control were taken from: Edminsten, N.G. and Bunyard, F.L., "A Systematic Procedure for Determining the Cost of Controlling Particulate Emissions from Industrial Sources", JAPCA, V20 N7, p. 446, July, 1970.

I. Fabric Filter Operating Cost:

Case - Teflon Felt at A/C = 5.8/1

$$G = S\left[\frac{0.7457}{6356E}\ PHK + M\right]$$

Where: G = Theoretical Annual Cost for Operation and Maintenance

S = Design Capacity, ACFM

P = Pressure Drop, Inches of Water

E = Fan Efficiency, Assumed to be 60% (Expressed as 0.60)

0.7457 - A Constant, 1 Horsepower = .7457 Kilowatt

H = Annual Operating Time, 6240 Hours (24 Hours/Day X 5 Days/Week X 52 Weeks/Year = 6240 Hours/Year)

K = Power Costs, $/KWH

M = Maintenance Cost, $/ACFM (Based on 25% Bag Replacement Per Year)

In this case:

S = 70,000 ACFM

P = 3.4 Inches of Water

E = 60%

H = 6,240 Hours

K = $0.021/KWH

M = (No. of Bags in House X 25% Replacement Rate X Cost Per Bag) ÷ S

Sample Calculations
(Continued)

$$M = \frac{1080 \text{ Bags X } .25 \text{ X } \$53/\text{Bag}}{70{,}000 \text{ ACFM}} = \$.20443/\text{ACFM}$$

Assuming a 60% fan efficiency reduces the above equation for G to:

$$G = S \quad (195.5 \text{ X } 10^{-6} \text{ PHK} + M)$$

Substituting the figures above yields:

$$G = 70{,}000 \ [(195.5 \text{ X } 10^{-6} \text{ X } 3.4 \text{ X } 6240 \text{ X } 0.021) + 0.20443]$$

$$= 70{,}000 \quad (.08710 + .20443)$$

$$= 70{,}000 \quad (.29153)$$

$$= 20{,}410 \quad \text{(Dollars)}$$

II. Total annualized cost of control is equal to the annual operating cost plus the annualized capital cost.

Annualized Capital Cost = 0.133 X Installed Costs

Assumptions:

1. Purchase and installation costs are depreciated over fifteen (15) years.
2. The straight line method of depreciation (6 2/3% per year) is used.
3. Other costs called capital charges are assumed to be equal to the amount of depreciation. Therefore, depreciation plus other capital charges amount to 13 1/3 percent of the initial capital costs of the equipment.

In this case: Teflon Felt at A/C = 5.8/1

Total Annualized Cost of Control = .133 X Installed Costs + Operating Costs

= (.133 X 153,700) + 20,410

= 40,852 (Dollars)

Electrostatic Precipitator

Operating and Annualized Costs

Sample Calculations

Formulae for calculating theoretical operating and annualized cost of control were taken from: Edminsten, N.G. and Bunyard, F.L., "A Systematic Procedure for Determining the Cost of Controlling Particulate Emissions from Industrial Sources", JAPCA V 20 N 7, p. 446, July, 1970.

I. Flange-to-flange cost for a 99% efficient ESP, sized for 70,000 ACFM was estimated as $215,600 by an ESP manufacturer. Typically, installation costs would be 70% of the flange-to-flange costs so a total "installed" cost would be approximately $366,520.

II. Operating Costs: Case 99% Efficiency

$$G = S\ (JHK + M)$$

Where: G = Theoretical Annual Cost for Operation and Maintenance

S Design Capacity in ACFM

J = Power Consumption (Total Connected Load X Power Factor) in KW/ACFM

H = Annual Operating Time, Hours/Year = 6,240

K = Power Cost ($0.021/KWH in this Case)

M · Maintenance Cost - Moderate Amount of 3% of the Flange-to-Flange Cost ($/ACFM)

$$G = 70,000\ \left(\frac{232}{70,000}\ X\ 6,240\ X\ 0.021 + \frac{0.03\ X\ 215,600}{70,000}\right)$$

$$= 70,000\ (0.4343 + .0924)$$

$$= 70,000\ (0.5267)$$

$$= 36,869\ \text{(Dollars)}$$

III. Total annualized cost of control is equal to the annual operating cost plus the annualized capital cost.

Annualized Capital Cost = 0.133 X Installed Costs

Assumptions:

1. Purchase and installation costs are depreciated over fifteen (15) years.

2. The straight line method of depreciation (6 2/3% per year) is used.

3. Other costs called capital charges are assumed to be equal to the amount of depreciation. Therefore, depreciation plus other capital charges amount to 13 1/3 percent of the initial capital costs of the equipment.

