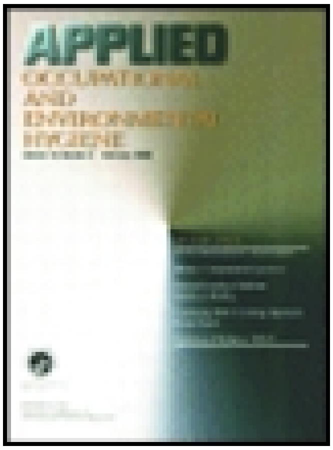

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Control of Asbestos Exposure during Brake Drum Service

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Control of Asbestos Exposure During Brake Drum Service

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An estimated 150,000 brake mechanics and garage workers in the U.S. are potentially exposed to asbestos, a known health hazard. Earlier studies of airborne asbestos exposures to mechanics during brake maintenance operations showed overexposure to asbestos fibers during brake servicing, especially brake assembly cleaning. Most brake service operations are performed by small businesses that lack resources to evaluate control devices.

The results from the evaluation of five control methods for containing asbestos brake dust during brake maintenance are presented. These controls included two commercial enclosure devices with ventilation provided by high-efficiency particulate air (HEPA) filter-equipped vacuums, a HEPA filter-equipped vacuum cleaner without an enclosure, a wet brush/recycle system which recirculated the cleaning solution, and an aerosol spray for wetting the brake assembly. Detailed surveys of the controls were conducted at five separate facilities during actual brake servicing operations to automobiles, pickup trucks, vans, and vehicles with a four-wheel rear axle. Personal and area air samples collected during brake repair to each vehicle were analyzed by phase contrast microscopy (PCM) and transmission electron microscopy (TEM).

Personal sampling results for the brake mechanics show that concentrations determined by PCM analysis ranged from less than 0.004 f/cc to 0.016 f/cc. All exposures were below the National Institute for Occupational Safety and Health (NIOSH) recommended limit of 0.1 f/cc. Analysis by TEM indicated not only the presence of asbestos fibers not detected by PCM but also at levels well below 0.1 f/cc. The highest exposures measured were found for workers servicing heavy duty trucks.

The results from this study indicate that all the devices tested, in combination with the work practices used, controlled the mechanics' asbestos exposure during brake servicing to less than the NIOSH recommended exposure limit and the Occupational Safety and Health Administration permissible exposure limit.
Sheehy, J.W.; Cooper, T.C.; O'Brien, D.M.: Control of Asbestos Exposure During Brake Drum Service. Appl.Ind.Hyg. 4:313–319; 1989.

Introduction

Vehicle brake maintenance procedures provide an arena for exposure to airborne asbestos fibers. From data contained in the National Occupational Hazard Survey, the National Institute for Occupational Safety and Health (NIOSH) estimates that a work force of a least 150,000 brake mechanics and garage workers in the United States are potentially exposed to asbestos.[1]

Repair facilities from small service stations to fleet garages follow similar brake servicing procedures. The vehicle is elevated, wheels are removed, and the brakes are inspected. Traditionally, brake dust was often cleaned from the drums and brake assemblies by blowing with compressed air or dry wiping/brushing.[2] At the time of this study, however, most brake servicing facilities we observed used wet brushing, wet wiping, squirt-bottle wash-off, or high-efficiency particulate air (HEPA) filtered vacuum cleaning systems. After cleaning, parts are replaced or repaired as needed, and the brake system is reassembled and adjusted.[3]

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 dust buildup inside the drum and brake assembly is removed and disposed of using appropriate control equipment and work practices, the risk can be minimized. However, small businesses and the many home mechanics that perform brake repair lack resources to perform an evaluation of these control measures.

The objective of this study was to determine asbestos exposure levels experienced by automobile mechanics using various control techniques during maintenance and replacement of drum brakes. The study focused on vehicles with brake drum sizes of 12 inches or less. Repairs of disk brakes were not evaluated in the study.

Description of Control Methods

Any procedure used to remove and collect the dust during brake servicing should limit asbestos brake dust emissions and effectively remove the brake dust that adheres to the brake parts, as well as the loose dust that collects in the drum. In this study, five methods for controlling exposure to asbestos during brake repair were evaluated. These included two commercial enclosure devices with ventilation provided by a HEPA filter-equipped vacuum, a HEPA filter-equipped vacuum cleaner with no enclosure, a wet brush/recycle system with recirculating cleaning solution, and an aerosol spray to wet the brake assembly.

