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UNIBESTOS DUST POTENTIAL CANCER TO OTHER APE [illegible] PE[illegible] UCTS — UN OF C (BERKLEY)

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SCHOOL OF PUBLIC HEALTH

EARL WARREN HALL
BERKELEY, CALIFORNIA 94720

FILE: [illegible]
11.C.6.C

September 11, 1970

Lee B. Grant, M.D.
Medical Director
Pittsburgh Plate Glass Company
One Gateway Center
Pittsburgh, Pennsylvania 15222

Dear Dr. Grant:

Enclosed are somewhat better copies of our report on the Unibestos project. These will give better reproductions than the copy sent to Mr. Price. I trust that these will reach you before your departure for Washington and that they will be useful to you.

Sincerely,

Douglas P. Fowler

Douglas P. Fowler
Industrial Hygienist

DPF:js
enc.

PLAINTIFF'S EXHIBIT U-104

Blumberg No. 5113

PROJECT TITLE: "Dust-Producing Potential of Construction Materials"

INVESTIGATORS: Bernard D. Tebbens, Sc.D.
Professor of Industrial Hygiene Engineering

J. LeRoy Balzer
Associate Specialist in Industrial Hygiene

W. Clark Cooper, M.D.
Professor of Occupational Health in Residence

Irving R. Tabershaw, M.D.
Professor of Occupational Medicine

FROM: Division of Environmental Health Sciences
School of Public Health
University of California
Berkeley, California 94720

DATED: September 9, 1970

DUST-PRODUCING POTENTIAL OF CONSTRUCTION MATERIALS

Bernard D. Tebbens, Sc.D., J. LeRoy Balzer
W. Clark Cooper, M.D., and Irving R. Tabershaw, M.D.

Purpose of Study

The purpose of this study was to develop methods for assessing the hazard potential of asbestos-containing construction materials. The methodology was to be developed during a systematic study of four commercial insulation products containing asbestos. The results include the actual concentrations of airborne asbestos fibers found to result from operations typical of the industrial uses of these products.

The necessity frequently arises in industry to predict the potential hazard during comminution of a solid material. In other words, "is the dust produced by sawing, drilling or filing of a solid containing a hazardous component necessarily of the same composition as the parent material?" At first glance, the answer must seem, "Obviously, yes." In reality, however, there are several factors which can result in a different distribution of components. Occupational exposures to potentially hazardous dusts may be affected by the conditions of use of the materials from which the dusts are generated or by the physical characteristics of the material.[1,2]

Occupational exposuresof construction craftsmen to airborne asbestos fibers are primarily a result of the comminution of thermal insulation materials during their installation, repair, and removal.[3] Inhalation of asbestos fibers has been shown to cause, or be associated with, an increased incidence of fibrotic and neoplastic disease.[4,5] However, at present, there are no thermally suitable alternatives to asbestos-containing materials for the prevention of heat loss from high-temperature (750°F and higher) pipes and boilers.

There are two major types of asbestos-containing thermal insulation products. One of these is made by binding a mat of amosite asbestos fibers with sodium silicate, either with or without the addition of diatomaceous earth (Product B). The minimum asbestos fiber content of this type is approximately 60%. The other major type is prepared by baking a slurry of calcium silicate and amosite and/or chrysotile asbestos fibers and contains approximately 10-15% asbestos (Products A, C and D).

It has been suggested that exposure of insulation workers to asbestos fibers might be substantially reduced by restricting the use of products which have a high asbestos content. However, the two types of materials differ significantly in their physical properties so that the asbestos concentrations in aerosols generated during the handling of the two types might differ in ways not directly related to the concentrations of asbestos in the parent materials.

The 60% asbestos/sodium silicate insulation has been described as being more readily cut and shaped than the calcium silicate products, requiring the application of less prolonged or intense force for a given shaping operation. There are also significant differences in the two types of asbestos fibers used in the materials, amosite being of greater specific gravity than chrysotile (3.5 vs. 2.5), and having individual fibrils of larger diameter than chrysotile (0.1 μm vs. 0.01 μm).

Thus, it would seem that there are theoretical arguments favoring the product with higher asbestos content. The greater ease of fabrication would mean a shorter period of production of the aerosol, and the larger, more dense amosite fibers would tend to fall out of the produced aerosol more rapidly than will chrysotile fibers.

Research Performed

Four thermal insulation products, 9-inch outside diameter and 3-inch inside diameter, containing differing asbestos types and concentrations were tested for respirable dust production under conditions simulating actual usage. These products were purchased "blind"; a reliable third party not connected with the University or any of the manufacturers concerned purchased the products through the normal market channels ordinarily used by him in his purchases of other insulation products. Thus, we entered the market randomly; the products used in this study are a "grab sample" of the products which might be delivered to any user. Product D was the only one of those tested which did not meet the original broad specifications; it was supplied as two 1 1/2-inch layers and not the single layer of the other products. The wholesaler confirmed that Product D is not supplied in a single layer in 3-inch thickness. Therefore, it was used as received since this is the way it would be supplied to insulators in actual practice.

A test chamber (shown in Figures I and II) was constructed measuring 10'4" long by 9'8" high by 10' wide. The total volume was 1,000 cubic feet.

The room was lined with 0.006" plastic sheeting to facilitate cleaning. Farr Company HP 200 filters were used to filter the supply air and the exhaust. Air exchange rate between test runs was 290 cubic feet per minute.

After each run, and between products, the room was flushed for a period which varied depending on the observed "dustiness" of the room but was a minimum of 20 minutes (about 6 air changes). Before each change of product (or change in process), a background air sample was taken in the "room" position (described below); each sample subsequently taken in that series (or run) was then corrected by having the background concentrations subtracted.

The following operations (described in greater detail below) were performed on each product by an insulation mechanic (journeyman asbestos worker).

I. Simulation of pipe covering, and tear-out of heat stressed pipe covering.

II. Power sawing of the products to simulate on-site fabrication of specific shapes of the material by a bandsaw; and the "scoring" of blocks.

III. Pounding with a simulated hammer to estimate the effects of force-fitting (not performed by the insulation mechanic).

In each of these operations (except the tear-out and pounding), the insulation mechanic was permitted to set his own pace; the specific plan of operations was determined in consultation with him so that practices usual to the trade were followed.

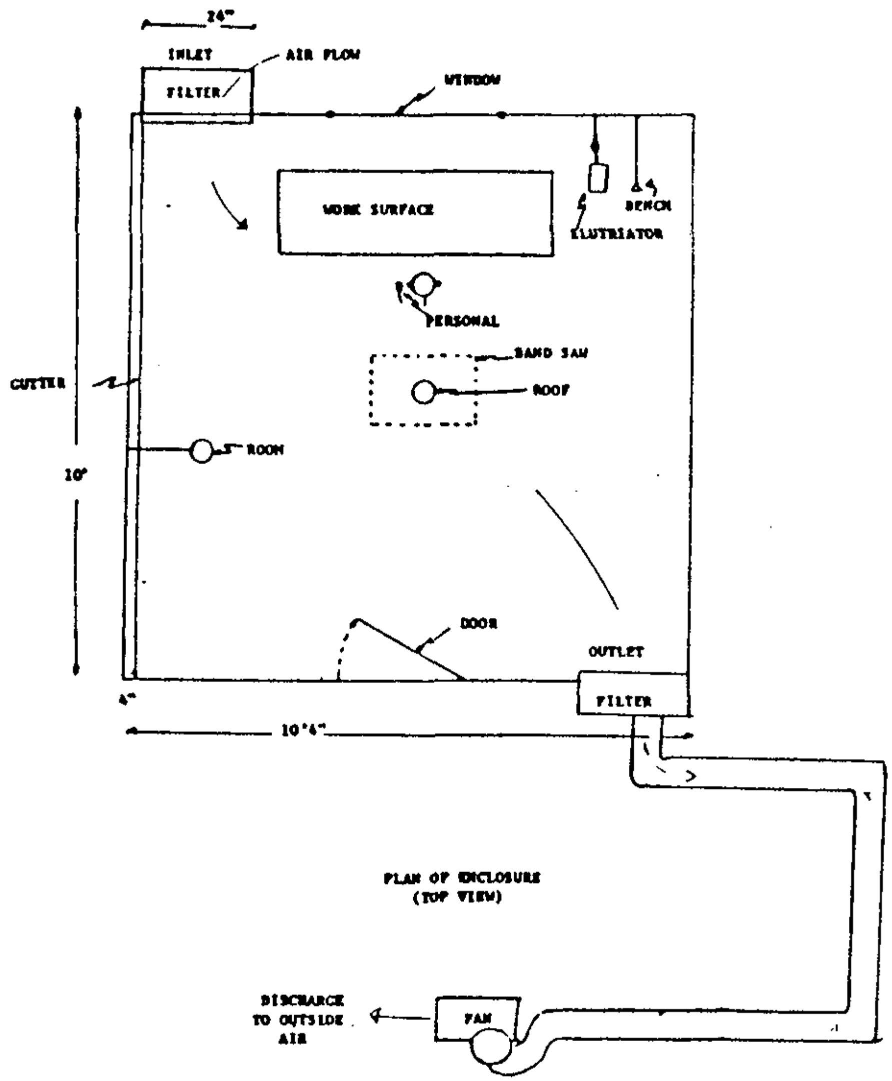
The insulation mechanic used a "Whitecap" supplied-air respirator throughout; the asbestos fiber concentrations in the air supplied to him were far below the proposed Threshold Limit Value.

Sampling and Analysis

Air samples were taken by drawing air through Millipore 0.8 μm mean pore size organic membrane filters. Filters of 37 mm diameter were used for the personal breathing zone samples and 47 mm diameter filters for all other samples. Additional samples were taken using Nuclepore membrane filters (0.8 μm mean pore size) for subsequent electron microscope analyses.

