OBSERVATIONAL STUDY OF FINAL CLEANING AND AHERA CLEARANCE SAMPLING AT ASBESTOS-ABATEMENT SITES IN NEW JERSEY

by

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FOREWORD

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The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

This report provides information on final cleaning procedures, visual inspections, and Asbestos Hazard Emergency Response Act (AHERA) clearance sampling practices observed at 20 asbestos-abatement projects in New Jersey. It provides matrices that cross-reference case history information on final cleaning procedures, visual inspection, and AHERA clearance practices at these sites.

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ABSTRACT

A study was conducted during the summer of 1988 to document final cleaning procedures and evaluate Asbestos Hazard Emergency Response Act (AHERA) clearance air-sampling practices used at 20 asbestos-abatement sites in New Jersey. Each abatement took place in a school building and involved removal of surfacing material, thermal system insulation, or suspended ceiling tiles. Final cleaning practices tend to be similar among abatement contractors. Meticulous attention to detail in cleaning practices is important to a successful final cleaning. Sites passing a stringent "no-dust" criterion of a thorough visual inspection are more likely to pass the AHERA transmission electron microscopy clearance test. AHERA sampling and analytical requirements and recommendations are not completely understood and followed by consultants conducting clearance air monitoring. Matrices are provided that cross-reference case history information on final cleaning procedures, visual inspections, and AHERA clearance practices at these sites.

This report was submitted in fulfillment of Contract No. 68-03-4006 by PEI Associates, Inc. for the U.S. Environmental Protection Agency's Risk Reduction Engineering Laboratory. This report covers a period of January 1988 to June 1989 and work was completed as of June 30, 1989.

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SECTION 1

INTRODUCTION

BACKGROUND

As required under the Asbestos Hazard Emergency Response Act (AHERA) of 1986, the U.S. Environmental Protection Agency (EPA) has issued a final rule regarding inspections, abatement, and management of asbestos-containing materials in schools (October 30, 1987; 52 CFR 41826). The final rule specifies a clearance sampling protocol for determining when an asbestos-abatement site is clean enough for the critical containment barriers to be removed. It further specifies the phase-in of transmission electron microscopy (TEM) as the analytical method to be used on air samples taken for clearance monitoring.

The final cleaning phase of an abatement project is paramount to achieving a successful abatement as defined in the AHERA final rule. Final cleaning applies to the phase of the abatement project that occurs after all visible asbestos-containing material has been removed from the substrate; the substrate has been brushed and wet-wiped; a sealant has been applied to the substrate and to plastic sheeting covering the floors, walls, and fixed objects to "lock-down" any invisible fibrils that might remain; and all plastic sheeting (excluding the critical containment barriers) has been removed. The final cleaning phase of the abatement involves the detailed cleaning of surfaces in preparation for final visual inspection and AHERA clearance sampling.

OBJECTIVES

The Risk Reduction Engineering Laboratory (RREL) of the EPA conducted a study to document final cleaning procedures and practices used at different asbestos-abatement projects. The study also evaluated AHERA clearance sampling practices used at these abatement sites.

This case history report presents the observations made at 20 asbestos-abatement projects in New Jersey during the summer of 1988. It includes matrices that cross-reference case history information on final cleaning procedures, visual inspections, and AHERA clearance practices at these sites.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The following are the principal conclusions reached during this study:

1) Final cleaning practices tend to be similar among abatement contractors. The sequence of cleaning activities depends on the surface from which the asbestos was removed and the physical structure of the work site. Meticulous attention to detail in cleaning practices is important to a successful final cleaning.

2) HEPA-filtration units used under normal operating conditions at asbestos abatement sites tend to perform below the manufacturer's nominal airflow. The average operating airflow ranged from 50 to 80 percent of the rated nominal airflow for 93 units representing seven model types.

3) Sites passing a stringent, "no-dust" criterion of a thorough visual inspection are more likely to pass the AHERA TEM clearance test. Thirty-three percent of the sites that passed only the Asbestos Safety Technician (AST) visual inspection, and were not subsequently inspected by the New Jersey Department of Health (NJDOH), passed AHERA TEM clearance on the first attempt. Ninety-three percent of the sites that passed a more thorough visual inspection by the NJDOH passed AHERA TEM clearance on the first attempt.

4) The initial AHERA Clearance Screening Test requiring an average asbestos concentration below 70 structures per square millimeter (s/mm^2) is achievable in many cases, thereby eliminating the need to employ the AHERA Z-test. All 18 sites cleared by TEM passed the prescreening AHERA TEM clearance criterion of 70 s/mm^2.

5) AHERA sampling and analytical requirements and recommendations are not completely understood and followed by consultants conducting clearance air monitoring. The following clearance air sampling and analytical techniques were observed:

   - Fewer than the required five clearance air samples inside the abatement area were collected at two sites.

- Improper sampling media was used to collect clearance air samples, i.e., filter pore size at three sites and filter type at two sites.

- Recommended air sampling flow rates were exceeded at two sites.

- Phase contrast microscopy was improperly used to clear one site.

- Eight of the 20 abatement sites failed to meet the EPA-recommended drying time of 24 hours after completing final cleaning and before conducting final clearance air monitoring.

- Nineteen of the 20 abatement sites used aggressive air sampling techniques. Fourteen of these 19 sites failed to meet the EPA-recommended aggressive air sweeping rate of at least 5 minutes per 1000 square feet of floor area.

- Fifteen of the 20 abatement sites failed to use the number of circulating fans recommended by AHERA during final clearance air monitoring. No circulating fans were used at eight of the sites.

RECOMMENDATIONS

Based on the conclusions outlined above, it is recommended that guidance documents be developed which address the following topics:

1) Procedures for visual inspections. This study suggests that work sites passing a stringent visual inspection are less likely to fail the clearance test and incur the expense of multiple rounds of sampling and analysis. Guidance for performing a thorough visual inspection would benefit both the building owner and abatement contractor.

2) Procedures and protocols of AHERA air monitoring. Improper final clearance air monitoring resulted partly from a lack of understanding of AHERA air monitoring procedures. The contractors expressed concern that the EPA-recommended protocols were in different documents, making it difficult to completely understand the current protocols. The contractors and AST's recommended that a guidance document be prepared that contained the procedures and protocols for proper AHERA clearance air monitoring.

3) Operation of HEPA filtration units. No specific guidance has been issued regarding the fundamental operating principles of these units (e.g., decreased airflow performance with increased static pressure due to filter loading and the addition of manifolds, flexible ductwork, etc.). Guidance for maximizing the operating airflow performance of air-filtration units used at asbestos abatement sites is needed.

SECTION 3

STUDY DESIGN AND METHODS

SITE SELECTION

Although selection of the 20 asbestos-abatement projects was based largely on availability, each site also met the following criteria:

1) Each abatement project was in a school building.

2) The abatement project involved a) removal of sprayed- or troweled-on surfacing material; b) removal of thermal system insulation of mechanical equipment (i.e., boilers, tanks, heat exchangers, pipes, etc.); or c) removal of suspended ceiling panels.

3) The abatement project was governed by written specifications that were to comply with the minimum requirements of the State of New Jersey, Asbestos Hazard Abatement Subcode (N.J.A.C. 5:23-8) and EPA guidance[1] for work practices and procedures to be used in performing asbestos-abatement projects.

4) The abatement project was to be cleared in accordance with the sampling protocol specified in the AHERA final rule (October 30, 1987; 52 CFR 41826).

SITE DOCUMENTATION

Appendix A contains the site documentation form that was used to document the following information for each abatement project:

1) The abatement area's use (classroom, corridor, boiler room, etc.) and dimensions.

2) The type (acoustical plaster, ceiling panels, pipe insulation, etc.) and quantity (square feet or linear feet) of asbestos-containing material (ACM) abated, and type and percentage of asbestos in the ACM.

3) Final cleaning procedures and work practices.

4) Performance of negative-pressure air filtration systems including the static pressure differential across critical containment barriers and the airflow of each air filtration unit.

5) Results of final visual inspections conducted by the asbestos safety technician and/or inspector from the Asbestos Control Service (ACS) of the New Jersey Department of Health, including reasons why the visual inspection failed.

The background information describing the abatement area, the ACM abated, and other miscellaneous information was obtained by interviewing at each site an asbestos safety technician (AST) certified by the New Jersey Department of Community Affairs and employed by an Asbestos Safety Control Monitor (ASCM) firm. The ASCM is employed by the School District or Local Education Agency. The AST continuously monitors and inspects the asbestos abatement project in accordance with the Asbestos Hazard Abatement Subcode (N.J.A.C. 5:23-8). The AST must be on the job site continuously during the abatement project to assure that the work is performed in accordance with the regulations specified in the Asbestos Hazard Abatement Subcode.

Appendix B contains the site documentation form that was used to document the AHERA clearance practices used at each site. This information included:

1) Conditions of sampling, i.e., aggressive versus nonaggressive sampling, use of fans to maintain air turbulence during clearance air sampling, etc.

2) Air sampling methods, i.e., filter medium, cassette type, flow rate, etc.

3) Performance of negative-pressure air filtration systems, including the static pressure differential across critical containment barriers and the airflow performance of each air filtration unit.

In addition to the information gathered on the site documentation forms (Appendix A and B), the following three documents were obtained for each site:

1) Technical specification for the abatement project.

2) The ACS inspector's report on the final visual inspection(s).

3) The AST's project report on the onsite supervision and AHERA clearance air monitoring.

AIRFLOW AND STATIC PRESSURE DIFFERENTIAL

The airflow performance of the air filtration units operating during both the final cleaning and AHERA clearance phases of the abatement was measured. The air velocity of the rectangular air-intake face of each air filtration unit was measured to estimate the airflow performance of the units. The air-intake face was divided into 16 equal rectangular areas (Appendix A), and the velocity was measured at the center of each area.[2] The greatest distance between centers was approximately 6 inches. The air velocity was measured with a calibrated, constant-temperature, thermal anemometer (Kurz Series 440 Air Velocity Meter). This instrument was calibrated with a National Bureau of Standards (NBS) traceable mass flow meter and associated equipment. This calibration device is traceable to NBS, Test Numbers 2.6/167716 A and B and 232.09/209.275.B. The air velocities (feet per minute) were converted to volumetric flow rate (cubic feet per minute) to estimate the operating airflow performance of each air filtration unit.

The static pressure differential across the critical containment barriers was measured at each site during both the final cleaning and AHERA clearance phases of the abatement. Generally, two locations were tested: one near the decontamination unit and one at a location farthest away from the decontamination unit. The static pressure differential (inches of water) was measured with a calibrated, electronic, digital micromanometer (Neotronics Model Type EPM 201).

QUALITY ASSURANCE OF AHERA CLEARANCE DATA

Clearance of each abatement site was based on the analyses of the final clearance air samples collected by the AST. The analyses were obtained from the laboratory report contained in the final project report prepared by the ASCM firm. The analysis of the samples and the corresponding quality control and quality assurance procedures were specified by the contract with the performing analytical laboratory to be conducted in accordance with the requirements in the AHERA final rule.

The conditions of sampling and the sampling procedures used by the AST were documented for comparison with the requirements specified in the AHERA final rule. The information was recorded on the site documentation form in Appendix B.

SECTION 4

RESULTS AND DISCUSSION

SITE DESCRIPTIONS

Table 1 presents a site description for the 20 asbestos-abatement projects evaluated. Sixteen of the abatement projects involved general occupancy areas (classrooms, offices, recreational rooms, corridors, etc.); three involved boiler rooms and mechanical equipment rooms; and one involved both types of areas. The ACM abated at 13 of the project sites involved surfacing material (acoustical plaster or fireproofing), 8 involved thermal system insulation on mechanical equipment (pipes and boilers), 3 involved both surfacing material and thermal system insulation, and 2 involved suspended ceiling tiles. The ACM contained chrysotile asbestos (from 2 to 93 percent) at 17 projects, amosite asbestos (from 2 to 10 percent) at 2 projects, and both chrysotile (from 10 to 75 percent) and amosite (from 30 to 40 percent) at 1 project.

The projects involved 11 abatement contractors, eight ASCM firms, and five analytical laboratories (Table 2). A single abatement contractor, ASCM firm, or analytical laboratory was involved in a maximum of 5, 6, or 12 projects, respectively.

VENTILATION AND STATIC PRESSURE DIFFERENTIALS

High-efficiency particulate air (HEPA) filtration systems serve as the primary engineering control for the removal of asbestos particulate from airstreams in active abatement areas. The HEPA units draw contaminated air from the abatement area and exhaust the filtered air to an exterior area, usually outside the building. This constant exhausting of large volumes of air from within the abatement area at a rate higher than that of the makeup air supplied to the abatement area creates a negative-pressure condition relative to surrounding areas, which ensures that any air leakage is inward.

Current EPA guidance[1] on work practices and procedures recommends the use of enough HEPA-filtration units to remove a volume of air equivalent to the work area volume at least four times per hour (i.e., four air changes per hour). This recommended air exchange rate is based on engineering judgment. Current OSHA regulations require the exhausting of a sufficient amount of air to create a pressure of -0.02 inch of water within the abatement area with respect to the area outside the enclosure.[3]

TABLE 1. SITE DESCRIPTION FOR 20 ASBESTOS-ABATEMENT PROJECTS

Site	Type of ACM[a]	Abatement area	Approximate quantity of ACM	Type and percent asbestos	
				Chrysotile	Amosite
A	Acoustical plaster	General occupancy[b]	19,100 ft^2	5 - 10	
B	Acoustical plaster	General occupancy	5,400 ft^2	2 - 6	
C	Pipe/boiler insulation	General occupancy and boiler room	QNS[c]	40 - 60	
D	Acoustical plaster	Boiler and mechanical equipment rooms	QNS	20 - 35	
	Boiler insulation	Boiler room	QNS	40 - 60	
E	Ceiling panels	General occupancy	1,500 ft^2		2 - 8
F	Pipe/boiler insulation	Boiler room	2,200 ft^2	30 - 40	
G	Boiler insulation	Boiler room	QNS	10 - 75	30 - 40
H	Acoustical plaster	General occupancy	21,000 ft^2	25 - 50	
	Pipe insulation	General occupancy	100 ft	40 - 60	
I	Acoustical plaster	General occupancy	5,100 ft^2	5 - 25	
J	Fireproofing	Mechanical equipment room	5,300 ft^2	10 - 25	
K	Acoustical plaster	General occupancy	8,200 ft^2	10 - 25	
L	Acoustical plaster	General occupancy	1,600 ft^2	15 - 25	
M	Pipe insulation	General occupancy	QNS	40 - 60	
N	Acoustical plaster	General occupancy	11,000 ft^2	10 - 25	
O	Ceiling tiles	General occupancy	2,100 ft^2		5 - 10
P	Acoustical plaster	General occupancy	8,500 ft^2	91 - 93	
	Pipe insulation	General occupancy	1,600 ft^2	24 - 60	
Q	Acoustical plaster	General occupancy	5,400 ft^2	2 - 6	
R	Pipe insulation	General occupancy	2,900 ft	10 - 25	
S	Acoustical plaster	General occupancy	7,200 ft^2	10 - 20	
T	Acoustical plaster	General occupancy	4,100 ft^2	10 - 25	

[a] ACM = Asbestos-containing material.

[b] General occupancy areas include classrooms, offices, recreational rooms corridors, etc.

[c] QNS = *Quantity of ACM not specified.*

TABLE 2. ABATEMENT CONTRACTORS, ASCM FIRMS, AND ANALYTICAL LABORATORIES USED AT THE 20 ASBESTOS-ABATEMENT PROJECTS

	Abatement contractor											ASCM firm								Laboratory				
Site	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6	7	8	1	2	3	4	5
A	X											X								X				
B		X											X								X			
C			X											X							X			
D			X											X							X			
E				X											X							X		
F	X														X							X		
G					X											X							X	
H			X											X							X			
I						X									X							X		
J							X										X							X
K								X										X			X			
L									X						X							X		
M			X											X							X			
N								X										X			X			
O	X													X							X			
P										X				X							X			
Q		X											X								X			
R	X																		X		X			
S	X																	X			X			
T											X					X							X	
Total	5	2	4	1	1	1	1	2	1	1	1	1	2	6	4	2	1	3	1	1	12	4	2	1

Air-intake volumes for each HEPA-filtration unit in operation during final cleaning and AHERA clearance sampling were measured at each of the 20 sites in this study. Seven different models were observed and evaluated. The average operating airflow for each model was compared with the manufacturer's nominal airflow, i.e., the manufacturer's advertised rated peak capacity. Actual average operating airflow ranged from 50 to 80 percent of the nominal airflow for these models. This reduction in airflow performance is comparable to another study which showed a 50 to 60 percent reduction in airflow capacity.[4] Figure 1 illustrates the actual average operating airflow as a percentage of nominal airflow for the seven observed models. The reduced airflow performance of the filtration units is probably due to the increased static pressure associated with extended and obstructed exhaust duct conditions and to increased particulate loadings on the filters. The significance of this reduced operating flow rate is in the procedure used to determine the number of air-filtration units necessary to achieve the desired minimum ventilation rate (i.e., four air changes per hour). Assuming the air-filtration units are operating at the manufacturer's specified nominal airflow rate could result in actual ventilation rates significantly below project design specifications.

Despite the lower-than-assumed ventilation rates of the observed HEPA-filtration units, enough units were used at all but one site to achieve a minimum of four air exchanges per hour during AHERA clearance sampling. Also, only two sites failed to meet the recommended air-exchange rate during final cleaning. Figure 2 shows the air-exchange rates during final cleaning and AHERA clearance sampling at each of the sites. Actual air-exchange rates ranged from 2 to 13 per hour during final cleaning and 3 to 13 per hour during AHERA clearance sampling.

Static pressure differential across the containment barriers was measured at one or more test locations at each of the 20 abatement sites during both final cleaning and AHERA clearance sampling. Eight of the 20 sites showed an average static pressure differential of at least -0.02 inch of water during final cleaning. Nine sites showed an average pressure differential of at least -0.02 inch of water during AHERA clearance sampling. The average static pressure differential for all sites ranged from -0.03 to -0.01 inch of water during both final cleaning and AHERA clearance sampling. Table 3 summarizes the average pressure differentials during final cleaning and AHERA clearance sampling at each site.

Continuous monitoring of the static pressure differential across the containment barriers was conducted at only one site. Ventilation smoke tubes were typically used at the beginning of each work shift at all abatement sites to verify visually that the containment enclosure remained under negative pressure (i.e., a noticeable inward movement of air existed through the decontamination facility).

At all of the observed abatement sites, the HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility or the waste load-out port. An interconnected flexible duct was used to vent the exhaust air directly outdoors through windows in the work area or through windows in areas outside the abatement

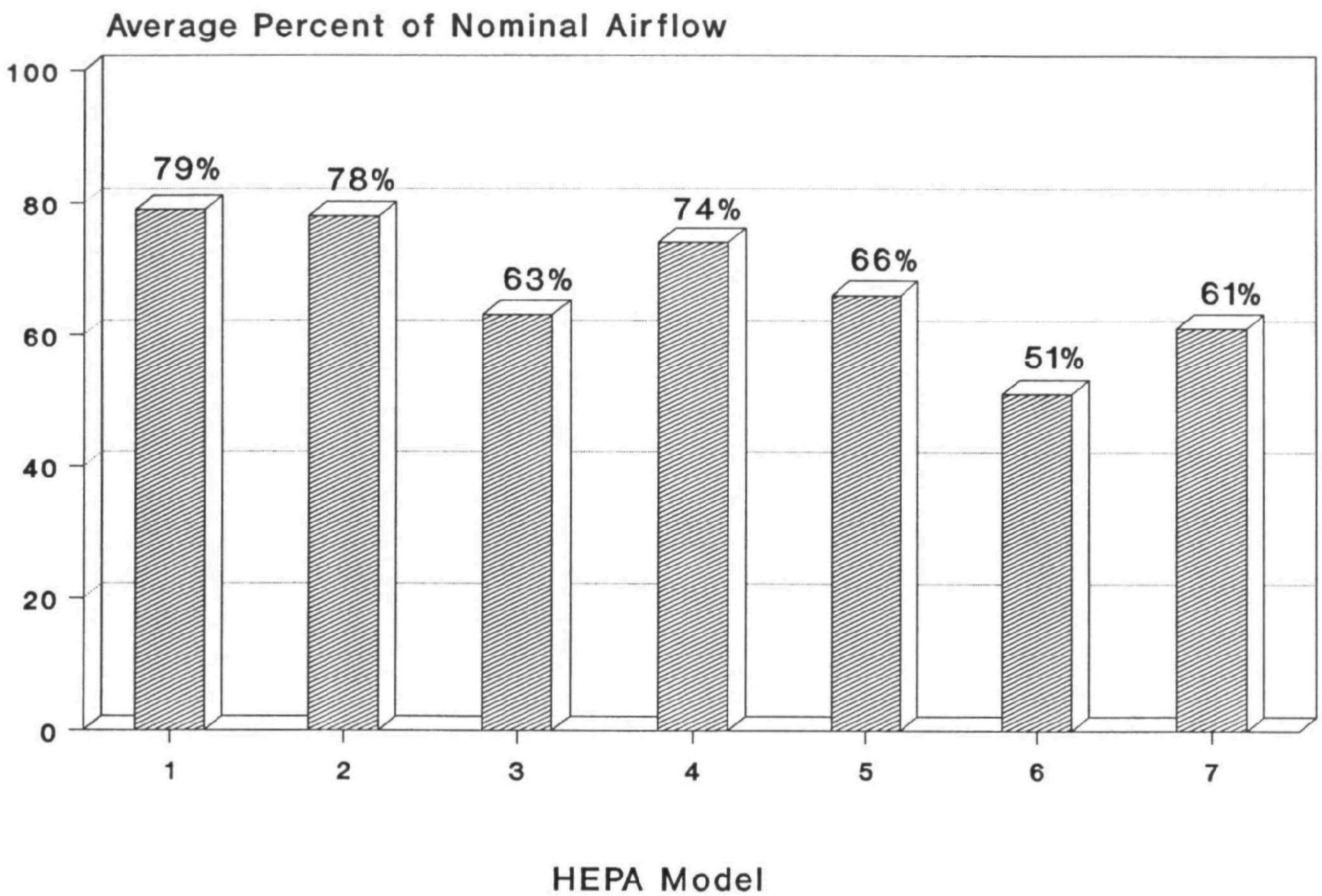

Figure 1. Airflow performance of HEPA filtration systems.

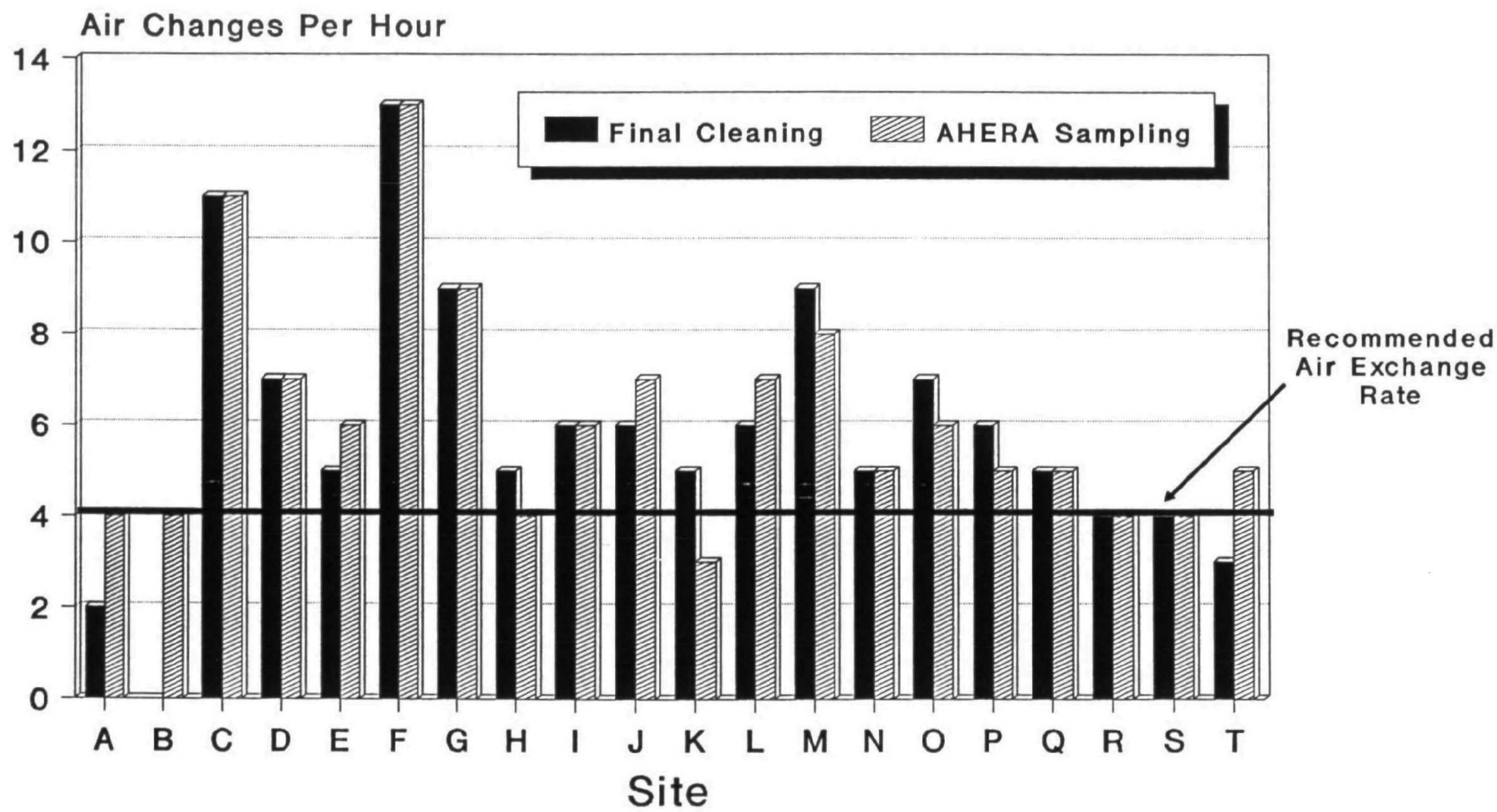

Figure 2. Air exchange rates in the abatement area at 20 asbestos abatement sites during final cleaning and AHERA clearance sampling.

TABLE 3. STATIC PRESSURE DIFFERENTIALS DURING FINAL CLEANING AND AHERA CLEARANCE SAMPLING

Site	Final cleaning	AHERA clearance sampling
A	-0.010	-0.023
B	-0.020	-0.020
C	-0.010	-0.015
D	-0.015	-0.020
E	-0.013	-0.010
F	-0.020	-0.020
G	-0.010	-0.010
H	-0.013	-0.015
I	-0.023	-0.023
J	-0.020	-0.010
K	-0.020	-0.010
L	-0.010	-0.010
M	-0.020	-0.015
N	-0.010	-0.010
O	-0.020	-0.020
P	-0.025	-0.020
Q	-0.010	-0.010
R	-0.015	-0.020
S	-0.015	-0.020
T	-0.015	-0.025

area. At five sites, it was noted that torn ductwork passed through areas outside and adjacent to the work site before being vented outdoors. This damaged ductwork allowed a percentage of the exhaust air to be distributed to adjacent building areas, which could have contaminated the perimeter areas of the abatement site.

Each asbestos-abatement contractor was responsible for maintaining the HEPA-filtration units. Prefilters, secondary filters, and HEPA filters were changed periodically during the abatement efforts. Table 4 summarizes the frequency of filter maintenance on each HEPA-filtration unit during the abatement activity. Generally, the prefilters and secondary filters were changed when they became visibly dirty. At several sites, the prefilters were changed only once a day. The HEPA filters were generally changed either when an audible alarm was actuated (indicating that minimum air was passing through the filters) or when a set length of time had elapsed, per manufacturer's specifications.

FINAL CLEANING WORK PROCEDURES AND PRACTICES

Upon completion of the abatement process, the work area must be cleaned in preparation for its restoration to normal use. Various work procedures and practices are used. The ultimate purpose of each is to ensure that postabatement concentrations of asbestos fibers are at or below the concentrations present before the abatement work began and that they are in compliance with the final clearance requirements under the AHERA final rule.

In this study, final cleaning began at each project site after the encapsulated plastic sheeting was removed from the walls, floors, and fixed objects. The critical barriers, windows, doors, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The air-filtration units remained in service.

Table 5 presents a matrix of the final cleaning procedures and work practices used at the 20 asbestos-abatement sites. At two abatement sites (Sites E and J), aggressive cleaning techniques were used. Aggressive cleaning involves sweeping the surfaces with the exhaust from a hand-held 1-horsepower leaf blower to dislodge any residual debris, and then allowing the airborne particulate to settle. Aggressive cleaning was conducted at Site E before the site was recleaned after it had failed the first AHERA clearance attempt; and at Site J after the walls and other surfaces had been sprayed with water and allowed to dry and hard-to-reach areas such as indented corners, crevices around doors and windows, etc., had been cleaned with a vacuum equipped with a HEPA filter.

Final cleaning was organized so the workers at 16 of the sites began in the areas farthest from the personnel decontamination facility and worked toward it. The opposite work direction was observed at the remaining four sites. No association appeared to exist between work direction and the location of the air-filtration units.

TABLE 4. FILTER MAINTENANCE SUMMARY AT 20 ASBESTOS-ABATEMENT PROJECTS

Abatement phase	HEPA system maintenance	Abatement site																			
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Beginning of project	Changed HEPA filter							X			X	X	X	X	X	X	X	X	X	X	X
Prior to final cleaning	Changed prefilter	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Changed secondary filter	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Changed HEPA filter	X	X	X	X	X	X	X	X	X											
During abatement	Prefilter changed daily							X	X					X		X	X	X			X
	Prefilter changed when visibly dirty	X	X	X	X	X	X			X	X	X	X		X				X	X	
	Secondary filter changed daily												X								
	Secondary filter changed when visibly dirty	X	X	X	X		X	X	X		X	X		X	X	X	X	X	X	X	X
	Secondary filter changed after each workshift									X											
	Secondary filter changed every 48 hours					X															
	HEPA filter changed when alarm activated	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
	HEPA filter changed per manufacturer's specifications	X	X	X	X	X	X	X	X	X				X		X				X	

TABLE 5. FINAL CLEANING WORK PRACTICES AND PROCEDURES MATRIX

Final cleaning practices and procedures	Abatement site and sequence of final cleaning[a]																				
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	Total
Worked toward decontamination facility	X	X			X	X			X	X	X	X	X	X	X	X	X	X	X	X	16
Worked away from decontamination facility			X	X			X	X													4
Aggressive cleaning "air sweeping" surfaces					X					X											2
Spraying of surfaces with amended water															2						1
Spraying of surfaces with water	1			1		1	3	1		1				2	2	1	3			1	11
Wire-brushing of abated surfaces			1				1						1	1							4
Scraping, brushing ceiling-wall intersections		1							1			1					1		1		5
HEPA-vacuuming of corners, crevices, floorwall intersections	2	2	2	2			2	2	2	2	1	2	2	3	1		2	2	2		16
Wet-wiping of horizontal and vertical surfaces																					
° Cotton rags dampened with amended water	3	3		3			4			3	2			4	3	3	4	3	3	2	13
° Paper bath towels dampened with amended water			3		1	2		3				3	3								6
° Sponge dampened with amended water									3												1
Dry sweeping of floors									3												1
Wet mopping of floors with amended water	4	4	4	4	2	3	5	4	4	4	3	4	4	5	4	4	5	4	4	3	20
Removing plastic sheeting from air-filtration units and associated exhaust ducts	5														5			5	5		4
Wet mopping of floors with amended water a second time	6	5		5	3		6	5	5	5		5	5	6	6			6			13
Wet-wiping and/or HEPA-vacuuming of designated areas based on AST's visual inspection	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	18
Wastewater and disposable cleaning materials placed in double-layer 6-mil-thick plastic bags	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	20
Wet-wiped asbestos-disposal bags before removing from abatement area																					0
Miscellaneous observations																					
° Cleaning water beneath vinyl floor tiles	X															X					2
° Use of agent to gel wastewater												X									1

[a] Number denotes sequence of final cleaning.

The sequence and nature of the cleaning tasks seemed to depend on the substrate from which the ACM was removed (e.g., concrete ceiling versus a T-bar grid system for suspended ceiling tiles) or on the physical structure (i.e., concrete walls, wood floor in a gymnasium, etc.) of the abatement area. Final cleaning usually began with the spraying of the walls, plastic critical containment barriers, and other surfaces with a water mist to remove any loosely bound debris. The resultant asbestos-containing water on the floor was gathered into pools by use of a rubber squeegee or (less frequently) with push-type brooms. The bulk of the pooled water was scooped up with plastic-bladed shovels. The water was placed in double-layered, 6-mil-thick, asbestos-disposal bags, which generally contained plastic that had been removed from the walls and floors or protective clothing that had been used by the workers. The residual water removed with a wet vacuum was also placed in the disposal bags. At one site, the wastewater in the disposal bags was solidified with a gelling compound to minimize the potential for its subsequent release during storage.

At two sites, some of the wash water penetrated the seams between the floor tiles and caused them to buckle. These buckled floor tiles were sporadically distributed throughout the abatement areas. At both sites, the asbestos-containing water beneath the floor tiles was allowed to dry, and the tiles were not repaired as part of the abatement. These areas could be potential sources of airborne asbestos fibers when repaired later by maintenance personnel.

Although to a lesser extent than the spraying of surfaces with water, some final cleaning began with the scraping or brushing of the substrate to remove any visible debris.

The surfaces, particularly hard-to-reach areas such as indented corners, crevices around doors and windows, floor-wall junctions, etc., were then cleaned with a HEPA-filtered vacuum. At several sites, final cleaning began with the HEPA-vacuuming of surfaces.

The vertical and horizontal surfaces were then wet-wiped with amended water. The contractors reportedly prepared the amended water solution by mixing approximately 1 or 2 ounces each of 50 percent polyoxyethlyene ester and 50 percent polyoxyethylene ether in 5 gallons of water.

The elevated horizontal and vertical surfaces were usually wiped first, and then all the other surfaces. All the surfaces except the floors were wiped with cotton rags, paper towels (bath size), or a sponge dampened with amended water. Several abatement contractors said they did not use cotton rags or sponges because their repeated use increased the potential for smearing residual particulate on the surfaces being cleaned. Although the paper towels were sometimes reused, such reuse appeared to be markedly less than that observed for cotton rags or sponges at other sites. Deterioration appeared to be the primary factor that prompted a worker to discard a paper towel. A bucket of amended water was either used by a single worker or shared by several workers and the same bucket was used for both rinsing and dampening of the rags or paper towels. The workers did not wipe the surfaces in any one direction. The cotton rags, paper towels, or sponges were not replaced frequently, especially during the cleaning of elevated and hard-to-access surfaces. Nor was the amended water changed frequently.

After the walls, windows, and other surfaces had been wet-wiped, the last step in the final cleaning involved a complete mopping of the floors with a clean mop head wetted with amended water. The floors were mopped once at 7 of the sites and twice at 13 of the sites. The mop heads were changed infrequently. No changes in the water were observed during this procedure at any of the sites.

Before the floors were mopped a second time at four of the sites, the plastic sheeting covering the air-filtration units and a plastic sleeve that covered the associated flexible exhaust ducts were removed. Both coverings had been installed before abatement work began. According to the contractors, this practice simplified the cleaning of this equipment, particularly the flexible exhaust ducts.

At all sites, wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered, 6-mil-thick, standard asbestos disposal bags. These standard asbestos disposal bags containing wastewater were not placed in leak-tight containers. The wastewater in the disposal bags was solidified with a gelling compound at 1 of the 20 abatement sites. The rags, paper towels, sponges, mop heads, and other materials used during final cleaning were also placed in these bags. The bags were not generally wet-wiped with amended water before being removed from the abatement area.

Final cleaning practices tended to be similar among abatement contractors. The sequence of cleaning activities depended on the surfaces from which the asbestos was removed and the physical structure of the work site. Meticulous attention to detail in cleaning practices is important to a successful final cleaning.

Upon completing final cleaning, the abatement contractor immediately requested a final visual inspection by an onsite AST. The AST conducted the visual inspection within 1 to 2 hours after notification. The AST identified areas that required further cleaning at 18 of the 20 sites. Further cleaning typically involved the vacuuming or wet-cleaning of those areas failed by the AST.

FINAL VISUAL INSPECTION

Final visual inspection involves examining the abatement area for evidence that the remedial actions have been successfully completed, as indicated by the absence of residue, dust, and debris.[1,5] The basic premise of a final visual inspection is that an area where residue or debris visible to the unaided eye is still present is not clean enough for clearance air sampling.

Final Visual Inspection by AST's

Upon completion of final cleaning, a final visual inspection was conducted at each of the 20 abatement sites by an onsite AST. Two of the 20 sites passed the first visual inspection, and 18 of the 20 sites required and passed a second visual inspection.

Final Visual Inspection by NJDOH's ACS

The New Jersey Department of Health's Asbestos Control Service (ACS) conducted final visual inspections at 15 of the 20 abatement projects. These included Sites A through C, H through I, and K through T. This inspection is a part of the State's traditional quality assurance program which provides a check and balance to asbestos abatement, ensuring that high-quality abatement and state-of-the art work practices are used.

The ACS inspector first visually examined all substrate surfaces to ensure that no ACM remained. Special attention was given to pipes, structural members, ceiling tile grid bars, and irregular surfaces with corners and hard-to-reach areas. If any quantity of ACM remained, the site failed the visual inspection and additional removal work was performed before another visual inspection was conducted.

The ACS inspector then determined if the work site had been adequately cleaned. All surfaces were examined for dust and debris, especially overhead areas (such as tops of suspended light fixtures and ventilation ducts) and areas under stationary fixtures. One or both of the following techniques were used for examining surfaces to establish that a "no dust" criterion had been achieved:

1) Using a damp cloth to collect dust from the surface and then inspecting the cloth for evidence of dust.

2) Darkening the room and shining a flashlight so that the light beam just glances across any smooth horizontal or vertical surface. A gloved finger is then run across the illuminated area; if a line is left on the surface, dust is still present.

If either of these techniques showed that dust still remained, the ACS inspector recommended recleaning of the work area before its reinspection. If debris was found, the ACS inspector collected bulk or wipe samples of the debris and submitted them for analysis by the New Jersey Department of Health's Public Health and Environmental Laboratories in Trenton, New Jersey.

From one to seven visual inspections were conducted at each abatement site. Figure 3 shows the percentage of sites that passed the visual inspection per given attempt. The largest percentage of sites (33.5%) passed the visual inspection on the second attempt. The cumulative percentages of sites passing the visual inspection were as follows: 40 percent by the first and second attempts, 66.7 percent by the third attempt, and 93.4 percent by the fourth attempt.

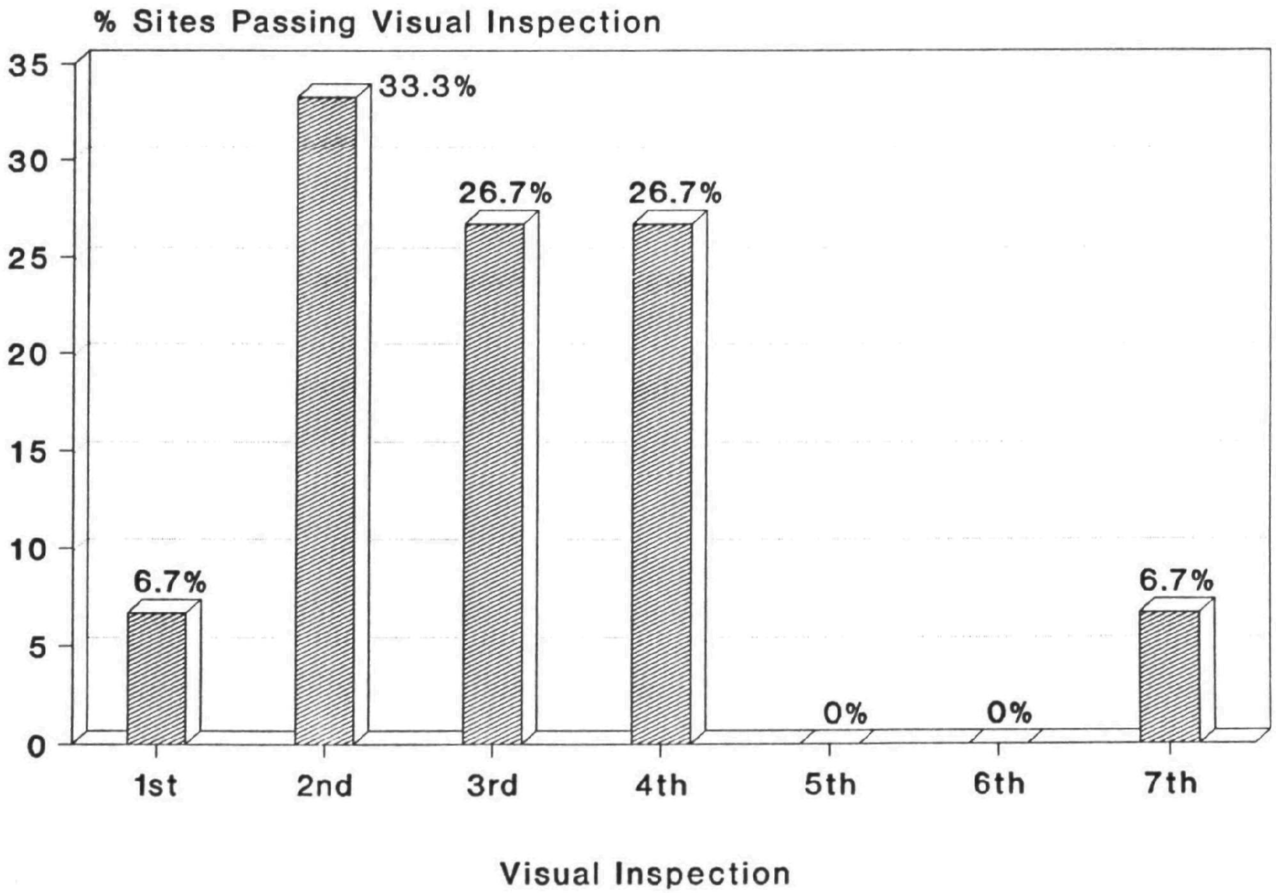

Figure 3. Percentage of 15 sites passing the ACS's visual inspection for each attempt.

Table 6 lists the reasons why sites failed the ACS inspectors' visual inspections at 15 sites. Fourteen of the 15 sites failed visual inspection for more than one reason. The most commonly identified reason (cited at 8 of the 15 sites) was the presence of debris on pipes, pipe fittings, and hangers. The next most common reason was debris on floors, on horizontal surfaces, and in wall-penetrations. Table 6 also lists 23 other less commonly reported reasons for failing the visual inspection.

Table 7 presents the asbestos analysis of 81 bulk samples collected by the ACS inspectors to determine the asbestos content of debris found during the visual inspections. Asbestos was present in approximately 90 percent (73 of 81) of these samples.

All 20 abatement sites passed an onsite AST visual inspection according to each AST requirement. Fifteen of the 20 sites were subsequently inspected by the NJDOH's ACS inspectors. Only one site passed the first visual inspection. Observation of inspection practices and procedures showed that the ACS inspectors conducted a more stringent and thorough visual inspection.

AHERA CLEARANCE PRACTICES

The asbestos abatement industry is halfway into its second year since the Asbestos Hazard Emergency Response Act (AHERA) Final Rule (40 CFR Part 763) went into full effect in December 1987. The final rule describes the sampling and analytical protocols to be used in determining whether an abatement activity is complete and the site is clean enough for reoccupancy. Airborne asbestos concentrations inside the abatement area must be statistically no larger than concentrations outside the abatement area ("outside" means outside the abatement area, not necessarily outside the building) before the contractor is released. The rule also describes an initial prescreening test that does not compare the concentrations inside the abatement area with those outside. This prescreening test is permitted to save analysis costs when airborne asbestos concentrations are so low they cannot be distinguished from background filter contamination.

AHERA PROTOCOLS

Specific air sampling protocols require the collection of 13 samples--5 samples inside the abatement area, 5 samples outside the abatement area (but not necessarily outside the building), 2 field blanks, and 1 sealed blank. Air samples are to be collected after the site has passed a thorough visual inspection and the area has been aggressively swept to dislodge any remaining dust. Before air monitoring is begun, floors, walls, and ceilings must be swept with the exhaust of a leaf blower having a minimum of 1 horsepower. Stationary fans should be used to provide continuous air circulation--one fan for each 10,000 cubic feet of workspace. Air samples must be collected on either 0.4-micrometer (µm) (or smaller) pore-size polycarbonate or 0.45-µm (or smaller) pore-size mixed cellulose ester membrane filters. Each filter should be mounted on a 5-µm pore-size mixed cellulose ester diffusing filter and cellulose support pad and contained in a three-piece cassette. An

TABLE 6. REASONS FOR FAILING NJDOH VISUAL INSPECTIONS AT 15 ASBESTOS-ABATEMENT PROJECTS

Reasons for failing NJDOH visual inspection	Abatement site A	B	C	H	I	K	L	M	N	O	P	Q	R	S	T	Total
Debris in horizontal surfaces	X	X	X			X							X	X		6
Debris in vertical surfaces						X										1
Debris in light fixtures					X						X	X		X	X	5
Debris in wall penetrations	X							X			X	X	X		X	6
Debris in floors		X			X			X	X				X	X	X	7
Debris at floor-wall junctions		X		X		X			X	X						5
Debris at ceiling-wall junctions		X			X						X	X			X	5
Debris in pipes, pipe fittings, pipe hangers			X	X		X		X		X	X		X		X	8
Debris in walls	X				X				X						X	4
Debris on skylights	X													X		2
Debris on windows	X	X										X				3
Debris on structural beams		X										X				2
Debris in electrical wires/fixtures				X	X									X		3
Debris in storage closets		X										X				2
Debris in shelves						X								X		2
Debris on scaffolding equipment/auxiliary equipment		X				X	X									3
Debris in ventilation ducts				X									X			2
Debris in clocks		X														1
Debris in exit sign														X		1
Debris in blackboards		X														1
Debris on heating units				X												1
Debris in ceiling gridwork										X						1
Debris on door jambs												X				1
Debris on counters														X		1
Debris behind lockers														X		1
Debris behind floor molding															X	1
Debris in immovable objects						X										1

extension cowl or retainer ring is also recommended. Air pump flow rates between 1 and 10 liters per minute should be used for 25-mm cassettes.

TABLE 7. ASBESTOS ANALYSIS OF BULK SAMPLES COLLECTED BY ACS INSPECTORS DURING THE FINAL VISUAL INSPECTIONS

Site	Number of samples	
	Collected	Containing asbestos
A	6	6
B	4	4
C	4	4
H	0	0
I	7	5
K	11	6
L	1	1
M	5	5
N	0	0
O	0	0
P	0	0
Q	0	0
R	33	32
S	7	7
T	3	3
Total	81	73

In most cases air-monitoring samples must be analyzed by transmission electron microscopy (TEM). Laboratories may choose between either the mandatory or nonmandatory TEM methods described in the AHERA final rule. The nonmandatory method supplements the mandatory method by including additional steps to improve the analysis. Under certain circumstances, a site may be cleared by phase contrast microscopy (PCM) analysis of samples depending on the size and nature of the abatement project.

The initial prescreening clearance test permits the five samples collected inside the abatement area to be analyzed and the site cleared if 1) at least 1199 liters of air are pulled through a 25-mm filter or 2799 liters of air are pulled through a 37-mm filter, and 2) the arithmetic mean concentration of these five samples is less than or equal to 70 s/mm². Otherwise, the five samples collected outside the abatement area must be analyzed and compared with the samples collected inside the work area by use of a Z-Test. The Z-Test is carried out by the following calculation:

$$Z = \frac{\bar{Y}_i - \bar{Y}_o}{0.8(1/n_i + 1/n_o)^{1/2}}$$

where $\bar{Y}_i$ = the average of the natural log of the inside samples

$\bar{Y}_o$ = the average of the natural log of the outside samples

n_i = the number of samples collected inside the work area

n_o = the number of samples collected outside the work area

If the Z statistic is less than or equal to 1.65, the site passes the clearance test and the site is considered clean enough for reoccupancy. If the abatement site does not satisfy either the prescreening test or the Z-Test, it must be recleaned and a new set of samples collected.

