IN-DEPTH SURVEY REPORT.

EVALUATION OF BRAKE DRUM SERVICE CONTROLS

AT

Cincinnati Bell
Maintenance Facility
Fairfax, Ohio

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NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
Division of Physical Sciences and Engineering
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PLANT SURVEYED:	Cincinnati Bell Maintenance Garage 6219 Wooster Pike Fairfax, Ohio 45227
SIC CODE	4811
SURVEY DATE	November 24, 1986 - February 5, 1987
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I INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency engaged in occupational safety and health research Located in the Department of Health and Human Services (formerly Department of Health, Education, and Welfare), it was established by the Occupational Safety and Health Act of 1970 This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions of the Occupational Safety and Health Administration (OSHA) in the Department of Labor An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards to safe levels The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering has been given the lead within NIOSH to study the engineering aspects of hazard control

Since 1976, ECTB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques Examples of these completed studies include the foundry industry, various chemical manufacturing or processing operations, spray painting, and the recirculation of exhaust air The objective of each of these studies has been to evaluate and document effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures These studies involve a number of steps or phases Initially, a series of walk-through surveys are conducted to select plants or processes with effective and potentially transferable control concepts or techniques Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury

Background

Asbestos is found in motor vehicle brake materials throughout industry Recognition of asbestos' carcinogenic properties has currently resulted in substitution of less toxic fibers for some brake materials However, asbestos is still used in a large number of brakes This study is concerned with the control of asbestos exposures to workers who are required to repair motor vehicle brakes

Dubrow and Wegman published a research and control priority assessment of occupational carcinogens (1) Their objective was to identify occupations with potentially high cancer risk by combining the results of 12 major occupational disease surveillance studies and to make recommendations concerning priorities for occupational cancer research and control on the basis of the results of this analysis in conjunction with other available epidemiologic, industrial hygiene, toxicologic, and employment data On the basis of the principles outlined in their paper, some priorities for research and control clearly stood out Their results pointed to the investigation and control of occupational exposure to asbestos as the number one priority in occupational cancer research and control "In this situation, where occupational disease surveillance studies point to a likely problem with a known carcinogenic agent, the priority should be placed on industrial hygiene investigations of asbestos exposure in the suspect occupations If likely exposure is found, control measures should be developed and instituted "

There are frequent asbestos exposures during brake repair in the vehicle maintenance work force NIOSH in the National Occupational Exposure Survey estimates that a work force of 151,000 brake mechanics and garage workers in the U S are potentially exposed to asbestos (2) Other estimates run as high as 900,000 workers potentially being exposed in brake servicing.(3)

A study of brake service operations is needed because of the following the known carcinogenic potential of asbestos, a large number of workers are potentially exposed, primarily small businesses perform brake servicing and lack resources to evaluate control devices; and the general lack of information on the effectiveness of control devices currently available Therefore, the Engineering Control Technology Branch undertook this study

The primary objective of this control technology assessment is to determine the effectiveness of various control techniques used during brake repair, and the transfer of the documented information to the appropriate individuals in industry, labor, academia, and the government (i e , industrial hygienists, safety engineers, OSHA, EPA, etc) A secondary objective of this assessment is to determine if additional research is needed

Description of Brake Servicing Operations

Repair facilities follow the same basic servicing procedures The vehicle is driven into a repair stall or bay for a brake system examination Pending repairs, the wheels are elevated, removed, and the brakes inspected Loose dust is cleaned from the drums and brake assemblies by vacuuming, wet or dry wiping/brushing, using compressed air, or a combination of these methods Parts are then replaced or repaired as needed and the brake system is reassembled and adjusted The test vehicle is then driven to check for proper fit and adjustment in the final phase of the servicing operation

The brake repairman and other service personnel in the garage area are potentially exposed to asbestos dust during and following the brake drum removal If the normal dust buildup inside the drum and brake assembly is removed and disposed of in a controlled manner, this hazard can be minimized

Site Selection

Preliminary surveys were conducted at 10 sites using a variety of control techniques These site visits were conducted to observe the control techniques in use and to select sites for detailed sampling studies Sites were selected primarily from fleet garages to control for variables such as vehicle type, use, and maintenance practice, and on the physical size of the garage Selection of sites were made, as judiciously as possible, based on criteria including

a) The type of control technique(s) being used at that site

b) The type and quantity of vehicles available for brake repair

Good work practices and a sound management approach were fundamental to the existence of suitable conditions for study

Health Effects

The health significance of the inhalation of chrysotile asbestos fibers in auto repair workers includes asbestosis and mesothelioma [4-8] In a detailed examination of 90 union motor vehicle maintenance workers in New York City,[7] with 10 or more years of shop work, 29 percent had decreased vital capacity, the percentage increased with age and most markedly after 20 years from the onset of auto work Many of the workers examined showed signs consistent with asbestosis, with observed changes noted in chest X-rays and indication of restrictive pulmonary function The prevalence of these changes was significantly higher after 20 years exposure, a result expected after occupational exposure to asbestos [8]

Many of the asbestos fibers originally present in the unused brake shoe chemically degrade due to the high temperature encountered in use Chrysotile asbestos fibers exist in automobile brake dust in various states of deformation One deformation product of chrysotile is forsterite Unlike chrysotile, the health effects of exposure to forsterite, or to transition series fibers (chrysotile/forsterite) with altered crystalline structures are not well documented In studies by Davis and Coniam[9] and Koshi[10] in which fibers of chrysotile, chrysotile/forsterite, and forsterite were injected into the pleural and peritoneal cavities of mice, the results suggested varying degrees of toxic effects Fiber implantation animal studies conducted by Pott, et al ,[11,12] and Davis, et al ,[13] suggest that the morphology and size of a fiber, regardless of fiber type, are responsible for its carcinogenicity Likewise, Stanton, et al ,[14] suggests that fibers less than 1 5 µm in diameter and greater than 8 µm in length pose the greatest risk in producing pleural sarcomas These studies tend to suggest that the physical morphology (size dimensions) and to a lesser degree chemical and surface characteristics of a fiber are the determining factors for inducing a biological effect The precise fiber dimensional characteristics required for these observed pathologic responses have been difficult to determine experimentally because of the difficulties encountered in producing fibers of specific size dimensions

Because of the observed health effects in auto repair workers and the lack of a clearly identified no-effect level for asbestos, it is important to minimize exposure to brake dust which may contain asbestos

II PLANT AND PROCESS DESCRIPTION

Vehicle Maintenance Facilities

The Cincinnati Bell system operates fleet garages at the following locations in Southwestern Ohio and Northern Kentucky

1 Atrium I (Cin)
2 Batavia, OH
3 Covington, KY
4 Evanston (Cin)
5 Fairfax, OH
6 Florence, KY
7 Hamilton, OH
8 Price Hill (Cin)
9 Reading, OH
10 Southgate, KY
11 Sawyer Court, OH (day)
12 Sawyer Court, OH (night)
13 West College Hill (Cin)
14 Williamstown, KY