Annualized Capital Costs = 0.133 (366,520) + 36,869

= 85,616 (Dollars)

APPENDIX A-4

Maintenance Procedures
Maintenance Schedule
Spare Parts List

MAINTENANCE PROCEDURES

Inspection and maintenance of bags, dampers, cylinders and actuators can be made without shutting down the collector. A Basic Maintenance schedule follows these procedures in Table A-1.

Switches in the damper control panel allow any individual cell to be removed from the automatic cleaning cycle. By turning the selected cell's toggle switch to the "OFF" position, its damper will remain in the normal open position. By turning the toggle switch to "MANUAL", the damper is moved to its reverse cleaning position. These switches may be utilized even when the automatic cleaning cycle is in operation.

Isolating A Cell

When high negative static pressure inside the baghouse prevents lifting of the hatch cover, turn the selected cell's toggle switch to "MANUAL" and that cell will become pressurized allowing opening of the hatch. Once the cell is open, turn switch to "OFF" position while working in the cell.

Whenever work is to be done inside a cell, a plywood or metal plate should be laid over the bags to:

- Prevent dislodging of the bags from the tube sheet.
- Prevent dropping of tools into the bags.
- Restrict ambient air from back flowing through the bags.

Bag Replacement

When replacing bags while the system remains in operation, it is best to use several boards in the cell so that a minimum of bags are exposed.

Step 1 - Remove Cage and Bag Together

Step 2 - Pull Bag From Cage

Step 3 - Insert Cage Into New Bag

Step 4 - Reinsert Cage

NOTE: - When inserting new bag, make certain snap rings are in place in the tube sheet and a total seal is obtained.
- When reinserting cage, make certain cage reaches the bottom of the bag.

The Cleaning Air System

The shock-drag cleaning system is working properly if (with all dampers closed) the static pressure on the shock-drag plenum manometer reads + 8 - 10" W.G.

NOTE: - The cleaning cycle must be turned "OFF" to make this reading.

If this reading is low, the possible causes are:

- Low air pressure at cylinders (must be 80 psi minimum); if less than 80 psi - check regulator and lines for leakage or freeze-up.
- Broken damper linkage (visually check damper positions).
- Missing damper gasketing (visually check).
- Shock-Drag drive worn (check for belt adjustment).
- Damper obstructed from closing properly.

It is important that the shock-drag system be maintained in proper working order to insure that the pressure drop across the collector is kept within design limits.

Shock Drag Fan and Motor

Check belts for wear and alignment. Check bearing for overheating and lubrication.

Pneumatic Valves and Cylinders

Care must be taken to prevent freezing of the air lines and valves. The air dryer and lubricator must also be maintained regularly or the cleaning air system may not function properly. Check for proper operation of cleaning damper solenoid valves by activating them via manual override.

The Cleaning Control Panel

The cleaning control panel is designed to control the shock-drag cleaning of the bags by controlling the position of the individual cell dampers. A damper's normal position is up, allowing system air to pass and the bags to collect dust. Selectively, one cell at a time, the control panel activates a cell solenoid, which through a pneumatic cylinder moves the cells damper to the down position. This stops the system air flow and allows reverse air to flow into the cell and clean the bags.

Two time delay relays provide variable control over the cleaning time and the time between cleaning. TD1 controls the time a cell is cleaning. TD2 controls the delay time between cells.

Control Panel Operation

Check for proper operation by scanning temperature and pressure gauges for abnormal readings.

Hopper Dump Valve Operation

The double dump valve is checked manually to see that both gates open. Should either one fail to open or close the difficulty lies in one of two possibilities: either a weld or linkage has broken, in which case re-welding would be necessary; or, the shaft supporting plate could be binding due to dirty parts in which case disassembly and cleaning would be necessary.

