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IN-DEPTH SURVEY REPORT

EVALUATION OF BRAKE DRUM SERVICE CONTROLS

AT

Cincinnati Gas and Electric Garages
Cincinnati, Evanston, and Monroe, Ohio
and Covington, Kentucky

REPORT WRITTEN BY
Thomas C Cooper
John W Sheehy, Ph D
Dennis M O'Brien, Ph.D
James D McGlothlin
William F. Todd

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NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
Division of Physical Sciences and Engineering
Engineering Control Technology Branch
4676 Columbia Parkway
Cincinnati, Ohio 45226

PLANTS SURVEYED.	Cincinnati Gas and Electric Garages 2120 Dana Avenue Cincinnati, Ohio 593 Todhunter Road Monroe, Ohio 4th and Main Cincinnati, Ohio Union Light, Heat, and Power (a Subsidiary of CG&E) 19th and Augustine Covington, Kentucky
SIC CODE	4311
SURVEY DATES·	October 1986, and January, February, March, and May 1987
SURVEY CONDUCTED BY	John W Sheehy Thomas C. Cooper William F Todd Dennis M O'Brien Frank W Godbey Michael G. Gressel Karen L Lenihan James D McGlothlin Harold Van Wagenen Paul A Hentz Cliff B Kohlmeyer
EMPLOYER REPRESENTATIVES CONTACTED	William Schick, Industrial Hygienist (513) 632-3427 James Kilgore, Safety Specialist (513) 632-3332 Al Benzing, Supervisor, Dana St. Garage Otis Ashcraft, Supervisor, Covington Garage William Witt, Supervisor, Monroe Garage Robert Weinel, Supervisor, 4th/Main Garage
EMPLOYEE REPRESENTATIVES CONTACTED	Bill Bingle, Assistant Business Manager, International Brotherhood of Electrical Workers (IBEW), Local 1347, 4100 Colerain Avenue, Cincinnati, Ohio 45223. (Report mailed to Nicholas Greco, Business Manager)
ANALYTICAL WORK PERFORMED BY	Eugenia Shtrom, PEI, and Data Chem formerly Utah Biomedical Testing Laboratory

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 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. 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 They concluded ". 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 "[1]

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 being potentially exposed in brake servicing.[3]

A study of brake service operations was 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 currently available control devices 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 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 ten 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 was 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, lung cancer, 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 Unlike chrysotile, the health effects of exposure to forsterite (a deformation product of chrysotile), 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.

The two sources of occupational exposure criteria considered in this study are (1) the NIOSH Recommended Exposure Limit (REL), and (2) the Department of Labor OSHA Permissible Exposure Limit (PEL)

NIOSH recommends that employee exposure to asbestos be reduced to the lowest feasible limit, due to the carcinogenic nature of this substance. The NIOSH REL published in 1976 is 0 1 fibers greater than 5 µm in length per cubic centimeter (f/cc) [15]

NIOSH submitted an update on the recommended asbestos criteria at the OSHA proposed rule-making hearings for asbestos in June 1984 [16] The NIOSH position is summarized below·

> The carcinogenic potential of asbestos is no longer in doubt, however, there is some uncertainty about the toxicological and morphological properties which determine the carcinogenic potency of various fibers NIOSH believes that on the basis of available information, there is no scientific basis for differentiating between asbestos fiber types for regulatory purposes Data available to date provide no evidence for the existence of a threshold level Virtually all levels of asbestos exposure studied to date demonstrated an excess of asbestos-related disease
>
> NIOSH continues to believe that both asbestos and smoking are independently capable of increasing the risk of lung cancer mortality When exposure to both occurs, the combined effect, with respect to lung cancer, appears to be multiplicative rather than additive From the evidence presented, we may conclude that asbestos is a carcinogen capable of causing lung cancer and mesothelioma, independent of smoking
>
> NIOSH has recommended that asbestos be controlled to the lowest detectable limit. It is our contention that there is no safe concentration of exposure to asbestos. Any standard, no matter how low the concentration, will not ensure absolute protection for all workers from developing cancer as a result of their occupational exposure However, lower exposures carry lower risks
>
> Since the only widely available method, NIOSH Method 7400,[17] is able to achieve (intralaboratory) accuracy of 12 8 percent RSD at an exposure limit of 0 1 f/cc (100,000 f/m^3) in a 400 liter sample, NIOSH and others have recommended an exposure limit (REL) of 0 1 f/cc for asbestos based on 8-hour time-weighted average concentrations with peak concentration not exceeding 0 05 fibers/cc [15] While this is a well understood practice, we cannot find compelling arguments to prevent a recommendation based on alternative sampling periods. In fact, such an approach may provide more protection than an 8-hour based sampling period that allows short-term exposures six or ten times greater than the 8-hour exposure limits being considered by OSHA Furthermore, since there is uncertainty regarding the cumulative dose required to initiate disease, it seems reasonable to make every attempt to control exposures to as narrow a range of concentrations as possible One way to accomplish this is to restrict the period over which workplace concentrations can be averaged
>
> Personal sampling pumps are available, with flow rates up to 3.5 lpm, which would allow a sampling time of two hours or less

Finally, we still believe that there are occasions, such as mixed fiber exposures, where fiber specificity is necessary Therefore, we recommend the use of electron microscopy in the event of process or product modification, in mixed fiber exposures, or when there are other reasons for characterization of fiber type and morphology

As noted, the occupational exposure criteria - the NIOSH REL and the OSHA PEL - are based on the readily available Phase Contrast Microscopy analytical method This method has inherent limitations based on the physics of the optical microscope and upon the ability of the counters to reliably discriminate the specified length to width ratio in a complex sample matrix The minimum diameter routinely observed is on the order of 0.5 µm The NIOSH 7400 method stipulates that only fibers longer than 5 µm be counted with a length to width ratio of either 3:1 ("A" rules) or 5:1 ("B" rules) (The "A" and "B" rules have other minor differences) The "A" rules use the same aspect ratio as the current OSHA PEL, and thus have the advantage of relating to current and historical compliance data They have the potential disadvantage of counting particles that may or may not be fibers In the present study, TEM offers the advantage of being able to determine the actual dimensions of all fibers that were counted, and thus, to differentiate the numbers of fibers with various length to width ratios A coarse analysis of these data indicates that fiber counts using NIOSH 7400-A and 7400-B counting rules would differ by less than 8 percent

