IN-DEPTH SURVEY REPORT.

CONTROL TECHNOLOGY FOR BRAKE DRUM SERVICE OPERATIONS

AT

Ohio Department of Transportation
Maintenance Facility
Lebanon, Ohio

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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 DHEW), 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 carried out by 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. 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 health hazard prevention and 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 document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concepts or techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

Background

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

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

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

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

The primary objective of this NIOSH control technology assessment is the determination of the level of exposure to brake dust using various control techniques 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 the determination of additional research needs.

Description of Brake Servicing Operations

Each facility follows 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 then 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. Test vehicle is 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 which were reported to have good controls. These site visits were conducted to subjectively evaluate the control systems in place at these sites. Sites with desirable characteristics were selected for in-depth studies to evaluate the source control effectiveness.

There were a number of factors involved in the selection of specific sites. 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 garage. Selection of sites were made, as judiciously as possible, based on criteria including:

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

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

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

The conduct of in-depth surveys at a particular location was also dependent on the project officer's success in securing cooperation from the facility owner.

Health Effects

The health significance of the inhalation of chrysotile asbestos fibers is well documented: instances of mesothelioma in auto repair workers have been identified.(4,5,6) In a detailed examination of 90 union motor vehicle maintenance workers in New York City,(7) with 10 or more years of shop work, 29 percent had decreased vital capacity; the percentage increased with age and most markedly after 20 years from the onset of auto work. Many of the workers examined showed signs consistent with asbestosis, with observed changes noted in chest X-rays and indication of restrictive pulmonary function. The prevalence of these changes was significantly higher after 20 years exposure, a result expected after occupational exposure to asbestos.(8)

Much of the asbestos originally present in the unused brake shoe chemically degrades 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 break down product), or 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.

II. PLANT AND PROCESS DESCRIPTION

Plant Description

Ohio's Department of Transportation (ODOT) maintains twelve district headquarters throughout the state, and smaller installations in each county. This study was conducted at District 8 regional headquarters. This garage provides vehicle repair and maintenance for the cars, trucks, and specialized equipment assigned to the eight counties of Southwest Ohio. Occupying 21 acres of ground purchased from the State of Ohio Lebanon Correctional Institution, District 8 headquarters is located just south of Ohio Route 63 on Ohio Route 741 - approximately four miles west of the City of Lebanon in Warren County. As the newest of the ODOT regional headquarters (the installation was completed in 1970), it is a modern and well equipped facility.

The district garage is responsible for maintaining satisfactory performance of 180 large trucks, 250 pickup trucks, 90 passenger cars, 25 vans, 25 loaders, and a number of other specialized road maintenance units. Garage repairs include brake work, general maintenance, and engine overhauls - requiring a substantial amount of specialized auxiliary equipment.

Building No. 1, a 36,000 square foot, two-story structure, contains both the garage and auxiliary functions. These include: (1) offices for administration and traffic engineering, (2) testing labs and their offices, (3) body shop, (4) wash bay, (5) parts department, (6) carpentry shop, (7) welding shop, and (8) paint shop. Location of the garage and auxiliary shops 3 through 8 are identified in Figure 1. The total of 13,200 square feet of garage space is divided into two main sections. The first section, 7,200 square feet, in the center of the east side of the building is equipped and used exclusively for light duty vehicles - as many as 15 such vehicles at a time. The remaining area, a second section in the center of the west side of the building, is equipped and used for the district's heavy equipment - loaders, graders, dump trucks, etc.

Light vehicles enter through six garage doors on the east wall and the heavy equipment through five huge doors on the west wall. The light vehicle area is separated from the heavy equipment repair section by a double row of lighted work benches and mechanic work stations. Garage walls are 24 feet high, the lower half constructed of 8-inch concrete blocks and the upper half insulated metal siding. Roofing is 1-1/2-inch metal decking sprayed with 2-inch thick rigid insulation. Past tests have identified this insulating layer as cellulosic with no asbestos content. While asbestos is not part of the garage ceiling and wall insulation, it is a component of the insulation around the hot water pipe joints of the building heating system. Hoists are mounted overhead in both garage areas for raising and moving various vehicles.

Since vehicles are not normally dispatched from this garage, fairly regular operations are conducted on a one-shift basis from 7:30 a.m. to 4:00 p.m. by 11 veteran mechanics, 2 body men, and 3 welders. Most of the approximately 300 to 500 brake jobs performed yearly are handled by 5 to 6 mechanics. Union representation covers all the garage workers except management. Originally represented for a number of years by OCSEA (Ohio Civil Service Employees

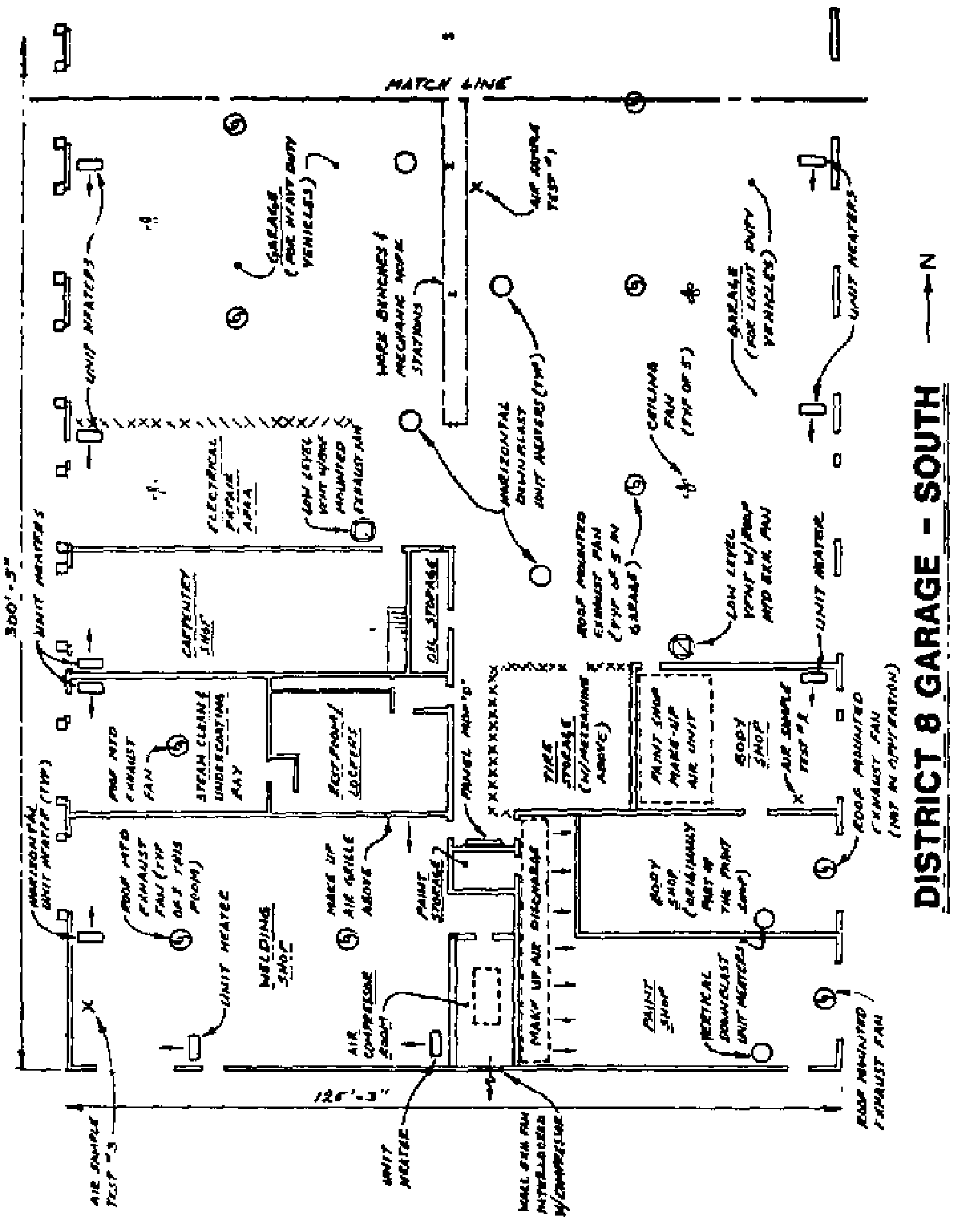

Figure 1
Floor Plan of ODOT Garage and Shops

Association), the workers have recently become members of a merged union comprising OCSEA and AFSCME (American Federation of State, County, and City Employees) Their new contract went into effect July 1, 1986

