IN-DEPTH SURVEY REPORT

EVALUATION OF BRAKE DRUM SERVICE CONTROLS

AT

United States Postal Service
Vehicle Maintenance Facility
Louisville, Kentucky

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I INTRODUCTION

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

Since 1976, ECTB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques Examples of these completed studies include the foundry industry, various chemical manufacturing or processing operations, spray painting, and the recirculation of exhaust air The objective of each of these studies has been to evaluate and document effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures

These studies involve a number of 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 "In this situation, where occupational disease surveillance studies point to a likely problem with a known carcinogenic agent, the priority should be placed on industrial hygiene investigations of asbestos exposure in the suspect occupations If likely exposure is found, control measures should be developed and instituted "

There are frequent asbestos exposures during brake repair in the vehicle maintenance work force NIOSH in the National Occupational Exposure Survey estimates that a work force of 151,000 brake mechanics and garage workers in the U S are potentially exposed to asbestos [2] Other estimates run as high as 900,000 workers 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 10 sites using a variety of control techniques These site visits were conducted to observe the control techniques in use and to select sites for detailed sampling studies Sites were selected primarily from fleet garages to control for variables such as vehicle type, use, and maintenance practice, and on the physical size of the garage. Selection of sites 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% 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% 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 (15) While this is a well understood practice, we can not 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 6 or 10 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" rules use the same aspect ratio as the current OSHA standard, 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 this data indicates that fiber counts using NIOSH 7400-A and 7400-B counting rules would differ by less than 8%

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 standard 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 standard does not set a ceiling or short-term exposure limit.

II PLANT AND PROCESS DESCRIPTION

Facility Description

The United States Post Office's (USPO) Louisville, Kentucky Vehicle Maintenance Facility was constructed in 1977 to replace an older building located in downtown Louisville The building is a masonry veneer exterior with a prestressed concrete roof. The repair area, body shop, and paint shop occupy a central high bay area (18 feet to truss, 21 feet to roof) of approximately 13,000 square feet. A wash rack is located directly to the north of the high bay area. Administrative offices and ancillary services (tire room, battery charge area, transmission area, and parts) are located directly to the south The body and paint shops are partitioned from the main shop area by concrete block walls and roll-up doors

The main shop area contains 12 open bays, 6 along each wall The six bays along the north wall are each equipped with outrigger-type vehicle lifts One of the south wall bays has this type of lift. Four have double pedestal-type lifts (in-floor) The eastern-most bay is used primarily for ignition tune-up work and has no lift No asbestos insulation is used

The garage area is 158' long and 81' wide with the long axis in a north-south direction. The body shop and paint shop are on the north side of the building The total area of the shop is 12,798 ft^2, the lift and work bay area having about 10,138 ft^2, the body shop 1,517 ft^2 and the paint shop 1,143 ft^2 The shop layout is shown in Figure 1.

Operations

The Vehicle Maintenance Facility is open from 6 00 a m TO 6 00 p m Eleven mechanics work overlapping 8 hour shifts to cover this period Thirteen others also work in this facility, a Fleet Manager, a General Foreman, 3 Supervisors, 2 Analysts, 2 Garagemen, and 4 Clerks All the mechanics perform brake service A total of 28-36 brake inspections/replacements are conducted each week Each brake job is inspected by a supervisor or a lead mechanic All the garage shop personnel are members of the American Postal Workers Union, AFL-CIO

Ventilation

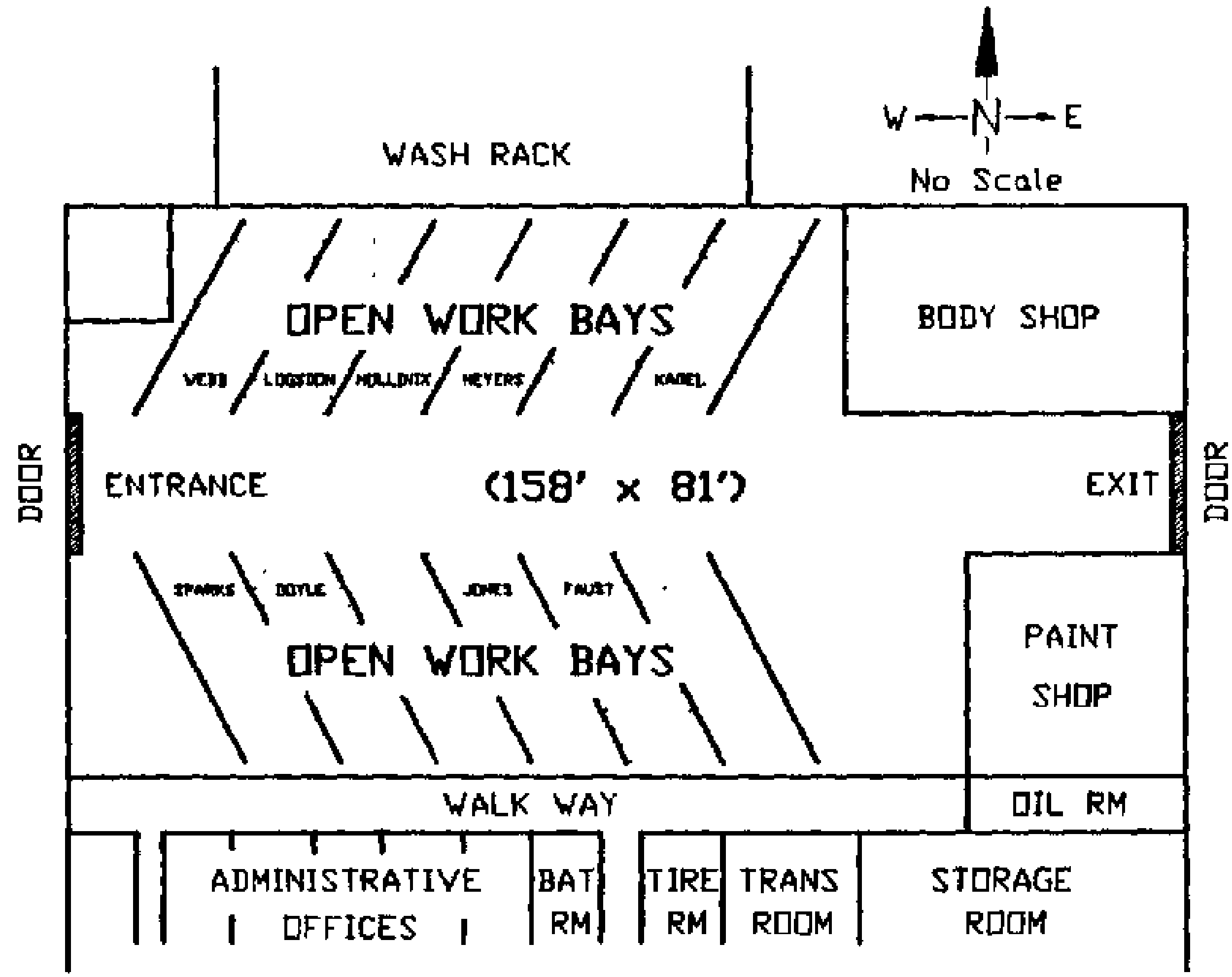
Three air handling units provide heated make-up air for the repair areas. A large (10,920 CFM) unit supplies 6,600 CFM to the main shop area through a central overhead plenum with six outlets The balance is ducted to other service areas The unit is thermostatically (on-off) controlled A bypass damper located at the air handler inlet allows recirculation during night time operation. Two smaller, unducted air handlers provide heated make-up air to the Paint (3,300 CFM) and Body (2,700 CFM) Shops All three air handlers have their air intakes located high on the east wall

