IN-DEPTH SURVEY REPORT

EVALUATION OF BRAKE DRUM SERVICE CONTROLS

AT

United States Postal Service
Vehicle Maintenance Facility
Nashville, Tennessee

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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 um in diameter and greater than 8 um 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 occpuational 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 15%

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 should 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 Maintenance Garage in Nashville services all the Federal postal vehicles for the Sectional Center District of Tennessee This involves 575 vehicles whose city routes cover nearly half of the state Records on all these Postal vehicles are kept by computer Each year, each vehicle has a minimum of two complete inspections If the computer record shows more than 500 miles per month usage, then the yearly scheduled inspections are increased from 2 to 3 An average city mail delivery route is within a 20-30 mile range with a minimum of 250-400 mail stops The local Postmaster keeps track of vehicle mileage and may shift vehicles from route to route so that total vehicle mileage on all routes stay approximately the same All the garage shop personnel are members of the American Postal Workers Union, AFL-CIO

In the entire Sectional Center District, the Nashville vehicle maintenance facility services the following:

1) Five hundred and seventy-five Jeep delivery vehicles - This category includes 1/4 and 1/2 ton special vehicles (Jeep engines and chassis but a larger enclosure than the standard Jeep delivery unit) Eighty to 85% of the 575 vehicles are the AM General Post Office delivery vehicle type, and the remainder are special vehicles

   Most of the delivery Jeeps and all the 1/4 and 1/2 Ton units have 6-cylinder engines - the remainder have 4-cylinder engines

   Most of the delivery Jeeps have 13" or 14" wheels and 10" long brake shoes

   Jeep delivery vehicles have the following specifications

   a) Manufacturer - AM General (formerly American Motors Corporation).

   b) Model-DJ5D

   c) Model year - 1973 to 1986

   d) Brake Type - All four wheels equipped with drum brakes

   e) Tires - Bias Ply

   f) Vehicle Weight - 2,310 pounds

   g) Transmission - Automatic.

   h) Differential - limited slip rear wheel drive

2) Thirteen seven-ton International trucks (disc brakes all four wheels)

3) Three Mack and two White tractors (drum brakes all four wheels)

4) Seven trailers

The garage is staffed with nine mechanics, one lead mechanic, four garagemen, one body man and two supervisors Six mechanics work from 6·00 a m to 2·30 p m. and four mechanics work from 9·30 a.m to 6·00 p m , with all 10 mechanics on duty from 9 30 a m to 2·30 p m

The garage building sides face East and West and is 202 feet long with a working area of 64 by 111 feet and a ceiling height of 20 feet There are seven bay doors on each side with each door approximately 14-feet high and 11-feet wide A plan of the working area is shown in Figure 1 When the garage was opened in 1979-80, building heat was provided by a bank of six electrical heaters (equipped with small fans) suspended in a row on each side of the garage (12 heaters) Because these units were expensive to operate, they are no longer used In their place, four gas-fired unit heaters were installed at each corner of the garage

There is an under-floor hose and pipe system to remove auto exhaust fumes These are located in the floor by the doors of the 14 bays Six of the bays are equipped with hydraulic lifts (both front and rear of each vehicle) so they can work on twelve elevated vehicles at the same time Each bay has a working width of 13 feet Numerous electrical cables are suspended from above alongside the bay These are extended for use to power the numerous power tools the mechanics use Much of the repair work is done with the mechanic standing under the elevated vehicle

Ventilation of the garage is minimal There is a series of roof-mounted fans on each side of the garage These are operated in summer to remove hot air from under the roof area In the cooler months, these fans are not used and the inlet dampers are kept closed There is no provision for providing fresh, heated air from the outside When the 14 bay doors can be left open during mild weather, they provide a lot of useful ventilation During colder weather, the garage air temperature is kept at 60-65°F at the mechanics working level

Process and Equipment Description

This facility is currently replacing asbestos brake shoes with the nonasbestos type when vehicle brakes are repaired Our control evaluation at this facility concentrated on Jeep vehicle maintenance to determine the variability of control effectiveness in the same model vehicle during 10 separate vehicle brake repair or inspections

A $760 brake washer assembly unit (Kleer-Flo Model LW-22 Rollabout) had been used to control potential asbestos exposure at this facility for several months prior to our survey Figure 2 shows this washer unit. Although the unit was not evaluated in use on any type of vehicles except jeeps, supervision reported good results when using this unit on the larger vehicles as well. The portable washer moves easily to the brake repair location. A water solution (Greasoff® No 19) recirculates through a flexible tube and brush to flood parts clean The upper tray raises to the work area to hold small parts ready for reassembly and to catch the solution. A pump in this machine pulls the solution through a nylon filter and then pumps the filtered solution through a flexible tube and out between the bristles of the brush, allowing a gentle flooding of the brake assembly area to wash down any dust and perform the necessary cleaning The solution is returned to the bottom tank where it is recirculated The upper tray is removable to permit use of the bottom tank for cleaning brakes on larger vehicles