With the garage situated on high ground, prevailing wind currents blowing through open doors provide natural ventilation during the warm months of the year Exhaust fumes from vehicle engine testing are removed by means of flexible hoses fitted over exhaust system test pipes Underground floor ducts channel the fumes to vertical pipes rising alongside inner walls to exhaust fans discharging outside the building roof The garage and each of the auxiliary areas contains its own general ventilation system The repair areas have five 3,100 cfm roof exhaust fans Four exhaust grilles (mounted approximately 18 inches above floor level) are connected to four similar capacity roof-mounted fans All nine fans are interlocked with a 880 MBH (million Btu per hour) 12,000 cfm direct-fired make-up air heating unit which automatically runs when any of the fans are operating For general heating, the garage has six unit heaters mounted along the outer walls about 12 feet above the floor and five unit heaters suspended close to the ceiling These unit heaters, each thermostatically controlled, are supplied with hot water from a gas-fired boiler

In early 1986, results of a Health and Safety Survey were formally submitted to ODOT District 8 by their engineering consultants (M E Building Inc of Columbus, Ohio) Their report covered in detail the heating, ventilating, and lighting facility upgrading required to meet 1986 building facility code requirements Normal garage operation requires use of the exhaust fan ventilation systems to maintain minimum fume levels in the garage, and especially the mezzanine level of the parts department With these fans operating in the winter months, the garage becomes too cold unless the garage make-up air heating unit is also operating. Unfortunately, running the air make-up unit to maintain minimum garage air temperature during winter months reportedly causes overheating of the adjacent painting and body shops.

Process and Equipment Description

This State of Ohio garage has been using a vacuum/enclosure unit (Clayton Associates, Inc , Farmingdale, New Jersey) to minimize occupational exposure during servicing of all motor vehicle brakes since early in 1986 - during brake inspection, repair, and particularly brake lining replacement The vacuum/enclosure unit consists of an adjustable height glove box for completely enclosing the brake assembly (after wheel removal) and dust removal via hose connection to a three-stage vacuum dust filter assembly Figure 2 shows the enclosure and the filter and collection bag assembly (lower left); Figure 3 shows a mechanic working within the glove box, while Figure 4 is a detailed sketch of the dust filter assembly [15] The first stage filter bag is similar to a conventional home vacuum cleaner bag and removes coarse particles and a portion of the dust The second stage, a 12- by 12-inch square prefilter, is similar to home hot air furnace filters and removes a major portion of the dust. The third stage is a high efficiency particulate filter (HEPA) which has been tested as removing 99.999 percent of particles larger than 0 12 microns in size All three filters are standard items purchased from outside suppliers Filter life is dependent on usage and

Figure 2
Vacuum Enclosure Unit

Figure 3
Vacuum Enclosure Positioned on Wheel

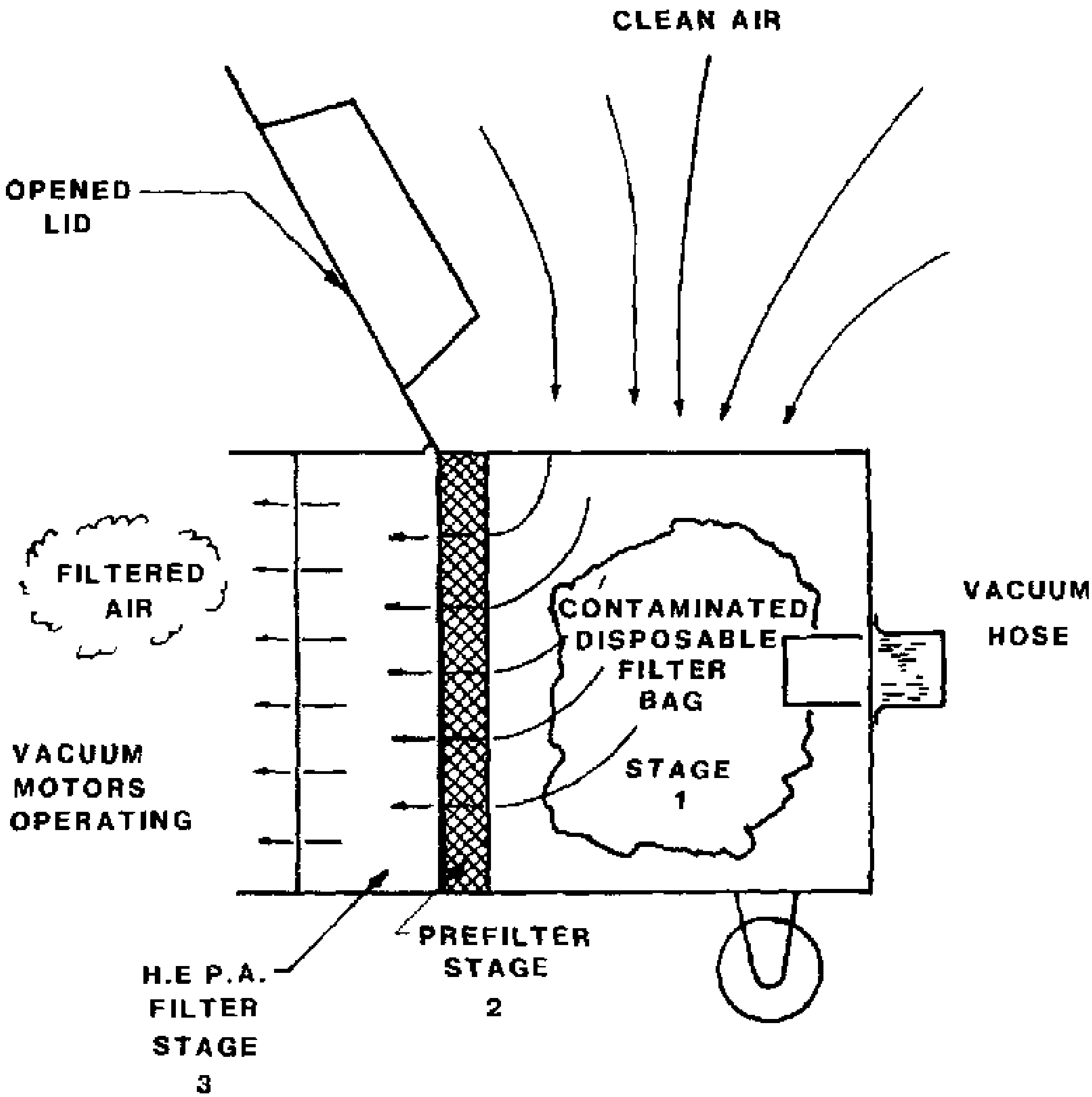

Figure 4
Dust Filter and Collection Bag Assembly
(Used with permission of Clayton Associates, Inc., Farmingdale, New Jersey.)

resultant total collection. With both vacuum pumps operating, the vacuum gauge mounted on the vacuum pump case normally shows about 4.5 inches water vacuum. When the vacuum reading drops to 1 to 2 inches after continued use, the bag and prefilter are subject to removal and replacement with new ones. It is estimated that under normal operations (up to 10 brake jobs per week), the first stage bag will likely need replacement in 1 to 2 months, the second stage prefilter in 3 to 12 months, and the third stage HEPA filter in 2 to 5 years.