OBSERVED PRACTICES

Aggressive Sampling

Prior to postabatement clearance air monitoring, a 24-hour drying time is recommended.[1] Air monitoring for postabatement clearance should be conducted under aggressive sampling conditions. The abatement area floors, walls, ledges, ceilings, and other surfaces should be swept with the exhaust from forced-air equipment (e.g., a minimum 1-horsepower leaf blower) to dislodge any remaining dust, and stationary fans should be used to keep fibers suspended during sampling. Current guidance on asbestos-abatement work practices and procedures recommends aggressive sweeping of the abatement area for a minimum of 5 minutes per 1000 ft^2 of floor area.[5] The AHERA rule recommends the use of at least one stationary fan per 10,000 ft^3 of workspace to keep the asbestos fibers suspended during sampling.

Eight of the 20 abatement sites failed to meet the EPA-recommended drying time of 24 hours after the completion of final cleaning before final clearance air monitoring was begun. The drying times for these eight sites ranged from 2 to 18 hours.

Nineteen of the 20 observed abatement sites used aggressive sampling techniques. Fourteen of these 19 sites failed to meet the recommended aggressive air-sweeping rate of at least 5 minutes per 1000 ft^2 of floor area. Table 8 presents actual and recommended aggressive sampling times for each observed site. Figure 4 shows the actual aggressive sampling rates per 1000 ft^2 of floor area for each of the 20 sites.

Only 12 of the 20 sites used stationary air fans to maintain a constant air movement during clearance air sampling. Box-type fans were used at nine of these sites, and pedestal-type fans were used at three sites. Fifteen of the observed sites failed to use the number of fans per given volume of workspace required by AHERA. The actual and required number of circulating fans for each site are presented in Table 8 and shown graphically in Figure 5.

TABLE 8. CLEARANCE SAMPLING AND ANALYTICAL PRACTICES OBSERVED AT 20 ASBESTOS-ABATEMENT SITES

Site	Clearance sampling			Aggressive air sweeping		Circulating fans		Analytical method[d]
	Flow rate, liters/min	Filter type[a]	Pore size	Actual duration[b]	Recommended duration	No. used	No. recommended[c]	
A	7-19	MCE	0.8	25	96	0	28	TEM
B	≤10	MCE	0.8	20	27	5	5	TEM
C	≤10	MCE	0.45	30	8	0	3	TEM
D	≤10	MCE	0.45	20	16	0	4	TEM
E	≤10	PC	0.4	30	75	6	17	TEM
F	≤10	PC	0.4	4	3	1	1	PCM
G	≤10	PC	0.4	0	10	2	2	TEM
H	≤10	MCE	0.45	30	30	0	10	TEM
I	≤10	PC	0.4	15	26	0	4	TEM
J	≤10	PC	0.4	20	27	4	8	PCM
K	≤10	MCE	0.8	20	42	4	12	TEM
L	≤10	MCE	0.45	10	8	0	28	TEM
M	9.3	MCE	0.45	60	16	2	4	TEM
N	9.5	MCE	0.45	13	55	0	3	TEM
O	≤10	MCE	0.45	34	22	2	7	TEM
P	≤10	MCE	0.45	30	43	4	4	TEM
Q	≤10	MCE	0.45	20	27	0	8	TEM
R	11-12	MCE	0.45	7	118	5	5	TEM
S	≤10	MCE	0.45	28	37	4	15	TEM
T	8	PC	0.4	15	21	4	6	TEM

[a] MCE = mixed cellulose ester; PC = polycarbonate; all filters were contained in three-piece cassettes with 50-mm extension cowls.

[b] Reported in minutes.

[c] Based on one fan per 10,000 ft^3 of work space.

[d] TEM = transmission electron microscopy; PCM = phase contrast microscopy.

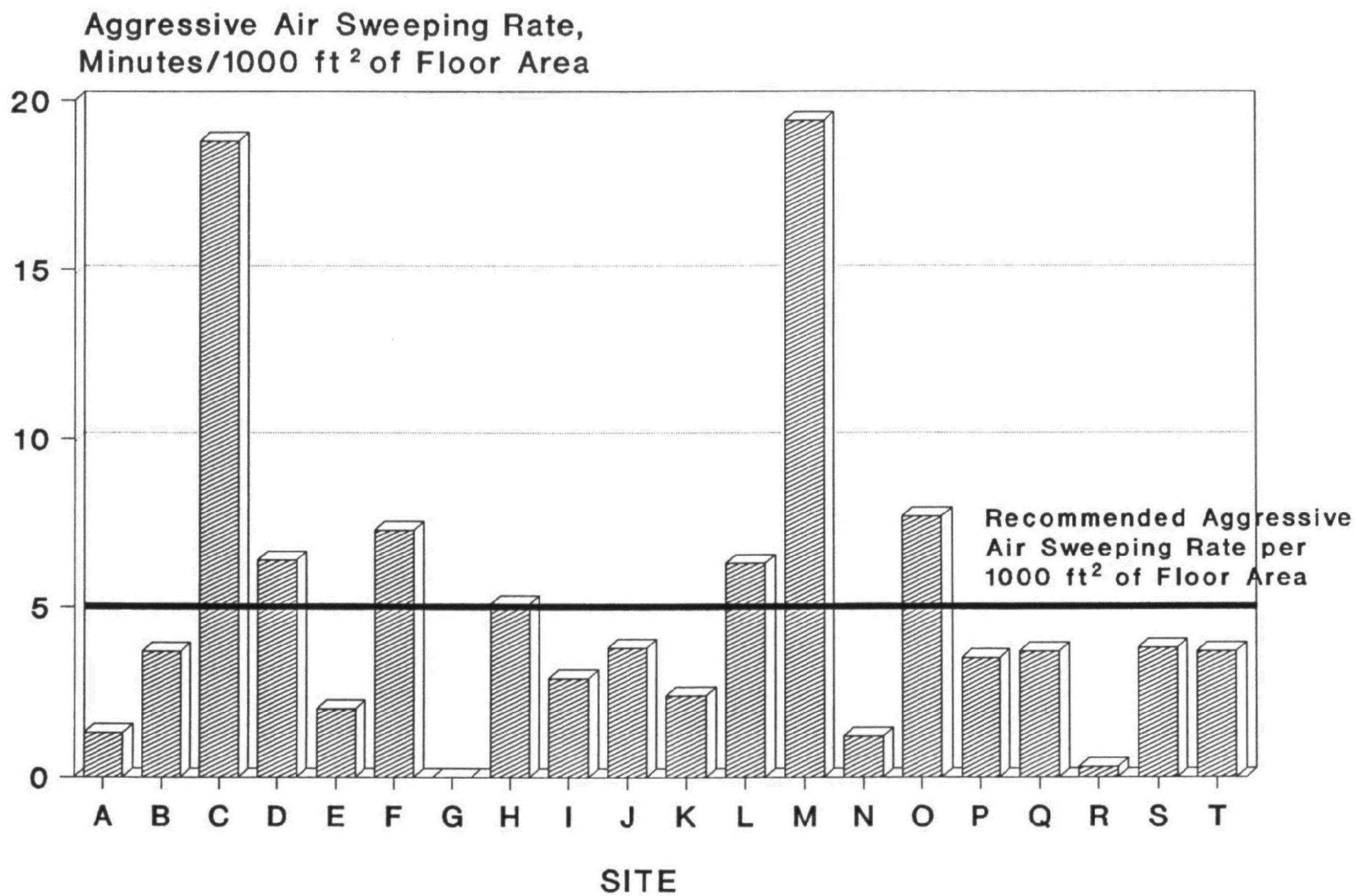

Figure 4. Observed aggressive sweeping times per 1000 square feet of floor area at 20 asbestos abatement sites.

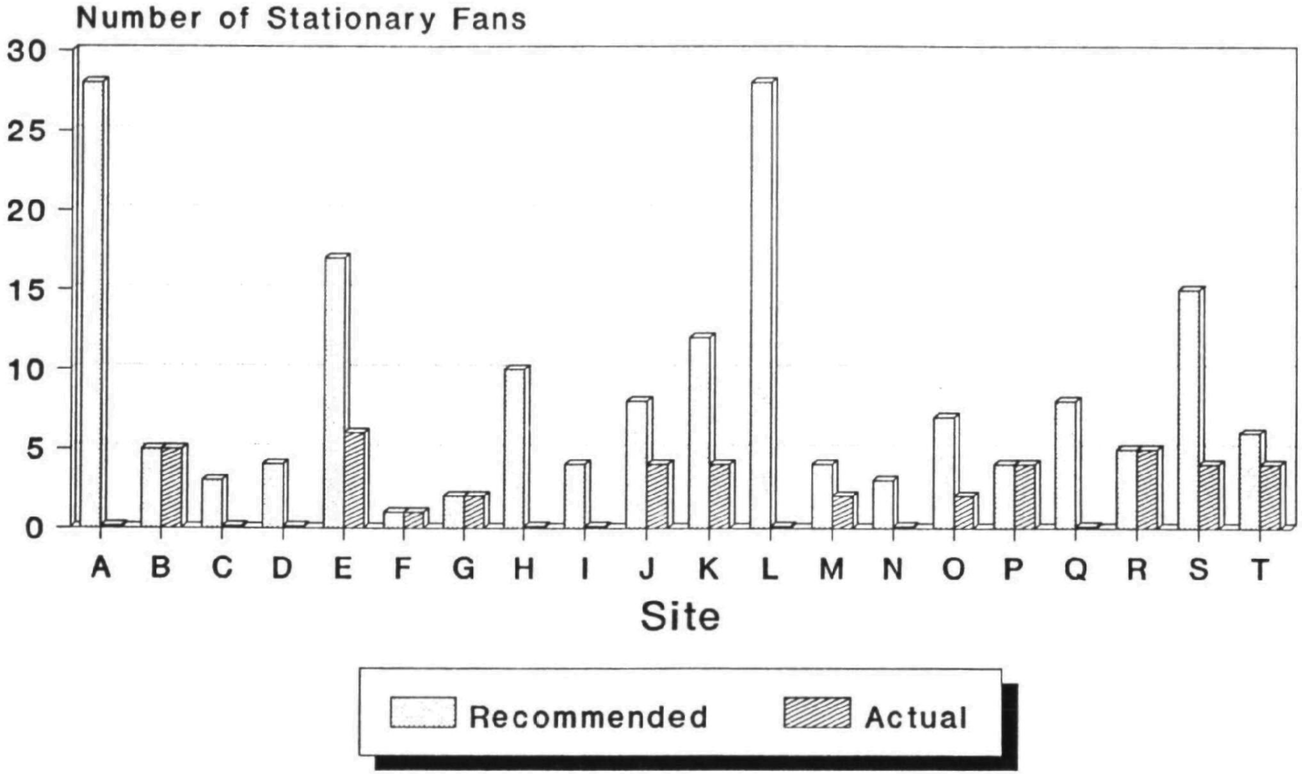

Figure 5. Recommended and actual number of stationary fans used during AHERA clearance air monitoring.

Filter Types

Mixed cellulose ester membrane filters were used in the collection of clearance air samples at 14 of the 20 observed abatement sites. Polycarbonate membrane filters were used at six sites. The AHERA rule permits the use of either filter type; however, the pore size must be less than or equal to 0.45 µm for mixed cellulose ester filters and 0.4 µm for polycarbonate filters. At three sites, 0.8-µm pore-size mixed cellulose ester membrane filters were used to collect clearance air samples, which did not comply with the AHERA regulations. All filters used for clearance air monitoring were 25 mm in diameter and were contained in three-piece cassettes with a 50-mm extension cowl. Table 8 summarizes the type of filter used for clearance air sampling at each site.

Flow Rates and Air Volumes

Each filter assembly was attached to an electric-powered pump operating at a specified airflow rate. The air samples were generally collected after a set length of time so a certain minimum air volume could be achieved. The AHERA rule states that pump flow rates between 1 and 10 liters per minute may be used for 25-mm-diameter filters. This was practiced at 18 of the 20 sites observed. Only at two sites were air samples collected at flow rates greater than 10 liters per minute. These results are summarized in Table 8. Air volumes ranged from 1320 to 4161 liters for the postabatement air samples collected inside and outside the abatement area at the observed sites. The AHERA rule recommends sampling between 1200 and 1800 liters of air for 25-mm-diameter filters.

Analytical Methods

At 18 of the 20 observed sites, the laboratory reports indicated that final clearance air samples were analyzed by TEM in accordance with either the mandatory or nonmandatory TEM methods described in AHERA (Table 2). At two sites, phase contrast microscopy was used to analyze the clearance air samples (Table 2). Although the samples were reportedly analyzed in accordance with NIOSH Method 7400 at these two sites, the clearance samples were collected using improper filters, i.e., collected using 0.4 µm pore size polycarbonate filters instead of 0.8 µm pore size mixed cellulose ester filters specified in the NIOSH Method.

Clearance Tests

Eighteen of the 20 sites were cleared by the AHERA TEM tests. One to three TEM clearance attempts were made per abatement site. Figure 6 shows the percentage of sites passing AHERA TEM clearance per attempt. Approximately 83.3 percent of the sites passed on the first attempt after passing a thorough visual inspection.

All of the 18 sites ultimately passed the AHERA TEM clearance criterion of the initial prescreening test (i.e., the average asbestos concentration of the samples collected inside the abatement area was less than or equal to 70 s/mm^2). Three sites initially failed the prescreening test, and two of

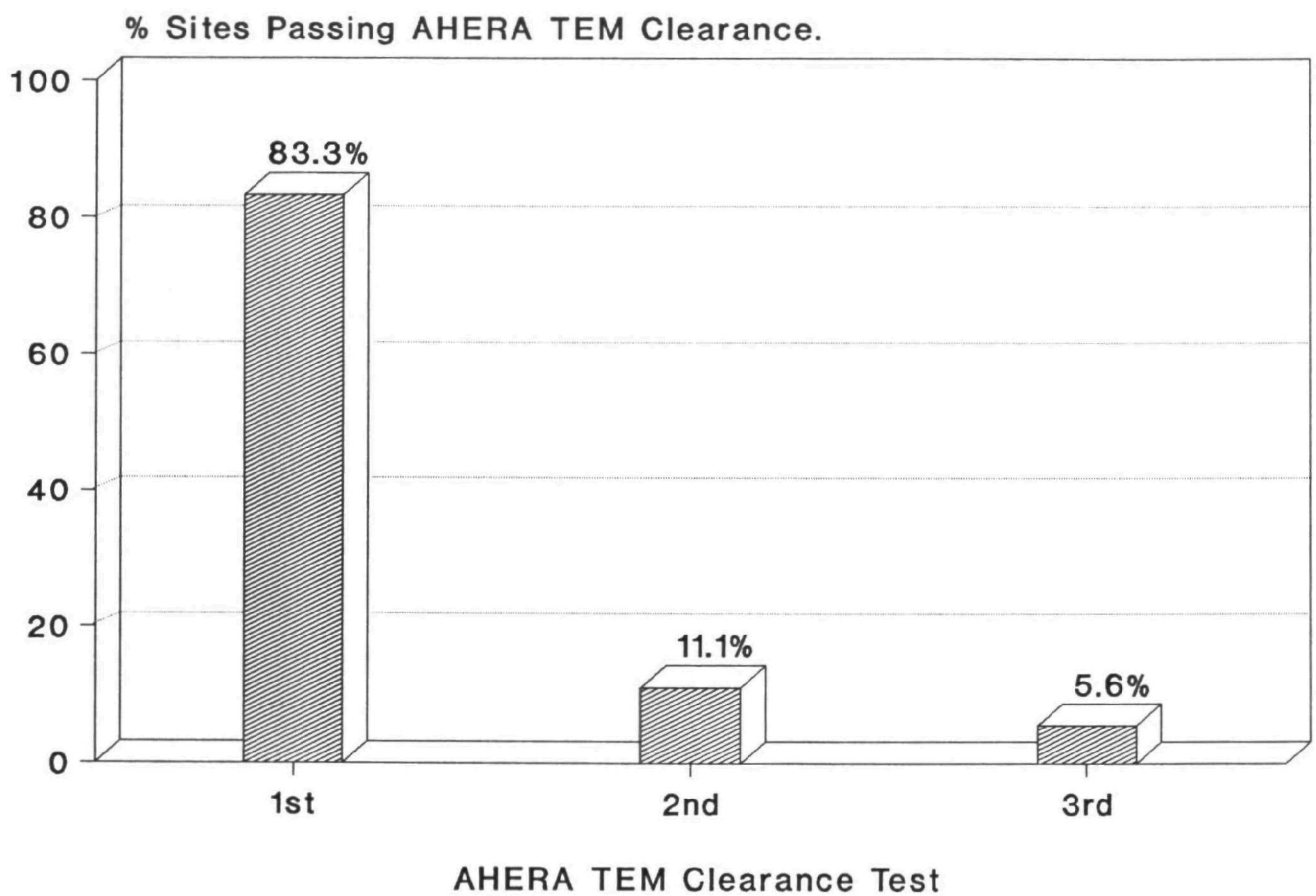

Figure 6. Percentage of 18 sites passing AHERA TEM clearance for each clearance attempt.

these sites subsequently tried to use the Z-Test to pass clearance. In each case, the site also failed the Z-Test and had to be recleaned. The Z-Test was used only twice at the 20 sites observed in this study, and it was never used to clear the abatement site. Figure 7 presents the average asbestos concentrations for each clearance attempt for the 18 sites that were cleared by TEM.

Occasionally, a site passed the initial prescreening test when one or more of the samples showed an asbestos concentration greater than or equal to 70 s/mm^2. As shown in Figure 8, this occurred at three sites in this study.

Three of the 20 sites were inspected by only the AST and subsequently cleared by TEM. Two of these 3 sites failed the first TEM clearance attempt after passing the AST visual inspection (see Case Studies E and G). One site required additional cleaning and passed TEM clearance on the second attempt. One site required three TEM clearance attempts after additional visual inspections by the AST before it was cleared (see Case Study G). Polycarbonate filters were used to collect air samples at this site. Background asbestos contamination on the field blanks showed an average asbestos concentration of 53 s/mm^2 on the first clearance attempt and 105 s/mm^2 on the second attempt. The field blanks were not analyzed on the third clearance attempt. Of the 15 sites that passed the NJDOH visual inspection, 14 subsequently passed TEM clearance on the first attempt.

Figure 9 integrates the percentage of sites passing TEM clearance with the total number of NJDOH visual inspections and TEM clearance attempts. As shown, the largest percentage (93.5%) of these sites passed the AHERA TEM clearance on the first attempt after having passed a thorough visual inspection by the NJDOH. Only 6.7 percent (one site) failed the AHERA TEM clearance after passing a thorough visual inspection. These data support the premise that effective final cleaning practices that meet the standards of a thorough visual inspection strongly influence whether the AHERA clearance test or other TEM clearance tests will be passed.[6]

One site involved the removal of less than 3000 square feet of asbestos-containing material. For smaller projects such as this, AHERA permits the use of phase contrast microscopy to analyze the clearance samples. Five samples must be collected inside the abatement area and each must have a fiber concentration of less than or equal to 0.01 f/cm^3 of air to pass the clearance criterion. Only one sample was collected at this site, and its fiber concentration was less than 0.01 f/cm^3. Site clearance was based on this one air sample, which is not in accordance with the five samples required by AHERA.

One other site was cleared by phase contrast microscopy analysis. According to AHERA regulations, however, clearance of this site required the use of the TEM clearance criterion. At this site, only two samples were collected inside the abatement area, and the fiber concentration associated with each was less than 0.01 f/cm^3. Site clearance was based on these two samples, where the PCM AHERA clearance criteria require a minimum of five samples inside the abatement area.

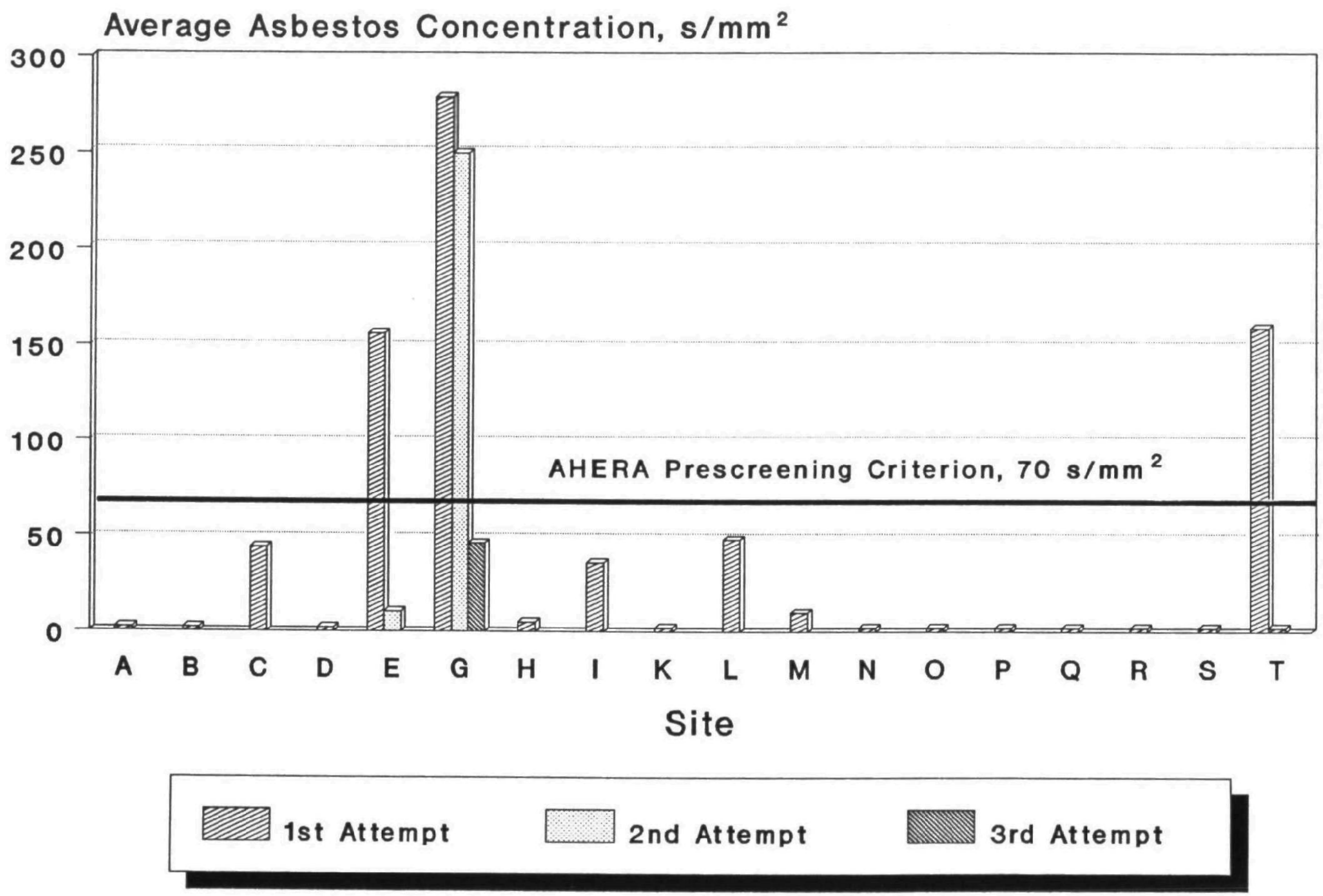

Figure 7. Average asbestos concentrations for each AHERA clearance attempt for the 18 sites cleared by TEM.

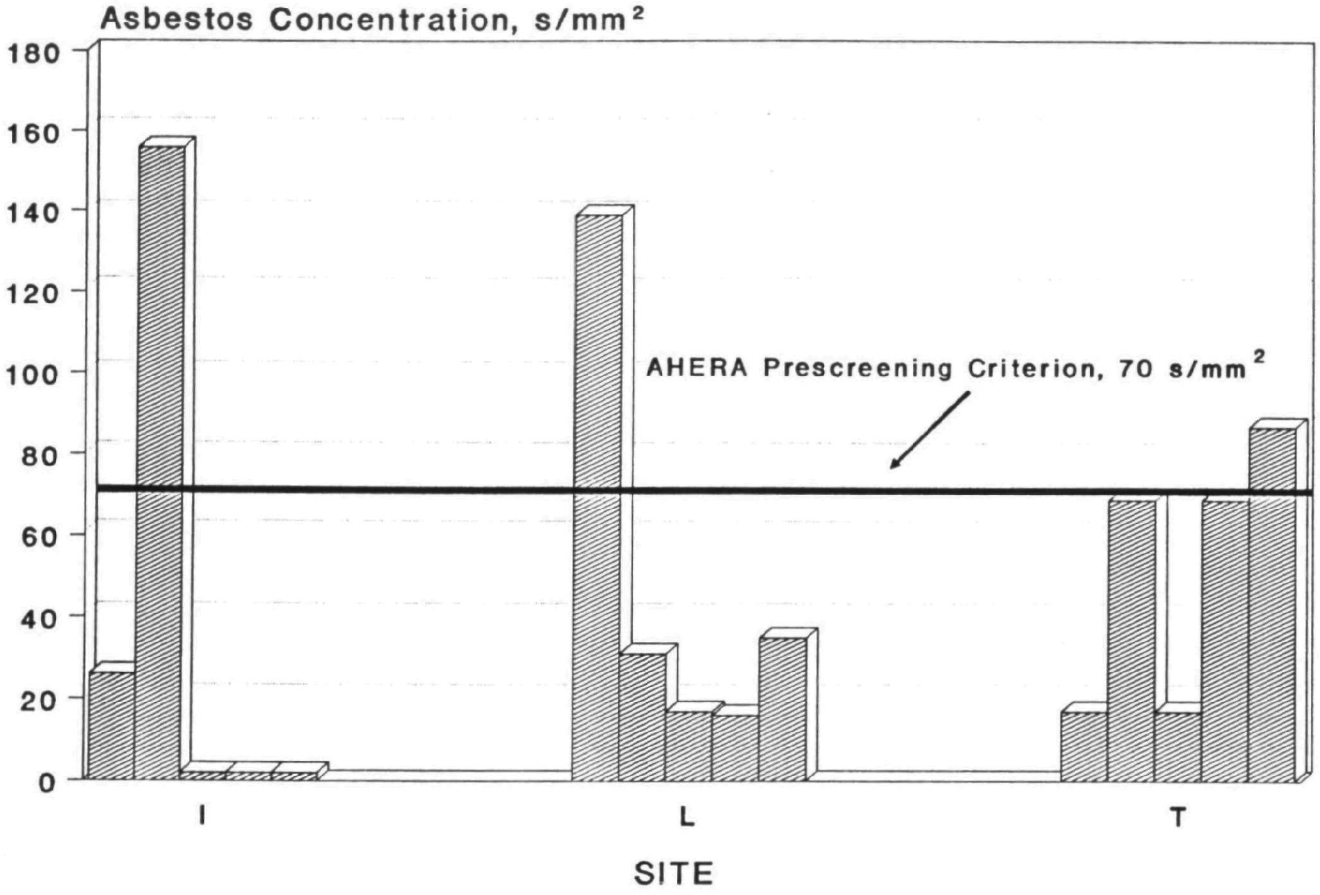

Figure 8. AHERA clearance results for sites with individual sample concentrations greater than 70 s/mm^2.

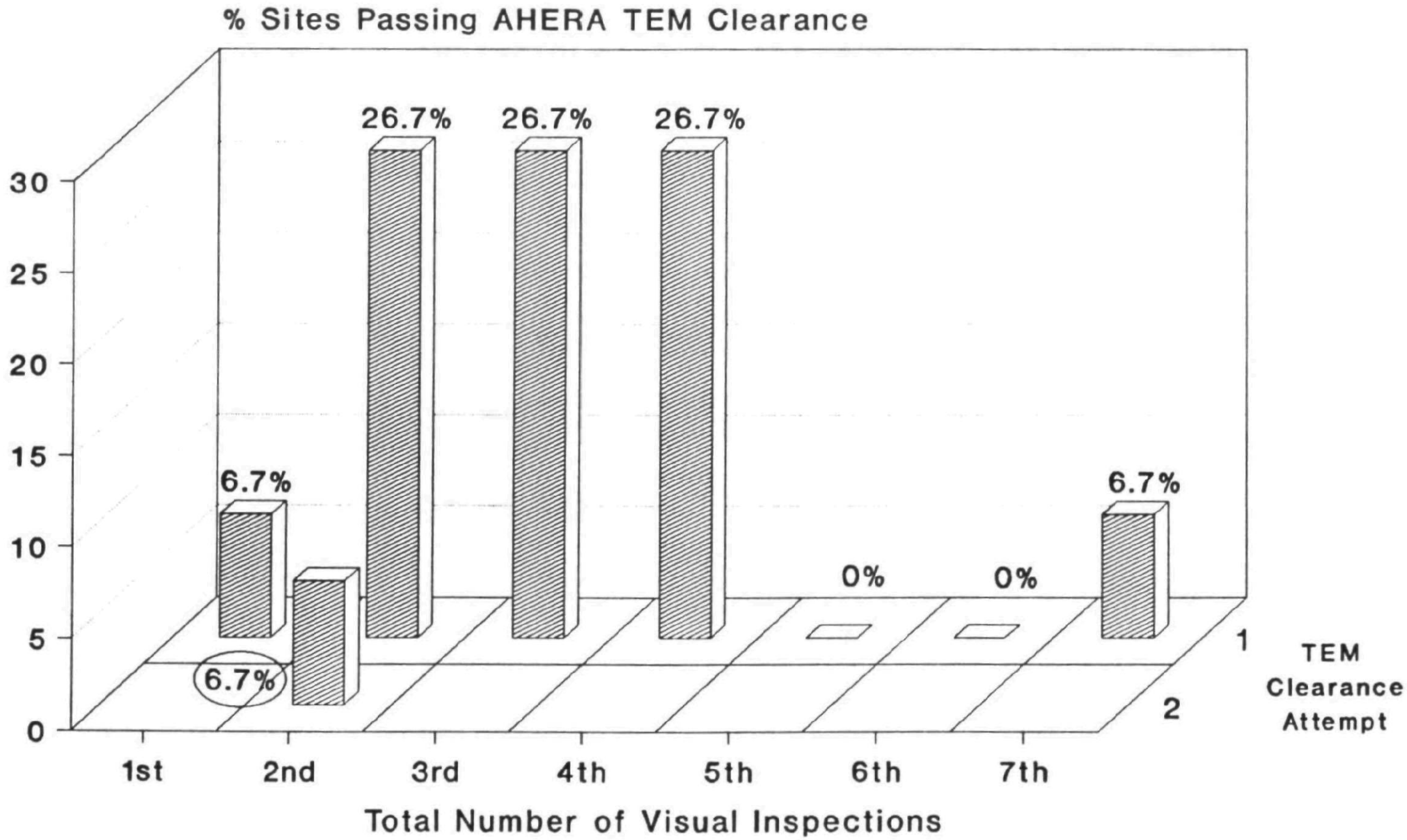

Figure 9. Percentage of 15 sites passing AHERA TEM clearance by total number of ACS visual inspections and AHERA clearance attempt.

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APPENDIX A

SITE DOCUMENTATION FORM OF FINAL CLEANING PROCEDURES AND VISUAL INSPECTION

I. GENERAL INFORMATION

1. Site number: __________ Form completed by: __________________________

2. Building visited: ____
   Address: ____

3. Removal contractor, address ____
   and phone number ____

4. ASCM firm, address and ____
   phone number ____

5. Name of AST: ____

6. Starting date of abatement: __________

7. Starting date of final cleaning: __________

8. Date site cleared: __________

9. Comments: ____

____

____

____

____

____

____

____

____

____

____

____

II. DESCRIPTION OF ABATEMENT SITE

1. Use of site (e.g., classroom, boiler room)

____

____

2. Dimensions of all areas within the site and ACM types in those areas.

Area	Dimensions (W, L, H)	Type of ACM* (PB, AC, etc.)	Location of ACM (Pipe, ceiling, etc.)

3. Comments ____

____

____

____

4. Draw a plan view of the abatement area on the following page.

---

* ACM types

PB = preformed block (Thermal System Insulation)
AC = air cell (Thermal System Insulation)
LP = layered paper (Thermal System Insulation)
CEM = cementitious insulation (Thermal System Insulation)
BD = asbestos board (Thermal System Insulation)
AP = acoustical plaster (surfacing material)
FP = fireproofing (surfacing material)
CT = ceiling tile (misc. material)
FT = floor tile (misc. material)
TR = transite (misc. material)
PAP = paper-like material (misc. material)
Other (describe)

PLAN VIEW OF ABATEMENT AREA

III. AIR-FILTRATION UNITS (AFU'S)

1. Location of AFU's (note of plan view of abatement area)

2. Are the AFU's vented to the outside of the building? ______________________
   Directly ________ Indirectly ________
   Comments: ____
   ____
   ____

3. How many AFU's are in use? _________

4. Types of AFU's

Unit No.	Manufacturer	Model	Unit No.	Manufacturer	Model

5. How frequently are filters changed?
   Prefilter ____
   Intermediate ____
   HEPA ____

6. Were the filters changed before final cleaning?
   Prefilter ___________ Intermediate ____________ HEPA ____________

7. Describe source(s) of makeup air: ________________________________
   ____
   ____

8. Are visual smoke tests conducted to demonstrate airflow into the abatement area (i.e., to document negative air-pressure conditions)? ______________
How often? ____
Where? ____

9. Is the negative air pressure monitored by the AST? __________________
If so, how often and where? ______________________________________

10. Measurement of pressure differential (inches W.G.) across critical containment barriers.

Test Location*

	1	2	3	4	5
Date Time					
MSMT 1					
MSMT 2					

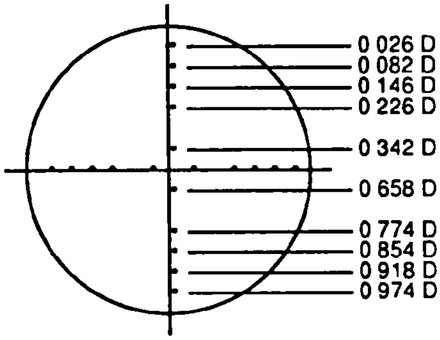
* Location of ΔP measurement shown on plan view of abatement area; description of each location is presented below.

Comments: ____

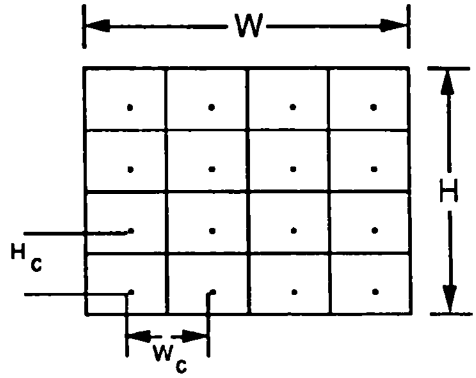
NEGATIVE AIR UNIT MEASUREMENT LOG

1 Negative air unit No ____

2 Dimensions of negative air intake and locations of velocity measurements



D = in



$W =$ in $H =$ in

$W_c =$ in $H_c =$ in

Measurement locations not more than 6 in apart

Negative air intake face velocity measurements (ft/min)

	Test 1	Test 2	Test 3
Date Time			
MSMT 1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
Average			

IV. FINAL CLEANING PROCEDURES

1. Starting date __________. Ending date __________.

2. Describe the work practies and procedures used during final cleaning.

GENERAL OBSERVATION NOTES ON FINAL CLEANING PROCEDURES

V. VISUAL INSPECTION

1. Did the site pass the visual inspection by the AST? ___________.
If not, include reasons.

____

____

____

____

2. Did the site pass the first visual inspection by the ACS inspector? ________.
If not, include reasons.

____

____

____

____

____

____

____

3. Describe any changes in cleaning methods used prior to the second visual inspection by the ACS inspector.

____

____

____

____

4. Did the site pass the second visual inspectin by the ASC inspector? _______.
If not, include reasons.

____

____

____

____

____

5. Describe any changes in cleaning methods used prior to the third visual inspection by the ACS inspector.

____

____

____

____

6. Did the site pass the third visual inspection by the ACS inspector? ________
If not, include reasons.

____

____

____

____

7. Describe any changes in cleaning methods used prior to the fourth visual inspection by the ACS inspector.

____

____

____

8. Did the site pass the fourth visual inspection by the ACS inspector? _______
If not, include reasons.

____

____

____

____

9. Describe any changes in cleaning method used prior to the fifth visual inspection by the ACS inspector.

____

____

____

APPENDIX B

SITE DOCUMENTATION FORM OF AHERA CLEARANCE PRACTICES

1. Did the AST conduct aggressive air sweeping of surfaces? ____________
   If yes, for how long? __________ minutes.

2. Were fans used to maintain aggressive air turbulence conditions during clearance sampling? __________.

   Type:

		Size (dia. blades)	How many?
Pedestal	__________	__________	__________
Box	__________	__________	__________
Other	__________	__________	__________

3. Air sampling filter media and cassette.

		w/50-mm cowl	w/o 50-mm cowl
25-mm, 0.8 µ MCE	__________	__________	__________
25-mm, 0.45 µ MCE	__________	__________	__________
25-mm, 0.4 µ PC	__________	__________	__________
Other	__________	__________	__________

4. Air sampling flow rate (range) __________ L/min.

5. Comments: ____

6. Measurement of pressure differential (inches W.G.) across critical containment barriers.

Test Location*

	1	2	3	4	5	6	7	8	9	10
Date Time										
MSMT 1										

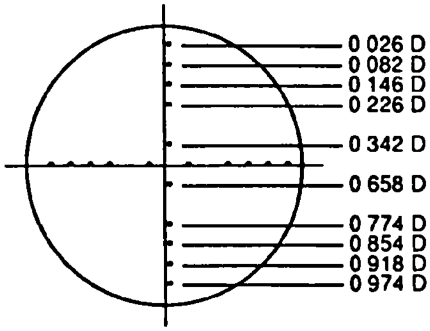
* Location of ΔP measurement shown on plan view of abatement area; description of each location is presented below.

Comments: ____________________

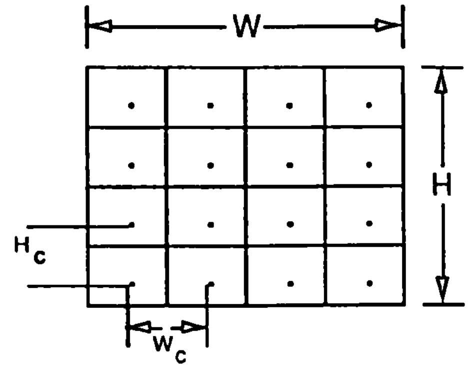
NEGATIVE AIR UNIT MEASUREMENT LOG

1 Negative air unit No ____

2 Dimensions of negative air intake and locations of velocity measurements



D= ______ in



$W=$ ______ in $H=$ ______ in

$W_c=$ ______ in $H_c=$ ______ in

Measurement locations not more than 6 in apart

Negative air intake face velocity measurements (ft/min)

	Test 1	Test 2	Test 3
Date Time			
MSMT 1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
Average			

APPENDIX C

CASE STUDIES

CASE HISTORY A

SITE DESCRIPTION

This abatement project involved removal of approximately 19,100 ft^2 of spray-applied asbestos-containing ceiling plaster from a single-story school building. The abatement area included corridors, classrooms, offices, and recreational rooms. The project specification indicated that the asbestos content of the ceiling plaster was approximately 5 to 10 percent chrysotile.

VENTILATION AND NEGATIVE AIR PRESSURE

Six high-efficiency particulate air (HEPA) filtration units were operated during the final cleaning period, and 11 were operated during AHERA clearance sampling. Table A-1 presents the measured air-intake volume for each unit. The average air-intake volume was approximately 1666 ft^3/min during final cleaning and 1648 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (280,000 ft^3) and the combined average air-intake volumes, the air exchange rates were approximately 2.1 air changes per hour during final cleaning and 3.9 air changes per hour during AHERA clearance sampling.

Figures A-1 and A-2 compare the measured air-intake volume of each HEPA-filtration unit operating during final cleaning and AHERA clearance sampling, respectively, with the unit's nominal airflow. The actual operating percentage of the nominal airflow ranged from 82 to 84 during final cleaning and 81 to 84 during AHERA clearance sampling.

Table A-2 presents the static pressure differential measured across the containment barriers at three locations. The number of locations tested was determined by available access to the critical containment barriers. The static pressure differential ranged from 0.00 to -0.01 in. water during final cleaning and -0.02 to -0.03 in. water during AHERA clearance sampling. The increased differential pressure is most likely attributable to the additional number of HEPA-filtration units that were operating.

The asbestos safety technician (AST) continually monitored the static pressure differential at Test Location 2 during final cleaning. These measurements showed a static pressure differential of -0.01 to -0.02 in. water. The project specification required maintenance of a minimum static pressure differential of -0.02 in. water across the containment barrier.

TABLE A-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS

Model	Unit	Airflow, ft^3/min. Mean	Min.	Max.	Std. dev.	95% Confidence interval Lower	Upper
			Final cleaning				
1	1	1649	1344	1764	118	1585	1712
1	2	1685	1512	1848	91	1637	1734
1	3	1680	1344	1848	122	1615	1745
1	4	1649	1344	1848	118	1585	1712
1	5	1696	1512	1848	95	1645	1746
1	6	1638	1344	1848	122	1573	1677
			AHERA clearance sampling				
1	1	1680	1596	1848	73	1641	1719
1	2	1670	1428	1848	107	1613	1726
1	3	1628	1344	1848	139	1554	1701
1	4	1649	1344	1848	145	1571	1726
1	5	1659	1512	1848	81	1613	1702
1	6	1612	1344	1932	163	1525	1699
1	7	1680	1344	1848	126	1613	1747
2	8	1643	1344	1848	129	1574	1712
2	9	1649	1344	1848	122	1584	1713
2	10	1617	1344	1848	141	1542	1692
2	11	1638	1344	1848	126	1571	1705

TABLE A-2. STATIC PRESSURE DIFFERENTIALS
ACROSS CONTAINMENT BARRIERS
(in. water)

Test location	Final cleaning	AHERA clearance
1	-0.01	-0.02
2	-0.01	-0.03
3	-0.01	-0.02

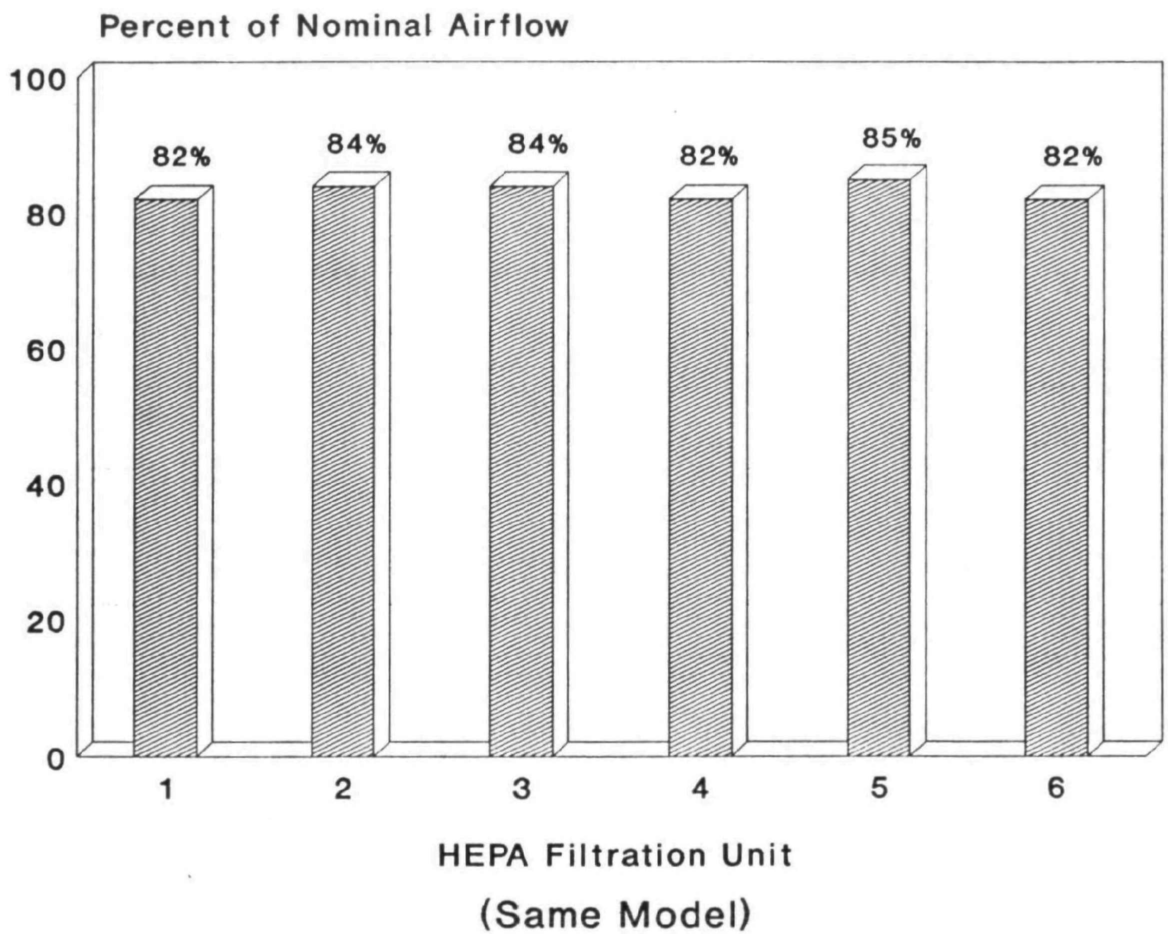


Figure A-1. Airflow performance for HEPA filtration systems operating during final cleanup.

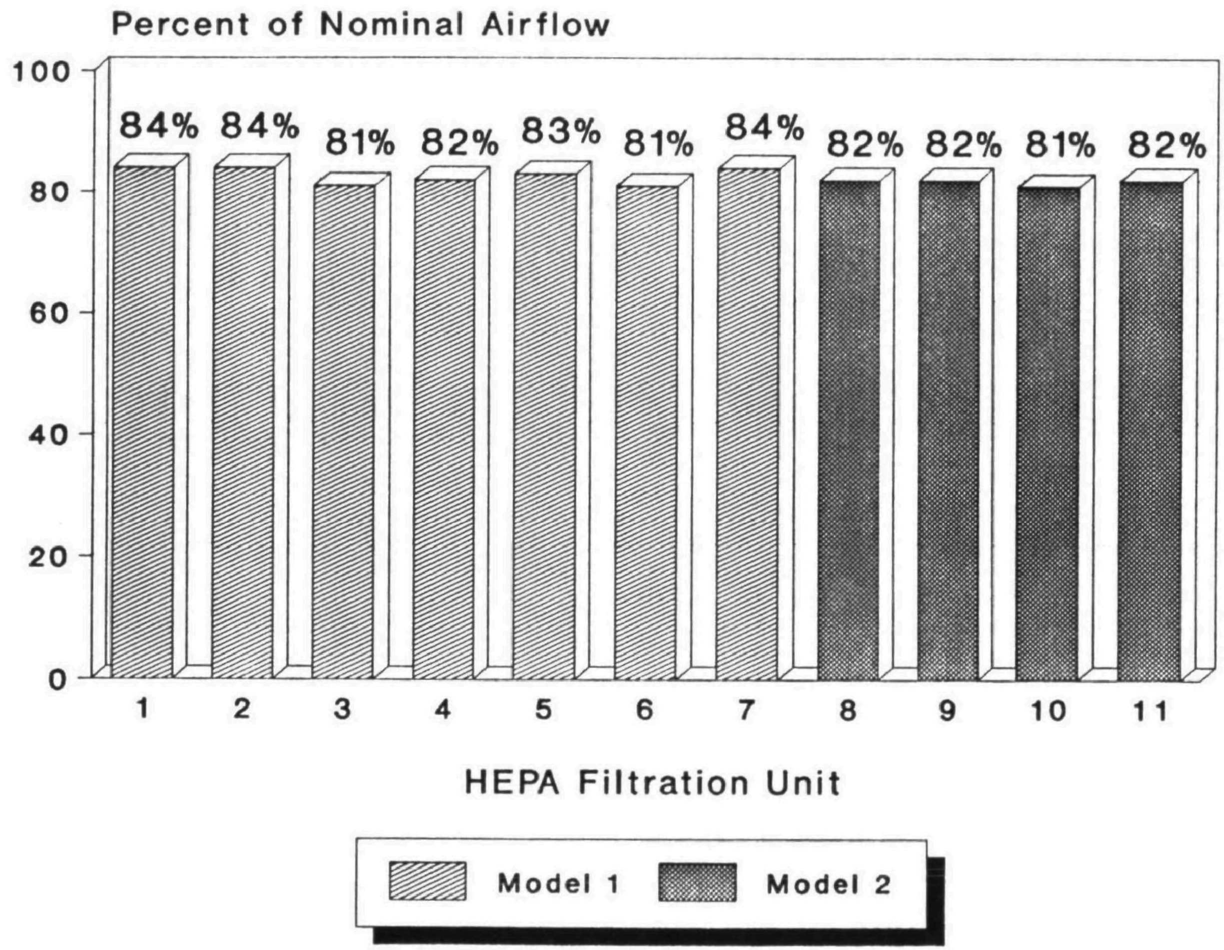


Figure A-2. Airflow performance for HEPA filtration systems operating during AHERA clearance.