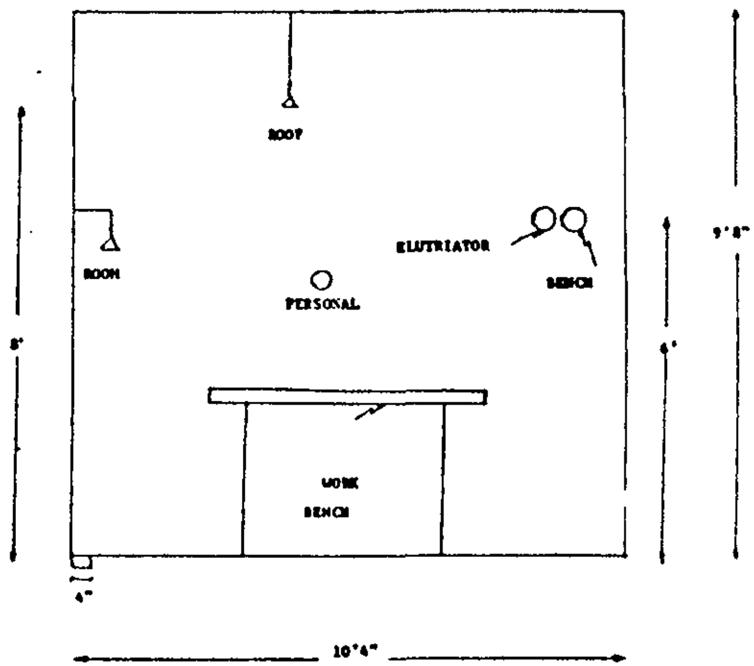
During the simulated pipe-covering, tear-out, and bandsawing, samples were taken at five locations within the test chamber: 1) in the middle of the chamber with the open-face filter holder 8 feet above the chamber floor level ("Roof" samples); 2) from a support projecting into the chamber approximately 1 foot from the wall opposite the work bench on which the covering was done, through an open-face filter holder about 6 feet above the floor ("Room" samples); 3) above the work bench (near the wall closest to the bench) with an open-face filter holder ("Bench" samples); 4) in the same location as the Bench samples but with the air drawn through a Hexhlet Horizontal Elutriator (Casella-Wilson) before passage through the in-line filter holder ("Elutriator" samples); 5) in the insulator's breathing zone with disposable Millipore Field Monitors (open face) ("Personal" samples). Sample air flow rates were: Roof, 0.7 cubic feet per minute (cfm); Room, 0.5 cfm; Bench, 0.5 cfm; Elutriator, 50 liters per minute (1.8 cfm); and Personal, 0.11 cfm. See Figures I and II for these locations.

FIGURE I



PLAN OF ENCLOSURE
(TOP VIEW)

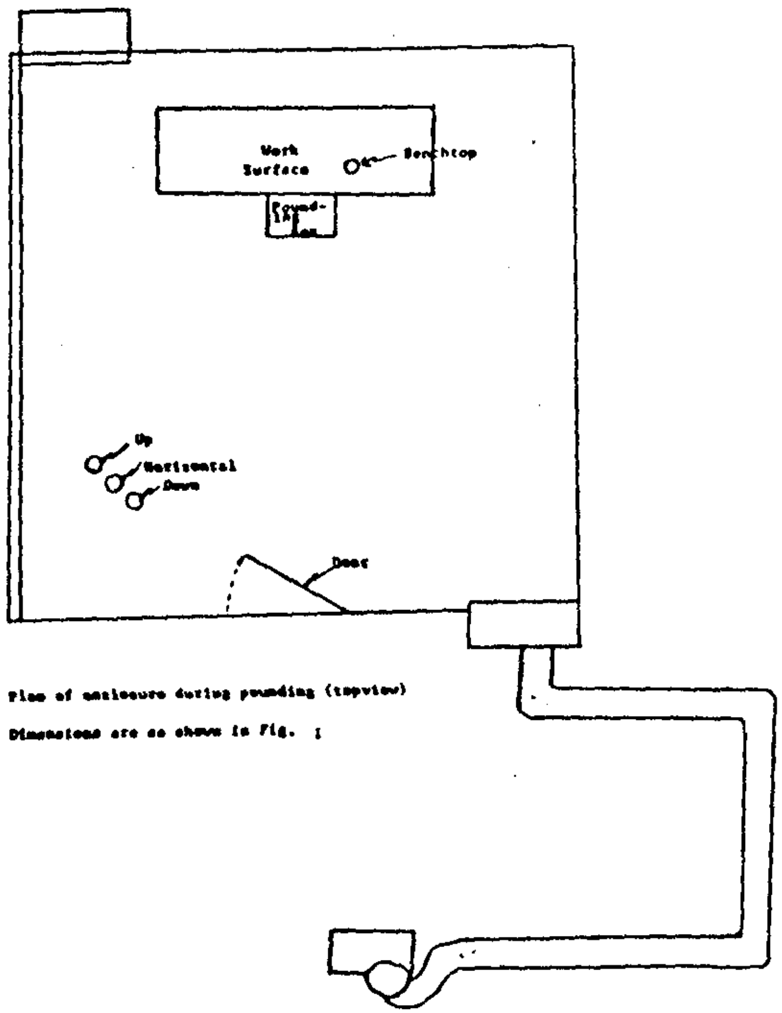
FIGURE II



PLAN OF EXCLOSURE
(SIDE VIEW)

During the scoring operation, only two sampling locations were utilized (Room and Personal samples) as shown in Figures I and II. The pounding operation was monitored with four samplers, one on the bench above the product being pounded ("Bench top") and three others approximately 5 feet distant from the pounding site, 4 feet above floor level. One of these filter holders was directed upward ("Up"), another directed downward ("Down"), and the other directed horizontally ("Horizontal"). Flow rates here were 1.9 cfm for the Mass, 1.0 cfm for the three others. These locations are shown in Figures III and IV.

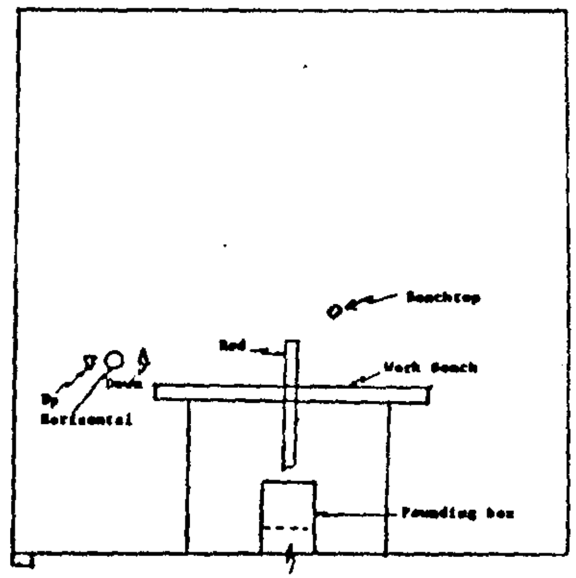
FIGURE III



Plan of enclosure during pounding (topview)

Dimensions are as shown in Fig. I

FIGURE IV



Plan of enclosure during pounding (side view)

Dimensions are as shown in Fig. II

Analysis of the collected samples was directed at obtaining two measures of the relative amount of dust production from the products being tested. All filters (except the 37mm Personal sample filters) were weighed before and after use, each such weighing proceeded by desiccation for two hours to stabilize weights. From this weight data, the gravimetric concentrations of total airborne dust were computed in milligrams per cubic meter (mg/m^3) by dividing the milligrams change in weight by the total cubic meters of air which had passed through the filter. This was the sole analysis applied to the "Bench", "Elutriator", and "Bench top" samples.

The other sample filters were analyzed to determine the concentrations of asbestos fibers in addition to the gravimetric analysis. This analysis was by the standard method for the determination of asbestos fibers collected on membrane filters:[6] a wedge of the weighed, exposed filter was cut from the filter and the wedge (about 1/8 of the total filter) placed on a standard microscope slide on which was placed a drop of a mounting medium which matched the index of refraction of the organic filter. The filter wedge thus "cleared" was examined with phase contrast microscopy at 430X magnification, with the microscopic field of examination limited to the area bounded by a Porton eyepiece reticle (0.0061 mm^2 per field). The asbestos fibers seen in each field were recorded and placed into several length and diameter categories, and the field shifted to another portion of the filter. This process was continued until 100 such fields had been examined, or until 300 fibers had been counted and sized.

When 300 fibers (or 100 fields) were accumulated from any one sample, the count within the field was completed and the count then terminated for that sample. The concentration of asbestos fibers per liter of air was determined by taking into account the area of the filter surface examined (0.0061 mm^2), the total exposed filter area (960 mm^2), the number of fibers counted, and the flow through the filter in milliliters. This result was expressed as fibers per milliliter (f/ml). The proposed Threshold Limit Value (American Conference of Governmental Industrial Hygienists) is only for those fibers longer than 5 micrometers (μm). Therefore, asbestos fiber concentrations expressed within this report are given for both total asbestos fibers and asbestos fibers longer than 5 μm in the tables of results, but the graphic expression of fibers per ml. is limited to fibers longer than 5 μm.