TABLE A-1

MAINTENANCE SCHEDULE

	DAILY	WEEKLY	BI-WEEKLY	MONTHLY	BI-MONTHLY	AS NECESSARY
DRAIN AIR COMPRESSOR TANKS	X					
ACTIVATE CLEANING DAMPER SOLENOID VALVES VIA MANUAL OVERRIDE TO CHECK FOR PROPER OPERATION			X			
CLEAN MAGNEHELIC LINES						X
CHECK HOPPER DUMP VALVE OPERATION					X	
REPLACE PLOTTER PAPER						X
DATE PLOTTER PAPER	X					
GREASE CLEANING-AIR FANS			X			
CHECK CONTROL PANEL OPERATION	X					
INSPECT HARDWARE AND FITTINGS				X		
CHECK BELT TENSION, CLEANING-AIR AND MAIN FANS				X*		
CHANGE OIL IN AIR COMPRESSORS					X	
VENT AIR FILTERS					X	
CHECK AIR REGULATOR OPERATION				X		
CLEAN CONTROL ROOM WORK AREA	X					

*TWO DAYS AFTER NEW BELTS, NORMAL OPERATION.

SPARE PARTS LIST

This spare parts list is divided into three sections:

SECTION I - Parts located from the boiler stack to the baghouse stack, excluding the control room control panel.

SECTION II - Parts located in the control room control panel.

SECTION III - General parts (locally available).

PARTS, SECTION I	IN STOCK	ORDER
Pneumatic Regulator	X	
Pneumatic Filter Assembly	X	
Pneumatic Pressure Gauge (160 psi)		X
Pneumatic Solenoid (Cat. No. 8342A) 4-2; Volts 110/50 120/60; Pipe 1/4 Orifice 3/16; Pressure Lt. Oil 100; Air Water 125; Serial No. 5 40525 K7)	12	
Pneumatic Air Restricter		X
Limit Switch Assembly	X	
Inlet Damper Actuator Cylinder/ Repair Kit		
Boiler Stack Cap Cylinder		
Burner Control Valve Diaphram		
Burner Spark Plug		
Bleed Air Cylinder/Repair Kit		
Burner Gas Pressure Switches		
Transmissometer, Moisture Absorbing Capsules		
Transmissometer, Air Filters		
Burner, Spark Plug Wire		

PARTS, SECTION I (continued)	IN STOCK	ORDER
Cleaning-Air Fans, Belts		
Cleaning-Air Fans, Sheaves		
Cleaning-Air Fans, Motor		
Double Dump Valves, Cylinder Repair Kit		
Double Dump Valves, Linkage		
System Fan, Belts		
System Fans, Pillot Blocks/Bearing		
Vortex Damper Cylinder, Repair Kit		
Vortex Damper, Positioner		
Air Compressor, Head Gaskets		
Air Compressor, Filter		
Air Compressor, Intercooler Safety Valve		
Cleaning Damper Cylinder, Repair Kit		

PARTS, SECTION II

Part	Manufacturer	Stock No.	In Stock
Aux. Contacts (N.C.)	Cutler Hammer	C320KA2	6
Aux. Contacts (No)	Cutler Hammer		6
Sectional Terminal Block	Cutler Hammer	C381TS	(25) In 1 Box
Type AA Relay	Cutler Hammer	9575H2526-66	1
Type M Relay 4 Pole Attachment	Cutler Hammer	C381EF	3 Face Plates 8 Buchanan
Rear Pole (N.O.)	Cutler Hammer	D26MPR	2
Variable Resistor	Clarostat	A43	2
Adj. Lever	Cutler Hammer	E50KL535	1
Overload Relay, Size 00	Cutler Hammer	A10ANOB	1
Limit Switch	Cutler Hammer	E50AL1	6
Selector Switch 2 Pos., Spr. Rt.	Cutler Hammer	T1371	15
Operator Standard Button	Cutler Hammer	Black T101 Red T102	4 6
Safety Breaker	Cutler Hammer	Ch 130	1
Fuse Clip Kit	Cutler Hammer	C350KE23-6381	1
Std. Indicating Light	Cutler Hammer	10250T185	3
Ill. Pushbutton	Cutler Hammer	10250T471	2

PARTS, SECTION III	IN STOCK	ORDER
Copper Tubing		
Copper Fittings		
Rubber Tubing		
Rubber Clamps		
Fasteners		
Grease Fittings		
Electrical Conduit, Flexible		
Wiring, High Temperature		
Electrical Fuses		
Light Bulbs		
Grease		
Oil		
Piping Cutout Valves		

APPENDIX A-5

Particle Size Distribution (Microns) From
Andersen Tests - Teflon Felt
Gas-to-Cloth Ratio 4.5-6/1