This vacuum/enclosure is manufactured in two different size units: (1) a unit for brake drum assemblies up to 17 inches in diameter and (2) a unit for brake drum assemblies up to 20 inches in diameter. The unit purchased by this garage was the larger model.

The manufacturer's recommended sequence of steps for use of their unit in brake shoe servicing is:

1. Raise the vehicle, remove the wheel, and set it safely aside.

2. Hoist the vehicle to the level which best suits the mechanic doing the job.

3. Roll the vacuum/enclosure unit in front of the wheel and start its vacuum pumps.

4. Make sure all the necessary auxiliary items are placed within the clean enclosure. Next move the entire unit forward so the enclosure completely envelops the brake assembly (be sure the rear side four way flap tightly wraps around the axle).

5. First order of business, and sometimes quite difficult, is removal of the wheel drum. Using the gloves and either a hammer or mallet for loosening the drum, the mechanic removes the drum and sets it safely aside face up within the enclosure.

6. Next, the vacuum hose with attached brush is manipulated to remove loose dust from the inside of the wheel drum, the surface of the brake shoes and related assembly, and the inside surfaces of the Lexan enclosure. This intensive vacuuming removes only part of the fine dust which clings to the various surfaces.

7. To remove the remainder of the fine dust, the brake is blown with compressed air and brushed. This generates dust clouds within the enclosure, gradually dissipating as the vacuum pumps pull the contaminated air through the sequence of three dust filters.

8. When the brake assembly and enclosure interior surfaces are cleaned of residual dust, the vacuum/enclosure unit is removed from the brake assembly and the brakes serviced.

The sequence of steps 1 through 8 normally occupies not more than a 5-minute period.

The glove box enclosure is constructed of clear Lexan plastic with the opaque backside comprising four overlapping neoprene fabric flexible strips These allow easy passage of the brake drum assembly into the enclosure and also provides the essential tight fit around the axle. Fastened to the front face of the enclosure and extending inwardly are two long gloves into which the mechanic shoves his hands and arms up to and sometimes past the elbows These normally loose-fitting gloves permit the mechanic to readily operate the following items which either penetrate the enclosure or are kept within it to assist dismantling of the brake drum and subsequent cleaning of the brake linings, pads, and other elements of the brake system These items comprise (1) a conventional compressed air gun, (2) a vacuum line with brush attachment, (3) a hammer and/or mallet, and (4) a separate brush The entire hood enclosure can be quickly moved up or down the four corner frame posts to permit servicing of motor vehicle brakes at nearly floor level as well as at higher levels A lift rack will position the vehicle to suit the stature and working levels for the various individual mechanics. Consequently, the hood enclosure is positioned at this working level The vacuum enclosure unit has an adequate power cord to reach the working bays and rolls readily to its destination

An important but infrequent operation, not observed during this in-depth plant survey, is the removal and replacement of the various filters from the vacuum/enclosure units The first stage bag filter is normally removed when about half full and the second stage freestanding prefilter removed when the unit vacuum gauge has dropped into the 1 to 2 inch water vacuum range The operator conducting this operation should wear a NIOSH-approved respirator for asbestos handling and follow the following sequence of steps in accordance with the recommendation of their manufacturer of the vacuum/enclosure unit

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

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

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

Disposal of the resultant waste containers should be done in accordance with Environmental Protection Agency (EPA) regulations detailed in Title 40, CFR, Part 61, Subparts A and B [16] These require that waste containers enclosing asbestos dust shall be buried in an EPA-approved hazardous waste disposal site

Removal of the third stage HEPA filter and especially its careful replacement to prevent any bypass leakage poses a problem With this in mind, the manufacturer of this unit has introduced an exchange service involving shipment of the complete basic assembly to the vacuum/enclosure plant and its immediate replacement by another reconditioned assembly containing a new HEPA assembly

The mechanics worked confidently with this vacuum enclosure unit and felt it did a good job of containing and collecting brake dust when employed on cars and light pickup trucks Their mass comment was that their unit was bulkier than necessary for light vehicles However, the situation appears different with large trucks and/or specialty units equipped with double wheel assemblies The brake assembly of these vehicles is different and much heavier than the light vehicles With the heavy vehicles the current model is not nearly as effective as for light vehicles Additionally, the high initial cost of the vacuum/enclosure unit may discourage purchase by small garages

In this study, eight smaller vehicles and one large dump (salt) truck were evaluated. The smaller vehicles, all with rear drum brakes, included two automobiles, one passenger van, and five half-ton pickup trucks The nine vehicles ranged in age from 1977 to 1985 with total vehicle mileage ranging from 16,000 to 106,000

III METHODOLOGY

Air Sampling and Analysis

Personal samples were collected in duplicate on 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 0 005 fibers/cc by PCM analysis

Area (source, background, and ambient) air samples were collected on cellulose ester filters Two source samples were collected 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 determine leakage past enclosure seals, or during tasks where the enclosure cannot be used. The minimum volume collected (840 liters) allowed a limit of detection of 0 002 fibers/cc by PCM Two background samples were collected at approximately 7.0 lpm for a 4-hour period encompassing pre- and post-brake job activities The 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 ambient samples were collected at 3 0 lpm for an approximate 8-hour period The ambient samples were used to determine environmental background levels of asbestos The minimum volume collected (1,400 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) by UBTL, Inc In addition to PCM analysis, approximately 90 percent of these samples were analyzed by light-field Transmission Electron Microscopy (TEM), using NIOSH equipment 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 For TEM analysis, fiber type and size distribution were obtained for all fibers (greater than approximately 0 25 um) 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

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 non-asbestiform constituents was performed using energy dispersive X-ray analysis

Real-Time Sampling

During the entire brake maintenance operation, relative respirable airborne dust levels were measured and recorded at four second intervals. Two Hand-held Aerosol Monitors (HAMs) and a personal computer (Apple II Plus) were used to measure and record the dust levels The HAMs (PPM, Inc , Knoxville, TN) 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 a 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 relative dust levels on a disk from which a plot was later made By comparing the plot to a video recording of that brake maintenance operation, dust sources due to work practices and enclosure leaks could be identified

The HAM's electro-optical system provides instantaneous measurements of respirable dust levels in mg/m^3 at one second intervals The HAM's data logger 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

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

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.

Work Practices

An ergonomic evaluation of brake maintenance was conducted to discern potential asbestos dust exposure during manual brake inspection and replacement while using the vacuum/enclosure. A representative worker was videotaped during routine brake inspection and brake replacement tasks on a 15 passenger van. Work cycle times and work analysis was performed from the video tapes in the NIOSH laboratory. Cycle times were taken while running the video tapes at normal speed while work analysis was conducted at both normal speed and by "freeze frame" techniques. Work analysis included breaking the job into general tasks which could be matched with real-time analysis of airborne dust and asbestos levels during brake inspection and replacement. Work tasks which could cause personal exposure to airborne asbestos were identified and recommendations to reduce such exposures are provided.