Another concern is that asbestos fibrils as small as 0.02 µm in diameter and less than 1 µm in length are visible only with electron microscopy These fibrils constitute a significant and variable proportion of the total fibers present in brake dust Thus PCM, in counting only optically visible particles, may not be a good indicator of the total fibers present Controversy over the health effect of small fibers (and thus what sizes of fibers <u>should</u> be counted) adds further ambiguity to this area

On June 20, 1986, OSHA issued a revised PEL, which reduced the PCM level to 0.2 f/cc, as an 8-hour time-weighted average (TWA) exposure. It also set an action level of 0.1 f/cc that triggers worker training, medical monitoring, and other requirements The new PEL does not set a ceiling or short-term exposure limit

II PLANT AND PROCESS DESCRIPTION

Facility Description

Cincinnati Gas and Electric (CG&E) has ten garages in the Cincinnati metropolitan area that service 1,400 vehicles These include cars, pickup trucks, vans, specialty vehicles slightly larger than a pickup truck, medium size trucks, and large specialized line trucks The maintenance of these vehicles is based on a thorough annual inspection of each vehicle with brake inspection included Each month, approximately 30 to 35 vehicles have all their wheels pulled for brake inspection with 65 percent to 70 percent of these vehicles undergoing brake replacement or repair

The ten garages range in size from a single-bay workstation to a 14-bay garage. There are a total of 89 mechanics at these ten garages who perform brake maintenance.

This study was performed during servicing of six vehicles at four different garages. The four garages are located in: Evanston, Ohio on Dana Avenue, 4th and Main in Cincinnati, Ohio, Monroe, Ohio, and in Covington, Kentucky. The Evanston Garage is located in a congested industrial area. The vehicle maintenance area is part of a larger building. Maintenance is performed on 250 vehicles assigned to this location in 10 work bays by 10 mechanics. The Cincinnati garage is located in the garage area beneath a high rise office building in the downtown area. Maintenance is performed on 225 vehicles in 3 work bays by 5 mechanics. This garage mainly services automobiles. The Monroe garage is located in a rural area, the vehicle maintenance garage is one of several buildings in the compound. Maintenance is performed on 115 vehicles in 4 work bays by 7 mechanics. The Covington garage is in a congested industrial area, the maintenance garage is part of a larger multipurpose garage. Maintenance is performed on 150 vehicles in three work bays by 8 mechanics.

Process and Equipment Description

Brake dust is suppressed at these facilities by use of a solvent (methyl chloroform) spray. The operator dispenses the solvent from the reusable, hand-held sprayer shown in Figure 1. It is used at all ten garages to control potential asbestos exposures during brake maintenance on all types of vehicles. The sprayer is filled with approximately one quart of solvent from a 55-gallon drum. A drum-mounted pump is used to transfer the solvent to the sprayer. The mechanic uses shop air (approximately 200 psig) to pressurize the sprayer. After the brake drum has been removed, the operator, holding the sprayer 12" to 18" from the brake components and drum, thoroughly wets all the exposed surfaces. The contaminated solvent, which is not recycled, is collected in a catch pan placed beneath the vehicle's wheel and emptied into a drum to be disposed of as hazardous waste.

One mechanic, instead of using this sprayer, used a parts brush and solvent (manual wet brush method) to remove the brake residue from the brake drum and brake components. This mechanic filled the catch pan with about 2 inches of solvent and set the pan on the floor near the vehicle. After pulling the drum, he held the drum in the solvent pan and used the brush to apply the solvent and clean the drum. He then wiped the drum with a dry rag. Next, he placed the pan beneath the wheel and manually cleaned the brake components with the brush, catching the contaminated solvent in the pan. Afterwards, he wiped the components with a dry rag. The contaminated solvent is emptied into a drum and disposed of as hazardous waste.

The solvent used in the sprayer is 1,1,1-trichloroethane (commonly known as methyl chloroform). 1,1,1-trichloroethane is irritating to the eyes on contact. Overexposure to the vapors depresses the central nervous system. Symptoms of overexposure include dizziness, incoordination, drowsiness, and increased reaction time. Unconsciousness and death can occur from exposure to excessive concentrations.[18] The current OSHA PEL is 350 parts of methyl