Six under-floor vents and four ceiling hoses (all rated at 300 CFM each) are exhausted through a single, centrifugal ceiling fan suspended from the shop roof. This system is operated on an as-needed basis It was observed to be operating during this survey. Ceiling suspended, centrifugal fans, are located in the NE and SW corners of the main shop area Both have an inlet located near the floor, and exhaust through the shop roof, both have a rated air volume of 4960 CFM, and both are operated on an as needed basis They were not observed being used during this survey.

The paint shop contains a 6' x 7' water-wash spray booth operated at a design flow rate of 4,200 CFM. The battery room has a separate exhaust system rated at 320 CFM. A separate air handler supplies 4,100 CFM of heated or cooled air to the office area

Process and Equipment Description

Our control evaluation at this facility concentrated on a variety of smaller vehicles to determine the variability of control effectiveness on different



U. S. POST OFFICE GARAGE
LOUISVILLE, KENTUCKY

Figure 1

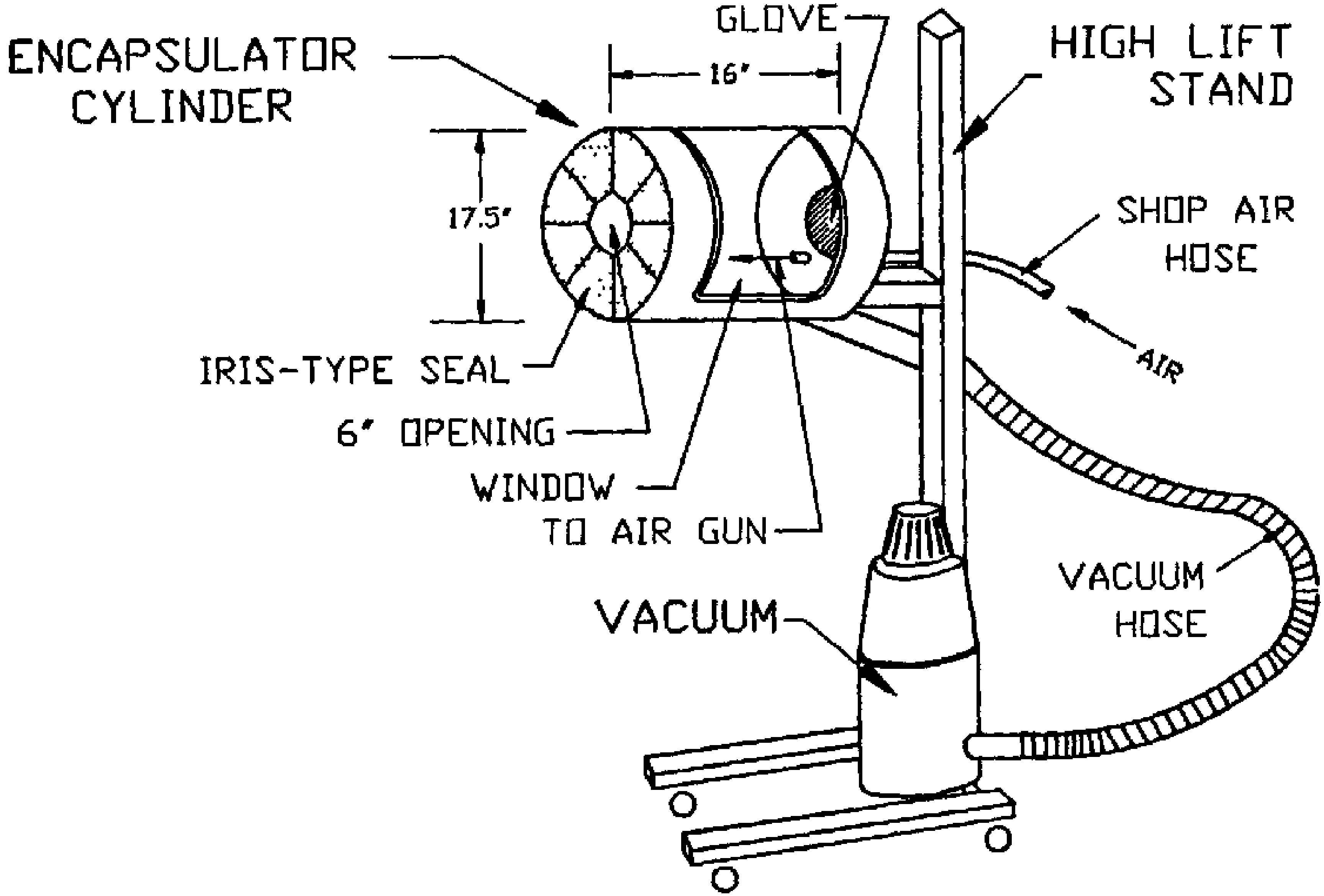
model vehicles during 11 separate vehicle brake repair or inspections The vehicles evaluated were 8 Jeeps, 1 Ford Pinto and 2 AMC Vans having 9", 11", and 14" diameter brake drums The age of the vehicles ranged from 1974 to 1984 and the mileage ranged from 16,505 to 85,253 miles The description of each vehicle is in Appendix B.

A vacuum/enclosure brake dust control unit has been in use since 1979 at the USPO Vehicle Maintenance Facility A 'Per-lux' unit was originally used, but was replaced in June 1986 by an $1,800 'Asbesto-CleneB' 500 system manufactured by Nilfisk of America, Inc This unit consists of a 17-1/2" diameter steel cylinder, 16" high, rotated 90° to lie on its side. The cylinder is equipped with a single rubber glove, and a quick-connect fitting for an air hose A cleaning nozzle (compressed air) is located inside the cylinder The top of the cylinder is partially closed by an iris-type rubber flap connected by a cloth covered elastic band so that a 6" diameter opening remains A plastic window is provided to observe the cleaning operation. The cylinder is mounted on a rolling stand Height is adjustable and is secured by a thumb-screw The cylinder is connected to a single motor Nilfisk vacuum cleaner Figures 2 and 3 show the Asbesto-CleneB system With the unit's enclosure on the vehicle's wheel and the vacuum on, this unit was observed to produce an indraft of 150-200 FPM at the seal's opening around the vehicle's axle, which corresponds to approximately 30-40 CFM The vacuum hose is readily removed from the cylinder/enclosure to function as a standard vacuum cleaner