The Evanston garage is the main garage of the Cincinnati Bell system Others listed (including the Fairfax garage) are classified as satellite garages Major vehicle overhauls are conducted only at the Evanston garage In turn, the satellite garages perform routine maintenance such as 10,000 mile inspections, brake work on light vehicles, tune-ups, etc The Fairfax garage averages seven vehicle brake inspections and three brake replacements (front and back) per month

Facility Description

Eighty-five assorted specialized vehicles are based at the Fairfax satellite garage Most of these are out on the job during the day shift, and during the evening shift, are parked either within the garage or in the large parking area behind the garage A schematic of the garage is shown in Figure 1 The garage dimensions are 182 feet in length, 123 feet in width, and 15 feet high Along the east wall of the building is a single hydraulic lift employed to raise light duty vehicles to any desired height for both brake inspection and replacement Enclosed break, locker and washroom, supply and office areas are partitioned off within this large garage The large company vehicle parking lot located directly behind the building, is approximately 130 feet in length and 200 feet in width This Fairfax satellite garage has two mechanics on its staff and they are assigned to the second shift only During the latter part of the 2nd shift, they were the only Bell employees actually present and working in the garage. The mechanics and other garage employees are members of the Communication Workers of America

During the November 24, 1986 survey, the main doors of the garage were generally open This provided some air circulation within the garage On December 9, 1986, the doors were also open, but during the remaining surveys (December 11 and 16, 1986 and January 12 and February 5, 1987) the doors were closed except to let vehicles in or out

Process and Equipment Description

These Cincinnati Bell garages have been employing identical vacuum units (Nilfisk Asbestos-Clene System) since 1977-78. The vacuum unit consists of a dust removal hose connected to a three-stage vacuum dust filter assembly Figure 2 is a detailed cutaway sketch of the portable vacuum cleaner Coarse particles are separated by centrifugal action in the bottom area Next, a