Each control method was evaluated at a different facility. This introduced many uncontrolled variables such as building layout, traffic pattern, and ventilation system. In addition, the types of vehicles and wheel sizes were not identical among the control methods tested.

Vacuum Enclosure Units

Two vacuum enclosures were evaluated. Vacuum enclosure A consisted of an adjustable height, clear plastic, two-glove box with an overlapping neoprene seal; a double motor HEPA filter-equipped vacuum unit; and connections inside the enclosure for an air hose and a vacuum hose. The glove box fit over the brake drum and backing plate on all vehicles except the large salt truck. Vacuum enclosure B consisted of a steel cylinder, with a single glove at one end and an iris-type seal at the other end, connected to a single motor HEPA filter-equipped vacuum cleaner. A plastic viewing window was located on one side, and inside the enclosure was an air hose connection. With enclosure B, the drum must be removed before the enclosure can be placed over the backing plate.

Vacuum Cleaning

The HEPA filter-equipped vacuum cleaner is used to vacuum dust from inside the brake drum and from around the brake assembly as well as dust that falls to the floor during brake drum removal. Vacuuming is done after the hubcap, wheel, and drum are removed. Air is drawn into the vacuum at about 50 cubic feet per minute. No enclosure and no compressed air or wet methods are used.

Wet brush/recycle

This system, shown in Figure 1, consists of a fluid reservoir, a pump, a delivery system (a low-velocity nozzle or brush), and a catch basin. An aqueous solution containing an organic solvent is pumped through a nylon filter, directed through a flexible tube, and forced out between the bristles of a brush. It provides for a gentle flooding of the brake assembly area to wash down the dust; the brush is used to assist in removal of the dust. The solution captured in a catch pan is returned and recirculated from a reservoir.

Aerosol Spray

This control method consists of a solvent (methyl chloroform) spray to wet and control potential asbestos exposures during brake maintenance. Typically, the operator dispenses the solvent from a refillable, hand-held sprayer. The sprayer is filled with approximately one quart of solvent. Shop air is used initially to pressurize the sprayer. In the brake cleaning procedure, a catch pan is placed under the brake assembly, and the exposed surfaces are wetted thoroughly. The sprayer is held about 18 inches from the brake drum and other components so that brake dust is not blown off to become airborne before it is wetted. Washing is then performed by moving the sprayer to about 12 inches from the parts. Some mechanics wipe the wetted parts and drum with rags.

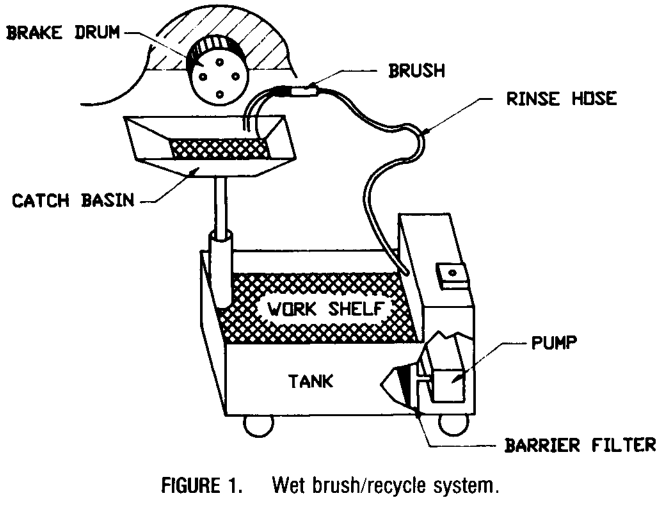

FIGURE 1. Wet brush/recycle system.

TABLE I. Air Sampling Summary

Sample Type	Location	Number of Samples	Flow Rate (L/min)	Duration (min)	Minimum Volume (L)
Personal	Worker	2[A]	2.5–3.0	120	300
Near-source	Fender/axle	2[A]	7.0	120	840
Background	Inside garage	2[B]	7.0	140–240	1000
Ambient	Outdoors	2[B]	3.0	260–480	800

[A]per vehicle
[B]per day

Airborne asbestos concentrations were also measured during brake servicing of a van by a "home mechanic" using a spray can solvent and garden hose.

