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Asbestos Fiber Release from the Brake Pads of Overhead Industrial Cranes

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The purpose of this evaluation was to determine the actual contribution of airborne asbestos fibers to the work environment from the operation of overhead cranes and hoists that use asbestos composition brake pads. The evaluation was conducted in a working manufacturing facility. Other potential sources of asbestos were accounted for by visual inspection and background air monitoring. An overhead crane assembly comprised of a trolley and two hoists was employed for this study. The crane was operated for two consecutive eight-hour shifts representative of a heavy-duty cycle. Forty-four personal and area air samples were collected during the assessment. Asbestos fibers were analyzed for by phase contrast (NIOSH 7400), and transmission electron (NIOSH 7402) microscopy methods. Eight-hour time-weighted average (TWA) asbestos fiber concentrations ranged from <0.005 to 0.011 fibers/cc (PCM), and <0.0026 to <0.0094 f/cc (TEM). There were no asbestos fibers detected by the TEM method from air samples collected during the operation of the cranes.

Keywords Asbestos, Brake Pads, Cranes, Hoists

Asbestos has been used in thermal insulation, building materials, gaskets and packings, friction products, and many other end-user goods for decades. Several asbestos-containing products such as gaskets, packing materials, and equipment brake pads remain in use as integral parts of industrial machinery systems. Previous studies have reported that asbestos fibers released from brake linings tend to be in the electron-microscope size range.[1] The purpose of this study was to determine the actual contribution of optically (phase contrast microscopy (PCM)) visible airborne asbestos fibers to the work environment from the operation of overhead cranes and hoists which use asbestos-composition brake pads.

The term *asbestos* refers to fibrous, naturally occurring silicate minerals that exhibit properties rendering them useful in commerce.[2] Such properties include resistance to heat, chemical corrosion, and frictional wear; high tensile strength; and flexibility.

Asbestos-composition friction products have been utilized for many years in brake/friction applications, including automobile and truck brakes, elevator brakes, and clutch assemblies. Traditionally, friction products have contained blends of asbestos, cellulose, synthetic fibers, and non-fibrous binding materials.

In July 1989, the Environmental Protection Agency (EPA) issued a final rule under the Toxic Substances Control Act (TSCA) to prohibit the manufacture, importation, processing, and distribution of asbestos in almost all products. This final rule sought to eliminate the use of asbestos in most commercial products in three stages over seven years beginning in 1990. In October 1991, the Fifth Circuit Court of Appeals vacated and remanded most of the ban and phase-out rule. As a result, asbestos-composition brake pads are still manufactured on a limited basis.

BACKGROUND

Overhead cranes are utilized for a variety of material handling needs and other industrial applications. They are available in a range of capacities, typically from 1 to 250 tons, and may be found in thousands of plants and facilities nationwide. Industrial uses include shipbuilding, automotive and heavy equipment assembly, and other industrial operations where heavy material loads have to be moved.

Overhead, or bridge cranes, are supported above the working surface by a movable bridge. The bridge travels horizontally along parallel girders which may be either self-supported or supported by the structure housing the crane. The bridge contains the essential working elements of the crane including the bridge motor and bridge drive systems, electrical controls, an operator's cab, and the trolley supporting the hoist(s).

The trolley is supported by wheels which move along a track perpendicular to the directional movement of the bridge. The trolley contains a motor and drive machinery that allow its movement to be controlled independently from the bridge. The movement of the bridge, and perpendicular movement of the trolley enable operation of the crane in all directions with respect to an x-y (Cartesian) coordinate system.

The trolley also contains the hoists, the hoist motors, and the hoist gear assemblies. Many overhead cranes operate with two hoists— the main hoist, which performs the majority of the work, and the auxiliary hoist which often has a lift capacity less than that of the main hoist.

The operation of overhead cranes is usually controlled in one of three ways—an operator's control cab attached to the crane, a pendant push-button control operated from the floor, or a wireless radio control. The inertia generated during the movement of the bridge, trolley, and hoists is controlled using friction brake products. The typical overhead industrial crane may contain four sets, or pairs, of brake shoes. One pair each may be found attached to the bridge drive gearing, the trolley drive gearing, the main hoist drive system, and the auxiliary hoist drive system. The brake shoes consist of friction materials bonded or riveted to metal brake shoes, which are in turn attached to brake calipers.