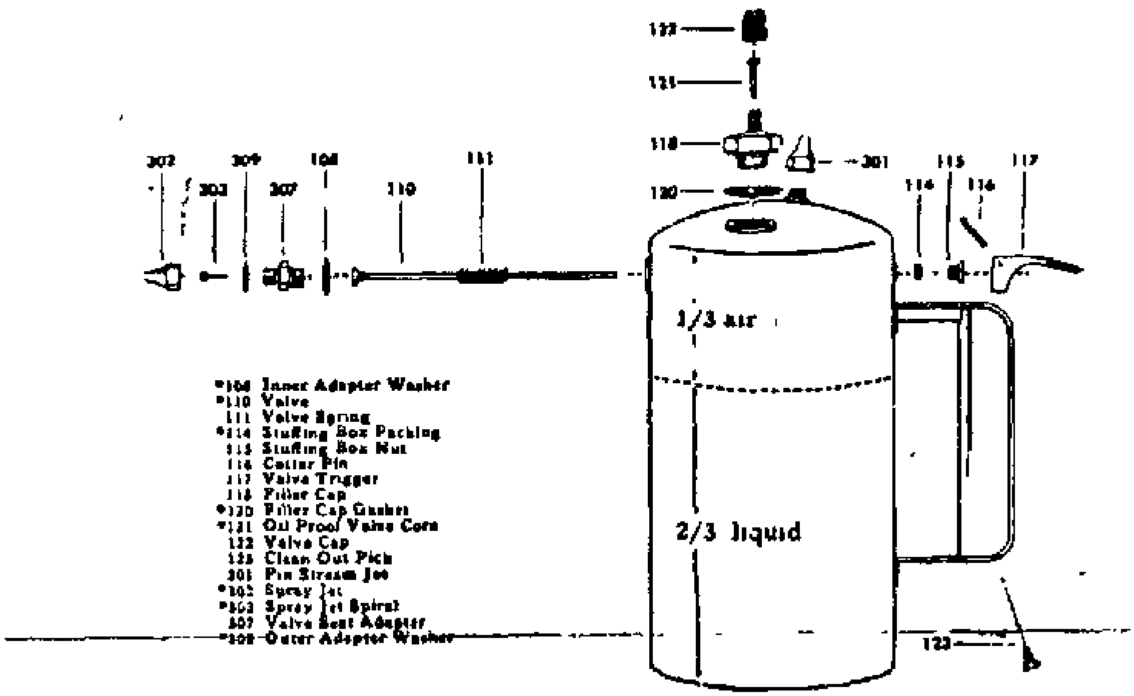

Figure 1. Model "A" Sprayer, 1 Quart Capacity

chloroform per million parts of air (ppm) or 1,910 mg/m^3 averaged over an 8-hour work shift The NIOSH REL is 350 ppm (1,910 mg/m^3) averaged over a 15-minute period

A 55-gallon drum of 1,1,1-trichloroethane costs $298 ($2 71 per quart) Each quart of solvent cleans approximately 4 wheels The Balkamp Model "A" Sprayer costs approximately $30

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 2 5 to 3 0 lpm using a DuPont P-4000 pump for the duration of one brake job, or 2 hours, whichever was longer. (Brake Jobs 1 and 2 were collected on one set of filters) The minimum volume collected (300 liters) allowed a limit of detection of approximately 0 005 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 rotary vane high volume pumps for the duration of one brake job or 2 hours, whichever was longer. The source samples were used to measure fibers escaping into the working environment during the brake service 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 for up to 4 hours encompassing pre- and post-brake job activities These samples were used as "background" samples 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 2 5 to 3 0 lpm using battery powered pumps for 3 to 8 hours These outdoor (ambient) samples were collected at 7 0 lpm using a high volume pump Ambient samples were used to determine environmental levels of asbestos The minimum volume collected (400 liters) allowed a limit of detection of 0 004 fibers/cc. (One pair of area samples, one pair of background samples, and one pair of ambient samples were collected for Brake Jobs 1 and 2 All other brake jobs have one set of filters for each brake job)

All filter air samples were analyzed by PCM according to NIOSH Method 7400 (17) In addition to PCM analysis, approximately 82 percent 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(19) was used For PCM analysis, all fibers with a 5.1 (or greater) aspect ratio were counted using Method 7400-B counting rules (Air samples taken on Brake Job 6 were analyzed by PCM using Method 7400-A counting rules instead of Method 7400-B counting rules, because the routine laboratory procedure for Method 7400 had been changed to "A" counting rules before these samples were analyzed) 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 three of the four sites 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 were 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 for the first five brake studies (Respirable Aerosol Monitors, RAMs, Model RAM-1 manufactured by GCA/Technology Division of Bedford, Massachusetts, were used on the last brake study The HAMs and RAMs operate on a similar electro-optical principle) The HAM's electro-optical system provides instantaneous measurement of respirable dust levels in mg/m^3 The HAM or RAM 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 three second intervals before it has to be reset. Before each brake maintenance job, the HAM or RAM was calibrated and zeroed The computer's clock was synchronized with that of a video camera DuPont P-4000 or MSA Model G pumps were connected by tubing to the HAM (the RAMs have their own built in pump), 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 (the RAM was set near the mechanic's work area at the height of 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 spread sheet 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 neither the HAM nor the RAM are specific for asbestos, if the asbestos fibers are dispersed along with other components of the brake dust, then the HAM or RAM should be a useful real time indicator for control of asbestos-laden dust

Ventilation

Air velocity meters were used to measure air velocities to determine airflow rates in the garages. 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 a review of 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

IV. RESULTS

Air Sampling Results

Individual filter sample results for airborne asbestos fibers are presented in Table A-1 of Appendix A Tables 1, 2A, and 2B summarize these results Table 2B does not include the TEM results for Brake Job 5, a vehicle having brake drums greater than 12" in diameter The brake drum diameters on the remaining 5 vehicles were less than or equal to 12" in diameter The PCM and TEM results for Brake Job 5 are summarized in Table B-1 of Appendix B. Generally, personal sample concentrations represented exposures while servicing brakes on only one vehicle, but one set of samples (Brake Jobs 1 and 2) was collected while servicing two vehicles

The results for samples analyzed by Phase Contrast Microscopy (PCM) are presented in Table 1 Personal sample concentrations for the brake mechanics averaged 0 006 fibers/cc, five of the personal samples were above the detection limit of 0.004 fibers/cc and ranged up to 0.016 fibers/cc. Source samples taken above the wheel (fender), and those hung over the axle and centered between the wheels (axle) averaged less than 0 002 fibers/cc Outdoor ambient samples and background samples collected at two separate locations in the garage averaged less than 0.002 fibers/cc The ten personal sample PCM concentrations for six brake jobs were 0 016 fibers/cc or less Personal sample concentrations reported here represented exposures while servicing brakes of no more than 2 to 3 hours per shift, therefore, the mechanics time-weighted average exposure would be even lower

The current OSHA PEL[15] of 0.2 fibers/cc (Action level 0 1 fibers/cc) and the NIOSH REL 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

Table 1

Asbestos Concentrations (by Phase Contrast Microscopy)
for 6 Vehicle Brake Jobs
(fibers/cc)

Sample Type	Number of Samples	Arithmetic[1] Mean	Range
Personal	10	0 006	<0.004 to 0 016
Fender	4	<0 002	<0 002
Axle	4	<0.002	<0.002
Background	10	<0 002	<0 002
Ambient	10	<0 002	<0 001 to <0.004