The vacuum cleaner's set of four filters (First Stage Filter a 6 mil poly liner bag - $1 42, Microfilter - $10.50, Main Filter - $30 94, and Hepa Filter - $109 44) are replaced about twice a year (Nilfisk states the Main Filter, which can be purged, should last 20 years before needing to be replaced) The filters are placed in a 5 gallon metal container, and filled to capacity with concrete The container can then be disposed of with ordinary garbage

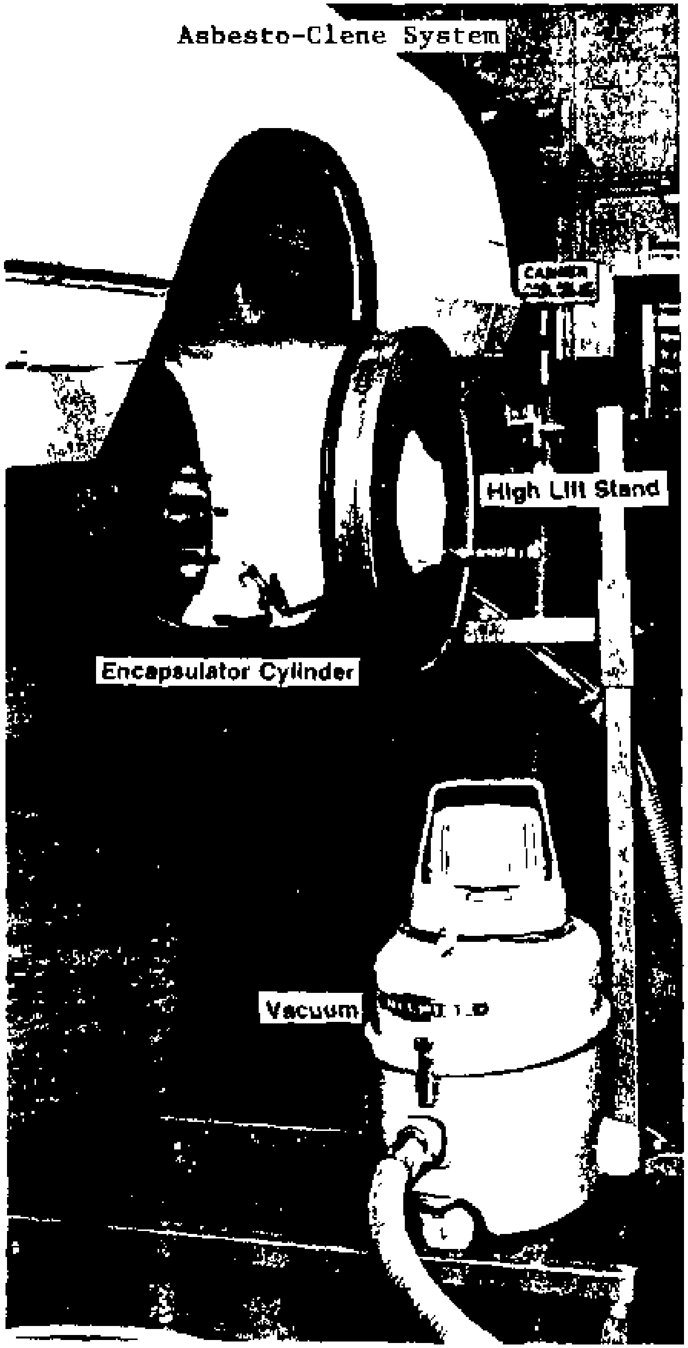
When the vehicle is brought in to the garage, its maintenance record is checked If maintenance has been within the last 1,000-1,500 miles, only two of the four wheels are pulled and the brakes inspected If there is more than 1,500 miles since the last maintenance, all four wheels are pulled and the brakes inspected This facility has been replacing its asbestos brake shoes with the nonasbestos type shoes (for which substitutes are available) since July 1986 By the end of 1987, all the smaller vehicles should have nonasbestos type brake shoes

The garage floor is painted once a year to maintain a cleanable nonskid surface. Pumice is added to the paint at the rate of 1 to 2 pounds/gallon to produce the nonskid surface Each mechanic is assigned a work bay and the responsibility for keeping it clean. Mop buckets are located around the garage Each saturday, the floor is thoroughly cleaned using a Convertamatic A TRAC 380 (Model 380 BD) manufactured by Advance Machine Company of Spring Park, Minnesota

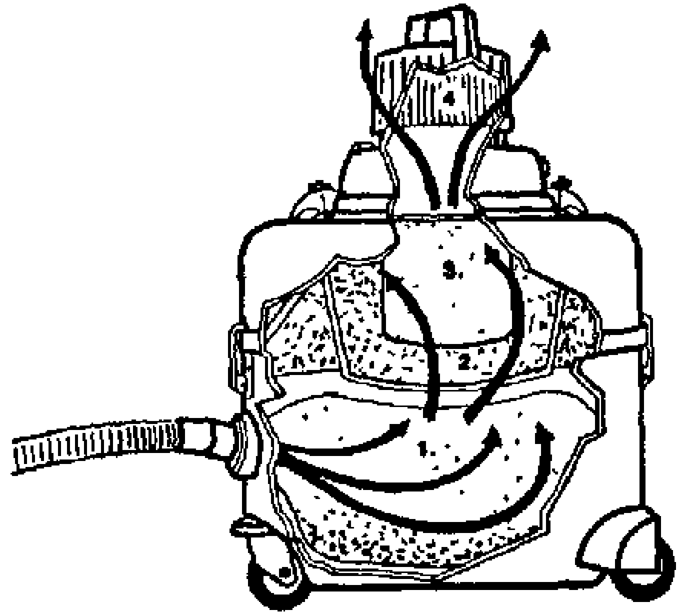


VACUUM ENCLOSURE SYSTEM

Figure 2



Nilfisk Asbesto-Clene® System



NILFISK FILTERING SYSTEM FOR TOXIC DUSTS

Figure 3

III METHODOLOGY

Air Sampling and Analysis

Personal air samples for asbestos were collected in duplicate on 25 mm, 0 8 micrometer pore size cellulose ester membrane filters. DuPont P-4000 pumps at 3 0 lpm were used for the duration of a vehicle's brake job, or 2 hours, whichever was longer The total volume collected (360 liters) allowed a limit of detection of approximately 0 004 fibers/cc by Phase Contrast Microscopy (PCM) analysis