Fractional Loading (Grains/dscf) From
Andersen Tests - Teflon Felt
Gas-to-Cloth Ratio 4.5-6/1
(Nozzle Wash Omitted From Stage 1)

Fractional Loading (Grains/dscf) From
Andersen Tests - Teflon Felt
Gas-to-Cloth Ratio 4.5-6/1
(Nozzle Wash Included in Stage 1)

Particle Size Distribution (Microns) From
Andersen Tests - Gore-Tex (With Some Woven Glass)
Gas-to-Cloth Ratio 4.5-6/1

Fractional Loading (Grains/dscf) From
Andersen Tests - Gore-Tex (With Some Woven Glass)
Gas-to-Cloth Ratio 4.5-6/1
(No Nozzle Wash Recorded)

Table A-2

Particle Size Distribution (Microns) From Andersen Tests
Teflon Felt - Gas-to-Cloth Ratio 4.5-6/1

Run No.	S1	S2	S3	S4	S5	S6	S7	S8	Back-Up
14*	>10.60	7.44	4.58	3.22	2.10	0.97	0.58	0.42	<0.42
15*	> 8.46	5.93	3.64	2.56	1.66	0.76	0.45	0.32	<0.32
16*	>11.63	8.16	5.03	3.54	2.31	1.07	0.65	0.47	<0.47
17*	> 9.61	6.74	4.15	2.91	1.89	0.87	0.52	0.37	<0.37
18*	> 9.55	6.70	4.12	2.90	1.88	0.86	0.51	0.37	<0.37
25	> 9.64	6.76	4.16	2.92	1.90	0.87	0.52	0.38	<0.38
26	> 9.75	6.84	4.21	2.96	1.92	0.88	0.52	0.38	<0.38
27	> 8.87	6.22	3.82	2.68	1.74	0.79	0.47	0.34	<0.34
28	> 8.96	6.28	3.86	2.71	1.76	0.80	0.47	0.34	<0.34
29	> 8.92	6.25	3.84	2.70	1.75	0.80	0.47	0.34	<0.34
33	> 8.77	6.15	3.78	2.65	1.72	0.79	0.47	0.33	<0.33
34	> 8.79	6.16	3.79	2.66	1.73	0.79	0.47	0.34	<0.34
35	> 8.80	6.17	3.80	2.67	1.73	0.79	0.47	0.34	<0.34
Mean	> 9.41	6.60	4.06	2.85	1.85	0.85	0.51	0.36	<0.36

*Nozzle Wash Not Recorded

Table A-3

Fractional Loading (Grains/dscf) From Andersen Tests*
Teflon Felt - Gas-to-Cloth Ratio 4.5-6/1

Run #	S1	S2	S3	S4	S5	S6	S7	S8	Back-Up	Total
14	.00135	.00070	.00064	.00090	.00085	.00074	.00057	.00033	.00082	.00690
15	.00201	.00107	.00115	.00069	.00055	.00038	.00021	.00007	.00015	.00628
16	.00246	.00086	.00098	.00095	.00107	.00074	.00035	.00009	.00064	.00814
17	.00132	.00087	.00138	.00066	.00069	.00048	.00024	.00011	.00023	.00598
18	.00234	.00154	.00141	.00110	.00161	.00066	.00034	.00018	.00027	.00945
25	.00039	.00024	.00052	.00049	.00034	.00029	.00027	.00020	.00017	.00291
26	.00022	.00023	.00037	.00062	.00029	.00031	.00022	.00009	.00013	.00248
27	.00038	.00026	.00031	.00020	.00014	.00015	.00005	.00009	.00019	.00177
28	.00033	.00022	.00029	.00032	.00016	.00018	.00011	.00011	.00009	.00181
29	.00018	.00020	.00029	.00020	.00017	.00016	.00008	.00005	.00005	.00138
33	.00123	.00088	.00101	.00077	.00062	.00041	.00016	.00009	.00023	.00540
34	.00070	.00046	.00064	.00073	.00063	.00041	.00023	.00016	.00024	.00420
35	.00041	.00053	.00075	.00046	.00040	.00038	.00021	.00013	.00015	.00342
Total	.01332	.00806	.00974	.00809	.00752	.00529	.00304	.00170	.00336	.06012
Mean	.00102	.00062	.00075	.00062	.00058	.00041	.00023	.00013	.00026	.00462

*Nozzle Wash Omitted From Stage 1

Table A-4

Fractional Loading (Grains/dscf) from Andersen Tests*
Teflon Felt - Gas-to-Cloth Ratio 4.5-6/1