[1] For each nondetectable samples, a value of 0 001 fiber/cc was assigned

Table 2A

Asbestos (TEM) Concentrations for 6 Vehicle Brake Jobs
(fibers/cc)

Sample Type	Number of Samples	Arithmetic Mean	Standard Deviation	Range	Geometric Mean
Personal	10	0 213	0 335	0.013-0 894	0 071
Fender	4	0 085	0.059	0 005-0 166	0.048
Axle	4	0 018	0 008	0 004-0.023	0 015
Background	7	0 005	0 003	<0 002-0 010	0 004
Ambient	7	<0 006	0.003	<0 004-0.012	0 005

Table 2B

Asbestos (TEM) Concentrations for 5 Vehicle Brake Jobs
(Brake Drum Sizes Less Than or Equal to 12" in Diameter)
(fibers/cc)

Sample Type	Number of Samples	Arithmetic Mean	Standard Deviation	Range	Geometric Mean
Personal	8	0 046	0 024	0.013-0.079	0 038
Fender	3	0 078	0 067	0 005-0 166	0 037
Axle	3	0.016	0 009	0 004-0 023	0.013
Background	6	0 004	0.002	<0 002-0 008	0 004
Ambient	6	0.005	0 003	<0 004-0 012	0 005

compared to the OSHA standard Based on the levels measured by both PCM and TEM, however, all the mechanics' exposures in this study would be well below these levels TEM analysis of these samples show more than 97 percent of the chrysotile fibers counted using "A" rules would also have been counted using "B" rules One set of samples for Brake Job 6 was analyzed using "A" counting rules and the analysis showed the results were near or below the detection limit, therefore, the results for Brake Job 6 were combined with the results obtained by using "B" rules

Little difference in average PCM personal sample concentrations were found among the six vehicles tested The highest personal sample concentrations, which averaged about three times the detection limit, were measured during a brake job on a van

The brake jobs were performed by five different mechanics at four different locations Because there was little difference among personal exposures by PCM and none of the axle and fender (source) samples analyzed by PCM were above the detection limit, comparisons among brake mechanics, type of vehicle, and garages could not be done using PCM sample results Background and ambient samples collected at these four garages were all below the detection limit.

Transmission Electron Microscopy (TEM) results are presented in Table B-1 of the Appendix and summarized in Tables 2A and 2B 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

Table 2A shows the asbestos (TEM) concentrations for all 6 brake jobs The arithmetic mean concentration for the personal samples was 0 213 fibers/cc, with a standard deviation of 0 335 fibers/cc. The arithmetic mean asbestos (TEM) background levels in the three garages averaged 0 005 fibers/cc, and the outdoor ambient level averaged 0.006 fibers/cc Source samples taken at the fender averaged 0.085 fibers/cc, and samples taken at the axle averaged 0.018 fibers/cc Two of the three fender sample asbestos (TEM) concentrations were above background levels indicating that some chrysotile asbestos is released using this control method

One brake job on a large vehicle (brake drums greater than 12" in diameter) produced asbestos (TEM) concentrations much higher than the other five brake jobs (See Table B-1 in the Appendix)The arithmetic mean concentration for the personal samples was 0 882 fibers/cc The arithmetic mean background level was 0.010 fibers/cc, and the outdoor ambient level averaged 0 010 fibers/cc Source samples taken at the fender averaged 0 106 fibers/cc, and sample taken at the axle averaged 0 022 fibers/cc All personal, axle, and fender samples were above background levels indicating that some chrysotile asbestos is released using this control method

Table 2B shows the asbestos (TEM) concentrations for the 5 vehicles having brake drums less than or equal to 12" in diameter The arithmetic mean concentration for the personal samples was 0.046 fibers/cc, with a standard deviation of 0 024 fibers/cc The arithmetic mean asbestos (TEM) background levels in the three garages averaged 0 004 fibers/cc, and the outdoor ambient level averaged 0 005 fibers/cc Source samples taken at the fender averaged 0.078 fibers/cc, and samples taken at the axle averaged 0 016 fibers/cc Two of the three fender sample concentrations were above background levels indicating that some chrysotile asbestos is released using this control method

For the 6 vehicles, chrysotile asbestos fibers greater than or equal to 5 µm in length were found in seven of the 32 samples analyzed by TEM Asbestos fibers that were in a matrix (M fibers) - partially hidden by particles - and X fibers - fibers that extended into another field - are not included in Tables 2A or 2B, but are denoted in Table A-1 of Appendix A Sixteen of 32 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 five by TEM and these results are shown in Table A-1 of Appendix A Both analyses showed all blanks were below detectable limits; thus, no corrections were made to the sample results for either method.

Bulk and Rafter Sample Results

Bulk samples were collected from the brake drums of the six vehicles tested In addition, rafter samples from three of the four garages were collected and analyzed The bulk sample results are presented in Table 3 Less than 1 percent of the material in the brake drum bulk samples was asbestos, but from 74 to 100 percent of the fibers in the brake drum bulk samples were chrysotile None of the brake drum bulk samples contained amphibole fibers From 1 to 15 percent of asbestos fibers and bundles were longer than 5 microns The rafter samples contained less than 1 percent asbestos, but the fibrous material consisted of 56 to 84 percent chrysotile, one rafter sample contained amphibole fibers which could have originated from either building insulation or brake drum residue. None of the asbestos fibers from the rafter samples were larger than 5 microns in length

Real-Time Sampling Results

Real-time total respirable dust data was collected using a Hand-held Aerosol Monitor (HAM) connected to an Apple II Plus computer on the first five brake studies (A Respirable Aerosol Monitor, RAM, was used on Brake Job 6) The real-time samples were collected alongside the personal samples on the brake mechanic Real-time data collection took place during actual brake maintenance operations, approximately an hour in duration, and was obtained during all six brake maintenance jobs. Five different operators performed the brake maintenance jobs on six vehicles