Area air samples for asbestos were collected on 0.8 micrometer, 25 mm cellulose ester filters. Millipore vacuum pumps were used to collect two area samples, one at the vehicle fender and one at the axle (source samples) The flow rate of the pumps was approximately 7 0 lpm and they sampled for the duration of a vehicle's brake job, or 2 hours, whichever was longer The source samples were used to measure fibers escaping into the working environment during the cleansing 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, in the general garage area (background), were collected using Gast pumps operating at approximately 7 0 lpm for a 4 to 6-hour period encompassing both pre- and post-brake job activities These background samples were used to determine effects of general shop cleanliness and overall containment effectiveness of the controls The minimum volume collected (1,680 liters) allowed a limit of detection of 0 001 fibers/cc Two other area samples were collected out of doors several hundred feet from the building DuPont P-4000 pumps operating at 3 0 lpm sampled for approximately 5 to 6 hour period to encompass both the pre- and post-brake job activities These ambient samples were used to determine environmental levels of asbestos The minimum volume collected (900 liters) allowed a limit of detection of 0 002 fibers/cc

All filter air samples were analyzed by Phase Contrast Microscopy (PCM) in accordance with NIOSH Method 7400 [17] In addition to PCM analysis, approximately 2/3 of these samples were analyzed by light-field Transmission Electron Microscopy (TEM). To facilitate analysis by PCM and TEM on the same samples, the direct transfer method of sample preparation described by Burdett and Rood[18] was used. For PCM analysis, all fibers with a 5 1 (or greater) ratio were counted using Method 7400-B counting rules. TEM analysis of these samples show that more than 92% of the chrysotile fibers counted using the "A" rules would also have been counted using the "B" rules For TEM analysis, fiber type and size distribution were obtained for all fibers (greater than approximately 0 25 µm diameter) using a magnification of 17,600X and counting either a minimum of 10 grids or 100 particles, whichever came first

Bulk Samples and Rafter Sample

Field blanks were prepared for each sampling date and submitted for PCM and TEM analysis. Eleven blanks were analyzed by PCM and 11 blanks by TEM and these results are shown in Table A-1 of Appendix A Analysis by PCM and TEM show all blanks were below detectable limits

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

Real-Time Monitoring

The entire brake maintenance operation was recorded on videotape A Hand-held Aerosol Monitor (HAM (ppm, Inc , Knoxville, Tennessee)) and a personal computer (Apple II Plus) were used to measure and record the dust levels. The HAM's electro-optical system provides instantaneous measurements of total dust levels in mg/m^3 at one second intervals The HAM sends a millivolt signal to the computer which records it as a relative dust level The computer program can record a maximum of 2,000 readings at a minimum of three second intervals before it has to be reset The HAM measured the dust levels in the operator's breathing zone Before each brake maintenance job, the HAM was calibrated and zeroed The computer's clock was synchronized with that of the video camera. DuPont P4000 or MSA Model G pumps was connected by tubing to the HAM, and the HAM in turn was connected by a 25-foot electrical lead to the computer, programmed to receive the data The brake maintenance operator wore the HAM during vehicle brake maintenance. The computer recorded these dust levels on a disk from which a plot was later made. By comparing the plot to the video recording of that brake maintenance operation, dust sources due to work practices and enclosure leaks could be identified Although the HAM is not specific for asbestos, if the asbestos fibers are dispersed along with the other components of the brake dust (which seems to be a reasonable assumption), then the HAM should be a useful real time indicator for control of asbestos laden dust

Using a spreadsheet program (Lotus 1-2-3), a real-time plot of the dust levels was made By comparing the peaks from this plot with the video, work practices producing elevated dust levels can be identified

Ventilation

Kurz Model No 480 and TSI Model No 1630 air velocity meters were used to measure air velocities to determine flow rates and wind directions in the garage Smoke tubes were used to assist in observation of general airflow patterns

Air temperature, humidity, and wind conditions were determined using an aspirated psychrometer and velocity meters

Ergonomic Evaluation of Brake Maintenance and Repair

An ergonomic evaluation was conducted on workers performing brake maintenance and repair to determine work practices which may cause personal asbestos dust exposure while using a brake washer assembly unit Each worker was videotaped during routine brake inspection and brake replacement tasks Work cycle times and work analysis were performed from videotapes in the laboratory Cycle times were taken while running the video tapes 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

Interviews were conducted with ten vehicle maintenance workers who do brake work Data were collected on a standardized questionnaire (see Appendix B), and analyzed Basic descriptive, demographic, and work history data were gathered from each worker Information from these interviews were compared to workplace observations by the NIOSH research team

IV RESULTS

Real-Time Sampling Results

Real-time total respirable dust data were collected using a Hand-held Aerosol Monitor (HAM) connected to an Apple II Plus computer The real-time samples were collected alongside the personal sample on the brake mechanic Real-time data collection was during actual brake maintenance operations, approximately and hour in duration, and was obtained during all 11 brake maintenance jobs Ten different operators performed the brake maintenance jobs on these 11 vehicles

The general brake maintenance procedure was

- Place the vehicle on a lift and raise it 3 to 4 feet
- Remove the wheel's lug bolts and wheel (average time 30 seconds).
- Remove the brake drum (average time 68 seconds)
- Install vacuum enclosure over wheel's backing plate, air wash brake components, vacuum drum and floor, remove enclosure and vacuum the inside of the enclosure (average time 195 seconds)
- Supervisor inspects brake components (average time 15 seconds) If brakes need replacing, start removing brake components If brakes do not need replacing, start reinstalling brake drum
- Remove brake components (average time 259 seconds)
- Install new brake shoes and reinstall brake components (average time 320 seconds)
- Reinstall brake drum (average time 20 seconds)
- Remount the wheel and tighten the lug bolts (average time 80 seconds)

To interpret the real-time computer data, the instruments background level (0 05 millivolts) is used as the reference point at this facility This background level is the HAM/Apple's internal noise level and values below it are considered to be unreliable as to accuracy and were not used Values above this reference level 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, brake drum components, and lug bolts; vacuuming; and tightening the lug bolts when remounting the wheel The greatest potential asbestos dust exposure occurs during the removal of the brake drums Each drum contains ground-up brake shoe residue which is likely to contain asbestos fibers. For 56% of the drums removed, dust levels were up to fifteen times that of the reference level The worker was exposed to elevated dust levels from 2% to 50% (averaging 10%) of the total time during the removal of the brake drum

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 ten times that of the reference level on 48% of the brake jobs The worker was exposed to elevated dust levels 10% of the total time during the loosening and tightening of the wheel's lug bolts. The dust levels were similar in magnitude during loosening as they were during tightening of the bolts The elevated real-time dust readings may also have been from oil mist aerosol from the wrench generated by the compressed air

The third greatest potential asbestos dust exposure occurs during vacuuming operations The air gun used to dislodge the brake shoe residue is at time inadvertently aimed at the enclosure's seal, forcing airborne residue out of the enclosure and into the worker's environment For 33% of the brake maintenance jobs, dust levels were up to four times that of the reference level The worker was exposed to elevated dust levels 15% of the total time during vacuuming

The fourth greatest potential asbestos dust exposure occurs during the removal of the brake components The components have ground-up brake shoe residue caked on them and are likely to contain asbestos fibers For 17% of the of the brake components removed, dust levels were up to two times that of the reference level The worker was exposed to elevated dust levels 4% of the total time during the removal of the brake components.