One gallon of Greasoff® No 19, a liquid concentrate, mixed with five gallons of water and is used to clean (40 to 50 wheels) before it needs to be discarded. (Four gallons of Greasoff® No. 19 cost $75) Greasoff® No. 19 contains the following hazardous ingredients, less than 5% by weight sodium metasilicate, a highly alkaline compound (pH 12 4), and less than 5% by weight ethylene glycol monobutyl ether, which is also known as 2-butoxy ethanol or by its common name of butyl Cellosolve Sodium metasilicate is severly irritating to the eyes, skin, and mucus membranes Ethylene glycol monobutyl ether or 2-butoxy ethanol is absorbed by the skin and is a hemolytic agent. The current OSHA standard for 2-butoxy ethanol is 50 ppm The 1981 Threshold Limit Value (TLV) listed in the American Conference of Govermental Industrial Hygienist (ACGIH) booklet reduced the TLV to 25 ppm Wearing of goggles or

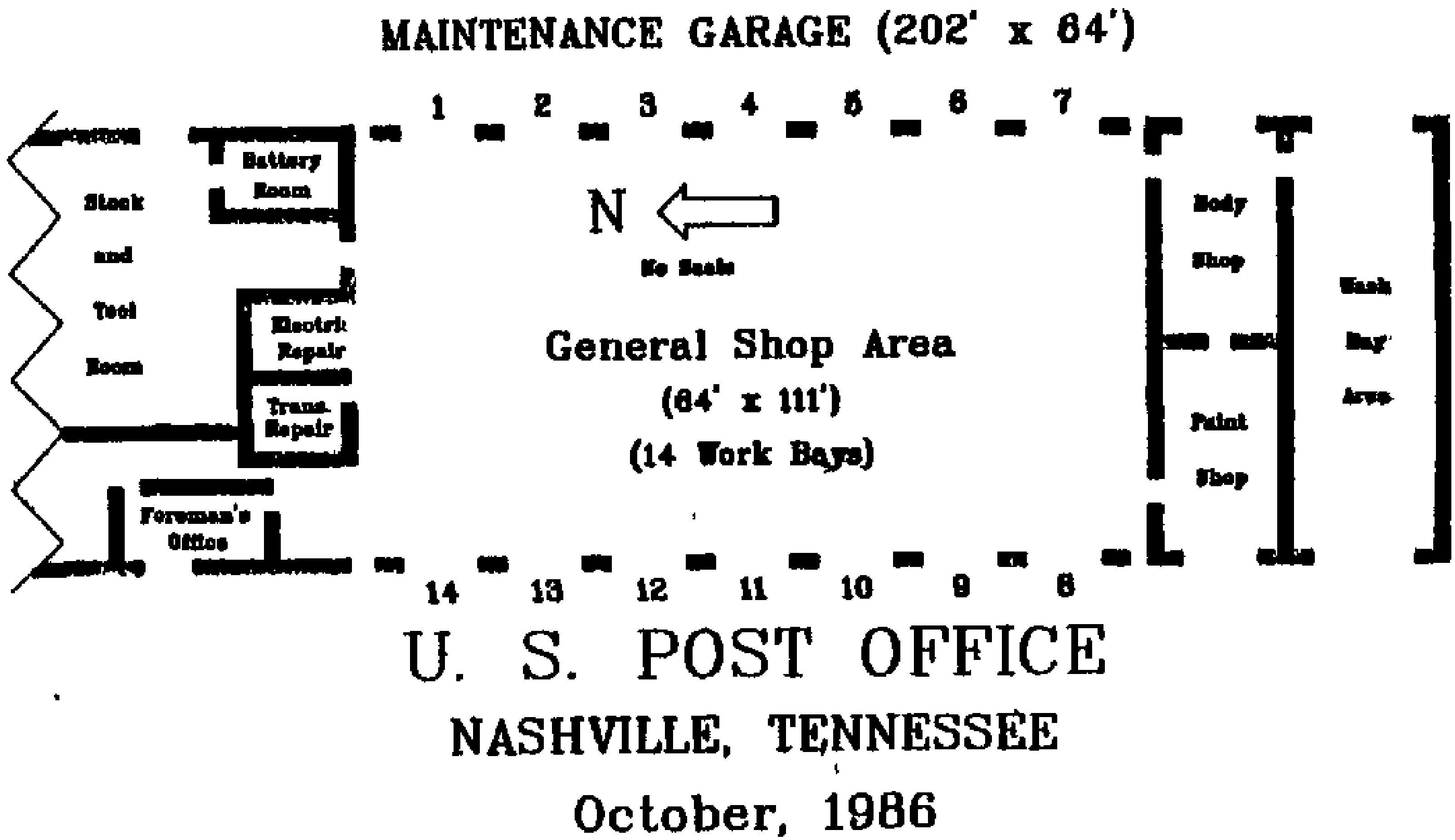

Figure 1. Floor Plan of USPS Garage and Shops.

