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Asbestos Emissions from Baghouse Controlled Sources

COLIN F. HARWOOD, Ph.D., DAVID K. OESTREICH*, PAUL SIEBERT and
JOHN D. STOCKHAM

IIT Research Institute, 10 West 35th Street, Chicago, Illinois 60616

There is virtually no information published on the absolute efficiency of baghouses in reducing the emissions of fine particles of asbestos. This lack of information is unfortunate because serious occupational health problems may result from the common practice of recirculating air to conserve energy. Emission testing has been conducted at five asbestos processing plants where the emissions are controlled by baghouses. The results showed that the mass removal efficiency frequently exceeded 99.00%. Membrane filter samples of the effluent were examined by optical and electron microscope. It was observed that despite the high mass efficiency, the number of fibers emitted, which were greater than 1.5 μm in length, was about 10^4 - 10^5 fibers/ m^3 , while the number of fibers less than 1.5 μm was 10^7 - 10^8 fibers/ m^3 . The significance of the size of the fibers in terms of probable health impact is briefly discussed.

Introduction

A RECENT SURVEY of asbestos processing plants revealed that baghouses are by far the most common device for controlling the emissions from these sources.¹ Asbestos has been declared a hazardous pollutant by the EPA, is known to cause asbestosis and is strongly associated with the formation of cancers, particularly mesothelioma. It is surprising, therefore, that a review of the published literature has revealed only one reference to the efficiency of baghouse devices to limit the emission of asbestos fibers. In that paper,² the efficiency was quoted simply as 99.992% on a mass basis and no details were given of the measurement technique used.

This paper details the efficiency testing of baghouses located at five asbestos processing plants. Information was obtained, not only on the mass efficiency of the dust collector, but also on the efficiency as a function of the size of the fiber challenging the filter. Size efficiency was obtained by counting the

number of fibers from a given volume of air by means of optical and electron microscopy. The use of an electron microscope enabled the smallest fibers, as small as 0.02 μm in diameter and 0.06 μm long, to be counted.

The procedure used by the authors is quite different from the OSHA procedure³ which requires that only those fibers longer than 5 μm be measured. At $> 5 \mu\text{m}$, unambiguous measurements by multiple observers may be made using the relatively simple optical microscope with phase contrast at 430X. The occupational health standard is based on information gained on the incidence of asbestosis among those workers occupationally exposed to asbestos at known concentration levels of fibers greater than 5 μm .

The importance of this study in terms of industrial hygiene is that it gives information on the possible consequences of the common practice of recirculating air from the baghouse back into the plant. The relationship between asbestos particle size and the induction of cancer has not yet been established; until such time, it is prudent to quantify the concentration of fibers of all sizes present in plant air.

*EPA Technical Center, Research Triangle Park, North Carolina 27711.

TABLE I
Baghouse Specifications

Feature	Plant				
	1	2	3	4	5
Location	Waukegan, Illinois	Denison, Texas	Marshville, N.C.	Asbestos, Quebec	Eden Mills, Vermont
Product	Asbestos Cement	Asbestos Cement	Asbestos Textiles	Milled Asbestos	Milled Asbestos
Baghouse Make and Model	Parsons Special Design	Wheelabrator Model 26	Wheelabrator Model 112	Wheelabrator Special Design	Wheelabrator Model B-607 Series VIII
Baghouse Capacity $\text{m}^3 \text{min}^{-1}$ (cfm)	1,132 (40,000)	736 (26,000)	473 (16,000)	127,000 (4,500,000)	8,490 (300,000)
Air to Cloth Ratio cfm:ft ²	2.0:1	2.6:1	3.0:1	3.0:0	3.2:1
Number of Compartments	4	1	1	11	8
Total Number of Bags	800	784	304	79,200	2,688
Bag Size					
Diameter, cm	12.7 (5")	12.7 (5")	20.3 (8")	12.7 (5")	20.3 (8")
Length, m	3.05 (10")	3.18 (10'5")	2.82 (9'3")	4.27 (14')	5.33 (17'6")
Bag Permeability cfm:ft ² at 0.5" H ₂ O	15 $\pm$ 5	15 $\pm$ 5	15 $\pm$ 5	25	16-20
Bag Construction					
Material	Cotton	Cotton	Cotton	Cotton	Cotton
Weave	Sateen	Sateen	Sateen	Sateen	Sateen
Thread Count	—	96 x 60	—	—	96 x 60
Pressure Drop In H ₂ O	6	5.7	2.2	3	4
Cleaning Cycle	Mechanical Shake	Mechanical Shake	Mechanical Shake	Mechanical Shake	Mechanical Shake