In addition to continually monitoring the differential pressure, the AST used ventilation smoke tubes for visually checking negative pressure (i.e., direction of airflow through openings in the containment barrier, such as the decontamination facility and waste load-out port). Reportedly, these qualitative checks were performed each morning.

The HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility and waste load-out port. Ten of the 11 operating units were positioned along exterior walls to facilitate venting the exhaust through windows via an interconnected flexible duct. The exhaust of 1 of the 11 units was vented through a doorway via an interconnected flexible duct that passed through a classroom outside of the abatement area. This is particularly noteworthy because the flexible duct was torn and a percentage of the exhaust air was released into the building. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor, who was responsible for maintaining the HEPA-filtration units, stated that the prefilters, secondary filters, and HEPA filters were changed before final cleaning was initiated. Thereafter, the prefilters and secondary filters were changed when they became "visibly dirty." The HEPA filters were changed every 600 to 700 hours (as recommended by the manufacturer) or when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls and either full- or half-facepiece air-purifying respirators equipped with dual-cartridge HEPA filters.

Cleaning Procedures

Final cleaning began after the encapsulated plastic sheeting was removed from the walls, floors, light fixtures, and other surfaces. The critical barriers, windows, doors, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The HEPA-filtration units remained in service.

Final cleaning was organized so the workers began in the areas farthest from the personnel decontamination facility and worked toward it. No association appeared to exist between the work direction and the location of the HEPA-filtration units.

Final cleaning began with the spraying of plaster and masonry walls, windows, plastic critical containment barriers, and other vertical surfaces with a light water mist to remove any visible debris. The resultant asbestos-containing water on the floor was gathered into pools by use of a rubber squeegee. The bulk of the pooled water was scooped up with plastic-bladed shovels, an approach that worked surprisingly well. The water was put into double-layered, 6-mil-thick asbestos-disposal bags, which generally contained plastic that had been removed from the walls and floors. The residual water removed with a wet vacuum was also placed in these bags.

Some of the asbestos-containing water penetrated the seams between the vinyl floor tiles and caused sections to buckle. The buckled sections were sporadically distributed throughout the abatement area. The asbestos-containing water beneath the floor tiles was allowed to dry, and the tiles were not repaired. These areas could be potential sources of airborne asbestos fibers when repaired later by maintenance personnel.

After the surfaces had dried, a vacuum equipped with a HEPA filter was used to clean crevices around windows, doors, and shelves; floor-wall interfaces; etc.

All of the vertical and horizontal surfaces were then wet-cleaned with amended water. The contractor reportedly prepared the amended water solution by mixing approximately 2 ounces each of 50 percent polyoxyethylene ester and 50 percent polyoxyethylene ether in 5 gallons of water.

The elevated horizontal and vertical surfaces were wiped first and then all other surfaces. All the surfaces except the floors were wiped with cotton rags dampened with amended water. A bucket of amended water was either used by a single worker or shared by several workers. The workers did not appear to wipe the surfaces in any one direction. The cloth rags were not replaced frequently, particularly during the cleaning of elevated and hard-to-access surfaces. Nor was the amended water changed frequently.

After the walls, windows, and other surfaces (shelves, ledges, counters, plastic-covered HEPA-filtration systems and associated exhaust ducts, etc.) were wet-wiped, the floor was mopped with a clean mop head that was wetted with amended water. No change in the water was observed during this procedure.

The last step in final cleaning effort involved removal of the plastic sheeting covering the HEPA-filtration units and associated exhaust ducts. The latter were covered with a plastic sleeve. According to the contractor, this simplified cleaning of this equipment.

Final cleaning involved one complete wet-cleaning of all surfaces. No aggressive cleaning (i.e., air sweeping of all vertical and horizontal surfaces to dislodge any remaining particulate) was conducted.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered 6-mil-thick standard disposal bags. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers or solidified with a gelling compound. The rags and mop heads used during cleaning also were placed in these bags. The bags were not wet-wiped with amended water before being removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an onsite AST, who was the building owner's representative. The AST conducted the visual inspection within 2 hours after notification. The AST identified several areas, particularly elevated horizontal surfaces, that required further cleaning. After these designated areas were recleaned, the AST conducted a final walk-through inspection to assure that the identified areas were clean.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

The site failed the first two visual inspections because of the presence of live electrical outlets inside the containment and the presence of asbestos-contaminated water in the toilets of the men's restroom and in the sink in the janitor's closet. Workers were observed dumping the contaminated mop water into drains, toilets, and sinks.

The site failed the third visual inspection because of the presence of debris on several skylights, on horizontal surfaces, in wall penetrations, and at the top of wooden and concrete walls. Pipe wrap was also left on pipes. Six bulk samples were collected to characterize the residual debris found on skylights, above windows, and in wall penetrations and the pipe wrap that was left. Chrysotile asbestos was identified in all samples. The asbestos content of the debris found in wall penetrations was approximately 6 percent chrysotile. The asbestos content of the pipe wrap was approximately 17 percent. All other samples were not sufficiently large to quantify the asbestos content.

The site passed the fourth visual inspection.

AHERA CLEARANCE SAMPLING BY AST

The AHERA clearance sampling was initiated approximately 18 hours after the site passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive blowdown of vertical and horizontal surfaces for approximately 25 minutes, which is equivalent to approximately 5 minutes per 3800 square feet of floor area. No floor fans were used subsequently to maintain air turbulence during sampling.

The clearance air samples were collected on 25-mm, 0.8-μm pore size, mixed cellulose ester membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The samples were collected at flow rates ranging from 7 to 19 liters per minute. The laboratory report indicates that the samples were analyzed in accordance with the AHERA mandatory TEM method.

Table A-3 presents the results of clearance samples the AST collected inside the abatement area. The samples met the initial AHERA clearance criterion, i.e., an average asbestos concentration of less than 70 structures per square millimeter (s/mm^2). The average asbestos concentration for the five inside samples was 0 s/mm^2.

TABLE A-3. AHERA CLEARANCE SAMPLE RESULTS

Sample Location[a]	Sample volume, liters	Asbestos concentration, s/mm²	s/cm³
Inside	4161	0	<0.0041[b]
Inside	4000	0	<0.0042[b]
Inside	3008	0	<0.0045[b]
Inside	2226	0	<0.0042[b]
Inside	4088	0	<0.0041[b]

[a] Outdoor samples and blanks were not analyzed because the average asbestos concentration for the five inside samples was less than 70 s/mm².

[b] Sensitivity of the analytical method.

CASE HISTORY B

SITE DESCRIPTION

This abatement project involved removal of approximately 5400 ft^2 of spray-applied asbestos-containing acoustical plaster from ceilings and fascias on the second floor of a two-story school building. The abatement area included corridors, classrooms, and offices. The project specification indicated that the asbestos content of the ceiling plaster was approximately 2 to 6 percent chrysotile.

VENTILATION AND NEGATIVE AIR PRESSURE

Performance of the two high-efficiency particulate air (HEPA) filtration units that operated during the final cleaning period was not measured. Two HEPA filtration units also were operated during AHERA clearance sampling; Table B-1 presents the measured air-intake volume of each of these units. The average air-intake volume was 1709 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (50,000 ft^3) and the combined average air-intake volume, the air exchange rate was approximately 4.1 air changes per hour during AHERA clearance sampling.

TABLE B-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS DURING AHERA CLEARANCE SAMPLING

		Airflow, ft^3/min.				95% Confidence interval	
Model	Unit	Mean	Min.	Max.	Std. dev.	Lower	Upper
1	1	1712	1512	1848	107	1655	1769
1	2	1706	1512	1848	102	1652	1760

Figure B-1 compares the measured air-intake volume of each HEPA-filtration unit operating during AHERA clearance sampling with the unit's nominal airflow. The actual operating percentages of the nominal air flow were 85 and 86 during AHERA clearance sampling.

Table B-2 presents the static pressure differential measured across the containment barriers at two test locations. The number of locations tested

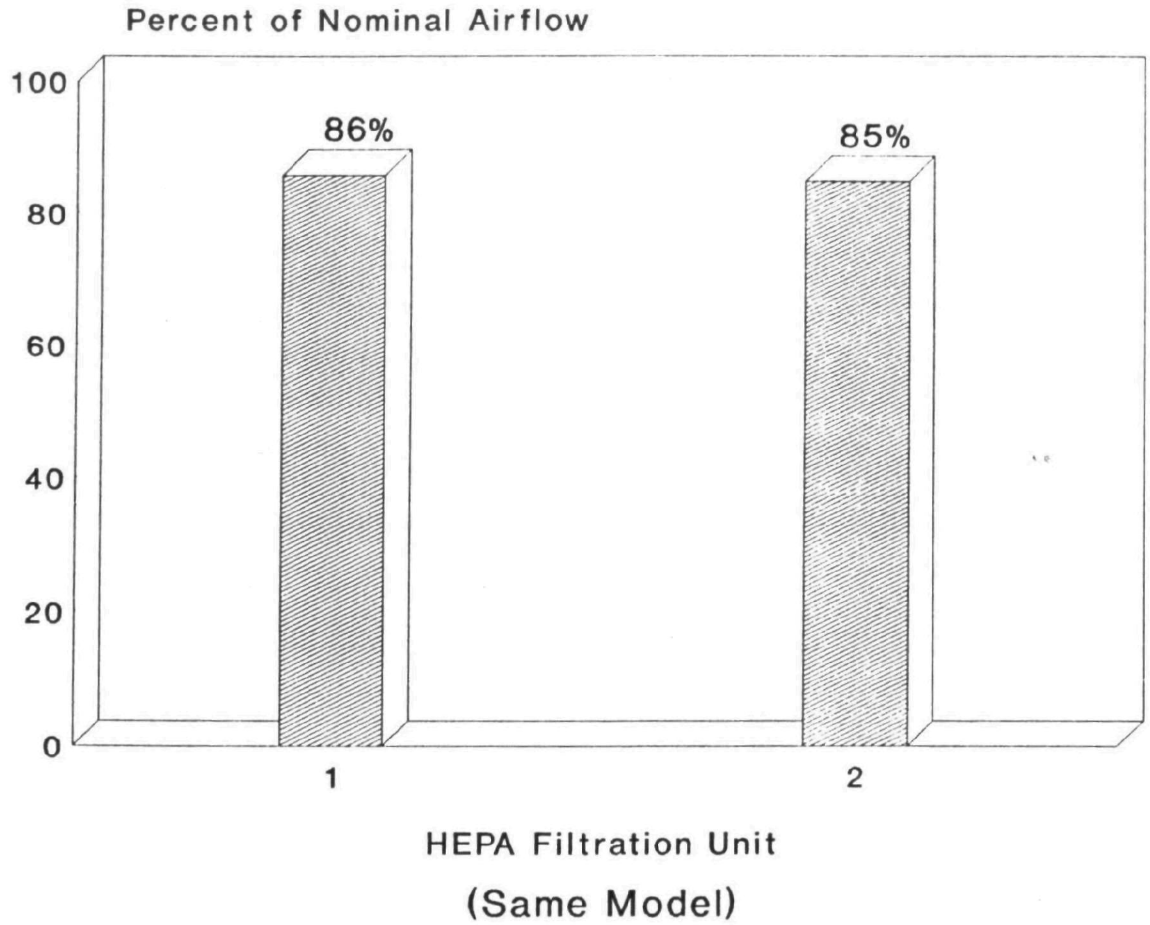


Figure B-1. Airflow performance for HEPA filtration systems operating during AHERA clearance.

was determined by available access to the critical containment barriers. As shown, static pressure differential was -0.02 in. water during final cleaning and -0.02 in. water during AHERA clearance sampling.

TABLE B-2. STATIC PRESSURE DIFFERENTIALS ACROSS CONTAINMENT BARRIERS (in. water)

Test location	Final cleaning	AHERA clearance
1	-0.02	-0.02
2	-0.02	-0.02

The asbestos safety technician (AST) did not monitor the static pressure differential across the containment barriers. Instead, ventilation smoke tubes were used to check negative pressure visually (i.e., the direction of airflow through openings in the containment barrier, such as the decontamination facility and waste load-out port). Reportedly, these qualitative checks were performed each morning before the workshift and twice during the workshift.

The HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility and waste load-out port. The two operating units were positioned along exterior walls to facilitate venting of the exhaust through windows via an interconnected flexible duct. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor who was responsible for maintaining the HEPA-filtration units, stated that the prefilters, secondary filters, and HEPA filters were changed before final cleaning was initiated. Thereafter, the prefilters and secondary filters were changed when they became "visibly dirty." The HEPA filters were changed every 600 to 700 hours (as recommended by the manufacturer) or when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls and either full- or half-facepiece air-purifying respirators equipped with dual-cartridge HEPA filters.

Cleaning Procedures

Final cleaning began after the removal of the encapsulated plastic sheeting from the walls, floors, and other surfaces. The critical barriers, windows, doors, fixed objects, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The HEPA filtration units remained in service.

Final cleaning was organized so the workers began in the areas farthest from the personnel decontamination facility and worked toward it. No association appeared to exist between the work direction and the location of HEPA-filtration units.

Final cleaning began with scraping and brushing of the ceiling-wall intersection areas to remove any residual debris on the substrate. Any resultant debris that fell to the floor was then removed with a HEPA-filtered vacuum. Hard-to-reach places (such as crevices around windows and doors) and floor-wall intersections were also cleaned with a HEPA-filtered vacuum.

Vertical and horizontal surfaces were then wet-cleaned with amended water. The amended water solution, which was prepared by the contractor, reportedly consisted of a mixture of approximately 1 ounce each of 50 percent polyoxyethylene ester and 50 percent polyoxyethylene ether in 5 gallons of water.

The elevated horizontal and vertical surfaces were wiped first, and then all other surfaces were wiped. All surfaces except the floors were wiped with cotton rags dampened with amended water. The workers did not appear to wipe the surfaces in any one direction. A bucket of amended water was either used by a single worker or shared by several workers. The same bucket was used for rinsing and dampening the rags. The cloth rags were not replaced frequently, particularly during the cleaning of elevated and hard-to-access surfaces. Nor was the amended water changed frequently.

After the walls, windows, and other surfaces (shelves, ledges, plastic-covered fixed objects, etc.) were wet-wiped, the floor was dry-swept and immediately thereafter mopped with a clean mop head wetted with amended water. No change in the water was observed during this procedure.

The last cleaning effort involved wet-cleaning easily accessible horizontal surfaces, and a complete wet-mopping of the floors with amended water.

No aggressive cleaning (i.e., air sweeping of all vertical and horizontal surfaces to dislodge any remaining particulate) was conducted.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered 6-mil-thick standard disposal bags. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers or solidified with a gelling compound. The rags and mop heads used during cleaning were also placed in these bags. The bags were not wet-wiped with amended water before being removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an onsite AST who was the building owner's representative. The AST conducted the visual inspection within 2 hours after notification. The AST identified several areas, particularly elevated horizontal surfaces and ceiling-wall intersections, that required further cleaning. After these designated areas were recleaned, the AST conducted a final walk-through inspection to assure that the identified areas were clean.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

The site failed the first visual inspection because of the presence of gross debris (both granular and fluffy) 1) on tops of closets, 2) in the corners of window sills, 3) at floor-wall and ceiling-wall junctions, 4) in cracks and crevices, 5) on ceiling rafters and beams, 6) on floors, and 7) on auxiliary equipment. Four bulk samples were collected to characterize the makeup of the residual debris. Samples were collected from the top of a closet, from window jambs, and from a wall-ceiling junction. Asbestos was identified in each sample collected; however, the samples were not sufficiently large to quantify the percentage of asbestos in each.

The site failed the second visual inspection because of debris on clocks, windows, ceiling beams, tops of blackboards, and horizontal surfaces in the classrooms and closets. The site passed the third visual inspection.

AHERA CLEARANCE SAMPLING BY AST

The AHERA clearance sampling was initiated approximately 24 hours after the site passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 20 minutes, which is equivalent to approximately 5 minutes per 1350 square feet of floor area. Five 18-inch-diameter box-type floor fans were subsequently used to maintain air turbulence during clearance sampling.

The clearance air samples were collected on 25-mm, 0.8-μm pore size, mixed cellulose ester membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The samples were collected at flow rates ranging from 9.5 to 10 liters per minute. The laboratory report indicates the samples were analyzed in accordance with the AHERA mandatory TEM method.

Table B-3 presents the results of clearance samples the AST collected inside the abatement area. The samples met the initial AHERA clearance criterion, i.e., an average asbestos concentration below 70 structures square millimeter (s/mm^2). The average asbestos concentration for the five inside samples was 0 s/mm^2.

TABLE B-3. AHERA CLEARANCE SAMPLE RESULTS

Sample location[a]	Sample volume, liters	Asbestos concentration	
		s/mm²	s/cm³
Inside	1500	0	<0.005[b]
Inside	1500	0	<0.005[b]
Inside	1500	0	<0.005[b]
Inside	1500	0	<0.005[b]
Inside	1500	0	<0.005[b]

[a] Outside samples and blanks were not analyzed because the average asbestos concentration for the five inside samples was less than 70 s/mm².

[b] Sensitivity of the analytical method.

CASE HISTORY C

SITE DESCRIPTION

This abatement project involved removal of thermal system insulation from a three-story school building. The asbestos-containing materials included insulation on the boiler, water tank, and fan duct in the boiler room and preformed block and air-cell-paper pipe insulation in the boiler room and adjacent corridors.

The project specification indicated that the asbestos content of the preformed block, air-cell-paper, and cementitious surface insulation was approximately 40 to 60 percent chrysotile. The specifications did not quantify the amount of asbestos-containing material in each location.

VENTILATION AND NEGATIVE AIR PRESSURE

Four high-efficiency particulate air (HEPA) filtration units were operated during the final cleaning period and during AHERA clearance sampling. Table C-1 presents the measured air-intake volume for each unit. The average air-intake volume was 1414 ft^3/min during final cleaning and 1412 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (32,000 ft^3) and the combined average air-intake volumes, the air exchange rates were approximately 10.7 air changes per hour during final cleaning and 10.6 air changes per hour during AHERA clearance sampling.

Figures C-1 and C-2 compare the measured air-intake volume for each HEPA-filtration unit operating during final cleaning and AHERA clearance sampling, respectively, with the unit's nominal airflow. The actual operating percentages of the nominal airflow ranged from 72 to 86 during final cleaning and 72 to 84 during AHERA clearance sampling.

Table C-2 presents the static pressure differential measured across the containment barriers. The number of locations tested was determined by available access to the critical containment barriers. The static pressure differential was -0.01 in. water during final cleaning and ranged from -0.01 to -0.02 in. water during AHERA clearance sampling.

The asbestos safety technician (AST) did not monitor the static pressure differential across the containment barriers. Instead, smoke tubes were used to check negative pressure visually (i.e., direction of airflow through openings in the containment barrier, such as the decontamination facility and waste load-out port). Reportedly, these qualitative checks were performed each morning before the workshift.

TABLE C-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS

Model	Unit	Airflow, ft^3/min Mean	Min.	Max.	Std. dev.	95% Confidence interval Lower	Upper
				Final cleaning			
1	1	721	652	815	57	690	751
2	2	1712	1428	1932	168	1622	1801
2	3	1591	1176	1848	191	1489	1693
2	4	1633	1344	1848	145	1555	1710
				AHERA clearance sampling			
1	1	718	652	815	45	694	742
2	2	1680	1512	1932	129	1611	1749
2	3	1575	1260	1848	147	1497	1653
2	4	1675	1512	1764	69	1638	1712

TABLE C-2. STATIC PRESSURE DIFFERENTIALS ACROSS CONTAINMENT BARRIERS (in. water)

Test location	Final cleaning	AHERA clearance
1	-0.01	-0.01
2	-0.01	-0.02

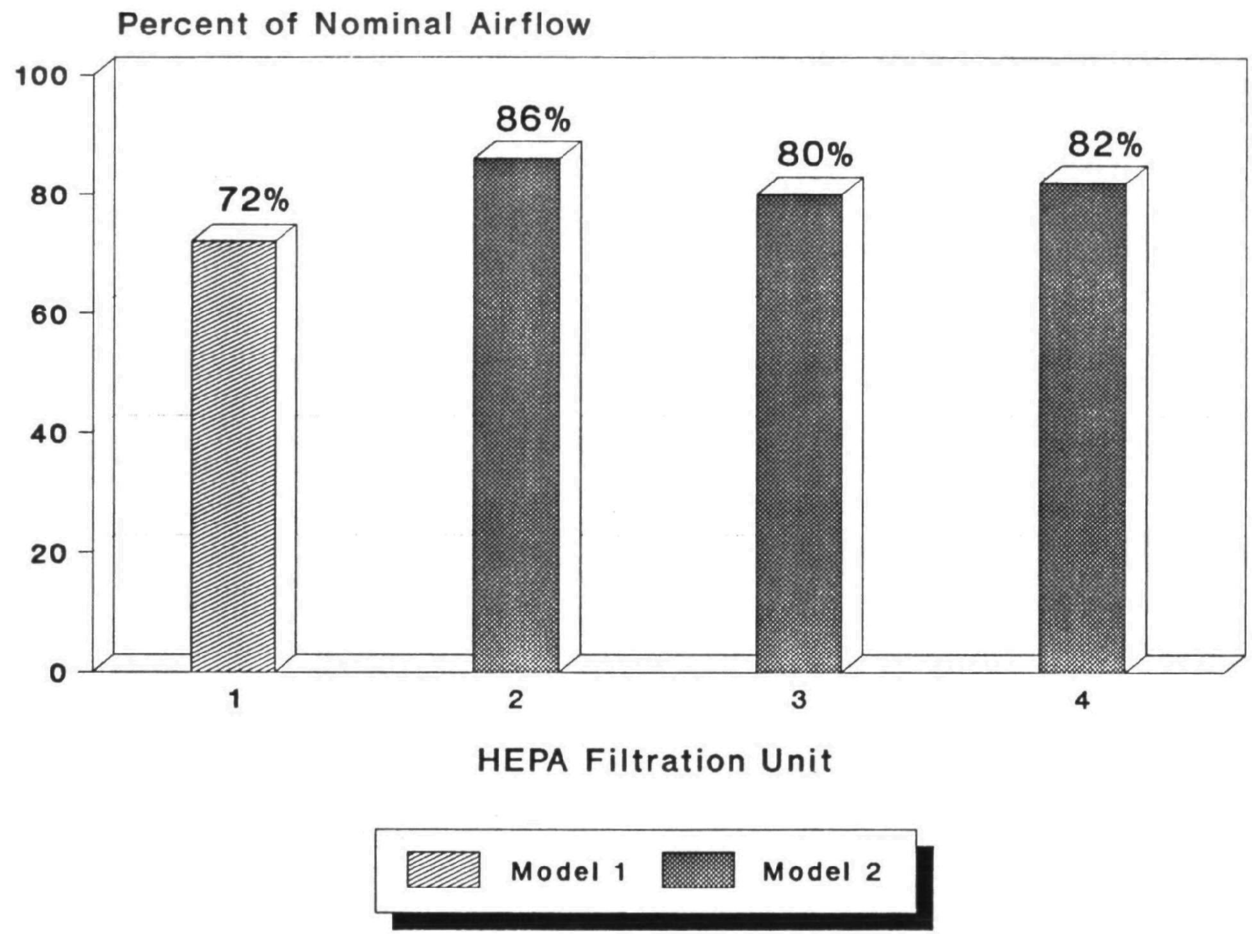


Figure C-1. Airflow performance for HEPA filtration systems operating during final cleanup.

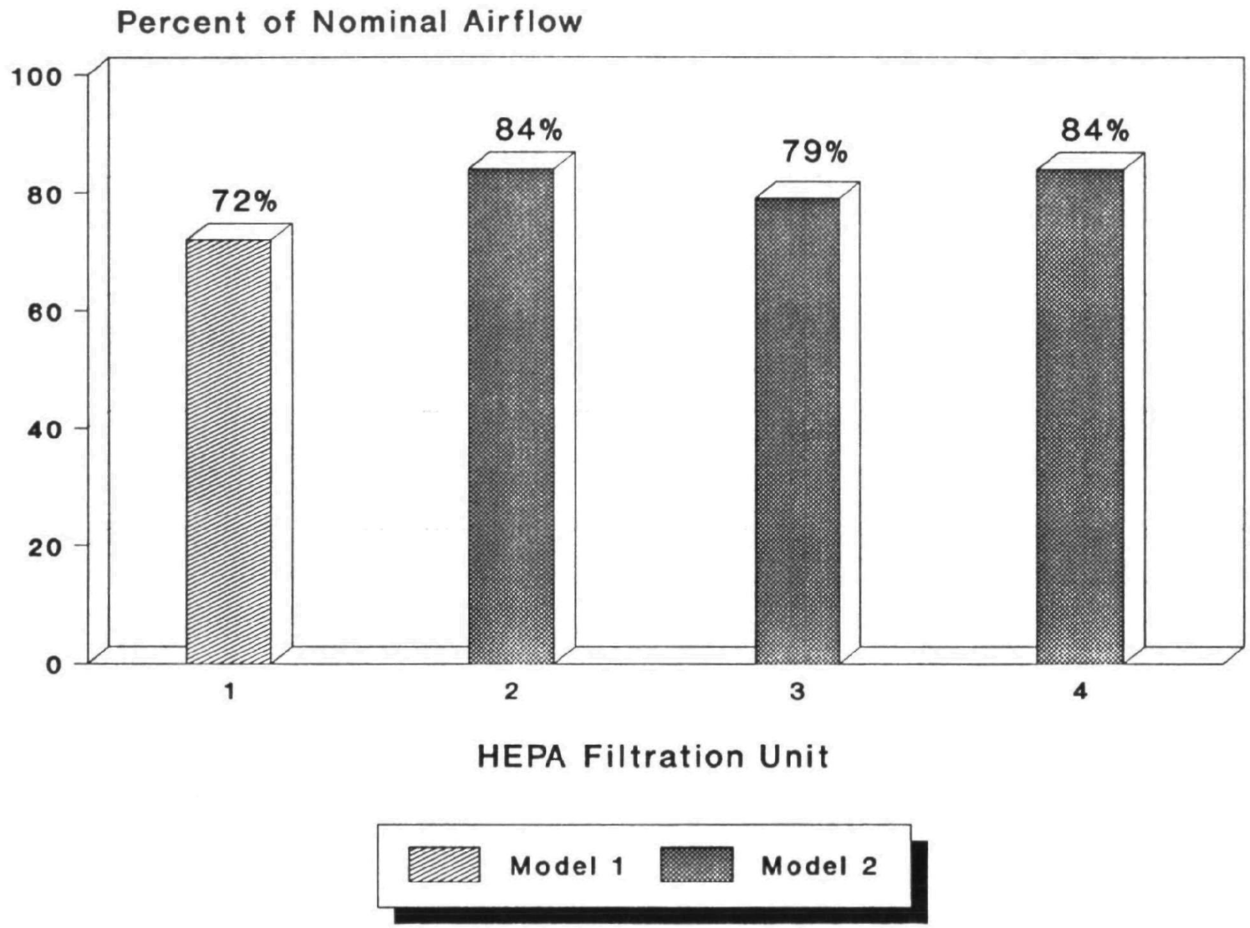


Figure C-2. Airflow performance for HEPA filtration systems operating during AHERA clearance.

The HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility and waste load-out port. Two of the four operating units were positioned along exterior walls to facilitate venting of the exhaust through windows via an interconnected flexible duct. The exhaust of two of the four units was vented through a doorway via an interconnected flexible duct that passed through a classroom outside of the abatement area. This is particularly noteworthy because as the flexible duct for one of the units was torn and a percentage of the exhaust air was released into the building. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor, who was responsible for maintaining the HEPA-filtration units, stated that the prefilters, secondary filters, and HEPA filters were changed before final cleaning was initiated. Thereafter, the prefilters and secondary filters were changed when they became "visibly dirty." The HEPA filters were changed every 600 to 700 hours (as recommended by the manufacturer) or when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls and either full- or half-facepiece air-purifying respirators equipped with dual cartridge HEPA filters.

Cleaning Procedures

Final cleaning began after the removal of the encapsulated plastic sheeting from the walls, floors, and other surfaces. The windows, doors, fixed objects, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The HEPA-filtration units remained in service.

Final cleaning was organized so the workers began in the areas nearest to the personnel decontamination facility and worked away from it. No association appeared to exist between the work direction and the location of HEPA-filtration units.

Final cleaning began with the wire-brushing of abated surfaces (pipes, boilers, tanks, and ventilation ducts) to remove any residual debris from the substrate. A fine-bristle brush, (e.g., a draftsman's brush) was then used to sweep the surfaces, after which they were wet-cleaned with absorbent paper towels dampened in amended water containing a standard surfactant mixture plus a penetrating encapsulant. A bucket containing the amended water with the encapsulant was most often used by a single worker. The paper towels were replaced frequently; however, occasionally they were not replaced until they began to deteriorate as a result of wiping rough surfaces. The amended water was not changed frequently.

After the surfaces had dried, a vacuum equipped with a HEPA filter was used to clean crevices around windows, doors, and shelves; floor-wall interfaces; etc. All other vertical and horizontal surfaces were then wet-cleaned with the amended water mixture described earlier.

The elevated horizontal and vertical surfaces were wiped first, and then all other surfaces were wiped. All of the surfaces except the floors were wiped with absorbent paper towels that had been dampened with the amended water. A bucket of amended water was either used by a single worker or shared by several workers. Although the workers did not appear to wipe the surfaces in any one direction, they approached this effort rather meticulously. Although the paper towels were reused, such reuse appeared to be markedly less than that observed for cotton rags at other sites. The absorbent paper towels seemed to work well on smooth surfaces. The amended water was not changed frequently.

After the walls and other surfaces (plastic-covered fixed objects) had been wet wiped, the floor was mopped with a clean mop head wetted with the amended water mixture. No change in the water was observed during this procedure.

The final cleaning effort involved a complete wet-mopping of the floors with a clean mop head and clean amended water. No aggressive cleaning (i.e., air sweeping of all vertical and horizontal surfaces to dislodge any remaining particulate) was conducted.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered 6-mil-thick standard disposal bags. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers or solidified with a gelling compound. The paper towels and mop heads used during cleaning also were placed in these bags. The bags were not wet-wiped with amended water before being removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an onsite AST, who was the building owner's representative. The AST conducted the visual inspection within 2 hours after notification. The AST identified several areas, particularly around pipe and ventilation duct hangars, that required further cleaning. After these designated areas were recleaned, the AST conducted a final walk-through inspection to assure that the identified areas were clean.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

Some minor debris was found on pipe elbows and joints and on some horizontal surfaces. These elbows, joints, and horizontal surfaces were cleaned while the inspector was in the containment area, and the site subsequently passed the first visual inspection. Four bulk samples were collected from pipe elbows to characterize the residual debris. Asbestos was identified in each sample; however, the samples were not large enough to quantify the percentage of asbestos in each.

AHERA CLEARANCE SAMPLING BY AST

The AHERA clearance sampling was initiated approximately 24 hours after the site passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 30 minutes, which is equivalent to approximately 5 minutes per 270 square feet of floor area. No floor fans were used subsequently to maintain air turbulence during sampling.

The clearance air samples were collected on 25-mm, 0.45-μm pore size, mixed cellulose ester membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The samples were collected at a flow rate of 9.25 liters per minute. The laboratory report, indicates that the samples were analyzed in accordance with the AHERA mandatory TEM method.

Table C-3 presents the results of clearance samples the AST collected inside the abatement area. The samples met the initial AHERA clearance criterion, i.e., an average asbestos concentration below 70 structures per square millimeter (s/mm²). The average asbestos concentration for the five inside samples was 44 s/mm².

TABLE C-3. AHERA CLEARANCE SAMPLE RESULTS

Sample location[a]	Sample volume, liters	Asbestos concentration	
		s/mm²	s/cm³
Inside	2091	0	<0.005[b]
Inside	2091	0	<0.005[b]
Inside	2091	0	<0.005[b]
Inside	2100	29	0.005
Inside	2100	58	0.010

[a] Outside samples and blanks were not analyzed because the average asbestos concentration for the five inside samples was less than 70 s/mm².

[b] Sensitivity of the analytical method.

CASE HISTORY D

SITE DESCRIPTION

This abatement project involved removal of spray-applied asbestos-containing ceiling plaster and thermal system insulation from a single-story school building. The ceiling plaster and its expanded metal lathe substrate were removed from a boiler room, a mechanical storage room, and an electrical distribution room. The thermal system insulation was removed from mechanical equipment (i.e., water tank, pipe joints, elbows, and fittings) in a boiler room.

The project specification indicated that the asbestos content of the ceiling plaster was approximately 20 to 35 percent chrysotile, and that the thermal insulation on the mechanical equipment surfaces was 40 to 60 percent chrysotile. The project specifications did not quantify the amount of asbestos-containing material in each location.

VENTILATION AND NEGATIVE AIR PRESSURE

Three high-efficiency particulate air (HEPA) filtration units were operated during the final cleaning period, and three were operated during AHERA clearance sampling. Table D-1 presents the measured air-intake volume for each unit. The average air-intake volume was 1778 ft^3/min during final cleaning and 1762 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (44,200 ft^3) and the combined average air-intake volumes, the air-exchange rates were approximately 7.2 air changes per hour during final cleaning and 7.1 air changes per hour during AHERA clearance sampling.

Figures D-1 and D-2 compare the measured air-intake volume of each HEPA-filtration unit operating during final cleaning and AHERA clearance sampling, respectively, with the unit's nominal airflow. The actual operating percentages of the nominal airflow ranged from 84 to 97 during final cleaning and 79 to 99 during AHERA clearance sampling. The reason for the significantly higher operating airflow performance of the third air filtration unit is not known.

Table D-2 presents the static pressure differential measured across the containment barriers at two locations. The number of locations tested was determined by available access to the critical containment barriers. The static pressure differential was -0.01 to -0.02 in. water during final cleaning and -0.02 in. water during AHERA clearance sampling.

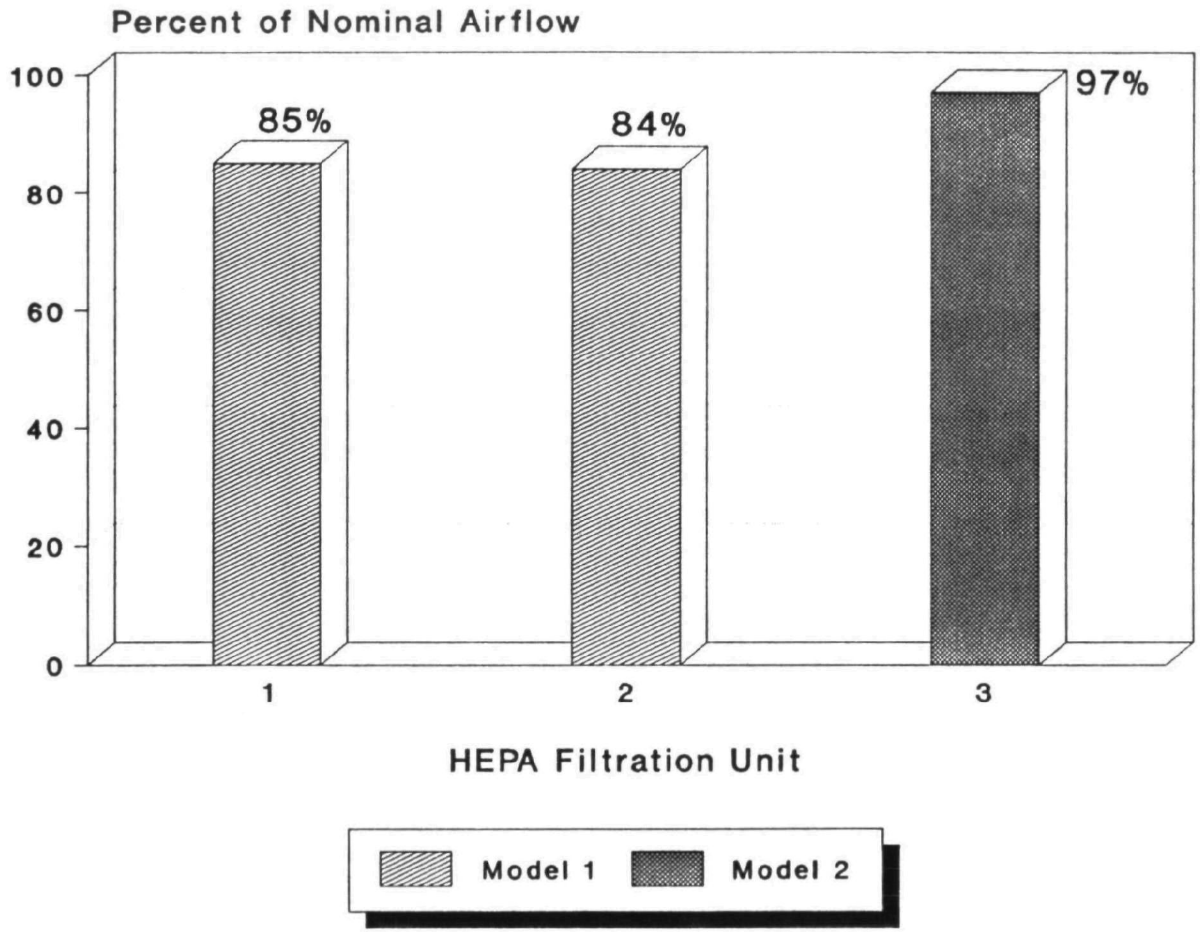


Figure D-1. Airflow performance for HEPA filtration systems operating during final cleanup.

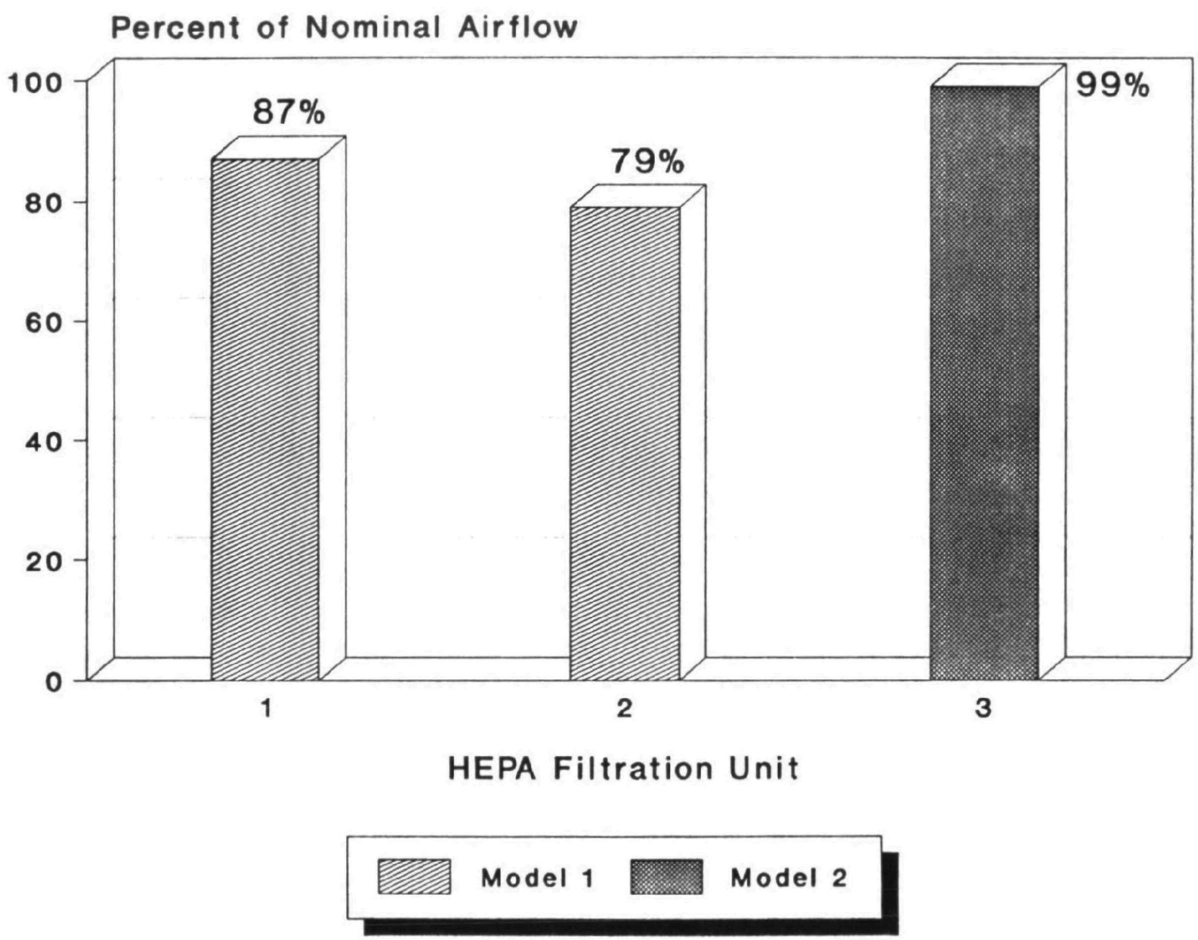


Figure D-2. Airflow performance for HEPA filtration systems operating during AHERA clearance.

TABLE D-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS

Model	Unit	Airflow, ft^3/min Mean	Min.	Max.	Std. dev.	95% Confidence interval Lower	Upper
Final cleaning							
1	1	1709	1428	1882	141	1634	1784
1	2	1680	1344	1848	133	1609	1751
2	3	1946	1719	2101	89	1899	1993
AHERA clearance sampling							
1	1	1735	1344	1865	141	1660	1810
1	2	1580	1176	1848	171	1489	1671
2	3	1970	1815	2101	95	1919	2020

TABLE D-2. STATIC PRESSURE DIFFERENTIALS ACROSS CONTAINMENT BARRIERS (in. water)

Test location	Final cleaning	AHERA clearance
1	-0.02	-0.02
2	-0.01	-0.02

The asbestos safety technician (AST) did not monitor the static pressure differential across the containment barriers. Instead, ventilation smoke tubes were used to check negative pressure visually (i.e., direction of airflow through openings in the containment barrier, such as the decontamination facility and waste load-out port). Reportedly, these qualitative checks were performed each morning before the workshift and twice during the workshift.

The HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility and waste load-out port. The four operating units were positioned along exterior walls to facilitate venting of the exhaust through windows via an interconnected flexible duct. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor, who was responsible for maintaining the HEPA-filtration units, stated that the prefilters, secondary filters, and HEPA filters were changed before final cleaning was initiated. Thereafter, the prefilters and secondary filters were changed when they became "visibly dirty." The HEPA filters were changed every 600 to 700 hours (as recommended by the manufacturer) or when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls, and either full- or half-facepiece air-purifying respirators equipped with dual-cartridge HEPA filters.

Cleaning Procedures

Final cleaning began after the removal of the encapsulated plastic sheeting from the walls, floors, and other surfaces. The critical barriers, windows, doors, fixed objects, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The HEPA filtration units remained in service.

Final cleaning was organized so the workers began in the areas nearest to the personnel decontamination facility and worked away from it. No association appeared to exist between the work direction and the location of the HEPA-filtration units.

Final cleaning began with the spraying of walls, plastic critical containment barriers, and other surfaces with a water mist to remove any loosely bound debris. The resultant asbestos-containing water on the floor was gathered into pools by use of a rubber squeegee. The water was removed with a wet-vacuum that was not equipped with a HEPA filter. The water was containerized in double-layered, 6-mil-thick asbestos-disposal bags, which usually contained plastic that had been removed from the walls and floors.

After the surfaces had dried, several workers conducted a visual inspection of pipe surfaces and wall-ceiling intersections to check for any residual material. If any material was found, the surface was wire-brushed. A HEPA-filtered vacuum was then used to clean crevices around doors, windows, floor-wall intersections, etc.

All of the vertical and horizontal surfaces were then wet-cleaned with amended water containing a standard surfactant mixture plus a penetrating encapsulant. The elevated horizontal and vertical surfaces were wiped first, and then all other surfaces were wiped. All the surfaces except the floors were wiped with cotton rags dampened with the amended water mixture. A bucket of amended water was either used by a single worker or shared by several workers. The workers did not appear to wipe the surfaces in any one direction. The cloth rags were not replaced frequently, particularly during the cleaning of elevated and hard-to-access surfaces. Nor was the amended water changed frequently.

After the walls, windows, and other surfaces (shelves, ledges, plastic-covered fixed objects, etc.) were wet-wiped, the floor was mopped with a clean mop head that was wetted with amended water. No change in the water was observed during this procedure.

Final cleaning involved one complete wet-mopping of floors. Aggressive cleaning (i.e., air sweeping of all vertical and horizontal surfaces to dislodge any remaining particulate) was not conducted.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered 6-mil-thick standard disposal bags. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers or solidified with a gelling compound. The rags and mop heads used during cleaning also were placed in these bags. The bags were not wet-wiped with amended water before being removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an onsite AST, who was the building owner's representative. The AST conducted the visual inspection within 2 hours after notification. The AST did not identify any areas that required further cleaning.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

The New Jersey Department of Health did not perform a visual inspection at this site.

AHERA CLEARANCE SAMPLING BY AST

The AHERA clearance sampling was initiated approximately 6 hours after the site had passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 20 minutes, which is equivalent to approximately 5 minutes per 790 square feet of floor area. No floor fans were used subsequently to maintain air turbulence during sampling.

The clearance air samples were collected on 25-mm, 0.45-μm pore size, mixed cellulose ester membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The samples were collected at an approximate flow rate of 10 liters per minute. The laboratory report indicated the samples were analyzed in accordance with the AHERA mandatory TEM method.

Table D-3 presents the results of the clearance samples the AST collected inside the abatement area. The samples met the initial AHERA clearance criterion; i.e., an average asbestos concentration of less than 70 structures per square millimeter (s/mm^2). The average asbestos concentration for the five inside samples was 0 s/mm^2.

TABLE D-3. AHERA CLEARANCE SAMPLE RESULTS

Sample Location[a]	Sample volume, liters	Asbestos concentration	
		s/mm^2	s/cm^3
Inside	2477	0	<0.002[b]
Inside	2506	0	<0.002[b]
Inside	2554	0	<0.002[b]
Inside	2582	0	<0.002[b]
Inside	2592	0	<0.002[b]

[a] Outside samples and blanks were not analyzed because the average asbestos concentration for the five inside samples was less than 70 s/mm^2.

[b] Sensitivity of the analytical method.

CASE HISTORY E

SITE DESCRIPTION

This abatement project involved removal of approximately 15,000 ft^2 of 2-ft by 4-ft lay-in asbestos-containing acoustical ceiling tiles, and approximately 500 linear feet of mixed-diameter pipe insulation from a single-story school building. The abatement area included corridors, classrooms, offices, and recreational rooms.

The project specification indicated that the asbestos content of the ceiling tiles was approximately 2 to 8 percent amosite, and that of the thermal system insulation was 30 to 40 percent chrysotile.