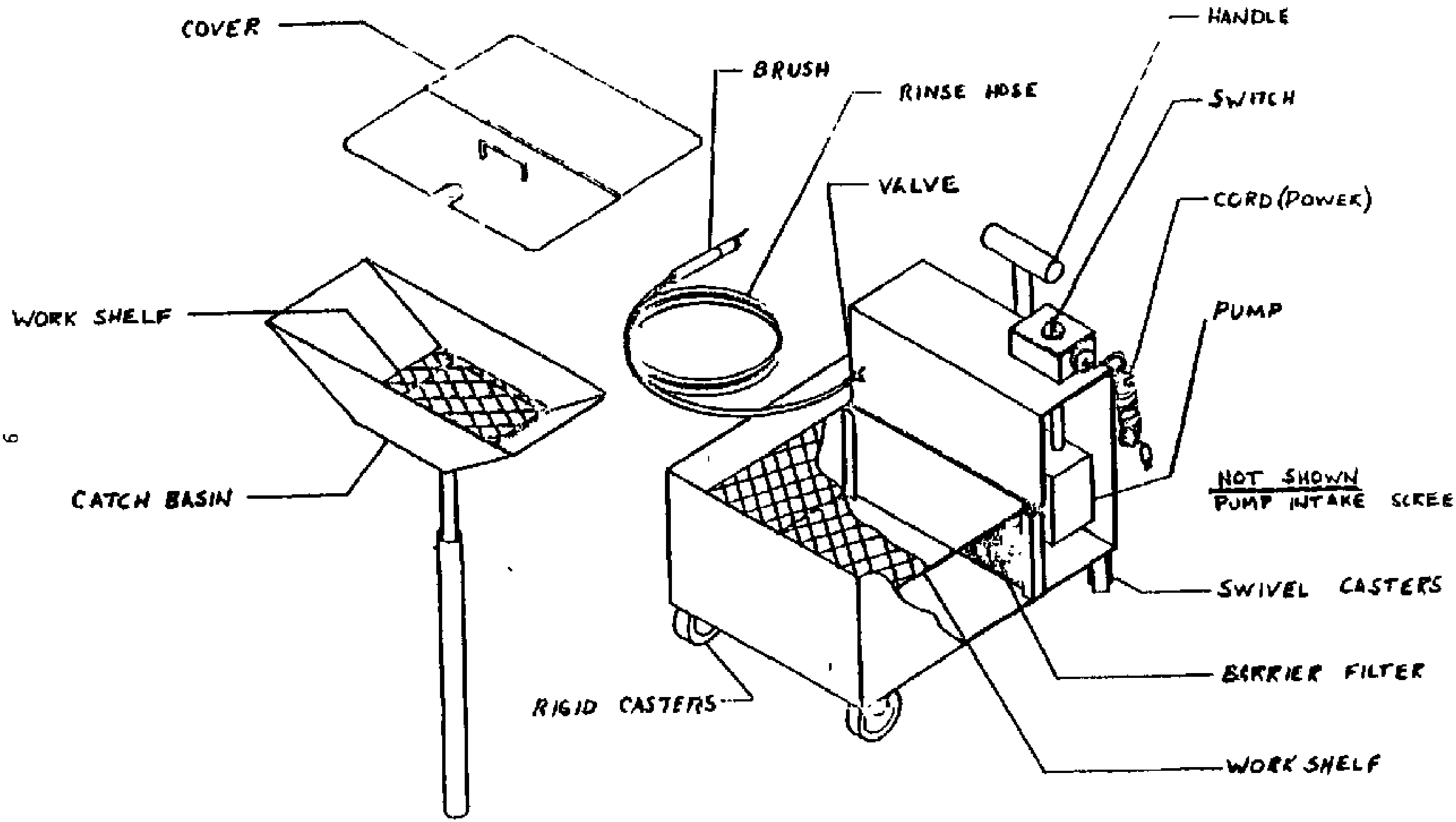

Figure 2. Brake Washer Assembly Unit.

side shield safety glasses and rubber or chemical resistant clothing is recommended for preventing skin contact when handling Greasoff® No 19

The washer unit has a six-gallon capacity During our survey, this facility disposed of the used liquid on a monthly basis Approximately 25 brake jobs were performed each month with the liquid being changed after each 10 to 12 brake jobs The ten gallons of used brake cleaner is placed in sealed five-gallon cans and marked in accordance with EPA instructions for disposal An EPA-approved contractor picks up the used liquid and disposes of it in an EPA-approved toxic waste site

Some of the features of the brake washer assembly include:

1) A gentle flow of solvent to the workshelf/catch basin area to wet the back plate and brake components in order to avoid spreading dust into the air and, at the same time, clean the components

2) A low center of gravity to avoid tipping and spillage of solution which may contain asbestos fibers

3) An adjustable work tray allowing the mechanic to position the tray at a height to avoid splashing and spillage

4) A design that can be used on both automobiles and trucks so the mechanic can maintain safe work practices for all types of vehicles.