The general brake maintenance procedure was

- Raise the vehicle a few inches off the floor

Table 3

Bulk Sample Results

Brake Job	Vehicle	Grids Examined	Amphibole Present	Chrysotile and Amphibole: Number of Fibers*	% of Fibers*	Fibers* >5 µm
1	1/2 ton pickup	10	No	88	85	4
2**	specialty van	10	No	100	99	1
3	van	7	No	106	98	1
4	small pickup	3	No	80	74	3
5**	boom truck	1	No	110	100	16
6	5 pass auto	4	No	102	90	2
Rafter	Dana Ave	9	Yes	73	63	7
Rafter	Covington	7	No	84	84	3
Rafter	Monroe	10	No	14	56	0

* Includes fibers, fibers in a matrix, and bundles
** Vehicle has tandem rear wheels

- Remove the wheel's lug bolts and wheel

- Remove the brake drum.

- Use pressurized hand-held sprayer to wash brake components and brake drum

- Inspect brake components If brakes need replacing, start removing brake components. If brakes do not need replacing, start reinstalling brake drum

- Complete removal of brake components

- Install new brake shoes and reinstall brake components

- Reinstall brake drum

- Remount the wheel and tighten the lug bolts

To interpret the real-time computer data, the HAM/Apple's background level (0 05 millivolts) is used as the reference point (For the RAM/Apple, the background level is 0 10 millivolts.) These background levels are due to the instruments' internal noise level and values below it are considered to be unreliable. Values above these base line levels are used to identify the dust sources. By determining the magnitudes (value above the reference point with time) of these dust exposures, relative dust exposures due to certain phases of the brake job can be identified and compared.

Real-time data detected brief elevations of respirable dust during the removal of brake drums, and lug bolts; spraying of brake components; installing new shoes and used brake components, and tightening the lug bolts when remounting the wheel The greatest potential asbestos dust exposure occurs during the spraying of the brake components and brake drums Air induced by the spray may dislodge brake dust before it can be thoroughly wetted This dust contains ground-up brake shoe residue which is likely to contain asbestos fibers For 83 percent of the drums removed, dust levels were up to three times that of the reference level during spraying The worker was exposed to elevated dust levels for 5 percent of the total brake job time during the spray washing phase of brake maintenance The elevated real-time dust readings may also be due in part to the solvent mist generated by the hand-held sprayer during washing

The second highest dust levels detected were during the loosening and tightening of the wheel's lug bolts with a pneumatic air wrench The dust levels were up to three times that of the reference level on 33 percent of the brake jobs. The worker was exposed to elevated dust levels 10 percent of the total brake job time during this phase of brake maintenance The elevated real-time dust readings may also be due in part to the oil mist aerosol from the wrench generated by the compressed air

Reinstalling brake components resulted in a slightly elevated dust exposure, up to eight times the background level, in 33 percent of the reinstallations

The worker was exposed to elevated dust levels (above background) 1 percent of the total brake job time during this phase of brake maintenance.

Over the entire brake job, the worker was exposed to elevated (above background) dust levels an average of 16 percent (4 to 5 minutes) of the entire work cycle

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 ensure 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 wet spray method is used at these garages to contain and collect all brake lining dust (including potentially hazardous asbestos fibers) This unit or the wet brush and solvent method (which are fully described in Section II) are used during all brake inspections, repair, and brake lining replacements In this study, the brake service job was monitored for drum-type brakes on the rear wheels for both single and tandem wheels

Work Practices

Table 4 shows the work task analysis of a brake inspection and replacement job while using the wet spray unit Potential asbestos exposure points while performing this task are also noted. The average work cycle time for a one-wheel brake replacement task is 30 to 40 minutes

As seen from Table 4, asbestos exposure during brake maintenance and repair may occur during the initial tasks of removing the wheel and brake drum from the vehicle, during spray washing of the brake components, removing and reinstalling the brake components, and replacing the lug bolts The spraying technique appeared to minimize dust exposures the spraying was started about 18" from the brake surfaces until wetted and then moved to within 12" of the surface to clean the the surfaces, and additional spraying of the brake components as they were being removed Bad work practices observed included using a dry rag to wipe the brake drum and assembly, the use of a hammer to loosen "frozen" brake drums without trying to capture the brake dust falling from the brake drum, and the drinking of coffee while performing brake maintenance

Demographic and work practices were obtained from an interview of one worker The worker was a 54-year old male whose left hand was dominant in performing work. Tools and equipment commonly used during brake maintenance and repair included brake spring remover, pliers, hammer, sprayer, brake adjustment

Table 4

Work Task Analysis of Brake Inspection and Replacement

Step	Work Task	Brake Dust Exposure Sources
1	Use pneumatic wrench to remove lugs from wheel	Loose dust around lugs and tire rim
2	Remove wheel from vehicle	
3	Remove brake drum and sets it on floor	Loose dust from drum and brake components may become airborne.
4	Worker spray washes brake drum and brake components for 1 to 3 minutes	Mist which may contain asbestos fibers becomes airborne
5	Worker wipes brake components and brake drum with a dry rag	Any remaining brake residue, which may contain asbestos fibers, dries on rag and can become airborne when rag reused
6	Inspects the brake assembly	
7	Worker removes and reinstalls brake components and installs new shoes.	Loose dust from brake components as they are being manipulated
8	Brake drum put back on vehicle	
9	Wheel is put back on vehicle	
10	Wheel lugs pneumatically tightened on wheel	Loose dust around lugs and tire rim

tool, brake shoe tool, power air tool, and impact wrench The worker said he had one day of training on how to protect himself from asbestos dust during brake maintenance and repair He remembered from this training to wash out the brake drums and components with the solvent sprayer provided and to avoid inhaling the solvent The worker indicated he had a physical examination before being hired by CG&E