Experimental

Plant Location

Five different plant locations were selected for study. The basis for the selection was the nature of the asbestos processing category which they represented. They included: two asbestos ore refining mills, two asbestos cement product plants (where the asbestos fibers can be considered to be bound into the product), and an asbestos

textile plant (where the asbestos fibers can be considered as loosely bound). In all the locations, chrysotile asbestos was used exclusively.

Baghouse emission control devices were used at all the locations, and details of the baghouse construction and operation are summarized in Table I. These installations are typical of good, accepted modern practice in the industry. Recirculation was practiced at three of the five locations in order to con-

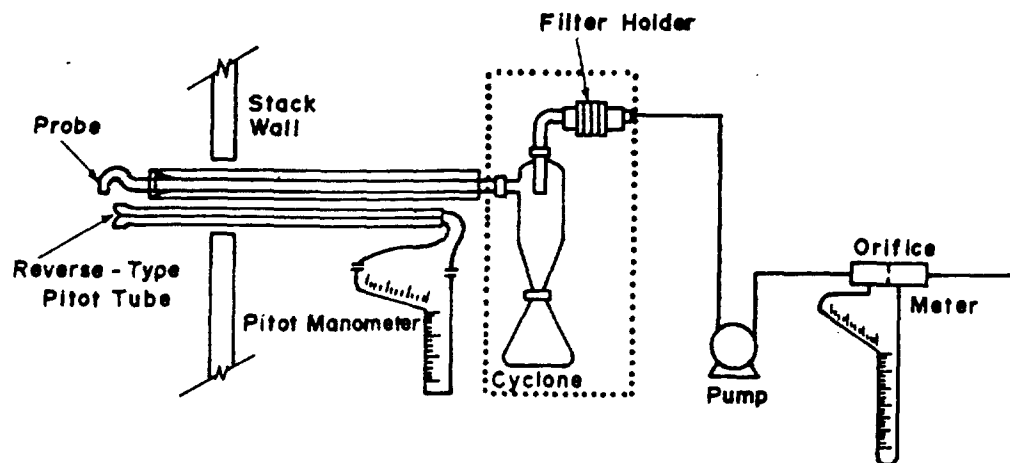


Figure 1. Sampling arrangement.

serve heat during the winter months.

Sampling Procedure

Sampling was conducted using, where possible, the EPA procedure detailed in the December 23, 1971, Federal Register, 36, 247. Two standard, EPA Method 5, isokinetic sampling systems as shown in Figure 1 were utilized to allow simultaneous sampling both upstream and downstream of the baghouse. The sampling probes and nozzles were fabricated from stainless steel. The probes had an I.D. of 1.27 cm (0.5 in.) and a length of 107 cm (42 in.), and the nozzles were 0.63 cm (0.25 in.) I.D.

Sampling points in the duct work were selected in regions where the most stable flow patterns existed. The ports were located, where possible, eight to ten diameters upstream from any bends, elbows, junctions, or other constrictions in the stack or duct.

In some instances, it was not possible to collect samples by the isokinetic sampling method. This was because of physical limitations in the plant design which made such points inaccessible, or because of the close proximity of accessible sections to fans or bends. Here, high volume samplers fitted with 20 cm x 25 cm (8 x 10 in.) membrane filters were used within the baghouse close

to the exit.

On the upstream side of the baghouse, samples were drawn through a cyclone followed by a 10 cm (4 in.) membrane filter of 0.8 μ m pore size. On the downstream side, no cyclone was used: the air stream was led directly to the membrane filter. After sampling, the filter was placed in a marked plastic folder. Material adhering to the inside of the probes and tubes was washed into a sample collector using acetone. The collector was then marked and sealed.