5) A reservoir equipped with a removable cover to prevent liquid evaporation when covered and as a work tray when the cover is removed for work on large vehicles

The manufacturer recommends the following sequence for use of their unit for brake shoe servicing

1) Fill the reservoir with one gallon of brake cleaner concentrate and five gallons of water

2) Make sure the switch is in OFF position and plug into power source

3) Make sure the brush is positioned toward the solvent supply or in the catch basin to prevent accidental spillage and loss of solution Do not leave brush and hose assembly on the floor

4) If the vehicle is on a lift, place the machine so that the catch basin is directly under the brake assembly Height of the catch basin can be adjusted for convenience of the mechanic If the vehicle is raised by a front-end lift or jack, (as is often the case with trucks) cleaning can be done by removing the catch basin, opening the hinged cover of the main reservoir tank and cleaning over the expanded metal mesh covering the fluid reservoir

5) Turn the switch ON and the fluid will be pumped through the brush hose assembly and cleaning can commence Regulation of the fluid flow is controlled by a valve at the hose-pump connection.

6) The "Flo-Thru" brush provides a wetting action to wash away dust, asbestos fibers, oil and grease Small parts can be conveniently cleaned and stored in the catch basin or in the main tank

7) Fluid should be disposed of in accordance with local, state and federal requirements The barrier filter should be washed at this time

The mechanics worked confidently with this brake washer assembly unit and believed it did a good job of containing and collecting brake dust when employed on any size vehicle

III METHODOLOGY

Air Sampling and Analysis

Personal air samples for asbestos were collected in duplicate on 0 8-um pore size, 25 mm-diameter cellulose ester membrane filters at 3 0 lpm for the duration of a single 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 cellulose ester filters Two area samples were collected at the vehicle fender and the axle (source samples) at approximately 7 0 lpm for the duration of a single brake job, or 2 hours, whichever was longer The source samples were used to measure fibers escaping into the working environment during the 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 were collected in the general garage area (background) at approximately 7 0 lpm for a 4-hour period encompassing pre- and post-brake job activities. These background samples were used to determine effects of general shop cleanliness and overall containment effectiveness of the controls The minimum volume collected (1,680 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 at 3 0 lpm for an approximate 8-hour period. These ambient samples were used to determine environmental levels of asbestos The minimum volume collected (1,440 liters) allowed a limit of detection of 0 001 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 7400B counting rules TEM analysis of these samples show that more than 85% 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 um 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 Twelve blanks were analyzed by PCM and 6 blanks by TEM and these results are shown in Table 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 were 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. Two Hand-held Aerosol Monitors (HAMs (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 four second intervals before it has to be reset The HAMs measured the dust levels in the operator's breathing zone and in the area beneath the vehicle's axle Before each brake maintenance job, the HAMs were calibrated and zeroed. The computer's clock was synchronized with that of the video camera DuPont P4000 or MSA Model G pumps were connected by tubing to each HAM, and each HAM in turn was connected by a 25-foot electrical lead to the computer, programmed to receive the data The brake maintenance operator wore one HAM and the other HAM was set beneath the axle of the vehicle undergoing 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 HAMs are not specific for asbestos, if the asbestos fibers are dispersed along with the other components of the brake dust (which seems to be a resonable 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 eight 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 total dust data were collected using Hand-Held Aerosol Monitors (HAM's) connected to an Apple II Plus computer Two real-time samples were collected: one alongside the personal sample on the brake mechanic, and the other just below the vehicle's axle Real-time data collection was during actual brake maintenance operations, approximately an hour in duration, and was obtained during all 10 brake maintenance jobs Nine different operators performed the brake maintenance jobs on these 10 vehicles

The general brake maintenance procedure was:

- Remove the wheel's lug bolts and the wheel (average time 17 seconds)

- Remove the brake drum (average time 17 seconds) Thirty-five percent of the operators let the cleansing liquid run down between the brake drum and the support plate for about 15 seconds before removing the drum

- Thoroughly wash the drum, brake shoes, and brake support plate for about 80 seconds

- Inspect the brake shoes. If they do not need replacing, reinstall the brake drum, wheel, and lug bolts (average time 60 seconds)

- For brake shoes that are to be replaced, remove the brake shoes (average time 100 seconds). For 30% of the replacements, the operator would wash the support plate and related gear for another 10 to 40 seconds

- Install the new brake shoes (average time 280 seconds)

- Reinstall the brake drum (average time 10 seconds)

- Remount the wheel and tighten the lug bolts (average time 60 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 total dust during the removal of the lug bolts and the drum, and during the reinstallation of the lug bolts The greatest potential asbestos dust exposure occurs during removal of the brake drums Each drum contains ground-up brake shoe residue which is likely to contain asbestos fibers For 38% of the drums removed, dust levels were up to nine times that of the reference level. For each brake job, the worker was exposed to elevated dust levels from 0 7% to 11 0% (averaging 3 6%) of the total time spent in removing the brake drums