VENTILATION AND NEGATIVE AIR PRESSURE

Twelve high-efficiency particulate air (HEPA) filtration units were operated during the final cleaning period, and 10 were operated during AHERA clearance sampling. Table E-1 presents the measured air-intake volume for each unit. The average air-intake volume was 1114 ft^3/min during final cleaning and 1348 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (173,000 ft^3) and the combined average air-intake volumes, the air exchange rates were approximately 4.6 air changes per hour during final cleaning and 5.6 air changes per hour during AHERA clearance sampling.

Figures E-1 and E-2 compare the measured air-intake volume of each HEPA-filtration unit operating during final cleaning and AHERA clearance sampling, respectively, with the unit's nominal airflow. The actual operating percentages of the nominal airflow ranged from 52 to 80 during final cleaning and 65 to 87 during AHERA clearance sampling.

Table E-2 presents the static pressure differential measured across the containment barriers at four locations. The number of locations tested was determined by available access to the critical containment barriers. The static pressure differential ranged from -0.01 to -0.02 in. water during final cleaning and was -0.01 in. water during AHERA clearance sampling.

The asbestos safety technician (AST) did not monitor the static pressure differential across the containment barrier. Instead, ventilation smoke tubes were used to check negative pressure visually (i.e., direction of airflow through openings in the containment barrier, such as the decontamination facility and waste load-out port). Reportedly, these qualitative checks were performed each morning before the workshift and once during the workshift.

TABLE E-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS

Model	Unit	Airflow, ft^3/min Mean	Min.	Max.	Std. dev.	95% Confidence interval Lower	Upper
				Final cleaning			
1	1	1512	1176	2184	224	1393	1631
1	2	1601	1344	1848	156	1518	1684
2	3	1342	734	1652	222	1224	1460
2	4	1015	551	1468	237	889	1141
2	5	1193	734	1652	225	1073	1312
2	6	1193	734	1468	215	1078	1307
2	7	1296	734	1468	220	1179	1413
2	8	1273	734	1652	220	1156	1390
3	9	701	567	810	47	661	741
3	10	739	567	851	76	698	780
3	11	732	648	851	62	699	764
3	12	772	567	891	78	731	813
				AHERA clearance sampling			
1	1	1722	1680	1848	59	1690	1754
1	2	1738	1512	1848	114	1677	1798
2	3	1577	1285	1927	223	1458	1696
2	4	1537	1101	1835	204	1428	1645
2	5	1262	734	1468	204	1153	1370
2	6	1640	1101	2019	220	1523	1757
2	7	1583	1285	1835	170	1492	1673
3	8	813	729	891	48	787	838
3	9	795	648	891	68	758	831
3	10	818	729	891	33	800	835

TABLE E-2. STATIC PRESSURE DIFFERENTIALS ACROSS CONTAINMENT BARRIERS (in. water)

Test location	Final cleaning	AHERA clearance
1	-0.01	-0.01
2	-0.02	-0.01
3	-0.01	-0.01
4	-0.01	-0.01

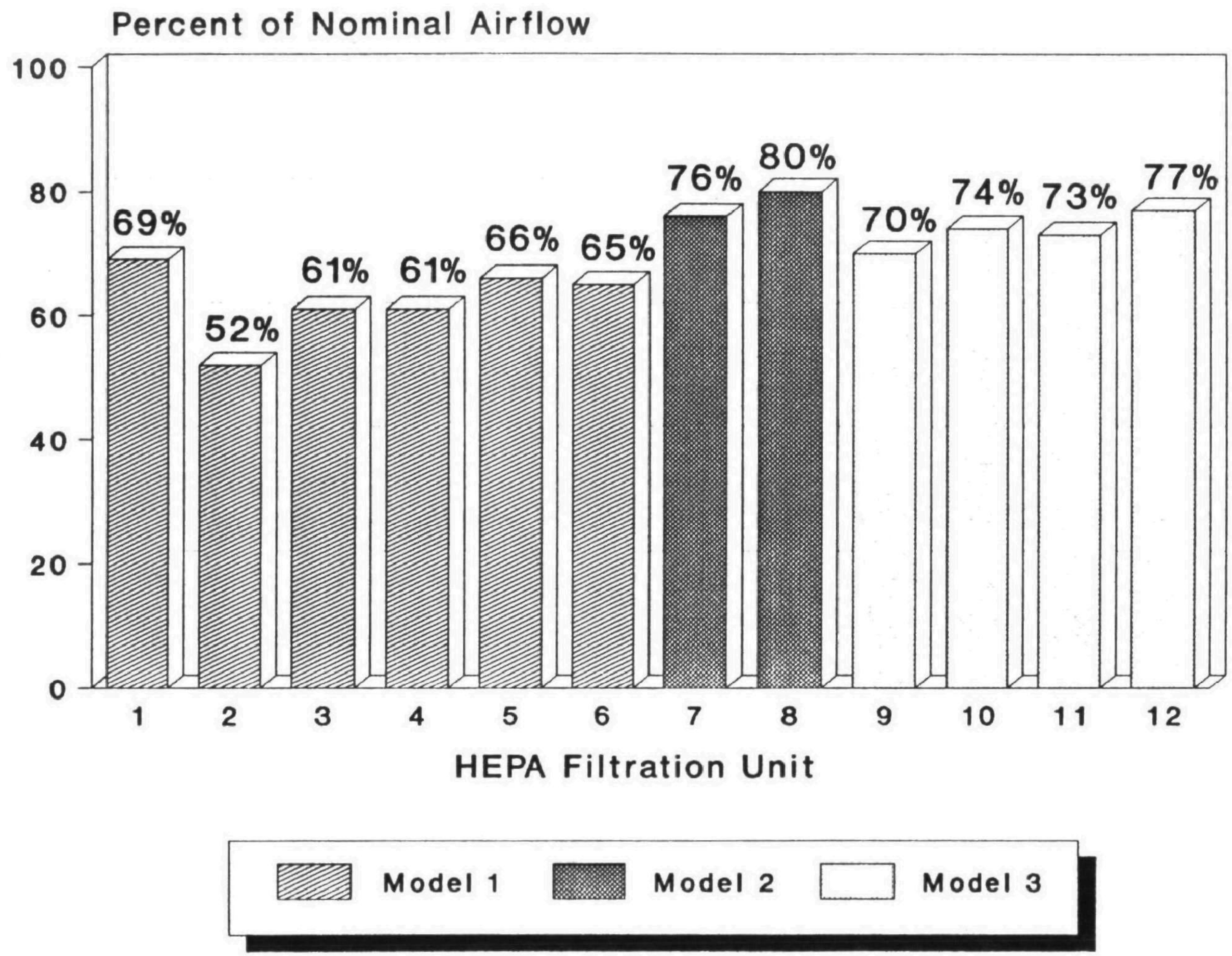


Figure E-1. Airflow performance for HEPA filtration systems operating during final cleanup.

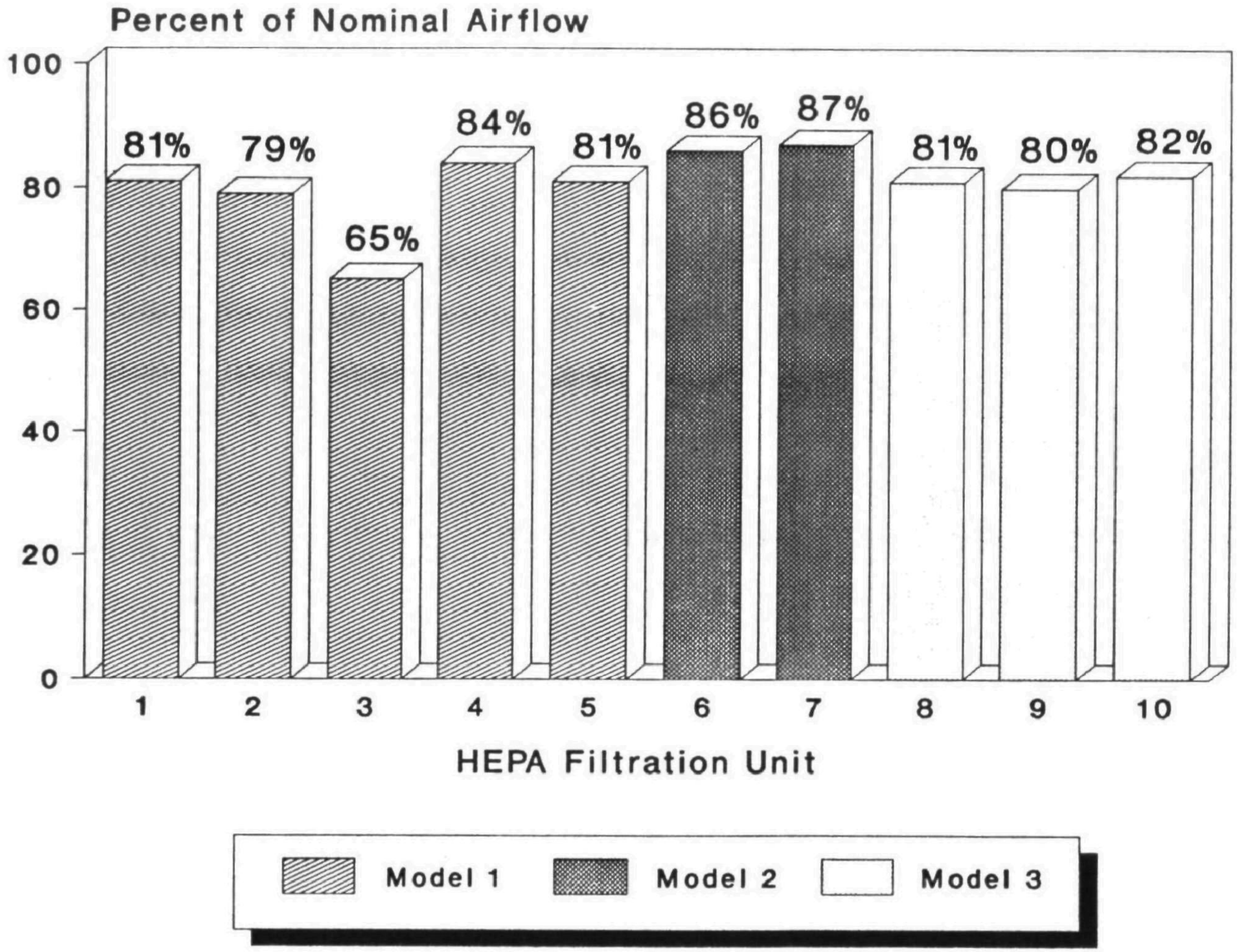


Figure E-2. Airflow performance for HEPA filtration systems operating during AHERA clearance.

The HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility and waste load-out port. The 11 operating units were positioned along exterior walls to facilitate venting of the exhaust through windows via an interconnected flexible duct. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor, who was responsible for maintaining the HEPA-filtration units, stated that the prefilters, secondary filters, and HEPA filters were changed before final cleaning was initiated. Thereafter, the prefilters were changed when they became "visibly dirty," and the secondary filters were changed about every 48 hours. The HEPA filters were changed every 500 to 700 hours (as recommended by the manufacturer) or when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls and either full- or half-facepiece air-purifying respirators equipped with dual-cartridge HEPA filters.

Cleaning Procedures

Final cleaning began after the encapsulated plastic sheeting was removed from the walls, floors, and other surfaces. The critical barriers, windows, doors, student wall lockers, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The HEPA filtration units remained in service.

Final cleaning was organized so the workers began in the areas farthest from the personnel decontamination facility and worked toward it. No association appeared to exist between the work direction and the location of HEPA-filtration units.

Final cleaning began with the wet-cleaning of all of vertical and horizontal surfaces with amended water. The contractor reportedly prepared the amended water solution by mixing approximately 1 ounce each of 50 percent polyoxyethylene ester and 50 percent polyoxyethylene ether in 5 gallons of water.

The T-bar grid network for the suspended ceiling tiles and vertical surfaces were wiped first, followed by all the other surfaces. The surfaces, excluding floors, were wiped with absorbent paper towels dampened with amended water. Each worker had a bucket of amended water to use. The workers did not appear to wipe the vertical surfaces in any one direction. The paper towels were not replaced frequently, especially during the cleaning of the T-bar grid network. Nor was the amended water changed frequently.

After the walls, windows, and other surfaces (shelves, ledges, counters, plastic-covered HEPA-filtration systems and associated exhaust ducts, fixed objects, etc.) were wet-wiped, the floor was mopped with a clean mop head wetted with amended water. No change in water was observed during this procedure.

Final cleaning involved one complete wet-mopping of floors. No aggressive cleaning (i.e., air sweeping of all vertical and horizontal surfaces to dislodge any remaining particulate) was conducted.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered, 6-mil-thick, standard disposal bags. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers or solidified with a gelling compound. The paper towels and mop heads used during cleaning were also placed in these bags. The bags were not wet-wiped with amended water before being removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an onsite AST, who was the building owner's representative. The AST conducted the visual inspection within 2 hours after notification. The AST did not identify any areas that required further cleaning.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

The New Jersey Department of Health did not perform a final visual inspection at this site.

AHERA CLEARANCE SAMPLING BY AST

First Attempt

The AHERA clearance sampling was initiated approximately 24 hours after the site had passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 30 minutes, which is equivalent to approximately 5 minutes per 3200 square feet of floor area. Six box-type floor fans with 18-inch blades were distributed throughout the abatement area and subsequently used to maintain air turbulence during sampling.

The clearance air samples were collected on 25-mm, 0.4-µm pore size, polycarbonate membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The samples were collected at flow rates ranging from 9 to 10 liters per minute. The laboratory report indicated the samples were analyzed in accordance with the AHERA mandatory TEM method.

Table E-3 presents the results of clearance samples the AST collected inside the abatement area. The samples did not meet the initial AHERA clearance criterion of an average asbestos concentration of less than 70 structures per square millimeter (s/mm²); the mean asbestos concentration in the inside samples was actually 156 s/mm². The AST did not analyze the five samples collected outside of the abatement area; thus, the Z-test comparison was not conducted.

TABLE E-3. AHERA CLEARANCE SAMPLE RESULTS--FIRST ATTEMPT

Sample location[a]	Sample volume, liters	Asbestos concentration	
		s/mm²	s/cm³
Inside	2851	312	0.042
Inside	2870	31	0.004
Inside	2890	250	0.034
Inside	2851	125	0.017
Inside	2860	62	0.008

[a] Outside samples and blanks were not analyzed.

Before recleaning of the site was begun, all surfaces, particularly the T-bar grid network, were swept with a 1-horsepower leaf blower for approximately 60 minutes. Recleaning of the site was initiated approximately 16 hours later. The site was then cleaned by the same procedures used during the first cleaning, except that the T-bar grid network was thoroughly cleaned with a HEPA-filtered vacuum prior to the wet-cleaning with amended water. Hard-to-reach areas, including floor-wall intersections and crevices around doors, were cleaned with a HEPA-filtered vacuum.

Second Attempt

The AHERA clearance sampling was initiated approximately 28 hours after the site had passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 15 minutes, which is equivalent to approximately 5 minutes per 6400 square feet of floor area or 5 minutes per 58,000 cubic feet of work space. Six box-type floor fans with 18-inch blades were distributed throughout the abatement area and subsequently used to maintain air turbulence during sampling.

The clearance air samples were collected on 25-mm, 0.4-µm pore size, polycarbonate membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The samples were collected at flow rates ranging from 9 to 10 liters per minute. The laboratory report indicated that the samples were analyzed in accordance with the AHERA mandatory TEM method.

Table E-4 presents the results of the AST's clearance samples collected inside the abatement area. The samples met the initial AHERA clearance criterion by having an asbestos concentration of less than 70 s/mm². The average asbestos concentration for the five inside samples was 26 s/mm².

TABLE E-4. AHERA CLEARANCE SAMPLE RESULTS--SECOND ATTEMPT

Sample location[a]	Sample volume, liters	Asbestos concentration	
		s/mm^2	s/cm^3
Inside	2264	26	0.004
Inside	2310	26	0.004
Inside	2277	0	0.004[b]
Inside	2287	0	0.004[b]
Inside	2264	0	0.004[b]

[a] Outside samples and blanks were not analyzed because the average asbestos concentration for the five inside samples was less than 70 s/mm^2.

[b] Sensitivity of the analytical method.

CASE HISTORY F

SITE DESCRIPTION

This abatement project involved removal of approximately 2200 ft^2 of thermal system insulation from a single-story school building. The abatement involved removal of asbestos-containing thermal insulation materials on mechanical equipment (i.e., boilers, boiler breeching, and pipes). The project specification indicated that the asbestos content of the thermal insulation was approximately 30 to 40 percent chrysotile.

VENTILATION AND NEGATIVE AIR PRESSURE

One high-efficiency particulate air (HEPA) filtration unit was operated during the final cleaning period, and one was operated during AHERA clearance sampling. Table F-1 presents the measured air-intake volume for each unit. The average air-intake volume was 1428 ft^3/min during final cleaning and 1428 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (6674 ft^3) and the average air-intake volumes, the air exchange rates were approximately 12.8 air changes per hour during final cleaning and 12.8 air changes per hour during AHERA clearance sampling.

TABLE F-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS

Model	Unit	Airflow, ft^3/min Mean	Min.	Max.	Std. dev.	95% Confidence interval Lower	Upper
Final cleaning							
1	1	1428	1008	1848	307	1264	1592
AHERA clearance sampling							
1	1	1428	1008	1848	277	1280	1576

Figure F-1 compares the measured air-intake volume for each HEPA-filtration unit operating during final cleaning and AHERA clearance sampling, with the unit's nominal air flow.

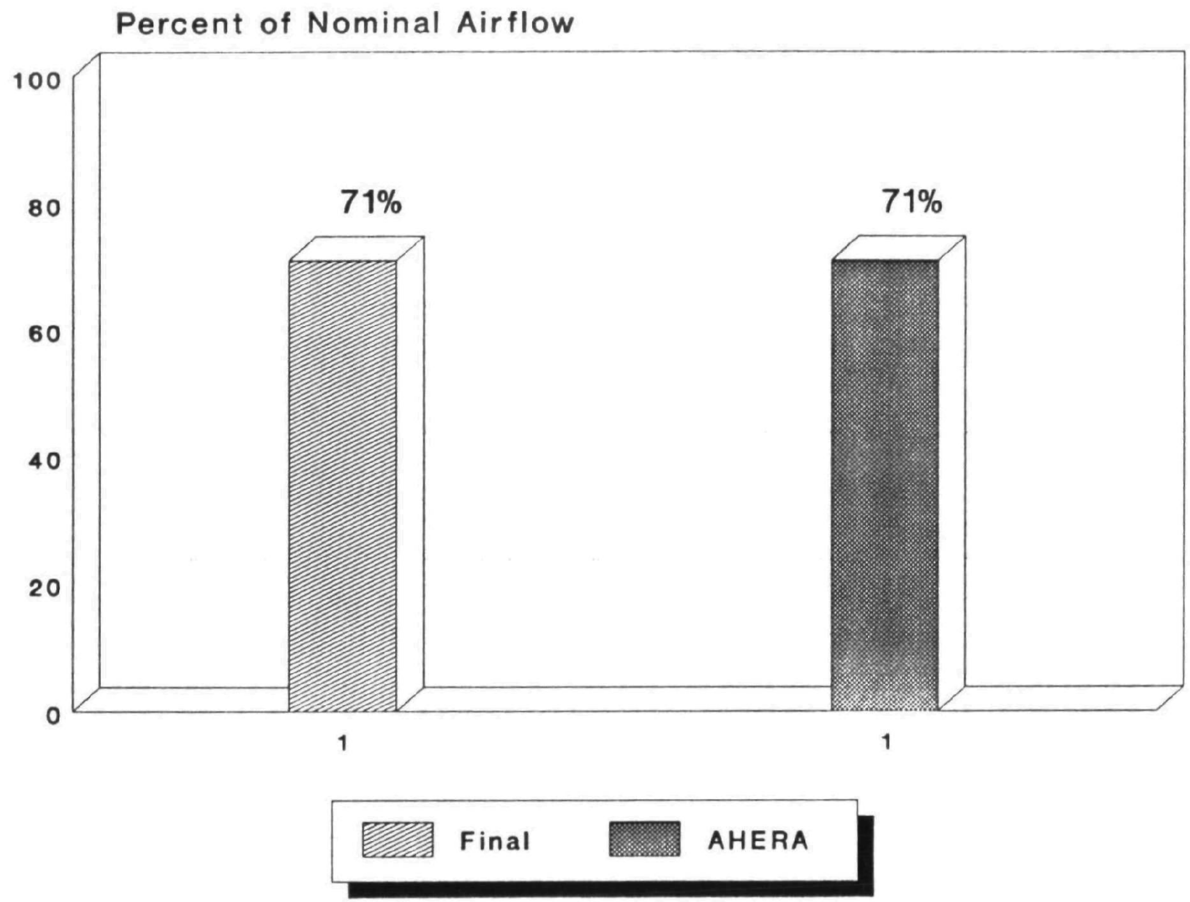


Figure F-1. Airflow performance for HEPA filtration systems operating during final cleanup and AHERA clearance.

Table F-2 presents the static pressure differential measured across the containment barriers at one location. The number of locations tested was determined by available access to the critical containment barriers. The static pressure differential was -0.02 in. water during final cleaning and -0.02 in. water during AHERA clearance sampling.

TABLE F-2. STATIC PRESSURE DIFFERENTIALS ACROSS CONTAINMENT BARRIERS (in. water)

Test location	Final cleaning	AHERA clearance
1	-0.02	-0.02

The asbestos safety technician (AST) did not monitor the static pressure differential across the containment barrier. Instead, ventilation smoke tubes were used to check the negative pressure visually (i.e., direction of airflow through openings in the containment barrier, such as the decontamination facility and waste load-out port). Reportedly, these qualitative checks were performed twice during a workshift, once in the morning, and once in the afternoon.

The HEPA-filtration unit was placed so that the makeup air entered the work area through the personnel decontamination facility and waste load-out port. The operating unit was positioned along an exterior wall to facilitate venting of the exhaust through a window via an interconnected flexible duct. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor, who was responsible for maintaining the HEPA-filtration units, stated that the prefilters, secondary filters, and HEPA filters were changed before final cleaning was initiated. Thereafter, the prefilters and secondary filters were changed when they became "visibly dirty." The HEPA filters were changed every 600 to 700 hours (as recommended by the manufacturer) or when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls and either full- or half-facepiece air-purifying respirators equipped with dual-cartridge HEPA filters.

Cleaning Procedures

Final cleaning began after the plastic sheeting was removed from the walls, floors, and other surfaces. The critical barriers, windows, doors, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The HEPA-air filtration units remained in service.

Final cleaning was organized so the workers began in the areas farthest from the personnel decontamination facility and worked toward it. No association appeared to exist between the work direction and the location of the HEPA-filtration units.

Final cleaning began with the spraying of walls, plastic critical containment barriers, and other surfaces with water to remove any loosely bound debris. The resultant asbestos-containing water on the floor was gathered into pools by use of a rubber squeegee. The bulk of the pooled water was scooped up with plastic-bladed shovels. The water was containerized in double-layered, 6-mil-thick, asbestos-disposal bags, which usually contained plastic that had been removed from the walls and floors. The residual water removed with a wet vacuum was also placed in these bags.

All of the vertical and horizontal surfaces were then wet-cleaned with amended water. The contractor reportedly prepared the amended water solution by mixing approximately 1 ounce each of 50 percent polyoxyethylene ester and 50 percent polyoxyethylene ether in 5 gallons of water.

The elevated horizontal and vertical surfaces were wiped first, followed by all the other surfaces. All of the surfaces except the floors were wiped with paper towels dampened with amended water. A bucket of amended water was either used by a single worker or shared by several workers. The workers did not appear to wipe the surfaces in any one direction. The paper towels were not replaced frequently, especially during the cleaning of elevated and hard-to-access surfaces. Nor was the amended water changed frequently.

After the walls, windows, and other surfaces were wet-wiped, the floor was mopped with a clean mop head wetted with amended water. No changes in the water was observed during this procedure.

No aggressive cleaning (i.e., air sweeping of all vertical and horizontal surfaces to dislodge any remaining particulate) was conducted.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered, 6-mil-thick, standard disposal bags. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers or solidified with a gelling compound. The paper towels and mop heads used during cleaning also were placed in these bags. The bags were not wet-wiped with amended water before being removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an onsite AST, who was the building owner's representative. The AST conducted the visual inspection within 1 hour after notification. The AST identified the following areas that required further cleaning: 1) debris in recessed areas on the side of the boiler, and 2) debris around valves. After these areas were recleaned, the AST conducted a final walk-through inspection to assure that the identified areas were clean.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

The New Jersey Department of Health did not perform a final visual inspection at this site.

AHERA CLEARANCE SAMPLING

The AHERA clearance sampling was initiated approximately 18 hours after the site passed the visual inspection conducted by the AST. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 4 minutes, which is equivalent to approximately 5 minutes per 700 ft^2 of floor area. One box-type floor fan with 18-inch blades was subsequently used to maintain air turbulence during sampling. Because this abatement project involved the removal of less than 3000 ft^2 of asbestos-containing material, AHERA allows the use of Phase Contrast Microscopy (PCM) to analyze the air samples collected to clear the site. The AST collected only one sample inside the work area for clearance purposes. This practice is not in accordance with the AHERA clearance protocol, i.e., five samples must be collected inside the abatement area and each must have a fiber concentration of less than or equal to 0.01 f/cm^3 of air to pass the clearance test. This sample consisted of a 25-mm, 0.4-μm pore size, polycarbonate membrane filter contained in a three-piece cassette with a 50-mm conductive cowl. The sample was collected at a flow rate of approximately 10 liters per minute. The laboratory report indicates that the samples were analyzed in accordance with the NIOSH Method 7400, which uses PCM.

Table F-3 presents the results of the AST's clearance sample collected inside the abatement area. The asbestos concentration for this sample was less than the AHERA limit of 0.01 fiber per cubic centimeter.

TABLE F-3. AHERA CLEARANCE SAMPLE RESULTS

Sample location	Sample volume, liters	Asbestos concentration	
		f/mm^2	f/cm^3
Inside	2000	19	0.004

CASE HISTORY G

SITE DESCRIPTION

This abatement project involved removal of asbestos-containing thermal insulation materials on mechanical equipment (i.e., boiler lagging, boiler breeching, and boiler gasket) in a two-story school building. The project specification indicated that asbestos content of the boiler lagging was approximately 10 to 15 percent chrysotile and 35 to 40 percent amosite; the asbestos content of the boiler breeching was 25 to 30 percent chrysotile and 30 to 35 percent amosite; and the asbestos content of the boiler gasket was 70 to 75 percent chrysotile. The project specification did not quantify the amount of asbestos-containing material in each location.

VENTILATION AND NEGATIVE AIR PRESSURE

Two high-efficiency particulate air (HEPA) filtration units were operated during the final cleaning period, and two were operated during AHERA clearance sampling. Table G-1 presents the measured air-intake volume for each unit. The average air-intake volume was 1713 ft^3/min during final cleaning and 1681 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (23,000 ft^3) and the combined average air-intake volumes, the air exchange rates were approximately 8.9 air changes per hour during final cleaning and 8.7 air changes per hour during AHERA clearance sampling.

TABLE G-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS

		Airflow, ft^3/min				95% Confidence interval	
Model	Unit	Mean	Min.	Max.	Std. dev.	Lower	Upper
Final cleaning							
1	1	1475	1400	1600	97	1423	1527
1	2	1950	1800	2200	112	1890	2010
AHERA clearance sampling							
1	1	1575	1400	1800	97	1523	1627
1	2	1788	1600	2000	111	1728	1847

Figures G-1 and G-2 compare the measured air-intake volume for each HEPA-filtration unit operating during final cleaning and AHERA clearance sampling, respectively, with the unit's nominal airflow. The actual operating percentages of the nominal air flow were 74 and 98 during final cleaning and 79 and 89 during AHERA clearance sampling. The reason for the significantly higher operating airflow performance of the second air filtration unit is not known.

Table G-2 presents the static pressure differential measured across the containment barriers at one location. The number of locations tested was determined by available access to the critical containment barriers. The static pressure differential was -0.01 in. water during final cleaning and -0.01 in. water during AHERA clearance sampling.

TABLE G-2. STATIC PRESSURE DIFFERENTIALS
ACROSS CONTAINMENT BARRIERS
(in. water)

Test location	Final cleaning	AHERA clearance
1	-0.01	-0.01

The asbestos safety technician (AST) did not monitor the static pressure differential across the containment barriers. Instead, ventilation smoke tubes were used to check the negative pressure visually (i.e., direction of airflow through openings in the containment barrier, such as the decontamination facility and waste load-out port). Reportedly, these qualitative checks were performed each morning.

The HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility and waste load-out port. The two operating units were positioned along exterior walls to facilitate venting of the exhaust through windows via an interconnected flexible duct. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor, who was responsible for maintaining the HEPA-filtration units, stated that the prefilters and secondary filters were changed before final cleaning was initiated. The HEPA filters were changed at the beginning of the project. Thereafter, the prefilters were changed daily and the secondary filters were changed when they became "visibly dirty." The HEPA filters were changed every 600 to 700 hours (as recommended by the manufacturer) or when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

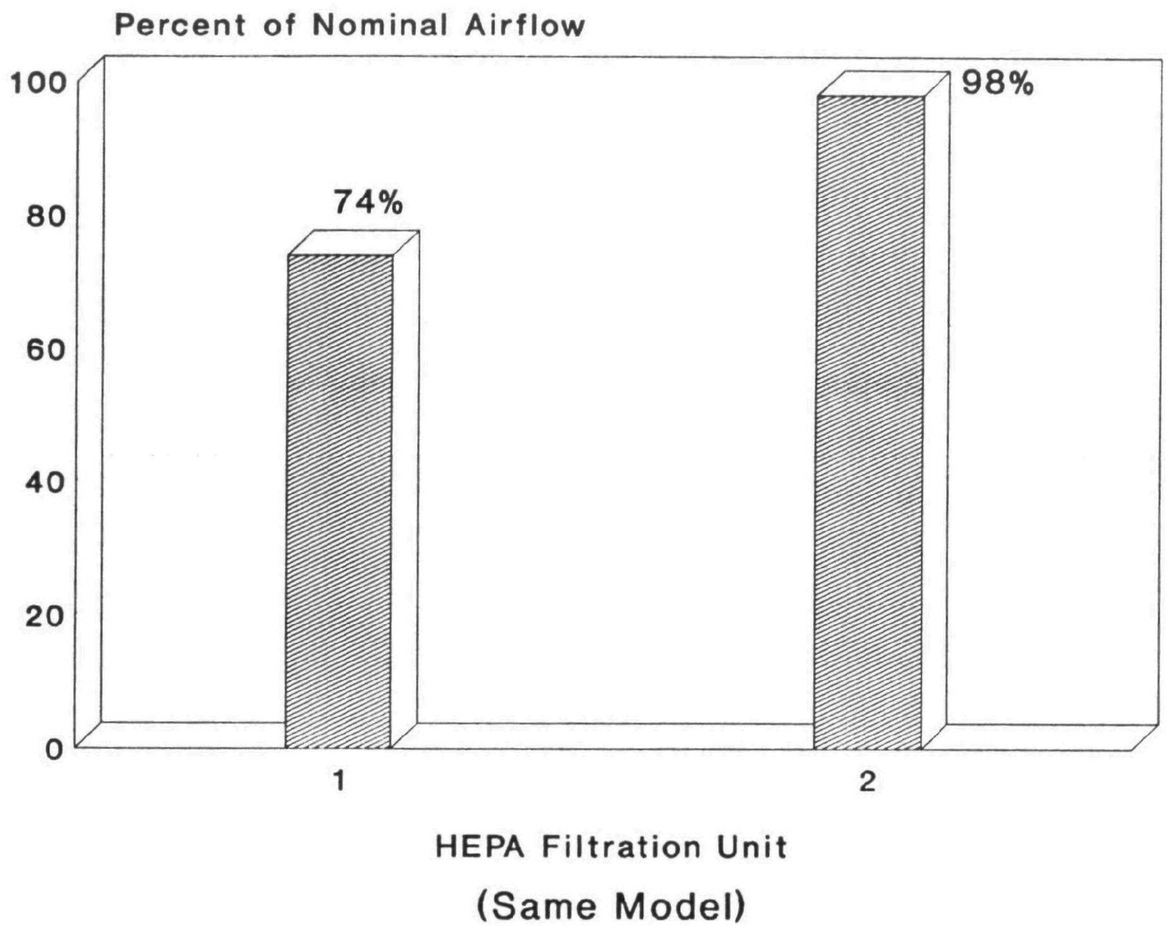


Figure G-1. Airflow performance for HEPA filtration systems operating during final cleanup.

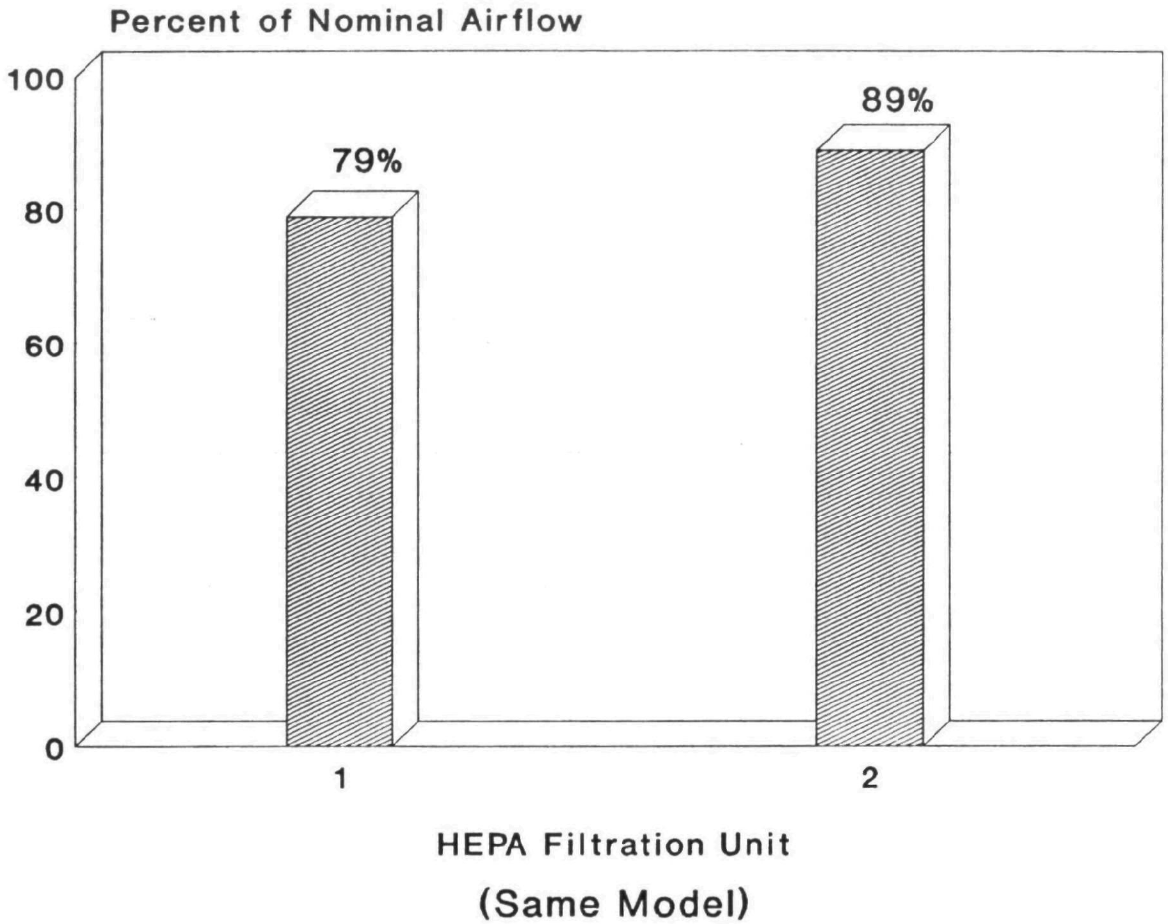


Figure G-2. Airflow performance for HEPA filtration systems operating during AHERA clearance.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls, and either full- or half-facepiece air-purifying respirators equipped with dual-cartridge HEPA efficiency particulate air filters.

Cleaning Procedures

Final cleaning began after the encapsulated plastic sheeting was removed from the walls, floors, and other surfaces. The windows, doors, stationary objects, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The HEPA filtration units remained in service.

Final cleaning began with the brushing of abated surfaces to remove any visible debris on the substrate. A vacuum equipped with a HEPA filter was then used to clean these surfaces and other areas, including crevices around electrical outlets, floor-wall intersections, etc. All of the vertical and horizontal surfaces were then sprayed with water. The bulk of the pooled water was scooped up with plastic-bladed shovels, which worked surprisingly well. The water was containerized in double-layered, 6-mil-thick, asbestos-disposal bags, which usually contained plastic that had been removed from the walls and floors. The residual water removed with a wet vacuum also was placed in these bags.

All of the vertical and horizontal surfaces were then wet-cleaned with amended water. The contractor reportedly prepared the amended water solution by mixing approximately 2 ounces each of 50 percent polyoxyethylene ester and 50 percent polyoxyethylene ether in 5 gallons of water.

The elevated horizontal and vertical surfaces were wiped first, and then all other surfaces. All the surfaces except the floors were wiped with cotton rags dampened with amended water. A bucket of amended water was either used by a single worker or shared by several workers. The workers did not appear to wipe the surfaces in any one direction. The cloth rags were not replaced frequently, particularly during the cleaning of elevated and hard-to-access surfaces. Nor was the amended water changed frequently.

After the surfaces were wet-wiped, the floor was mopped with a clean mop head wetted with amended water. No change in the water was observed during this procedure.

Final cleaning involved one complete wet-cleaning of the floors. No aggressive cleaning (i.e., air sweeping of all vertical and horizontal surfaces to dislodge any remaining particulate) was conducted.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered, 6-mil-thick, standard disposal bags. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers or solidified with a gelling compound. The rags and mop heads used during cleaning also were placed in these bags. The bags were not wet-wiped with amended water before being removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an onsite AST, who was the building owner's representative. The AST conducted a visual inspection within 1 hour after notification. The AST identified the presence of debris on several pipe valves. After the designated areas were recleaned, the AST conducted a final walk-through inspection assure that the identified areas were clean.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

The New Jersey Department of Health did not perform a visual inspection of this site.

AHERA CLEARANCE SAMPLING BY AST

First Attempt

The AHERA clearance sampling was initiated approximately 2 hours after the site had passed a visual inspection conducted by the AST. The AST did not conduct aggressive air sweeping of vertical and horizontal surfaces; however, two box-type floor fans with 18-inch blades were used to create air turbulence during the sampling.

The clearance air samples were collected on 25-mm, 0.4-µm pore size, polycarbonate membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The AST stated that the polycarbonate filters were checked for background asbestos contamination prior to sampling. The samples were collected at flow rates ranging from 9 to 10 liters per minute. The laboratory report indicates that the samples were analyzed in accordance with the AHERA mandatory TEM method.

Table G-3 presents the results of the AST's clearance samples collected inside the abatement area. The samples did not pass the initial AHERA clearance criterion of less than 70 structures per square millimeter (s/mm^2). The actual mean asbestos concentration for the inside samples was 279 s/mm^2; therefore, the five outside samples (4 in the perimeter of the abatement area and one outdoors) and three field blanks were analyzed. The AHERA z-test was used to compare the five inside samples and five outside samples. Because the calculated Z statistic (1.76) was greater than the AHERA limit of 1.65, recleaning was required.

The recleaning included a general wet-cleaning of most surfaces with cotton rags dampened with amended water, limited vacuuming of crevices, and wet-mopping of the floor with amended water.

TABLE G-3. AHERA CLEARANCE SAMPLE RESULTS--FIRST ATTEMPT

Sample location	Sample volume, liters	Asbestos concentration	
		s/mm²	s/cm³
Inside	1852	386	0.074
Inside	1823	186	0.036
Inside	1809	253	0.058
Inside	1822	372	0.072
Inside	1820	200	0.038
Outside	1854	190	0.037
Outside	1834	204	0.039
Outside	1820	70	0.013
Outside	1847	54	0.010
Outside	1847	109	0.020
Blank	-	53	-
Blank	-	40	-
Blank	-	67	-

Second Attempt

The AHERA clearance sampling was initiated approximately 3 hours after the site had passed the AST's visual inspection. The AST did not conduct aggressive air sweeping of vertical and horizontal surfaces; however, two box-type floor fans with 18-inch blades were used to create air turbulence during sampling.

The AST collected the same number of samples and used the same sampling and analytical methodology as during the first clearance attempt.

Table G-4 presents the results of the clearance samples the AST collected inside the abatement area. The samples did not pass the initial AHERA clearance criterion of 70 s/mm^2; the mean asbestos concentration for the inside samples was actually 250 s/mm^2. The AST did not analyze the five samples collected outside the abatement area; therefore, the Z-test comparison was not conducted.

Failing the AHERA clearance a second time resulted in a thorough recleaning of the site. This included vacuuming of all abated surfaces, floor-wall intersections, areas along electrical conduits and outlets, valves, etc. The vacuuming was followed by a complete spraying of all vertical and horizontal surfaces with water and a wet cleaning with cotton rags dampened with amended water.

TABLE G-4. AHERA CLEARANCE SAMPLE RESULTS--SECOND ATTEMPT

Sample location[a]	Sample volume, liters	Asbestos concentration	
		s/mm^2	s/cm^3
Inside	1852	203	0.039
Inside	1823	44	0.008
Inside	1809	334	0.077
Inside	1822	378	0.073
Inside	1820	291	0.067
Blank	-	149	-
Blank	-	60	-
Blank	-	104	-

[a] Outside samples were not analyzed.

Third Attempt

The AHERA clearance sampling was initiated approximately one hour after the site passed the AST's visual inspection. The AST did not conduct aggressive air sweeping of vertical and horizontal surfaces; however, two box-type floor fans with 18-inch blades were used to create air turbulence during sampling.

The AST collected the same number of samples and used the same sampling and analytical methodology as in the first and second clearance attempts.

Table G-5 presents the results of the AST's clearance samples collected inside the abatement area. The samples passed the AHERA prescreening clearance criterion (i.e., an average asbestos concentration of less than 70 s/mm^2); the average asbestos concentration for the five inside samples was 46 s/mm^2.

TABLE G-5. AHERA CLEARANCE SAMPLE RESULTS--THIRD ATTEMPT

Sample location[a]	Sample volume, liters	Asbestos concentration	
		s/mm^2	s/cm^3
Inside	1732	53	0.012
Inside	1699	35	0.008
Inside	1743	35	0.008
Inside	1743	70	0.016
Inside	1690	35	0.008

[a] Outside samples and blanks were not analyzed because average asbestos concentration for the five inside samples was less than 70 s/mm^2.

CASE HISTORY H

SITE DESCRIPTION

This abatement project involved removal of asbestos-containing acoustical ceiling plaster, spray-applied fireproofing, and mixed diameter pipe insulation from a single-story school building. The abatement area included corridors, adjacent vestibules, classrooms, offices, and recreational rooms.

The project specification stated that the removal involved approximately 1600 ft^2 of fireproofing containing 25 to 50 percent chrysotile, approximately 21,000 ft^2 of acoustical plaster containing 10 to 25 percent chrysotile, and approximately 100 linear feet of air-cell-paper insulation containing 40 to 60 percent chrysotile.

VENTILATION AND NEGATIVE AIR PRESSURE

Five high-efficiency particulate air (HEPA) filtration units were operated during the final cleaning period, and five were operated during AHERA clearance sampling. Table H-1 presents the measured air-intake volume of each unit. The average air-intake volume was 1487 ft^3/min during final cleaning and 1400 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (95,500 ft^3) and the combined average air-intake volumes, the air exchange rates were approximately 4.7 air changes per hour during final cleaning and 4.4 air changes per hour during AHERA clearance sampling.

Figures H-1 and H-2 compare the measured air-intake volume of each HEPA-filtration unit operating during final cleaning and AHERA clearance sampling, respectively, with the unit's nominal airflow. The actual operating percentages of the nominal airflow ranged from 67 to 83 during final cleaning and from 65 to 72 during AHERA clearance sampling.

Table H-2 presents the static pressure differential measured across the containment barriers at four locations. The number of locations tested was determined by available access to the critical containment barriers. The static pressure differential ranged from -0.01 to -0.02 in. water during final cleaning and - 0.01 to -0.02 in. water during AHERA clearance sampling. The increased differential pressure is most likely attributable to the additional number of HEPA-filtration units that were operating.

The asbestos safety technician (AST) did not monitor the static pressure differential across the containment barrier. Instead, ventilation smoke tubes were used to check the negative pressure visually (i.e., direction of

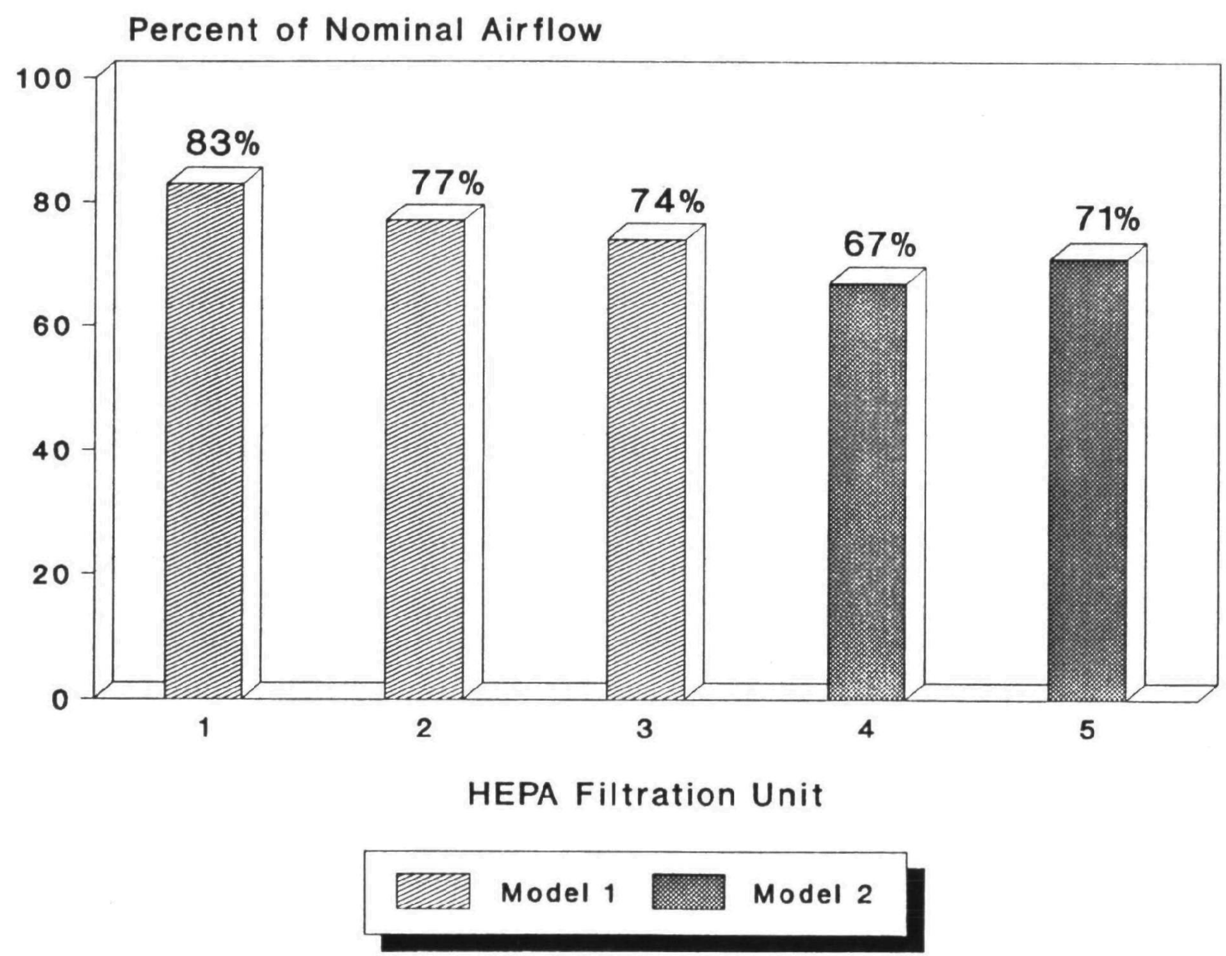


Figure H-1. Airflow performance for HEPA filtration systems operating during final cleanup.