Sample Analysis

The mass collection efficiency was determined by accurately weighing the samples collected before and after the baghouse. The filters were weighed on an electronic balance having a sensitivity of ± 0.1 mg. On the upstream side, the dust deposited in the probe, the sampling train, and cyclone was washed with water into a weighing bottle. It was then dried in a vacuum oven at 110°C, cooled and reweighed. From these weights, the mass efficiency was calculated.

Fiber Counting

Optical microscope analysis was performed using the method described in the NIOSH criteria document on asbestos.⁵ A

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Eden Mills, Vermont
Milled Asbestos
Wheelabrator Model B-607 Series VIII

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3.2:1

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2,688

20.3 (8")
5.33 (17'6")

16-20

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portion of the membrane filter, approximately 1 centimeter square, was removed from the central part of the filter and mounted on a slide. Using a 1:1 solution of dimethyl phthalate and diethyl oxalate, the filter was allowed to clear. A clean cover slip was placed on top of the sample and the fiber concentration determined. The light microscope used was equipped with phase-contrast and polarized light. The objective lens of 4 mm resulted in a total magnification of 500X. From randomly chosen fields, the number of fields for a total count of 100 fibers was noted (with a minimum of 20 fields observed), or 100 fields were observed when the distribution was sparse.

For the electron microscope analysis, a circle of the sample filter 3.5 mm in diameter was cut. This piece of filter was placed on top of a carbon-coated 100 mesh electron microscope grid. The grid with the filter on it was placed in a condensation washer using acetone as a solvent. The filter medium was dissolved away by the acetone, depositing the fibers of the sample undisturbed on the carbon substrate of the grid. The specimen was then counted on a Hitachi HU-11 transmission electron microscope at a magnification of 16,364X.

The optical microscope analysis enumerated the fibers greater than 1.5 μm in length and a minimum diameter of 0.5 μm . The

electron microscope analysis counted fibers down to 0.06 μm in length and 0.020 μm in diameter.

Calculation of Fiber Numbers

To relate the number of fibers to the asbestos concentration in the air, the following equation was used:

$$\frac{\text{no. of fibers}}{\text{m}^3 \text{ of air}} = \left[\frac{\text{no. of fibers counted}}{\text{no. of fields}} \right] \times \left[\frac{\text{effective filter area, cm}^2}{\text{area of microscope's field of view, cm}^2} \right] \times \left[\text{volume of air sampled, m}^3 \right]^{-1}$$

where:

Effective filter area = 81.7 cm^2 for 4 in. filter in EPA train

Effective filter area = 63.2 cm^2 for 4 in. Hi-Vol filter

Effective filter area = 425.4 cm^2 for 8" x 10" Hi-Vol filter

Area of field of view = $6.514 \times 10^{-4} \text{ cm}^2$ for optical microscope (500X)

Area of field of view = $1.344 \times 10^{-7} \text{ cm}^2$ for electron microscope (16,364X)

Efficiency Calculation

To calculate the efficiencies, both by mass and by number, the following relationships were used:

Mass Efficiency (%) =

$$100 \left[1 - \frac{\text{Mass in a given volume of air after the baghouse}}{\text{Mass in the same volume of air before the baghouse}} \right]$$

Number Efficiency (%) =

$$100 \left[1 - \frac{\text{No. of fibers per cubic meter after the baghouse}}{\text{No. of fibers per cubic meter before the baghouse}} \right]$$

Results

Mass Removal Efficiency

The mass efficiencies of the five baghouses are given in Table II. It is observed that the efficiency is extremely high and, in all instances, exceeded 99.99%. At two locations,

the mass collected on the upstream side of the filter was too small to be weighed, although a faint coloration of the otherwise pure white filter could be observed.

Fiber Removal Efficiency

In Table III, the number of fibers up-

TABLE II
Mass Removal Efficiencies for Baghouse Controlled Asbestos
Emission Sources at Five Plant Locations