GENERAL PROCESS DESCRIPTION

This evaluation was performed in a building utilized for product subassembly and light welding at a mining equipment manufacturing plant. No manufacturing activities were in progress during the evaluation. The building size was approximately 107′ × 270′ × 30′.

The building contained a total of six overhead cranes and two light-duty jib cranes. The main runway, situated along the center of the building, contained two overhead cranes, each with a 15-ton main hoist and a 5-ton auxiliary hoist. Two additional runways, each situated on either side of the main runway, contained two 5-ton overhead cranes.

One of the two 15-ton cranes which plant personnel reported as being manufactured and installed in 1941, was used for this evaluation. As reported by the plant's test engineer, the brake shoes on the bridge, trolley, and auxiliary hoist were original (i.e., installed in 1941). The brake shoes on the main hoist were replaced in the mid- to late 1960s. Prior to our arrival at the site, the unused 15-ton crane was parked at one end of the main runway opposite the end where the work was performed. With only a few exceptions, an 80-foot portion of the approximate 270-foot-long runway was used during the study. See Figure 1.

The evaluation was performed over two consecutive eight-hour shifts. Based on normal plant operations, a test duty cycle was prepared by a crane engineer. The duty cycle analysis was prepared to reflect a representative worst-case scenario of a duty cycle for cranes in manufacturing facilities operating at a Crane Manufacturer's Association of America (CMAA) Class "C" rating. The test loads included a 6.75-ton weight for the main hoist and a 1.98-ton weight for the auxiliary hoist.

The first shift duty cycle included eight steps, with a total cycle time of approximately six minutes per cycle. This resulted in a frequency of 10 duty cycles per hour. The first shift duty cycle included the following steps:

1. main hoist lowering 15 feet unloaded
2. main hoist raising 15 feet under load with 2 "jogs" (i.e., engage brakes)
3. trolley motion $\frac{1}{2}$ span (20 feet)
4. bridge motion of 80 feet
5. trolley motion $\frac{1}{2}$ span (20 feet)
6. main hoist lowering 15 feet under load with 2–3 jogs
7. reverse above 5 steps unloaded
8. crane remained stationary for 3 minutes

During the first shift duty cycle, the auxiliary hoist was intermittently raised and lowered, though no load was attached.

The second shift duty cycle was similar to the first shift duty cycle; however, operation of the auxiliary hoist with a weighted load attached was added during the second shift. Operation of

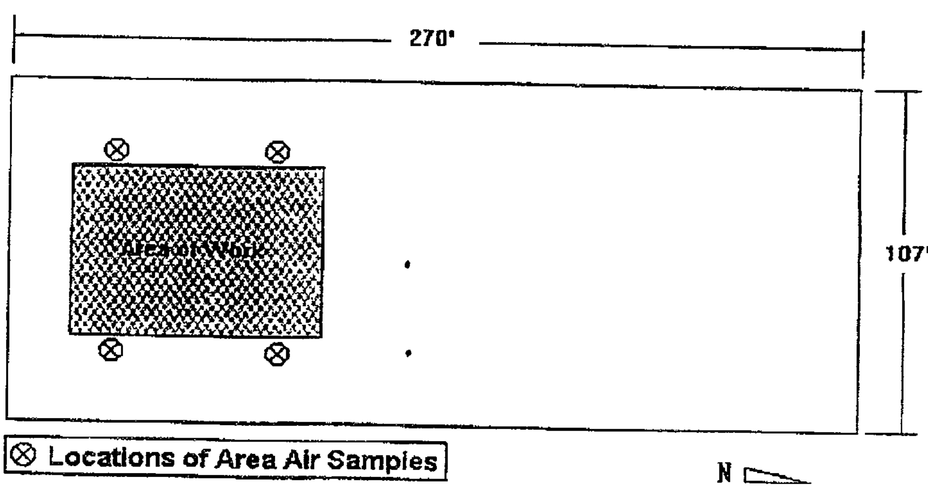

FIGURE 1
Facility layout.

the auxiliary hoist with its attached load was performed during the reverse steps of the main hoist duty cycle.