Reinstalling brake components resulted in a slightly elevated dust level, up to two times the background level, in 33% of the reinstallations. The worker was exposed to elevated dust levels 0 3% of the total time during the reinstallation of the brake components

Air Sampling Results

Individual filter sample results for airborne asbestos fibers are presented in Table A-1 of Appendix A and are summarized in Tables 1 and 2. The results for

Table 1

Phase Contrast Microscopy Concentrations for 10 Vehicles
(fibers/cc)

Sample Type	Number of Samples	Arithmetic Mean	Range
Personal	22	<0.004	<0 004 - 0 006
Fender	7	<0 002	<0 001 - <0 002
Axle	8	<0 002	<0 001 - <0.002
Background	5	<0.001	<0 001
Ambient	8	<0 002	<0 001 - 0 002

Table 2

TEM Concentrations for 10 Vehicle Brake Jobs
(fibers/cc)

Sample Type	Number of Samples	Arithmetic Mean	Standard Deviation	Range	Geometric Mean
Personal	12	0 044	0 042	<0.007 - 0 139	0.031
Fender	11	0 023	0.024	<0 003 - 0 087	0 019
Axle	11	0 026	0 045	<0.002 - 0 164	0 015
Background	5	0 002	<0 001	<0 002 - 0 003	0.001
Ambient	4	0 004	0 002	<0 002 - 0 008	0 004

samples analyzed by Phase Contrast Microscopy (PCM) are presented in Table 1 Personal asbestos sample concentrations for the brake mechanics averaged 0 004 fibers/cc with only one sample (0 006 fibers/cc) above the 0 004/fibers/cc detection limit Source samples taken above the wheel (fender) averaged less than 0 002 fibers/cc, source samples hung over the axle and centered between the wheels averaged less than 0 002 fibers/cc; background samples collected at two separate locations in the garage averaged less than 0 001 fibers/cc; and outdoor ambient samples averaged less than 0.002 fibers/cc As stated earlier, TEM analysis of these samples show that more than 95% of the chrysotile fibers counted using the "A" rules would also have been counted using the "B" rules

Twenty-one of the 22 personal samples taken during 11 brake jobs were below the detection limit of 0 004 fibers/cc Because personal sample concentrations represented exposures while servicing brakes, and this usually takes no more than 2 to 3 hours per shift, the mechanics time-weighted averages exposure would be even lower than the measured levels.

Only 2 of the 56 samples analyzed by PCM were above the detectable limit. Ten other samples were overloaded and could not be analyzed by PCM Thus, analyses comparing brake mechanics, type of vehicle, and differences between brake inspection and brake replacements, were not done

Transmission Electron Microscopy (TEM) results are summarized in Table 2 All fibers identified as chrysotile or amphibole asbestos with an aspect ratio of 3 1 or greater were counted (fibers 0 25 microns and longer are included) A few samples contained fibers that were not identified (no I D), but could possibly be asbestos

The arithmetic mean TEM concentration (Table 2) for all personal samples was 0 044 fibers/cc, with a standard deviation of 0 042 fibers/cc This concentration was higher than the background levels in the building (which averaged 0 002 fibers/cc) and the outdoor ambient levels (which averaged 0 004 fibers/cc) Source samples taken at the axle averaged 0 026 fibers/cc, while samples taken at the fender (above the wheel) averaged 0 023 fibers/cc The TEM source sample results were only slightly above background levels Because most concentrations were below detectable limits and detectable concentrations were not much above detectable limits, tests of significance were not performed on this data

Asbestos fibers (chrysotile or amphibole) greater than or equal to 5 μm in length were found in only 11 of the 43 samples analyzed by TEM Three personal samples showed fibers greater than 5 μm. Asbestos fibers that were in a matrix (partially hidden by particles) M-fibers and X-fibers - fibers that extended into another field - are not included in Table 2, but are denoted in Appendix A Twenty-one of 43 samples analyzed by TEM contained M or X asbestos fibers, and two of these samples would show substantially higher concentrations had M or X fibers been included

Bulk and Rafter Sampling Results

Bulk samples were collected from the drums of eleven of the vehicles tested. In addition, a rafter sample was collected and analyzed The bulk sample results are presented in Table 3 Less than 1% of the total material (dust) in each of the bulk samples and the rafter sample were asbestos, although asbestos constituted virtually all the fibers that were found From 62 to 100% of the fibers in 9 of the 11 brake drum bulk samples were chrysotile, with one of the eleven samples containing 100% chrysotile asbestos fibers One of the brake drum bulk samples contained amphibole fibers From 0 to 2% of asbestos fibers and bundles were longer than 5 microns Two percent of the fibers from brake job No. 3 bulk sample were larger than 5 µm The remaining ten bulk samples contained 1% or fewer chrysotile fibers longer than 5 microns The rafter sample contained 45% chrysotile fibers with all of the asbestos fibers less than 5 microns

The OSHA Standard or 0 2 fibers/cc (Action level 0 1 fibers cc) and the NIOSH recommended exposure limit of 0.1 fibers/cc for asbestos (8-hour time-weighted average) are based on PCM analysis of asbestos using "A" counting rules. "B" counting rules were utilized in this research study As noted earlier, TEM analysis of these samples show that more than 95% of the chrysotile fibers counted using the "A" rules would also have been counted using the "B" rules Based on the levels measured by both PCM and TEM however, the mechanic's exposure in this study would be well below these recommended levels.

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 brake vacuum enclosure unit is used at this garage to contain and collect all brake lining dust (including potentially hazardous asbestos fiber content) The unit (which is fully described in Section II) is used during all brake inspection, repair, and brake lining replacement In this study, the entire brake service job was monitored, including all four wheels. The results discussed below represent fiber (PCM) and asbestos (TEM) concentrations during the entire brake job consisting of all four wheels

The effectiveness of the brake vacuum enclosure assembly is evidenced by the very low exposures for the brake mechanics Twenty-one of the 22 personal samples analyzed by PCM were below the detectable limits of 0 004 fibers/cc, well below the current OSHA standard of 0 2 fibers/cc and the NIOSH recommended standard of 0 1 fibers/cc Low fiber concentrations (by PCM) were

Table 3

Bulk Sample Results

Brake Job	Vehicle & Year	Sample No.	Grids Examined	Amphibole	Number of Chrysotile and Amphibole Fibers*	% of Total Fibers Chrysotile and Amphibole	Chrysotile and Amphibole Fibers* >5 µm
1	Jeep 1981	1	10	No	0	0	0
2	" 1975	2	10	No	0	0	0
3	" 1977	3	9	No	99	90	2
4	" 1976	4	6	No	83	85	1
5	" 1976	5	4	No	107	94	0
6	Van 1984	6	2	No	125	99	6
7	Jeep 1982	7	10	No	56	98	0
8	Auto 1979	8	7	No	96	89	1
9	Jeep 1983	9	1	No	107	100	0
10	Van 1977	10	6	No	97	96	1
11	Jeep 1974	11	10	1	21	62	0
Rafter		12	10	No	9	60	0