The second highest dust levels detected were during the removal of the lug bolts from the wheels These levels were up to three times the reference level on 38% of the brake jobs When reinstalling the wheel and tightening the lug bolts, dust levels were up to 1.5 times above the reference level in 10% of the operations For each brake job, the worker was exposed to elevated dust levels 0 2% of the total time spent in loosening and tightening of the lug bolts

Removing the old and installing the new brake shoes resulted in slightly elevated dust levels, up to 1 5 times above the reference level, in 9% of the brakes replaced For each brake job, the worker was exposed to elevated dust levels from 0.2% to 0 3% of the total time spent in removing and installing of the brake shoes

On the third brake maintenance operation, there were prolonged elevated dust exposures during the time it took to remove the lugs from two wheels. The dust levels were seven to eight times above the reference level and averaged 5.1% of the total brake maintenance time for two wheels on one vehicle When the air-impact wrench was replaced, dust levels and exposure time both dropped, indicating a faulty air-impact wrench

Also noted was the cleanliness of the wheels, the amount of road dust on the rims Of the forty wheels, 20% could be described as clean, 60% fair, and 20%

dirty From the real-time data, there was no clear relationship between dust exposures and cleanliness of the wheel

The greatest potential to asbestos exposure is during the removal of the brake drum This potential appears to be reduced when the cleansing liquid is allowed to flow between the brake drum and brake support plate before the drum is removed

The high dust level experienced during the removal and tightening of the lug bolts appears to be due more to the air-impact wrench than the road dust on the rim One faulty or worn out air-impact wrench significantly increased the total dust levels when it was used on two of the forty wheels, as noted previously, by directing compressed air onto the wheel being serviced The elevated real-time dust readings may also have been from an oil mist aerosol from the wrench generated by the compressed air

Thorough washing of the brake support plate, brake shoes, and gear used to attach the brake shoes appeared to remove or wet most of the asbestos dust before the operator started to manually remove the old shoe and install the new shoes. As a result, total dust levels were low or not measurable during 91% of brake shoe replacements

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 samples analyzed by Phase Contrast Microscopy (PCM) are presented in Table 1. Personal asbestos sample concentrations for the brake mechanics averaged less than the detection limit of 0 004 fibers/cc, with only one sample above 0 004 fibers/cc Source samples taken above the wheel (fender) averaged less than 0 002 fibers/cc, source samples hung over the axle and centered between the wheels averaged less than 0 002 fibers/cc, background samples collected at two separate locations in the garage averaged less than 0 001 fibers/cc, and outdoor ambient samples averaged less than 0 001 fibers/cc. As stated earlier, TEM analysis of these samples show that more than 85% of the chrysotile fibers counted using the "A" rules would also have been counted using the "B" rules

Nineteen of the 20 personal samples taken during 10 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 1 of the 76 samples analyzed by PCM was above the detectable limit, 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

Table 1

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

Sample Type	Number of Samples	Arithmetic Mean	Range
Personal	20	<0 004	<0 004 – 0.006
Fender	10	<0 002	<0 002
Axle	10	<0.002	<0 002
Background	16	<0.001	<0 001
Ambient	8	<0 001	<0.001

Table 2

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

Sample Type	Number of Samples	Arithmetic Mean	Standard Deviation	Range
Personal	10	0 008	0 003	<0 006 – 0 013
Fender	10	0 009	0 012	<0 002 – 0 040
Axle	10	0 004	0 004	<0 002 – 0 016
Background	8	0 002	0 001	<0 001 – 0 006
Ambient	4	0 002	0 001	<0 002 – 0 003

The arithmetic mean TEM concentration (Table 2) for all personal samples was 0.008 fibers/cc, with a standard deviation of 0 003 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 0 002 fibers/cc) Source samples taken at the axle averaged 0 004 fibers/cc, while samples taken at the fender (above the wheel) averaged 0 009 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 um in length were found in only 12 of the 48 samples analyzed by TEM Two personal samples showed fibers greater than 5 um 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 Four of 48 samples analyzed by TEM contained M or X asbestos fibers, and one of these samples would show substantially higher concentrations had M or X fibers been included

Bulk and Rafter Sample Results

Bulk samples were collected from the drums of nine 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 83 to 100% of the fibers in the 9 brake drum bulk samples were chrysotile, with two of the nine samples containing 100% chrysotile asbestos fibers Two of the brake drum bulk samples contained amphibole fibers From 0 to 3% of asbestos fibers and bundles were longer than 5 microns Three percent of the fibers from brake job No 1 bulk sample were larger than 5 um The remaining eight bulk samples contained 1% or fewer chrysotile fibers longer than 5 microns The rafter sample contained 99% chrysotile fibers with 7% of the asbestos fibers larger 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 85% 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 insure proper use and operating conditions, and the education and commitment of both workers and management to occupational health are also important ingredients of a complete, effective, and durable control system These principles of control apply to all