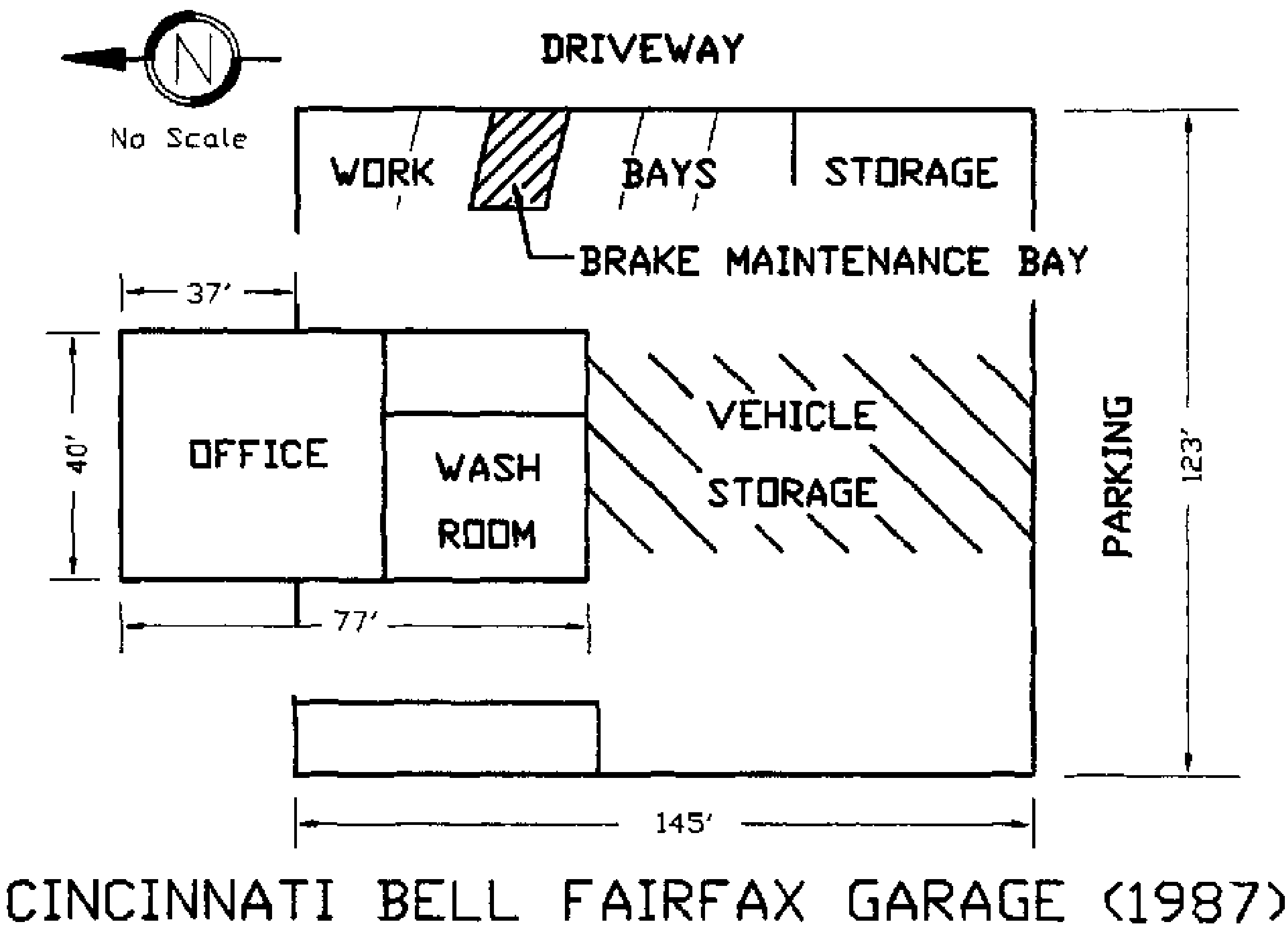

Figure 1 Layout of Garage

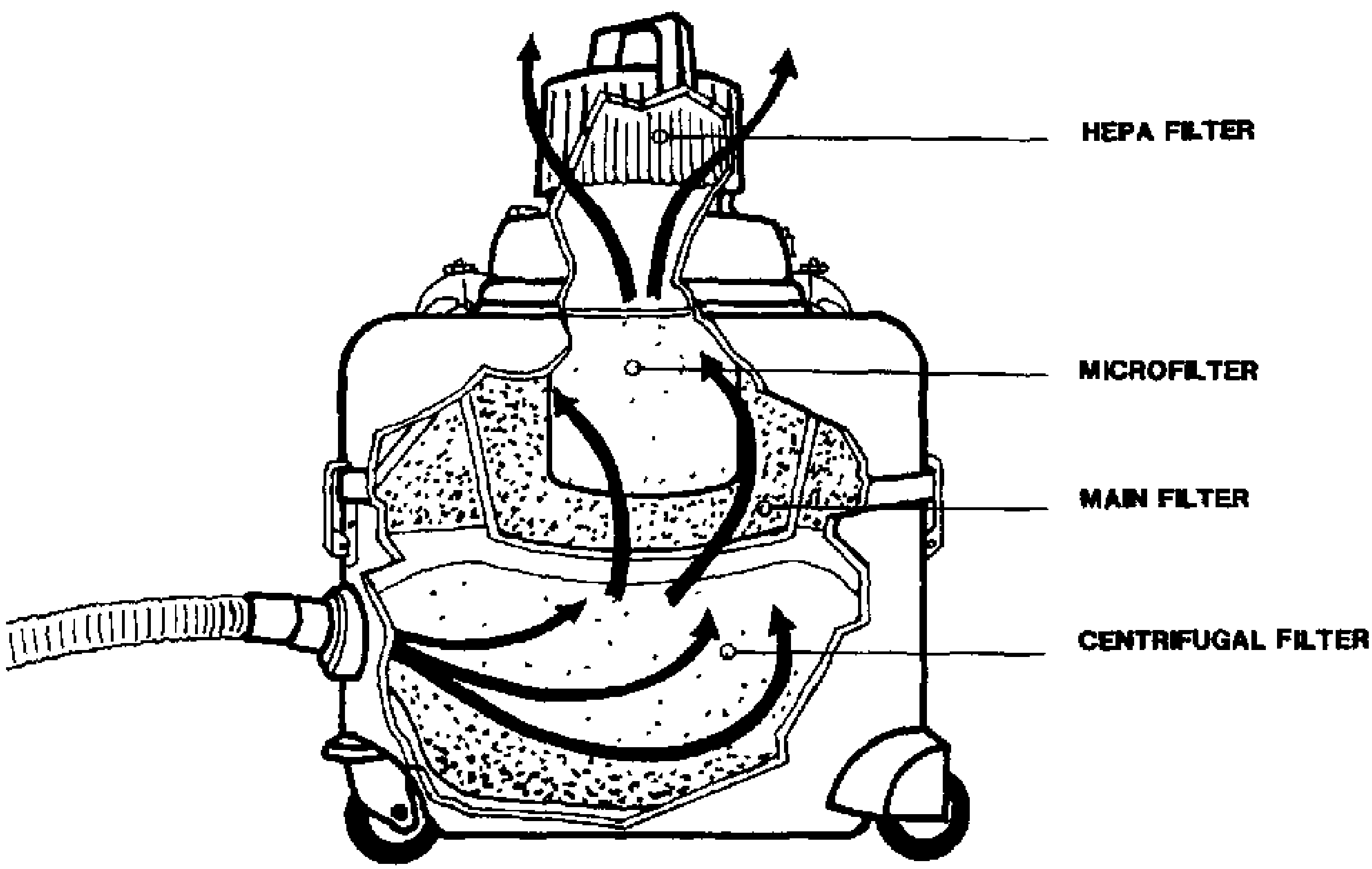

Figure 2 HEPA-Vacuum Schematic
(Adapted from drawing by Nilfisk of America, Inc , Malvern, Pa. Used with Permission)

main filter collects finer particles, and lastly, a High Efficiency Particulate Air filter (HEPA) is used to remove very fine dust (99 97% removal of 0 3 micron dust)

Within months after the model GA-71 Nilfisk systems with glove boxes were purchased and put into operation in all the Bell garages, the Safety Supervisor for all installations received complaints from some mechanics, that use of the cylindrical glove boxes resulted in more dust escaping from the brake assembly into the ambient air than occurred prior to the purchase of the vacuum/enclosure systems The Safety Supervisor, Mr Axt, said that they conducted air sampling comparisons (both area and personal) between the vacuum units with the enclosure, and the vacuum units without the enclosure (using the vacuum to suck loose dirt from the brake assembly surface) He stated his results showed little difference in the samples Thereafter, the enclosures were not used, but use of the vacuum units continued The primary purpose for conducting a survey at a Cincinnati Bell facility was to evaluate a HEPA vacuum unit without an enclosure

An important but infrequent operation, not observed during this in-depth plant survey, is the removal and replacement of the various filters from the vacuum units The first stage bag filter is normally removed when about half full and the second stage freestanding prefilter removed when the unit vacuum gauge has dropped into the 1 to 2 inch water vacuum range

Ventilation

The ventilation information for the Fairfax garage was obtained from Cincinnati Bell A wall exhaust fan on the washroom wall pulls 3,800 cfm and another fan at the rear of the garage pulls 5,000 cfm. This is a total of 8,800 cfm in a building having a garage area of 1,620 square feet and a volume of 24,300 cubic feet which provides 22 air changes per hour There is also a vehicle exhaust system which removes engine exhaust by attaching to a vehicle exhaust pipe The system pulls 385 cfm and runs only when work is being performed that requires that the engine be running There appears to be no provision for makeup air in the garage area The makeup air must infiltrate into the garage through doors and windows and may result in negative building pressure during cold weather when the building is closed The garage is heated by steam and has no air conditioning

One of the major concerns of Cincinnati Bell in their garages is carbon monoxide from engine exhaust The Fairfax garage has a carbon monoxide alarm which is set to turn on an auxiliary ventilation fan when the carbon monoxide level reaches between 35 and 39 ppm

Company Asbestos Exposure Guidelines

The company's concern for asbestos goes beyond the use of the Nilfisk control system for brake service The company has issued a document titled "Guidelines for Occupational Asbestos Exposure" which covers Potential Health Problems, OSHA Standards, and Asbestos Exposure Responsibility The Asbestos Exposure Responsibility defines management's responsibility in terms of inspecting and testing the work site, gives guidelines for the use of engineering controls, and details the use of protective clothing for isolating the worker from asbestos fibers The guidelines also define the nonmanagement responsibilities for workers to follow all prescribed work practices including safety rules, personal hygiene, and cooperation in monitoring and testing procedures Workers also have the responsibility to report any suspected environmental condition or personal symptom which may indicate a potential asbestos problem The company issued a December 1986 directive on Instructions for Wearing Asbestos Protection Clothing This directive spells out when the employee is to wear protective clothing, how this clothing is to be worn and how it is to be removed and disposed of Because of the levels measured in the garage, protective equipment was not required for the brake mechanics Each brake mechanic is given one hour per month of health and safety training

Equipment Studied

In this study, drum brake servicing for seven vehicles was evaluated The vehicles, all with rear drum brakes, included two automobiles and five utility vans The model years for the seven vehicles ranged from 1977 to 1982 with total vehicle mileage ranging from 52,000 to 92,000 Vehicle information and temperature data are shown in Table 1

III METHODOLOGY

Air Sampling and Analysis

Personal air samples for asbestos were collected in duplicate on 25 mm, 0.8 μm pore size cellulose ester membrane filters at 3 0 lpm using a Dupont P-4000 pump for the duration of a single brake job, or 2 hours, whichever was longer The minimum volume collected (360 liters) allowed a limit of detection of approximately 0 004 fibers/cc by Phase Contrast Microscopy (PCM) analysis.