Interviews also were conducted with three Department of Transportation maintenance workers who do brake work. Data were collected on a standardized questionnaire (shown in Appendix B), and analyzed on a popular software spreadsheet (Symphony). Basic descriptive, demographic, and work history data were gathered from each worker. Information from the interviews were compared to work place observations by the NIOSH research team.

IV. RESULTS

Individual filter sample results for airborne asbestos fibers are presented in Table 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 sample concentrations for the brake mechanics averaged less than 0.004 fibers/cc with no samples above the detection limit of 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 0.001 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.

All 18 personal samples taken during nine brake jobs were below the detectable limit of 0.004 fibers/cc. Therefore, the mechanics' exposure was well below the OSHA standard of 0.2 fibers/cc, the action level of 0.1 fibers/cc, and the NIOSH recommended exposure limit of 0.1 fibers/cc for asbestos based on 8-hour time-weighted average concentration.[19] 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.

Table 1

Phase Contrast Microscopy Concentrations for 9 Vehicles
(fibers/cc)

Sample Type	Number of Samples	Arithmetic Mean	Range
Personal	18	[0.004	[0.004
Fender	9	[0.002	[0.002
Axle	9	[0.001	[0.002
Background	10	[0.001	[0.002
Ambient	12	[0.001	[0.001

[= less than

Table 2a

TEM Concentrations for 9 Vehicle Brake Jobs
(fibers/cc)

Sample Type	Number of Samples	Arithmetic Mean	Standard Deviation	Range	Geometric Mean
Personal	18	0.031	0.066	[0.013–0.294	0.012
Fender	9	0.025	0.049	[0.004–0.161	0.007
Axle	9	0.044	0.101	0.003–0.330	0.008
Background	11	0.003	0.004	[0.002–0.012	0.001
Ambient	10	0.004	0.004	[0.003–0.016	0.002

[= less than

Table 2b

TEM Concentrations for 8 Vehicle Brake Jobs
(Excluding Large Salt Truck)
fibers/cc

Sample Type	Number of Samples	Arithmetic Mean	Standard Deviation	Range	Geometric Mean
Personal	16	0.017	0.018	[0.013-0.065	0.010
Fender	8	0.008	0.009	[0.004-0.031	0.005
Axle	8	0.008	0.008	0.003-0.028	0.005
Background	11	0.003	0.004	[0.002-0.012	0.001
Ambient	10	0.004	0.004	[0.003-0.016	0.002

[= less than

Only 3 of the 58 samples analyzed by PCM were 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 Tables 2a and 2b All fibers identified as chrysotile or amphibole asbestos with an aspect ratio of 3 1 or greater were counted (fibers 0 25 microns and longer are included) A few samples contained fibers that were not identified (no I D), but could possibly be asbestos

The arithmetic mean TEM concentration (Table 2a) for all personal samples was 0.031 fibers/cc, with a standard deviation of 0 07 fibers/cc The mean personal sample concentration was higher than the background levels in the building which averaged 0 003 fibers/cc, and the outdoor ambient levels which averaged 0 004 fibers/cc There is no statistical difference between the background and ambient average concentrations Source samples taken at the axle averaged 0 044 fibers/cc, while samples taken at the fender (above the wheel) averaged 0 025 fibers/cc

TEM average results excluding the large salt truck are shown in Table 2b The arithmetic mean TEM concentration for personal samples was 0 017 fibers/cc, and for both the fender and axle source samples the TEM mean concentration was 0 008 fibers/cc The TEM source sample concentrations for the eight smaller vehicle brake jobs were only slightly above background levels.

Asbestos fibers (chrysotile or amphibole) greater than or equal to 5 um in length were found in only 8 of the 57 samples analyzed by TEM Two personal samples showed fibers greater than 5 um Asbestos fibers that were in a matrix (partially hidden by particles) and X fibers - fibers that extended into another field - are not included in Table 2, but are denoted in Appendix A Eighteen of 57 samples analyzed by TEM contained M or X asbestos fibers, and seven of these samples would show substantially higher concentrations had M or X fibers been included.

Field blanks were prepared for each sampling date and submitted for PCM and TEM analysis Twelve blanks were analyzed by PCM and 10 blanks by TEM and these results are shown in Table 1 of Appendix A Analysis by PCM show all blanks were below detectable limits One of the 10 blank samples analyzed by TEM contained a single asbestos fiber, a second blank contained an X fiber. Because of the very low asbestos fiber counts on the blanks, no blank correction was made to the TEM sample results

Bulk samples were collected from the rear wheel drums of each of the nine vehicles tested In addition, a rafter sample and a quality control bulk sample were collected and analyzed The bulk sample results are presented in Table 3 From 54 to 100 percent of the fibers in the 9 brake drum bulk samples were chrysotile, with five of the nine samples containing 100 percent chrysotile asbestos fibers None of the brake drum bulk samples contained amphibole fibers From 1 to 30 percent of asbestos fibers and bundles were longer than 5 microns Thirty percent of the fibers from brake job No 3 bulk sample (a half-ton pickup truck) were larger than 5 um The remaining eight bulk samples contained 12 percent or fewer chrysotile fibers longer than

Table 3

Bulk Sample Result

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	15 pass van	22	3	No	7	65	3
2	1/2 ton pickup	16	4	No	106	100	12
3	1/2 ton pickup	19	6	No	56	54	17
4	6 pass auto	17	10	No	27	77	2
5	1/2 ton pickup	6	1	No	163	100	1
6	salt (dump) truck	8	1	No	100	100	11
7	2 dr pass auto	2	1	No	129	100	7
8	1/2 ton pickup	1	1	No	115	100	1
9	1/2 ton pickup	15	10	No	69	100	1
Rafter		18	10	20%	70	85	5
Quality Control		10	1	No	92	100	41

* Includes fibers, fibers in a matrix, and bundles.
] = greater than

5 microns. The rafter sample contained 65 percent chrysotile and 20 percent amphibole fibers with 5 percent of the asbestos fibers larger than 5 microns.

Real-Time Sampling Results

Real-time total respirable 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 six of the nine brake maintenance jobs including one van, one car, one large salt truck, and three half-ton pickup trucks. Three different operators performed the brake maintenance jobs on these six vehicles.

The real-time data results and review of the video indicated brief elevated respirable dust levels during certain phases of the brake maintenance operations. These brief peaks represented on average less than 3 percent of actual brake maintenance job. The brief peak dust levels did not always occur during the same work phases for each job. Peaks usually occurred during the air washing cycle and the physical removal of the brake drum from the wheel. The most frequent peak occurred during the air-washing step. At times, the air gun would inadvertently be aimed at the back of the enclosing flap on the vacuum/enclosure unit and force some dust-laden air out of the enclosure. This took place during servicing of 3 of the 12 wheels evaluated and the peaks averaged about 10 seconds each time. The HAMs could identify peak dust levels which were 2 to 5 times above the background levels.

Peaks occurred when the vacuum/enclosure unit was removed from the vehicle for 2 of the 12 wheels monitored. The duration of these peaks was about 8 seconds with levels being one to two times that of the background levels. Peaks occurred on 2 of the 12 wheels when the brake drum was taken out of the vacuum/enclosure enclosure, these peaks lasted 8 seconds and were two to three times the background level. The combination of all these peaks increased average dust concentrations no more than 0.1% above the background levels.

Real-time data obtained during servicing of the large salt truck showed peak emissions differed markedly from the five smaller vehicles evaluated. The drums on the salt truck were too large and heavy for the workers to manipulate inside the enclosure; therefore, the drums had to be removed before the vacuum/enclosure unit was installed and the brake assembly cleaned.