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 um
1	Jeep 1976	2	9	No	83	83	3
2	1977	3	4	No	97	88	0
3	1977	4	3	1	116	96	0
4	1978	5	10	No	66	97	0
5	1977	6	4	No	115	97	0
6	1978	7	4	No	112	97	1
7	1981	8	10	1	41	100	0
9	1973	9	10	No	54	100	0
10	1974	10	10	No	19	86	0
Rafter		1	8	No	100	99	7

* Includes fibers, fibers in a matrix, and bundles

situations, but their optimum application varies from case to case The application of these principles are discussed below

Engineering controls

The brake washer assembly 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 washer assembly is evidenced by the very low exposures for the brake mechanics. Nineteen of the 20 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 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 10 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 10 brake jobs The importance of this source sample is that it shows dust fibers were not being propelled by the brake washer assembly unit liquid toward the other side of the vehicle. As noted earlier, TEM analysis of these samples show that more than 85% of the chrysotile fibers counted using the "A" rules would also have been counted using the "B" rules

TEM results were also used to evaluate the effectiveness of the brake washer assembly unit The TEM results are not directly comparable to the PCM data because TEM includes all size fibers whereas PCM includes only fibers longer than 5 um and with a diameter greater than about 0 3 um , and TEM includes only fibers identified as asbestos whereas PCM includes all fibers (larger than 5 um) The TEM personal sample results (Table 2) show asbestos fibers were controlled to very low levels with use of the brake washer assembly The personal sample arithmetic mean concentration and geometric mean concentrations were 0.003 and 0.009 fibers/cc, respectively, for all 10 brake jobs

Fender sample asbestos concentrations were very low, ranging from the detectable limit of 0 004 to a high of 0 040 fibers/cc The axle source samples were also very low, ranging from 0 004 to a high of 0 016 fibers/cc

Background and ambient asbestos concentrations by TEM averaged 0 002 fibers/cc These low asbestos levels indicate that the asbestos in the personal and source samples was from activities such as brake servicing and not from outdoor sources or from resuspended dust in the garage

The sampling at the Nashville Postal Service garage was conducted in mild weather (October), with some doors open most of the time Natural ventilation

Table 4

Work Task Analysis of Brake Inspection and Replacement

Step	Work Task	Brake Dust Exposure Sources
1	Use pneumatic wrench to remove five lugs from wheel	Loose dust around lugs and tire rim
2	Remove wheel from vehicle	
3	Remove brake drum and sets on floor	Loose dust from drum and brake components may become airborne
4	Worker positions brake assembly washer unit under brake assembly	
5	Worker uses wet brush stylus to clean brake components	
6	Worker removes brake components and cleans each piece	When brake components are not throughly washed in step 5, loose dust from components during removal and installation in steps 6 and 8
7	Worker cleans axle surface	
8	Worker assembles brake components and installs new brake shoes	
9	Brake drum is wet-washed with brake washer assembly unit, wiped clean, and put back on brake unit	
10	Wheel is put back on vehicle	
11	Wheel lugs are pneumatically tightened on wheel	Loose dust around lugs and tire rim

due to the open doors may have helped to minimize the airborne asbestos levels, although there was no measurable increase in the personal, source, or background levels when some doors were closed

Work Practice Results

Table 4 shows the work task analysis of a brake inspection and replacement job while using the brake washer 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 12 minutes

As seen from Table 4 asbestos exposure during brake maintenance and repair may occur during the initial tasks of removing the wheel and brake drum from the vehicle Good work practices observed by some of the workers to reduce these exposure points are the use of a wet brush on the wheel and on the back of the brake drum and assembly to suppress dust before removing the brake drum Bad work practices included using a dry rag to wipe down the brake drum and assembly as a substitute for the wet wash unit, the use of a hammer to loosen "frozen" brake drums without first suppressing dust with wet control methods, and taking soiled clothing home to wash

Demographic and work practices were obtained from interviews of eight workers All eight workers were male, ranged in age from 19 to 54 years, and the average age was 38 2 $\pm$ 12 8 years As a group these men had 4 0 $\pm$ 1.9 years experience as mechanics, and performed 5 6 $\pm$ 2 5 brake jobs per week The other job duties included general maintenance, engine tune-up, repair work, and use of hydraulic equipment Seven of the workers indicated their right hand was dominant in performing work, while one claimed to be ambidextrous Tools and equipment commonly used during brake maintenance and repair included brake spring remover, pliers, hammer, brake washer unit, solvent, dust mask, brake adjustment tool, brake shoe tool, power air tool; and impact wrench Five of eight employees indicated they were provided with training with regard to asbestos exposure during brake maintenance, the training lasted anywhere from one to eight hours, and usually took place when employees started working with the U S Postal Service Workers remembered from their training· the use of a respirator, clean-up procedures and safety precautions, and not to use compressed air to blow out brake dust All eight workers indicated they had a physical examination before being hired by the Postal Service, and all but one employee indicated having a physical exam within the past year, one employee indicated a physical exam in March 1985. Three of eight workers reported having an X-ray as part of their physical examination Analysis of workers with and without X-rays showed an age dependent pattern with all three workers who had X-rays being over 40 years of age 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 brake washer assembly unit Personal protective equipment worn by all workers included work clothing and a respirator, gloves and other items such as safety glasses and safety shoes were not indicated Shower facilities were available for all workers, however, only three indicated regular use before leaving work Two trainee workers reported they did not change out of their work clothes before leaving work The U S Postal Service provides work clothes and laundry service for the regular work force.