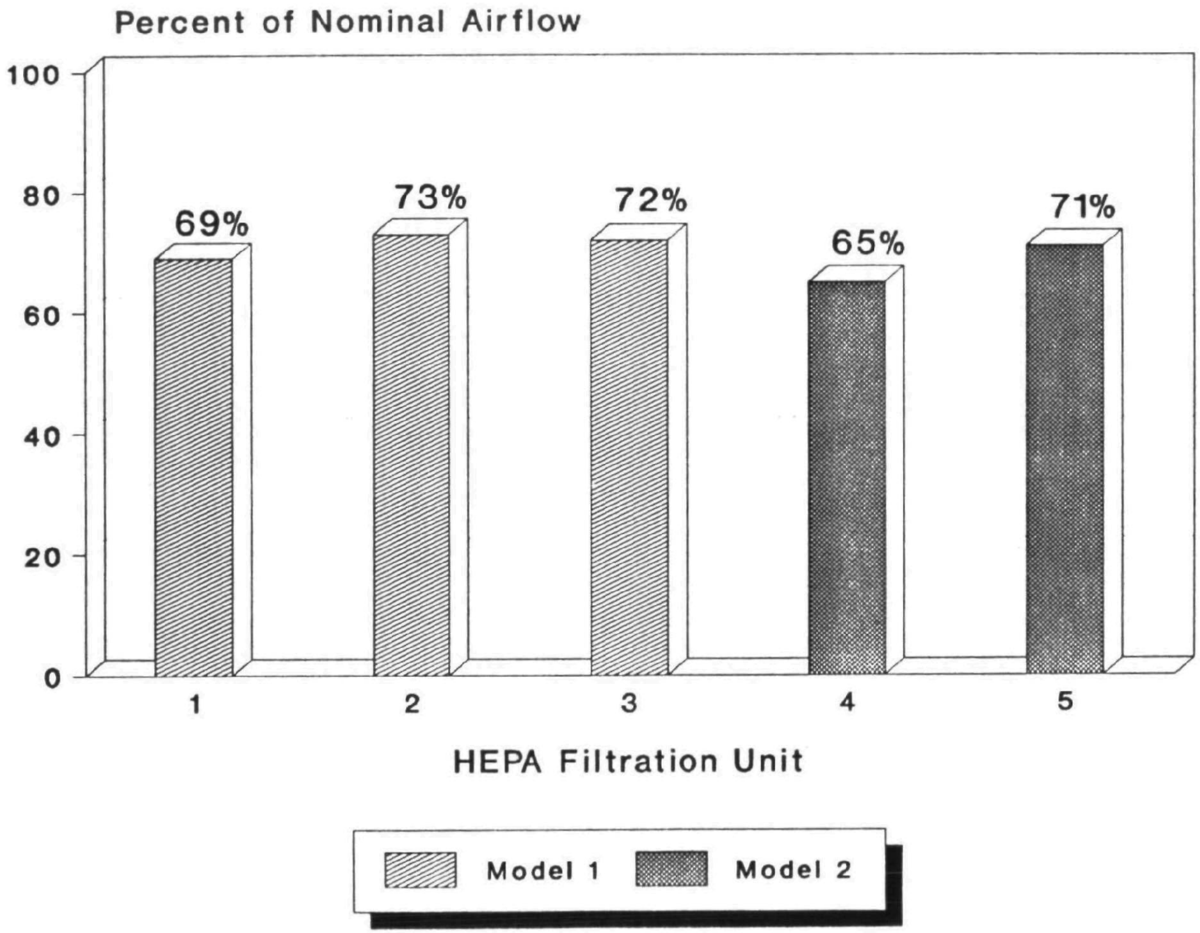


Figure H-2. Airflow performance for HEPA filtration systems operating during AHERA clearance.

TABLE H-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS

Model	Unit	Airflow, ft^3/min			Std. dev.	95% Confidence interval	
		Mean	Min.	Max.		Lower	Upper
Final cleaning							
1	1	1661	1344	1848	136	1589	1733
1	2	1547	1344	1680	104	1491	1602
1	3	1475	1176	1764	129	1406	1544
2	4	1344	840	1680	272	1197	1489
2	5	1410	1008	1596	151	1330	1491
AHERA clearance sampling							
1	1	1370	1176	1512	93	1321	1420
1	2	1465	1344	1680	111	1406	1524
1	3	1444	1344	1680	99	1391	1497
2	4	1302	840	1680	269	1159	1445
2	5	1418	1260	1680	102	1363	1472

TABLE H-2. STATIC PRESSURE DIFFERENTIALS
ACROSS CONTAINMENT BARRIERS
(in. water)

Test location	Final cleaning	AHERA clearance
1	-0.01	-0.02
2	-0.01	-0.01
3	-0.01	-0.01
4	-0.02	-0.02

airflow through openings in the containment barrier, such as the decontamination facility). Reportedly, these qualitative checks were performed once in the morning and once in the afternoon.

The HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility and waste load-out port. Four of the five operating units were positioned along exterior walls to facilitate venting of the exhaust through windows via an interconnected flexible duct. The exhaust of the fifth unit was vented through a doorway via an interconnected flexible duct that passed through an area outside of the abatement area. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor, who was responsible for maintaining the HEPA-filtration units, stated that the prefilters, secondary filters, and HEPA filters were changed before final cleaning was initiated. Thereafter, the prefilters were changed daily and the secondary filters were changed when they became "visibly dirty." The HEPA filters were changed every 600 to 700 hours (as recommended by the manufacturer) or when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls and either full- or half-facepiece air-purifying respirators equipped with dual-cartridge HEPA filters.

Cleaning Procedures

Final cleaning began after the plastic sheeting was removed from the walls, floors, and other surfaces. The critical barriers, windows, doors, stationary objects, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The HEPA filtration units remained in service.

Final cleaning was organized so the workers began in the areas nearest to the personnel decontamination facility and worked away from it. No association appeared to exist between the work direction and the location of HEPA-filtration units.

Final cleaning began with the spraying of walls, plastic critical containment barriers, and other vertical surfaces with a water mist to remove any loosely bound debris. The resultant asbestos-containing water on the floor was gathered into pools by use of a rubber squeegee. The bulk of the pooled water was scooped up with plastic-bladed shovels. The water was containerized in double-layered, 6-mil-thick, asbestos-disposal bags, which usually contained plastic that had been removed from the walls and floors. The residual water removed with a wet vacuum was also placed in these bags.

After the surfaces had dried, a vacuum equipped with a HEPA filter was used to clean crevices around windows, doors, and shelves; floor-wall interfaces; etc.

All of the vertical and horizontal surfaces were then wet-cleaned with amended water. The contractor reportedly prepared the amended water solution by mixing approximately 1 ounce each of 50 percent polyoxyethylene ester and 50 percent polyoxyethylene ether in 5 gallons of water.

The elevated horizontal and vertical surfaces were wiped first and then all other surfaces. All surfaces, except the floors, were wiped with absorbent paper towels dampened with amended water. The contractor stated that cotton rags were not used because their repeated use increases the potential of smearing residual particulates on the surfaces being cleaned. A bucket of amended water was either used by a single worker or shared by several workers. The workers did not appear to wipe the surfaces in any one direction. The paper towels were not replaced frequently, particularly during the cleaning of elevated and hard-to-access surfaces. Nor was the amended water changed frequently.

After the walls and other surfaces had been wet-wiped, the floor was mopped with a clean mop head wetted with amended water. No change of the water was observed during this procedure.

Final cleaning involved one complete wet-mopping of floors with a clean mop head and amended water. No aggressive cleaning (i.e., air sweeping of all vertical and horizontal surfaces to dislodge any remaining particulate) was conducted.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered, 6-mil-thick, standard disposal bags. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers or solidified with a gelling compound. The paper towels and mop heads used during cleaning also were placed in these bags. The bags were not wet-wiped with amended water before being removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an (AST, who was the building owner's representative. The AST conducted a visual inspection within 2 hours after notification. The AST identified several areas, especially elevated horizontal surfaces (including the tops of pipes and ventilation ducts), that required further cleaning. After these designated areas were recleaned, the AST conducted a final walk-through inspection to assure that the identified areas were clean.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

The site failed the first visual inspection because of the presence of debris 1) on heating units, 2) on pipes in the hallways and classrooms, 3) on electrical wires and outlet boxes, 4) at floor-wall corners, and 5) around air vents. These things were corrected, and the site passed the second visual inspection.

AHERA CLEARANCE SAMPLING BY AST

The AHERA clearance sampling was initiated approximately 24 hours after the site passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 30 minutes, which is equivalent to approximately 5 minutes per 1000 square feet of floor area. No floor fans were used subsequently to maintain air turbulence during sampling.

The clearance air samples were collected on 25-mm, 0.45-μm pore size, mixed cellulose ester membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The samples were collected at flow rates of approximately 10 liters per minute. The laboratory report indicates that the samples were analyzed in accordance with the AHERA mandatory TEM method.

Table H-3 presents the results of the AST's clearance samples collected inside the abatement area. The samples met the initial AHERA clearance criterion by having an asbestos concentration less than 70 structures per square millimeter (s/mm^2). The average asbestos concentration for the seven inside samples was 4 s/mm^2.

TABLE H-3. AHERA CLEARANCE SAMPLE RESULTS

Sample location[a]	Sample volume, liters	Asbestos concentration	
		s/mm^2	s/cm^3
Inside	2000	0	<0.005[b]
Inside	2008	0	<0.005[b]
Inside	2000	25	0.005
Inside	2024	0	<0.005[b]
Inside	2000	0	<0.005[b]
Inside	2080	0	<0.005[b]
Inside	2064	0	<0.005[b]

[a] Outside samples and blanks were not analyzed because the average asbestos concentration for the five inside samples was less than 70 s/mm^2.

[b] Sensitivity of the analytical method.

CASE HISTORY I

SITE DESCRIPTION

This abatement project involved removal of approximately 5100 ft^2 of spray-applied, asbestos-containing, acoustical ceiling plaster from a single-story school building. The abatement area included corridors, classrooms, offices, a lobby, and an auditorium. The project specification indicated that the asbestos content of the ceiling plaster was approximately 5 to 25 percent chrysotile.

VENTILATION AND NEGATIVE AIR PRESSURE

Four high-efficiency particulate air (HEPA) filtration units were operated during the final cleaning period, and four were operated during AHERA clearance sampling. Table I-1 presents the measured air-intake volume for each unit. The average air-intake volume was 991 ft^3/min during final cleaning and 1013 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (40,000 ft^3) and the combined average air-intake volumes, the air-exchange rates were approximately 5.9 air changes per hour during final cleaning and 6.1 air changes per hour during AHERA clearance sampling.

Figures I-1 and I-2 compare the measured air-intake volume for each HEPA-filtration unit operating during final cleaning and AHERA clearance sampling, respectively, with the unit's nominal airflow. The actual operating percentages of the nominal air flow ranged from 46 to 57 during final cleaning and from 47 to 53 during AHERA clearance sampling.

Table I-2 presents the static pressure differential measured across the containment barriers at three locations. The number of locations tested was determined by available access to the critical containment barriers. The static pressure differential ranged from -0.02 to -0.03 in. water during both final cleaning and AHERA clearance sampling.

The asbestos safety technician (AST) did not monitor the static pressure differential across the containment barriers. Instead, ventilation smoke tubes were used to check the negative pressure (i.e., direction of airflow through openings in the containment barrier, such as the decontamination facility and waste load-out port). Reportedly, these qualitative checks were performed each morning.

The HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility and waste load-out

TABLE I-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS

Model	Unit	Airflow, ft^3/min			Std. dev.	95% Confidence interval	
		Mean	Min.	Max.		Lower	Upper
Final cleaning							
1	1	943	756	1176	108	886	1000
1	2	1135	941	1344	147	1057	1213
1	3	913	864	1021	61	880	945
1	4	974	864	1099	76	933	1015
AHERA clearance sampling							
1	1	1055	924	1176	78	1013	1097
1	2	1053	941	1176	79	1011	1095
1	3	937	864	1021	48	912	963
1	4	1008	903	1099	58	977	1039

TABLE I-2. STATIC PRESSURE DIFFERENTIALS ACROSS CONTAINMENT BARRIERS (in. water)

Test location	Final cleaning	AHERA clearance
1	-0.02	-0.03
2	-0.02	-0.02
3	-0.03	-0.02

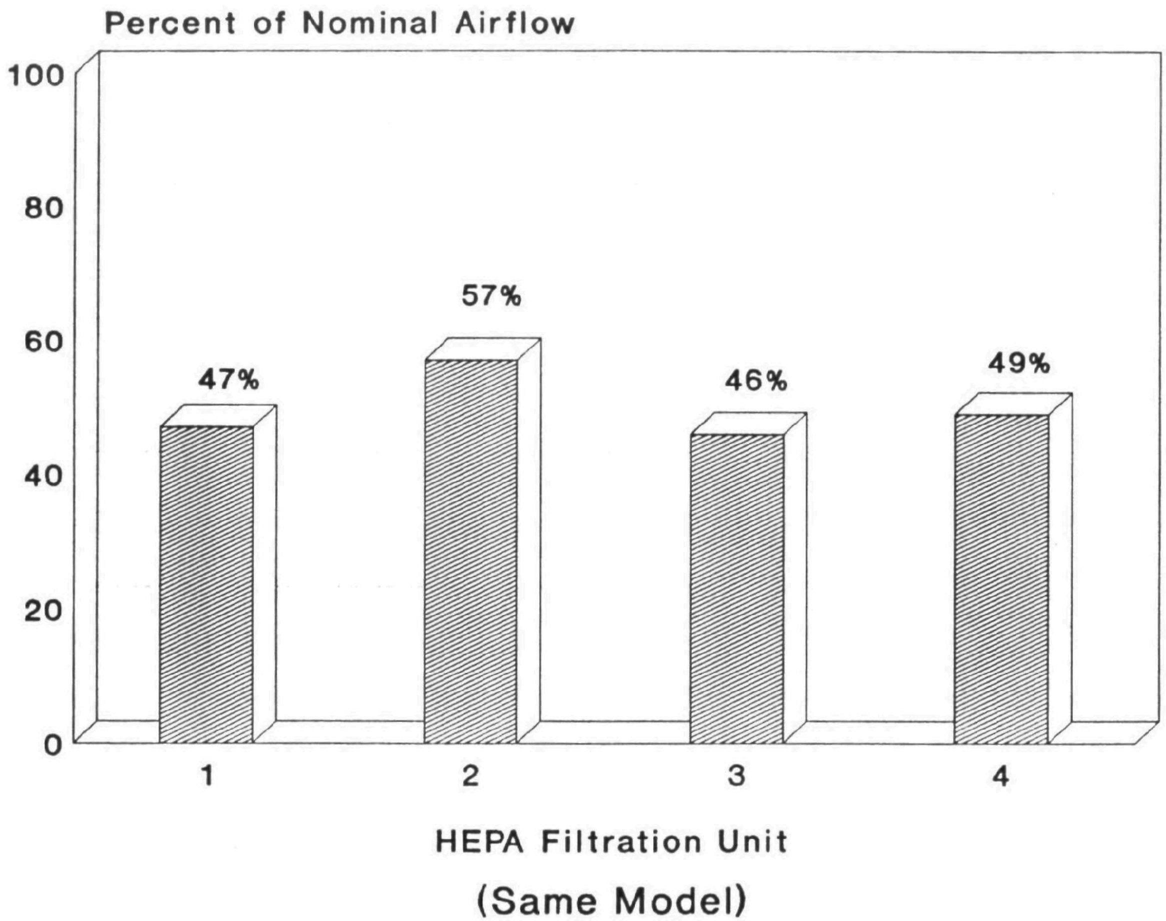


Figure I-1. Airflow performance for HEPA filtration systems operating during final cleanup.

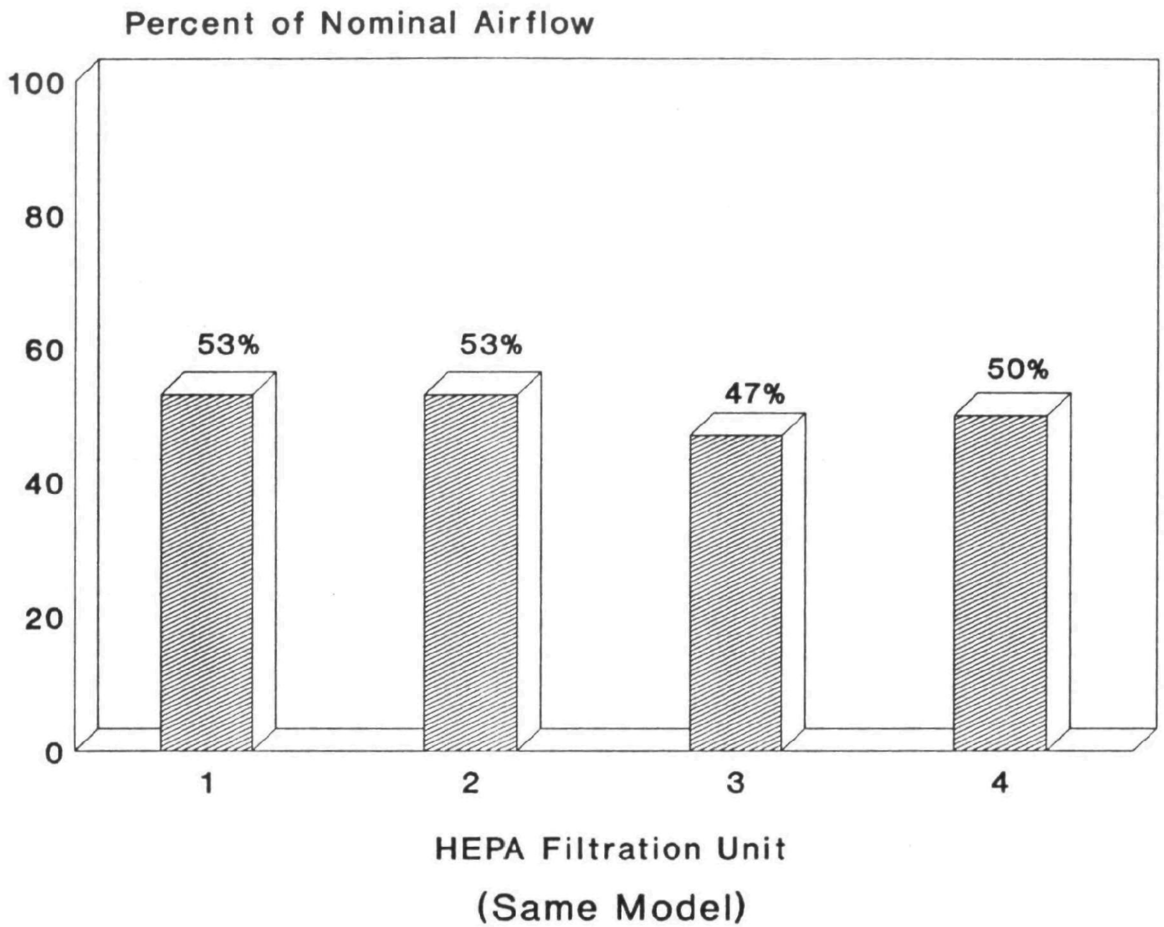


Figure I-2. Airflow performance for HEPA filtration systems operating during AHERA clearance.

port. The four operating units were positioned along exterior walls to facilitate venting of the exhaust through windows via an interconnected flexible duct. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor, who was responsible for maintaining the HEPA-filtration units, stated that the prefilters, secondary filters, and HEPA filters were changed before final cleaning was initiated. Thereafter, the prefilters were changed when they became "visibly dirty," and the secondary filters were changed after each workshift. The HEPA filters were changed every 900 to 1000 hours or when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls and either full- or half-facepiece air-purifying respirators equipped with dual-cartridge HEPA filters.

Cleaning Procedures

Final cleaning began after the encapsulated plastic sheeting was removed from the walls, floors, light fixtures, and other surfaces. The windows, doors, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The HEPA filtration units remained in service.

Final cleaning was organized so the workers began in the areas farthest from the personnel decontamination facility and worked toward it. No association appeared to exist between the work direction and location of HEPA-filtration units.

Final cleaning began with the wire-brushing of the ceiling-wall intersections to remove any visible debris. The floor-wall intersections, indented corners, crevices around doors, shelves, etc., were then cleaned with a HEPA-filtered vacuum.

All of the vertical and horizontal surfaces were then wet-cleaned with amended water. The contractor reportedly prepared the amended water solution by mixing approximately 1 ounce each of 50 percent polyoxyethylene ester and 50 percent polyoxyethylene ether in 5 gallons of water.

The elevated surfaces were wiped first and then all other surfaces. All the surfaces except the floors were wiped with sponges dampened with amended water. A bucket of amended water was used by a single worker. The workers did not appear to wipe the surfaces in any one direction. The sponges were not replaced frequently, especially during the cleaning of elevated and hard-to-access surfaces. Nor was the amended water changed frequently.

After the walls, and other surfaces (shelves, ledges, etc.) were wet-wiped, the floor was mopped with a clean mop head wetted with amended water. No change in the water was observed during this procedure.

The last step in the final cleaning involved one complete mopping of floors with a clean mop head and clean amended water. No aggressive cleaning (i.e., air sweeping of all vertical and horizontal surfaces to dislodge any remaining particulate) was conducted.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered, 6-mil-thick, standard disposal bags. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers or solidified with a gelling compound. The sponges and mop heads used during cleaning were also placed in these bags. The bags were not wet-wiped with amended water before being removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an onsite AST, who was the building owner's representative. The AST conducted a visual inspection within 2 hours after notification. The AST identified several areas that required further cleaning, baseboards, cornice ledges, and ceiling-wall intersections. After these areas were recleaned, the AST conducted a final walk-through inspection to assure that the identified areas were clean.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

The site failed the first visual inspection because of the presence of residual materials or granular loose debris on 1) corkboards on walls, 2) tops of wood partitions under the stage, 3) light fixtures and electrical cords, 4) ceiling-wall junctions, and 5) the carpeted area around the stage. Five bulk samples were collected to characterize the makeup of the residual debris. Samples were collected from the stage area, ceiling and walls, light fixtures, and corkboards. Four of the five samples were found to contain chrysotile asbestos. The samples were not sufficiently large to quantify the percentage of asbestos in each.

The site failed the second visual inspection because of the presence of debris 1) at wall-ceiling junctions, 2) above entry doorway, 3) on electrical wires, and 4) on corkboards.

The site failed the third visual inspection because of the presence of debris at wall-ceiling junctions and on the floor. Two bulk samples were collected. The sample collected from the debris on the floor contained no asbestos. The sample collected at the wall-ceiling junction contained 2 percent chrysotile.

The site passed the fourth visual inspection.

AHERA CLEARANCE SAMPLING BY AST

The AHERA clearance sampling was initiated approximately 24 hours after the site had passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 15 minutes, which is equivalent to approximately 5 minutes per 1700 square feet of floor area. No floor fans were used subsequently used to maintain air turbulence during sampling.

The clearance air samples were collected on 25-mm, 0.4-μm pore size, polycarbonate membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The samples were collected at flow rates of approximately 10 liters per minute. The laboratory report indicates that the samples were analyzed in accordance with the AHERA mandatory TEM method.

Table I-3 presents the results of the AST's clearance samples collected inside the abatement area. The samples met the initial AHERA clearance criterion, which stipulates an asbestos concentration of less than 70 structures per square millimeter (s/mm²). The average asbestos concentration for the five inside samples was actually 36 s/mm². The reason for the elevated concentration (156 s/mm²) of one inside sample is not known.

TABLE I-3. AHERA CLEARANCE SAMPLE RESULTS

Sample location[a]	Sample volume, liters	Asbestos concentration s/mm²	Asbestos concentration s/cm³
Inside	2300	26	0.004
Inside	2231	156	0.027
Inside	2185	0	<0.005[b]
Inside	2400	0	<0.005[b]
Inside	2352	0	<0.005[b]

[a] Outside samples and blanks were not analyzed because the average asbestos concentration for the five inside samples was less than 70 s/mm².

[b] Sensitivity of the analytical method.

CASE HISTORY J

SITE DESCRIPTION

This project abatement involved removal of approximately 5300 ft^2 of spray-applied asbestos-containing fireproofing from structural steel and metal ceiling decks in a two-story school building. The abatement area included two electrical transformer vaults and two mechanical equipment rooms. The project specification indicated that the asbestos content of the cementitious fireproofing was approximately 10 to 25 percent chrysotile.

VENTILATION AND NEGATIVE AIR PRESSURE

Six high-efficiency particulate air (HEPA) filtration units were operated during the final cleaning period, and five were operated during AHERA clearance sampling. Table J-1 presents the measured air-intake volume for each unit. The average air-intake volume was 1358 ft^3/min during final cleaning and 1468 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (78,435 ft^3) and the combined average air-intake volumes, the air exchange rates were approximately 6.3 air changes per hour during final cleaning and 6.7 air changes per hour during AHERA clearance sampling.

Figures J-1 and J-2 compare the measured air-intake volume for each HEPA-filtration unit operating during final cleaning and AHERA clearance sampling, respectively, with the unit's nominal airflow. The actual operating percentages of the nominal airflow ranged from 59 to 77 during final cleaning and from 62 to 77 during AHERA clearance sampling.

Table J-2 presents the static pressure differential measured across the containment barriers at one location. The number of locations tested was determined by available access to the critical containment barriers. The static pressure differential was -0.02 in. water during final cleaning and -0.01 in. water during AHERA clearance sampling.

The asbestos safety technician (AST) did not monitor the static pressure differential across the containment barrier. Instead ventilation smoke tubes were used to check negative pressure visually (i.e., direction of airflow through openings in the containment barrier, such as the decontamination facility. Reportedly, these qualitative checks were performed each morning.

TABLE J-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS

Model	Unit	Airflow, ft^3/min Mean	Min.	Max.	Std. dev.	95% Confidence interval Lower	Upper
Final cleaning							
1	1	1176	1008	1428	123	1110	1242
1	2	1075	941	1260	85	1030	1121
1	3	1299	1008	1764	196	1194	1403
1	4	1549	1344	1848	157	1465	1632
1	5	1512	1344	1680	103	1457	1567
1	6	1538	1344	1680	93	1489	1588
AHERA clearance sampling							
1	1	1239	1008	1512	153	1158	1320
1	2	1530	1260	1680	130	1460	1599
1	3	1528	1344	1680	108	1470	1585
1	4	1523	1344	1848	148	1444	1601
1	5	1523	1344	1680	126	1456	1589

TABLE J-2. STATIC PRESSURE DIFFERENTIALS ACROSS CONTAINMENT BARRIERS (in. water)

Test location	Final cleaning	AHERA clearance
1	-0.02	-0.01

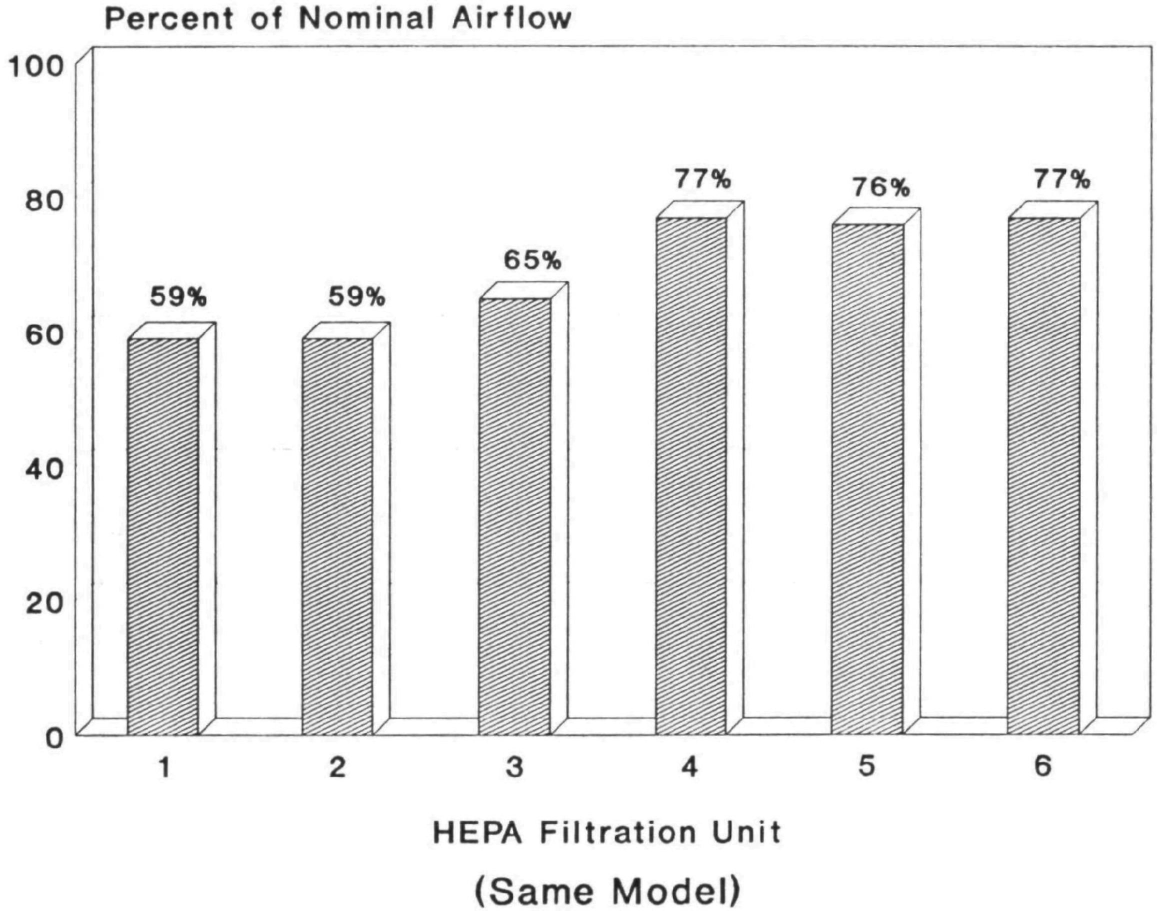


Figure J-1. Airflow performance for HEPA filtration systems operating during final cleanup.

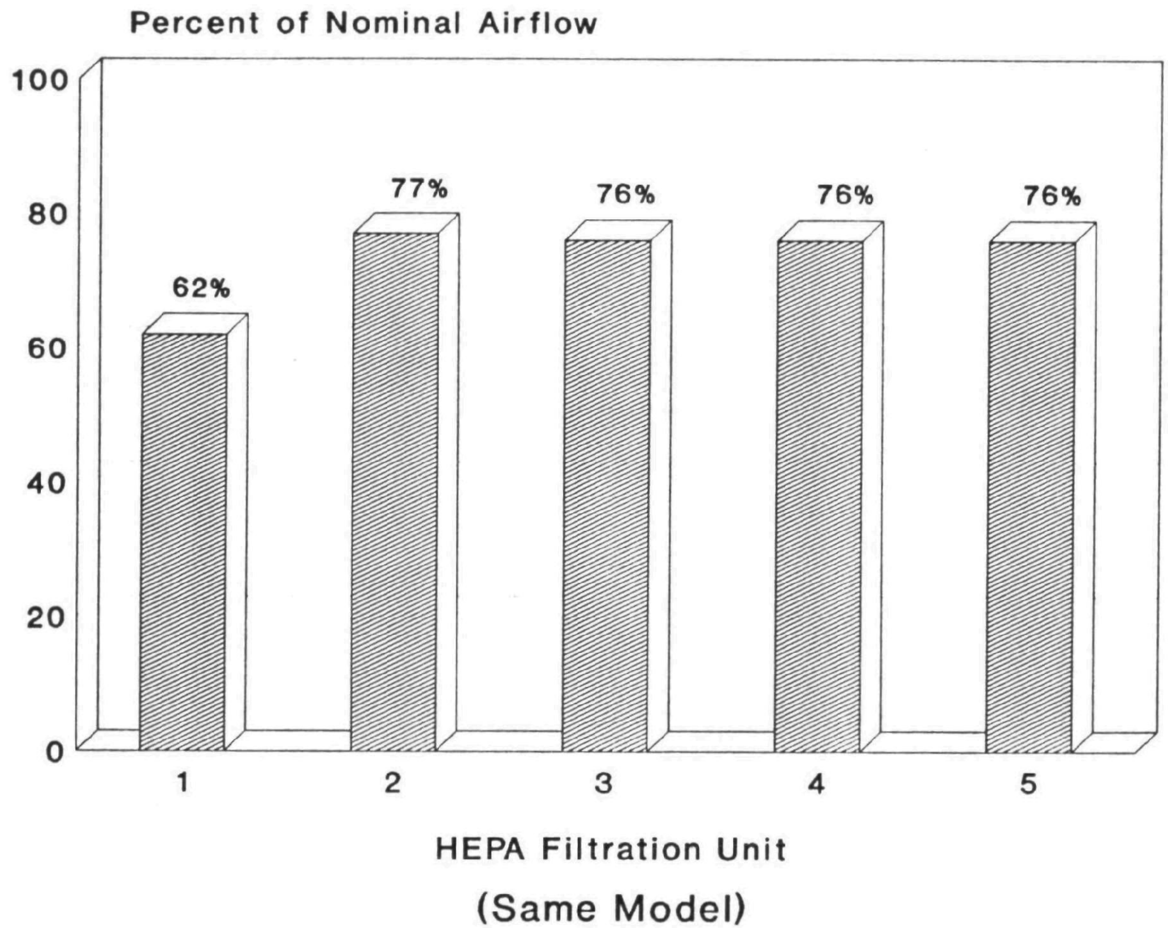


Figure J-2. Airflow performance for HEPA filtration systems operating during AHERA clearance.

The HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility and waste load-out port. The six operating units were positioned along exterior walls to facilitate venting of the exhaust through windows via an interconnected flexible duct. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor, who was responsible for maintaining the HEPA-filtration units, stated that the prefilters and secondary filters were changed before final cleaning was initiated; the HEPA filters were changed at the beginning of the project. Thereafter, the prefilters and secondary filters were changed when they became "visibly dirty." The HEPA filters were changed when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls and either full- or half-facepiece air-purifying respirators equipped with dual-cartridge HEPA filters.

Cleaning Procedures

Final cleaning began after the encapsulated plastic sheeting was removed from the walls, floors, and other surfaces. The critical barriers, windows, doors, stationary objects, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The HEPA filtration systems remained in service.

Final cleaning was organized so the workers began in the areas farthest from the personnel decontamination facility and worked toward it. No association appeared to exist between the work direction and the location of HEPA-filtration units.

Final cleaning began with the spraying of the abated substrate, walls, plastic critical containment barriers, and other surfaces with water to remove any loosely bound debris. The resultant asbestos-containing water on the floor was gathered into pools by use of a rubber squeegee. The bulk of the pooled water was scooped up with plastic bladed shovels, an approach that worked surprisingly well. The water was put into double-layered, 6-mil-thick, asbestos-disposal bags, which usually contained plastic that had been removed from the walls and floors. The residual water removed with a wet vacuum was also placed in these bags.

After the surfaces had dried, a vacuum equipped with a HEPA filter was used to clean crevices around equipment brackets, doors, pipe hangers, floor-wall interfaces, etc. The surfaces, especially the hard-to-clean areas such as crevices around equipment brackets and hangers, were then swept with a hand-held, 1-horsepower leaf blower to dislodge any residual debris. The abatement area was then vacated to allow the airborne debris to settle overnight.

All of the vertical and horizontal surfaces were then wet-cleaned with amended water. The contractor reportedly prepared the amended water solution by mixing approximately 1 ounce each of 50 percent polyoxyethylene ester and 50 percent polyoxyethylene ether in 5 gallons of water.

The elevated horizontal and vertical surfaces were wiped first and then all other surfaces. All the surfaces, except the floors were wiped with cotton rags dampened with water. A bucket of water was either used by a single worker or shared by several workers. The workers did not appear to wipe the surfaces in any one direction. The cloth rags were not replaced frequently, especially during the cleaning of elevated and hard-to-access surfaces. Nor was the water changed frequently.

After the walls and other surfaces had been wet wiped, the floor was mopped with a clean mop head wetted with amended water. No change in the water was observed during this procedure.

The last step in the final cleaning effort involved removal of the plastic sheeting covering the HEPA-filtration units and associated exhaust ducts. The latter were covered with a plastic sleeve. According to the contractor, this covering simplified the cleaning of this equipment.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered 6-mil-thick standard disposal bags. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers or solidified with a gelling compound. The rags and mop heads used during cleaning also were placed in these bags. The bags were not wet-wiped with amended water before being removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an onsite AST, who was the building owner's representative. The AST conducted a visual inspection within 2 hours after notification. The AST identified several areas, particularly elevated horizontal surfaces, that required further cleaning. After these designated areas were recleaned, the AST conducted a final walk-through inspection to assure that the identified areas were clean.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

The New Jersey Department of Health did not perform a final visual inspection at this site.

AHERA CLEARANCE SAMPLING

The AHERA clearance sampling was initiated approximately 18 hours after the site had passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 20 minutes, which is equivalent to approximately 5 minutes per 1300 square feet of floor area. Four box-type floor fans with 18-inch blades were subsequently used to maintain air turbulence during sampling.

The AST collected only two samples inside the work area for clearance purposes. This practice is not in accordance with AHERA clearance procedures, i.e., five samples must be collected inside the abatement area. These samples were collected on 25-mm, 0.4-μm pore size, polycarbonate membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The samples were collected at flow rate of approximately 10 liters per minute. Reportedly, the samples were analyzed by PCM in accordance with the NIOSH 7400 Method.

Table J-3 presents the results of the AST's clearance samples collected inside the abatement area.

TABLE J-3. CLEARANCE SAMPLE RESULTS BY PCM

Sample location	Sample volume, liters	Asbestos concentration, f/cm³
Inside	1350	<0.001[a]
Inside	1350	0.002

[a] Sensitivity of the analytical method.

CASE HISTORY K

SITE DESCRIPTION

This abatement project involved removal of approximately 8200 ft^2 spray-applied, asbestos-containing, acoustical plaster from an "egg crate" design structural concrete ceiling in a single-story school building. The abatement area included corridors, offices, and mechanical arts classrooms. The project specification indicated that the asbestos content of the ceiling plaster was approximately 10 to 25 percent chrysotile.

VENTILATION AND NEGATIVE AIR PRESSURE

Six high-efficiency particulate air (HEPA) filtration units were operated during the final cleaning period, and four were operated during AHERA clearance sampling. Table K-1 presents the measured air-intake volume for each unit. The average air-intake volume was 1566 ft^3/min during final cleaning and 1440 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (115,000 ft^3) and the combined average air-intake volumes, the air-exchange rates were approximately 4.9 air changes per hour during final cleaning and 3.0 air changes per hour during AHERA clearance sampling.

Figures K-1 and K-2 compare the measured air-intake volume of each HEPA-filtration unit operating during final cleaning and AHERA clearance sampling, respectively, with the unit's nominal airflow. The actual operating percentages of the nominal airflow ranged from 54 to 88 during final cleaning and from 49 to 83 during AHERA clearance sampling.

Table K-2 presents the static pressure differential measured across the containment barriers at one location. The number of locations tested was determined by available access to the critical containment barriers. The static pressure differential was -0.02 in. water during final cleaning and -0.01 in. water during AHERA clearance sampling.

The asbestos safety technician (AST) did not monitor the static pressure differential across the containment barriers. Instead ventilation smoke tubes were used to check the negative pressure visually (i.e., direction of air flow through openings in the containment barrier, such as the decontamination facility). Reportedly, these qualitative checks were performed each morning and afternoon.

TABLE K-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS

Model	Unit	Airflow, ft^3/min			Std. dev.	95% Confidence interval	
		Mean	Min.	Max.		Lower	Upper
Final cleaning							
1	1	1075	924	1260	103	1020	1130
2	2	1769	1680	1848	76	1729	1809
2	3	1586	1344	1848	111	1527	1644
2	4	1649	1344	1848	136	1576	1721
2	5	1612	1512	1680	74	1572	1651
2	6	1706	1512	1848	83	1662	1750
AHERA clearance sampling							
1	1	975	672	1176	128	907	1044
2	2	1554	1176	1848	181	1458	1650
2	3	1570	1344	1848	159	1485	1655
2	4	1659	1428	1848	134	1587	1731

TABLE K-2. STATIC PRESSURE DIFFERENTIALS ACROSS CONTAINMENT BARRIERS (in. water)

Test location	Final cleaning	AHERA clearance
1	-0.02	-0.01

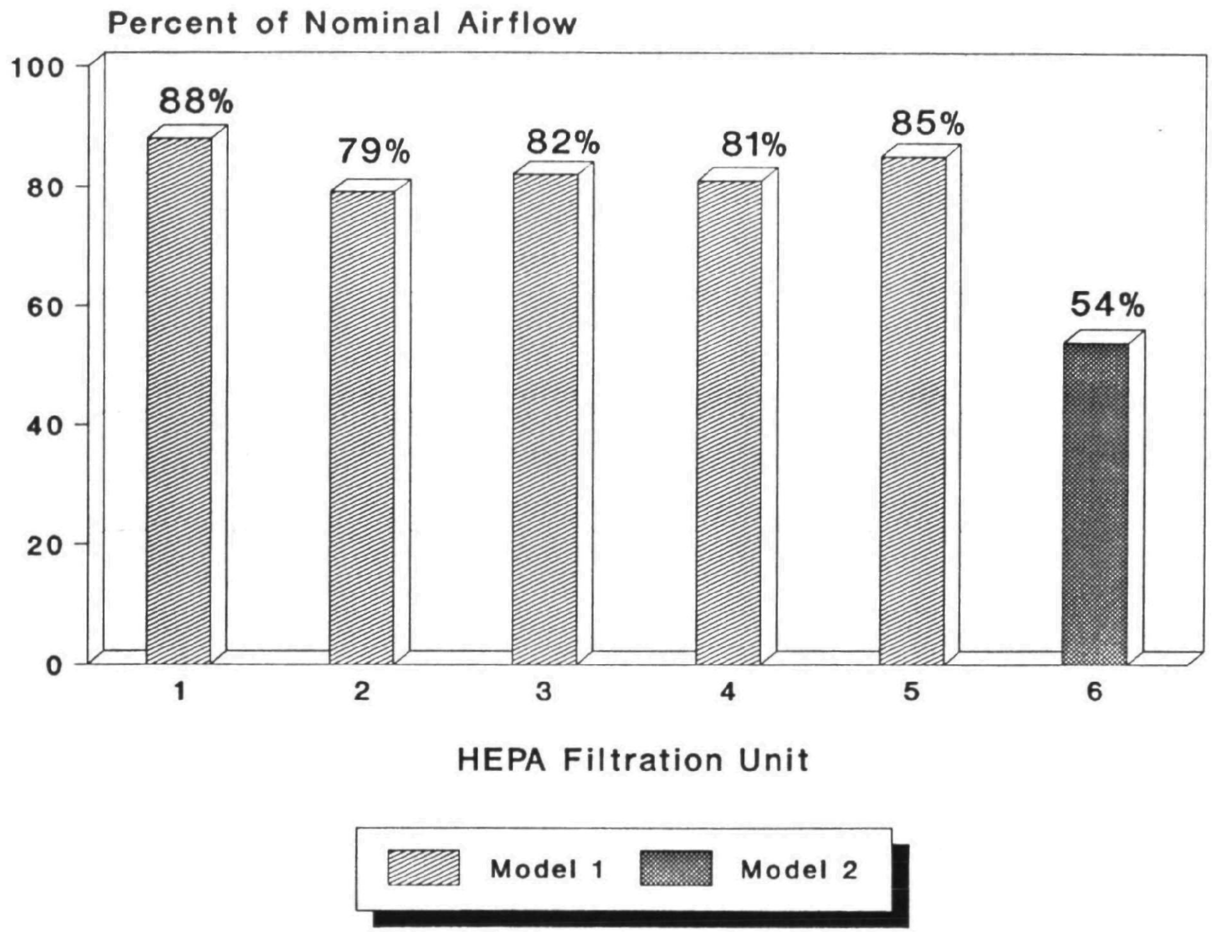


Figure K-1. Airflow performance for HEPA filtration systems operating during final cleanup.

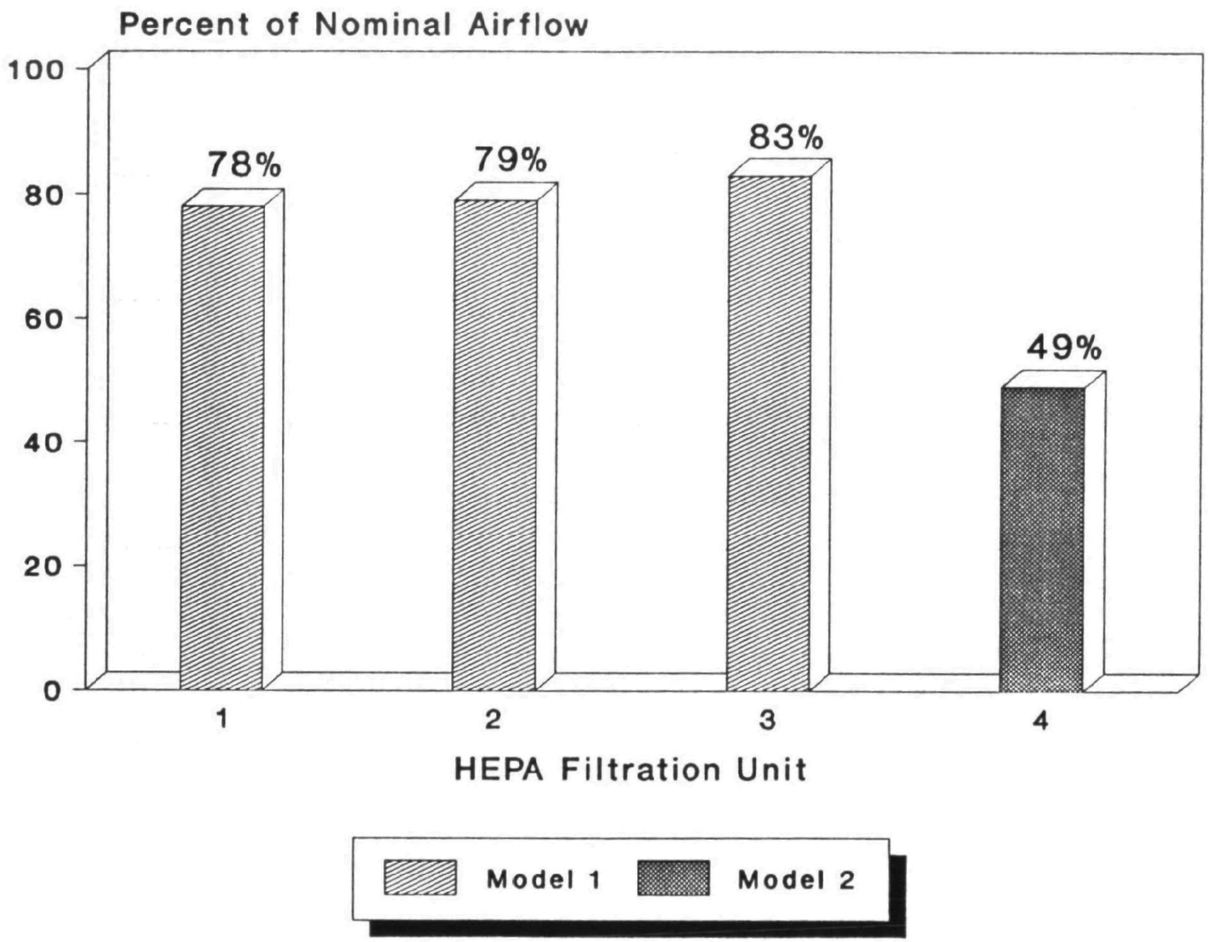


Figure K-2. Airflow performance for HEPA filtration systems operating during AHERA clearance.

The HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility and waste load-out port. The five operating units were positioned along exterior walls to facilitate venting of the exhaust through windows via an interconnected flexible duct. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor, who was responsible for maintaining the HEPA-filtration units, stated that the prefilters and secondary filters were changed before final cleaning was initiated and the HEPA filters were changed at the beginning of the project. Thereafter, the prefilters and secondary filters were changed when they became "visibly dirty." The HEPA filters were changed when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls and either full- or half-facepiece air-purifying respirators equipped with dual-cartridge HEPA filters.

Cleaning Procedures

Final cleaning began after the encapsulated plastic sheeting was removed from the walls, floors, and other surfaces. The critical barriers, windows, doors, lighting fixtures, stationary objects, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The HEPA filtration units remained in service.

Final cleaning was organized so the workers began in the areas farthest from the personnel decontamination facility and worked toward it. No association appeared to exist between the work direction and the location of HEPA-filtration units.

Final cleaning began with cleaning of surfaces with a vacuum equipped with a HEPA filter. Particular attention was given to vacuuming the joints between planks of the hardwood floor, floor-wall intersections, and crevices around doors.

All of the vertical and horizontal surfaces were then wet-cleaned with amended water. The contractor reportedly prepared the amended water solution by mixing approximately 1 ounce each of 50 percent polyoxyethylene ester and 50 percent polyoxyethylene ether in 5 gallons of water.

The elevated horizontal (light fixtures) and vertical surfaces were wiped first, and then all the other surfaces. All the surfaces except the floors were wiped with cotton rags dampened with amended water. A bucket of amended water was either used by a single worker or shared by several workers. The workers did not appear to wipe the surfaces in any one direction. The cloth rags were not replaced frequently, especially during the cleaning of elevated and hard-to-access surfaces. Nor was the amended water changed frequently.

After the walls and other surfaces were wet-wiped, the floor was hand-wiped with clean cotton rags wetted with amended water. No changes in the water were observed during this procedure.

No aggressive cleaning (i.e., air sweeping of all vertical and horizontal surfaces to dislodge any remaining particulate) was conducted.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered 6-mil-thick, standard disposal bags. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers or solidified with a gelling compound. The rags and mop heads used during cleaning also were placed in these bags. The bags were not wet-wiped with amended water before being removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an onsite AST, the building owner's representative. The AST conducted a visual inspection within 2 hours after notification. The AST identified several areas that required further cleaning, including indented corners, door frames, light fixtures, electrical conduit, and crevices along baseboards. After these designated areas were recleaned, the AST conducted a final walk-through inspection to assure that the identified areas were clean.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

The site failed the first visual inspection because of the presence of gross debris on the concrete substrate surfaces, under pipe hangers, on vertical and horizontal surfaces, and on the scaffolding equipment. Seven bulk samples were collected to characterize the residual debris found on the floor, at ceiling-wall intersections, and on the top of a wooden beam, a window, and a pipe. Asbestos was identified in four of the seven samples; however, the samples were not sufficiently large to quantify the percentage of asbestos in each.

The site failed the second visual inspection because of gross debris found behind immovable wooden shelves, at floor-wall junctions, behind student lockers, on horizontal surfaces, and on other immovable objects. Four bulk samples were collected to characterize the residual debris found on the horizontal surfaces (shelves) and floors. Asbestos was identified in two of the four bulk samples; however, the samples were not sufficiently large to quantify the percentage of asbestos in each.

The site failed the third visual inspection because of gross debris found on horizontal surfaces, behind immovable objects, and at floor-wall intersections. Conditions were found to be much the same as during earlier visual inspections.

The site passed the fourth visual inspection.

AHERA CLEARANCE SAMPLING BY AST

The AHERA clearance sampling was initiated approximately 24 hours after the site had passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 20 minutes, which is equivalent to approximately 5 minutes per 2100 square feet of floor area. Four pedestal-type floor fans with 24-inch blades were used subsequently to maintain air turbulence during sampling.

The clearance air samples were collected on 25-mm, 0.8-μm pore size, mixed cellulose ester membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The samples were collected at flow rates of approximately 10 liters per minute. The laboratory report, indicates the samples were analyzed in accordance with the AHERA mandatory TEM method.

Table K-3 presents the results of the clearance samples the AST collected inside the abatement area. The samples met the initial AHERA clearance criterion by having an average asbestos concentration of less than 70 structures per square millimeter (s/mm^2). The average asbestos concentration for the five inside samples was actually 0 s/mm^2.

TABLE K-3. AHERA CLEARANCE SAMPLE RESULTS

Sample location[a]	Sample volume, liters	Asbestos concentration	
		s/mm^2	s/cm^3
Inside	Not Reported	0	<0.005[b]
Inside	Not Reported	0	<0.005[b]
Inside	Not Reported	0	<0.005[b]
Inside	Not Reported	0	<0.005[b]
Inside	Not Reported	0	<0.005[b]

[a] Outside samples and blanks were not analyzed because the average asbestos concentration for the five inside samples was less than 70 s/mm^2.

[b] Sensitivity of the analytical method.

CASE HISTORY L

SITE DESCRIPTION

This abatement project involved removal of approximately 1600 ft^2 of trowel-applied, asbestos-containing, acoustical ceiling plaster from a single-story school building. The abatement area was an auditorium. The project specification indicated that the asbestos content of the ceiling plaster was approximately 15 to 25 percent chrysotile.

VENTILATION AND NEGATIVE-AIR PRESSURE

Three high-efficiency particulate air (HEPA) filtration units were operated during the final cleaning period, and three were operated during AHERA clearance sampling. Table L-1 presents the measured air-intake volume for each unit. The average air-intake volume was 1260 ft^3/min during final cleaning and 1305 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (36,000 ft^3) and the combined average air-intake volumes, the air exchange rates were approximately 6.3 air changes per hour during final cleaning and 6.5 air changes per hour during AHERA clearance sampling.

TABLE L-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS

Model	Unit	Airflow, ft^3/min			Std. dev.	95% Confidence interval	
		Mean	Min.	Max.		Lower	Upper
Final Cleaning							
1	1	1586	1344	1848	194	1482	1689
2	2	657	530	734	67	621	693
3	3	1538	1176	1848	165	1451	1626
AHERA clearance sampling							
1	1	1533	1176	1848	194	1430	1636
2	2	665	571	734	61	632	697
3	3	1717	1512	1848	94	1667	1767

Figures L-1 and L-2 compare the measured air-intake volume of each HEPA-filtration unit operating during final cleaning and AHERA clearance sampling, respectively, with the unit's nominal airflow. The actual operating percentages of the nominal airflow ranged from 66 to 79 during final cleaning and from 67 to 86 during AHERA clearance sampling.

Table L-2 presents the static pressure differential measured across the containment barriers at three locations. The number of locations tested was determined by available access to the critical containment barriers. The static pressure differential was -0.01 in. water during both final cleaning and AHERA clearance sampling.

TABLE L-2. STATIC PRESSURE DIFFERENTIALS ACROSS CONTAINMENT BARRIERS (in. water)

Test location	Final cleaning	AHERA clearance
1	-0.01	-0.01
2	-0.01	-0.01
3	-0.01	-0.01

The asbestos safety technician (AST) did not monitor the static pressure differential across the containment barriers. Instead, ventilation smoke tubes were used to check the pressure visually (i.e., direction of air flow through openings in the containment barrier, such as the decontamination facility). Reportedly, these qualitative checks were performed each morning.

The HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility and waste load-out port. The three operating units were vented through a doorway via an interconnected flexible ducts that passed through a hallway outside of the abatement area. This is particularly noteworthy, because the flexible duct from two of the three units was torn and a percentage of the exhaust air was released into the building. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor, who was responsible for maintaining the HEPA-filtration units, stated that the prefilters and secondary filters were changed before final cleaning was initiated, and the HEPA filters were changed at the beginning of the project. Thereafter, the prefilters were changed when they became "visibly dirty, and the secondary filters were changed daily. The HEPA filters were changed when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

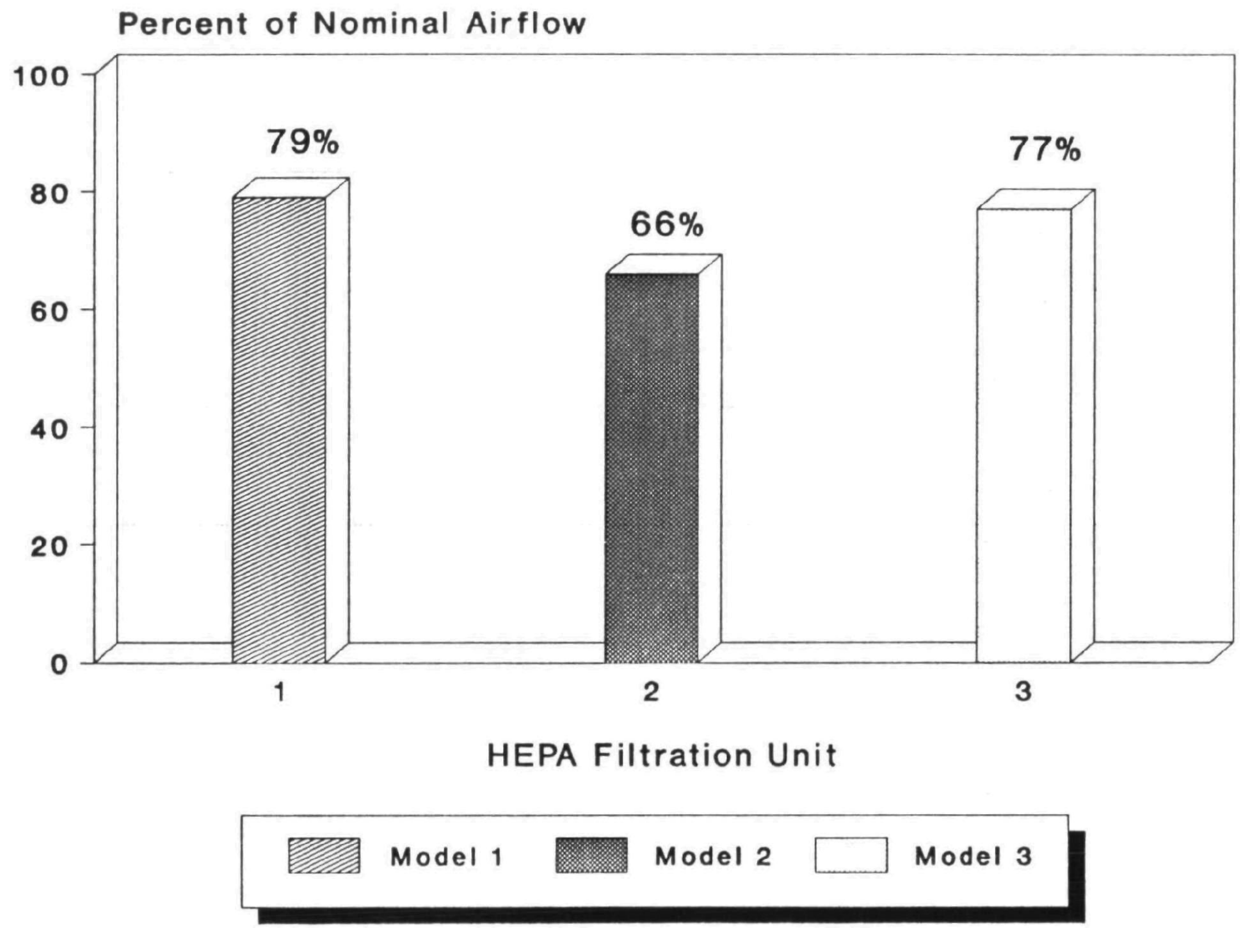


Figure L-1. Airflow performance for HEPA filtration systems operating during final cleanup.

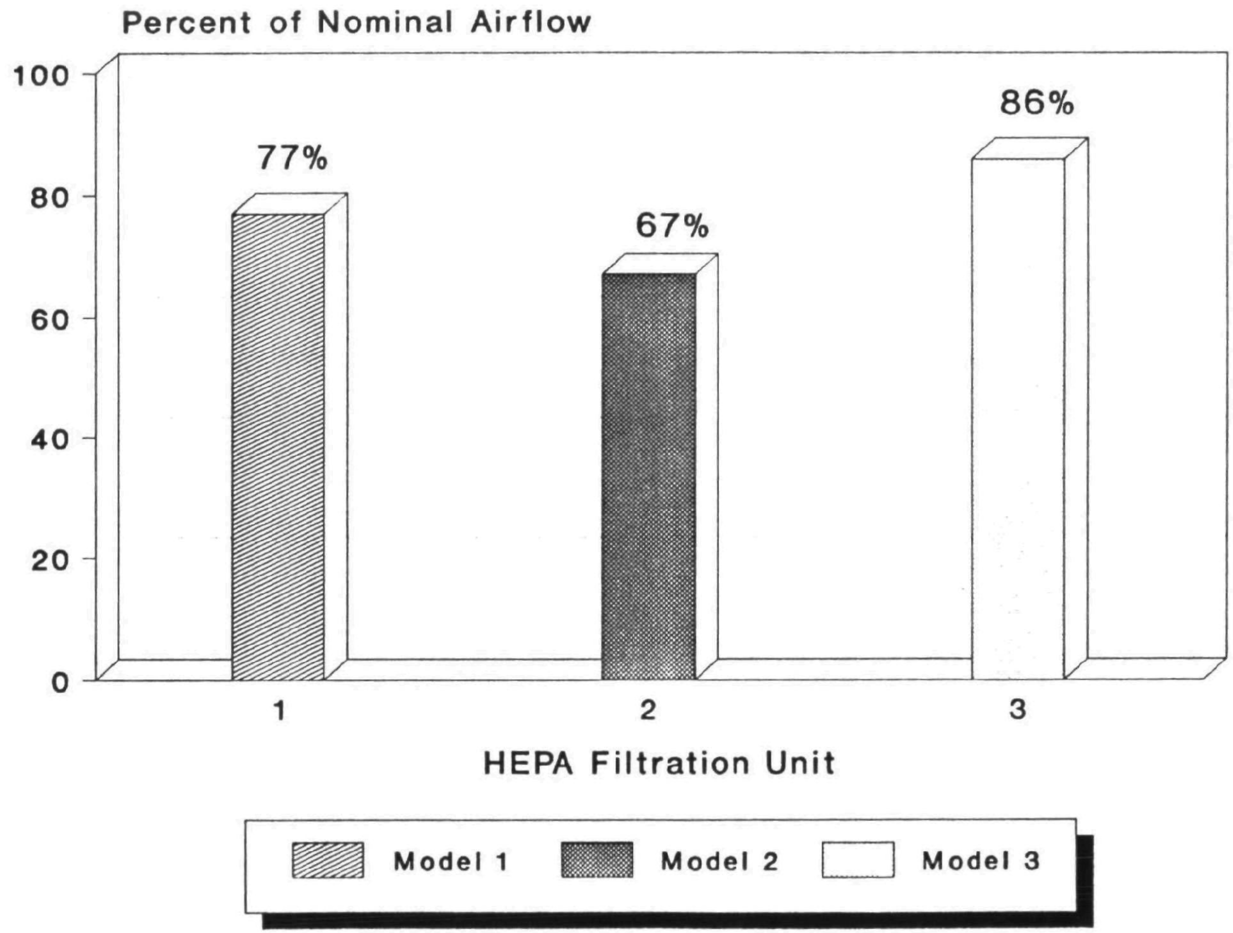


Figure L-2. Airflow performance for HEPA filtration systems operating during AHERA clearance.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls and either full- or half-facepiece air-purifying respirators equipped with dual-cartridge HEPA filters.

Cleaning Procedures

Final cleaning began after the plastic sheeting was removed from the walls, floors, and all auditorium chairs. The critical barriers, doors, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The HEPA filtration units remained in service.

Final cleaning was organized so the workers began in the areas farthest from the personnel decontamination facility and worked toward it. No association appeared to exist between work direction and the location of HEPA-filtration units.

Final cleaning began with the wire-brushing of the ceiling-wall intersections. The surfaces were then cleaned with a HEPA- filtered vacuum. Particular attention was given to vacuuming the crevices around the floor-mounting brackets of the auditorium chairs.

All of the vertical and horizontal surfaces were then wet-cleaned with amended water. The contractor reportedly prepared the amended water solution by mixing approximately 1 ounce each of 50 percent polyoxyethylene ester and 50 percent polyoxyethylene ether in 5 gallons of water.

The elevated vertical surfaces were wiped first and then all other surfaces. All the surfaces except the floors were wiped with absorbent paper towels dampened with amended water. A bucket of amended water was either used by a single worker or shared by several workers. The workers did not appear to wipe the surfaces in any one direction. The paper towels were not replaced frequently, especially during the cleaning of elevated surfaces. Nor was the amended water changed frequently.

After the walls and plastic-covered auditorium chairs were wet-wiped, the floor was mopped with a clean mop head wetted with amended water. No changes in the water were observed during this procedure.

Final cleaning involved one complete mopping of the floor with a clean mop head and amended water. No aggressive cleaning (i.e., air sweeping of all vertical and horizontal surfaces to dislodge any remaining particulate) was conducted.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered, 6-mil-thick, standard disposal bags. A commercial gelling compound was added to the bag to solidify the wastewater. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers. The paper towels and mop heads used during cleaning also were placed in these bags. The bags were not wet-wiped with amended water before being removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an onsite AST, who was the building owner's representative. The AST conducted a visual inspection within 2 hours after notification. The AST identified several areas, particularly elevated horizontal surfaces, that required further cleaning. After these designated areas were recleaned, the AST conducted a final walk-through inspection to assure that the identified areas were clean.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

The site failed the first visual inspection because of the presence of debris on the upper ledge of the auditorium ceiling and on the wooden blocks used to hold up the polyethylene walls. One bulk sample was collected to characterize the debris found on the ceiling ledge. Chrysotile asbestos was identified in this sample, but the sample was not sufficiently large enough to quantify the asbestos content.

The site passed the second visual inspection.

AHERA CLEARANCE SAMPLING BY AST

The AHERA clearance sampling was initiated approximately 24 hours after the site had passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 10 minutes, which is equivalent to approximately 5 minutes per 800 ft^2 of floor area. Two box-type floor fans with 18-inch blades were subsequently used to maintain air turbulence during sampling.

The clearance air samples were collected on 25-mm, 0.45-μm pore size, mixed cellulose ester membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The samples were collected at flow rates of approximately 10 liters per minute. The laboratory report indicates that the samples were analyzed in accordance with the AHERA mandatory TEM method.

Table L-3 presents the results of the clearance samples the AST collected inside the abatement area. The samples met the initial AHERA clearance criterion, i.e., an average asbestos concentration of less than 70 structures per square millimeter (s/mm^2). The average asbestos concentration for the five inside samples was actually 48 s/mm^2. The reason for the elevated concentration (139 s/mm^2) for one of the inside samples is not known.

TABLE L-3. AHERA CLEARANCE SAMPLE RESULTS

Sample location[a]	Sample volume, liters	Asbestos concentration	
		s/mm^2	s/cm^3
Inside	1440	139	0.037
Inside	1320	31	0.009
Inside	1440	17	0.005
Inside	1440	16	0.005
Inside	1440	35	0.009

[a] Outside samples and blanks were not analyzed because the average asbestos concentration for the five inside samples was less than 70 s/mm^2.

[b] Sensitivity of the analytical method.

CASE HISTORY M

SITE DESCRIPTION

This abatement project involved removal of asbestos-containing thermal insulation materials (preformed block and air-cell-paper pipe insulation) from a three-story school building. The abatement area included corridors, classrooms, offices, storage areas, and a gymnasium. The project specification indicated that the asbestos content of the thermal insulation was approximately 40 to 60 percent chrysotile. The specifications did not quantify the amount of asbestos-containing material in each location.

VENTILATION AND NEGATIVE AIR PRESSURE

Three high-efficiency particulate air (HEPA) filtration units were operated during the final cleaning period, and three were operated during AHERA clearance sampling. Table M-1 presents the measured air-intake volume for each unit. The average air-intake volume was 1630 ft^3/min during final cleaning and 1501 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (33,300 ft^3) and the combined average air-intake volumes, the air exchange rates were approximately 8.8 air changes per hour during final cleaning and 8.1 air changes per hour during AHERA clearance sampling.

TABLE M-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS

		Airflow, ft^3/min				95% Confidence interval	
Model	Unit	Mean	Min.	Max.	Std. dev.	Lower	Upper
		Final cleaning					
1	1	1549	1176	1680	122	1484	1614
2	2	1633	1344	1848	168	1543	1722
2	3	1709	1478	1932	118	1646	1772
		AHERA clearance sampling					
1	1	1170	1008	1344	117	1107	1232
2	2	1664	1344	1848	149	1585	1744
2	3	1670	1512	1848	102	1615	1724

Figures M-1 and M-2 compare the measured air-intake volume for each HEPA-filtration unit operating during final cleaning and AHERA clearance sampling, respectively, with the unit's nominal airflow. The actual operating percentages of the nominal airflow ranged from 77 to 85 during final cleaning and from 59 to 84 during AHERA clearance sampling.

Table M-2 presents the static pressure differential measured across the containment barriers at two locations. The number of locations tested was determined by available access to the critical containment barriers. The static pressure differential was -0.02 in. water during final cleaning and ranged from -0.01 to -0.02 in. water during AHERA clearance sampling.

TABLE M-2. STATIC PRESSURE DIFFERENTIALS ACROSS CONTAINMENT BARRIERS (in. water)

Test location	Final cleaning	AHERA clearance
1	-0.02	-0.02
2	-0.02	-0.01

The asbestos safety technician (AST) did not monitor the static pressure differential across the containment barriers. Instead ventilation smoke tubes were used to check negative pressure visually (i.e., direction of air flow through openings in the containment barrier, such as the decontamination facility and waste load-out port). Reportedly, these qualitative checks were performed each morning and afternoon.

The HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility and waste load-out port. The three operating units were positioned along exterior walls to facilitate venting the exhaust through windows via an interconnected flexible duct. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor, who was responsible for maintaining the HEPA-filtration units, stated that the prefilters and secondary filters were changed before final cleaning was initiated and the HEPA filter was changed at the beginning of the project. Thereafter, the prefilters were changed daily, and the secondary filters were changed when they became "visibly dirty." The HEPA filters were changed every 600 to 700 hours (as recommended by the manufacturer) or when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls and either full- or

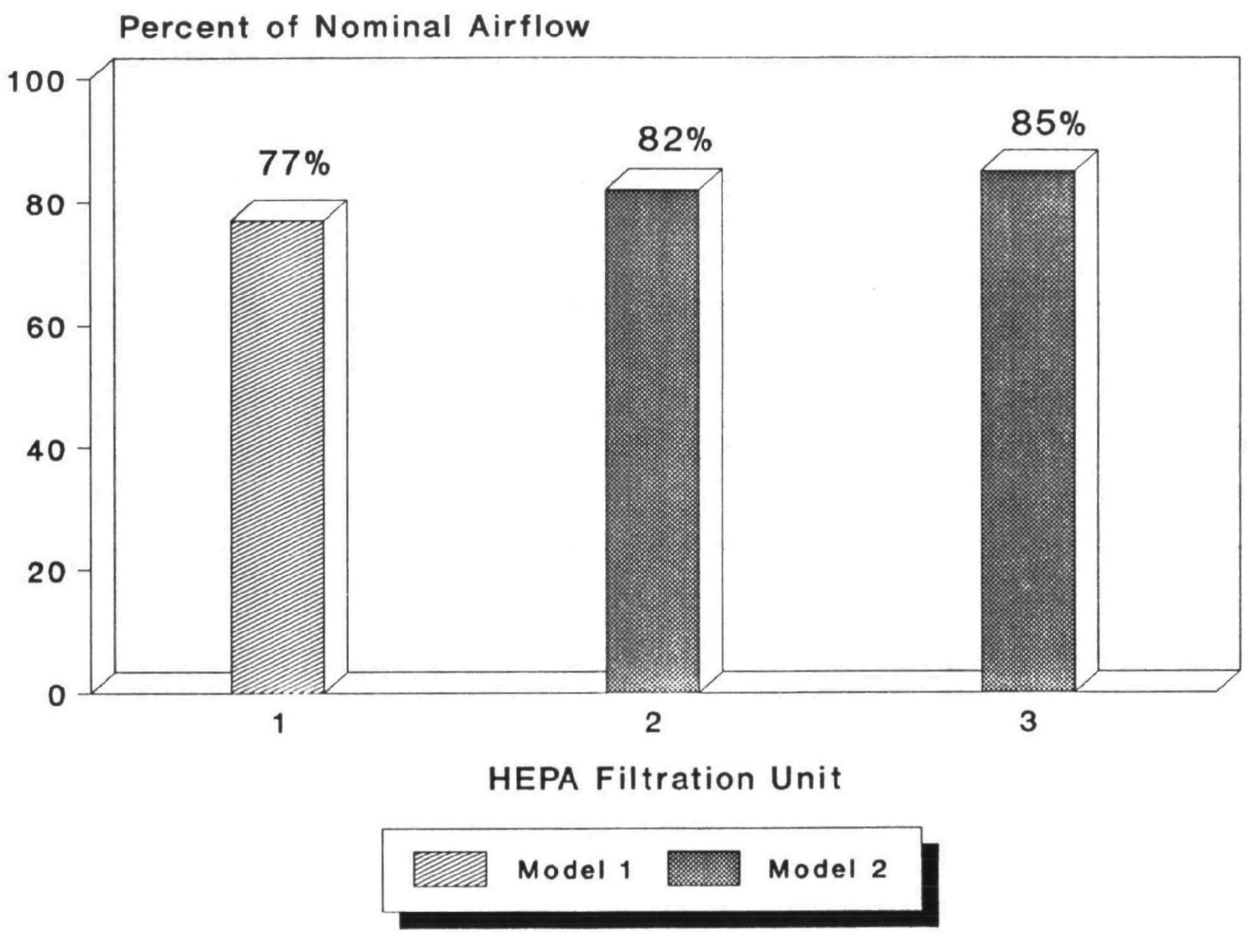


Figure M-1. Airflow performance for HEPA filtration systems operating during final cleanup.

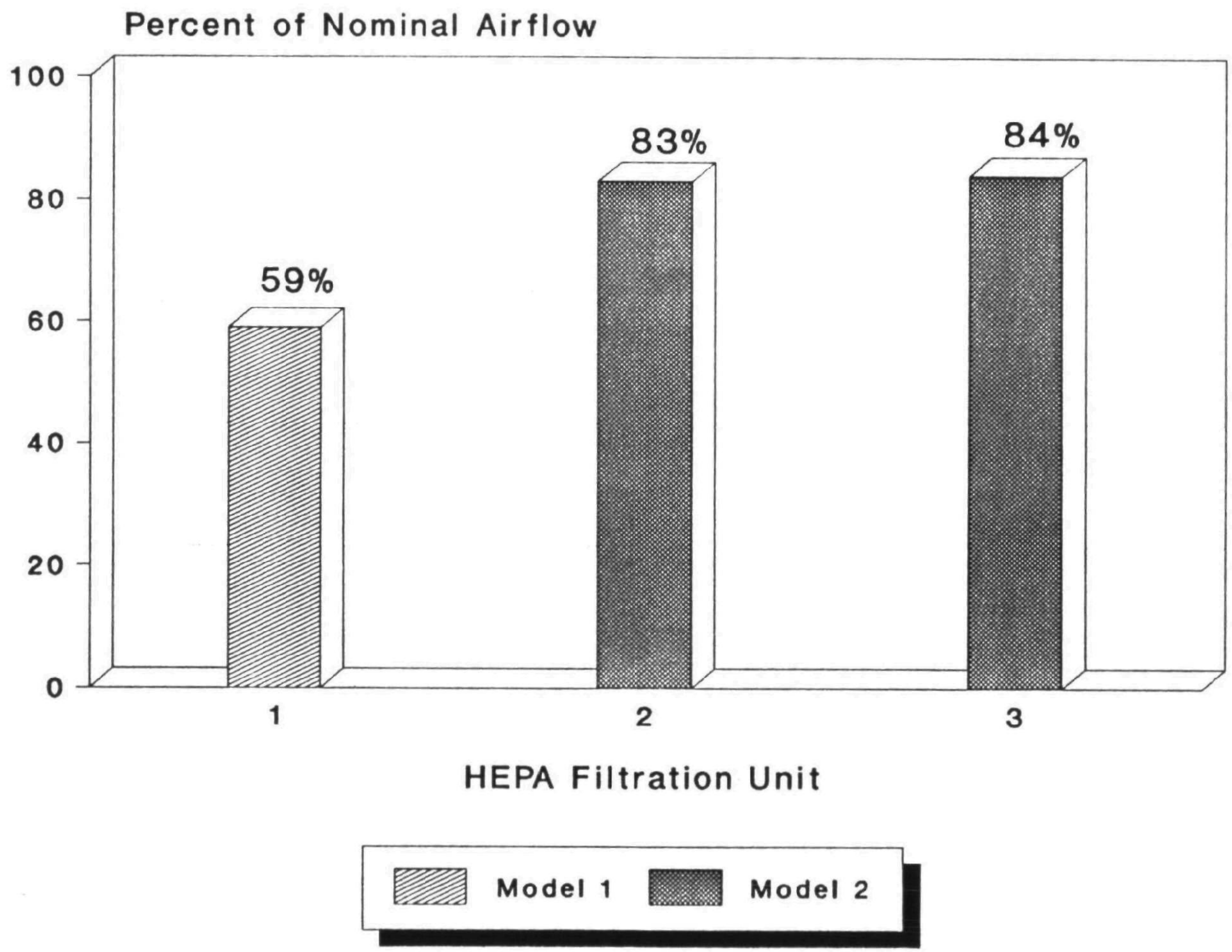


Figure M-2. Airflow performance for HEPA filtration systems operating during AHERA clearance.

half-facepiece air-purifying respirators equipped with dual cartridge HEPA filters.

Cleaning Procedures

Final cleaning began after the encapsulated plastic sheeting was removed from the walls, floors, and other surfaces. The critical barriers, doors, stationary objects, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The HEPA filtration units remained in service.

Final cleaning was organized so the workers began in the areas farthest from the personnel decontamination facility and worked toward it. No association appeared to exist between work direction and the location of the HEPA-filtration units.

Final cleaning began with the brushing of the pipes to remove any visible debris. These surfaces and points where the pipes penetrated walls were cleaned with a HEPA-filtered vacuum. Detailed cleaning of the joints between the planks of the hardwood floor in the gymnasium and the floor-wall intersection was also accomplished with a HEPA-filtered vacuum.

All of the vertical and horizontal surfaces were then wet-cleaned with amended water. The contractor reportedly prepared the amended water solution by mixing approximately 1 ounce each of 50 percent polyoxyethylene ester and 50 percent polyoxyethylene ether in 5 gallons of water.

The elevated horizontal and vertical surfaces were wiped first and then all other surfaces. All the surfaces except the floors were wiped with absorbent paper towels dampened with amended water. A bucket of amended water was either used by a single worker or shared by several workers. The workers did not appear to wipe the surfaces in any one direction. The paper towels were not replaced frequently, especially during the cleaning of elevated and hard-to-access surfaces. Nor was the amended water changed frequently.

After the walls and other surfaces were wet-wiped, the floor was mopped with a clean mop head wetted with amended water. No changes in the water were observed during this procedure.

The last step in the final cleaning was a complete wet-mopping of the floors with a clean mop head and amended water. No aggressive cleaning (i.e., air sweeping of all vertical and horizontal surfaces to dislodge any remaining particulate) was conducted.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered, 6-mil-thick, standard disposal bags. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers or solidified with a gelling compound. The rags and mop heads used during cleaning also were placed in these bags. The bags were not wet-wiped with amended water before being removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an onsite AST, who was the building owner's representative. The AST conducted a visual inspection within 2 hours after notification. The AST identified several areas that required further cleaning, including debris on elbows and joints of pipes, and debris at wall penetrations of pipes. After these designated areas were recleaned, the AST conducted a final walk-through inspection to assure that the identified areas were free of debris.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

The site failed the first visual inspection because of the presence of debris on the floors (in corners and behind pipes at the walls) and on pipe joints and elbows. Four bulk samples were collected to characterize the residual debris found on the floors and pipes. The asbestos content of the debris found on the floor was approximately 30 percent chrysotile. Chrysotile asbestos was also identified in the residual debris found on the pipes; however, the samples were not large enough to quantify the asbestos content.

The site failed the second visual inspection because of debris on pipes, on the floors, and in wall penetrations. One bulk sample was collected to characterize the debris found on the pipes. Although chrysotile asbestos was identified in the residual debris found on the pipes, the sample was not large enough to quantify the asbestos content.

The site passed the third visual inspection.

AHERA CLEARANCE SAMPLING BY AST

The AHERA clearance sampling was initiated approximately 24 hours after the site had passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 60 minutes, which is equivalent to approximately 5 minutes per 260 ft^2 of floor area. Floor fans were not used subsequently to maintain air turbulence during sampling.

The clearance air samples were collected on 25-mm, 0.45-μm pore size, mixed cellulose ester membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The samples were collected at flow rates of approximately 9.25 liters per minute. The laboratory report indicates, the samples were analyzed in accordance with the AHERA mandatory TEM method.

Table M-3 presents the results of the clearance samples the AST collected inside the abatement area. The samples met the initial AHERA clearance criterion, i.e., an average asbestos concentration of less than 70 structures per square millimeter (s/mm^2). The average asbestos concentration for the five inside samples was actually 10 s/mm^2.

TABLE M-3. AHERA CLEARANCE SAMPLE RESULTS

Sample location[a]	Sample volume, liters	Asbestos concentration	
		s/mm²	s/cm³
Inside	2035	0	<0.005[b]
Inside	2035	0	<0.005[b]
Inside	2035	0	<0.005[b]
Inside	2035	0	<0.005[b]
Inside	2035	50	Not Reported

[a] Outside samples and blanks were not analyzed because the average asbestos concentration for the five inside samples was less than 70 s/mm².

[b] Sensitivity of the analytical method.

CASE HISTORY N

SITE DESCRIPTION

This abatement project involved removal of approximately 11,000 ft^2 of spray-applied, asbestos-containing, acoustical plaster from an "egg crate" design structural concrete ceiling in a single-story school building. The abatement area included corridors, classrooms, offices, and mechanical arts classrooms. The project specification indicated that the asbestos content of the ceiling plaster was approximately 10 to 25 percent chrysotile.

VENTILATION AND NEGATIVE AIR PRESSURE

Four high-efficiency particulate air (HEPA) filtration units were operated during the final cleaning period, and four were operated during AHERA clearance sampling. Table N-1 presents the measured air-intake volume for each unit. The average air-intake volume was 1245 ft^3/min during final cleaning and 1253 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (66,300 ft^3) and the combined average air-intake volumes, the air exchange rates were approximately 4.5 air changes per hour during final cleaning and 4.6 air changes per hour during AHERA clearance sampling.

TABLE N-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS

Model	Unit	Airflow, ft^3/min			Std. dev.	95% Confidence interval	
		Mean	Min.	Max.		Lower	Upper
Final cleaning							
1	1	672	528	766	112	612	731
1	2	1007	792	1188	118	944	1069
1	3	1691	1320	1848	142	1616	1767
1	4	1609	1320	1848	145	1531	1686
AHERA clearance sampling							
1	1	586	502	660	52	558	614
1	2	1246	1056	1452	123	1180	1311
1	3	1596	1452	1716	100	1543	1649
1	4	1584	1320	1848	140	1509	1659

Figures N-1 and N-2 compare the measured air-intake volume for each HEPA-filtration unit operating during final cleaning and AHERA clearance sampling, respectively, with the unit's nominal airflow. The actual operating percentages of the nominal airflow ranged from 34 to 85 during final cleaning and from 29 to 80 during AHERA clearance sampling.

Table N-2 presents the static pressure differential measured across the containment barriers at one location. The number of locations tested was determined by available access to the critical containment barriers. The static pressure differential was -0.01 in. water during both final cleaning and AHERA clearance sampling.

TABLE N-2. STATIC PRESSURE DIFFERENTIALS ACROSS CONTAINMENT BARRIERS (in. water)

Test location	Final cleaning	AHERA clearance
1	-0.01	-0.01

The asbestos safety technician (AST) did not monitor the static pressure differential across the containment barriers. Instead ventilation smoke tubes were used to check the negative pressure visually (i.e., direction of airflow through openings in the containment barrier, such as the decontamination facility and waste load-out port). Reportedly, these qualitative checks were performed each morning.

The HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility. Three of the four operating units were positioned along exterior walls to facilitate venting the exhaust through windows via an interconnected flexible duct. The exhaust of the fifth unit was vented through a doorway via an interconnected flexible duct that passed through a room outside of the abatement area. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor, who was responsible for maintaining the HEPA-filtration units, stated that the prefilters and secondary filters were changed before final cleaning was initiated and the HEPA filter was changed at the beginning of the project. Thereafter, the prefilters and secondary filters were changed when they became "visibly dirty." The HEPA filters were changed when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls and either full- or

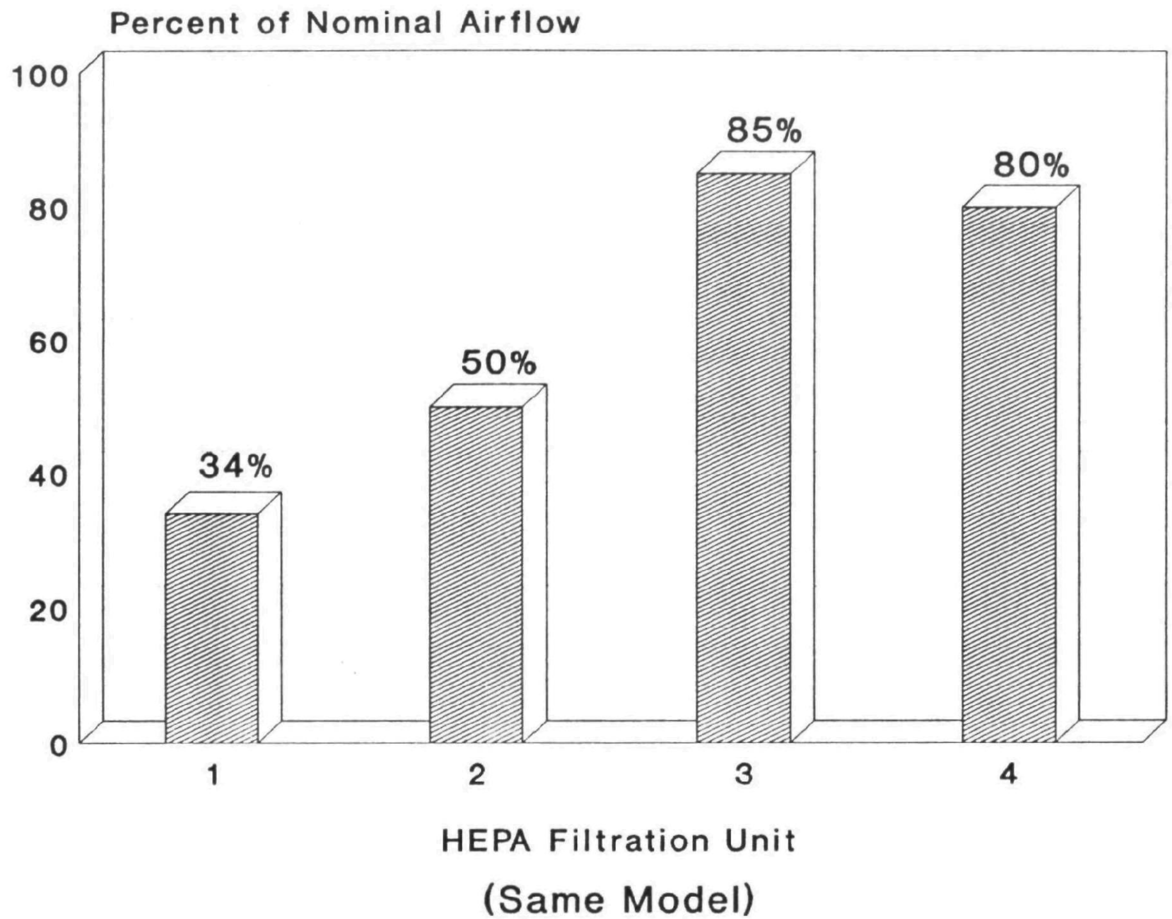


Figure N-1. Airflow performance for HEPA filtration systems operating during final cleanup.

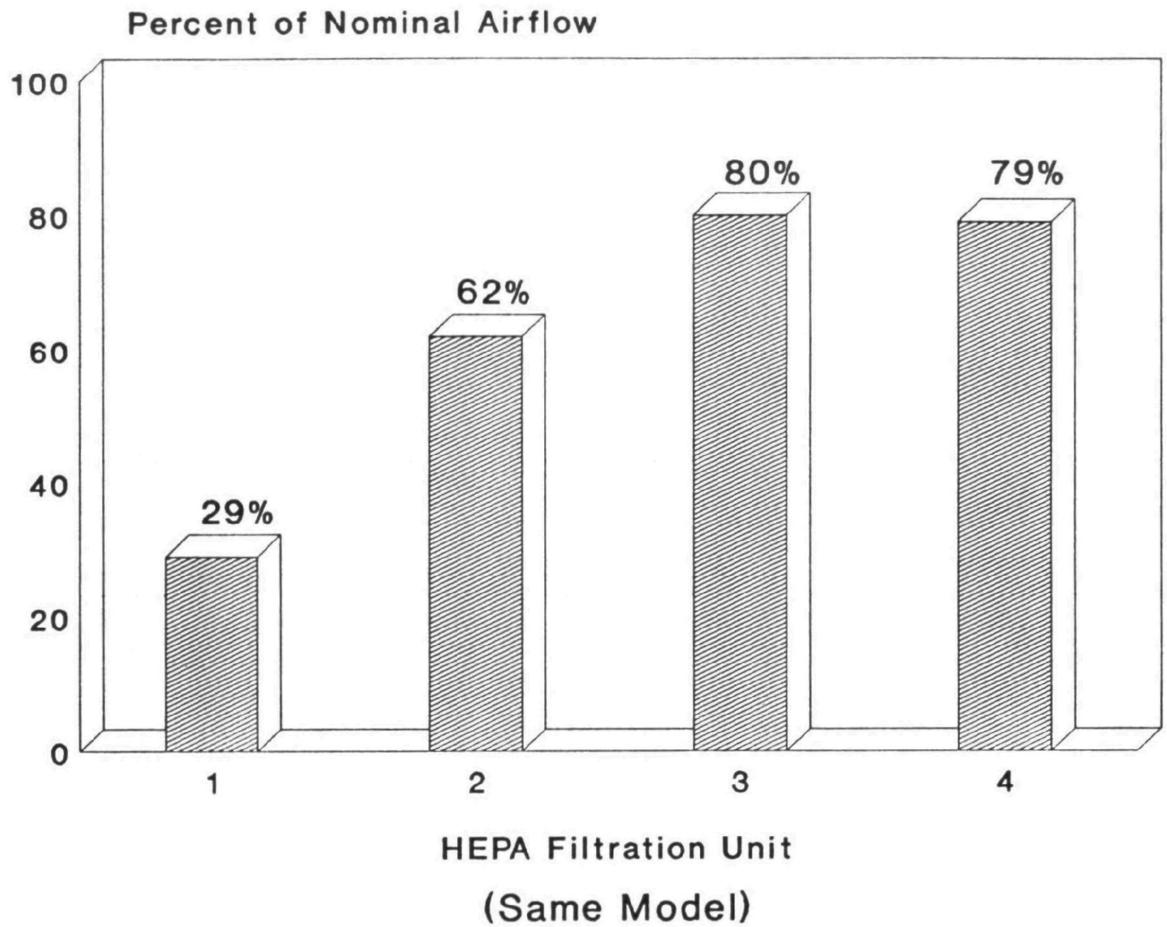


Figure N-2. Airflow performance for HEPA filtration systems operating during AHERA clearance.

half-facepiece air-purifying respirators equipped with dual-cartridge HEPA filters.

Cleaning Procedures

Final cleaning began after the encapsulated plastic sheeting was removed from the walls and floors. The critical barriers, doors, lighting fixtures, stationary objects such as machinery, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The HEPA filtration units remained in service.

The final cleaning was organized so the workers began in the areas farthest from the personnel decontamination facility and worked toward it. No association appeared to exist between the work direction and the location of HEPA-filtration units.

Final cleaning began with the wire-brushing of the concrete substrate surface to remove any visible debris. The ceiling, walls, plastic critical containment barriers, and other surfaces were then sprayed with water to remove any loosely bound debris. The resultant asbestos-containing water on the floor was gathered into pools by use of a rubber squeegee. The bulk of the pooled water was scooped up with plastic bladed shovels. The water was containerized in double-layered, 6-mil-thick, asbestos-disposal bags, which usually contained plastic that had been removed from the walls and floors. The residual water removed with a HEPA-filtered wet vacuum was also placed in the disposal bags.

After the surfaces had dried, a vacuum equipped with a HEPA filter was used to clean crevices around windows, doors, room partitions, shelves, floor-wall interfaces, etc.

All of the vertical and horizontal surfaces were then wet-cleaned with amended water. The contractor reportedly prepared the amended water solution by mixing approximately 1 ounce each of 50 percent polyoxyethylene ester and 50 percent polyoxyethylene ether in 5 gallons of water.

The elevated horizontal and vertical surfaces were wiped first and then all the other surfaces. All the surfaces except the floors were wiped with cotton rags dampened with amended water. A bucket of amended water was either used by a single worker or shared by several workers. The workers did not appear to wipe the surfaces in any one direction. The cloth rags were not replaced frequently, especially during the cleaning of elevated and hard-to-access surfaces. Nor was the amended water changed frequently.

After the walls, windows, and other surfaces (shelves, ledges, plastic-covered stationary equipment, etc.) were wet-wiped, the floor was mopped with a clean mop head wetted with amended water. No changes in the water were observed during this procedure.

The last step in the final cleaning involved one complete wet-mopping of the floors with clean mop heads and amended water. No aggressive cleaning (i.e., air sweeping of all vertical and horizontal surfaces to dislodge any remaining particulate) was conducted.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered, 6-mil-thick, standard disposal bags. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers or solidified with a gelling compound. The rags and mop heads used during cleaning were also placed in these bags. The bags were not wet-wiped with amended water before being removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an onsite AST, who was the building owner's representative. The AST conducted a visual inspection within 2 hours after notification. The AST identified several areas that required further cleaning, including corners at floor-wall intersections and the tops of lighting fixtures. After these designated areas were recleaned, the AST conducted a final walk-through inspection to assure that the identified areas were clean.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

The site failed the first visual inspection because of the presence of debris on light fixtures, the tops of heating elements, on conduit pipe, on the walls behind ventilation ducts, and on the floors. One bulk sample was taken to characterize the residual debris found on the walls. Chrysotile asbestos was identified in this sample; however, the sample was not large enough to quantify the asbestos content.

The site passed the second visual inspection.

AHERA CLEARANCE SAMPLING BY AST

The AHERA clearance sampling was initiated approximately 24 hours after the site passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 13 minutes, which is equivalent to approximately 5 minutes per 4,200 ft^2 of floor area. Two pedestal-type floor fans with 18-inch blades were subsequently used to maintain air turbulence during sampling.

The clearance air samples were collected on 25-mm, 0.45-µm pore size, mixed cellulose ester membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The samples were collected at flow rates of approximately 9.5 liters per minute. The laboratory report indicates that the samples were analyzed in accordance with the AHERA mandatory TEM method.

Table N-3 presents the results of the clearance samples the AST collected inside the abatement area. The samples met the initial AHERA clearance criterion, i.e., an average asbestos concentration of less than 70 structures per square millimeter (s/mm²). The average asbestos concentration for the five inside samples was actually 0 s/mm².