The major dust releases for the salt truck occurred before application of the vacuum/enclosure. One drum proved to be especially difficult and time consuming to remove, taking nearly 15 minutes versus 5 minutes for the second drum. Respirable dust levels exceeded background levels during about 1 of the 15 minutes required to pull the one drum with peak levels as much as 20 times greater than the background levels.

Dust exposures appeared to be also dependent on the mechanic. One mechanic performed four of the brake maintenance operations. The duration of elevated dust exposures during his brake maintenance procedures averaged less than 0.4 percent of the time versus over 1 percent for a second mechanic.

As might be expected, the peak dust exposure period was 9 times longer for brake shoe inspection and replacement than for brake inspections only. (The dust concentration exceeded background levels 4.5 percent of the maintenance period for brake replacement, as opposed to 0.5 percent for inspection only). Brake replacement averaged about twice as long to complete as brake inspections, one hour versus a half hour.

V. CONTROL TECHNOLOGY

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

Engineering controls

The vacuum/enclosure unit is used at this garage to contain and collect all brake lining dust (including potentially hazardous asbestos fiber content). The vacuum/enclosure unit (which is fully described in Section II) is used during all brake inspection, repair, and brake lining replacement. The unit is applied during certain brake servicing tasks: removal of the wheel drum, vacuuming loose dust, brushing, blowing with compressed air, and more vacuuming. In this study, the entire brake service job was monitored, although not all tasks involve use of the vacuum/enclosure unit. The results discussed below represent fiber (PCM) and asbestos (TEM) concentrations during the entire brake job consisting of both rear wheels.

The effectiveness of the vacuum/enclosure is evidenced by the very low exposures for the brake mechanics. A total of 18 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 rear wheel so that this sample included dust emissions from both wheels. The fender sample concentration for each of the nine brake jobs was less than 0.002 fibers/cc. The other source sample, hung over the axle, showed concentrations of 0.002 fibers/cc or less for all nine brake jobs. The importance of this source sample is that it shows dust fibers were not being blown out the back of the vacuum/enclosure unit toward the other side of the vehicle.

TEM results were also used to evaluate the effectiveness of the vacuum/enclosure 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 um; and TEM includes only fibers identified as asbestos whereas PCM includes all fibers (larger than 5 um). The TEM personal sample results (Tables 2a and 2b) show asbestos fibers were controlled to very low levels with use of the vacuum/enclosure. The personal sample arithmetic mean concentration and geometric mean concentrations were 0.031 and 0.012 fibers/cc, respectively, for all nine brake jobs and 0.017 and 0.010 fibers/cc, respectively, for the eight smaller vehicle brake jobs.

Fender sample asbestos concentrations, except for the salt truck, were very low ranging from 0.001 to 0.031 fibers/cc, the axle source samples were also very low ranging from 0.003 to 0.028 fibers/cc. The two relatively high concentrations (0.161 and 0.330 fibers/cc) were for the fender and axle samples on the large salt truck. These samples were taken on the fender and axle while replacing the brakes for a salt truck, the only large vehicle evaluated at this facility. Because of the large size of the wheels, the drum had to be removed before the vacuum/enclosure unit could be placed on the wheel. Two mechanics struggled to get the drum off the wheel including pounding of the drum, and this may account for the higher concentrations at the fender and axle. One of the personal samples showed no asbestos fibers, while the other sample was almost five times the highest personal concentration measured for other vehicles by TEM.

Background and ambient asbestos concentrations by TEM averaged 0.003 and 0.004 fibers/cc, respectively. 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 Lebanon ODOT garage was conducted in mild weather (July-October) with doors open except for the evaluation of the last vehicle (No. 9) which was performed with doors closed. Natural ventilation due to the open doors may have helped to minimize the airborne asbestos levels, although there was no increase in the personal, source, or background levels when vehicle No. 9 was evaluated with the doors closed. It may be worthwhile to conduct a follow-up evaluation of two or three more brake jobs in the winter to see if closed doors do in fact result in increased asbestos levels.

The vacuum/enclosure unit was evaluated for brake jobs on eight small and medium size vehicles: two automobiles, one van, and five pickup trucks; plus one large salt dump truck. The use of the vacuum/enclosure resulted in very low exposures based on personal samples, and very low asbestos emissions (release of asbestos) based on source samples; however, the low exposures and low emissions do not rule out the possibility that less sophisticated control methods or equipment may satisfactorily control asbestos during brake servicing. In this study, only one large vehicle was evaluated. This evaluation showed that higher asbestos concentrations were measured (by TEM) at the fender above the wheel and at the axle and points to the potential difficulty of using the vacuum/enclosure for large vehicles.

Work Practice Results

Table 4 shows the brake inspection work tasks and potential brake dust exposure sources during these work activities. Analysis of both rear wheels for the 15 passenger van shows the average work cycle time for a one-wheel brake inspection task to be 16.18 ($\pm$1.7) minutes.

Table 5 shows the brake maintenance and replacement tasks and potential brake dust exposure sources. The average work cycle time for a one-wheel brake inspection and replacement task was 25 minutes.

Brake dust emissions may be a problem during steps 1, 2, and 4 for brake inspection (Table 4), and during steps 1, 2, 4, 8, 9, and 11 for brake inspection and replacement (Table 5). These emission sources may be minor compared to the amount of brake dust inside the plexiglas enclosure. The advantage of the enclosure is that it is under negative pressure while the vacuum is running, thus reducing the potential for airborne asbestos to leak from the chamber. The disadvantage is that workers who are not well trained to operate and maintain the vacuum/enclosure unit may greatly increase their personal exposure to brake asbestos through poor work practices.

Work practices may affect worker dust exposure through: (1) use of the pressurized air hose forcing the vacuum/enclosure diaphragm (in the back) open and releasing airborne dust from the chamber; (2) incomplete air washing and vacuuming of brake dust; (3) trapped dust behind brake components which may become airborne during change and replacement; and (4) poor maintenance of vacuum/enclosure unit (i.e., not changing filters regularly, and thorough cleaning of chamber). It was also noted that vacuum/enclosure glove size may be a problem for workers who have large muscular hands where the glove wrist may restrict worker hands from being properly seated into the gloves. When this happens worker performance and dust removal efficiency may be effected. The manufacturer is working on the glove fit problem.

This vacuum/enclosure unit appears to be an effective device for dust control. However, from an ergonomic point of view the unit is somewhat cumbersome to use and maintain. As noted above, brake inspection took approximately 16 minutes, while brake inspection and replacement took 25 minutes per wheel. Much of this time was spent on installation and use of the vacuum/enclosure enclosure unit. In addition, because this is a dry control device (as opposed to a wet control device) the potential for residual brake dust to become airborne is always present. Therefore, training in the operation and maintenance of this unit is important for developing good work practices which could reduce potential brake asbestos exposure.