* Includes fibers, fibers in a matrix, and bundles

also found for the source sample placed on the fender directly above the wheel After completing servicing to the first wheel, this sample was moved to the fender above the other wheels so that this sample included dust emissions from all four wheels The fender sample concentration for each of the 11 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 11 brake jobs The importance of this source sample is that it shows dust fibers were not being propelled by the brake vacuum enclosure assembly unit air wash gun toward the other side of the vehicle

TEM results were also used to evaluate the effectiveness of the brake vacuum enclosure assembly unit The TEM results are not directly comparable to the PCM data because TEM includes all size fibers whereas PCM includes only fibers greater than 5 µm; and TEM includes only fibers identified as asbestos whereas PCM includes all fibers (larger than 5 µm) The TEM personal sample results (Table 2) show asbestos fibers were controlled to low levels with use of the brake vacuum enclosure assembly The personal sample arithmetic mean concentration and geometric mean concentrations were 0 044 and 0 031 fibers/cc, respectively, for all 11 brake jobs Two of the twelve personal samples exceeded the recommended NIOSH asbestos level of 0 1 fiber/cc and a third sample approached this level

Fender sample asbestos concentrations ranged from the detectable limit of <0 003 to a high of 0.087 fibers/cc, the axle source samples ranged from <0 002 to a high of 0 164 fibers/cc. One of eleven axle samples exceeded the recommended NIOSH standard and one of eleven fender samples approached this level

Background and ambient asbestos concentrations by TEM arithmetic average was <0 002 to 0.004 fibers/cc These low asbestos levels indicate that the asbestos present was from activities such as brake servicing and not from outdoor sources or resuspended dust in the garage

The sampling at the Louisville Postal Service garage was conducted in mild weather (February) The doors were opened only to allow vehicles to enter or exit the garage

Work Practice Results

Table 4 shows the work task analysis of a brake inspection and replacement job while using the brake vacuum enclosure assembly unit Potential asbestos exposure points while performing this task are also noted The average work cycle time for a one-wheel brake inspection task was 10 minutes and 22 minutes for a one-wheel brake replacement task

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 air washing of the brake components, removing and reinstalling the brake components, and replacing the lug bolts Good work practice observed by some of the workers to reduce these exposure points are to take care during air washing to aim the air gun only at the brake components and not at the enclosures seal, and again vacuuming the brake components after

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 connects vacuum to enclosure turns vacuum on, places enclosure over brake assembly and backing plate	
5	Worker uses air gun to clean brake components, leaves vacuum running until visible airborne dust removed from enclosure	Airborne dust blown through enclosure's iris-type seal around the vehicle's axle
6	Worker removes vacuum hose from enclosure, vacuums drum and floor.	
7	Worker removes enclosure, some worker's vacuums inside of enclosure and brake components	
8	Supervisor inspects the brake assembly	
9	Worker removes and reinstalls brake components and installs new shoes	Loose dust from brake components as they are being manipulated
10	Brake drum put back on vehicle.	
11	Wheel is put back on vehicle	
12	Wheel lugs pneumatically tightened on wheel	Loose dust around lugs and tire rim

removing the enclosure Bad work practices included using a dry rag to wipe the brake drum and assembly, and the use of a hammer to loosen "frozen" brake drums without trying to capture the brake dust falling from the brake drum.

Demographic and work practices were obtained from interviews of ten workers All ten workers were male and ranged in age from 29 to 54 years The average average was 39 ± 8 3 years As a group these men had 2 4 ± 0 94 years experience as mechanics at this facility, and performed 3 6 ± 1 4 brake jobs per week Eight of the workers indicated their right hand was dominant in performing work, while two claimed to be left hand dominant Tools and equipment commonly used during brake maintenance and repair included brake spring remover, pliers, hammer, brake vacuum unit (Per-lux or Nilfisk), respirator, brake adjustment tool, brake shoe tool, power air tool, and impact wrench All of the employees interviewed indicated they were provided with training to protect themselves from asbestos dust during brake maintenance and repair The training lasted from 20 minutes to 2 hours, and usually took place when employees started working at this facility Workers most frequently remembered from their training: the use of a respirator, how to use the vacuum unit, and not to use compressed air to blow out brake dust All ten workers indicated they had a physical examination before being hired by the Postal Service, and only one employee indicated having a chest X-ray as part of the physical exam

Personal protective equipment worn by all workers included work clothing and a respirator. Gloves, safety glasses and safety shoes were not indicated. This U.S. Postal Service facility provides lockers, showers, work clothes, and laundry service for these workers While shower facilities were available for all workers, only three of the workers said they take showers and change into "street" clothes before going home When asked if the workers did anything special to protect themselves for brake dust all indicated use of a dust respirator, and use of the dry vacuum and wheel cover unit Some workers indicated washing of hands, taking showers and changing into "street" clothes before going home. A few of the workers indicated that they had second jobs and stayed in their work clothes to save time

With regard to the use of the vacuum wheel cover unit, three workers indicated that they used the Per-lux wheel cover assembly in place of the Nilfisk wheel cover assembly because it was easier to use and more efficient in removing the dust from the wheel hub Two design deficiencies were noted about the Per-lux the lack of a "see-through" window on the unit, and worn rubber gaskets which decreased the seal efficiency when the vacuum unit was turned on There were no complaints about the Nilfisk vacuum itself However, there were several design deficiencies regarding the Nilfisk's Asbesto-Cleneß 500 system including: the poorly designed rubber seal at the back of the encapsulator cylinder, the absence of a light inside of the cylinder to see the brake components while cleaning, the difficulty in changing glove sizes and glove hand (left or right), and the bulkiness of the vacuum unit making it hard to maneuver and use in tight work spaces

In summary, these interviews revealed that brake maintenance and repair workers are aware of the health hazards of asbestos dust exposure while working In addition, they generally used control devices such as disposable respirators, and the brake vacuum wheel cover assembly when performing brake maintenance and repair Individual work practices to increase protection included washing hands before work breaks and lunch, showering after work, and not taking work clothes home

VI CONCLUSIONS AND RECOMMENDATIONS

The use of this brake vacuum enclosure assembly resulted in low asbestos exposures, for the vehicles tested, indicating effective control of the asbestos dust Although it was not possible to evaluate an uncontrolled situation to determine an efficiency for the controls, other work[2] has 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 This data suggest that the present technique was substantially effective in controlling asbestos dust during brake servicing

Fender and axle source sample results showed no major differences among the vehicles tested. There was almost no difference in asbestos exposures between brake inspections and brake replacements based on TEM results