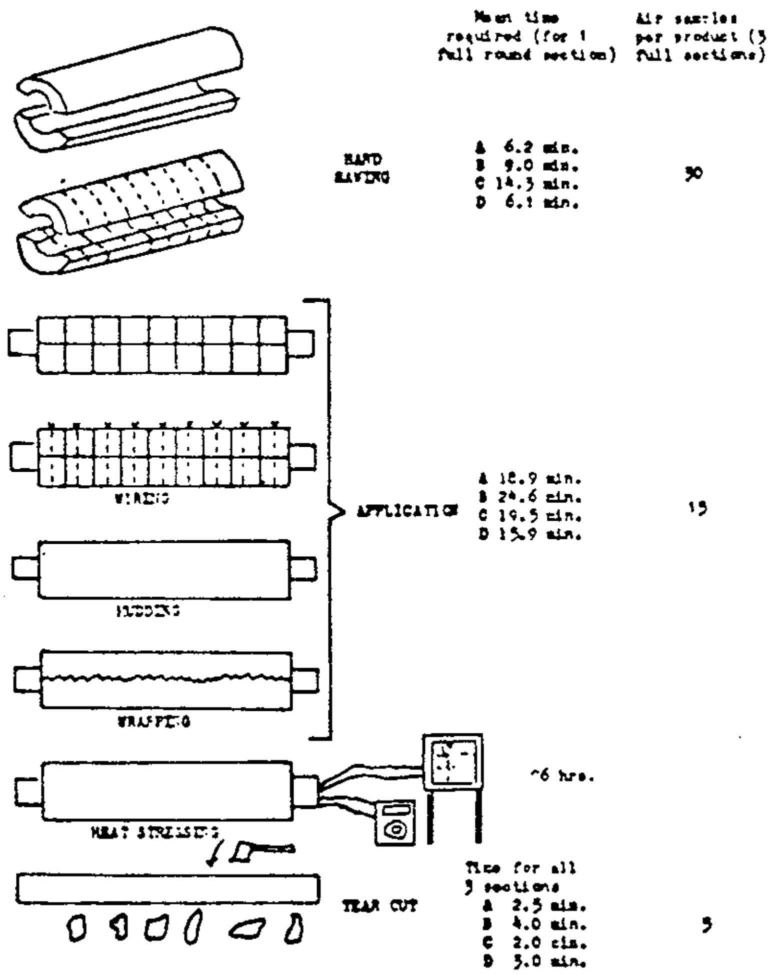
Specific Operations

I. Pipe-covering.

Three "runs" were made on each product during the simulation of pipe covering. For each of these runs, two 36-inch long half-round sections of insulation were cut into 18 separate pieces by cutting across at 4" intervals, the major axis of the 36-inch long sections. These 4" sections were then wired in place around a 48-inch long piece of 3" I.D. cast-iron pipe so that the final covering of the pipe extended for approximately 35" (with about 1 inch lost because of saw blade width). The wired insulation was "mudded" with a mix which was constant throughout the series of tests, and the mudded surface wrapped with medium-weight canvas, using wheat-paste adhesive. The material removed by these operations was weighed at the completion. The wrapped pipes were air dried for at least two days and then heat-stressed. The heat stressing was accomplished by inserting Cal-Rod heaters into the pipes; current flow into the heaters was controlled by chrome alumel thermocouples (within the pipes but not touching the heaters) actuating standard temperature control relays; potential differences in the thermocouples were monitored by a multi-channel recorder which was activated for 15 minutes in each 12-hour period. Temperatures in the pipes were held at 1150°F (±25°F) for 96 hours, with current to the Cal-Rod heaters shut off with a timing switch at the completion of that time.

When all products had been applied and heat-stressed, the insulation was removed from the pipes in simulation of ship-board tear-out operations. All three pipes for one product were placed in the chamber, and the mechanic given a knife, a hatchet, and a three-minute time limit within which to remove all three coverings. Air samples were taken for five minutes, in order to standardize results, since only one sampling opportunity was available for each product. Figure V shows a schematic diagram (flow chart) of this series.

FIGURE 9
Pipe Covering and Tear-Out



Results (Pipe Covering)

Tables 1-4 show the results of the air sampling for these operations, expressed as milligrams of total particulate per cubic meter of air (mg/m^3), total asbestos fibers per milliliter of air (f/ml), and asbestos fibers longer than 5 micrometers per milliliter of air (f/ml 5). All concentrations have been corrected for background. The concentrations from the various products are shown graphically in Figures IV-IX, where fiber concentrations (f/ml) are given only for those fibers longer than 5 μm.

Airborne Asbestos Fiber Concentrations and Total Airborne Dust (Gravimetric) Concentrations from All Pipe Covering Operations: Product A

Table 1.

Pipe Covering Results Product A

Operation	Samples									
	Personal		Roof			Room			Bench	Elutriator
	f/ml	f/ml(>5)	f/ml	f/ml(>5)	mg/m³	f/ml	f/ml(>5)	mg/m³	mg/m³	mg/m³
Handsawing	27.264	24.059	9.394	8.150	20.216	10.261	8.899	4.070	10.054	1.416
	27.711	24.967	25.269	23.863	4.169	15.592	14.191	6.541	6.037	8.567
	56.385	48.326	9.119	8.388	4.689	2.254	2.102	4.303	10.655	0.346
	31.011	27.551	13.851	13.041	2.779	9.166	8.795	0.439	1.516	0.479
	32.010	27.005	15.751	14.911	1.359	5.227	5.170	0.105	6.243	1.346
	26.940	24.269	31.299	29.934	8.392	15.449	15.091	5.753	63.250	1.517
Mean	33.556	29.363	17.467	16.381	6.936	9.658	9.041	3.535	16.293	2.278
Standard Deviation	11.380	9.400	8.979	8.771	6.922	5.363	10.318	2.690	23.239	3.121
Application	18.306	16.634	19.072	18.615	10.011	4.221	4.120	2.4[illegible]	1.782	3.292
	13.728	12.202	15.829	15.532	5.546	3.036	12.675	2.5[illegible]	1.601	1.167
	18.494	15.944	21.091	20.489	6.601	9.654	9.444	3.479	0.997	1.278
Mean	16.843	14.927	18.664	18.212	7.206	8.970	8.746	2.841	1.460	1.912
Standard Deviation	2.659	1.947	2.655	2.503	2.443	4.466	4.320	0.554	0.411	1.196
Tearout	49.231	47.621	26.951	25.268	10.374	7.783	7.477	9.524	21.074	3.960

Airborne Asbestos Fiber Concentrations and Total Airborne Dust (Gravimetric) Concentrations from All Pipe Covering Operations: Product B

Table 2.

Pipe Covering Results Product B

Operation	Samples									
	Personal		Roof			Room			Bench	Elutriator
	f/ml	f/ml(5)	f/ml	f/ml(5)	mg/m³	f/ml	f/ml(5)	mg/m³	mg/m³	mg/m³
Handsawing	142.335	121.046	110.190	97.600	9.756	65.035	57.957	-0.183	6.377	2.733
	192.523	154.477	160.567	150.615	13.316	149.792	135.403	17.432	15.297	1.489
	215.808	178.759	62.569	56.420	1.806	25.276	21.979	2.976	16.432	6.297
	281.287	240.529	223.856	217.867	17.530	198.633	185.284	15.123	38.307	17.937
	248.425	202.810	156.853	147.279	24.931	101.402	90.482	7.885	19.578	3.376
	302.645	265.676	108.366	92.876	———	109.910	97.925	19.553	9.912	21.068
Mean	230.506	193.869	137.067	127.076	13.468	108.341	94.509	10.464	17.651	8.820
Standard Deviation	59.223	37.675	35.807	36.968	8.627	61.150	37.510	8.111	11.175	8.490
Application	57.135	69.708	36.802	30.342	10.160	25.051	19.897	8.355	7.136	1.282
	126.325	109.162	38.755	34.488	10.776	32.099	27.001	9.861	5.903	2.779
	158.140	133.364	50.617	46.751	13.479	39.048	35.327	9.669	7.679	7.841
Mean	113.867	97.411	42.058	37.196	11.472	32.066	27.408	9.295	6.906	3.967
Standard Deviation	51.642	43.048	7.476	8.533	1.764	7.076	7.723	0.820	0.910	3.637
Tearout	282.021	268.395	71.477	69.121	19.156	137.946	133.166	27.289	35.370	3.713

Airborne Asbestos Fiber Concentrations and Total Airborne Dust (Gravimetric) Concentrations from All Pipe Covering Operations: Product C

Table 3.

Pipe Covering Results Product C

Operation	Samples									
	Personal		Roof			Room			Bench	Elutriator
	f/ml	f/ml(>5)	f/ml	f/ml(>5)	mg/m³	f/ml	f/ml(>5)	mg/m³	mg/m³	mg/m³
Handsawing			1.802	1.779	4.529	0.993	0.931	4.337	2.615	0.905
	5.493	5.415	3.322	2.858	8.048	2.491	2.248	4.592	0.085	0.661
	13.519	11.761	4.853	4.443	1.056	6.586	5.889	1.442	0.205	2.449
	11.187	10.562	5.084	4.911	11.891	4.506	3.798	3.637	1.894	0.393
	11.809	11.023	3.561	3.296	6.603	4.129	3.810	7.908	10.534	5.000
	8.384	6.443	4.083	3.978	10.131	3.002	3.005	4.266	6.788	30.201
Mean	10.278	9.037	3.784	3.544	7.043	3.618	3.280	4.367	3.354	6.402
Standard Deviation	2.810	2.891	1.193	1.141	3.909	1.918	1.674	2.077	3.921	11.680
Application	5.828	4.339	5.912	5.923	4.444	1.920	1.767	3.734	1.481	0.849
	5.922	4.932	5.502	5.280	4.871	7.304	6.819	3.412	6.125	1.636
	7.837	6.245	2.509	2.346	17.929	5.186	4.979	5.430	4.840	1.619
Mean	6.529	5.172	4.661	4.516	9.081	4.803	4.522	4.192	4.149	1.321
Standard Deviation	1.134	0.976	1.872	1.907	7.665	2.712	2.557	1.084	2.875	0.402
Tearout	13.383	12.524	8.893	8.328	4.327	5.393	5.025	6.593	33.134	1.386

Airborne Asbestos Fiber Concentrations and Total Airborne Dust (Gravimetric) Concentrations from All Pipe Covering Operations: Product D

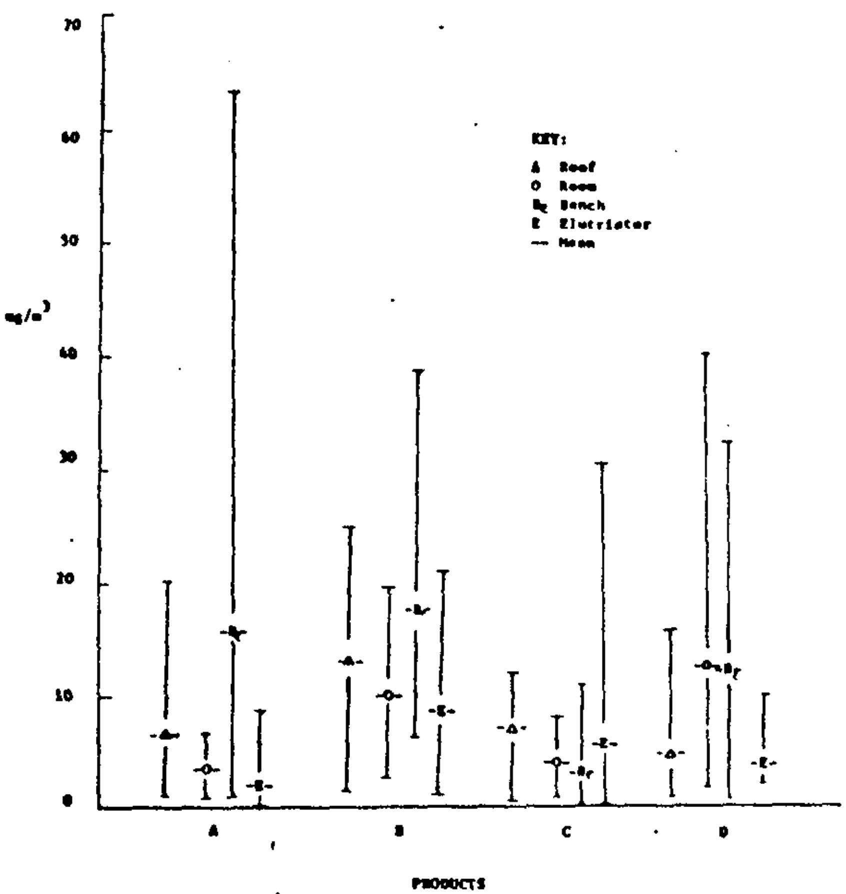
Table 4.