Methodology

Air Sampling and Analysis

Two personal air samples for asbestos were collected side-by-side in the breathing zone of each worker for the duration of a single brake job, or for 2 hours, whichever was longer (Table I). Samples were collected on 25-mm diameter, 0.8 μm pore size, cellulose ester membrane filters at flow rates of 2.5–3.0 L/min using a personal sampling pump. The minimum volume collected (300 L) allowed a limit of detection (LOD) of approximately 0.004 f/cc by phase contrast microscopy (PCM) analysis.

To determine if fibers escaped into the work environment, two area samples per vehicle (near-source samples) were collected: one near the fender and the other under the axle. Each utilized the above-described media at a flow rate of approximately 7 L/min using rotary vane vacuum pumps for the duration of a brake job, or 2 hours, whichever was longer.

Two background samples were collected in the garage at least 10 feet from brake repair activities, at flow rates of 7–10 L/min for a 4-hour sample period. These background samples were used to determine the effects of general shop cleanliness and overall effectiveness of the dust control procedures. Samples were also collected out-of-doors (ambient samples) to determine environmental concentrations of fibers. These ambient samples were collected at a flow rate of approximately 3 L/min using personal sampling pumps for up to 8 hours.

All filtered air samples were analyzed by PCM using NIOSH Method 7400.[4] In addition to PCM analysis, approximately 80 percent of these samples were analyzed by transmission electron microscopy (TEM) using NIOSH Method 7402.[4] To facilitate analysis by PCM and TEM on the same samples, the direct transfer method of sample preparation[5] was used, modified by the omission of the filter etching. (Six samples, etched and recounted by TEM, showed no difference in fiber count from the unetched samples.) TEM analysis was performed to identify asbestos fibers and measure concentrations for fibers too small to be detected by optical microscopy analysis.

For PCM analysis, all fibers with a 5:1 (or greater) length to width aspect ratio were counted using NIOSH Method 7400-B. (A small number of samples were analyzed using Method 7400-A counting rules because the routine laboratory procedure for Method 7400 was changed to "A" counting rules before these samples were analyzed.) While the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) and the NIOSH Recommended Exposure Limit (REL) are expressed in terms of fibers having a 3:1 (or greater) aspect ratio, the difference in counting rules has little practical significance in the case of brake dust, since few fibers were identified in this study with aspect ratios between 3:1 and 5:1 (see "Results" section).

For TEM analysis, fibers were identified by morphology, selected area electron diffraction (SAED), and energy-dispersive X-ray (EDX) analysis. Fibers were classified in one of four categories: chrysotile, amphibole, ambiguous, and no identification. SAED patterns were observed for all fibers.[6] Fibers were also identified by asbestos structure (fibers, bundles, clusters, and matrices) and sized by length and width. All fibers with a 3:1 (or greater) aspect ratio were counted using TEM. The analysis was performed using a magnification of 17,600× (grid area of 0.000081 cm^2) and counting either a minimum of 10 grid openings or 100 fibers, whichever came first. The limit of resolution was approximately 0.06 μm, thus the minimum fiber length that could be measured was three times the limit of resolution, or about 0.2 μm. One or two field blanks were prepared for each vehicle sampled and submitted for PCM and TEM analysis.

A bulk brake dust sample from each vehicle and a settled dust sample from each repair facility were collected and analyzed for asbestos by TEM. The percentage of asbestos in the bulk samples were qualitatively established by estimating the ratio of the number of asbestos fibers to dust particles, and the percentage of asbestos of the total fibers present was quantified.

Results

Asbestos Concentrations as Determined by PCM

Table II presents the average and range of personal sample concentrations for airborne asbestos fibers determined by PCM for the five different control methods used during brake service. These results include exposures encountered while workers serviced brakes of small- and medium-sized vehicles and two large vehicles. Area (near-source) samples (PCM) collected near the fender and over the axle of all vehicles were less than 0.002 f/cc.