Area air samples for asbestos were also collected on 25 mm, 0.8 μm pore size cellulose ester filters Two area samples were collected at the fender and the axle (source samples) at approximately 7 0 lpm using Gast or Millipore rotary vane high volume pumps for the duration of a single brake job, or 2 hours, whichever was longer The source samples were used to measure fibers escaping into the working environment during the vacuuming and repair activity. The minimum volume collected (840 liters) allowed a limit of detection of 0 002 fibers/cc by PCM Two additional area samples were collected in the general garage area (background) at approximately 7 0 lpm (Gast pumps) for a 4-hour period encompassing pre- and post-brake job activities These background samples were used to determine effects of general shop cleanliness and overall containment effectiveness of the controls The minimum volume collected (1,000 liters) allowed a limit of detection of 0 002 fibers/cc Two other area samples were collected out-of-doors at 3 0 lpm using P-4000 pumps for an approximate 8-hour period These ambient samples were used to determine environmental background levels of asbestos The minimum volume collected (900 liters) allowed a limit of detection of 0.002 fibers/cc

Table 1

Vehicle Information

Date	Type	Vehicle Mileage	Year	Transmission Man/ Auto	Tires	FWD/ RWD	Indoor Air Temperature °F
11-24-86	Chevette 2DR	69124	1977	Man	Rad	RWD	60
11-24-86	Chevy Van 1/2 Ton	92465	1977	Auto	Bias	RWD	60
12-9-86	Chevette Scooter	62741	1982	Man	Rad	RWD	62
12-11-86	Chevy Van 1/2 Ton	52498	1977	Auto	Bias	RWD	41-59*
12-16-86	Chevy Van 1/2 Ton	57111	1978	Man	Bias	RWD	62
01-12-87	Dodge Van 1/2 Ton	88259	1978	Man	Bias	RWD	62
02-05-87	Dodge Van 1/2 Ton	80580	1979	Man	Bias	RWD	63

FWD = Front wheel drive
RWD = Rear wheel drive
* Low temperature occurred when doors were opened

All filter air samples were analyzed by PCM in accordance with NIOSH Method 7400[15] In addition to PCM analysis, approximately 2/3 of these samples were analyzed by light-field Transmission Electron Microscopy (TEM) To facilitate analysis by PCM and TEM on the same samples, the direct transfer method of sample preparation described by Burdett and Rood[16] was used For PCM analysis, all fibers with a 5 1 (or greater) aspect ratio were counted using Method 7400B counting rules For TEM analysis, fiber type and size distribution were obtained for all fibers (greater than approximately 0 25 μm in length) using a magnification of 17,600X and counting either a minimum of 10 grids or 100 particles, whichever came first All fibers with a 3 1 (or greater) aspect ratio were counted using TEM

Field blanks were prepared for each sampling date and submitted for PCM and TEM analysis

Bulk Samples and Rafter Sample

A bulk brake dust sample for each vehicle and a bulk rafter sample for the site were collected and analyzed for asbestos by TEM The percentage of asbestos in the bulk samples was qualitatively determined by estimating the ratio of the number of asbestos fibers to total dust particles The percentage of fibers that were asbestos was quantitatively determined, the length and diameter of asbestos and other fibers was measured Elemental analysis of the nonasbestiform constituents was performed using energy dispersive X-ray analysis

Real-Time Sampling

The entire brake maintenance operation, was recorded on videotape A Hand-Held Aerosol Monitor (HAM) from PPM, Inc , and a personal computer (Apple II Plus) were used to measure and record the dust levels The HAM's electro-optical system provides instantaneous measurements of respirable dust levels in mg/m^3 at one second intervals The HAM sends a millivolt signal to the computer which records it as a relative dust level The computer program can record a maximum of 2,000 readings at a minimum of four second intervals before it has to be reset Before each brake maintenance job, the HAM was calibrated and zeroed The computer's clock was synchronized with that of a video camera DuPont P4000 or MSA Model G pumps were connected by tubing to the HAM, which in turn was connected by a 25-foot electrical lead to the computer, programmed to receive the data The brake mechanic wore the HAM in his breathing zone while performing the brake maintenance job. The computer recorded the relative dust levels on a disk from which a plot was later made

Using a spreadsheet program (Lotus 1-2-3), a real-time plot of the relative dust levels was made By comparing the peaks from this plot with the video, work practices producing elevated dust levels can be identified Although the HAM's are not specific for asbestos, if the asbestos fibers are dispersed along with other components of the brake dust, then the HAM should be a useful real time indicator for control of asbestos-laden dust

Ventilation

Kurz Model No 480 and TSI Model No 1630 air velocity meters were used to measure air velocities to determine air flow rates in the garage Smoke tubes were used to assist in observation of general airflow patterns Air temperature and humidity were determined using an aspirated psychrometer

Work Practices

An evaluation was conducted on workers performing brake maintenance and repair to determine work practices which may cause personal asbestos dust exposure during manual brake inspection and replacement The workers were videotaped during routine brake inspection and brake replacement tasks Work cycle times and work analysis were determined in the laboratory from the videotapes Cycle times were taken while running the videotapes at normal speed while work analysis was conducted at both normal speed and by "stop-action" techniques Work analysis included breaking the job into general tasks which could be matched with airborne dust levels during brake inspection and replacement Work tasks which could cause personal exposure to brake dust were identified

Each worker was asked for comments or suggestions on special steps that would reduce their potential exposures to brake dust during brake maintenance operations

IV RESULTS

Air Sampling Results

Individual filter sample results for airborne asbestos fibers are presented in Table 1 of Appendix A and are summarized in Tables 2 and 3 The results for samples analyzed by Phase Contrast Microscopy (PCM) are presented in Table 2 Personal sample concentrations for the brake mechanics averaged 0 007 fibers/cc; eight of the personal samples were above the detection limit of 0 004 fibers/cc and ranged up to 0 016 fibers/cc. The 7400-B rules (5:1 aspect ratio) were used for this, but the OSHA standard is based on a 3 1 aspect ratio Source samples taken above the wheel (fender) averaged less than 0.002 fibers/cc; source samples hung over the axle and centered between the wheels averaged less than 0 002 fibers/cc, background samples collected at two separate locations in the garage averaged less than 0 001 fibers/cc, and outdoor ambient samples averaged less than 0 001 fibers/cc

The 13 personal sample PCM concentrations for seven brake jobs were 0 016 fibers/cc or less. Because personal sample concentrations represented exposures while servicing brakes, and this usually takes no more than 2 to 3 hours per shift, the mechanics' time-weighted average exposure would be even lower