Pipe Covering Results Product D

Operation	Samples									
	Personal		Roof			Room			Bench	Elutriator
	f/ml	f/ml(>5)	f/ml	f/ml(>5)	mg/m³	f/ml	f/ml(>5)	mg/m³	mg/m³	mg/m³
Handsawing	26.059	27.298	1.848	1.803	0.376	5.337	4.683	2.044	9.743	4.908
	31.019	26.788	25.248	23.651	3.276	6.264	18.626	6.329	7.169	2.519
	30.384	29.378	3.309	3.201	15.497	10.316	9.181	4.058	10.036	0.191
	27.525	24.147	13.398	13.139	3.763	16.032	15.653	40.231	13.500	5.872
	34.318	32.684	2.962	2.676	1.092	8.794	7.598	13.454	1.360	4.253
	41.368	34.829	12.206	10.458	3.001	4.076	3.870	10.579	32.321	4.349
Mean	32.112	29.187	9.829	9.155	4.501	8.470	9.935	12.776	12.355	3.682
Standard Deviation	5.162	4.878	9.050	8.476	5.547	4.352	5.977	14.096	10.582	2.030
Application	20.287	18.880	20.560	19.466	11.155	7.287	23.608	7.352	7.320	2.787
	28.576	25.963	24.300	24.122	21.725	11.123	10.555	11.739	4.528	2.573
	23.179	22.216	19.110	18.576	14.483	18.089	17.593	14.854	5.462	5.255
Mean	24.013	22.353	21.317	20.721	15.788	12.166	17.252	11.315	5.770	3.538
Standard Deviation	4.206	3.543	2.681	2.979	5.406	5.477	6.533	3.769	1.421	1.491
Tearout	68.242	45.848	41.001	39.686	24.868	12.318	11.766	9.943	35.156	1.782

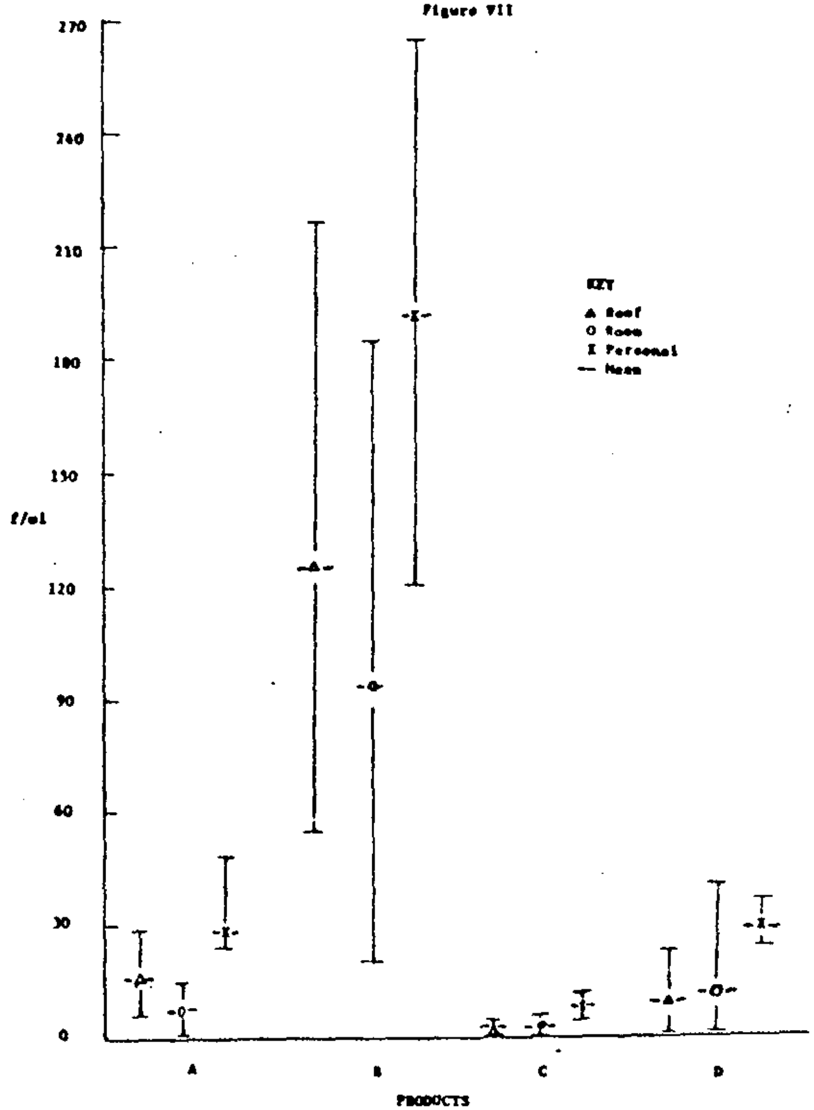
Pipe Covering
[Sawing (Gravimetric mg/m^3)]

Figure VI

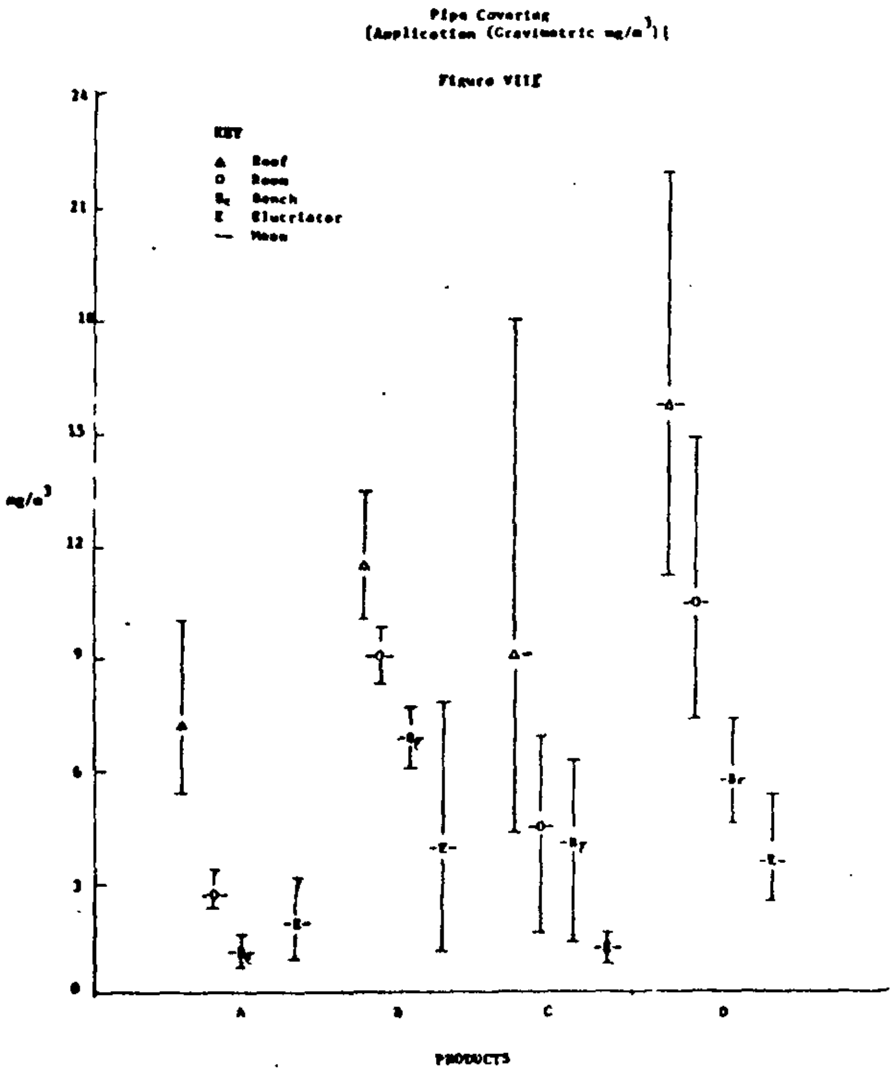


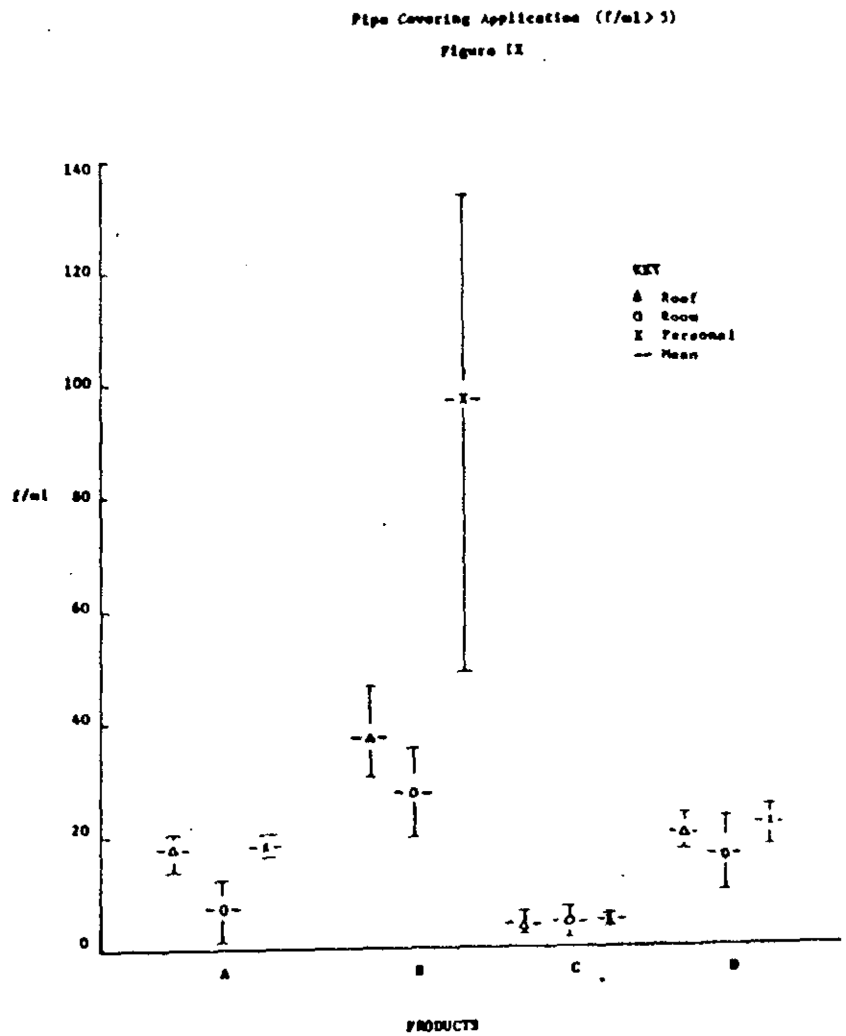
Pipe Covering [Sawing (f/ml >5)]