Questionnaire Results on Work Practices, Personal Protective Equipment, and Hygiene

Three workers were interviewed using a standardized questionnaire (Appendix B, Figure 1). All three workers were male, ranged in age from 22 to 38 years, work experience from one to six years, and performed an average of two brake changes per week. Other work duties included clutch work, transmission, rebuilding motors, and general repair. All three workers were right handed

Table 4

Work Task Analysis of Brake Inspection

Step	Work Task	Brake Dust Exposure Sources
1	Remove hubcap	Loose dust around and inside hubcap
2	Use pneumatic wrench to remove nine lugs from tire	Loose dust around lugs and tire rim
3	Remove Tire from automobile	
4	Use pneumatic wrench to remove seven internal lugs	Loose dust around lugs and brake drum
5	Remove axle shaft from brake housing	
6	Install vacuum/enclosure unit on brake housing	
7	Turns on vacuum unit, inserts hands into vacuum/enclosure gloves, and removes brake drum	Note dust exposure contained in vacuum/enclosure see-through plexiglas dome during next series of steps
8	Uses right hand to activate pressurized air hose to blow dust from brake housing and drum, while left hand holding vacuum tube and brush is used to vacuum dust from brake surfaces	
9	Turn off vacuum/enclosure unit and remove from brake housing	
10	Inspect brake shoes, housing, and drum for wear and repair.	
11	If O K. reinstall brake drum on brake housing, reinsert axle shaft, install internal lugs, tire, and external studs	

Table 5

Work Task Analysis of Brake Inspection and Replacement

Step	Work Task	Brake Dust Exposure Sources
1	Remove hubcap	Loose dust around and inside hubcap
2	Use pneumatic wrench to remove five lugs from tire	Loose dust around lugs and tire rim
3	Install vacuum/enclosure on brake housing	
4	Turns on vacuum unit, inserts hands into vacuum/enclosure gloves, and removes brake drum	Note dust exposure contained in vacuum/enclosure see-through plexiglas dome during next series of steps
5	Uses right hand to activate pressurized air hose to air wash dust from brake housing and drum, while left hand holding vacuum tube and brush is used to vacuum dust from brake surfaces.	
6	Turn off vacuum/enclosure unit and remove from brake housing	
7	Inspect brake shoes, housing, and drum for wear and repair	
8	Use wire brush to scrape brake housing	Brake dust may become airborne during wire scraping
9	Removes brake springs, washers, adjuster, cable guide, parking brake link, and primary and secondary shoes	Trapped brake dust behind brake components may become airborne
10	Replace primary and secondary shoes and any other components that need replacing	
11	Assemble shoes, brake springs and other components	Trapped brake dust on brake housing may become airborne
12	Mount tire, and tire lugs	

and used this hand most often during work. Tools commonly used during brake maintenance were: air impact wrench, screwdriver, hammer, brake pliers, spring remover, air hose, wire brush, pliers, and needle-nose pliers. Workers said one to four hours of training was provided for using the vacuum/enclosure unit. They said the things remembered most about the training was how to properly use the unit, and the health hazards associated with asbestos exposure. None of the workers interviewed said they had a physical examination before being hired. Two of the workers said they use a fluidized brake cleaner to suppress brake dust trapped behind brake parts to decrease their exposure after taking the vacuum/enclosure unit off the brake housing. Workers said before getting the vacuum/enclosure unit that asbestos which fell to the floor was swept up after sprinkling "Floor Dry" over the dust. None of the workers used personal protective equipment. However, showers were provided for workers who wanted to shower before going home. A laundry service provided five pairs of clean work clothes for workers who paid approximately six dollars per week. One worker did not shower or change into clean work clothes because he worked a second job.

Specific worker suggestions and complaints about the vacuum/enclosure unit were: (1) the unit is too big in some instances and could not be easily maneuvered between cars; (2) when brake drums are hard to remove the vacuum/enclosure unit cannot be used until drums are loosened with a hammer, this may cause loose asbestos to become airborne, (3) have to adjust truck height to fit vacuum/enclosure unit when working on floor (the vacuum/enclosure unit can be adjusted up but not down below its base height); (4) the vacuum/enclosure unit is an economic disadvantage when working at a flat rate versus an hourly rate because of the extra tasks involved in using it; (5) knee pads should be provided for working low to the ground during brake inspection and replacement; (6) vacuum/enclosure flap enclosures in back of the unit may become loose after several brake jobs and the seal may not contain the brake dust as effectively as when new; (7) work visibility may also become a problem after several brake jobs because the inside of the vacuum/enclosure plexiglas dome gets dirty and is hard to clean, also the outside may become scratched and impair visibility; (8) there are no vacuum hose attachments on the vacuum/enclosure unit to keep hose out of the way after use. The workers at this maintenance shop fabricated a hose hook (Appendix B, Figure 2) to keep the hose off the floor and in good repair, (9) the vacuum filter was checked and found to be 1/2 full after four months of operation where four brakes per week were inspected and/or replaced. The workers thought the vacuum filter was very good.

Monitoring

No medical monitoring is conducted.

VI. CONCLUSIONS AND RECOMMENDATIONS

The use of this vacuum/enclosure unit for smaller vehicles, such as pickup trucks, vans, and automobiles, resulted in very low exposures to fibers (PCM) and very low asbestos exposures (TEM) based on personal samples. For larger vehicles -- only one large vehicle was evaluated in this study -- the vacuum/enclosure can be applied on a limited basis. Personal exposures to fibers were low while using the vacuum/enclosure to service the brakes of a large salt truck; but one of the two personal samples analyzed by TEM while servicing the salt truck showed the asbestos fiber concentration to be almost five times higher than the highest personal concentration that occurred while servicing the smaller vehicles. Two source samples taken at the fender and axle while servicing the salt truck showed relatively high asbestos concentrations.

The use of the vacuum/enclosure resulted in very low asbestos exposures, and very low asbestos emissions (release of asbestos) for the eight smaller size vehicles tested; however, these low exposures and low emissions do not rule out the possibility that less sophisticated control methods or equipment may satisfactorily control asbestos during brake servicing.

Differences among the eight smaller and medium size vehicles tested in the study were very small based on TEM results. The brake mechanics highest exposure for each of the three types of vehicles tested including five pickup trucks, two automobiles, and one van were: 0.05, 0.01, and 0.03 fibers/cc respectively compared to a detection limit of 0.01 fibers/cc for personal samples. These data show no trend or excursion due to vehicle type. (The TEM results include asbestos fibers of any size, measured using 17,600X magnification.)

Fender and axle source sample results showed no major differences among the eight smaller vehicles tested. Fender and axle samples for the salt truck were about an order of magnitude higher than for the smaller vehicles. There was almost no difference between brake inspections and brake replacements based on TEM results.

TEM results were of much greater value than PCM results for evaluating the vacuum enclosure device. The primary value of the PCM data was to demonstrate that exposures were well below the OSHA standard and emission of fibers were very low. TEM results allowed comparison among vehicle types and between personal or source samples and background and ambient levels.

Bulk sample results analyzed by TEM show that the rear brakes of the vehicles tested in this study contained chrysotile asbestos fibers and, therefore, had asbestos-type brakes. The drums of the nine vehicles tested contained between 54 and 100 percent chrysotile fibers with 5 vehicles having 100 percent chrysotile fibers. Less than one percent of the material (dust) in each the bulk samples was asbestos. The rafter sample collected in the garage contained 85 percent asbestos fibers; but less than 1 percent of dust in the sample was asbestos.

An analysis of the video and real-time data indicates that some dust emission peaks may be reduced by altering work practices such as: (1) leaving the vacuum on while installing and removing the unit from the vehicle and when removing the brake drum from the enclosure; and (2) operate the air gun inside the enclosure so as not to aim it at the enclosing flap of the vacuum/enclosure unit.

The vacuum/enclosure unit appears to be an effective device for dust control, but from an ergonomic point of view, the unit is somewhat cumbersome to use and maintain. Much of the time for brake inspection was spent on installation and use of the vacuum/enclosure unit.

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

A follow-up evaluation which includes at least two brake service jobs during the cold weather months is recommended to assess the effect of closed doors on asbestos levels.