The OSHA Standard(17) of 0 2 fibers/cc (Action level 0 1 fibers/cc) and the NIOSH recommended exposure limit of 0 1 fibers/cc for asbestos (8 hour time weighted average) are based on PCM analysis of asbestos using "A" counting rules "B" counting rules were utilized in this research study and the results cannot be directly compared to the OSHA standard Based on the levels

Table 2

Phase Contrast Microscopy Concentrations for 7 Vehicles
(fibers/cc)

Sample Type	Number of Samples	Arithmetic Mean	Range
Personal	13	0 007	<0 004 to 0 016
Fender	5	<0 002	<0 001 to 0 002
Axle	5	<0 002	<0 002
Background	12	<0 001	<0 002
Ambient	12	<0 001	<0 002

Table 3

TEM Concentrations for 7 Vehicle Brake Jobs
(fibers/cc)

Sample Type	Number of Samples	Arithmetic Mean	Standard Deviation	Range	Geometric Mean	Geometric Standard Deviation
Personal	13	0 020	0 013	<0 011-0 045	0 016	2 1
Fender	5	0 007	0 049	<0 004-0 015	0 006	2 2
Axle	5	0 007	0 007	<0 004-0 020	0 005	2.3
Background	7	0 004	0 004	<0 004-0 012	0.003	2 0
Ambient	7	<0 004	—	<0 005	<0 004	-

measured by both PCM and TEM, however, the mechanic's exposure in this study would be well below these recommended levels TEM analysis of these samples show more than 90% of the chrysotile fibers counted using "A" rules would also have been counted using "B" rules

Small differences in average PCM personal sample concentrations were found among the vehicles tested The highest personal sample concentrations, which averaged about three times the detection limit, were measured during the first two brake jobs involving a two-passenger auto and a van There was no difference in PCM concentrations between the van and the auto The remaining personal sample concentrations varied little, ranging from below the detection limit to twice the detection limit. One mechanic did all the brake jobs except for Vehicle No 6, and the exposure for the second mechanic, who did Brake Job No 6, was the same as the overall average exposure for the first mechanic Only one of the axle and fender (source) samples analyzed by PCM was above the detection limit, thus, comparisons among brake mechanics and type of vehicle could not be done using the source sample results

Transmission Electron Microscopy (TEM) results are summarized in Table 3 All fibers identified as chrysotile or amphibole asbestos with an aspect ratio of 3 1 or greater were counted (fibers 0 25 microns and longer are included) A few samples contained fibers that were not identified (no I D), but could possibly be asbestos

The arithmetic mean TEM concentration for all personal samples was 0.020 fibers/cc, with a standard deviation of 0 013 fibers/cc The mean TEM background level in the building averaged 0.004 fibers/cc, and the outdoor ambient level averaged less than 0 004 fibers/cc Source samples taken at the axle averaged 0 007 fibers/cc, and samples taken at the fender (above the wheel) averaged 0 007 fibers/cc The TEM source sample concentrations were only slightly above TEM background levels

Asbestos fibers (chrysotile) greater than or equal to 5 µm in length were found in only one of the 35 samples analyzed by TEM Asbestos fibers that were in a matrix (partially hidden by particles) and X fibers - fibers that extended into another field - are not included in Table 3, but are denoted in Table 1 of Appendix A Eight of 35 samples analyzed by TEM contained M or X asbestos fibers, and three of these samples would have shown substantially higher concentrations had M or X fibers been included

Field blanks were prepared for each sampling date and submitted for PCM and TEM analysis Seven blanks were analyzed by PCM and by TEM and these results are shown in Table 1 of Appendix A Analysis by PCM showed all blanks were below detectable limits, thus, no corrections were made to the PCM sample results One of the 7 blank samples analyzed by TEM contained a single asbestos fiber Because of the very low asbestos fiber counts on the blanks, no blank corrections were made to the TEM sample results

Bulk and Rafter Sample Results

Bulk samples were collected from the rear wheel drums of six of the seven vehicles tested In addition, a rafter sample from the garage was collected and analyzed The bulk sample results are presented in Table 4 Less than one percent of the material in the brake drum bulk samples was asbestos, but from 24 to 100 percent of the fibers in the brake drum bulk samples were chrysotile, and in five of the six samples at least 96 percent of the fibers were chrysotile None of the brake drum bulk samples contained amphibole fibers From 0 to 9 percent of asbestos fibers and bundles were longer than 5 microns The rafter sample contained less than 1% asbestos, but the fibrous material consisted of 68 percent chrysotile and no amphibole fibers, none of the rafter sample asbestos fibers were larger than 5 microns

Real-Time Sampling Results

Real-Time total respirable dust data were collected using a Hand-Held Aerosol Monitor (HAM) connected to an Apple II Plus computer One sample was collected alongside the personal sample on the brake mechanic Real-Time data collection was during actual brake maintenance operations, approximately an hour in duration, and was obtained for each of the seven brake maintenance jobs One operator performed all but one of the brake maintenance jobs on these seven vehicles The real-time data results (Table 5) and review of the video indicated brief elevated respirable dust levels during certain phases of the brake maintenance operations These brief peaks represented, on average, less than 2% of the time of the actual brake maintenance job The brief peak dust levels did not always occur during the same work phases for each job Peaks usually occurred during the installation of new brake shoes (44% of the brake maintenance jobs) as the used hardware and new shoes were being snapped into place The source of the dust would come from the used hardware and the backing plate The HAM identified peak dust levels above the background levels, when the drums were removed during 25% of the jobs, and the used brake shoes were removed during 19% of the jobs Accumulated loose dust inside the brake drum was often seen to fall from the drum as the drum was being removed As the used shoes were being removed, dust would come from the brake springs and other hardware as they were being manipulated, and the HAM showed increased dust levels while removing the shoes on 3 of the wheels. The most frequent dust source was during the removal and reinstallation of the lug bolts and wheel (47% of the jobs) Dust on the wheel and lug bolts would be dislodged when the air gun is used to loosen or tighten the lug bolts However, most of this dust is probably road dust containing small amounts if any of asbestos Combining all these dust sources during brake maintenance resulted in HAM readings that were above the background levels less than 1 5% of the time

These results show the relative dust concentrations measured during the various brake jobs on the different vehicles Relative respirable dust concentrations during brake repair to Vehicle Nos 5 and 8 were 3 times the next highest concentration (Vehicle No 4) For Vehicle No 8, the higher dust concentrations occurred while servicing brake drums and shoes, and for Vehicle No 5 while removing and installing lug bolts and tires Only for brake repair to vehicle No 5, was there a detectable release of emissions during vacuuming Overall, about the same amount of dust is released when removing or installing tires as when servicing the brake drums and shoes A much smaller level of dust is observed during vacuuming