Of 83 personal samples collected on brake mechanics in our study, the highest concentration determined by PCM was 0.016 f/cc. This is about four times the LOD for the personal samples (0.004 f/cc). Personal sample concentrations represent only those exposures which occurred while servicing brakes (usually 2–3 hours per shift) and not the time-weighted average (TWA) exposure for the entire work shift. Usually, only one brake repair was performed per day, thus the TWA exposure of the mechanic would be lower. The arithmetic mean fiber concentration, while using either of the vacuum enclosures or the wet brush/recycle with recirculating solution, was 0.004 f/cc. Arithmetic mean exposures while using the vacuum only and the aerosol spray methods were 0.007 f/cc. The exposure for a "home" mechanic using a spray can solvent and garden hose during a brake replacement averaged 0.007 f/cc using Method 7400 "A" rules.

TABLE II. Personal Sample Fiber Concentrations by Control Method (PCM)

Control Method	Number of Samples	Arithmetic Mean (f/cc)	Range (f/cc)
Vacuum enclosure A	18	< 0.004	< 0.004
Vacuum enclosure B	22	< 0.004	< 0.004–0.006
Vacuum only	13	0.007	< 0.004–0.016
Wet brush/recycle	20	< 0.004	< 0.004–0.006
Aerosol spray	8	0.007	< 0.003–0.016
Water hose and solvent	2	0.007	< 0.006–0.008

The OSHA PEL of 0.2 f/cc[7] (8-hour TWA) and the NIOSH REL of 0.1 f/cc[8] for asbestos are based on PCM analysis of asbestos using "A" counting rules (3:1 aspect ratio). "B" counting rules (5:1 aspect ratio) were utilized in this study, except where noted, and the results cannot be compared directly to the OSHA PEL or the NIOSH REL. However, TEM analysis of the filter air samples showed that 82 to 95 percent of all fibers counted using a 3:1 aspect ratio would also have been counted if a 5:1 aspect ratio was used. This analysis indicates that there would be little difference in fiber concentration using either fiber aspect ratio criteria.

Personal samples analyzed by PCM indicated that the mechanics' TWA exposures all would be below the NIOSH REL for asbestos of 0.1 f/cc and the OSHA PEL of 0.2 f/cc even if they performed brake servicing for the entire work shift. These levels were achieved with the work practices normally used by the mechanic.

Asbestos Concentrations as Determined by TEM

Asbestos concentrations obtained in the breathing zones of the mechanics and analyzed using TEM are summarized in Table III for each control method evaluated. (These results exclude exposures encountered while workers serviced brakes to the two large vehicles.) All fibers identified as chrysotile or amphibole asbestos with an aspect ratio of 3:1 or greater were counted (fibers ≥ 0.2 μm in length). Amphibole asbestos was found on only 7 of 219 filtered air samples analyzed (one or two amphibole fibers per filter).

Arithmetic mean asbestos exposures ranged from less than 0.013 f/cc while using the wet brush/recycle with recirculating solution to 0.052 f/cc for the aerosol spray method. The arithmetic mean exposures for the aerosol spray and vacuum enclosure B were significantly higher than that for the wet brush/recycle ($p < 0.05$). Geometric mean asbestos exposures ranged from less than 0.013 f/cc to 0.045 f/cc for the five control methods evaluated.

TABLE III. Personal Sample Asbestos Concentrations by Control Method (TEM)

Control Method	Number of Samples	Arithmetic Mean (f/cc)	Range* (f/cc)	Geom. Mean (f/cc)
Vacuum enclosure A	16	0.021	0.010–0.065	0.017
Vacuum enclosure B	12	0.044	< 0.013–0.139	0.028
Vacuum only	13	0.022	< 0.011–0.045	0.019
Wet brush/recycle	10	< 0.013	< 0.013–< 0.014	< 0.013
Aerosol spray	6	0.052	0.013–0.079	0.045
Water hose and solvent	2	0.039	0.039	0.039

*Limits of detection vary with the sample volume.