TABLE N-3. AHERA CLEARANCE SAMPLE RESULTS

Sample location[a]	Sample volume, liters	Asbestos concentration	
		s/mm²	s/cm³
Inside	Not reported	0	<0.005[b]
Inside	Not reported	0	<0.005[b]
Inside	Not reported	0	<0.005[b]
Inside	Not reported	0	<0.005[b]
Inside	Not reported	0	<0.005[b]

[a] Outside samples and blanks were not analyzed because the average asbestos concentration for the five inside samples was less than 70 s/mm².

[b] Sensitivity of the analytical method.

CASE HISTORY O

SITE DESCRIPTION

This abatement project involved removal of approximately 2,100 ft^2 of 2-ft by 4-ft lay-in, asbestos-containing, acoustical ceiling tiles from a two-story school building. The abatement area included corridors, classrooms, and offices. The project specification indicated that the asbestos content of the ceiling plaster was approximately 5 to 10 percent amosite.

VENTILATION AND NEGATIVE-AIR PRESSURE

Three high-efficiency particulate air (HEPA) filtration units were operated during the final cleaning period, and three were operated during AHERA clearance sampling. Table O-1 presents the measured air-intake volume for each unit. The average air-intake volume was 1621 ft^3/min during final cleaning and 1453 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (44,400 ft^3) and the combined average air-intake volumes, the air exchange rates were approximately 6.6 air changes per hour during final cleaning and 5.9 air changes per hour during AHERA clearance sampling.

TABLE O-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS

Model	Unit	Airflow, ft^3/min Mean	Airflow, ft^3/min Min.	Airflow, ft^3/min Max.	Std. dev.	95% Confidence interval Lower	95% Confidence interval Upper
Final cleaning							
1	1	1549	1344	1764	133	1478	1619
1	2	1680	1428	1848	115	1619	1741
1	3	1633	1512	1848	107	1576	1690
AHERA clearance sampling							
1	1	1412	1176	1680	161	1327	1498
1	2	1402	1008	1680	180	1306	1498
1	3	1596	1344	1680	126	1477	1610

Figures O-1 and O-2 compare the measured air-intake volume for each HEPA-filtration unit operating during final cleaning and AHERA clearance sampling, respectively, with the unit's nominal airflow. The actual operating percentage of the nominal air flow ranged from 77 to 84 percent during final cleaning and from 70 to 77 percent during AHERA clearance sampling.

Table O-2 presents the static pressure differential measured across the containment barriers at two locations. The number of locations tested was determined by available access to the critical containment barriers. The static pressure differential was -0.02 in. water during both final cleaning AHERA clearance sampling.

TABLE O-2. STATIC PRESSURE DIFFERENTIALS ACROSS CONTAINMENT BARRIERS (in. water)

Test location	Final cleaning	AHERA clearance
1	-0.02	-0.02
2	-0.02	-0.02

The asbestos safety technician (AST) did not monitor the static pressure differential across the containment barriers. Instead, ventilation smoke tubes were used to check the negative pressure visually (i.e., direction of airflow through openings in the containment barrier, such as the decontamination facility and waste load-out port). Reportedly, these qualitative checks were performed each morning and afternoon.

The HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility and waste load-out port. The three operating units were positioned along exterior walls to facilitate venting the exhaust through windows via an interconnected flexible duct. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor, who was responsible for maintaining the HEPA-filtration units, stated that the prefilters and secondary filters were changed before final cleaning was initiated and the HEPA filters were changed at the beginning of the project. Thereafter, the prefilters were changed daily and secondary filters were changed when they became "visibly dirty." The HEPA filters were changed every 600 to 700 hours (as recommended by the manufacturer) or when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls and either full- or

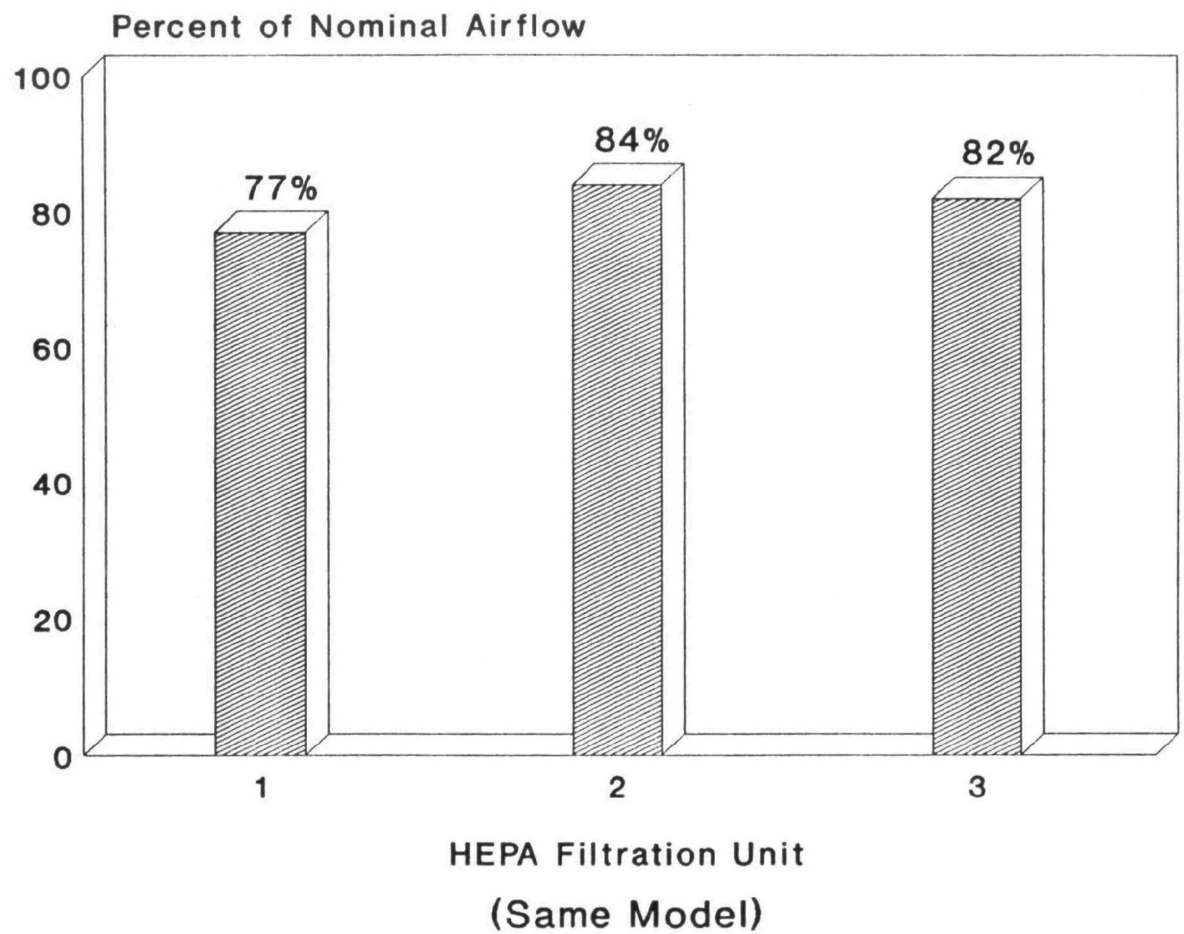


Figure O-1. Airflow performance for HEPA filtration systems operating during final cleanup.

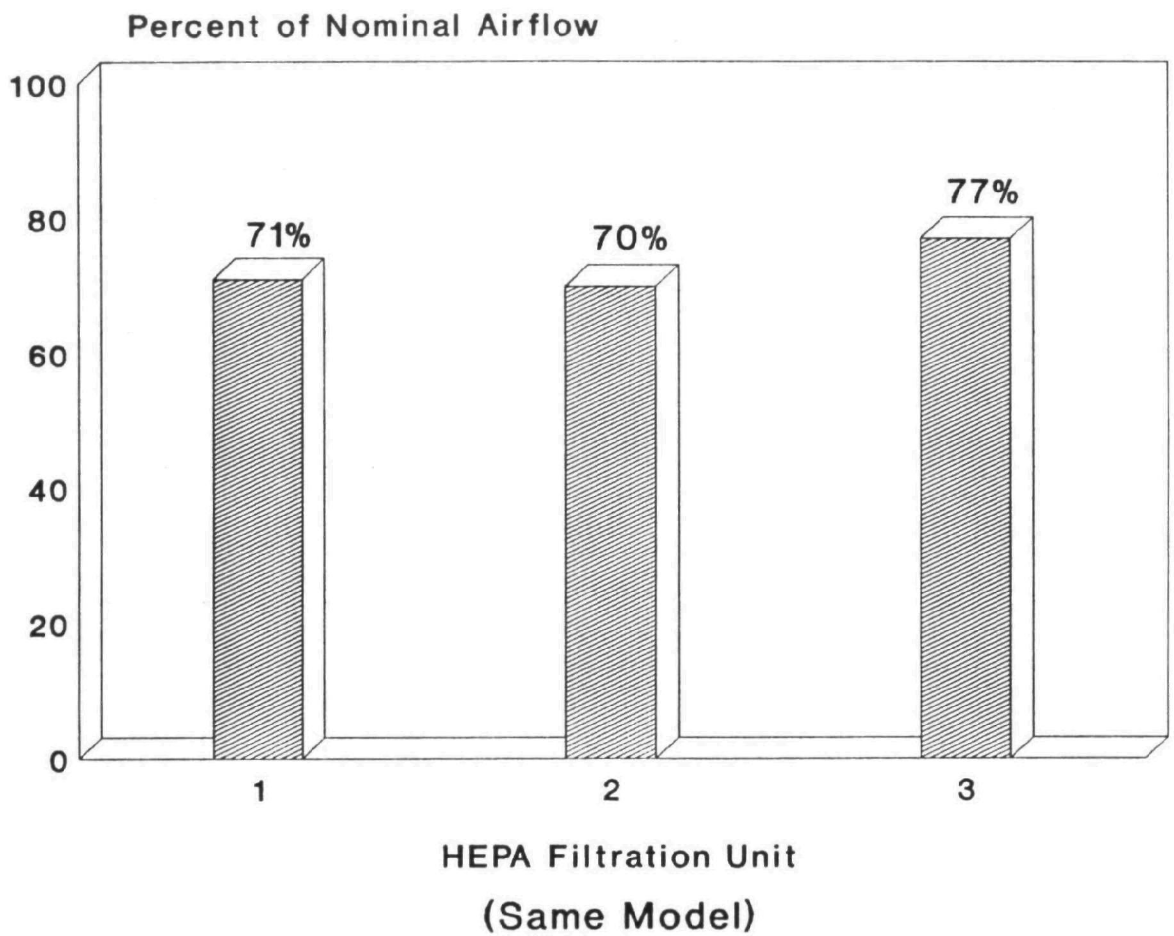


Figure O-2. Airflow performance for HEPA filtration systems operating during AHERA clearance.

half-facepiece air-purifying respirators equipped with dual-cartridge HEPA filters.

Cleaning Procedures

Final cleaning began after the encapsulated plastic sheeting was removed from the walls and floors. The critical barriers, windows, doors, student lockers, water fountains, and heating, ventilation, and air-conditioning (HVAC) vents, etc., remained sealed. The HEPA filtration units remained in service.

The final cleaning was organized so the workers began in the areas farthest from the personnel decontamination facility and worked toward it. No association appeared to exist between the work direction and the location of the HEPA-filtration units.

Final cleaning began with the cleaning of the T-bar ceiling grid network and hard-to-reach areas (such as indented corners and crevices) with a vacuum equipped with a HEPA filter. The vertical and horizontal surfaces were then sprayed with amended water. The contractor reportedly prepared the amended water solution by mixing approximately 1 ounce each of 50 percent polyoxyethylene ester and 50 percent polyoxyethylene ether in 5 gallons of water.

The resultant asbestos-containing water on the floor was gathered into pools by use of a rubber squeegee. The residual water was removed with a wet vacuum and placed in double-layered, 6-mil-thick, asbestos-disposal bags, which usually contained plastic that had been removed from the walls and floors.

All of the vertical and horizontal surfaces were then wet-cleaned with amended water. The elevated horizontal and vertical surfaces were wiped first and then all other surfaces. All of the surfaces except the floors were wiped with cotton rags dampened with amended water. A bucket of amended water was either used by a single worker or shared by several workers. The workers did not appear to wipe the surfaces in any one direction. The cloth rags were not replaced frequently, especially during the cleaning of elevated and hard-to-access surfaces. Nor was the amended water changed frequently.

After the walls, windows, and other surfaces (plastic-covered student lockers, light fixtures, HEPA-filtration systems and associated exhaust ducts, etc.) were wet-wiped, the floor was mopped with a clean mop head wetted with amended water. No changes in the water were not observed during this procedure.

The last step in final cleaning involved removal of the plastic sheeting covering the HEPA-filtration units and associated exhaust ducts. The latter were covered with a polyethylene plastic sleeve. According to the contractor, this simplified cleaning of this equipment.

Final cleaning involved one complete wet-cleaning of the floors. No aggressive cleaning (i.e., air sweeping of all vertical and horizontal surfaces to dislodge any remaining particulate) was conducted.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered, 6-mil-thick, standard disposal bags. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers or solidified with a gelling compound. The rags and mop heads used during cleaning also were placed in these bags. The bags were not wet-wiped with amended water before being removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an onsite AST, who was the building owner's representative. The AST conducted a visual inspection within 2 hours after notification. The AST identified several areas that required further cleaning, including 1) ledges along staircases, 2) indented corners, and 3) lighting fixtures. After these designated areas were recleaned, the AST conducted a final walk-through inspection to assure that the identified areas were clean.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

The site failed the first visual inspection because of the presence of debris on overhead pipes, on the grid system framework for suspended ceiling panels, and in corners of floor-wall intersections. The site passed the second visual inspection.

AHERA CLEARANCE SAMPLING BY AST

The AHERA clearance sampling was initiated approximately 24 hours after the site had passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 34 minutes, which is equivalent to approximately 5 minutes per 650 ft^2 of floor area or 6 minutes per 6600 ft^3 of work space. Four box-type floor fans with 18-inch blades were subsequently used to maintain air turbulence during sampling.

The clearance air samples were collected on 25-mm, 0.45-μm pore size, mixed cellulose ester membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The samples were collected at flow rates of approximately 10 liters per minute. The laboratory report indicates that the samples were analyzed in accordance with the AHERA mandatory TEM method.

Table O-3 presents the results of the clearance samples the AST collected inside the abatement area. The samples met the initial AHERA clearance criterion, i.e., an average asbestos concentration of less than 70 structures per square millimeter (s/mm^2). The average asbestos concentration for the five inside samples was actually 0 s/mm^2.

TABLE O-3. AHERA CLEARANCE SAMPLE RESULTS

Sample location[a]	Sample volume, liters	Asbestos concentration	
		s/mm^2	s/cm^3
Inside	Not reported	0	<0.005[b]
Inside	Not reported	0	<0.005[b]
Inside	Not reported	0	<0.005[b]
Inside	Not reported	0	<0.005[b]
Inside	Not reported	0	<0.005[b]

[a] Outside samples and blanks were not analyzed because the average asbestos concentration for the five inside samples was less than 70 s/mm^2.

[b] Sensitivity of the analytical method.

CASE HISTORY P

SITE DESCRIPTION

This abatement project involved removal of trowel-applied, asbestos-containing, acoustical ceiling plaster and mixed-diameter pipe insulation from a single-story school building. The abatement area included corridors, classrooms, and offices. The project specification indicated that the abatement involved approximately 8500 ft^2 of acoustical ceiling plaster containing 91 to 93 percent chrysotile and approximately 1600 linear feet of mixed--diameter pipe insulation. The latter included hard-packed pipe insulation (24 percent chrysotile), air-cell-paper pipe insulation (4 to 10 percent chrysotile), and hard-packed joint insulation (60 percent chrysotile).

VENTILATION AND NEGATIVE-AIR PRESSURE

Five high-efficiency particulate air (HEPA) filtration units were operated during the final cleaning period, and four were operated during AHERA clearance sampling. Table P-1 presents the measured air-intake volume for each unit. The average air-intake volume was 1566 ft^3/min during final cleaning and 1570 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (77,000 ft^3) and the combined average air-intake volumes, the air-exchange rates were approximately 6 air changes per hour during final cleaning and 4.9 air changes per hour during AHERA clearance sampling.

Figures P-1 and P-2 compare the measured air-intake volume for each HEPA-filtration unit operating during final cleaning and AHERA clearance sampling, respectively, with the unit's nominal airflow. The actual operating percentages of the nominal airflow ranged from 69 to 85 during final cleaning and from 74 to 85 during AHERA clearance sampling.

Table P-2 presents the static pressure differential measured across the containment barriers at two locations. The number of locations tested was determined by available access to the critical containment barriers. The static pressure differential ranged from -0.02 to -0.03 in. water during final cleaning and was -0.02 in. water during AHERA clearance sampling.

The asbestos safety technician (AST) did not monitor the static pressure differential across the containment barriers. Instead, ventilation smoke tubes were used to check the negative pressure visually (i.e., direction of airflow through openings in the containment barrier, such as the decontamination facility and waste load-out port). Reportedly, these qualitative checks were performed each morning and afternoon.

TABLE P-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS

Model	Unit	Airflow, ft^3/min Mean	Min.	Max.	Std. dev.	95% Confidence interval Lower	Upper
			Final cleaning				
1	1	1596	1260	1848	171	1505	1687
1	2	1549	1344	1848	148	1470	1628
2	3	1381	1092	1680	163	1294	1467
2	4	1596	1428	1848	115	1535	1657
2	5	1706	1512	1848	93	1657	1756
			AHERA clearance sampling				
1	1	1502	1344	1680	102	1447	1556
1	2	1701	1428	1848	144	1624	1778
2	3	1470	1344	1680	103	1415	1525
2	4	1607	1428	1848	129	1538	1675

TABLE P-2. STATIC PRESSURE DIFFERENTIALS ACROSS CONTAINMENT BARRIERS (in. water)

Test location	Final cleaning	AHERA clearance
1	-0.03	-0.02
2	-0.02	-0.02

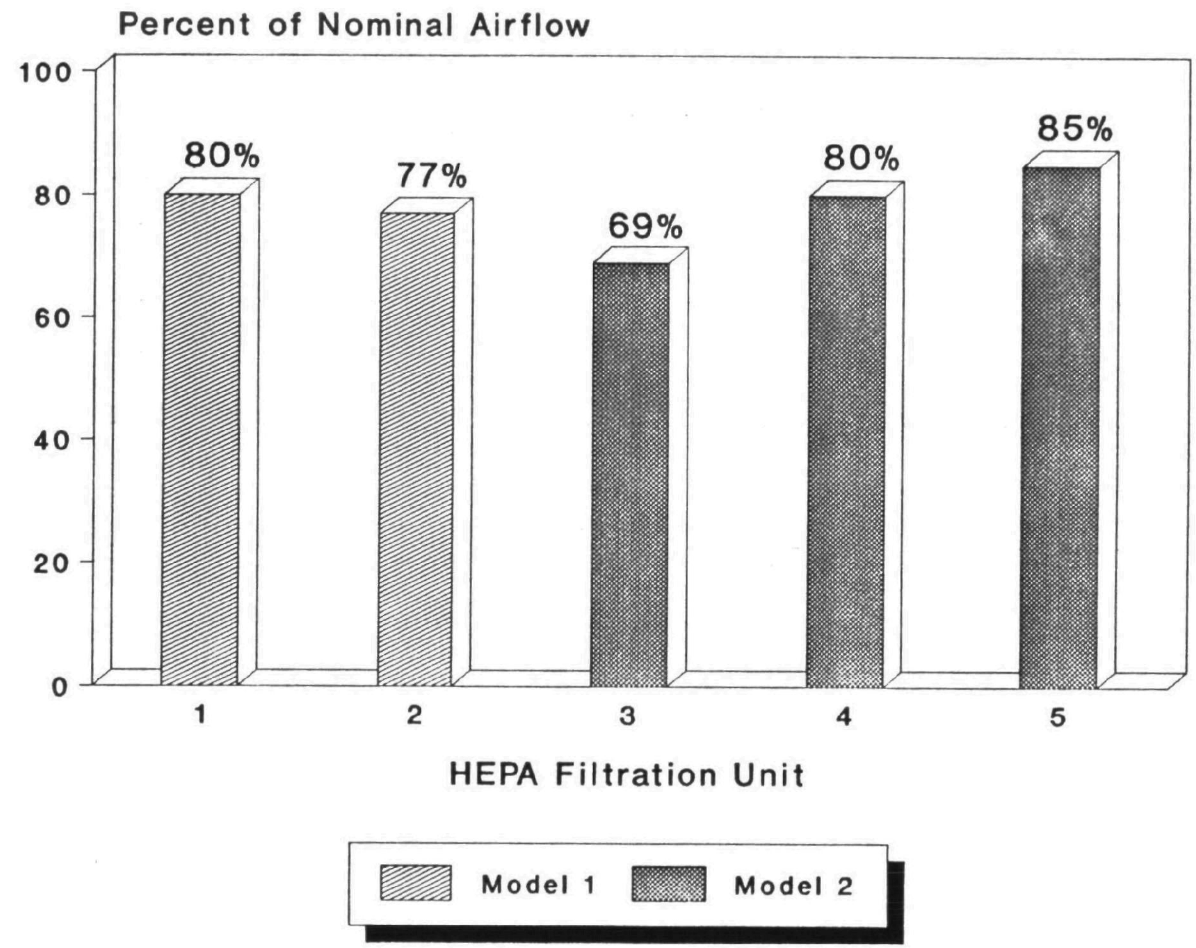


Figure P-1. Airflow performance for HEPA filtration systems operating during final cleanup.

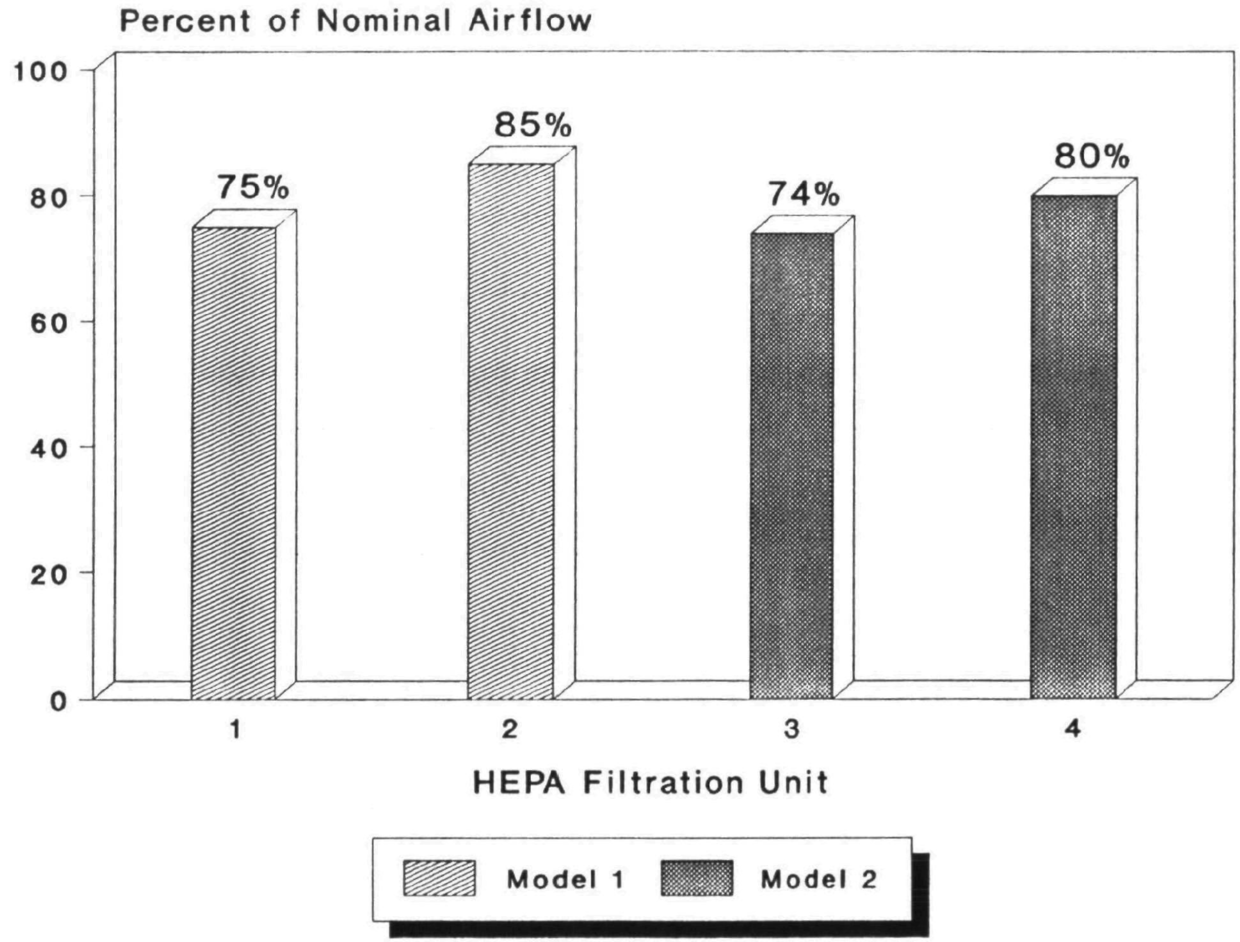


Figure P-2. Airflow performance for HEPA filtration systems operating during AHERA clearance.

The HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility and waste load-out port. Three of the five operating units were positioned along exterior walls, to facilitate venting the exhaust through windows via an interconnected flexible duct. The exhaust of two of the five units was vented through a doorway via an interconnected flexible duct that passed through a classroom outside of the abatement area. This is particularly noteworthy because the the flexible duct for one of the two units was torn and a percentage of the exhaust air was released into the building. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor, who was responsible for maintaining the HEPA-filtration units, stated that the prefilters and secondary filters were changed before final cleaning was initiated and the HEPA filters were changed at the beginning of the project. Thereafter, the prefilters were changed daily and the secondary filters were changed when they became "visibly dirty." The HEPA filters were changed when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls and either full- or half-facepiece air-purifying respirators equipped with dual-cartridge HEPA filters.

Cleaning Procedures

Final cleaning began after the plastic sheeting was removed from the walls and floors. The critical barriers, windows, doors, chalkboards, student lockers, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The HEPA filtration units remained in service.

The final cleaning was organized so the workers began in the areas farthest from the personnel decontamination facility and worked toward it. No association appeared to exist between the work direction and the location of the HEPA-filtration units.

Final cleaning began with the spraying of the walls, windows, plastic critical containment barriers, and other vertical surfaces with water to remove any loosely bound debris. The resultant asbestos-containing water on the floor was gathered into pools by use of a rubber squeegee. The bulk of the pooled water was scooped up with plastic bladed shovels, an approach that worked surprisingly well. The water was containerized in double-layered, 6-mil-thick, asbestos-disposal bags, which generally contained plastic that had been removed from the walls and floors. Residual water removed with a HEPA-filtered wet vacuum was also placed in these bags.

Some of the asbestos-containing water penetrated the seams between the vinyl floor tiles in classrooms and caused sections to buckle. Some of these buckled floor tiles were present in each of the classrooms of the abatement area. The asbestos-containing water beneath the floor tiles was allowed to dry, and the tiles were not repaired. These areas could represent potential sources of airborne asbestos fibers when repaired later by maintenance personnel.

After the surfaces had dried, a vacuum equipped with a HEPA filter was used to clean crevices around windows, doors, baseboards, shelves, floor-wall interfaces, etc.

All of the vertical and horizontal surfaces were then wet-cleaned with amended water. The contractor reportedly prepared the amended water solution by mixing approximately 2 ounces each of 50 percent polyoxyethylene ester and 50 percent polyoxyethylene ether in 5 gallons of water.

The elevated horizontal and vertical surfaces were wiped first and then all the other surfaces. All of the surfaces except the floors were wiped with cotton rags dampened with amended water. A bucket of amended water was either used by a single worker or shared by several workers. The workers did not appear to wipe the surfaces in any one direction. The cloth rags were not replaced frequently, especially during the cleaning of elevated and hard-to-access surfaces. Nor was the amended water changed frequently.

After the walls, windows, and other surfaces (shelves, ledges, etc.) were wet-wiped, the floor was mopped with a clean mop head wetted with amended water. No changes in the water were observed during this procedure. No aggressive cleaning (i.e., air sweeping of all vertical and horizontal surfaces to dislodge any remaining particulate) was conducted.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered, 6-mil-thick, standard disposal bags. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers or solidified with a gelling compound. The rags and mop heads used during cleaning were also placed in bags. The bags were not wet-wiped with amended water and removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an onsite AST, the building owner's representative. The AST conducted a visual inspection within 2 hours of notification. The AST identified several areas that required further cleaning, including ceiling-wall intersections and the tops of lighting fixtures. After these designated areas were recleaned, the AST conducted a final walk-through inspection to assure that the identified areas were clean.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

The site failed the first visual inspection because of the presence of debris on pipes, in the openings where the pipes penetrated the walls, on electrical fixtures and wires, in door jambs, at ceiling-wall junctions, on walls, inside a fireplace and chimney, and in a sink used for disposal of asbestos-containing waste- water. Six bulk samples were collected to characterize the residual debris found in these locations. The debris found in the fireplace had an asbestos content of 11 percent chrysotile; that found at the ceiling-wall junction contained approximately 4 percent chrysotile. No asbestos was identified in the sample of slurry found on a wall. Chrysotile asbestos also was identified in debris found on the tops of doors and on walls; however, the samples were not large enough to quantify the asbestos content.

The site failed the second visual inspection because of debris behind the fireplace, at ceiling-wall junctions, and on floors and residual slurry found on walls and underneath stairs. Eight bulk samples were collected to characterize the debris and slurry found during this inspection, and chrysotile asbestos was identified in all of them. The asbestos content of the debris found at the ceiling-wall junction was approximately 6 percent. All the other samples were not large enough to quantify the asbestos content.

The site passed the third visual inspection.

AHERA CLEARANCE SAMPLING BY AST

The AHERA clearance sampling was initiated about 2 hours after the site had passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 30 minutes, which is equivalent to approximately 5 minutes per 1400 ft^2 of floor area. No floor fans were used subsequently to maintain air turbulence during sampling.

The clearance air samples were collected on 25-mm, 0.45-µm pore size, mixed cellulose ester membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The samples were collected at flow rates of approximately 10 liters per minute. The laboratory report indicates that the samples were analyzed in accordance with the AHERA mandatory TEM method.

Table P-3 presents the results of the clearance samples the AST collected inside the abatement area. The samples met the initial AHERA clearance criterion, i.e., an average asbestos concentration of less than 70 structures per square millimeter (s/mm^2). The average asbestos concentration for the five inside samples was actually 0 s/mm^2.

TABLE P-3. AHERA CLEARANCE SAMPLE RESULTS

Sample location[a]	Sample volume, liters	Asbestos concentration	
		s/mm²	s/cm³
Inside	2299	0	<0.005[b]
Inside	2221	0	<0.005[b]
Inside	2270	0	<0.005[b]
Inside	2291	0	<0.005[b]
Inside	2318	0	<0.005[b]

[a] Outside samples and blanks were not analyzed because the average asbestos concentration for the five inside samples was less than 70 s/mm².

[b] Sensitivity of the analytical method.

CASE HISTORY Q

SITE DESCRIPTION

This abatement project involved removal of approximately 5400 ft^2 of spray-applied asbestos-containing acoustical plaster from ceilings and fascias on the first floor of a two-story school building. The abatement area included corridors, classrooms, and offices. The project specification indicated that the asbestos content of the acoustical plaster was approximately 2 to 6 percent chrysotile.

VENTILATION AND NEGATIVE AIR PRESSURE

Three high-efficiency particulate air (HEPA) filtration units were operated during the final cleaning period, and three were operated during AHERA clearance sampling. Table Q-1 presents the measured air-intake volume for each unit. The average air-intake volume was 1371 ft^3/min during final cleaning and 1438 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (55,120 ft^3) and the combined average air-intake volumes, the air exchange rates were approximately 4.5 air changes per hour during final cleaning and 4.7 air changes per hour during AHERA clearance sampling.

TABLE Q-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS

Model	Unit	Airflow, ft^3/min			Std. dev.	95% Confidence interval	
		Mean	Min.	Max.		Lower	Upper
Final cleaning							
1	1	1235	999	1443	131	1165	1305
1	2	1162	944	1499	122	1097	1227
2	3	1717	1596	1848	94	1667	1767
AHERA clearance sampling							
1	1	1394	1221	1491	98	1342	1447
1	2	1245	999	1499	161	1160	1331
2	3	1675	1344	1848	124	1609	1741

Figures Q-1 and Q-2 compare the measured air-intake volume of each HEPA-filtration unit operating during final cleaning and AHERA clearance sampling, respectively, with the unit's nominal airflow. The actual operating percentages of the nominal airflow ranged from 59 to 86 during final cleaning and from 62 to 84 during AHERA clearance sampling.

Table Q-2 presents the static pressure differential measured across the containment barriers at two locations. The number of locations tested was determined by available access to the critical containment barriers. The static pressure differential was -0.01 in. water during both final cleaning and AHERA clearance sampling.

TABLE Q-2. STATIC PRESSURE DIFFERENTIALS ACROSS CONTAINMENT BARRIERS (in. water)

Test location	Final cleaning	AHERA clearance
1	-0.01	-0.01
2	-0.01	-0.01

The asbestos safety technician (AST) did not monitor the static pressure differential across the containment barrier. Instead, ventilation smoke tubes were used to check the negative pressure visually (i.e., direction of airflow through openings in the containment barrier, such as the decontamination facility and waste load-out port). Reportedly, these qualitative checks were performed each morning.

The HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility and waste load-out port. The three operating units were positioned along exterior walls to facilitate venting the exhaust through windows via an interconnected flexible duct. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor, who was responsible for maintaining the HEPA-filtration units, stated that the prefilters and secondary filters were changed before final cleaning was initiated and the HEPA filters were changed at the beginning of the project. Thereafter, the prefilters were changed daily, and the secondary filters were changed when they became "visibly dirty." The HEPA filters were changed when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls and either full- or

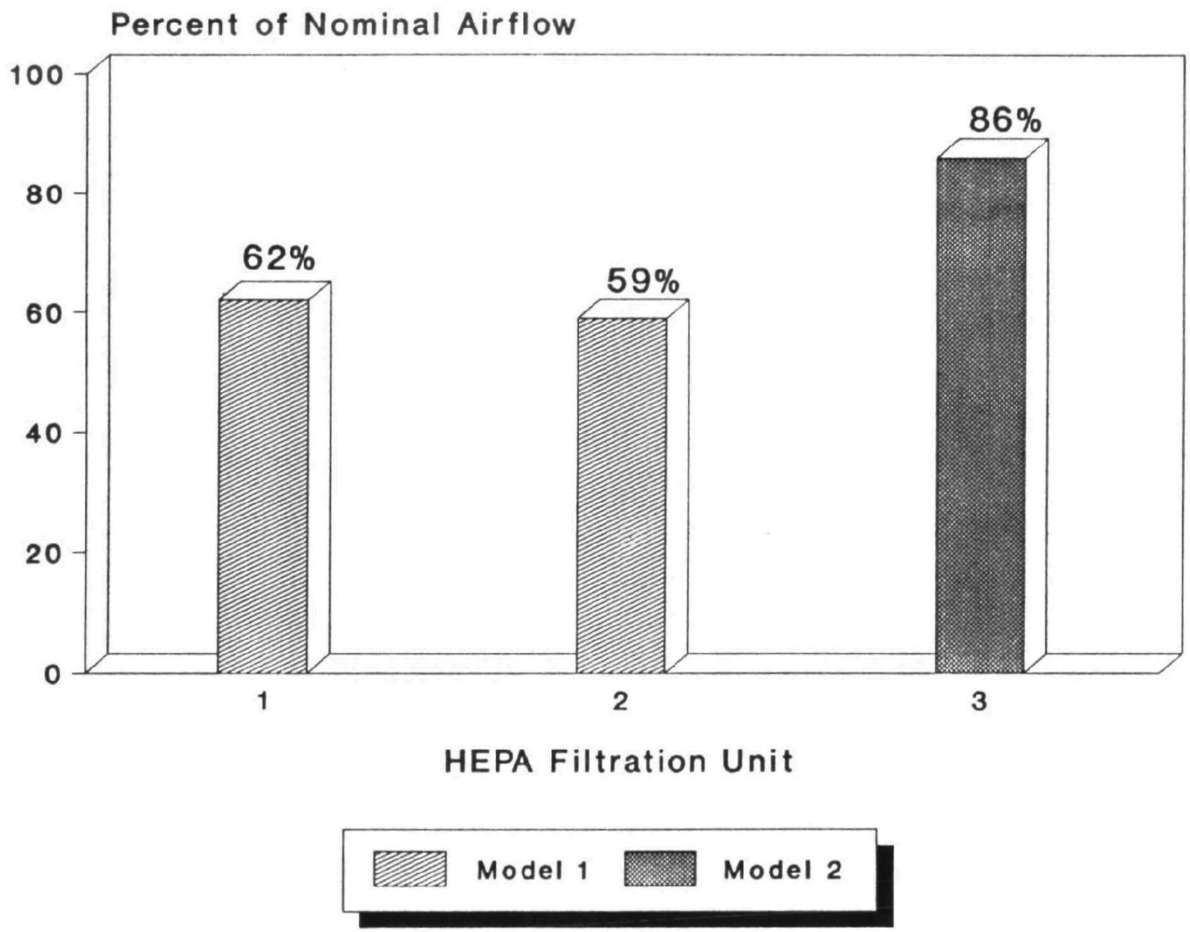


Figure Q-1. Airflow performance for HEPA filtration systems operating during final cleanup.

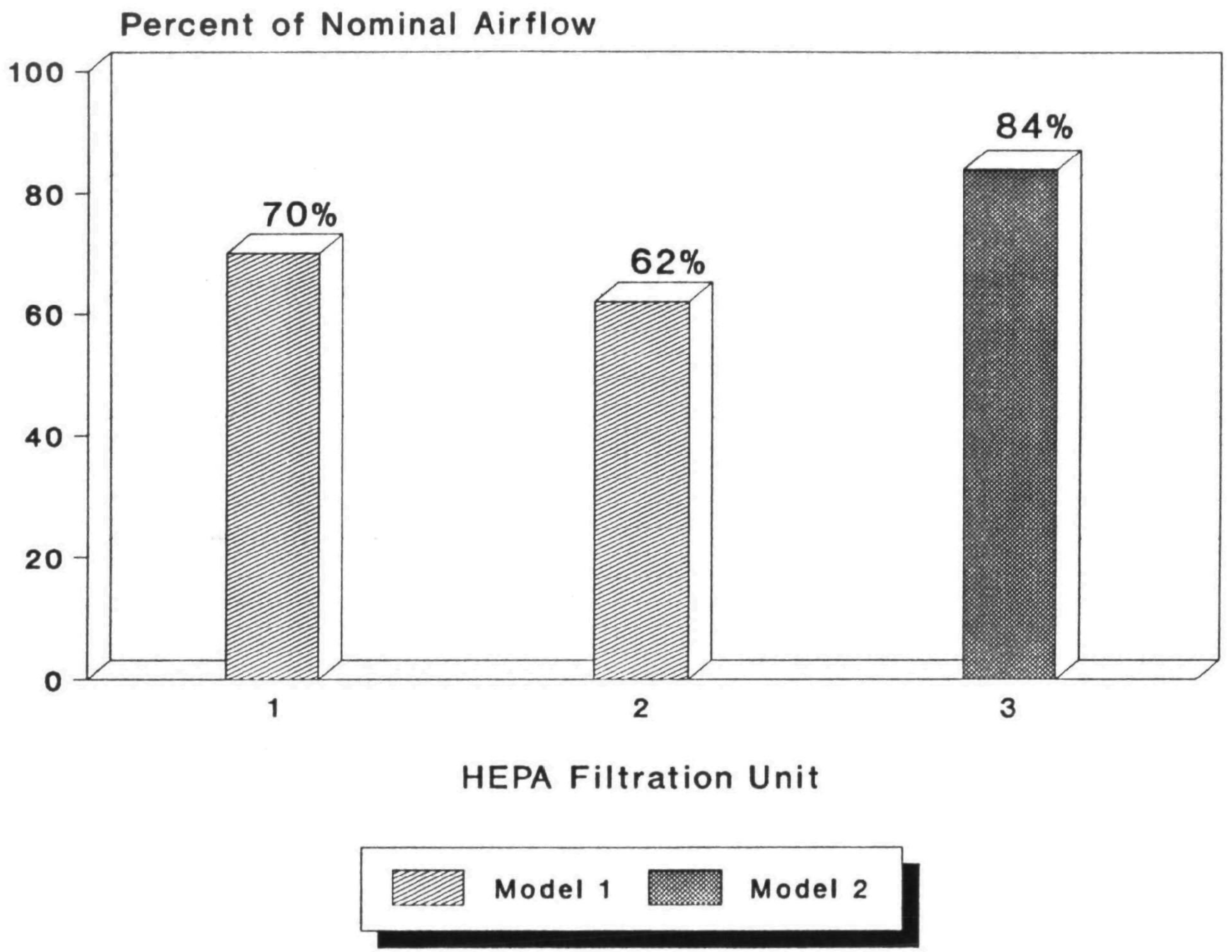


Figure Q-2. Airflow performance for HEPA filtration systems operating during AHERA clearance.

half-facepiece air-purifying respirators equipped with dual-cartridge HEPA filters.

Cleaning Procedures

Final cleaning began after the plastic sheeting was removed from the walls, floors, and other surfaces such as closets. The critical barriers, windows, doors, chalkboards, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The HEPA filtration units remained in service.

The final cleaning was organized so the workers began in the areas farthest from the personnel decontamination facility and worked toward it. No association appeared to exist between the work direction and the location of the HEPA-filtration units.

Final cleaning began with the wire-brushing of the ceiling-wall interface to remove any visible debris. A vacuum equipped with a HEPA filter was then used to clean crevices around windows, doors, shelves, stairs, floor-wall intersections, baseboards, etc.

The walls, windows, plastic critical containment barriers, and other vertical surfaces were then sprayed with a light water mist to remove any loosely bound debris. The resultant asbestos-containing water on the floor was gathered into pools by use of a rubber squeegee. The bulk of the pooled water was scooped up with plastic-bladed shovels, a approach that worked surprisingly well. The water was containerized in double-layered, 6-mil-thick, asbestos-disposal bags, which usually contained plastic that had been removed from the walls and floors. The residual water removed with a wet vacuum was also placed in these bags.

All of the vertical and horizontal surfaces were then wet-cleaned with amended water. The contractor reportedly prepared the amended water solution by mixing approximately 2 ounces each of 50 percent polyoxyethylene ester and 50 percent polyoxyethylene ether in 5 gallons of water.

The elevated horizontal and vertical surfaces were wiped first and then all the other surfaces. All of the surfaces except the floors were wiped with cotton rags dampened with amended water. A bucket of amended water was either used by a single worker or shared by several workers. The workers did not appear to wipe the surfaces in any one direction. The cloth rags were not replaced frequently, especially during the cleaning of elevated and hard-to-access surfaces. Nor was the amended water changed frequently.

After the walls, windows, and other surfaces (shelves, ledges, tops of closets, etc.) had been wet-wiped, the floor was mopped with a clean mop head wetted with amended water. No changes in the water were observed during this procedure.

No aggressive cleaning (i.e., air sweeping of all vertical and horizontal surfaces to dislodge any remaining particulate) was conducted.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered, 6-mil-thick, standard disposal bags. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers or solidified with a gelling compound. The rags and mop heads used during cleaning also were placed in these bags. The bags were not wet-wiped with amended water before being removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an AST, the building owner's representative. The AST conducted a visual inspection within 2 hours after notification. The AST identified several areas that required further cleaning,including tops of storage closets and light fixtures, baseboard moldings, and indented corners at window ledges. After these designated areas were recleaned, the AST conducted a final walk-through inspection to assure that the identified areas were clean.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

The site failed the first visual inspection because of the presence of debris on top of storage closets, on structural beams. The site also failed the second visual inspection for two reasons: 1) debris in openings at wall penetrations, and 2) debris on several light fixtures. The site failed the third visual inspection as well because of debris found at wall-ceiling intersections, in door jams, and in the corners of window sills. The site passed the fourth visual inspection.

AHERA CLEARANCE SAMPLING BY AST

The AHERA clearance sampling was initiated approximately 24 hours after the site had passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 20 minutes, which is equivalent to approximately 5 minutes per 1400 ft^2 of floor area. Five box-type floor fans with 20-inch blades were subsequently used to maintain air turbulence during sampling.

The clearance air samples were collected on 25-mm, 0.45-μm pore size, mixed cellulose ester membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The samples were collected at flow rates of approximately 10 liters per minute. According to the laboratory report, the samples were analyzed in accordance with the AHERA mandatory TEM method.

Table Q-3 presents the results of the clearance samples the AST collected inside the abatement area. The samples met the initial AHERA clearance criterion, i.e., an average asbestos concentration of less than 70 structures per square millimeter (s/mm^2). The average asbestos concentration for the five inside samples was actually 0 s/mm^2.

TABLE Q-3. AHERA CLEARANCE SAMPLE RESULTS

Sample location[a]	Sample volume, liters	Asbestos concentration	
		s/mm²	s/cm³
Inside	Not reported	0	<0.005[b]
Inside	Not reported	0	<0.005[b]
Inside	Not reported	0	<0.005[b]
Inside	Not reported	0	<0.005[b]
Inside	Not reported	0	<0.005[b]

[a] Outside samples and blanks were not analyzed because the average asbestos concentration for the five inside samples was less than 70 s/mm².

[b] Sensitivity of the analytical method.

CASE HISTORY R

SITE DESCRIPTION

This abatement project involved removal of approximately 2900 linear feet of asbestos-containing thermal insulation from a single-story school building. This included mixed-diameter air-cell-paper pipe insulation and hard-pack fitting insulation. The abatement area included corridors, classrooms, offices, storage rooms, stairwells, and recreational rooms. The project specification indicated that the asbestos content of the thermal surface insulation was approximately 10 to 25 percent chrysotile.

VENTILATION AND NEGATIVE AIR PRESSURE

Eight high-efficiency particulate air (HEPA) filtration units were operated during the final cleaning period, and nine were operated during AHERA clearance sampling. Table R-1 presents the measured air-intake volume for each unit. The average air-intake volume was 1616 ft^3/min during final cleaning and 1501 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (221,000 ft^3) and the combined average air-intake volumes, the air exchange rates were approximately 3.6 air changes per hour during final cleaning and 3.7 air changes per hour during AHERA clearance sampling.

Figures R-1 and R-2 compare the measured air-intake volume of each HEPA-filtration unit operating during final cleaning and AHERA clearance sampling, respectively, with the unit's nominal airflow. The actual operating percentages of the nominal airflow ranged from 76 to 85 during final cleaning and from 69 to 82 during AHERA clearance sampling.

Table R-2 presents the static pressure differential measured across the containment barriers at two locations. The number of locations tested was determined by available access to the critical containment barriers. The static pressure differential ranged from -0.01 to -0.02 in. water during final cleaning and was -0.02 in. water during AHERA clearance sampling.

The asbestos safety technician (AST) did not monitor the static pressure differential across the containment barrier. Instead, ventilation smoke tubes were used to check the negative pressure visually (i.e., direction of airflow through openings in the containment barrier, such as the decontamination facility) Reportedly, these qualitative checks were performed each morning.