In summary, this information revealed that these workers were aware of the hazards of asbestos exposure while working on brakes In addition, they generally used control devices such as disposable quarter mask respirators for nuisance dust and the brake washer assembly unit when performing brake maintenance and repair

VI CONCLUSIONS AND RECOMMENDATIONS

The use of this brake washer assembly resulted in very 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 washer, 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 85% 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, all of which were quite low

Bulk sample results analyzed by TEM show that the brakes of the vehicles tested in this study contained chrysotile asbestos fibers and, therefore, had asbestos-type brakes Fibers found in the drums of the nine vehicles tested were between 83 and 100% chrysotile, with 2 vehicles having 100% chrysotile fibers 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

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) allowing the cleansing fluid to flow between the brake drum and brake support plate before the drum is removed, and (2) after removing the brake drum, throughly wetting the wheel hub and the back of the brake assembly to suppress dust and then thoroughly washing the brake support plate, brake shoes, and brake components used to attach the brake shoes before the operator starts to manually remove the old shoes

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

Mild weather with some of the doors open may have resulted in lower ambient levels than might occur during cold weather when the doors are normally kept closed

Since asbestos was identified in most brake dust samples, showers are recommended as a good practice before going home from work to remove any residual dust from the body, and a laundry service should be 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

Maintenance and regular changing of the brake washer assembly solution is 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	PCM Fibers/cc	Asbestos Fibers/Filter	TEM Asbestos Fibers/cc	Asbestos[2] M or X Fibers
25964	10-27-86	1	1976	Pers	I	367	1500	0 0041	2,377	0 006	0
25960	10-27-86	1	1976	Pers	I	360	1500	0 0042	–	–	–
25961	10-27-86	1	1976	Fend	I	911	1500	0 0016	19,012	0 021	0
25959	10-27-86	1	1976	Axle	I	1160	1500	0 0013	2,377	0 002	0
25955	10-27-86	1	1976	Bckg	I	1702	1500	0 0009	4,753	0 003	0
25962	10-27-86	1	1976	Bckg	I	1718	1500	0 0009	9,506	0 006	0
25963	10-27-86	1	1976	Amb	I	1413	1500	0 0011	2,377	0 002	0
25956	10-27-86	1	1976	Amb	I	1413	1500	0 0011	–	–	–
25953	10-27-86	2	1977	Pers	R	367	1500	0 0041	2,377	0 006	0
25951	10-27-86	2	1977	Pers	R	360	1500	0 0042	–	–	–
25954	10-27-86	2	1977	Fend	R	911	1500	0 0016	28,519	0 031	1
25957	10-27-86	2	1977	Axle	R	1160	1500	0 0013	2,377	0 002	0
25250	10-27-86	2	1977	Bckg	R	1732	1500	0 0009	–	–	–
25249	10-27-86	2	1977	Bckg	R	1763	1500	0 0009	–	–	–
25247	10-28-86	3	1977	Pers	R	360	1500	0 0042	33,272	0 092	5
25242	10-28-86	3	1977	Pers	R	367	1500	0 0041	–	–	–
25241	10-28-86	3	1977	Fend	R	1160	1500	0 0013	2,377	0 002	0
25248	10-28-86	3	1977	Axle	R	911	1500	0 0016	14,259	0 016	0
25246	10-28-86	3	1977	Bckg	R	1702	1500	0 0009	2,377	0 001	0
25245	10-28-86	3	1977	Bckg	R	1680	1500	0 0009	4,753	0 003	0
25243	10-28-86	3	1977	Amb	R	1469	1500	0 0010	4,753	0 003	0