TEM results were of much greater value than PCM results for evaluating the brake assembly vacuum enclosure since the asbestos levels were quite low. The primary use of the PCM data was to demonstrate that exposures were well below the OSHA standard and NIOSH recommended level, since both the standard and recommended level are based on the PCM procedure As noted earlier, TEM analysis of these samples show that more than 95% of the chrysotile fibers counted using the "A" rules would also have been counted using the "B" rules Since the TEM method is more sensitive, this allowed comparison between personal or source samples and background and ambient levels

Bulk sample results analyzed by TEM show that the brakes on nine out of eleven vehicles tested in this study contained chrysotile asbestos fibers and, therefore, had asbestos-type brakes The drums on these nine vehicles tested contained between 62 and 100% chrysotile fibers with 3 vehicles having 98 to 100% chrysotile fibers Less than 1% of the total material (dust) in each of the bulk samples and the total particles in the rafter sample were asbestos, although asbestos constituted virtually all 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 work practices such as (1) avoid aiming the air gun at the enclosure's seal around the wheel's axle enclosing the backing plate, and (2) vacuum the brake components on the backing plate after the enclosure has been removed

Training in the operation and maintenance of this unit is important for developing good work practices which could reduce potential brake asbestos exposure

Install a light inside the enclosure to improved visibility during the air washing phase of brake maintenance to check for completeness of air washing of the brake components

Replace the iris-type seal on the Asbesto-Cleneß encapsulator cylinder with an overlapping panel-type seal. The panels are completely closed when the unit is not in use and forms a tighter seal around the vehicle's axle when in-place This tighter seal should reduce the amount of brake dust escaping from the enclosure during air washing during such times as when the air gun is accidentally aimed at the enclosure's seal (Nilfisk has recently changed the encapsulator cylinder iris-type seal on their 'Asbesto-Cleneß' 500 system to an overlapping panel-type seal)

For brake drums that are difficult to remove, requiring extensive hammering to loosen prior to removing, use the vacuum to capture the brake residue as it falls from the drum rather than waiting to vacuum the residue from the floor (Nilfisk has recently modified the encapsulator cylinder on their 'Asbesto-Cleneß' 500 system to permit the removal of the brake drum while inside the enclosure.)

With the facility going to nonasbestos brake shoes, there is a continued need to stress the hazard of asbestos dust exposure during brake maintenance and the need to use good work practices on all brake maintenance jobs. The worker, knowing that some brake shoes are nonasbestos, may now believe their is no asbestos hazard and become careless in his effort to contain the brake residue Such careless work practices can result in high asbestos exposures when a vehicle still having asbestos-type brake shoes undergoes brake maintenance

Since asbestos was identified in most 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, continue the use of the laundry service provided for cleaning soiled work clothing

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

When weather conditions permit, leave the entry and exit doors to the garage open This should reduce ambient dust levels within the building

Maintenance and regular changing of the brake vacuum enclosure's seal and the filters in the vacuum unit are encouraged for maximum efficiency of this unit (see manufacturer's recommendations)

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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[2]	PCM Fibers/cc	TEM Asbestos Fibers/ Filter	TEM Asbestos Fibers/cc	TEM Asbestos[3] M or X Fibers
2574	09-Feb-87	1	1981	pers	R	364	<1500	0.004			
25373	09-Feb-87	1	1981	pers	R	361	2000	0.006	2377	<0.007	3
25368	09-Feb-87	1	1981	fend	R	1160	<1500	0.001	52284	0.045	13
2595	09-Feb-87	1	1981	axle	R	923	<1500	0.002	9506	0.010	1
2578	09-Feb-87	1,2		bckg		2145	<1500	0.001			
25395	09-Feb-87	1,2		bckg		2108	<1500	0.001	4753	0.002	0
25475	09-Feb-87	1,2		amb		897	<1500	0.002	2377	<0.003	0
2592	09-Feb-87	1,2		amb		828	<1500	0.002			
25397	09-Feb-87	2	1975	pers	R	361	<1500	0.004			
25377	09-Feb-87	2	1975	pers	R	364	<1500	0.004	9506	0.026	0
25364	09-Feb-87	2	1975	axle	R	1160	<1500	0.001	2377	<0.002	0
25389	09-Feb-87	2	1975	fend	R	923	<1500	0.002	2377	<0.003	0
2569	10-Feb-87	3	1977	pers	I	364	<1500	0.004			
25478	10-Feb-87	3	1977	pers	I	361	<1500	0.004	4753	0.013	1
25399	10-Feb-87	3	1977	axle	I	1160	<1500	0.001	33272	0.029	3
25378	10-Feb-87	3	1977	fend	I	923	<1500	0.002	2377	<0.003	1
25367	10-Feb-87	3,4		bckg		1575	<1500	0.001			
25384	10-Feb-87	3,4		bckg		1582	<1500	0.001	2377	<0.002	0
25355	10-Feb-87	3,4,5,6		amb		1224	2000	0.002	9506	0.008	0
25393	10-Feb-87	3,4,5,6		amb		1039	<1500	0.001			
25361	10-Feb-87	4	1976	pers	I	391	<1500	0.004	14259	0.036	0
25363	10-Feb-87	4	1976	pers	I	394	<1500	0.004			
2559	10-Feb-87	4	1976	axle	I	1247	<1500	0.001	4753	0.004	0
25382	10-Feb-87	4	1976	fend	I	992	<1500	0.002	2377	<0.002	0
25400	10-Feb-87	5	1976	pers	I	345	<1500	0.004	19012	0.055	1

(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[2]	PCM Fibers/cc	TEM Asbestos Fibers/ Filter	TEM Asbestos Fibers/cc	TEM Asbestos[3] M or X Fibers
2589	10-Feb-87	5	1976	pers	I	343	<1500	0 004	47531	0.139	5
25375	10-Feb-87	5	1976	axle	I	1102	<1500	0 001	180617	0 164	44
25371	10-Feb-87	5	1976	fend	I	877	<1500	0.002	76049	0 087	3
25392	10-Feb-87	5,6		bckg		2138	<1500	0 001			
25380	10-Feb-87	5,6		bckg		2122	<1500	0 001	4753	0 002	2
25396	10-Feb-87	6	1984	pers	R	346	<1500	0 004			
25385	10-Feb-87	6	1984	pers	R	348	<1500	0 004	4753	0 014	0
25358	10-Feb-87	6	1984	axle	R	1102	ovld		14259	0 013	3
25354	10-Feb-87	6	1984	fend	R	877	ovld		33272	0 038	7
25365	11-Feb-87	7	1982	pers	I	364	<1500	0 004			
25374	11-Feb-87	7	1982	pers	I	361	<1500	0 004	38025	0 105	3
25471	11-Feb-87	7	1982	axle	I	1131	<1500	0 001	33272	0 029	2
25457	11-Feb-87	7	1982	fend	I	900	<1500	0 002	4753	0.005	1
25381	11-Feb-87	7,8,9		bckg		2722	ovld				
2560	11-Feb-87	7,8,9		bckg		2722	ovld		4753	0 002	0
25370	11-Feb-87	7,8,9		amb		1167	<1500	0.001			
25369	11-Feb-87	7,8,9		amb		1174	<1500	0 001	2377	0 002	0
25466	11-Feb-87	8	1979	pers	I	348	<1500	0.004			
2564	11-Feb-87	8	1979	pers	I	346	<1500	0 004	28519	0 082	0
2566	11-Feb-87	8	1979	axle	I	1122	<1500	0 001	4753	0 004	0
2576	11-Feb-87	8	1979	fend	I	892	<1500	0 002	19012	0 021	1
2597	11-Feb-87	9	1983	pers	I	364	<1500	0 004			
2553	11-Feb-87	9	1983	pers	I	361	<1500	0 004	9506	0.026	0
25210	11-Feb-87	9	1983	axle	I	1160	ovld		4753	0 004	0
2570	11-Feb-87	9	1983	fend	I	923	ovld		9506	0 010	0