The performance of repetitive duty cycles during the first and second shifts resulted in the brakes being applied, on average, 39 times per 6-minute cycle. This resulted in approximately 390 applications of the brakes per hour. In terms of average brake usage per duty cycle, the brakes on the bridge were applied 9 times, on the trolley 11 times, on the main hoist 9 times, and on the auxiliary hoist 10 times.

Prior to initiating the process evaluation, all heating and ventilation within the building was deactivated. All doors and windows were closed in an effort to minimize air currents in the building. Air flow within the building was qualitatively assessed by observing smoke flow patterns in the air current. Air currents were determined to be relatively stable with no significant air flow detected. Temperature measurements averaged 75.5°F at ground level and 85.5°F at crane level (approximately 25 feet above the finished floor). The outdoor temperature averaged 19°F.

METHOD

NIOSH Method 7400-Issue 2 (Fibers by Phase Contrast Microscopy [PCM] August 15, 1994)[3] was selected for this work, given its use by the Occupational Safety and Health Administration (OSHA) as the standard for evaluating personal exposure to asbestos and other fibers.[4] NIOSH Method 7402 Asbestos by Transmission Electron Microscopy [TEM])[5] was selected as a backup/verification if interference were experienced during sample analysis. The 7402 method is prescribed by NIOSH for confirmation of results obtained by NIOSH method 7400.[6] Accordingly, the 7402 method specifies that only asbestos fibers meeting the size requirement specified in the 7400 method be counted. This means that only asbestos fibers greater than 5 μm in length and 0.25 μm wide were measured and quantified.[7]

Following the review and selection of sampling and analytical methods, a standard operating procedure was developed. The procedure included an atmospheric screening test, baseline sample collection, and the sampling protocol for the process evaluation.

Step 1. Atmospheric Screening Test

The atmospheric screening test was conducted to determine whether ambient atmospheric contaminants would adversely affect the analyst's ability to evaluate sample filters at low fiber concentrations. The screening was performed using different sampling collection durations and air flow rates. The information obtained from the analysis of the screening samples (e.g., estimated dust loading, fiber density, fiber concentration) was used to develop the final sampling strategy for the baseline and process evaluation samples. Sampling parameters and sample results for the atmospheric screening test may be found in the Results section in Table I.

Step 2. Baseline Samples

Baseline air samples were collected indoors and outside the building. The purpose of the baseline sampling was to determine the existing background or ambient asbestos fiber level, absent the crane/hoisting operations. A total of five indoor samples and five outdoor samples were collected. Two sample blanks were also obtained. The results from the baseline samples were compared to the results of the exposure samples obtained during the study to determine the actual contribution of airborne asbestos fibers from the activities monitored.

Step 3. Monitoring of the Subject Process

Bulk samples of the brake pad material were obtained and analyzed prior to initiating the duty cycle evaluation. One bulk sample each was obtained from the bridge, trolley, and the main and auxiliary hoist brake pads. Samples were extracted from the existing brake pads using a knife to scrape material from the surface of the pads. The selected pad surfaces consisted of an exposed edge where the brake pad material fits into the brake shoe, an area that does not come into contact with the brake wheel during brake use. The objective was to collect a sample without altering the existing contact surface or the performance specification of the brake pads. Analysis was performed using Polarized Light Microscopy (PLM) with dispersion staining. The results of laboratory analysis indicated that each brake shoe material contained 12 percent chrysotile asbestos by weight. The laboratory which performed the analysis was accredited by the National Institute for Standards and

TABLE I

Air sample results summary table for atmospheric screening test

Sample no.	Description/location	Flow rate (L/min)	Duration (min)	Volume (liters)	PCM result (f/cc)
SS-1	Center of crane bay	4.0	482	1928	<0.005
SS-2	Crane working area	4.0	242	968	<0.010
SS-3	Crane working area	3.0	247	741	<0.010
SS-4	Blank	n/a	n/a	n/a	0 fibers/100 fields
SS-5	Blank	n/a	n/a	n/a	0 fibers/100 fields

TABLE II
Sample distribution for first shift and second shift sampling

Location	No. of first shift samples	No. of second shift samples	Total
Floor level	8	8	16
Crane control	0	1	1
Crane level	2	2	4
Outdoors	1	1	2
Personal (operator)	1	0	2
Personal (bystanders)	0	3	2
Blank	2	3	5
Total	14	18	32

Technology (NIST), and the American Industrial Hygiene Association (AIHA) for PLM analysis.