25244	10-28-86	3	1977	Amb	R	1440	1500	0 0010	–	–	–
251000	10-28-86	4	1978	Pers	I	367	1500	0 0041	2,377	0 007	0
25999	10-28-86	4	1978	Pers	I	367	1500	0 0041	–	–	–
25238	10-28-86	4	1978	Fend	I	911	1500	0 0016	2,377	0 003	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	PCM Fibers/cc	TEM Asbestos Fibers/ Filter	TEM Asbestos Fibers/cc	Asbestos[2] M or X Fibers
2588	10-28-86	4	1978	Axle	I	1160	1500	0 0013	2,377	0 002	0
25237	10-28-86	4	1978	Bckg	I	1958	1500	0 0008	–	–	–
2556	10-28-86	4	1978	Bckg	I	1950	1500	0 0008	–	–	–
2554	10-29-86	5	1977	Pers	R	365	1500	0 0041	2,377	0 007	0
25988	10-29-86	5	1977	Pers	R	360	1500	0 0042	–	–	–
25993	10-29-86	5	1977	Fend	R	911	1500	0 0016	4,753	0 005	0
25994	10-29-86	5	1977	Axle	R	1160	1500	0 0013	2,377	0 002	0
25992	10-29-86	5	1977	Bckg	R	1807	1500	0 0006	2,377	0 001	0
25985	10-29-86	5	1977	Bckg	R	1800	1500	0 0006	2,377	0 001	0
25991	10-29-86	5	1977	Amb	R	1450	1500	0 0010	2,377	0 002	0
2552	10-29-86	5	1977	Amb	R	1445	1500	0 0010	–	–	–
25987	10-29-86	6	1978	Pers	I	360	1500	0 0042	2,377	0 007	0
2593	10-29-86	6	1978	Pers	I	365	1500	0 0041	–	–	–
2567	10-29-86	6	1978	Fend	I	918	1500	0 0016	2,377	0 003	0
25986	10-29-86	6	1978	Axle	I	1170	1500	0 0013	4,753	0 004	0
25981	10-29-86	6	1978	Bckg	I	1807	1500	0 0006	–	–	–
25978	10-29-86	6	1978	Bckg	I	1800	1500	0 0006	–	–	–
25970	10-29-86	7	1981	Pers	R	365	1500	0 0041	2,377	0 007	0
25969	10-29-86	7	1981	Pers	R	360	1500	0 0042	–	–	–
25975	10-29-86	7	1981	Fend	R	1160	1500	0 0013	2,377	0 002	0
25976	10-29-86	7	1981	Axle	R	1160	1500	0 0013	2,377	0 002	0
25966	10-30-86	8	1976	Pers	R	356	2000	0 0056	2,377	0 007	0
25965	10-30-86	8	1976	Pers	R	351	1500	0 0043	–	–	–
25967	10-30-86	8	1976	Fend	R	1170	1500	0 0013	2,377	0 002	0
2575	10-30-86	8	1976	Axle	R	918	1500	0 0016	2,377	0 003	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	PCM Fibers/cc	TEM Asbestos Fibers/ Filter	TEM Asbestos Fibers/cc	Asbestos[2] M or X Fibers
25974	10-30-86	8	1976	Bckg	R	2026	1500	0.0007	9,506	0.005	1
25968	10-30-86	8	1976	Bckg	R	2025	1500	0.0007	2,377	0.001	0
25973	10-30-86	8	1976	Amb	R	1400	1500	0.0011	2,377	0.002	0
25972	10-30-86	8	1976	Amb	R	1400	1500	0.0011	-	-	-
25234	10-30-86	9	1973	Pers	R	377	1500	0.0040	4,753	0.013	0
25233	10-30-86	9	1973	Pers	R	372	1500	0.0040	-	-	-
25232	10-30-86	9	1973	Fend	R	1177	1500	0.0013	47,531	0.040	0
25231	10-30-86	9	1973	Axle	R	926	1500	0.0017	4,753	0.005	1
25229	10-30-86	9	1973	Bckg	R	1514	1500	0.0010	-	-	-
25230	10-30-86	9	1973	Bckg	R	1500	1500	0.0010	-	-	-
25226	10-30-86	10	1974	Pers	R	366	1500	0.0042	2,377	0.007	0
25228	10-30-86	10	1974	Pers	R	365	1500	0.0041	-	-	-
25227	10-30-86	10	1974	Fend	R	1160	1500	0.0013	2,377	0.002	0
25225	10-30-86	10	1974	Axle	R	911	1500	0.0016	2,377	0.003	0
25958	10-27-86	1,2		Blank		0	1500		0	-	0
25952	10-27-86	1,2		Blank		0	1500		-	-	-
25240	10-28-86	3,4		Blank		0	1500		0	-	0
25239	10-28-86	3,4		Blank		0	1500		-	-	-
2573	10-29-86	5,6,7		Blank		0	1500		0	-	0
25979	10-29-86	5,6,7		Blank		0	1500		-	-	-
25982	10-29-86	5,6,7		Blank		0	1500		0	-	0
25980	10-29-86	5,6,7		Blank		0	1500		-	-	-
25235	10-30-86	8,9,10		Blank		0	1500		0	-	0
25236	10-30-86	8,9,10		Blank		0	1500		-	-	-
25223	10-30-86	8,9,10		Blank		0	1500		0	-	0
25224	10-30-86	8,9,10		Blank		0	1500		-	-	-

1 AM General DJ5D Jeep
2 M = Matrix fiber, X = Fiber extended beyond grid