Figure VII



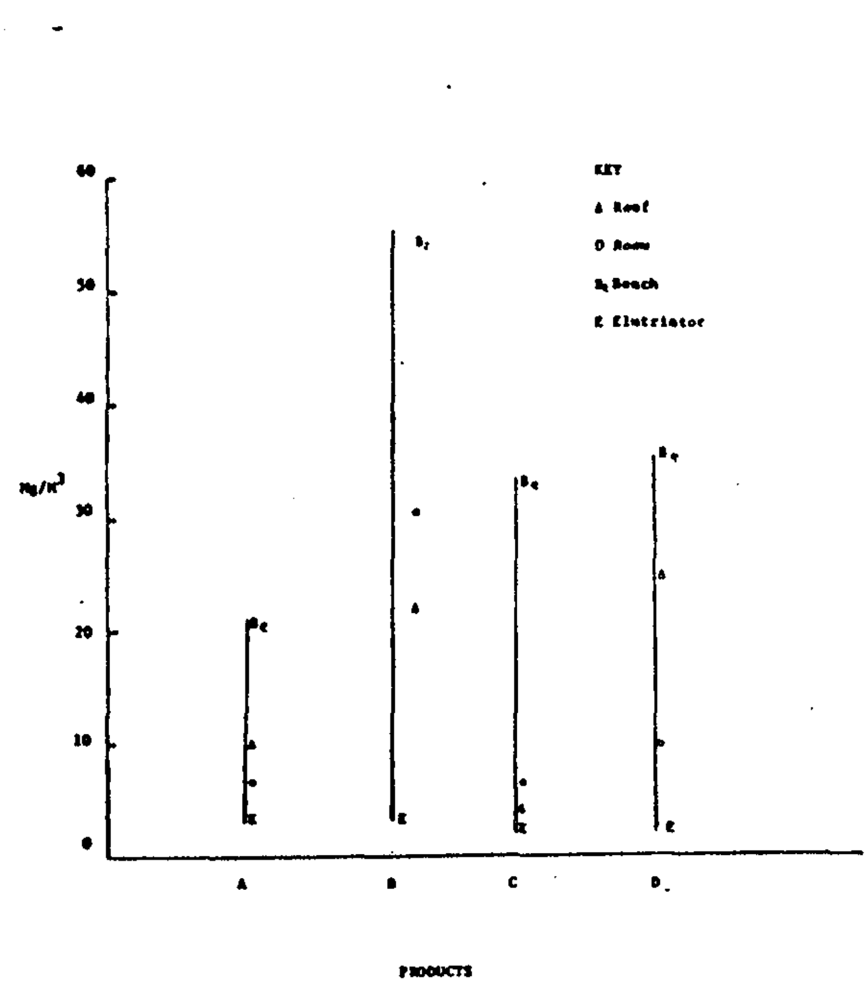
Total Airborne Dust (Gravimetric) and Airborne Asbestos
Fiber Concentrations: Handsawing Portion of Pipe Covering





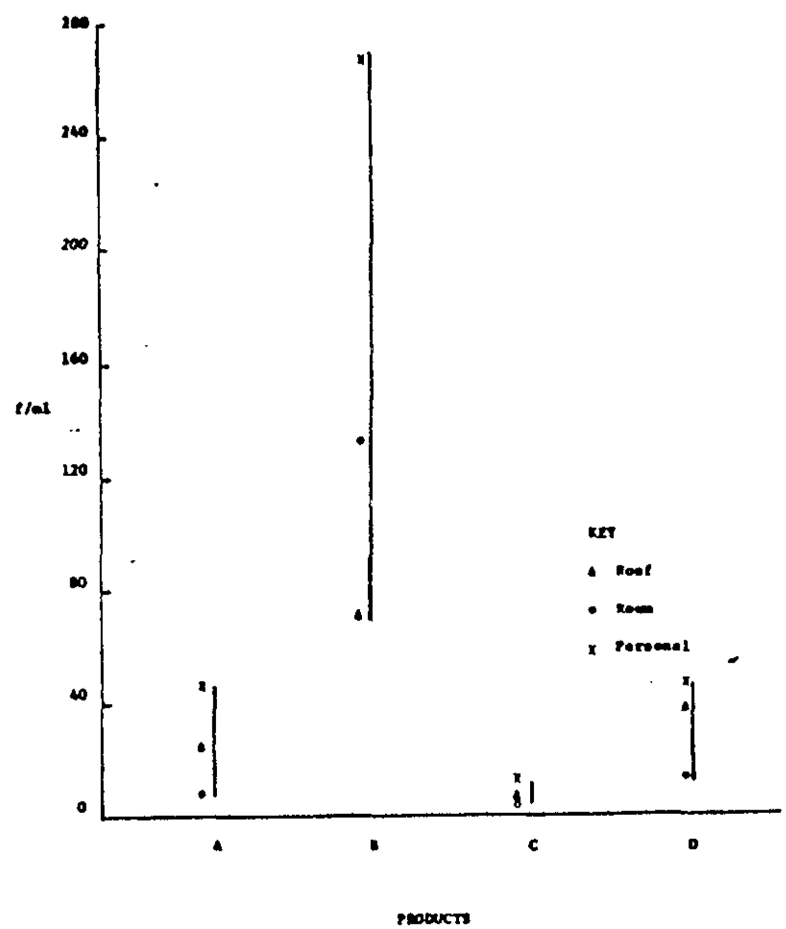
Total Airborne Dust (Gravimetric) and Airborne Asbestos Fiber Concentrations: Application Portion of Pipe Covering

Pipe Covering Tear-Out
Gravimetric (Mg/M³)
FIGURE X



Pipe Covering Tear-Out
(f/ml >5)

FIGURE XI



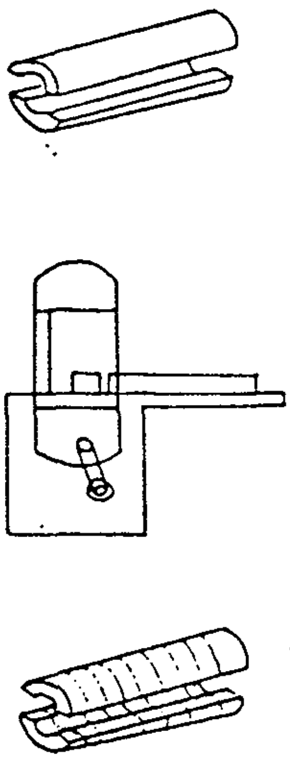
Total Airborne Dust (Gravimetric) and Airborne Asbestos
Fiber Concentrations: Tear-Out Portion of Pipe Covering

II. Power Sawing (Bandsaw)

Six 3-foot long half-round sections were cut into (approximately) 4-inch long sections (making 9 cuts per 3-foot section), using a Dewalt bandsaw with a 1/2-inch blade with 6-blade points per inch. The linear velocity of the point tips was about 3000 feet per minute. A background sample was taken before each product change. The saw was placed in the center of the room (under the Roof filter holder). Two half-sections were cut, while samples were taken, then the saw shut off and the filters changed. This process was repeated twice more for each product. Figure XII shows a flow chart for this operation.

BAND SAWING

FIGURE XII



Mean Time Required (for 1 full section)	Air Samples Per Product
A 3.0 min.	
B 2.8 min.	15
C 2.3 min.	
D 3.3 min.	