Asbestos concentrations near the vehicle fender and axle (excluding the two large trucks) are presented in Table IV. Arithmetic mean asbestos concentrations near the fender ranged from 0.006 to 0.115 f/cc; arithmetic mean asbestos concentrations near the axle ranged from less than 0.006 to 0.027 f/cc. The aerosol spray method average fender concentration (0.115 f/cc) was five times the average fender concentration for vacuum enclosure B and an order of magnitude higher than for the other three control methods. Dust was observed escaping from the seal of vacuum enclosure B during brake cleaning with compressed air.

TABLE IV. Near-Source Sample Asbestos Concentrations (TEM)

Control Method	Fender: Number of Samples	Fender: Arithmetic Mean (f/cc)	Fender: Range (f/cc)	Axle: Number of Samples	Axle: Arithmetic Mean (f/cc)	Axle: Range (f/cc)
Vacuum enclosure A	8	0.010	< 0.004–0.031	8	0.009	< 0.003–0.028
Vacuum enclosure B	11	0.024	< 0.005–0.092	11	0.027	< 0.004–0.164
Vacuum only	5	0.008	< 0.004–0.015	5	0.008	< 0.004–0.020
Wet brush/recycle	10	0.010	< 0.004–0.040	10	< 0.006	< 0.004–0.016
Aerosol spray*	2	0.115	0.063–0.166	2	0.023	0.022–0.023
Water hose and solvent	1	0.006	—	1	0.017	—

*Three brake jobs evaluated.

TEM results are not directly comparable to the PCM data because 1) TEM counts include all fibers, regardless of length, whereas PCM include only fibers greater than 5 μm in length; 2) TEM counts includes fibers too thin to be seen using PCM; and 3) TEM data include only fibers identified as asbestos, whereas PCM data include any fiber type. TEM analyses indicated that only 8 of 57 personal samples contained asbestos fibers 5 μm or longer.

Large Vehicles

Two vehicles with rear wheel brake drums 16–17 inches in diameter were evaluated in this study. A salt truck was sampled while using vacuum enclosure A, and a boom truck was sampled using the aerosol spray method. Fiber concentrations determined by PCM for both large vehicles were below the 0.004 f/cc LOD; however, asbestos exposures determined by TEM analysis were 0.15 f/cc for the salt truck and 0.88 f/cc for the boom truck. These results are based on two simultaneous personal samples taken during brake service to the rear wheels of the respective vehicles. In Figure 2, the results for these two vehicles are compared to the maximum asbestos concentrations (TEM) measured during brake service to vehicles with 8- to 12-inch drum sizes using the same controls.

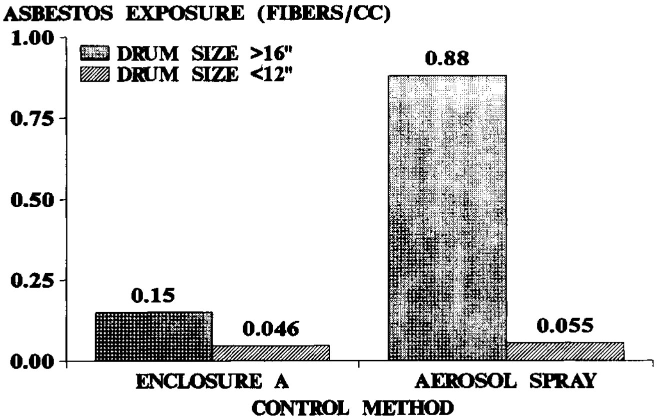

FIGURE 2. Asbestos exposures: trucks vs. smaller vehicles (analysis by TEM).

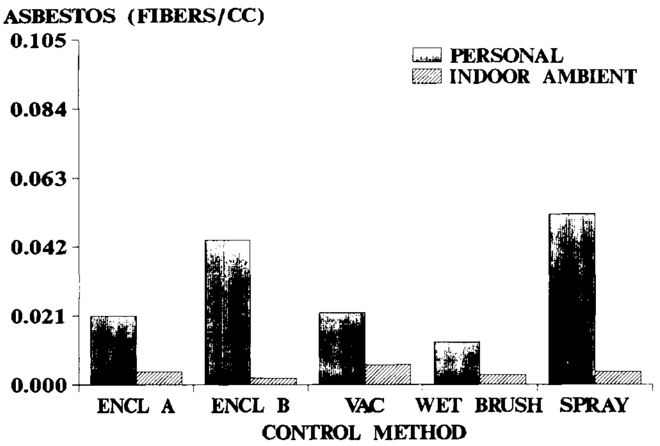

FIGURE 3. Personal vs. background asbestos levels (analysis by TEM).