Run #	S1	S2	S3	S4	S5	S6	S7	S8	Back-Up	Total
25	.06820	.00024	.00052	.00049	.00034	.00029	.00027	.00020	.00017	.07072
26	.00458	.00023	.00037	.00062	.00029	.00031	.00022	.00009	.00013	.00684
27	.03616	.00026	.00031	.00020	.00014	.00015	.00005	.00009	.00019	.03755
28	.01859	.00022	.00029	.00032	.00016	.00018	.00011	.00011	.00009	.02007
29	.02686	.00020	.00029	.00020	.00017	.00016	.00008	.00005	.00005	.02806
33	.05979	.00088	.00101	.00077	.00062	.00041	.00016	.00009	.00023	.06396
34	.04434	.00046	.00064	.00073	.00063	.00041	.00023	.00016	.00024	.04784
35	.07978	.00053	.00076	.00046	.00040	.00038	.00021	.00013	.00015	.08280
Total	.33830	.00302	.00419	.00379	.00275	.00229	.00133	.00092	.00125	.35784
Mean	.04229	.00038	.00052	.00047	.00034	.00029	.00017	.00012	.00016	.04474

*Nozzle Wash Included in Stage 1

Table A-5

Particle Size Distribution (Microns) From Andersen Tests*
Gore-Tex (With Some Woven Glass) - Gas-to-Cloth Ratio 4.5-6/1

Run #	S1	S2	S3	S4	S5	S6	S7	S8	Back-Up
8	>11.42	8.02	4.94	3.48	2.26	1.05	0.63	0.46	<0.46
10	>11.34	7.96	4.90	3.45	2.24	1.04	0.62	0.45	<0.45
19	> 8.54	5.99	3.68	2.58	1.67	0.76	0.45	0.32	<0.32
Mean	>10.43	7.32	4.51	3.17	2.06	0.95	0.57	0.41	<0.41

Table A-6

Fractional Loading (Grains/DSCF) From Andersen Tests*
Gore-Tex (With Some Woven Glass) - Gas-to-Cloth Ratio 4.5-6/1

Run #	S1	S2	S3	S4	S5	S6	S7	S8	Back-Up	Total
8	.00730	.00212	.00213	.00110	.00118	.00125	.00068	.00034	.00064	.01674
10	.00024	.00011	.00008	.00005	.0	.00005	.00006	.00004	.00020	.00083
19	.00157	.00083	.00127	.00074	.00107	.00124	.00133	.00068	.00083	.00956
Total	.00911	.00306	.00348	.00189	.00225	.00254	.00207	.00106	.00167	.02713
Mean	.00304	.00102	.00116	.00063	.00075	.00085	.00069	.00035	.00056	.00905

*Nozzle Wash Omitted From Stage 1

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-600/7-79-094		

4. TITLE AND SUBTITLE	5. REPORT DATE
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15. SUPPLEMENTARY NOTES IERL-RTP project officer is J.H. Turner, MD-61, 919/541-2925.

16. ABSTRACT The report gives results of a full-scale investigation (following a pilot plant study) of applying high-velocity fabric filtration to coal-fired boiler fly ash control. Two filter systems were applied separately to two 60,000 lb steam/hr coal-fired boilers. Performance evaluated over a year included total mass removal efficiency and fractional efficiencies. One filter system used Teflon felt as the filter medium; the other used Gore-Tex, a PTFE laminate on PTFE woven backing. During the year, a limited number of glass felt and woven glass bags were introduced into the house containing Gore-Tex. Installed, operating, and annualized costs were computed for five filter media (Teflon felt, Gore-Tex PTFE laminate, two weights of woven glass, and a felted glass fabric) in a fabric filter systems capable of handling 70,000 acfm. The lighter weight woven glass fabric is the least expensive filter medium overall and (assuming that a 4-year bag life is feasible) this makes fabric filtration an economically attractive alternative to electrostatic precipitation. The 15 oz woven glass fabric had a projected annualized cost of $0.36/acfm at an air-to-cloth ratio of 5.8/1.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Fluorocarbon Fibers	Pollution Control	13B	
Filtration	Glass Fibers	Stationary Sources	07D	11B
Fabrics	Felts	Fabric Filters	11E	
Fly Ash	Woven Fabrics	Bag Houses	21B	
Coal		High Velocity Tests	21D	
Boilers			13A	

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