Plant Location	Sampling Location	Volume of Air Samples (m ³)	Total Mass of Dust Collected (g)	Concentration of Dust Collected (g. m ⁻³)	Mass Removal Efficiency (%)
Waukegan, Illinois	Upstream	1.755	7.6092	4.336	100.0 (within experimental limits)
	Downstream	12.984	0.0000	0.000	
Marshville, N.C.	Upstream	2.765	1.5894	0.5748	> 99.99
	Downstream	6.404	0.0002	3.120 x 10 ⁻⁵	
Denison, Texas	Upstream	4.183	53.9653	12.901	100.0 (within experimental limits)
	Downstream	195.0 ⁽¹⁾	0.0000	0.000	
Asbestos, Quebec	Upstream	0.0014	0.1648	117.7	> 99.99
	Downstream	101.8 ⁽¹⁾	0.0103	1.011 x 10 ⁻⁴	
Eden Mills, Vermont	Upstream	3.085	17.9220	5.809	> 99.99
	Downstream	143.0 ⁽¹⁾	0.0084	5.874 x 10 ⁻⁵	

Note: All samples taken isokinetically by EPA Method 5 except those marked (1), which were taken by hi-vol sampler.

TABLE III
Upstream and Downstream Fiber Concentrations and Removal Efficiencies for
Baghouse Controlled Asbestos Emission Sources at five Plant Locations

Plant Location	Sampling Location	Fibers Counted by Optical Microscope at a Magnification of 500X		Fibers Counted by Electron Microscope at a Magnification of 16,364X	
		Fibers per Cubic Meter	Removal Efficiency %	Fibers per Cubic Meter	Removal Efficiency %
Waukegan, Illinois	Upstream	> 10 ¹⁰	> 99.99	> 10 ¹⁴	> 99.99
	Downstream	6.4 x 10 ³		1.1 x 10 ⁷	
Marshville, N.C.	Upstream	8.1 x 10 ⁸	> 99.99	2.5 x 10 ¹¹	98.69
	Downstream	1.4 x 10 ⁴		3.3 x 10 ⁹	
Denison, Texas	Upstream	1.0 x 10 ⁶	97.18	3.2 x 10 ⁷	57.90
	Downstream	2.9 x 10 ⁴		1.4 x 10 ⁷	
Asbestos, Quebec	Upstream	2.2 x 10 ⁹	99.96	1.2 x 10 ¹²	99.88
	Downstream	8.2 x 10 ⁵		1.4 x 10 ⁹	
Eden Mills, Vermont	Upstream	1.4 x 10 ⁹	> 99.99	1.4 x 10 ¹³	> 99.99
	Downstream	4.5 x 10 ⁴		1.3 x 10 ⁸	

TABLE IV
The Number of Fibers Exiting from Five Baghouse Controlled Asbestos Emission Sources
as Counted by Optical and Electron Microscopes

Plant Location	Number of Fibers Exiting Greater than 1.5 μm weight		Number of Fibers Exiting Greater than 0.06 μm length	
	Concentration Fibers m^{-3}	Number per Minute	Concentration Fibers m^{-3}	Number per Minute
Waukegan, Illinois	6.4×10^3	7.2×10^8	1.1×10^7	1.2×10^{10}
Marshville, N.C.	1.4×10^4	1.0×10^9	3.3×10^9	2.4×10^{11}
Denison, Texas	2.9×10^4	1.4×10^9	1.4×10^7	6.6×10^9
Asbestos, Quebec	8.3×10^5	1.1×10^{11}	1.4×10^9	1.8×10^{14}
Eden Mills, Vermont	4.5×10^4	3.8×10^7	1.3×10^8	1.1×10^{11}

stream and downstream of the five baghouses are presented. In general terms, the number of fibers greater than 1.5 μm in length exiting from the baghouse is of the order of 10^4 fibers per cubic meter, while the number of fibers greater than 0.06 μm in length is of the order of 10^8 fibers per cubic meter. A similar ratio is found in the number of fibers approaching the baghouse, where 10^9 and 10^{13} fibers per cubic meter of greater than 1.5 μm and greater than 0.06 μm are found, respectively.

Very high removal efficiencies are found in all instances. Based on the available data, it does not appear that the removal efficiencies are size dependent. Similar efficiencies are found with the greater than 1.5 μm fibers and the greater than 0.06 μm fibers. One exception to the very high efficiency values occurred at Denison. At this location, high grain loadings were observed in the upstream duct, and it is possible that partial blockage of the probe prevented fibers from reaching the filter. The number of fibers on the downstream side was comparable to the other locations.

Despite very high collection efficiencies, very large numbers of fibers were found to

exit from the baghouse. This is shown in Table IV, where the total number of fibers exiting per minute and their concentration in the air stream has been tabulated for each plant location.