All workers wore clean work clothes Gloves, safety glasses, and safety shoes were not required Although the wearing of a respirator was not mandatory, one worker did wear a model W-2908 3M half face air supplied respirator The air pump, a Rhine Model B-2 (Rhine Air, Santee, CA), was placed outside the garage with an air line leading under the closed garage door to the worker The worker wearing this respirator performed brake maintenance on a tandem wheel boom truck CG&E does provide lockers and showers for their workers A uniform cleaning service is available for employee's use

VI. DISCUSSION

The effectiveness of the wet spray method and the wet brush method are evidenced by the exposures for the brake mechanics below the limits of detection, as measured by PCM Historical studies have shown peak exposures (using NIOSH Analytical Methods P&CAM #239) of around 1 fiber/cc and time-weighted average exposure of around 0 2 fibers/cc with dry brushing or compressed air blowing.[2] Three of the 10 personal samples analyzed by PCM (Table 1) were below the detectable limits of 0 004 fibers/cc and the remaining five samples ranged from 0.004 fibers/cc to 0.016 fibers/cc, all well below the current OSHA PEL of 0.2 fibers/cc and the NIOSH REL of 0 1 fibers/cc. Low fiber concentrations (by PCM) were also found for the source sample placed on the fender directly above the wheel After completing service to the first wheel, this sample was moved to the fender above the other wheels so that this sample included dust emissions from both rear wheels The fender sample concentration for each of the six brake jobs was less than 0.002 fibers/cc The other source sample, hung over the axle, showed concentrations of less than 0 002 fibers/cc for all six brake jobs The importance of this source sample is that it shows large numbers of asbestos fibers were not being propelled by the wet spray toward the other side of the vehicle

TEM results were also used to evaluate the effectiveness of the wet spray method and the manual wet brush method 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 (longer than 5 µm)

The personal sample arithmetic mean asbestos concentration by TEM for the spray methods on brake drums less than or equal to 12" in diameter was 0 046 fibers/cc (range 0 013 to 0 079 fibers/cc) The TEM personal sample arithmetic mean concentration for the manual wet brush method on a vehicle with brakes less than or equal to 12" in diameter was 0 022 fibers/cc, ranging from 0 013 to 0 039 fibers/cc

Fender sample asbestos concentration by TEM for the spray wash method on a vehicle with brake drums less than or equal to 12" in diameter was 0 063 fibers/cc For the manual wet brush method, the concentration was 0 005 fibers/cc The axle source sample for the spray wash method was 0 023 fibers/cc For the manual wet brush method, the concentration was 0.004 fibers/cc

Background asbestos concentrations by TEM ranged from <0 002 to 0 008 fibers/cc for the wet spray and the manual wet brush methods for vehicles having brake drums less than or equal to 12" in diameter Ambient asbestos concentrations by TEM ranged from less than 0 004 to less than 0.012 fibers/cc One of six background samples was detectable. None of the four ambient samples had detectable fibers There is no practical or statistical difference between the ambient and background levels These low asbestos levels indicate that most of the asbestos present in the personal samples was from activities such as brake servicing and not from outdoor sources (ambient) or resuspended dust (background) in the garage

The results of the wet spray method on a vehicle having brake drums greater than 12" in diameter (a tandem wheel vehicle) were substantially higher The personal sample arithmetic mean asbestos (TEM) concentration was 0 882 fibers/cc The fender sample was 0 106 fibers/cc and the axle sample was 0 022 fibers/cc Background and ambient dust concentrations were both 0.010 fibers/cc These higher asbestos levels indicate that most of the asbestos present in the personal samples was from activities the brake servicing and not from outdoor sources (ambient) or resuspended dust (background) in the garage. Table 5 summarizes the TEM sample results for these various combinations of brake drum sizes, and wet spray and manual wet brush methods

VII. CONCLUSIONS AND RECOMMENDATIONS

Personal exposures (PCM) were low compared to the OSHA PEL and the NIOSH REL and were an order of magnitude lower than historical personal exposures[2] occurring during brake servicing operations These data suggest that the present techniques involving the use of a wet spray wash or the manual application of a solvent with a brush were substantially effective in controlling asbestos dust during brake servicing

Since the asbestos levels were quite low, the TEM results were of much greater value than PCM results for making comparisons and evaluations of the wet spray method and the manual wet brush and solvent method Thirty-three of the 38 PCM samples were below detectable limits while 13 of the 36 TEM samples were below detectable limits The primary use of the PCM data was to demonstrate that exposures were well below the OSHA PEL and NIOSH REL, since both the standard and recommended level are based on the PCM procedure Since the TEM method is more sensitive, it usually allows comparison between personal or source samples and background and ambient levels Furthermore, TEM is capable of speciating asbestos fibers, while PCM results includes both asbestos and nonasbestos fibers As noted earlier, TEM analysis of these samples show that more than 97 percent of the chrysotile fibers counted using the "A" rules would also have been counted using the "B" rules

Table 5

Summary of TEM Results

METHOD	DRUM SIZE	NO SAMPLES	ARITH MEAN	GEOM MEAN	RANGE
Personal Samples					
Spray	≤12"	6	0 052	0.045	0 013 - 0 079
Spray	>12"	2	0 882	-	0.870 - 0 894
Brush	≤12"	2	0 026	-	0 013 - 0 039
Fender Samples					
Spray	≤12"	2	0.115	0 102	0 063 - 0 166
Spray	>12"	1	0 106	-	-
Brush	≤12"	1	0 005	-	-
Axle Samples					
Spray	≤12"	2	0 023	0.023	-
Spray	>12"	1	0 022	-	-
Brush	≤12"	1	0 004	-	-
Background Samples					
Spray	≤12"	4	<0 004	-	<0 002 -<0.004
Spray	>12"	1	0.010	-	-
Brush	≤12"	2	0 006	-	<0 004 - 0 008
Ambient Samples					
Spray	≤12"	2	<0.008	-	<0.004 -<0 012
Spray	>12"	1	0 010	-	-
Brush	≤12"	2	<0 004	-	-