TABLE R-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS

Model	Unit	Airflow, ft^3/min Mean	Min.	Max.	Std. dev.	95% Confidence interval Lower	Upper
				Final cleaning			
1	1	1701	1512	1848	92	1652	1750
1	2	1638	1344	1848	129	1569	1707
1	3	1638	1344	1848	139	1564	1712
1	4	1638	1344	1848	107	1581	1695
1	5	1586	1344	1848	132	1515	1656
1	6	1654	1344	1848	114	1593	1714
1	7	1554	1344	1680	103	1499	1609
1	8	1517	1344	1848	147	1439	1596
				AHERA clearance sampling			
1	1	1523	1344	1764	129	1454	1591
1	2	1649	1512	1848	102	1594	1703
1	3	1376	1260	1596	93	1326	1425
1	4	1402	1176	1596	121	1337	1466
1	5	1381	1260	1512	94	1331	1431
1	6	1481	1260	1680	122	1416	1545
1	7	1607	1512	1848	88	1559	1654
1	8	1507	1344	1764	109	1449	1565
1	9	1586	1344	1848	115	1524	1647

TABLE R-2. STATIC PRESSURE DIFFERENTIALS ACROSS CONTAINMENT BARRIERS (in. water)

Test location	Final cleaning	AHERA clearance
1	-0.01	-0.02
2	-0.02	-0.02

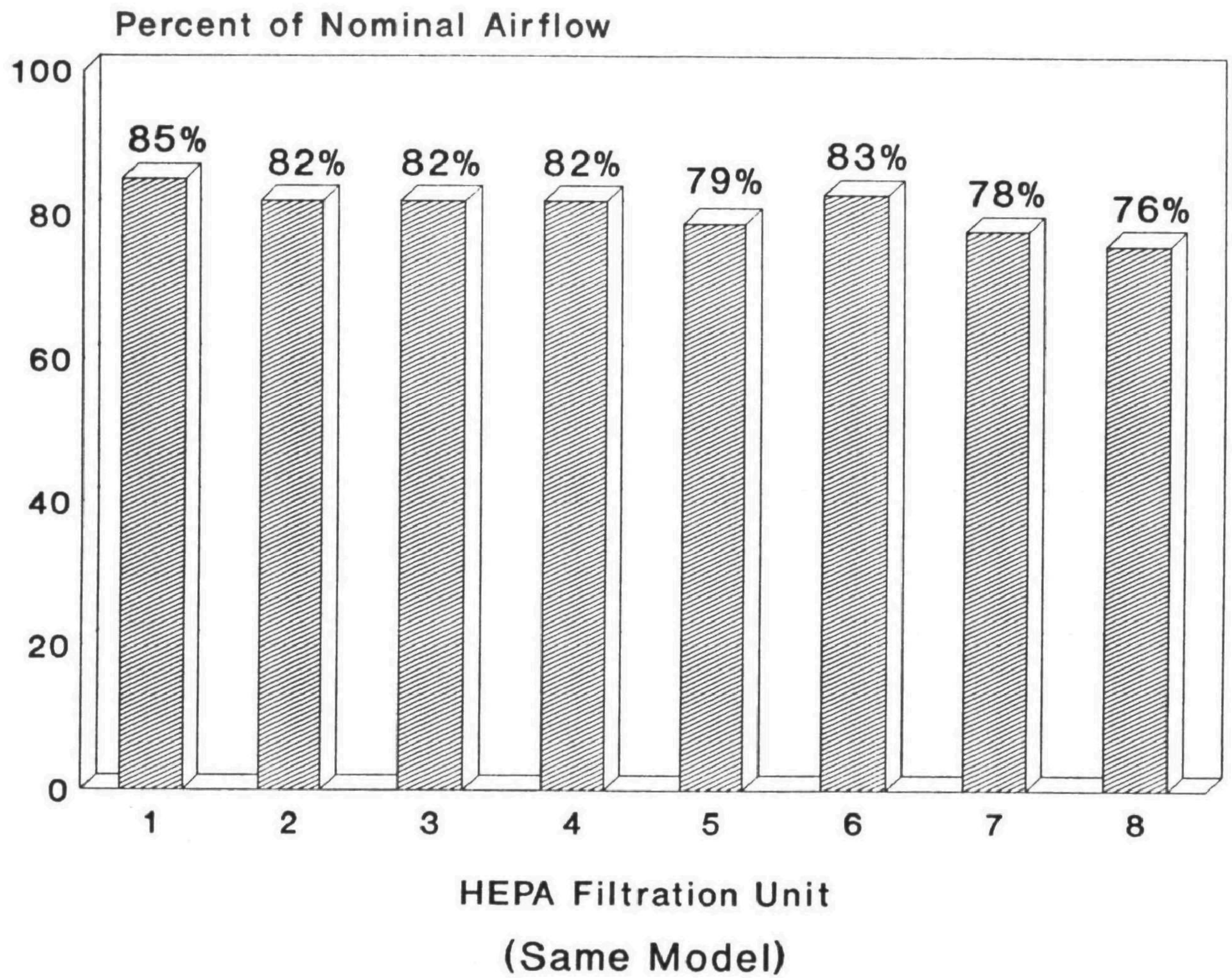


Figure R-1. Airflow performance for HEPA filtration systems operating during final cleanup.

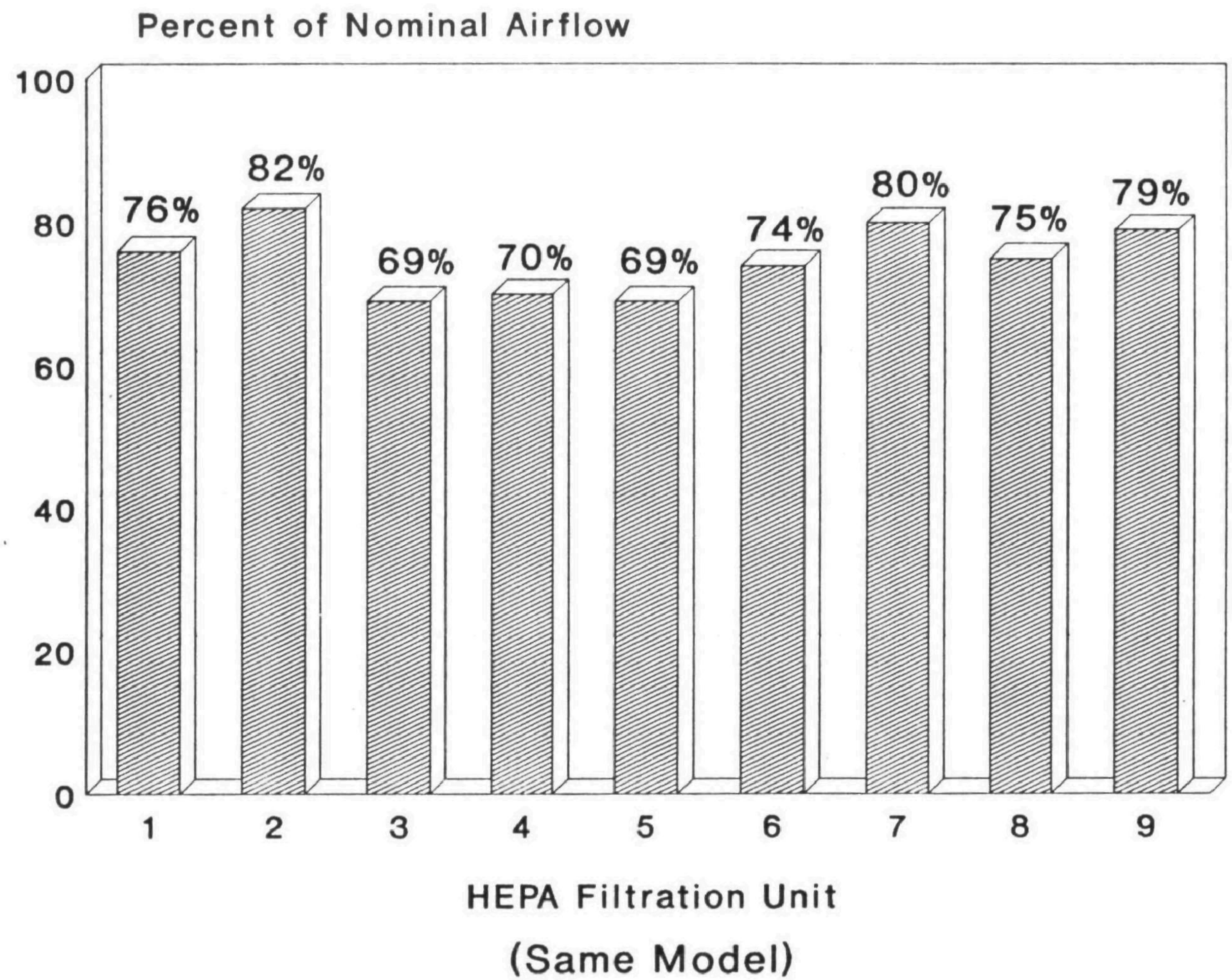


Figure R-2. Airflow performance for HEPA filtration systems operating during AHERA clearance.

The HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility. The nine operating units were positioned along exterior walls to facilitate venting the exhaust through windows via an interconnected flexible duct. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor, who was responsible for maintaining the HEPA-filtration units, stated that the prefilters and secondary filters were changed before final cleaning was initiated and the HEPA filters were changed at the beginning of the project. Thereafter, the prefilters and secondary filters were changed when they became "visibly dirty." The HEPA filters were changed when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls and either full- or half-facepiece air-purifying respirators equipped with dual-cartridge HEPA filters.

Cleaning Procedures

Final cleaning began after the plastic sheeting was removed from the walls and floors. The critical barriers, windows, doors, storage closets, student wall lockers, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The HEPA filtration units remained in service.

Final cleaning was organized so the workers began in the areas farthest from the personnel decontamination facility and worked toward it. No association appeared to exist between the work direction and the location of the HEPA-filtration units.

Final cleaning with dry sweeping of the floors with a garage- type bristle broom. The dry sweeping technique was also used in a classroom with a carpeted floor, where it appeared to pulverize some of the debris into the carpet. The gathered debris was then removed with a HEPA-filtered vacuum. To a limited extent, corners at floor-wall intersections were also cleaned with a HEPA-filtered vacuum. No cleaning of elevated horizontal surfaces (e.g., tops of ventilation ducts) with a HEPA-filtered vacuum was observed.

The vertical and horizontal surfaces were then wet-cleaned with amended water. The contractor reportedly prepared the amended water solution by mixing approximately 1 ounce each of 50 percent polyoxyethylene ester and 50 percent polyoxyethylene ether in 5 gallons of water.

The horizontal and vertical surfaces that were wiped were limited to those that could be reached without a step-ladder. Thus, surfaces such as the tops of ventilation ducts were not wet-cleaned. All the surfaces except the floors were wiped with cotton rags dampened with amended water. A bucket of amended water was either used by a single worker or shared by several workers. The workers did not appear to wipe the surfaces in any one direction. The cloth rags were not replaced frequently, especially during the cleaning of elevated and hard-to-access surfaces. Nor was the amended water changed frequently.

After the walls and other surfaces (shelves, ledges, plastic-covered HEPA-filtration systems and associated exhaust ducts, etc.) had been wet-wiped, the floor was mopped with a clean mop head wetted with amended water. No changes in the water were observed during this procedure.

The last step in final cleaning involved removal of the plastic sheeting covering the HEPA-filtration units and associated exhaust ducts. The latter were covered with a plastic sleeve. According to the contractor, this simplified the cleaning of this equipment.

Final cleaning involved a second complete wet-mopping of the floors. No aggressive cleaning (i.e., air sweeping of all vertical and horizontal surfaces to dislodge any remaining particulate) was conducted.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered, 6-mil-thick, standard disposal bags. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers or solidified with a gelling compound. The rags and mop heads used during cleaning also were placed in these bags. The bags were not wet-wiped with amended water before being removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an onsite AST, the building owner's representative. The AST conducted a visual inspection within 2 hours after notification. The AST did not identify any areas that required further cleaning.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

The site failed the first visual inspection because of the presence of gross debris on top of ventilation ducts, in wall penetrations; on horizontal surfaces; and on pipes, pipe fittings, elbows, and joints throughout the entire containment area. Pipe insulation was also present on counters and floor coverings. Five bulk samples were collected to characterize the residual debris noted during this inspection. The average asbestos content of three samples collected from the pipe wrap debris contained approximately 45 percent chrysotile. The asbestos content of the debris collected from a pipe elbow was approximately 80 percent chrysotile.

The site failed the second visual inspection because of gross debris on ventilation ducts; pipes; pipe hangers; elbows and joints; conduit; and other horizontal surfaces. Residual debris was also found in wall penetrations throughout the containment area. Five bulk samples were collected to characterize the residual debris noted during the inspection. The average asbestos content of the pipe wrap debris found in the wall penetrations was approximately 30 percent chrysotile; the average content of that on pipe joints and elbows was approximately 60 percent chrysotile. The asbestos content of some debris found on top of a ventilation duct was approximately 50 percent chrysotile.

The site failed the third visual inspection because of the presence of debris in wall penetrations and in dust on horizontal surfaces throughout the containment area. Four bulk samples were collected to characterize the residual debris found in the wall penetrations. The average asbestos content of these samples was approximately 50 percent chrysotile.

The site failed the fourth visual inspection because of the presence of debris behind lockers; on pipes, pipe joints, and elbows; on tops of ventilation ducts and other horizontal surfaces throughout the containment area; and in wall penetrations. Six bulk samples were collected to characterize the residual debris noted during the inspection. The average asbestos content of samples of debris from the tops of ventilation ducts was approximately 50 percent chrysotile. The asbestos content of the corrugated pipe wrap found behind the student lockers was approximately 90 percent chrysotile.

The site failed the fifth visual inspection because of the presence of debris on pipes, pipe elbows, and joints; on student lockers; behind counters; and on the floor at random locations throughout the containment area. Eight bulk samples were collected to characterize the debris found behind counters and on pipe elbows and joints. The average asbestos content of the debris found behind the counter was about 40 percent chrysotile; the average content of that found on pipe fittings was approximately 40 and 70 percent chrysotile.

The site failed the sixth visual inspection because of the presence of debris on ventilation fans and ducts, floors, horizontal surfaces, and pipe elbows. Five bulk samples were collected to characterize the residual debris noted on pipe elbows and ventilation ducts. Chrysotile asbestos was identified in each bulk sample; however, the samples were not large enough to quantify the asbestos content in each.

The site passed the seventh visual inspection.

AHERA CLEARANCE SAMPLING BY AST

The AHERA clearance sampling was initiated approximately 24 hours after the site had passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 7 minutes, which is equivalent to approximately 5 minutes per 17,000 ft^2 of floor area. No floor fans were used subsequently used to maintain air turbulence during sampling.

The clearance air samples were collected on 25-mm, 0.45-μm pore size, mixed cellulose ester membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The samples were collected at flow rates ranging from 11 to 12 liters per minute. The laboratory report indicates that the samples were analyzed in accordance with the AHERA mandatory TEM method.

Table R-3 presents the results of the clearance samples the AST collected inside the abatement area. The samples met the initial AHERA clearance criterion, i.e., an asbestos concentration of less than 70 structures per square millimeter (s/mm^2). The average asbestos concentration for the five inside samples was actually 0 s/mm^2.

TABLE R-3. AHERA CLEARANCE SAMPLE RESULTS

Sample location[a]	Sample volume, liters	Asbestos concentration	
		s/mm^2	s/cm^3
Inside	2040	0	<0.005[b]
Inside	2040	0	<0.005[b]
Inside	2040	0	<0.005[b]
Inside	2040	0	<0.005[b]
Inside	2040	0	<0.005[b]

[a] Outside samples and blanks were not analyzed because the average asbestos concentration for the five inside samples was less than 70 s/mm^2.

[b] Sensitivity of the analytical method.

CASE HISTORY S

SITE DESCRIPTION

This abatement project involved removal of approximately 7200 ft^2 of trowel-applied asbestos-containing acoustical ceiling plaster from a single-story school building. The abatement area included a gymnasium and stage, corridors, and storage areas. The project specification indicated that the asbestos content of the acoustical ceiling plaster was approximately 10 to 20 percent chrysotile.

VENTILATION AND NEGATIVE AIR PRESSURE

Eight high-efficiency particulate air (HEPA) filtration units were operated during the final cleaning period, and eight were operated during AHERA clearance sampling. Table S-1 presents the measured air-intake volume of each unit. The average air-intake volume was 1328 ft^3/min during final cleaning and 1199 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (152,000 ft^3) and the combined average air-intake volumes, the air exchange rates were approximately 4.2 air changes per hour during final cleaning and 3.8 air changes per hour during AHERA clearance sampling.

Figures S-1 and S-2 compare the measured air-intake volume of each HEPA-filtration unit operating during final cleaning and AHERA clearance sampling, respectively, with the unit's nominal airflow. The actual operating percentages of the nominal airflow ranged from 43 to 82 during final cleaning and from 46 to 82 during AHERA clearance sampling.

Table S-2 presents the static pressure differential measured across the containment barriers at two locations. The number of locations tested was determined by available access to the critical containment barriers. The static pressure differential ranged from -0.01 to -0.02 in. water during final cleaning and was -0.02 in. water during AHERA clearance sampling.

The asbestos safety technician (AST) did not monitor the static pressure differential across the containment barrier. Instead, ventilation smoke tubes were used to check the negative pressure visually (i.e., direction of airflow through openings in the containment barrier, such as the decontamination facility and waste load-out port). Reportedly, these qualitative checks were performed each morning and afternoon.

TABLE S-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS

Model	Unit	Airflow, ft^3/min Mean	Min.	Max.	Std. dev.	95% Confidence interval Lower	Upper
Final cleaning							
1	1	1486	1008	1848	231	1362	1609
1	2	1549	1260	1848	181	1453	1645
1	3	1649	1428	1848	126	1582	1715
1	4	1612	1344	1764	123	1546	1677
1	5	1544	1176	1848	170	1453	1634
1	6	1638	1344	1848	136	1565	1711
2	7	721	571	856	81	678	764
2	8	429	310	489	64	395	463
AHERA clearance sampling							
1	1	1478	840	1848	299	1319	1638
1	2	1633	1344	1848	122	1568	1698
1	3	1502	1176	1848	151	1421	1582
1	4	1491	1008	1764	225	1371	1611
1	5	1549	1260	1848	190	1447	1650
2	6	823	489	978	134	751	894
2	7	657	489	734	80	614	700
2	8	460	359	571	56	431	490

TABLE S-2. STATIC PRESSURE DIFFERENTIALS ACROSS CONTAINMENT BARRIERS (in. water)

Test location	Final cleaning	AHERA clearance
1	-0.02	-0.02
2	-0.01	-0.02

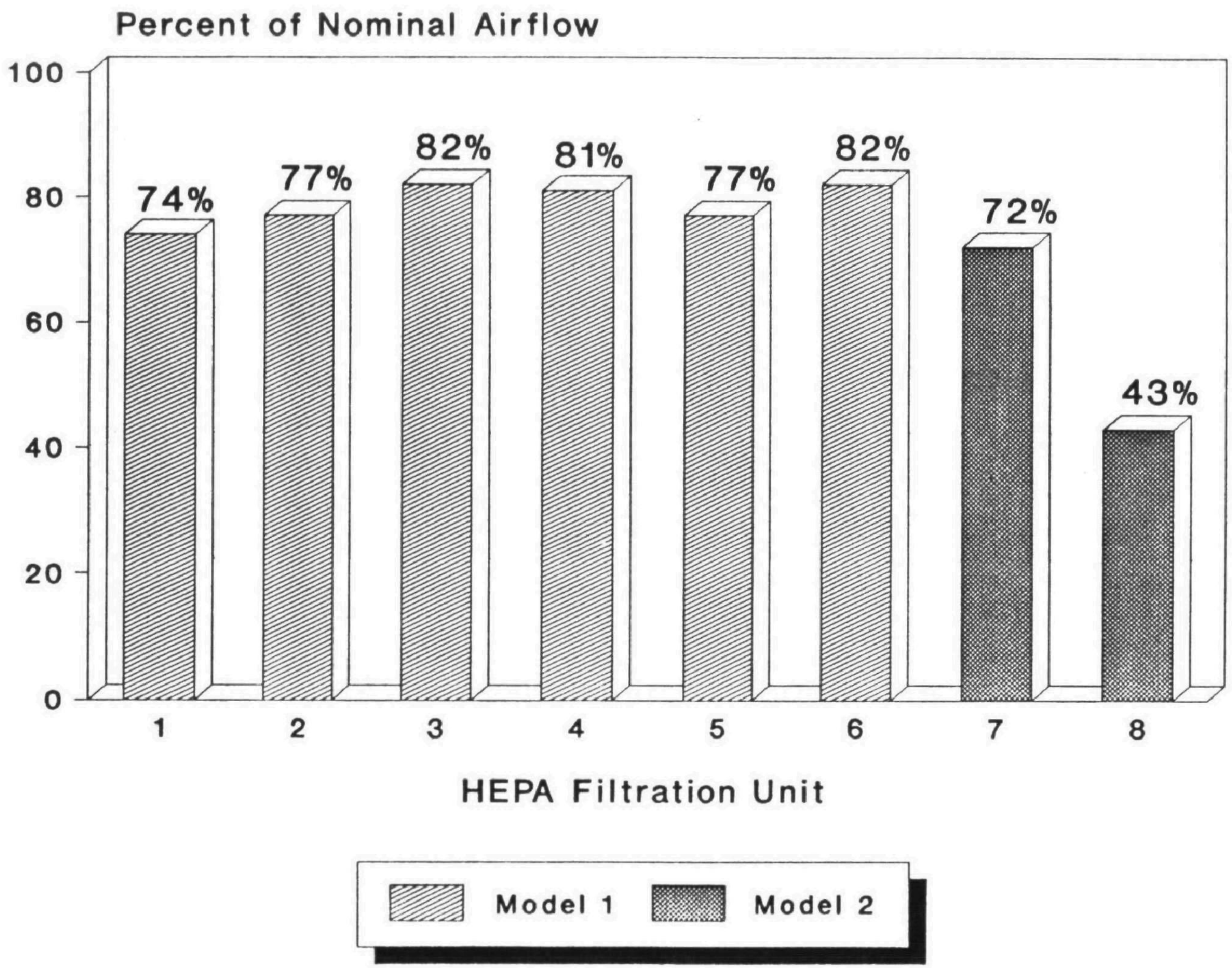


Figure S-1. Airflow performance for HEPA filtration systems operating during final cleanup.

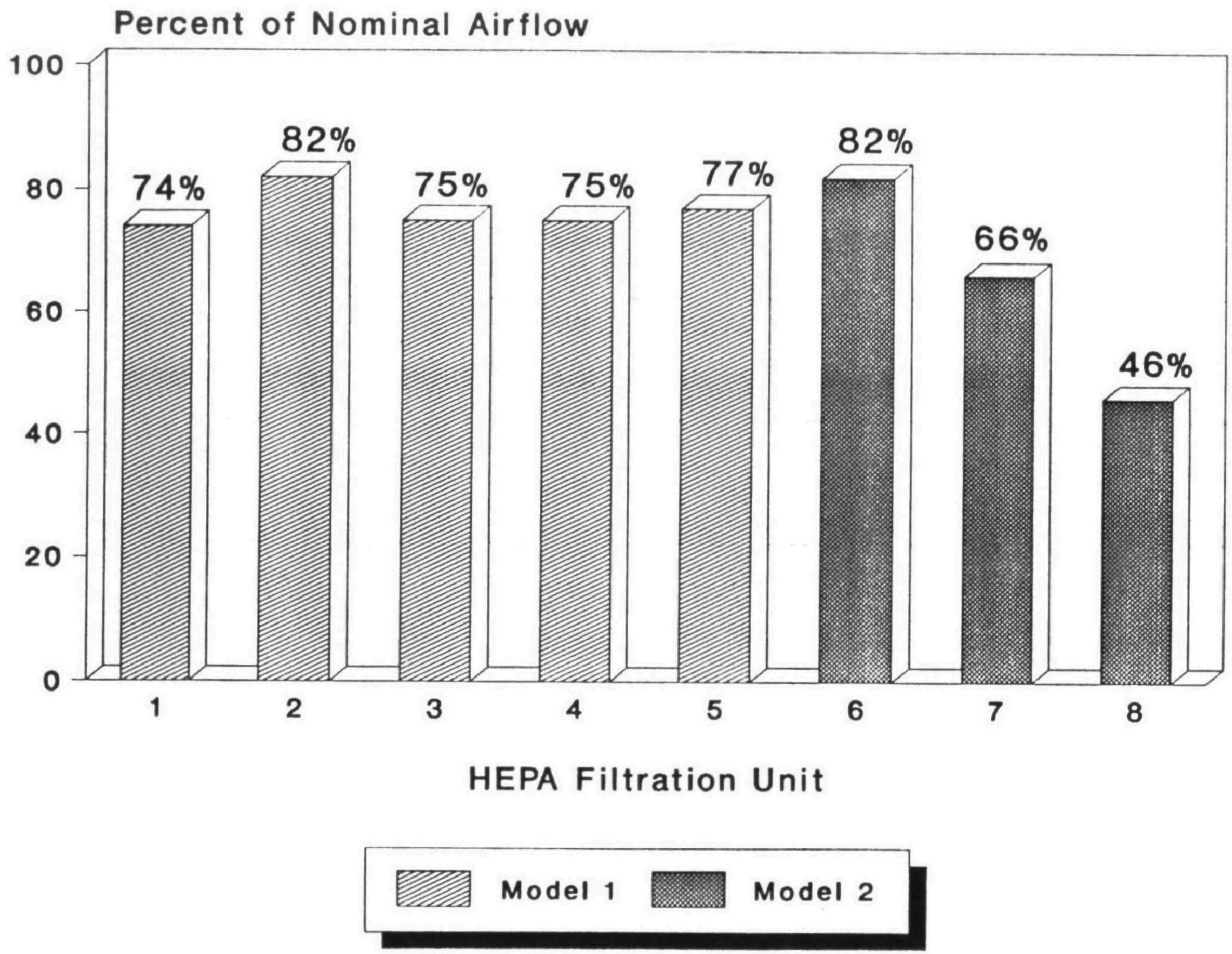


Figure S-2. Airflow performance for HEPA filtration systems operating during AHERA clearance.

The HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility. Eight of the nine operating units were positioned along exterior walls to facilitate venting the exhaust through windows via an interconnected flexible duct. The exhaust of one of the nine units was vented through a doorway via an interconnected flexible duct that passed through a classroom outside of the abatement area. This is particularly noteworthy because the flexible duct was torn and a percentage of the exhaust air was released into the building. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor, who was responsible for maintaining the HEPA-filtration units, stated that the prefilters and secondary filters were changed before final cleaning was initiated and the HEPA filters were changed at the beginning of the project. Thereafter, the prefilters and secondary filters were changed when they became "visibly dirty." The HEPA filters were changed every 600 to 700 hours (as recommended by the manufacturer) or when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls and either full- or half-facepiece air-purifying respirators equipped with dual-cartridge HEPA filters.

Cleaning Procedures

Final cleaning began after the plastic sheeting was removed from the walls, floors, light fixtures, and other surfaces. The critical barriers, windows, doors, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The HEPA filtration units remained in service.

Final cleaning was organized so the workers began in the areas farthest from the personnel decontamination facility and worked toward it. No association appeared to exist between work direction and the location of the HEPA-filtration units.

Final cleaning began with the wire-brushing of the ceiling-wall intersections to remove any visible debris. These surfaces and crevices around doors, wall fixtures, electrical conduit, floor-wall intersections, etc., were cleaned with a HEPA-filtered vacuum.

All of the vertical and horizontal surfaces were then wet-cleaned with amended water. The contractor reportedly prepared the amended water solution by mixing approximately 1 ounce each of 50 percent polyoxyethylene ester and 50 percent polyoxyethylene ether in 5 gallons of water.

The elevated horizontal and vertical surfaces were wiped first and then all the other surfaces. All of the surfaces except the floors were wiped with cotton rags dampened with amended water. A bucket of amended water was either used by a single worker or shared by several workers. Although the workers did not appear to wipe the surfaces in any one direction, the surfaces were wiped meticulously. The cloth rags were not replaced frequently, especially during the cleaning of elevated and hard-to-access surfaces. Nor was the amended water changed frequently.

After the walls, windows, and other surfaces (shelves, ledges, plastic-covered HEPA-filtration systems and associated exhaust ducts, etc.) were wet-wiped, the floor was mopped with a clean mop head wetted with amended water. No changes in the water were observed during this procedure.

The last step in the final cleaning effort involved removal of the plastic sheeting covering the HEPA-filtration units and associated exhaust ducts. The latter were covered with a plastic sleeve. According to the contractor, this simplified the difficulty in cleaning of this equipment.

Final cleaning involved one complete wet-mopping of the floors. No aggressive cleaning (i.e., air sweeping of all vertical and horizontal surfaces to dislodge any remaining particulate) was not conducted.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered, 6-mil-thick, standard disposal bags. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers or solidified with a gelling compound. The rags and mop heads used during cleaning also were placed in these bags. The bags were not wet-wiped with amended water before being removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an onsite AST, the building owner's representative. The AST conducted a visual inspection within 2 hours after notification. The AST identified several areas, especially elevated horizontal surfaces, that required further cleaning. After these designated areas were recleaned, the AST conducted a final walk-through inspection to assure that the identified areas were clean.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

The site failed the first visual inspection because of the presence of debris on floor surfaces, electrical wires and fixtures, behind floor moldings, behind shelving units, and behind balcony seats. Seven bulk samples were collected to characterize the debris noted during the inspection. Chrysotile asbestos was identified in all six samples; however, the samples were not large enough to quantify the asbestos content in each.

The site failed the second visual inspection because of the presence of minor debris on the tops of the exit sign, skylights, and stage fixtures, and dust on the balcony floor and shelving units.

The site passed the third visual inspection.

AHERA CLEARANCE SAMPLING BY AST

The AHERA clearance sampling was initiated approximately 6 hours after the site passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 28 minutes, which is equivalent to approximately 5 minutes per 1300 ft^2 of floor area. Four pedestal-type floor fans with 18-inch blades were subsequently used to maintain air turbulence during sampling.

The clearance air samples were collected on 25-mm, 0.45-μm pore size, mixed cellulose ester membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The samples were collected at flow rates of approximately 10 liters per minute. According to the laboratory report, the samples were analyzed in accordance with the AHERA mandatory TEM method.

Table S-3 presents the results of the AST's clearance samples collected inside the abatement area. The samples met the initial AHERA clearance criterion, i.e., an average asbestos concentration of less than 70 structures per square millimeter (s/mm^2). The average asbestos concentration for the five inside samples was actually 0 s/mm^2.

TABLE S-3. AHERA CLEARANCE SAMPLE RESULTS

Sample location[a]	Sample volume, liters	Asbestos concentration	
		s/mm^2	s/cm^3
Inside	Not reported	0	<0.005[b]
Inside	Not reported	0	<0.005[b]
Inside	Not reported	0	<0.005[b]
Inside	Not reported	0	<0.005[b]
Inside	Not reported	0	<0.005[b]

[a] Outside samples and blanks were not analyzed because the average asbestos concentration for the five inside samples was less than 70 s/mm^2.

[b] Sensitivity of the analytical method.

CASE HISTORY T

SITE DESCRIPTION

This abatement project involved removal of approximately 4100 ft^2 of spray-applied asbestos-containing acoustical ceiling plaster from a three-story school building. The abatement area included a cafeteria and stairwell. The project specification indicated that the asbestos content of the acoustical ceiling plaster was approximately 10 to 25 percent chrysotile.

VENTILATION AND NEGATIVE AIR PRESSURE

Two high-efficiency particulate air (HEPA) filtration units were operated during the final cleaning period, and three were operated during AHERA clearance sampling. Table T-1 presents the measured air-intake volume of each unit. The average air-intake volume was 1617 ft^3/min during final cleaning and 1433 ft^3/min during AHERA clearance sampling. Based on the volume of the work area (57,000 ft^3) and the combined average air-intake volumes, the air exchange rates were approximately 3.4 air changes per hour during final cleaning and 4.6 air changes per hour during AHERA clearance sampling.

TABLE T-1. AIRFLOW PERFORMANCE OF HEPA-FILTRATION UNITS

		Airflow, ft^3/min				95% Confidence interval	
Model	Unit	Mean	Min.	Max.	Std. dev.	Lower	Upper
			Final cleaning				
1	1	1575	1344	1764	131	1505	1645
1	2	1659	1428	1848	113	1599	1719
			AHERA clearance sampling				
1	1	1355	1176	1680	122	1290	1419
1	2	1559	1260	1764	139	1485	1633
1	3	1386	1176	1680	163	1299	1473

Figures T-1 and T-2 compare the measured in-take volume for each HEPA-filtration unit operating during final cleaning and AHERA clearance sampling, respectively, with the unit's nominal airflow. The actual operating percentage of the nominal airflow ranges from 79 to 83 percent during final cleaning and from 68 to 78 percent during AHERA clearance sampling.

Table T-2 presents the static pressure differential measured across the containment barriers at two locations. The number of locations tested was determined by available access to the critical containment barriers. The static pressure differential ranged from -0.01 to -0.02 in. water during final cleaning and from -0.02 to -0.03 in. water during AHERA clearance sampling.

TABLE T-2. STATIC PRESSURE DIFFERENTIALS ACROSS CONTAINMENT BARRIERS (in. water)

Test location	Final cleaning	AHERA clearance
1	-0.02	-0.02
2	-0.01	-0.03

The asbestos safety technician (AST) did not monitor the static pressure differential across the containment barrier. Instead, ventilation smoke tubes were used to check the negative pressure visually (i.e., direction of air flow through openings in the containment barrier, such as the decontamination facility and waste load-out port). Reportedly, these qualitative checks were performed each morning.

The HEPA-filtration units were placed so that the makeup air entered the work area through the personnel decontamination facility and waste load-out port. The three operating units were positioned along exterior walls to facilitate venting the exhaust through windows via an interconnected flexible duct. The discharge air from the HEPA-filtration units was not monitored for fiber content.

The contractor, who was responsible for maintaining the HEPA-filtration units, stated that the prefilters and secondary filters were changed before final cleaning was initiated and the HEPA filters were changed at the beginning of the project. Thereafter, the prefilters were changed daily, and the secondary filters were changed when they became "visibly dirty." The HEPA filters were changed when an audible alarm was actuated by a differential pressure sensor set by the manufacturer.

FINAL CLEANING

Personal Protective Equipment

The personal protective equipment worn by the workers during final cleaning consisted of full-body disposable coveralls, and either full- or half-facepiece air-purifying respirators equipped with dual-cartridge HEPA filters.

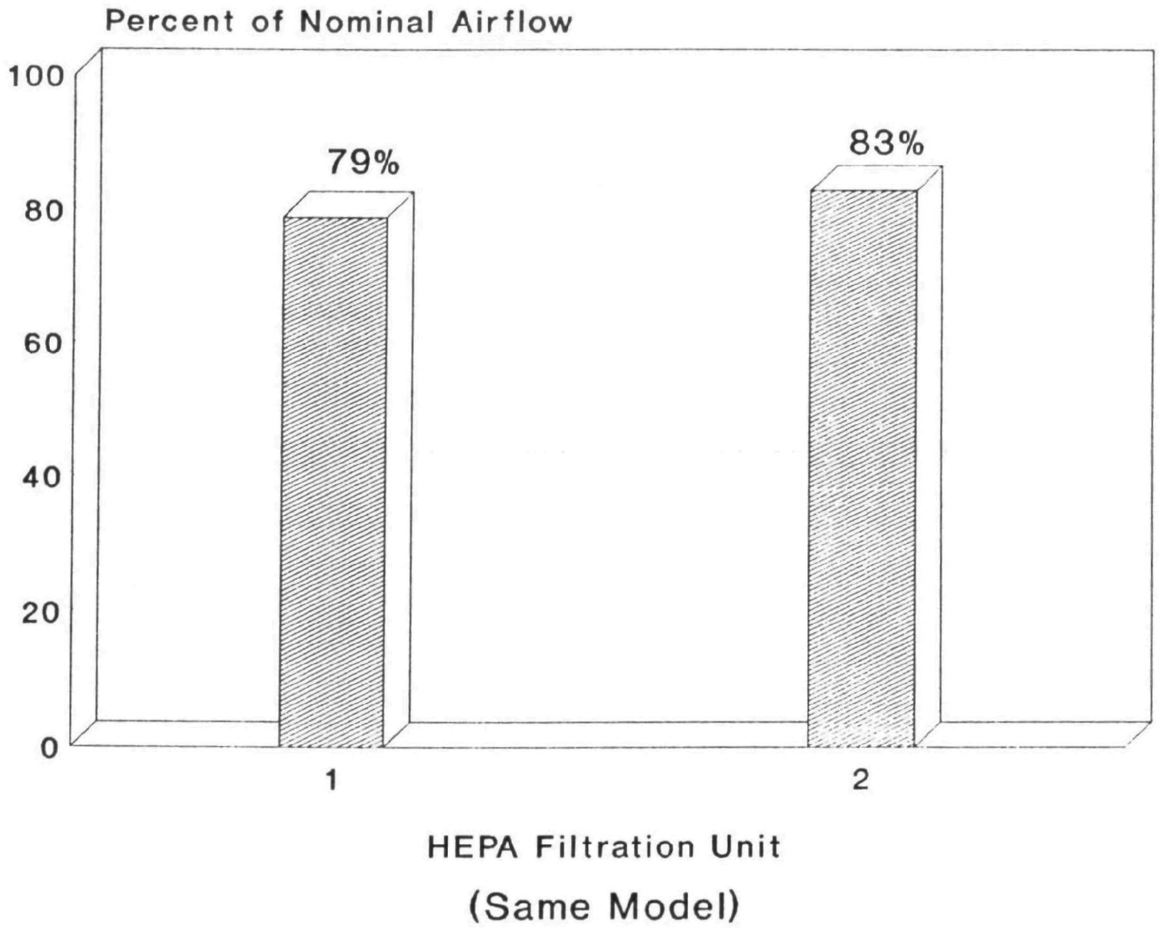


Figure T-1. Airflow performance for HEPA filtration systems operating during final cleanup.

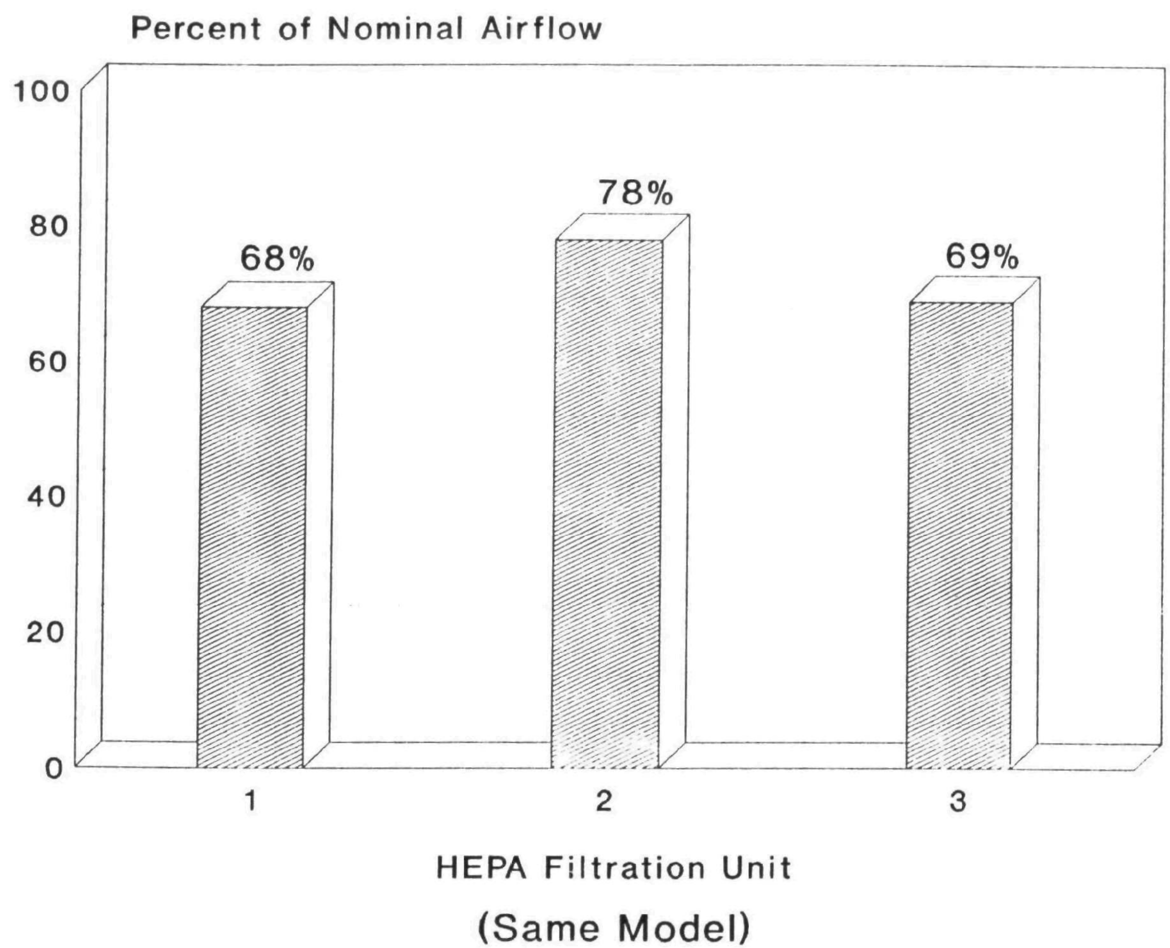


Figure T-2. Airflow performance for HEPA filtration systems operating during AHERA clearance.

Cleaning Procedures

Final cleaning began after encapsulated plastic sheeting was removed from the walls, floors, light fixtures, and other surfaces. The critical barriers, windows, doors, and heating, ventilation, and air-conditioning (HVAC) vents remained sealed. The HEPA filtration units remained in service.

The final cleaning was organized so the workers began in the areas farthest from the personnel decontamination facility and worked toward it. No association appeared to exist between work direction and the location of the HEPA-filtration units.

Final cleaning began with the spraying of walls, windows, plastic critical containment barriers, and other vertical surfaces with a water mist to remove any visible debris. The resultant asbestos-containing water on the floor was gathered into pools by use of a rubber squeegee. The bulk of the pooled water was scooped up with plastic-bladed shovels, an approach that worked surprisingly well. The water was containerized in double-layered, 6-mil-thick, asbestos-disposal bags, which usually contained plastic that had been removed from the walls and floors. The residual water removed with a wet vacuum was also placed in these bags.

All of the vertical and horizontal surfaces were then wet-cleaned with amended water. The contractor reportedly prepared the amended water solution by mixing approximately 1 ounce each of 50 percent polyoxyethylene ester and 50 percent polyoxyethylene ether in 5 gallons of water.

The elevated horizontal and vertical surfaces were wiped first, and then all other surfaces were wiped. All the surfaces except the floors were wiped with cotton rags dampened with amended water. A bucket of amended water was either used by a single worker or shared by several workers. The workers did not appear to wipe the surfaces in any one direction. The cloth rags were not replaced frequently, especially during the cleaning of elevated and hard-to-access surfaces. Nor was the amended water changed frequently.

After the walls, windows, and other surfaces were wet-wiped, the floor was mopped with a clean mop head wetted with amended water. No changes in the water were observed during this procedure.

No aggressive cleaning (i.e., air sweeping of all vertical and horizontal surfaces to dislodge any remaining particulate) was conducted.

Wastewater from the wet-wiping and mopping operations was treated as asbestos-containing water and placed in double-layered, 6-mil-thick, standard disposal bags. These standard asbestos disposal bags which contained wastewater were not placed in leak-tight containers or solidified with a gelling compound. The rags and mop heads used during cleaning were also placed in these bags. The bags were not wet-wiped with amended water before being removed from the abatement area.

Upon completing final cleaning, the abatement contractor requested a final visual inspection by an onsite AST, who was the building owner's representative. The AST conducted a visual inspection within 2 hours after notification. The AST identified several areas, particularly tops of lighting fixtures, that required further cleaning. After these designated areas were recleaned, the AST conducted a final walk-through inspection to assure that the identified areas were clean.

FINAL VISUAL INSPECTION BY NEW JERSEY DEPARTMENT OF HEALTH, ASBESTOS CONTROL SERVICE

The site failed the first visual inspection because of the presence of debris on walls, floors, pipes, light fixtures, wall-ceiling junctions, and wall penetrations. Three bulk samples were collected to characterize the debris found during the inspection. The asbestos content of the debris sampled from the wall penetration was approximately 4 percent chrysotile and 10 percent amosite. Chrysotile asbestos also was identified in the two samples collected from debris in the wall-ceiling junctions; however, the samples were not large enough to quantify the asbestos content.

The site passed the second visual inspection.

AHERA CLEARANCE SAMPLING BY AST

First Attempt

The AHERA clearance sampling was initiated approximately 24 hours after the site passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 15 minutes, which is equivalent to approximately 5 minutes per 1400 ft^2 of floor area. No floor fans were used subsequently to maintain air turbulence during sampling.

The clearance air samples were collected on 25-mm, 0.4-μm pore size, polycarbonate membrane filters contained in a three-piece cassette with a 50-mm conductive cowl. The samples were collected at flow rates ranging from 9 to 10 liters per minute. The laboratory report, indicates that the samples were analyzed in accordance with the AHERA mandatory TEM method.

Table T-3 presents the results of the clearance samples the AST collected inside the abatement area. The site failed the initial AHERA clearance criterion, an average asbestos concentration of less than 70 structures per square millimeter (s/mm^2). The mean asbestos concentration for the inside samples was actually 159 s/mm^2. Therefore, the five inside samples were compared with the five outside samples by use of the AHERA Z-test. The calculated Z statistic (2.44) was greater than the AHERA limit of 1.65; therefore, recleaning was required.

Second Attempt

This AHERA clearance sampling was initiated approximately 12 hours after the site passed the visual inspection. Using a hand-held electric leaf blower, the AST conducted aggressive air sweeping of vertical and horizontal surfaces for approximately 10 minutes, which is equivalent to approximately 5 minutes per 2100 ft^2 of floor area or 5 minutes per 28,600 ft^3 of work space. No floor fans were used subsequently to maintain air turbulence during sampling.

TABLE T-3. AHERA CLEARANCE SAMPLE RESULTS-FIRST ATTEMPT

Sample location	Sample volume, liters	Asbestos concentration	
		s/mm²	s/cm³
Inside	1713	181	0.042
Inside	1706	18	0.004
Inside	1725	72	0.017
Inside	1753	91	0.021
Inside	1742	434	0.100
Outside	1720	72	0.017
Outside	1711	18	0.004
Outside	1698	0	<0.005[a]
Outside	1638	18	0.004
Outside	1689	0	<0.005[a]
Blank	-	18	-
Blank	-	87	-
Blank	-	0	-

[a] Sensitivity of the analytical method.

The AST collected the same number of samples and used the same sampling and analytical methodology as during the first clearance attempt.

Table T-4 presents the results of clearance samples the AST collected inside the abatement area. The site passed the initial AHERA clearance criterion, i.e., an asbestos concentration of less than 70 s/mm². The average asbestos concentration for the five inside samples was actually 52 s/mm².

TABLE T-4. AHERA CLEARANCE SAMPLE RESULTS-SECOND ATTEMPT

Sample location[a]	Sample volume, liters	Asbestos concentration	
		s/mm²	s/cm³
Inside	1713	17	0.004
Inside	1706	70	0.016
Inside	1725	17	0.004
Inside	1753	70	0.016
Inside	1742	87	0.020

[a] Outside samples and blanks were not analyzed because the average asbestos concentration for the five inside samples was less than 70 s/mm².

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

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Observational Study of Final Cleaning and AHERA Clearance Sampling at Asbestos-Abatement Sites in New Jersey		5. REPORT DATE June 30, 1989 6. PERFORMING ORGANIZATION CODE
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15. SUPPLEMENTARY NOTES Thomas J. Powers, Project Officer (513-569-7550)		

16. ABSTRACT

A study was conducted during the summer of 1988 to document final cleaning procedures and evaluate Asbestos Hazard Emergency Response Act (AHERA) clearance air-sampling practices used at 20 asbestos-abatement sites in New Jersey. Each abatement took place in a school building and involved removal of surfacing material, thermal system insulation, or suspended ceiling tiles. Final cleaning practices tend to be similar among abatement contractors. Meticulous attention to detail in cleaning practices is important to a successful final cleaning. Sites passing a stringent "no-dust" criterion of a thorough visual inspection are more likely to pass the AHERA transmission electron microscopy clearance test. AHERA sampling and analytical requirements and recommendations are not completely understood and followed by consultants conducting clearance air monitoring. Matrices are provided that cross-reference case history information on final cleaning procedures, visual inspections, and AHERA clearance practices at these sites.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO OF PAGES
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