Table 4

Bulk Sample Results

Brake Job	Vehicle Type	Sample No	Grids Examined	Amphibole Present	Number of Chrysotile and Amphibole Fibers*	% of Total Fibers* Chrysotile and Amphibole	Chrysotile and Amphibole Fibers* >5 µm
1	2 pass auto	CB-1	10	No	68	100	3
3	2 pass auto	CB-3	9	No	102	96	9
4	1/2 ton van	CB-4	5	No	100	98	6
5	1/2 ton van	CB-5	5	No	102	97	3
6	1/2 ton van	CB-6	2	No	116	99	7
8	1/2 ton van	CB-8	1	No	24	24	0
Rafter		R-1	10	No	13	68	0

* Includes fibers, fibers in a matrix, and bundles

Table 5

"Relative" Total Respirable Dust Concentrations in Millivolt Seconds at the Worker

	Brake Task			
	Removing and Installing			
Vehicle	Lug Bolts and Tires	Brake Drums and Shoes	Vacuuming	Total
1	0 6	0	0	0 6
2	1 4	0	0	1 4
3	1 6	0 7	0	2.3
4	0	2 7	0	2 7
5	4 5	2 1	1 2	7 9
6	0 6	0.6	0	1.2
8	0 6	6.4	0	7 0
Average	1 3	1 8	0 2	3 3

This table summarizes the HAM data from Table 2 in Appendix A

V CONTROL TECHNOLOGY

Occupational exposures can be controlled by the application of a number of well-known principles, including engineering measures (ventilation, isolation, and substitution), work practices, and personal protection Ongoing monitoring and maintenance of controls to insure proper use and operating conditions, and the education and commitment of both workers and management to occupational health are also important ingredients of a complete, effective, and durable control system These principles of control apply to all situations, but their optimum application varies from case to case The application of these principles are discussed below

Engineering controls

The vacuum unit with a HEPA filter is used at this garage to contain and collect all brake lining dust (including potentially hazardous asbestos fiber content) The vacuum unit (which is fully described in Section II) is used during all brake inspection, repair, and brake lining replacement Vacuuming is done after the hubcap and wheel drum are removed Loose dust is removed from inside the drum and around the brake assembly After the disassembly, small parts (springs, screws, etc) are generally vacuumed No blowing with compressed air or wet methods are used No special attachments were used with the vacuum hose. Air was drawn into the 1-1/4 inch diameter nozzle at about 95 feet per second (50 cubic feet per minute) In this study, the entire brake service job was monitored, although not all tasks involve use of the vacuum unit The results discussed below represent fiber (PCM) and asbestos (TEM) concentrations during the entire brake job to both rear wheels

The adequacy of the vacuum only method is evidenced by the low exposures for the brake mechanics Personal exposures (PCM) were low compared to the OSHA standard of 0 2 fibers/cc and the NIOSH recommended standard of 0 1 fibers/cc, and PCM personal sample concentrations were low compared to historical personal sample exposures[2] during brake service operations in which compressed air, dry brushing, or wet brushing were used Five of 13 personal samples analyzed by PCM were below the detectable limits of 0 004 fibers/cc (Appendix A, Table 1), and the remaining eight personal samples were 0 016 fibers/cc or less The 7400-B rules (5 1 aspect ratio) were used for the PCM analysis Low fiber concentrations (by PCM) were also found for the source sample placed on the fender directly above the wheel After completing servicing to the first wheel, this sample was moved to the fender above the other rear wheel so that this sample included dust emissions from both rear wheels The fender sample concentrations for five separate brake jobs were 0 002 fibers/cc or less The other source sample, hung over the axle, showed concentrations (by PCM) of less than 0 002 fibers/cc for five brake jobs The importance of this source sample is that it shows that room air currents were not carrying dust fibers away from the worker toward the other side of the vehicle and into the room air

Seventy-nine percent of the air samples, including personal, axle, fender, background and ambient samples, analyzed by PCM, were below detectable limits; therefore, parametric tests of significance were not performed However, because 8 of 13 personal sample values (PCM) were detectable, a nonparametric sign test[18] was applied comparing the number of personal samples that were detectable with the number of background samples that were detectable and the sign test showed that the number of detectable personal samples was significantly greater than the number of detectable background samples

TEM results were also used to evaluate the effectiveness of the vacuum with HEPA filter unit The TEM results are not directly comparable to the PCM data because TEM includes all size fibers whereas PCM includes only fibers greater than 5 µm, and TEM includes only fibers identified as asbestos whereas PCM includes all fibers (larger than 5 µm) The TEM personal sample results (Table 3) show asbestos fibers were controlled to very low levels with use of the vacuum The personal sample arithmetic mean and geometric mean concentrations were 0 020 and 0 016 fibers/cc, respectively, for all seven brake jobs

Fender source sample asbestos concentrations were very low ranging from less than 0 004 to 0 015 fibers/cc. The axle source samples were also very low ranging from less than 0 004 to 0 020 fibers/cc Source sample asbestos concentrations (TEM) were only slightly higher than background sample asbestos concentrations (TEM).

Background asbestos concentrations by TEM averaged 0 004 fibers/cc, and ambient asbestos concentrations averaged less than 0 004 fibers/cc These low asbestos levels indicate that the asbestos present in the personal and source samples was from activities such as brake servicing and not from outdoor sources or from resuspended dust in the garage It was thought that vehicle traffic through the building may stir up dust and may result in higher indoor asbestos concentrations but this was not the case.

The majority of the TEM air sample concentrations were below the detection limit (0 002 to 0 013 asbestos fibers/cc), therefore, parametric tests of significance were not performed A sign test, however, was applied comparing detectable personal and detectable background TEM sample results and the test showed no difference

All the bulk samples collected from the rear wheels of the vehicles evaluated contained chrysotile asbestos In five of the six bulk samples (Table 4) at least 96 percent of the fibers were chrysotile asbestos Therefore, low TEM asbestos concentrations observed were not due to nonasbestos brakes The TEM air sample concentrations did not correlate directly with the bulk sample results For example, the TEM analysis for Vehicle No 8 showed about the highest personal sample concentrations even though the bulk sample showed only 24 percent of the fibers were chrysotile

The sampling at the Fairfax maintenance garage was conducted during the late autumn and winter months in cool to cold weather Doors were generally open during sampling for vehicles Nos 1, 2 and 3, and were closed while sampling the remaining vehicles Frequently, cars or trucks would leave the facility and the door was opened for that, but was closed again after the vehicle left Airborne asbestos levels would be expected to be higher with doors closed than when open during mild weather with increased natural ventilation

In summary, the use of the vacuum unit (with HEPA filter) during brake servicing of seven small and medium size vehicles resulted in low exposures based on both personal and source sample results Personal exposures (PCM) were low compared to the OSHA standard of 0 2 fibers/cc and the NIOSH recommended standard of 0 1 fibers/cc. PCM personal sample concentrations were low compared to historical personal sample exposures[2] that occurred during brake service operations involving the use of compressed air, dry brushing and wet brushing Also, few asbestos fibers of any size were found on personal samples analyzed by TEM Although the vacuum unit was effective for small and medium size vehicles, it is not known whether it is also effective for large vehicles The vacuum unit may be a suitable control when replacing brakes for large vehicles (because no enclosure is used, the control is not limited by wheel size), however, additional research would be needed to evaluate the vacuum unit for large vehicles