Results (Bandsaw)

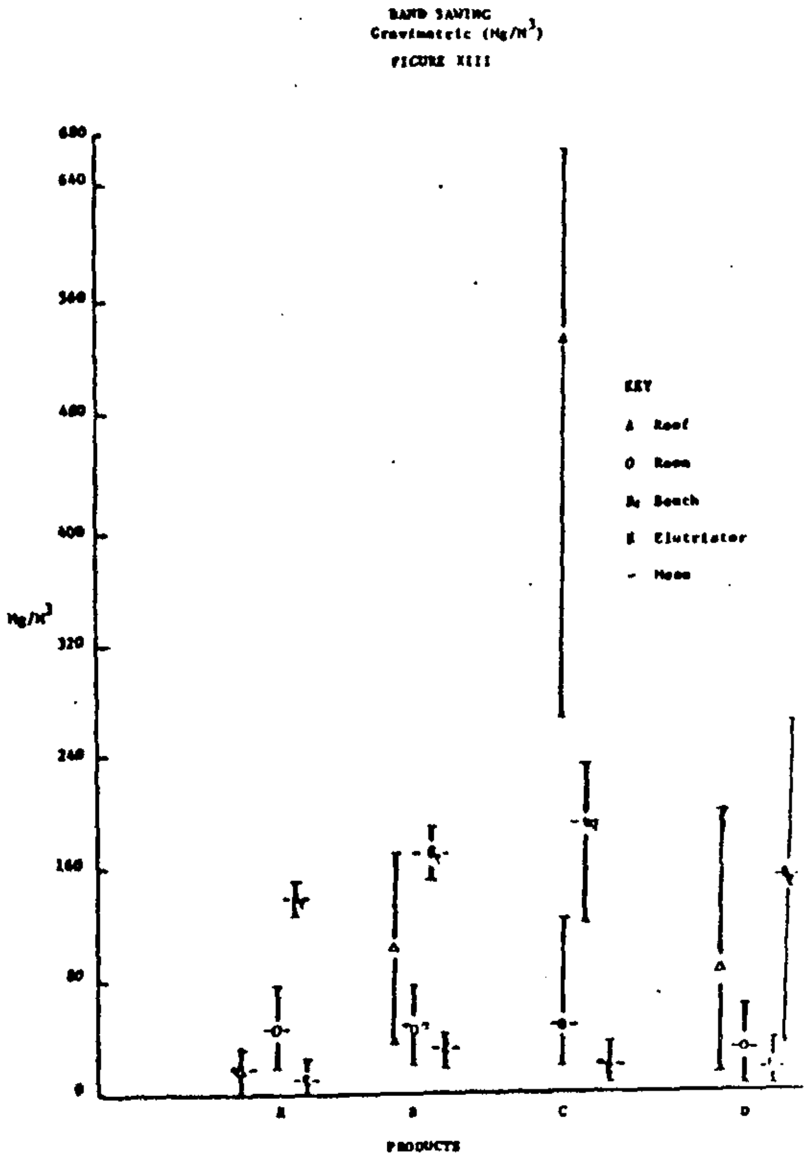
Table 5 shows the results for the bandsawing for all products with (again) the results listed as total asbestos fibers per milliliter, fibers (longer than 5 μm) per milliliter, and total particulate milligrams per cubic meter. In Figures XIII and XIV are again shown the graphic representations of results.

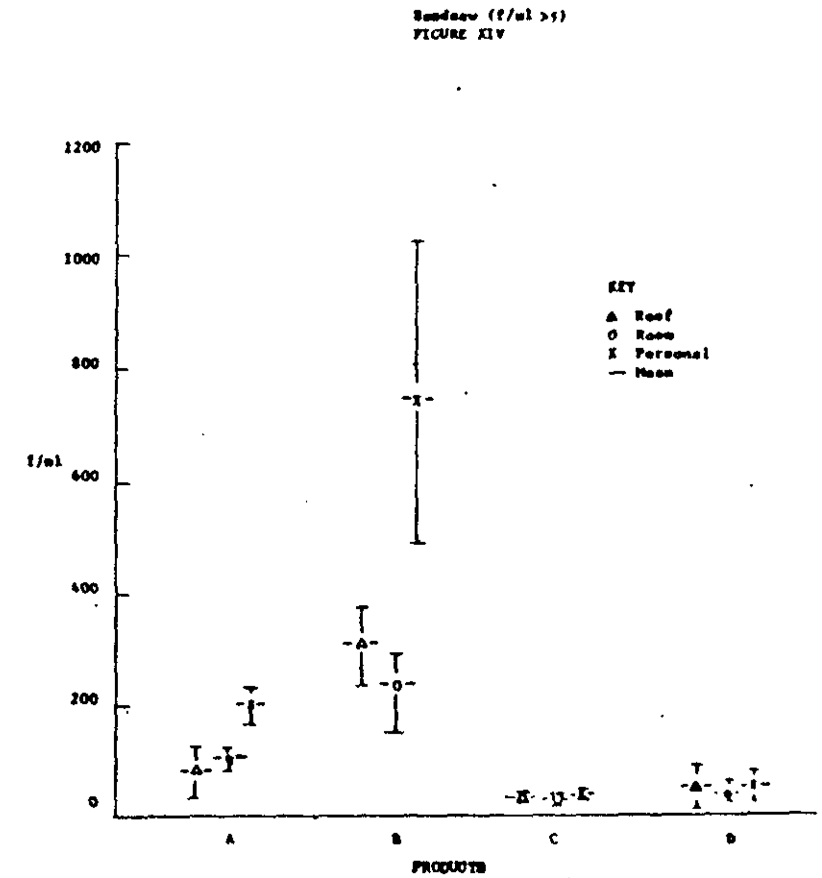
Airborne Asbestos Fiber Concentrations and Total Airborne Dust (Gravimetric) Concentrations from Bandsawing: All Products

Table 5.

Band Sawing Results

Product	Samples									
	Personal		Roof			Room			Bench	Elutriator
	f/ml	f/ml(>5)	f/ml	f/ml(>5)	mg/m³	f/ml	f/ml(>5)	mg/m³	mg/m³	mg/m³
A	243.097 225.615 179.757	234.282 217.200 170.852	4.609 122.546 114.875	3.970 117.086 109.589	2.813 35.385 31.288	108.578 104.620 91.271	103.771 99.560 89.731	22.006 28.072 74.035	166.924 167.319 162.061	18.461 0.523 27.076
Mean	216.156	207.445	80.610	76.882	23.162	101.490	97.687	41.370	165.435	15.353
Standard Deviation	32.712	32.821	66.103	63.255	17.741	9.068	7.205	28.451	2.928	13.547
B	562.076 1138.125 ------	488.731 1020.792 ——	265.243 397.770 329.009	239.967 371.379 315.365	34.143 108.671 168.879	138.888 300.599 278.316	135.096 291.976 269.691	30.850 36.717 74.000	176.661 186.634 155.764	29.563 40.437 36.976
Mean	850.101	754.262	330.676	308.852	103.898	239.267	232.254	47.189	172.286	35.659
Standard Deviation	407.328	376.224	46.267	65.943	67.495	87.642	84.877	23.398	15.672	5.555
C	51.072 46.228 40.641	47.670 41.322 36.490	31.906 29.204 38.966	30.953 28.963 36.628	266.617 669.642 668.523	33.501 29.011 28.918	32.643 27.275 26.321	28.450 75.759 122.735	220.860 229.507 122.276	31.113 11.772 20.128
Mean	45.980	61.896	33.359	32.175	534.927	30.477	28.746	75.648	190.881	21.004
Standard Deviation	5.220	5.712	5.041	3.985	232.364	2.620	3.408	47.163	59.571	9.700
D	68.060 27.425 81.991	61.975 23.897 75.181	19.544 17.201 94.883	17.429 17.079 93.184	14.228 35.178 196.372	45.798 22.177 53.533	45.060 21.028 51.366	6.473 24.838 60.458	151.581 34.126 261.276	16.519 5.097 34.565
Mean	59.159	53.684	43.876	42.564	81.926	40.503	39.151	30.590	148.994	18.727
Standard Deviation	28.351	26.678	44.189	43.839	99.665	16.335	16.009	27.448	138.596	14.858





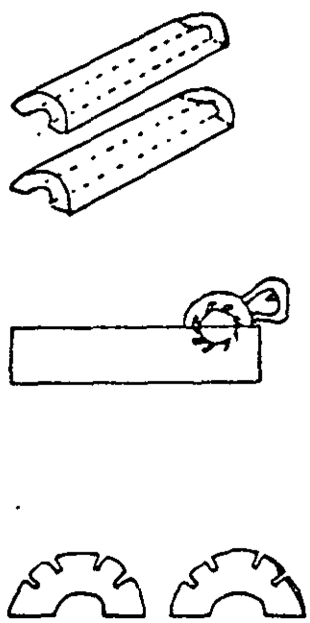
Total Airborne Dust (Gravimetric) and Airborne
Asbestos Fiber C...

III. Power Sawing (Scoring)

Two 3-foot half-round sections were scored to a depth of 1 1/4 inches, to simulate the scoring of flat blocks of insulation, as is done to facilitate the thermal insulation of large vessels (e.g., boilers) with large radii. Each section of the insulation was scored longitudinally four times while samples were taken; the filters were then changed and the process repeated. As above, a background sample was taken with each change of product, and an additional personal sample was taken during the clean-up process. This was done using a Ram hand circular saw ("Skilsaw" type) with a 7-inch diameter blade with 1 blade point per outside circumference inch. The linear velocity of the point tips was about 3000 feet per minute, as it was for the bandsaw. The flow chart and schematic of this operation are shown in Figure XV.

SCORING

FIGURE XV



Time required for both sections	Air samples per product
A 2.4 min. B 2.2 min. C 2.1 min. D 1.4 min.	6

Results (Scoring)

Table 6 shows the scoring results, Figures XVI and XVII their graphical representation.

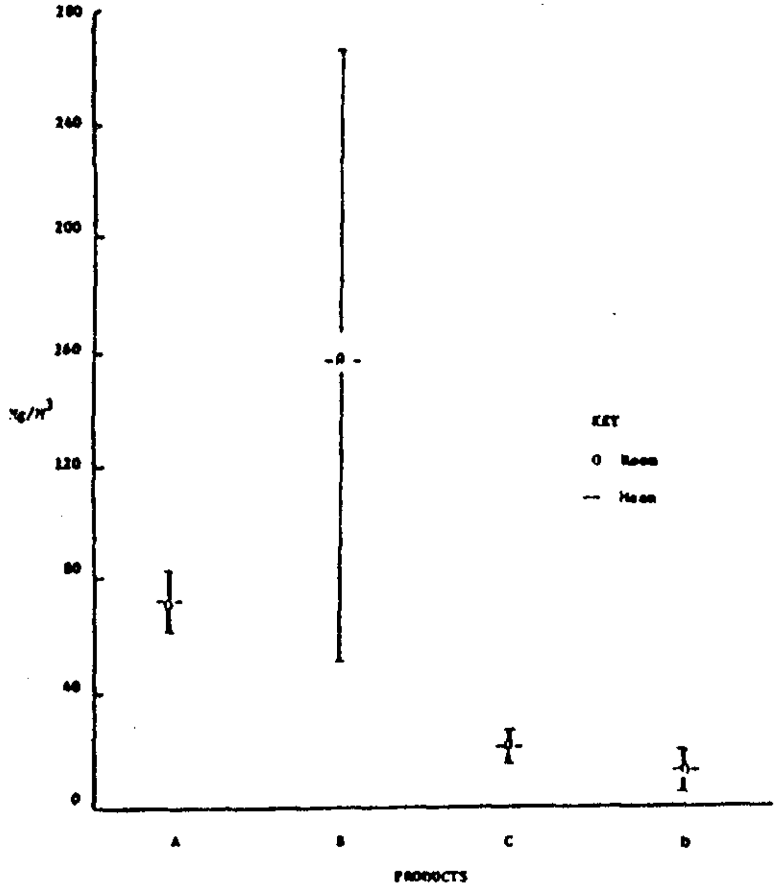
Airborne Asbestos Fiber Concentrations and Total Airborne Dust (Gravimetric) Concentrations from Scoring: All Products

Table 6.