TEM Personal sample results (Tables 5 and B-1) showed a major difference between vehicles having brake drums greater than 12" in diameter and those having smaller brake drums One possible explanation is that the brake surface area is greater resulting in a greater amount of brake dust that needs to be controlled Also, the wheel well area is larger making the area to be sprayed less accessible This requires the operator to have his head further into the wheel well so that the spray gun will be close enough to the brake components being washed to see if they are clean Since the wheel well acts as a partial enclosure, airborne dust and mist generated during spraying tends to build up within the wheel well resulting in an area of higher concentrations into which the mechanic enters when spray washing and checking for completeness of cleaning

Bulk sample results analyzed by TEM show that less than 1 percent of the total material (dust) in the brake drum contained asbestos; the brakes on all six vehicles tested in this study contained chrysotile asbestos fibers and, therefore, had asbestos-type brakes Fibers in the drums for these six vehicles were between 74 and 100 percent chrysotile with three vehicles having 98 to 100 percent chrysotile fibers Less than 1 percent of the total material (dust) in the rafter sample was asbestos; although asbestos constituted 56 to 84 percent of the fibers that were found

An analysis of the video and real-time total dust data indicates that some dust emission peaks may be reduced by altering spraying practices (1) start spraying the brake components at a distance of 18", gradually moving to within 12" as the components become saturated with solvent to avoid loosening the dust, and (2) repeat spray wash of the brake components as they are being removed

For brake drums that are difficult to remove, requiring extensive hammering to loosen, some solvent could be placed in a pan beneath the drum to capture the brake residue as it falls from the drum rather than waiting to clean the residue from the floor at a later time

Since asbestos was identified in all of the brake dust samples, workers should be encouraged to shower to remove residual dust and change in to street clothes before leaving work at the end of the day For workers going to second job, a clean pair of work clothes should be obtained Also, the use of the laundry service provided for cleaning soiled work clothing should be continued

Further education about personal hygiene (i e , showers at work) and changing soiled work clothing before leaving work would provide additional protection by not bringing asbestos dust to the home environment

Since asbestos fibers may be present in the air and on the mechanic's hands during brake maintenance, another potential hazard is the ingesting of these fibers For this reason, the mechanic should not eat, drink, or smoke in his work area while he is performing brake maintenance

Training in the operation and maintenance of the sprayer unit is important for developing good work practices which could reduce potential brake asbestos exposure For the wet spray method, the spray tip needs to be maintained to provide a fine spray from the nozzle versus a spray jet which tends to blast the brake surface and cause brake dust to become airborne The mist should be sufficient to saturate the brake residue and when the sprayer is brought to within 12" of the components, the spray volume should be sufficient to wash the brake residue from the components

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APPENDIX A

Table A-1

Sample Number	Date	Job No	Vehicle[1] Year	Sample Type	Brake Replace(R) or Inspect(I)	Sample Volume	PCM Fibers/ Filter	PCM Fibers/cc	TEM Asbestos Fibers/ Filter	TEM Asbestos Fibers/cc	TEM Asbestos[2] M or X Fibers
25511	07-Oct-86	1,2	Job	pers	Job	309	<1500	<0 005	19012	0 062	0
25520	07-Oct-86	1,2	No 1	pers	No 1	423	1501	0 004	28519	0 067	1
25504	07-Oct-86	1,2	1981	fend	(I)	1058	<1500	<0 001	175864	0.166	11
25507	07-Oct-86	1,2		axle		1058	<1500	<0 001	23765	0 022	1
25510	07-Oct-86	1,2	Job	bckg	Job	2019	<1500	<0.001	<4700	<0 002	0
25514	07-Oct-86	1,2	No 2	bckg	No. 2	2572	<1500	<0 001	<4700	<0 002	1
25508	07-Oct-86	1,2	1983	amb	(R)	1317	<1500	<0 001	<4700	<0 004	0
25513	07-Oct-86	1,2		amb		1317	<1500	<0 001	<4700	<0 004	0
25331	07-Jan-87	3	1982	pers	(R)	379	6000	0 016	4753	0 013	0
25335	07-Jan-87	3	1982	pers	(R)	380	4000	0 011	23765	0 063	2
25319	07-Jan-87	3		bckg	(R)	1125	<1500	<0 001	<4700	<0 004	0
25349	07-Jan-87	3		bckg	(R)	1125	<1500	<0 001			
25303	07-Jan-87	3		amb	(R)	1158	<1500	<0 001	4700	<0 004	0
25327	07-Jan-87	3		amb	(R)	1148	<1500	<0 001			
25543	04-Feb-87	4	1983	pers	(R)	366	<1500	<0 004	14259	0 039	0
25522	04-Feb-87	4	1983	pers	(R)	364	<1500	<0 004	<4700	<0.013	0
25318	04-Feb-87	4	1983	fend	(R)	954	<1500	<0 002	<4700	<0 005	3
25502	04-Feb-87	4	1983	axle	(R)	1199	<1500	<0 001	4753	0 004	0
25342	04-Feb-87	4		bckg	(R)	1238	<1500	<0 001	<4700	<0 004	1
25217	04-Feb-87	4		bckg	(R)	1208	<1500	<0.001	9506	0.008	0
25340	04-Feb-87	4		amb	(R)	1293	<1500	<0 001	<4700	<0 004	2
25535	04-Feb-87	4		amb	(R)	1293	<1500	<0 001	<4700	<0 004	0
25460	12-Mar-87	5	1981	pers	(R)	452	<1500	<0 003	404012	0 894	31
25456	12-Mar-87	5	1981	pers	(R)	452	<1500	<0 003	393210	0.870	21

(continued)

APPENDIX A

Table A-1 (continued)