Work Practices

Several work practices employed by the brake mechanics were (1) to always use the Nilfisk vacuum, (2) if dust is created, try to avoid breathing it by moving away until it clears, and (3) clean up as soon as the job is complete Generally, the mechanics vacuumed each individual part removed from the brake assembly

A particular work practice determined by one mechanic was that he should not use a dry rag to clean his hands after finishing the brake job The mechanic realized this when he saw a sudden increase in dust levels, from the real time instruments, when wiping his hands with a dry rag

Monitoring

The goals of the Cincinnati Bell monitoring program for occupational asbestos exposure are to (1) evaluate exposures and use this information to ensure the health and safety of company personnel; (2) to comply with Federal and State standards and regulations; and (3) to complete work operations in a safe and legal manner Motor vehicle maintenance workers are covered under the Occupational Safety and Health Administration (OSHA) Industry Standard (1910 1001)

Cincinnati Bell has a written policy for dealing with the potential of asbestos exposure at work sites This policy is concerned primarily with noncompany work sites and includes inspection of the work site, bulk sampling and ambient air tests where asbestos is suspected, personal monitoring tests during actual work operations, instructions on the wearing of appropriate protective clothing and equipment, and proper personal hygiene practices

Mechanics are given preemployment as well as follow-up physicals including chest X-ray

Hygiene

Showers are provided for workers, including brake mechanics, at the Fairfax garage

VI CONCLUSIONS AND RECOMMENDATIONS

The use of the vacuum (with a HEPA filter) for vehicles such as vans and automobiles, resulted in very low exposures to fibers (PCM) and very low asbestos exposures (TEM) based on personal samples, indicating effective control of the asbestos dust Personal exposures (PCM) were low compared to the OSHA standard of 0 2 fibers/cc, the NIOSH recommended standard of 0 1 fibers/cc, and historical personal sample exposures(2) while using compressed air, dry brushing, or wet brushing for brake servicing. Although it was not possible to evaluate an uncontrolled situation to determine an efficiency for the controls, other work(2) has shown peak exposures while using dry brushing or compressed air of around 15 fibers/cc and time weighted average exposures of around 0 2 fibers/cc (PCM) using NIOSH method P&CAM 239 Few asbestos fibers of any size were found on the mechanics' personal samples analyzed by TEM

These data for the present study suggest that the present technique was substantially effective in controlling asbestos dust from brake service These results appear applicable for the servicing of smaller vehicles such as pickup trucks, vans, and automobiles However, without additional research, a distinction should be made between the effectiveness of this control for larger vehicles and that for smaller vehicles The replacement cost for the HEPA filtered vacuum evaluated in this study is approximately $800 to $1,100 (1985 dollars) (19)

Differences in personal and source sample concentrations among the seven vehicles evaluated using the vacuum only control were very small based on PCM and TEM results Personal sample concentrations by PCM for the two automobiles and five vans averaged 0 008 and 0 006 fibers/cc, respectively, compared to a detection limit of 0 004 fibers/cc for the personal samples TEM personal sample concentrations averaged 0 024 fibers/cc and 0 021 fibers/cc for the automobiles and vans, respectively These data indicate no difference due to vehicle type

TEM results were of greater value than PCM results for evaluating the vacuum (with HEPA filter) control method since most TEM personal and source sample results were above the detection limit, while most personal or source sample PCM results were below the detection limit Therefore, actual values are more often available from TEM analysis Furthermore, TEM is capable of speciating asbestos fibers, while PCM results includes both asbestos and nonasbestos fibers

The fiber composition of the dust in the rear brake drums for five vehicles evaluated in this study was between 96 and 100 percent chrysotile asbestos indicating these five vehicles had asbestos-type brakes; however, the fiber composition of the dust in the rear brake drums of a sixth vehicle was 24 percent chrysotile The composition of the brake lining for a seventh vehicle was not determined. Because primarily asbestos-type drum brakes were monitored in this study, the study results should be applicable to other facilities servicing asbestos type drum brakes

Real time sampling and analysis and review of a videotape of the individual brake jobs point out that some dust emission peaks may be reduced by implementing altered work practices such as (1) vacuum each piece of hardware as it is removed. This can be done by draping the vacuum hose over the vehicle spring with the hose intake near the operator's work area and as each piece of hardware is removed, place it in front of the suction, (2) immediately vacuum any dirt that falls from the wheel, brake drum, and brake assembly, and (3) do not use a dry rag to clean hands after completing a brake job Asbestos can accumulate in the rag and become airborne due to normal subsequential use of the rag Using water and a suitable soap to clean the hands is best Using a damp disposable rag or paper towel that is properly disposed of immediately after use would also be better than reusing a dry rag

During removal and replacement of the various filters from the vacuum units the operator should wear a NIOSH-recommended respirator for asbestos handling and follow the sequence of steps in accordance with the recommendation of the manufacturer of the vacuum unit (This operation was not observed during this study)

1 Start the vacuum pumps and prop open the flap on top of this assembly to allow access to these separate filter units By so doing, the bag and prefilter are under negative pressure with the dust being drawn to the surface of the filters This action substantially reduces the possibility of hazardous dust being emitted from the filters during their removal

2. Carefully wrap a minimum 6 mil thickness impermeable plastic bag around the first stage filter bag Simultaneously pull the bag filter loose and fasten the enveloping bag opening with tape With the first stage filter bag successfully removed, employ the same technique and work practices to enclose the second prefilter

3 These waste containers should be labeled as "Containing Asbestos Fibers - Avoid Breathing Dust "

Disposal of the resultant waste containers should be done in accordance with Environmental Protection Agency (EPA) regulations [20] These require that waste containers enclosing asbestos dust shall be buried in an EPA-approved hazardous waste disposal site

The vacuum unit with the HEPA filter appears to be an effective device for dust control from an ergonomic point of view and appeared easy to use However, the effectiveness of the unit as a control is likely to vary with the work practice used and the size of the vehicle