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Appendix A

Table 1

Sample Number	Date	Brake Job No	Vehicle Type	Make	Year	Sample Type	Repl or Insp	Dry Bulb Temp	Wet Bulb Temp	Volume	PCM Fibers/ Filter	PCM Fibers/cc	TEM Asbestos Fibers/ Filter	TEM Asbestos Concentration Fibers/cc	TEM Asbestos N or X Fibers* Counted
2520	29-Jul-86	1	van 15 pass	Ford	1983	pers	insp	80	68	366	1500	0 0041	19012	0 052	1
2510	29-Jul-86	1	van 15 pass	Ford	1983	pers	insp	80	68	366	1500	0 0041	1426	0 004	0
2523	29-Jul-86	1	van 15 pass	Ford	1983	axle	insp	80	68	1434	1500	0.0010	14259	0 010	13
2534	29-Jul-86	1	van 15 pass	Ford	1983	fend	insp	80	68	1140	1500	0 0013	1426	0 001	0
2517	29-Jul-86	1	van 15 pass	Ford	1983	bckg	insp	80	68	1523	1500	0 0010	1426	0 001	0
251	29-Jul-86	1	van 15 pass	Ford	1983	bckg	insp	80	68	1540	1500	0 0010	1426	0.001	0
2547	29-Jul-86	1	van 15 pass	Ford	1983	amb	insp	80	68	1296	1500	0 0012	4753	0 004	0
2524	29-Jul-86	1	van 15 pass	Ford	1983	amb	insp	80	68	1296	1500	0.0012	4753	0.004	0
2541	30-Jul-86	2	truck-h ton	Dodge	1985	pers	insp	86	68	360	1500	0 0042	9506	0.026	3
253	30-Jul-86	2	truck-h ton	Dodge	1985	pers	insp	86	68	360	1500	0 0042	1426	0 004	0
2531	30-Jul-86	2	truck-h ton	Dodge	1985	fend	insp	86	68	778	1500	0 0019	23765	0 031	0
2522	30-Jul-86	2	truck-h ton	Dodge	1985	axle	insp	86	68	790	1500	0 0019	9506	0 012	2
2581	30-Jul-86					bckg	insp	86	68	2430	na	-	1426	0 001	0
2538	30-Jul-86					bckg	insp	86	68	781	na	-	9506	0.012	0
2549	30-Jul-86					bckg	insp	86	68	2017	na	-	4753	0 002	0
2526	30-Jul-86					amb	insp	86	68	1401	1500	0 0011	1426	0 001	0
2516	30-Jul-86					amb	insp	86	68	1401	1500	0 0011	1426	0 001	0
25117	30-Jul-86	3	truck-h ton	Dodge	1985	pers	insp	86	68	363	1500	0 0041	1426	0.004	0
2514	30-Jul-86	3	truck-h ton	Dodge	1985	pers	insp	86	68	369	1500	0 0041	4753	0.013	0
25134	30-Jul-86	3	truck-h ton	Dodge	1985	fend	insp	86	68	784	1500	0 0019	1426	0.002	0
2513	30-Jul-86	3	truck-h ton	Dodge	1985	axle	insp	86	68	796	1500	0 0019	4753	0 006	0
25115	05-Aug-86	4	auto 6pass	Plym	1979	pers	repl	78	66	396	1500	0 0038	4753	0 012	0
257	05-Aug-86	4	auto 6pass	Plym	1979	pers	repl	78	66	396	1500	0 0038	4753	0 012	0
2533	05-Aug-86	4	auto 6pass	Plym	1979	axle	repl	78	66	1542	1501	0 0010	1426	0.001	3
2527	05-Aug-86	4	auto 6pass	Plym	1979	fend	repl	78	66	1828	1500	0 0008	14259	0 008	2
2537	05-Aug-86	4	auto 6pass	Plym	1979	bckg	repl	78	66	2093	1500	0.0007	4753	0 002	0
25144	05-Aug-86	4	auto 6pass	Plym	1979	bckg	repl	78	66	2059	1500	0.0007			
25138	05-Aug-86	4	auto 6pass	Plym	1979	amb	repl	78	66	1254	1500	0.0012	9506	0.008	1
2530	05-Aug-86	4	auto 6pass	Plym	1979	amb	repl	78	66	1254	1500	0 0012			
25142	06-Aug-86	5	truck-h ton	Dodge	na	pers	insp	78	69	360	1500	0.0042	1426	0 004	0
2519	06-Aug-86	5	truck-h ton	Dodge	na	pers	insp	78	69	360	1500	0.0042	1426	0 004	0
2545	06-Aug-86	5	truck-h ton	Dodge	na	axle	insp	78	69	794	1500	0.0019	4753	0 006	0
2518	06-Aug-86	5	truck-h ton	Dodge	na	fend	insp	78	69	946	1500	0.0016	4753	0 005	0
25105	06-Aug-86					bckg		78	69	2099	1500	0 0007	14259	0 007	1
25118	06-Aug-86					bckg		78	69	2046	1500	0 0007			
2512	06-Aug-86					amb		78	69	1269	1500	0 0012	1426	0 001	0

(continued)

Table 1 (continued)

Sample Number	Date	Brake Job No	Vehicle Type	Make	Year	Sample Type	Repl or Insp	Dry Bulb Temp	Wet Bulb Temp	Volume	PCM Fibers/ Filter	PCM Fibers/cc	TEM Asbestos Fibers/ Filter	TEM Asbestos Concentration Fibers/cc	TEM Asbestos M or X Fibers* Counted
25108	06-Aug-86					amb				1269	[1500	0 0012			
25121	06-Aug-86	6	salt truck	Chev	1977	pers	insp	83	70	420	[1500	0 0036	1426	0 003	0
25128	06-Aug-86	6	salt truck	Chev	1977	pers	insp	83	70	420	[1500	0 0036	123600	0 294	3
2535	06-Aug-86	6	salt truck	Chev	1977	fend	insp	83	70	1182	[1500	0 0013	190123	0 161	6
25132	06-Aug-86	6	salt truck	Chev	1977	axle	insp	83	70	980	[1500	0 0015	323200	0 330	7
2515	03-Sep-86	7	auto 2 dr	Plym	1979	pers	insp	68	66	360	[1500	0 0042	1426	0.004	0
2539	03-Sep-86	7	auto 2 dr	Plym	1979	pers	insp	68	66	360	[1500	0 0042	1426	0 004	0
2544	03-Sep-86	7	auto 2 dr	Plym	1979	axle	insp	68	66	1160	[1500	0 0013	1426	0 001	0
2536	03-Sep-86	7	auto 2 dr	Plym	1979	fend	insp	68	66	900	[1500	0 0017	1426	0 002	0
25120	03-Sep-86					bckg		68	66	2402	2000	0 0008	1426	0.001	0
259	03-Sep-86					bckg		68	66	2429	[1500	0 0006	1426	0 001	0
2546	03-Sep-86					amb		68	66	1290	[1500	0 0012	4753	0 004	0
254	03-Sep-86					amb		68	66	1284	[1500	0 0012	1426	0 001	0
2521	03-Sep-86	8	truck h-ton	Dodge	1979	pers	repl	76	67	513	[1500	0 0029	14259	0 028	4
2528	03-Sep-86	8	truck h-ton	Dodge	1979	pers	repl	76	67	513	[1500	0 0029	33272	0 065	3
25135	03-Sep-86	8	truck h-ton	Dodge	1979	fend	repl	76	67	1320	[1500	0 0011	19012	0 014	3
252	03-Sep-86	8	truck h-ton	Dodge	1979	axle	repl	76	67	1702	[1500	0 0009	47531	0 028	6
25984	03-Oct-86	9	truck 1/2-ton	GMC	1980	pers	repl	80	72	456	[1500	0 0033	9506	0 021	1
25997	03-Oct-86	9	truck 1/2-ton	GMC	1980	pers	repl	80	72	456	[1500	0.0033	4753	0 010	3
25977	03-Oct-86	9	truck 1/2-ton	GMC	1980	axle	repl	80	72	1334	2000	0.0015	4753	0.004	2
25971	03-Oct-86	9	truck 1/2-ton	GMC	1980	fend	repl	80	72	1035	[1500	0.0014	4753	0 005	0
25990	03-Oct-86	9	truck 1/2-ton	GMC	1980	bckg	repl	80	72	2057	[1500	0 0007	1426	0.001	0
25983	03-Oct-86	9	truck 1/2-ton	GMC	1980	bckg	repl	80	72	2040	[1500	0 0007	1426	0.001	0
25995	03-Oct-86	9	truck 1/2-ton	GMC	1980	amb	repl	80	72	906	[1500	0.0017	14259	0 016	0
25989	03-Oct-86	9	truck 1/2-ton	GMC	1980	amb	repl	80	72	1278	[1500	0 0012	1426	0 001	0
2511	29-Jul-86		blank							0	[1500		4753		0
25125	30-Jul-86		blank							0	[1500		0		0
256	30-Jul-86		blank							0	[1500		0		0
25102	05-Aug-86		blank							0	[1500		0		0
25113	05-Aug-86		blank							0	[1500				
2543	08-Aug-86		blank							0	[1500		0		0
2542	06-Aug-86		blank							0	[1500		0		1
2550	06-Aug-86		blank							0	[1500				
2548	03-Sep-86		blank							0	[1500		0		0
2532	03-Sep-86		blank							0	[1500		0		0
25998	03-Oct-86		blank							0	[1500		0		0
25996	03-Oct-86		blank							0	[1500		0		0