Scoring Results

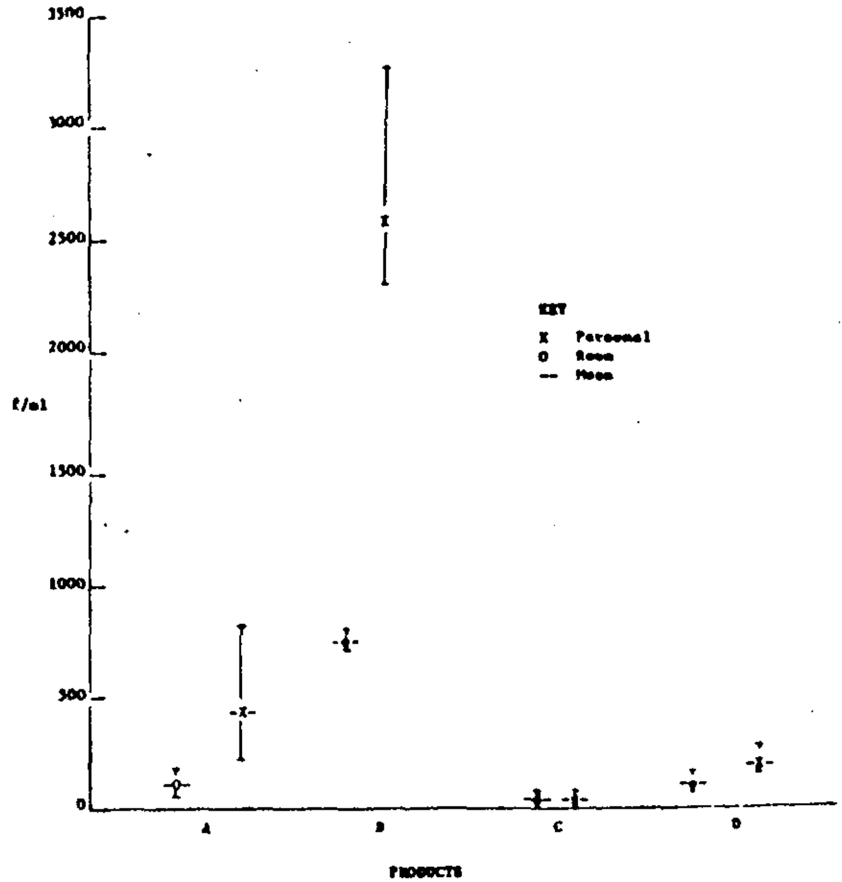
Product	Samples: Personal f/ml	Samples: Personal f/ml(>5)	Samples: Room f/ml	Samples: Room f/ml(>5)	Samples: Room mg/m³
A	264.861 869.319 373.496 613.663	231.622 826.796 336.058 374.626	201.760 64.317	191.957 61.411	83.656 63.508
Mean	680.335	662.276	133.029	126.684	73.582
Standard Deviation	266.832	263.369	97.177	92.310	14.247
B	2885.442 2747.988 2645.346 3568.408	2541.928 2325.928 2348.968 3252.135	744.429 843.131	722.147 801.229	52.381 267.282
Mean	2961.796	2629.740	793.835	761.688	159.832
Standard Deviation	416.198	444.835	69.716	55.919	151.959
C	57.408 67.230 59.969 35.836	50.283 65.593 66.087 29.460	17.582 27.986	16.011 26.326	20.389 94.784
Mean	55.333	47.676	22.784	21.169	52.587
Standard Deviation	13.506	14.777	7.357	7.295	59.677
D	209.947 179.981 190.175 250.268	177.317 165.438 171.771 228.790	50.023 97.949	47.006 95.293	19.403 6.105
Mean	207.598	185.703	73.986	71.150	12.754
Standard Deviation	31.052	29.131	33.889	34.144	9.403

Scoring
Gravimetric (Mg/M^3)
FIGURE XVI



Scoring (f/ml >5)

FIGURE XVII

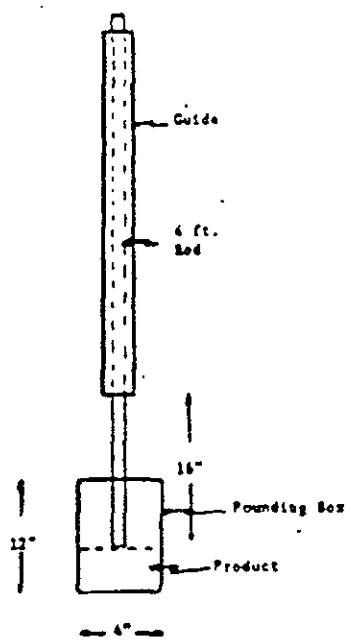


Total Airborne Dust (Gravimetric) and Airborne
Asbestos Fiber Concentrations: Scoring

IV. Pounding

A 4-inch section of insulation (recovered from the Bandsawing) was placed in a 4-inch wide by 9 1/2-inch long by 12-inch deep (internal dimensions) box, and a 4-foot long section of 1/2-inch (I.D.) iron pipe (weight 4 lb. 2 oz.) dropped through a guide section of 3-inch pipe a distance of 16 inches onto the rounded outer surface of the pipe covering. This drop was repeated 50 times, and then the pumps started and 5-minute air samples taken. The process was repeated twice more, using the same piece of pipe covering throughout for each product. As usual, background samples were taken with each product change. Figure XVIII shows this experimental arrangement; the locations of the air samples are shown in Figures III and IV, p. 6a.

FIGURE XVIII



Plan of Pounding Box
And Rod Arrangement

Results (Pounding)

Table 7 gives the results from this experiment, as do Figures XIX and XX.

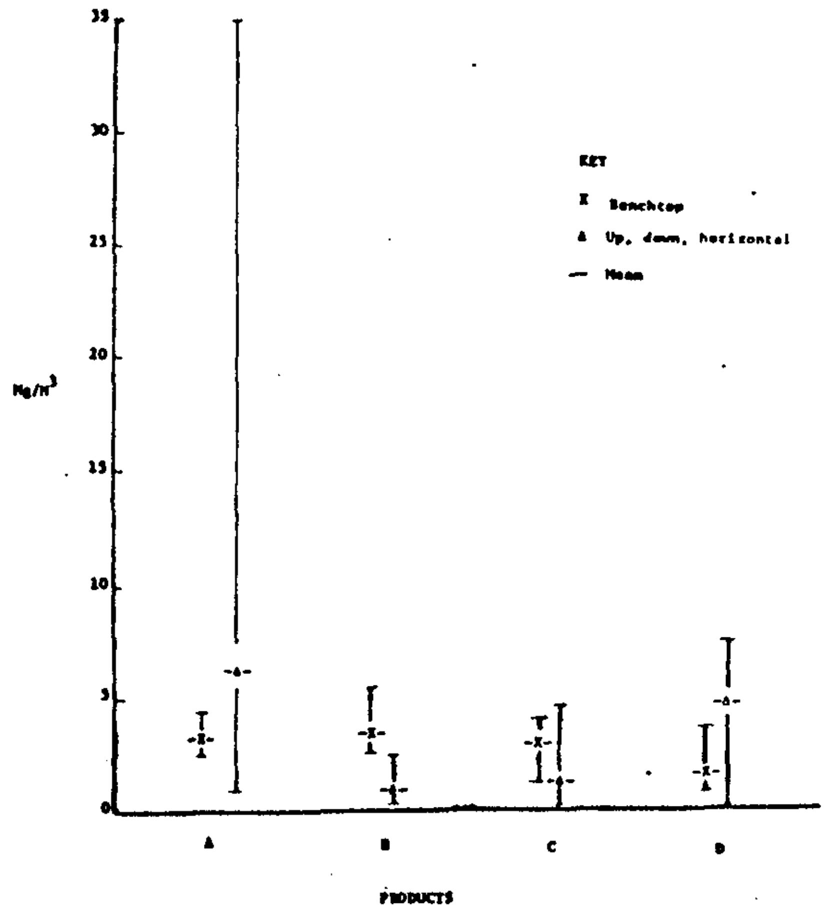
Airborne Asbestos Fiber Concentrations and Total Airborne Dust (Gravimetric) Concentrations from Pounding: All Products

Table 7.