(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[2]	PCM Fibers/cc		TEM Asbestos Fibers/ Filter	TEM Asbestos Fibers/cc	TEM Asbestos[3] M or X Fibers
25515	12-Feb-87	10	1977	pers	I	364	<1500	0 004				
25606	12-Feb-87	10	1977	pers	I	361	<1500	0 004		2377	0 007	0
25538	12-Feb-87	10	1977	axle	I	1209	ovld			33272	0 028	1
2583	12-Feb-87	10	1977	fend	I	961	ovld			14259	0 015	1
25607	12-Feb-87	10,11		bckg		1800	<1500	0 001				
25624	12-Feb-87	10,11		bckg		1800	ovld			4753	0.003	0
25647	12-Feb-87	10,11		amb		891	<1500	0 002				
2557	12-Feb-87	10,11		amb		897	<1500	0 002		2377	0.003	0
25614	12-Feb-87	11	1974	pers	R	361	<1500	0 004				
25529	12-Feb-87	11	1974	pers	R	364	<1500	0 004		4753	0 013	0
25320	12-Feb-87	11	1974	axle	R	1160	<1500	0 001		4753	0 004	1
2568	12-Feb-87	11	1974	fend	R	923	ovld			23765	0.026	1
2577	02-09-87	1		Blank		0	<1500		–	–	–	
25391	02-09-87	1		Blank		0	<1500		0	–	0	
25388	02-09-87	2		Blank		0	<1500		–	–	–	
25394	02-09-87	2		Blank		0	<1500		0	–	0	
2572	02-10-87	3		Blank		0	<1500		–	–	–	
2596	02-10-87	3		Blank		0	<1500		0	–	0	
25356	02-10-87	4		Blank		0	<1500		–	–	–	
25387	02-10-87	4		Blank		0	<1500		0	–	0	
25398	02-10-87	5		Blank		0	<1500		–	–	–	
25390	02-10-87	5		Blank		0	<1500		0	–	0	
25379	02-10-87	6		Blank		0	<1500		–	–	–	
25386	02-10-87	6		Blank		0	<1500		0	–	0	
25360	02-11-87	7		Blank		0	<1500		–	–	–	

(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[2]	PCM Fibers/cc	TEM Asbestos Fibers/ Filter	TEM Asbestos Fibers/cc	TEM Asbestos[3] M or X Fibers
25352	02-11-87	7		Blank		0	<1500	0	–	0	
25451	02-11-87	8		Blank		0	<1500	–	–	–	
25455	02-11-87	8		Blank		0	<1500	0	–	0	
2591	02-11-87	9		Blank		0	<1500	–	–	–	
2586	02-11-87	9		Blank		0	<1500	0	–	0	
2585	02-12-87	10		Blank		0	<1500	–	–	–	
2558	02-12-87	10		Blank		0	<1500	0	–	0	
25351	02-12-87	11		Blank		0	<1500	–	–	–	
25537	02-12-87	11		Blank		0	<1500	0	–	0	

1 See Appendix B for vehicle description
2 ovld - Filter overloaded
3 M = Matrix fiber, X = Fiber extended beyond grid

APPENDIX B

NIOSH Brake Maintenance Study
Description of Vehicle

DATE	VEHICLE NO	JOB NO	DESCRIPTION OF VEHICLE
2-9-87	1170430	1	Jeep, AM General DJ-5L, 1981, 26,854 miles use for postal delivery, nonasbestos brake shoes, GVWR, 3,350 pounds, bias tires, automatic transmission, RWD and 11" diameter drum brakes
2-9-87	5709113	2	Jeep, AM General, 1975, 58,473 miles use for postal delivery, nonasbestos brake shoes, GVWR, 3,287 pounds, bias tires, automatic transmission, RWD and 11" diameter drum brakes
2-10-87	7104337	3	Jeep, AM General DJ-5F, 1977, 85,253 miles use for postal delivery, nonasbestos brake shoes, GVWR, 3,350 pounds, bias tires, automatic transmission, RWD and 11" diameter drum brakes
2-10-87	6110706	4	Jeep, AM General DJ-5D, 1976, 52,050 miles use for postal delivery, nonasbestos brake shoes, GVWR, 3,350 pounds, bias tires, automatic transmission, RWD and 11" diameter drum brakes
2-10-87	6110672	5	Jeep, AMC DJ-5D, 1976, 42,604 miles use for postal delivery, nonasbestos brake shoes, GVWR, 3,350 pounds, bias tires, automatic transmission, RWD and 11" diameter drum brakes
2-10-87	3293063	6	Van, AMC FJ-8C, 1984, 14,364 miles use for postal delivery, nonasbestos brake shoes, GVWR, 5,350 pounds, bias tires, automatic transmission, RWD and 11" diameter drum brakes
2-11-87	1170689	7	Jeep, AM General DJ-5L, 1982, 16,505 miles use for postal delivery, nonasbestos brake shoes, GVWR, 3350 pounds, bias tires, automatic transmission, RWD and 9" diameter drum brakes
2-11-87	900081	8	Ford Pinto 1979, 28,967 miles use for postal delivery, GVWR, 3791 pounds, bias tires, automatic transmission, RWD and 11" diameter drum brakes.

(continued)

APPENDIX B (Continued)

NIOSH Brake Maintenance Study
Description of Vehicle

DATE	VEHICLE NO	JOB NO	DESCRIPTION OF VEHICLE
2-11-87	319378	9	Jeep, AM General DJ-M5, 1983, 19,093 miles use for postal delivery, nonasbestos brake shoes, GVWR, 3,350 pounds, bias tires, automatic transmission, RWD and 11" diameter drum brakes
2-12-87	6400543	10	Van, AMC FJ-9, 1977, 89,912 miles use for postal delivery, nonasbestos brake shoes, GVWR, 7,400 pounds, bias tires, automatic transmission, RWD and 14" diameter drum brakes
2-12-87	4186890	11	Jeep, AM General DJ-5C, 1974, 48,163 miles use for postal delivery, nonasbestos brake shoes, GVWR, 3,350 pounds, bias tires, automatic transmission, RWD and 9" diameter drum brakes