* M = Matrix fiber, X = Fiber extended beyond grid
[= Less than

Figure 1
NIOSH Brake Maintenance Study
Ergonomics and Work Practices Form
(Please Fill In or Check the Space Provided)

Today's Date: ________Day ________Month ________Year
Time: ________a.m./p.m.

Employee Name: ____________________

Gender: ________Male ________Female

Social Security Number: ______ ______ ______

Date of Birth: ______Day ______Month ______Year

Date Started This Job: ______Day ______Month ______Year

How many brake jobs do you do per week: ______

What are your other job duties: ____________________

____

What hand do you use most in performing this job: ___Left ___Right ___Both

What tools do you commonly use to perform this brake job: ____________________

____

Were you provided with any safety or health training regarding protection from asbestos exposure during brake maintenance? _____Yes _____No
If so, when was this training provided. _____Month _____Year

How long did this training last: _____[day _____]day _____[week _____]week

What things do you remember about your training regarding brake maintenance?

____

____

Did you have a physical examination before being hired? _____Yes _____No
If yes, when did you last have this examination? _____Month _____Year

Did this examination include a chest X-ray? _____Yes _____No

Do you do anything "special" to protect yourself from potential exposure to asbestos? ____________________

____

RESEARCHER OBSERVATIONS

Is the worker wearing personal protective equipment?
_____Gloves _____Work Clothing _____Respirator _____Other

Are showers provided for the workers? _____Yes _____No

Do the workers change into clean work clothes when they report to work?
_____Yes _____No
If not, does the worker wear his work clothes home? _____Yes _____No

Briefly record job description with attention to any work practices good or bad which may influence the worker's exposure to brake dust: ____________________

____

____

Appendix B

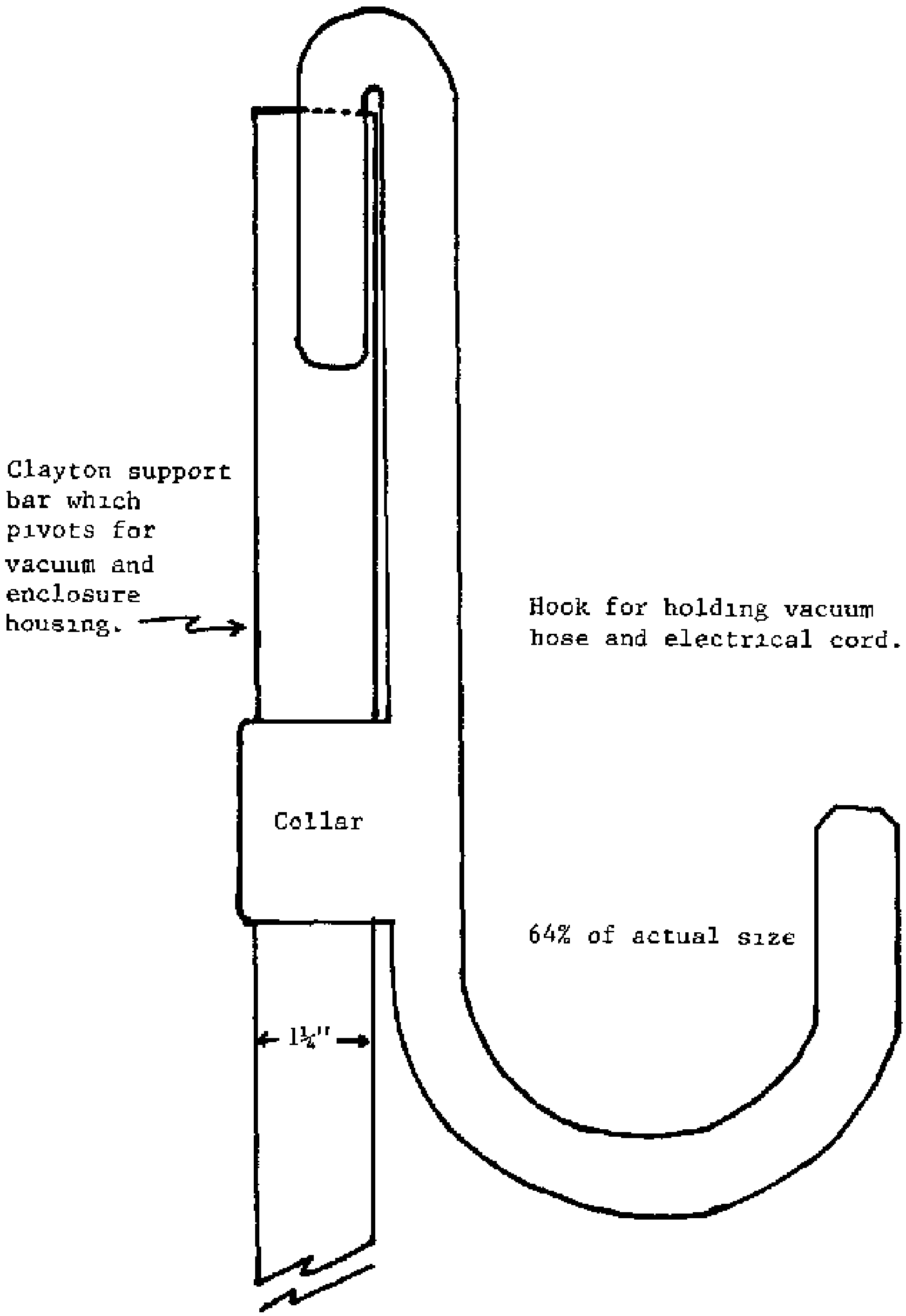

Figure 2
Drawing of Hose Hook for Vacuum Enclosure Unit