Visual inspection of the installed brake shoes indicated moderate wear. Plant personnel reported that the brake shoes on the bridge, trolley, and auxiliary hoist were installed when the crane was manufactured. The brake shoes on the main hoist were reportedly replaced in the mid- to late 1960s.

Air sample collection focused on two levels within the building—the bridge/trolley level, and the main floor. Sample collection at the bridge/trolley level was conducted using portable, battery-operated air sampling pumps. The portable pumps were used to collect air samples on and around the trolley, and in the area formerly occupied by the operator's cab. The sample collected from the operator cab area was intended to represent fiber concentrations to which an operator may have been exposed, were the cab still present.

Sampling locations at the main floor level were evenly distributed within, and adjacent to, the crane areaway (also referred to as the hoisting area) and were obtained using high-flow air sampling pumps. The collection of samples within and adjacent to the crane areaway (hoisting area) was intended to represent fiber concentrations to which both floor-level crane operators and bystanders may be exposed. Representative personal samples were also collected using portable air sampling pumps.

Thirty-two air samples were collected during the process evaluation. The sample distribution for the first and second shifts is described in Table II. Four locations were selected for the collection of the floor-level (five to six feet above the floor) samples. The sample filter cassettes were changed halfway through each shift, resulting in eight floor-level samples per shift. The floor-level sample locations remained constant from the first to the second shift. During the second shift, a personal sampling pump was attached to the crane's pendant control to represent the operator's exposure. Three personal samples were also collected during the second shift. The personal samples were obtained from the breathing zones of the investigators, who were evaluating the duty cycles while observing from the hoisting and adjacent areas.

RESULTS AND DISCUSSION

The results of air sampling and analysis are presented in the following tables. Each table gives the sample location/description, flow rate duration, volume, and result. Table I lists sample data and test results for the Atmospheric Screening Test. The sample data and test results for the Baseline Samples are presented in Table III. The sample data and test results for the Process Evaluation are presented in Table IV. All sample results reported in Table I are based on sample analysis by PCM using NIOSH Method 7400. Sample results reported in Tables III and IV are based on analysis by PCM using NIOSH Method 7400 and confirmatory analysis by TEM using NIOSH Method 7402.

TABLE III
Air sample results summary table for baseline sample collection

Sample no.	Description/location	Flow rate (L/min)	Duration (min)	Volume (liters)	PCM result (f/cc)	TEM result (f/cc)
111596-MP1	Baseline: Outdoors	2.7	240	648	<0.010	<0.0054
111596-MP2	Baseline: Outdoors	2.9	240	696	<0.010	<0.0050
111596-MP3	Baseline: Outdoors	2.75	240	660	<0.010	<0.0053
111596-MP4	Baseline: Outdoors	2.6	240	624	<0.010	<0.0056
111596-MP5	Baseline: Outdoors	2.45	240	588	<0.010	<0.0060
111596-MP6	Baseline: Indoors	12.0	180	2160	<0.005	<0.0016
111596-MP7	Baseline: Indoors	12.0	180	2160	<0.005	<0.0016
111596-MP8	Baseline: Indoors	12.0	180	2160	<0.005	<0.0016
111596-MP9	Baseline: Indoors	12.0	180	2160	0.006	<0.0016
111596-MP10	Baseline: Indoors	12.0	180	2160	<0.005	<0.0016
111596-MP11	Blank	n/a	n/a	n/a	1 fiber/100 fields	—
111596-MP12	Blank	n/a	n/a	n/a	1 fiber/100 fields	—

PCM Results

All PCM results reported in Table I were below the limit of quantitation (LOQ). With one exception, all Baseline Sample results (Table III) were also below their respective LOQs. The one exception was marginally above its respective LOQ. PCM analysis indicated one fiber each on the blank samples. A total of 27 samples were collected during the Process Evaluation (Table IV). Fifteen of the 27 samples were reported by the laboratory as being below the respective LOQs.