Discussion

The Recirculation of Cleaned Air

The result of a survey taken as part of this study has revealed that the recirculation of air exhausted from baghouses used to clean asbestos dust from air is common practice in the industry. The American Conference of Governmental Industrial Hygienists has the responsibility through the Ventilation Committee of publishing a Manual of Recommended Practice, which establishes the governmental recommendations as regards the recirculation of air within a plant. These recommendations are considered and cited in the standard of the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor.

The recent energy crisis has occasioned a need to conserve heat as a national policy. Prior to this, regulations prohibited the recirculation of plant air containing hazardous materials even though recirculation was eco-

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nomically attractive. This regulation was predicated upon the premise that no control device is foolproof. A temporary loss in control efficiency would create considerable risk of exposure of workers to dangerous levels of toxic materials.

The impact of the energy crisis has led the ventilation committee to propose circumstances which would allow the recirculation of cleaned air, provided certain criteria were met by the system. A formula has been proposed which would establish the limits of contaminant concentration in the exiting air;

$$C_R = \frac{1}{2} (TLV - C_o) \times \frac{Q_T}{Q_R} \times \frac{1}{K}$$

where

C_R = maximum permitted concentration of contaminant in exit air from the collection after cleaning, in any consistent units

TLV = threshold limit value of contaminant

C_o = concentration of contaminant in workers breathing zone with local exhaust discharged outside

Q_T = total ventilation flow through affected space, cfm

Q_R = recirculated air flow, cfm

K = an "effectiveness of mixing" factor, usually varying from 3 to 10

It should be remembered that this equation has only been proposed, not accepted, at this stage. For asbestos, the TLV value would be that presently accepted as the OSHA standard, that is, 2 fibers per cubic centimeter (where a fiber is greater than 5 μ m and with an aspect ratio of greater than 3:1 length to breadth). As has been shown, only a small portion of the true asbestos concentration in the recirculated air is accounted for by this standard.

Two methods are proposed that would increase the safety of such a system and guard against a temporary breakdown in the collection efficiency. One is that a back-up filter should be fitted to remove the contaminant in the event of a failure of the primary con-

trol. The application of such a system would obviously add considerably to the costs. The second method would be to use a monitor which would stop the recirculation, or activate a rapid acting by-pass to the outside air, in the event of a failure of the collector. The problem would be to produce a monitor for asbestos which would be fast acting and modest in cost. At the present time, no such monitoring device exists for asbestos, despite considerable research effort to achieve this objective.⁴

Exposure Levels for Asbestos

The present accepted standard for asbestos exposure has been determined by OSHA to be 2 fibers per cubic centimeter, for fibers longer than 5 μ m. The measurement method and the rationale behind this exposure level is well presented in the NIOSH document "Occupational Exposure to Asbestos".⁵

The selection of the size of 5 μ m as the shortest size of the fibers which are counted stems from British practice.⁶ The British use this criteria for two reasons. Firstly, it represents that size which is readily detectable using a relatively simple optical microscope, while detection for smaller fibers and particularly submicron fibers requires the use of an electron microscope, which is both time-consuming and costly to use. Secondly, a wide body of information on the exposure levels and incidence of asbestosis has been generated over many years using the 5 μ m size limit in establishing the exposure levels. Thus, the use of the optical microscope gives an *index* of exposure which has had wide practical applicability.

The problem with using this index is that the ratio of the numbers of fibers greater than 5 μ m in length to those less than 5 μ m in length is very much a function of the industry. Thus, textile-producing industries have a greater proportion of longer fibers than, for example, those industries using asbestos as a filler in plastics or paints.

The fiber size considered to be most dangerous is not established at this time. Evi-

dence in the literature on this subject is confusing and reveals the uncertainty. Stanton⁷ has performed experiments that have indicated that fibers, including fibers of materials other than asbestos but having a similar morphology (e.g., alumina), in the size range of 10-100 μm are most harmful, and that their ability to produce tumors decreases with decreasing length. However, his findings have been criticized because of the method of application. The method required that 40 g of the powdered asbestos be placed in contact with the pleura and held in place by a fiber glass patch attached surgically. Thus, the normal free movement of the particles was prevented. This work might also be criticized from the standpoint that, in all probability, the larger fibers do not find their way through the human body defense mechanisms.