Indoor and Outdoor Ambient Concentrations

The arithmetic mean asbestos concentrations inside the garages were 0.006 f/cc or less. As determined by TEM, indoor ambient arithmetic mean asbestos concentrations are compared to arithmetic mean asbestos exposures in Figure 3 for the five control methods evaluated. These data indicate that nearly all of the mechanics' asbestos exposure was due to job tasks and not indoor ambient asbestos concentrations. Outdoor ambient arithmetic mean concentrations were 0.006 f/cc or less.

Bulk and Settled Dust Samples

A bulk sample of brake dust was collected from each vehicle serviced to determine if the friction materials contained asbestos. Each brake dust sample consisted of a few grams of dust from the drum of each brake serviced. Bulk samples were analyzed for asbestos by TEM. Generally, less than 1 percent of the particles present in the bulk brake dust samples was asbestos although several samples contained as much as 1 percent asbestos. These results are summarized in Table V. Settled dust samples were collected from each facility to indicate potential building contamination. Settled dust samples were analyzed for asbestos by TEM.

Most of the fibers present in both the brake and settled dust samples were chrysotile asbestos. Two of seven settled dust samples contained amphibole asbestos; one settled dust sample contained 20 percent (of total fibers) amphibole asbestos. Other fibers in both the brake dust and settled dust samples were determined to be nonasbestos.[6]

For most vehicles, the percentage of fibers longer than 5 μm was less than about 3 percent. TEM analysis of the bulk brake dust samples showed that the aspect ratio of 90 to 97 percent of fibers was greater than or equal to 5:1 for each of the five major controls evaluated.

Discussion

All the control techniques studied prevented exposures in excess of the OSHA PEL or NIOSH REL, as determined using the PCM analytical method.

TABLE V. TEM Analysis of Bulk Brake and Settled Dust Samples

Control	Sample Type	Number of Samples	Percent Asbestos in Total Dust	Percent Asbestos of Total Fibers	Percent of Fibers* ≥ 5 μm
Vacuum enclosure A	Brake dust	9	< 1	54–100	1–17
	Settled dust	1	NA	85	5
Vacuum enclosure B	Brake dust	11	< 0.1–1	0–100	0–6
	Settled dust	1	< 1	60	0
Vacuum only	Brake Dust	6	< 0.1–1	24–100	0–9
	Settled Dust	1	< 0.1	68	0
Wet brush/recycle	Brake dust	9	< 1	83–100	0–3
	Settled dust	1	NA	99	7
Aerosol spray	Brake dust	6	< 1	74–100	1–16
	Settled dust	3	< 1	56–84	0–7
Water hose and solvent	Brake dust	1	NA	84	0

*Includes fiber bundles. NA = Not available.

Comparison to Historical Data

TWA exposures of about 0.2 f/cc and peak exposures of about 15 f/cc while using dry brushing, wet brushing, or compressed air during brake repair have been reported.[3] Analyses were performed using NIOSH Method P&CAM 239 (PCM). The reported TWA asbestos concentrations during compressed air cleaning of brakes ranged from 0.03 to 0.19 f/cc; concentrations during wet brush brake cleaning ranged from 0.23 to 0.28 f/cc. A reported asbestos exposure using a squirt bottle to wash the brake drums was 0.21 f/cc. Fiber concentrations determined by PCM in our study were one to two orders of magnitude lower. A statistical comparison between our study results (for the servicing of vehicles such as pickup trucks, vans, automobiles, and several large trucks) and historical data (for brake servicing using compressed air, dry brushing, and squirt bottles) showed that if variables, such as workers, vehicle types, and facilities, had been controlled between our study and the historical study, then exposures in our study would be significantly lower ($p < 0.005$) for PCM exposure data.

In two 1979 surveys,[9,10] the brakes of automobiles were cleaned using compressed air. The asbestos exposure of the mechanics ranged from 0.14 to 0.95 f/cc as determined by TEM using SAED and EDX. The sampling times ranged from 2 to 4.5 hours. The TEM exposure data from our study were an order of magnitude lower than those of the 1979 surveys. This, again, demonstrates a major difference between exposures when using the controls evaluated in our study and the methods used in the earlier studies.