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Appendix A

Table 1

Sample Number	Date	Brake Job No	Vehicle Type	Make	Year	Sample Type	Repl or Insp	Dry Bulb Temp.	Wet Bulb Temp.	Volume	PCM** Fibers/ Filter	PCM** Fibers/cc	TEM Asbestos Fibers/ Filter	TEM Asbestos Concentration Fibers/cc	TEM Asbestos M or X Fibers* Counted
2579	24-Nov-86	1	auto 2pass	Chevy		pers	repl	60	54	392	6000	0.0153	2377	0.006	0
2590	24-Nov-86	1	auto 2pass	Chevy		pers	repl	60	54	385	3000	0.0078	4753	0.012	0
25218	24-Nov-86	1	auto 2pass	Chevy		axle	repl	60	54	1160	1500	0.0013	2377	0.002	0
25222	24-Nov-86	1	auto 2pass	Chevy		fend	repl	60	54	923	1500	0.0016	2377	0.003	0
25204	24-Nov-86					bckg		60	54	2228	1500	0.0007	4753	0.002	1
2594	24-Nov-86					bckg		60	54	2250	1500	0.0007			
25201	24-Nov-86					amb		60	54	915	1500	0.0016	2377	0.003	0
25214	24-Nov-86					amb		60	54	1106	1500	0.0014			
25203	24-Nov-86	2	van-h ton	Chevy	1977	pers	repl	60	54	367	6000	0.0163	2377	0.006	0
2582	24-Nov-86	2	van-h ton	Chevy	1977	pers	repl	60	54	361	2000	0.0055	9506	0.026	0
2598	24-Nov-86	2	van-h ton	Chevy	1977	axle	repl	60	54	1160	1500	0.0013	2377	0.002	0
25100	24-Nov-86	2	van-h ton	Chevy	1977	fend	repl	60	54	923	1500	0.0016	14259	0.015	0
25301	09-Dec-86	3	auto 2pass	Chevy	1982	pers	repl	62	59	361	1500	0.0042	14259	0.039	0
25350	09-Dec-86					bckg		62	59	900	1500	0.0017	2377	0.003	0
25326	09-Dec-86					bckg		62	59	938	1500	0.0016			
25219	09-Dec-86					amb		62	59	1547	1500	0.0010	2377	0.002	0
25322	09-Dec-86					amb		62	59	1262	1500	0.0012			
25323	11-Dec-86	4	van10 h-ton	Chevy	1977	pers	repl	50	41	378	1500	0.0040	4753	0.013	1
2562	11-Dec-86	4	van10 h-ton	Chevy	1977	pers	repl	50	41	378	1500	0.0040	2377	0.006	0
25209	11-Dec-86	4	van10 h-ton	Chevy	1977	axle	repl	50	41	930	1500	0.0016	4753	0.005	2
25220	11-Dec-86					bckg		50	41	1155	1500	0.0013	2377	0.002	0
25211	11-Dec-86					bckg		50	41	1140	1500	0.0013			
25306	11-Dec-86					amb		50	41	1089	1500	0.0014			
25347	11-Dec-86					amb		50	41	1089	1500	0.0014	2377	0.002	0

(continued)

Appendix A

Table 1 (continued)

Sample Number	Date	Brake Job No	Vehicle Type	Make	Year	Sample Type	Repl or Insp	Dry Bulb Temp.	Wet Bulb Temp	Volume	PCM** Fibers/ Filter	PCM** Fibers/cc	TEM Asbestos Fibers/ Filter	TEM Asbestos Concentration Fibers/cc	TEM Asbestos M or X Fibers* Counted
25317	16-Dec-86	5	van h-ton	Chevy	1978	pers	repl	62	51	369	2000	0 0054	9506	0.026	0
25542	16-Dec-86	5	van h-ton	Chevy	1978	pers	repl	62	51	363	2000	0 0055	4753	0.013	0
25526	16-Dec-86	5	van h-ton	Chevy	1978	axle	repl	62	51	961	1500	0 0016	19012	0 020	2
25536	16-Dec-86	5	van h-ton	Chevy	1978	fend	repl	62	51	1209	3000	0.0025	2377	0 002	0
25205	16-Dec-86					bckg		62	51	1170	1500	0 0013	2377	0 002	0
2580	16-Dec-86					bckg		62	51	1140	1500	0 0013			
25336	16-Dec-86					amb		62	51	1206	1500	0 0012	2377	0.002	0
25532	16-Dec-86					amb		62	51	1206	1500	0 0012			
25523	12-Jan-87	6	h-ton	Dodge	1978	pers	repl	62	51	426	3000	0 0070	19012	0 045	4
25321	12-Jan-87	6		Dodge	1978	pers	repl	62	51	433	4000	0.0092	2377	0.005	0
25308	12-Jan-87	6		Dodge	1978	fend	repl	62	51	1334	1500	0 0011	9506	0 007	5
2599	12-Jan-87					bckg		62	51	1290	1501	0 0012	2377	0 002	0
25328	12-Jan-87					bckg		62	51	1350	1500	0 0011			
25208	12-Jan-87					amb		62	51	1353	1500	0 0011	2377	0 002	0
25213	12-Jan-87					amb		62	51	1353	1500	0 0011			
25528	21-Jan-87					amb				1380	1500	0 0011	2377	0.002	0
25346	05-Feb-87	8	van h-ton	Dodge	1979	pers	repl	63	50	379	1500	0 0040	14259	0 038	0
25348	05-Feb-87	8	van h-ton	Dodge	1979	pers	repl	63	50	381	1500	0 0039	9506	0.025	0
25341	05-Feb-87	8	van h-ton	Dodge	1979	axle	repl	63	50	968	1500	0.0015	4753	0 005	1
25316	05-Feb-87	8	van h-ton	Dodge	1979	fend	repl	63	50	992	1500	0.0015	9506	0 010	2
25616	05-Feb-87					bckg		63	50	1230	1500	0 0012	14259	0 012	0
25334	05-Feb-87					bckg		63	50	1215	1500	0.0012	9506	0.008	0
25634	05-Feb-87					amb		63	50	1124	1500	0 0013	2377	0 002	0
25212	24-Nov-86		blank							0	1500		2377		0
25206	24-Nov-86		blank							0	1500		4753		0
25313	09-Dec-86		blank							0	1500		2377		0
25314	11-Dec-86		blank							0	1500		2377		0
25503	16-Dec-86		blank							0	1500		2377		0
25338	12-Jan-87		blank							0	1500		2377		0
25601	05-Feb-87		blank							0	1500		2377		0

* M = Matrix fiber, X = Fiber extended beyond grid
** All 1500 PCM results were below detection limit

Appendix A

Table 2

"Relative" Total Respirable Dust Concentrations at Worker

(Summary of Real-Time Sampling from HAM)

	General Brake Job							
	Removing and Installing							
	Lug Bolts and Tires		Brake Drums and Shoes		Vacuuming		Total	
Vehicle	Dust	% of Job Time	Dust	% of Job Time	Dust	% of Job Time	Dust	%
1	0 6	16	0	0	0	0	0 6	0 4
2	1 4	22	0	0	0	0	1 4	1 1
3	1 6	35	0 7	1 0	0	0	2 3	1 7
4	0	0	2 7	2 3	0	0	2 7	1 3
5	4.5	17	2 2	1 9	1 2	1 3	7 9	3 1
6	0 6	8	0 6	2 0	0	0	1 2	0 9
8	0 6	7	6 4	5 8	0	0	7 0	3 5
Total	9 3		12 5		1 2		23 0	
% of Total	40 3		54 5		5 2		100 0	