Pott,⁸ on the other hand, has performed experiments using asbestos dry milled to a fine size. Two size groups were used, one with 95% of the fibers less than 5 μm , and a second with 99% of the fibers less than 3 μm (with 93% less than 1 μm). The size was checked by electron microscopy, which also showed that the fibrous structure had been retained through the grinding process. It was found that with both groups, tumors developed in 40% of the rats after intraperitoneal injection of the asbestos. However, the small sized fibers required a longer incubation period than the larger fibers (about 20 months versus 12 months) to achieve the 40% tumor level.

A further important point when discussing the exposure index for asbestos is that it is based on the probability of a worker contracting asbestosis, not cancer. With the present exposure levels, the probability of a worker getting asbestosis is 1% if a 30 year working life in the industry is pursued. There is no definitive information on the chances of developing a cancer. Recognition of the carcinogenic aspect of asbestos is comparatively recent, and it is estimated that, in humans, a 30 year incubation period is required

before the cancer develops. Therefore, there are no adequate dose records upon which to relate the delayed response.

Reasonable scientific predictions are made based on animal experiments but, because of the massive doses used to accelerate the incubation period, there is justifiable doubt as to the conclusions reached. Again, a degree of susceptibility may be required within an individual such that a small dose might be fatal to him, while a much larger dose would leave a second person unaffected.

It is apparent from the literature that there are many unanswered questions about the danger associated with asbestos. Until the answers to these questions are more clearly understood, asbestos should be treated with caution.

Conclusions

Baghouses used for the control of asbestos emissions have been shown to operate at very high efficiencies on both a mass basis and on a number of fibers basis. Even with these high efficiencies, there are substantial numbers of fibers which penetrate the fabric filter. Recirculated air may contain enough fibers to be of concern from the standpoint of cancer induction but the dose/response relationship between asbestos exposure and cancer is not well understood. There is certainly, a possibility that a human health penalty could off-set the economic advantages of recirculation.

If bag failure results while recirculation is being practiced, the probability of undesirable health effects could be expected to increase substantially. It is recommended that a rapid-acting detection system be developed which would activate a by-pass system in the event of a bag failure.

It has been shown that recirculated air contains well below the current Threshold Limiting Value of 2 fibers per cubic centimeter (fibers equal to or greater than 5 μm in length). This would imply that workers would be protected from asbestosis unless the bags were to fail.

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The help and cooperation of Johns-Manville, Raybestos, and GAF in performing these studies is gratefully acknowledged. The help of Erdmann Lubecke, Tom Blaszkak, Dr. Ranade, Anant Somudra, and David Becker of the IITRI staff is also acknowledged.

George D. Clayton & Associates Renamed Clayton Environmental Consultants, Inc.

Now a Marsh & McLennan company, Clayton will deliver technical and professional services to clients on a uniform international basis.

Founder George D. Clayton will serve as chairman, based in Fallbrook, California. Alonzo C. Rand is president and Truman F. Maxwell has been appointed operations manager at Southfield.

Founded in 1954, Clayton's environmental control programs service industry and government in the areas of air, water, noise, radiation, food and drug, industrial hygiene, agricultural chemistry and solid waste pollution. Robert D. Soule heads industrial hygiene activities.

Stern Becomes President of Air Pollution Control Association

Dr. Arthur C. Stern now is president of the APCA. An international authority on air pollution control technology, Dr. Stern is Professor, Department of Environmental Sciences and Engineering, University of North Carolina, Chapel Hill, NC.

October Meeting to Feature Fabric Filtration Equipment

The Niagra Frontier Section of the Air Pollution Control Association will conduct a 2nd international specialty meeting on "The User and Fabric Filtration Equipment" at the Statler Hilton in Buffalo, NY. Dates are October 6-7, 1975.

The conference is said to be aimed at the user, with emphasis on the baghouse process. Theory, methods, systems and case histories will be explored. Leading manufacturers will exhibit fabric filtration equipment.

For information, contact I. Arthur Hoekstra, Air Pollution Control Division, Erie County Dept. of Environmental Quality, 95 Franklin St., Buffalo, NY 14202 (716) 846-7762.