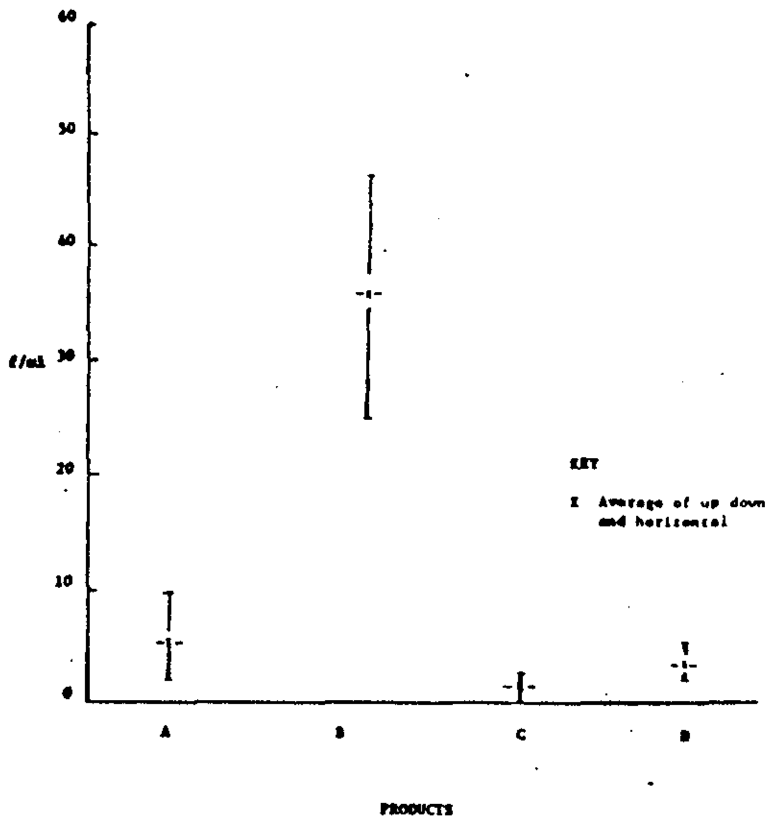
Pounding Results

Product	Samples			
	Benchline	Up, Down, Horizontal		
	mg/m^3	mg/m3	f/ml	f/ml(>5)
A		1.060	2.104	2.438
		1.683	7.602	7.807
		2.356	6.267	6.399
		1.666	2.341	10.301
		2.349	9.849	2.675
		34.925	6.956	5.104
	2.650	——	2.814	3.068
	4.417	1.642	9.731	10.152
	2.650	3.056	5.415	5.926
Mean	3.239	6.607	5.675	5.991
Standard Deviation	1.020	11.677	2.970	3.009
B		——	46.649	47.615
		0.295	29.660	31.417
		1.001	35.417	37.447
		0.463	47.753	49.997
		0.463	26.809	28.737
		2.482	25.908	27.837
	2.570	0.295	66.888	49.625
	2.570	2.415	32.816	34.255
	10.708	——	41.822	65.132
Mean	3.569	1.059	37.050	39.109
Standard Deviation	1.731	3.708	8.877	9.827
C		0.280	0.825	1.018
		2.299	1.614	2.031
		0.056	1.276	1.412
		4.655	2.627	2.650
		0.280	1.952	2.144
		1.626	2.346	2.425
	4.283	1.626	1.163	1.581
	1.285	0.953	1.557	1.975
	4.497	0.953	1.332	1.524
Mean	3.355	1.414	1.632	1.862
Standard Deviation	1.796	1.426	0.381	0.320
D		0.157	3.987	3.921
		5.811	2.214	2.148
		6.871	3.041	3.271
		5.104	4.519	4.690
		4.852	2.473	2.463
		7.546	2.698	2.764
	3.641	6.518	5.229	3.636
	1.571	6.164	2.095	2.766
	0.643	0.334	3.337	3.546
Mean	1.952	4.818	3.288	3.412
Standard Deviation	1.535	2.721	1.627	1.180

Pounding
Gravimetric (Mg/M^3)
FIGURE XIX



Pounding (f/ml >5)
FIGURE XX



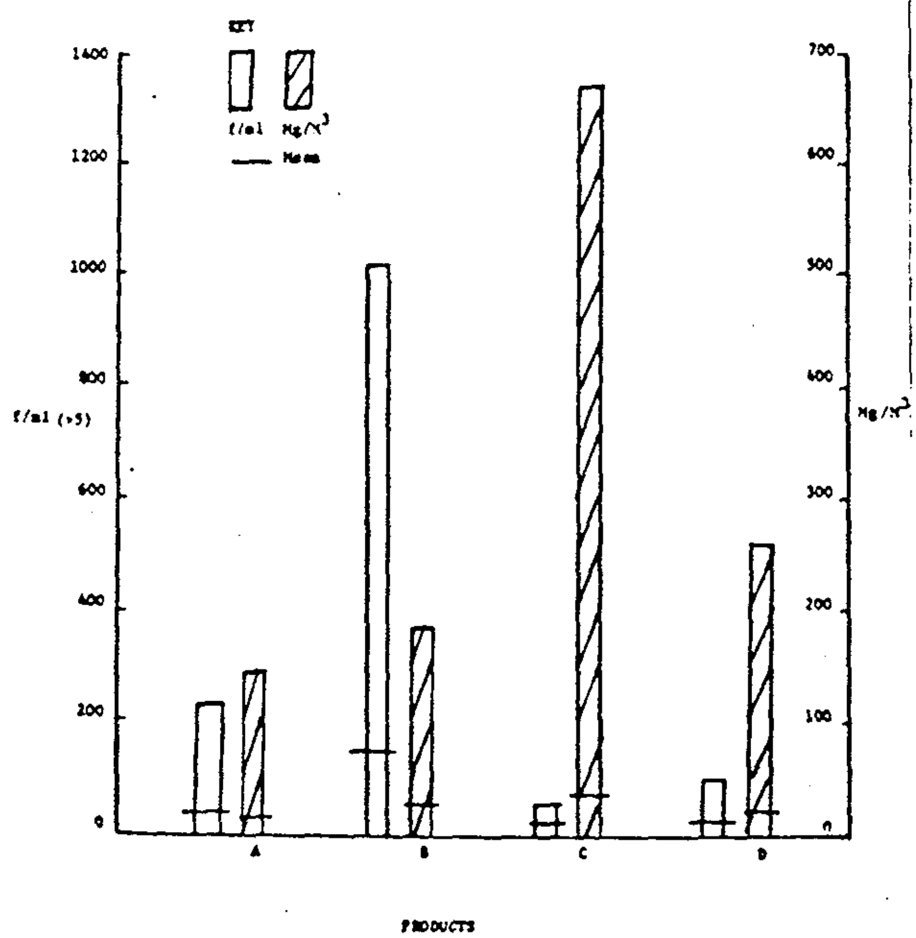
Total Airborne Dust (Gravimetric) and Airborne Asbestos Fiber Concentrations: Pounding

Discussion of Results

It is clear from the foregoing results that Product B produces significantly more airborne asbestos fibers from similar manipulations than any of the other products. This is shown by Figure XXI, where the ranges and means of all results (except those from the scoring) have been accumulated.

Accumulated Ranges and Means
for all samples (except scoring)

FIGURE XXI



One question which has not yet been answered is: "What are the sizes of the airborne asbestos fibers produced from these products?" Answer to this question is provided by an examination of the diameters of the asbestos fibers counted on the Personal filter samples for all products, (for the hand-sawing portion of the pipe-covering operation) in Table 8.

Table 8

Asbestos Fiber Diameters from Personal Samples

Product	50% less than (geometric mean)	90% less than	geometric standard deviation
A	1.45 μm	2.8 μm	1.66
B	1.7 μm	3.0 μm	1.59
C	1.6 μm	3.0 μm	1.60
D	1.6 μm	2.9 μm	1.56

Another concern which arises from an examination of the data is with the total gravimetric concentrations of airborne particulate matter which were measured. In many cases, these were orders of magnitude above the proposed Threshold Limit Value of 10 mg/m^3 for inert dusts. This indicates that, even if these products contained no asbestos, their use in enclosed spaces similar to our test chamber would produce concentrations of airborne dust which would be unacceptable. Analysis of the "respirability" of these dust concentrations (from the comparison of the Elutriator samples with other samples) is proceeding and will be the subject of future publications.

It must be understood at this point that the results of this study are subject to several qualifications. Perhaps the most important of these is that exposures of workers in the actual application and manipulation of these materials would often be different than those found here. Higher concentrations would be postulated if several men were working within an enclosed space, or if the available space was more confined. More likely, actual concentrations (as we have measured in many diverse job situations) would be lower due to slower pace of the work, natural ventilation, or greater space available for dilution.

Another qualification is that the Pounding and Scoring operations performed here are not strictly comparable to actual trade practices. The pounding operation was (in essence) a destructive test; most applications would not be accompanied by repetitive blows concentrated on a small area of the surface of a product. However, (despite the fact that this is considered a poor trade practice) some insulators will not consider an installation complete on a large vessel until they have thoroughly pounded the applied insulation material, raising clouds of visible dust.

Scoring is ordinarily done to facilitate "bending" of flat blocks of insulation to fit a curved surface. Product B is not supplied in flat blocks, and it is therefore unlikely that scoring will be done to this product. But mechanization is proceeding in this trade (as in others) and the use of power saws of various sorts is becoming more common for tasks which have traditionally been done by hand.

A third important qualification affecting the application of the results found here is due to our sampling method. None of the data are time-weighted average concentrations; they represent "peak" exposures. Nevertheless, the relative hazard judgements implied by the different concentrations found are valid, since the time limitations were imposed by the products themselves. That is, a product which is easier to work will require less time for installation of a given segment, but in actual practice this will mean that the insulator will install more of these segments. He will thus be exposed to more repetitions of peak exposures, not necessarily to a lower time-weighted average exposure. Further, the purported ease of fabrication of Product B was not found in our tests. This can be seen from the times shown in Figures V, XII, and XV. It is worthy of particular note that Product B was the only product for which the 3-minute tear-out time limit was not met. This was due to the "springiness" of this product; the wires rebounded from the hatchet blade instead of breaking cleanly.

Our hypothesis that the product containing the highest percentage of asbestos might not produce the greatest concentrations of airborne asbestos fibers has not been validated by this study. From the raw data, it would appear that our conclusion must be: "The concentrations of airborne asbestos fibers are directly related to the percentage of asbestos in the parent products." We do not believe this to be a general rule; we suspect that design of materials to reduce airborne dust production is possible and that factors not apparent to us at this point may eventually prove to be of more importance in this design than the percentage of asbestos. Our examination of the products used in this study is continuing; we hope at some future time to be able (within reasonable bounds of certainty) to predict airborne asbestos fiber production from given operations on specific products. This prediction would arise from consideration of such factors as density, relative strength of the bonds between the asbestos fibers and the matrix, resistance to specific kinds of applied forces, and others.

From a practical point of view, it is clear that none of these products should be used without industrial hygiene control. Any cutting operation should be accompanied by controls on the dust arising from that operation, preferably controls (such as local exhaust ventilation) which would prevent the dissemination of dust into the breathing zone of the workman doing the cutting, or the breathing zones of those working near him. Where this cannot be done, personal respiratory protection is a poor (but necessary) second choice.

Conclusions

1. A method by which construction materials can be tested for their potential for airborne dust generation has been developed.

2. Four insulation materials containing asbestos have been tested using the method; the material containing the highest percentage of asbestos produced the highest concentrations of airborne asbestos fibers under conditions of the test.

3. Measurement of the total airborne dust concentration is a "poor" indicator of the airborne asbestos fiber concentration.

4. Comminution (by hand or mechanical methods) of any of these products within confined spaces may result in airborne asbestos fiber

concentrations orders of magnitude greater than the proposed ceiling value of the Threshold Limit Value.

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