Sample Number	Date	Job No	Vehicle[1] Year	Sample Type	Brake Replace(R) or Inspect(I)	Sample Volume	PCM Fibers/ Filter	PCM Fibers/cc	TEM Asbestos Fibers/ Filter	TEM Asbestos Fibers/cc	TEM Asbestos[2] M or X Fibers
25465	12-Mar-87	5	1981	fend	(R)	1207	1500	0 001	128333	0.106	5
25469	12-Mar-87	5	1981	axle	(R)	1518	1500	0 001	33272	0 022	1
25479	12-Mar-87	5		bckg	(R)	1905	1500	0 001	19012	0 010	1
25468	12-Mar-87	5		bckg	(R)	1920	1500	0 001			
25458	12-Mar-87	5		amb	(R)	779	1500	0 002			
25494	12-Mar-87	5		amb	(R)	1935	1500	0 001	19012	0 010	0
25718	06-May-87	6	1980	pers	(R)	302	1501	0 005	9506	0.031	1
25703	06-May-87	6	1980	pers	(R)	302	2000	0 007	23765	0.079	2
25722	06-May-87	6	1980	axle	(R)	1045	1500	0 001	23765	0 023	2
25732	06-May-87	6	1980	fend	(R)	830	1500	0 002	52284	0 063	0
25730	06-May-87	6	1980	bckg	(R)	1125	1500	0 001	(4700	(0 004	0
25726	06-May-87	6	1980	bckg	(R)	1088	1500	0.001			
25705	06-May-87	6	1980	amb	(R)	385	1500	0 004	(4700	(0 012	0
25711	06-May-87	6	1980	amb	(R)	385	1500	0 004			
25524	07-Oct-86	1,2		blank		0	1500		0	–	0
25309	07-Oct-86	1,2		blank		0	1500				
25329	07-Jan-87	3		blank		0	1500		0	–	0
25315	04-Feb-87	4		blank		0	1500		0	–	0
25462	12-Mar-87	5		blank		0	1500		0	–	0
25477	12-Mar-87	5		blank		0	1500				
25720	06-May-87	6		blank		0	1500		0	–	0

1 See Appendix B for vehicle description
2 M = Matrix fiber, X = Fiber extended beyond grid

APPENDIX B

Table B-1

NIOSH Brake Maintenance Study
Summary of Mean TEM Results

Method	Mean[3]	Brake Job No [4]	Pers	Axle	Fend	Bckg	Amb
Wet Spray[1]	Ar	All	0 213	0 018	0 085	0 005	0 006
& Wet Wash[2]	Ge		0 071	0 015	0 048	0 004	0.005
Wet Spray	Ar	1,2,3,5,6	0.260	0 022	0 112	0.005	0.005
	Ge		0 094	0 022	0 104	<0 004	0.006
Wet Spray	Ar	1,2,3,6	0 052	0 023	0 115	<0 004	0.006
	Ge		0 045	0 023	0 102	<0 003	0 005
Wet Spray	Ar.	1,2	0 064	0 023	0.166	<0 002	<0 004
Wet Spray	Ar	3,6	0 046	0 023	0 063	0 004	0 008
	Ge.		0.037	–	–	0 004	0 007
Wet Spray	Ar.	5	0 882	0 022	0 106	0 010	0.010
Wet Wash	Ar	4	0.026	0 004	0 005	0 006	<0 004
Wet Wash[5]	Ar	(11 vehicles)	0 013	0 006	0 010	0 003	0 003
Wet Wash Range[5]			<0 013 to 0.013	<0 004 to 0 016	<0 004 to 0 040	<0.002 to 0 006	<0 003 to 0 003

1 – Wet Spray Method using Balkamp Model "A" Sprayer.
2 – Manual Wet Brush and Solvent Method.
3 – Means, Ge is geometric mean and Ar is arithmetic mean
4 – Brake drum sizes on all vehicles (except Brake Job No 5) are less than or equal to 12" in diameter. Brake size on Brake Job No 5 are greater than 12" in diameter. All vehicles except Brake Job 2 and 5 have single wheels Vehicles for Brake Jobs 2 and 5 have tandem wheels
5 – Results from a wet wash method of controlling brake dust using a washer assembly unit that pumps a recycled water solution through a brush onto the brake components[20]

APPENDIX C

NIOSH Brake Maintenance Study
Description of Vehicle

DATE	VEHICLE NO	JOB NO	DESCRIPTION OF VEHICLE
10-7-86	3111	1	Chevrolet Custom 10 Pickup, 1981, 87,560 miles, 12,000 miles on brakes, 25% brake wear, used for customer service, asbestos brake shoes, GVWR, 1000 pounds, radial tires, automatic transmission, RWD, and 11" diameter brake drums
10-7-86	3121	2	Ford Econoline Van, 1983, 33,546 miles used as a trouble shooter truck, asbestos brake shoes, GVWR, 10,000 pounds, bias tires, automatic transmission, RWD, tandem rear wheels, and 12" diameter brake drums.
1-7-87	3380	3	Chevrolet Van, 1982, 62,281 miles, 90% brake wear, used for electrical maintenance, asbestos brake shoes, GVWR, 6600 pounds, bias tires, automatic transmission, RWD, and 11" diameter brake drums
2-4-87	2904	4	Ford Ranger Pickup, 1983, 74,038 miles, 15,000 miles on brakes, 90% brake wear, used by meter reader and installer, asbestos brake shoes, GVWR, 4360 pounds, radial tires, automatic transmission, RWD, 9" diameter brake drums
3-12-87	5819	5	Ford Boom Truck, 1981, 66,049 miles used for line maintenance, asbestos brake shoes, GVWR, 26,500 pounds, bias tires, automatic transmission, RWD, tandem rear wheels, 16 5" diameter brake drums, and brake shoes 5 5" wide.
5-6-87	1129	6	AMC Concord, four door sedan, 1980, 72,603 miles, 25,850 miles on brakes, 50% brake wear, used for electric line inspection, asbestos brake shoes, GVWR, 2000 pounds, radial tires, automatic transmission, RWD, and 10" diameter brake drums

- For vehicles 1 and 2, one set of samples were collected for both vehicles
- Used wet spray method on all vehicles except vehicle 4
- Used manual wet brush and solvent method to clean brake dust from brake components on vehicle 4
- Vehicles 2 and 5 have tandem rear wheels All other vehicles have single rear wheels