Personal sample concentrations during brake repair were significantly higher than indoor background levels as determined by PCM ($p < 0.03$) and TEM ($p < 0.005$) when using the aerosol spray method. Personal sample concentrations during brake repair for the other control methods were not statistically different than indoor background levels based on both PCM and TEM results.

A minimal control (water hose and solvent) brake repair operation was evaluated in our study. The measured asbestos exposures as determined by PCM and TEM were comparable to the five major control methods. The results for the minimal control method is based on a single brake job.

Vehicle and Drum Size

Most of the vehicles evaluated in the study were automobiles and light trucks with 8- to 12-inch drum sizes; two large vehicles with 16- to 17-inch drums were evaluated. Personal sample concentrations during brake service to the latter, as determined by PCM, were at or below the detection limit (0.004 f/cc), as were most of the personal sample concentrations (PCM) during brake service to the smaller vehicles. There was no difference based on PCM measurements between large vehicles and small- and medium-sized vehicles. However, asbestos exposures as determined by TEM during brake service to the large vehicles were an order of magnitude greater than during brake service to vehicles with smaller drum sizes. Larger brake shoe surfaces and bulkier drums probably contain more residual dust.

Statistical analysis of TEM data showed that when using the aerosol spray method, the average personal sample concentration for brake repair of the large boom truck was significantly higher than the highest exposure during brake repair of the smaller vehicles ($p < 0.01$); but for vacuum enclosure A, the exposure during brake repair of the large vehicle was not shown to be statistically different than that for the smaller vehicles. Except for the effect of drum size, differences in personal and near-source sample concentrations due to vehicle model, miles traveled, number of drums per vehicle, etc., were small.

Control Method Design Strengths and Weaknesses

Vacuum enclosures permit the use of compressed air, which appeared to effectively remove brake dust adhering to the brake components and the shoes. However, when pointed at the back of the enclosure, the compressed air blast may be strong enough to deflect some seals, resulting in the escape of brake dust during brake cleaning. Vacuum enclosure manufacturers could incorporate a means to regulate the air pressure in compressed air cleaning hoses. Brake dust is collected dry, and care must be taken to avoid exposure during enclosure maintenance and vacuum filter replacement. Available vacuum enclosure sizes limit their use to certain brake drum sizes. The two-glove vacuum enclosures are superior because both hands can manipulate parts and tools within the enclosure.

The principal advantages of aerosol spray systems are low cost and the capability to be used on all sizes of brake drums. Care must be taken to hold the sprayer at a proper distance from the brake to wet the brake, yet not so close that the force of the spray resuspends the dust. The effectiveness of the solvent spray systems as an exposure control method appears to be more dependent on work practices than the other techniques. In some cases, the solvent may contain potentially hazardous component(s).

The wet brush/recycle system can be used on all sizes of brake drums. Limited wetting of the brakes can be accomplished with the drum in place. Dust that otherwise would have fallen to the floor is wetted and collected in the catch basin beneath the wheel. This may provide better control when difficult-to-remove drums are encountered. The low velocity delivery of the wet brush/recycle effectively cleans the brake components. The contaminated fluid provides a dust free, though bulkier method of disposal.

HEPA filter-equipped vacuum cleaners can be used on brakes of any size. These systems do not use compressed air, nor do they generate dust that must be contained as do the vacuum enclosure systems. However, the drums must be removed before the vacuum cleaner can be used, thus there is a potential for asbestos release during drum removal. They do not clean the brake components as effectively as some other systems and require small vacuum nozzles to reach smaller parts of the brake assembly. As with the vacuum enclosures, maintenance and replacement of HEPA and primary filters present an occasion for asbestos exposure.

Fiber Size and Potential Health Effects

In this study, a fiber size analysis (including fibers not identified as asbestos) was performed on a composite sample of all personal TEM samples from the five major controls (Figure 4). The majority of these fibers are less than 0.1 μm in diameter and less than 4 μm in length.