TEM Results

TEM analysis was performed on the baseline and process evaluation samples to determine whether fibers detected by PCM analysis were asbestos fibers. The analysis was performed using

TABLE IV
Air sample results summary table for Process Evaluation Samples

Sample location	No. of samples	Sample period (min.)	PCM result (f/cc)	8-Hr. TWA (PCM f/cc)	TEM result (f/cc)
NE corner of hoisting area—1st shift	2	225 225	0.006 <0.005	<0.006	<0.0026 <0.0026
NE corner of hoisting area—2nd shift	2	225 225	<0.005 0.006	<0.006	<0.0026 <0.0026
NW corner of hoisting area—1st shift	2	225 225	<0.005 <0.005	<0.005	<0.0026 <0.0026
NW corner of hoisting area—2nd shift	2	225 225	0.011 <0.005	<0.008	<0.0026 <0.0026
SE corner of hoisting area—1st shift	2	225 225	0.005 <0.005	<0.005	<0.0026 <0.0026
SE corner of hoisting area—2nd shift	2	225 225	<0.005 0.006	<0.006	<0.0026 <0.0026
SW corner of hoisting area—1st shift	2	225 225	0.005 0.006	0.006	<0.0026 <0.0026
SW corner of hoisting area—2nd shift	2	225 225	<0.005 <0.005	<0.005	<0.0026 <0.0026
Center of crane bridge on guard rail—1st shift	1	435	<0.005	<0.005	<0.0031
Center of crane bridge on guard rail—2nd shift	1	401	<0.005	<0.004	<0.0036
Beneath bridge at former operator cab—1st shift	1	435	<0.005	<0.005	<0.0031
Beneath bridge at former operator cab—2nd shift	1	470	<0.005	<0.005	<0.0030
Beneath crane on pendant control—2nd shift	1	435	0.006	0.005	<0.0032
Personal (bystander)—1st shift	1	417	0.008	0.007	<0.0034
Personal (bystander)—2nd shift	1	149	0.035	0.011*	<0.0094
Personal (bystander)—2nd shift	1	225	0.011	0.005*	<0.0066
Personal (bystander)—2nd shift	1	206	0.010	0.004*	<0.0069
Outdoors—1st shift	1	465	<0.005	<0.005	<0.0025
Outdoors—2nd shift	1	435	<0.005	<0.005	<0.0027
Blanks	5	—	0.2 fibers/100 flds (average)	—	—

*Fibers were determined by TEM to be non-asbestiform.

TEM in conjunction with NIOSH Method 7402, which is recommended by NIOSH as a backup/verification for PCM analysis. The samples generated during the atmospheric screening test were not analyzed by TEM because the PCM results did not indicate interference due to particulate matter or other obstructive material.

The TEM analysis indicated the presence of asbestos fibers on only two of the 44 samples analyzed; one asbestos fiber each was reported on two of the baseline samples. No asbestos fibers were reported on any of the process evaluation samples, including the personal samples and the blanks.

All samples collected during this evaluation yielded analytical results below the OSHA eight-hour time-weighted average (TWA) permissible exposure limit (PEL) for asbestos of 0.1 f/cc.[8] With the exception of the personal air samples, all but one of the area samples were reported to be less than 0.01 f/cc, 10 times below the OSHA PEL as measured by PCM. The sample reported to be greater than 0.01 f/cc was only marginally above this value. The sample was further evaluated by NIOSH Method 7402, which revealed that the fibers were non-asbestiform.

CONCLUSIONS

The purpose of this evaluation was to determine the contribution of airborne asbestos fibers to the work environment from the operation of overhead cranes with asbestos-containing brake shoes. The air monitoring results revealed that airborne asbestos fiber concentrations were in all cases below the OSHA eight-hour TWA exposure limit of 0.1 f/cc. Further analysis of air samples by the TEM method determined that no asbestos fibers were detected in the size range determined by the NIOSH 7402 method during the operation of the crane and hoists. The operation of cranes and hoists fitted with asbestos-containing brakes did not contribute measurable (optically visible) airborne asbestos fiber concentrations to the crane operators or bystanders.

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