The potential health impact of the fibers present in brake dust is not completely understood. However, Stanton[11] attempted to estimate the tumorigenic potential in humans according to a fibers diameter and length matrix. Stanton noted that long, thin fibers produced the greatest tumorigenic incidence in experimental animals. Figure 4 plots the fiber sizes measured in this study with an overlay of Stanton's classification based on his animal studies. About 1 percent of the fibers in the samples from our study fit the classification of medium and high tumorigenic potential. Pott[12] has summarized other studies concerning the carcinogenic potency of asbestos fibers. These studies indicate tumor induction extends to fibers shorter in length than those given by Stanton. Pott also notes that, although the carcinogenic potential of short fibers may be low, many short fibers may induce a tumor as easily as a few long fibers.

Conclusions

All of the five methods tested, in combination with the work practices used, controlled the mechanics' asbestos exposure during brake servicing to less than 20 percent of the NIOSH REL and 10 percent of the OSHA PEL. In our study, the brake mechanics' exposures for 2-hour sampling periods ranged from less than 0.004 f/cc to 0.016 f/cc (counting rules 7400B). Personal exposures, as determined by PCM, were at least an order of magnitude lower than personal exposures reported in the literature for brake service operations involving compressed air, dry brush, or wet brush cleaning.[3]

TEM results include asbestos fibers of all sizes. Brake mechanics' average asbestos exposures, as determined by TEM, for five control methods ranged from less than 0.013 f/cc to 0.052 f/cc. These low exposures further support the PCM results which showed that these methods controlled asbestos emissions during brake repair of small- and medium-sized vehicles such as automobiles and light trucks.

Brake service to two heavy duty trucks (16- to 17-inch drum size) showed higher asbestos concentrations, as determined by TEM, than for smaller size vehicles. The large trucks had greater brake shoe surface area and bulkier drums. Although mechanics' exposure in our study were well below the NIOSH REL for asbestos as determined by PCM, the TEM results point to a greater potential for asbestos exposure while servicing heavy duty trucks.

	FIBER LENGTH (μm)				
DIAMETER (μm)	>0.2 - 1	>1 - 4	>4 - 8	>8 - 64	>64
<0.1	30%	26	2	<1	0
>0.1 - 0.25	8	11	<1	<1	0
>0.25 - 0.5	1	12	<1	<1	0
>0.5 - 1.5	0	3	2	<1	0
>1.5 - 2.5	0	0	0	<1	<1

LOW TUMOR RATE IN ANIMALS *
MODERATE TUMOR RATE IN ANIMALS
HIGH TUMOR RATE IN ANIMALS

FIGURE 4. Fiber size distribution for composite of all personal samples (TEM). (* Stanton et al.[11]).

Except for the effect of drum size, differences in personal and near-source sample concentrations (as determined by TEM) among the vehicles evaluated were very small, and no trends with respect to mileage, model, model year, etc., were observed.

Not all control devices of a given type will be equivalent. Differing controls and work practices, techniques, and drum sizes contributed to the observed test differences. Other factors to consider are equipment cost, reliability, ease of use, production rate, and method of disposal of brake residue.

Fibers in dust samples obtained from the brake drums of 40 of the 43 vehicles tested in this study were mostly chrysotile. The other three vehicles appeared to have nonasbestos-type brake shoes. Fiber size distribution for all fibers, including those not identified as asbestos, showed that only 4 percent of the fibers measured during brake service would have been counted using PCM. Furthermore, 90 percent of the fibers identified by TEM had an aspect ratio of 5:1 or greater.

Recommendations

Mechanics should use asbestos control methods during brake servicing irrespective of the lining material. (The health effects of many asbestos substitutes have not been fully investigated.) Workers involved in brake repair must be trained *and supervised* in the correct work practices and proper use of the control system.

Compressed air cleaning or vacuum cleaners without HEPA filters should never be used to clean brakes. Any spills of brake dust or contaminated solutions containing brake dust should be cleaned up immediately by either vacuuming (HEPA) or thorough wet mopping and remopping. The difficulty of total cleanup even on well-sealed concrete suggests the use of a pan or a disposable, impervious floor cover sheet under each wheel area. Disposal of asbestos-contaminated material should be done in accordance with federal and state regulations.

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