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DUST-PRODUCING POTENTIAL OF CONSTRUCTION MATERIALS

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Abstract

A detailed report of a comparative study of the dust-producing potential of four asbestos insulation materials and one non-asbestos material (mineral wool). The test operations, sampling and analysis procedures are described and the procedure adopted and results are appraised. It is concluded that before a material is marketed, specialists should evaluate its health safety from available data. When these are lacking, materials should be pretested. The onus of choice, however, will always pose problems when irreducible variables are present (as in the case of dust production).

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Introduction

In 1970, we began a study of the relative dust-producing potential of four commercial insulation products containing asbestos fibre. Our objective has been to develop a method by which this potential can be assessed. A new insulation material containing "mineral wool" fibre instead of asbestos fibre has since been introduced commercially as a substitute for one of the four original products. This report compares the airborne dust generated from all five products during hand and machine operations representative of current insulation trade practices in the United States, and discusses the application of our testing method as an approach to the reduction of potentially injurious exposures to airborne dust.

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Test operations

All operations except pounding were performed by an insulation mechanic, a member of Local 16 of the International Association of Heat and Frost Insulators and Asbestos Workers. All work was done inside a closed room, 10 ft. x 10 ft. 4" x 9 ft. 8" (approximately 305 x 315 x 295 cm or 3.05m³) provided with an exhaust fan for the removal of contaminated air between products and operations. The insulation mechanic was supplied with filtered air through a supplied-air respirator hood.

Three major types of operations were performed on each product:

(1) Hand-sawing, pipe-covering and tear-out. This was a duplication of the sequence of operations through which the mechanic would ordinarily go in the application of insulation to a section of pipe, using hand tools.

Each section was sawn into nine equal pieces, and then re-assembled on a section of iron pipe, wired in place and covered with canvas, which was glued on with wheat paste adhesive. After application, the insulation (three full sections, each 3 feet (91.5 cm) long), was heated at 621° C for 96 hours, using a heater inside the pipe to which the insulation was applied. The heat-stressed material was then removed from the pipe by the mechanic, using a hatchet, with a time limit of one minute for each section.

(2) Power sawing (band sawing and scoring). Sections of each product were cut into smaller pieces with a bandsaw, which had 6 teeth per inch of blade (2.4 cm) and a blade tip linear velocity of about 3,000 feet per minute (915 m/min). Other sections were "scored" 4 times longitudinally to a depth of 2.5 cm, using a 19 cm diameter circular saw, which had one tooth per inch of blade circumference (0.4 cm), and a blade tip linear velocity of about 3,000 feet per minute (915 m/min).

(3) Pounding. As a simulation of the effects of mishandling, forcing to fit, and other types of forceful hand operations, a piece of the insulation was placed in a box, and a 4 1/8 lb (1.87 kg) weight was dropped upon it 50 times from a height of 16 inches (41 cm).

Sampling and analysis

Air samples were taken by drawing air through 0.8 µm mean pore size membrane filters. Millipore membrane was used for the "elutriator" samples, and for the "personal" breathing zone samples; Nuclepore membrane was used for all other samples. The filter diameters were 37 mm for the "personal" samples and 47 mm for all others.

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 (2.44 m) above the chamber floor level ("roof" samples); (2) from a support projecting into the chamber approximately 1 foot (30.5 cm) from the wall opposite the work bench on which the covering was done,

through an open floor ("room" closest to the samples); (4) the air drawn before passage samples); (5) with disposable Sample air flow (28.3 l/min) of 50 l/min, and show these loc

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through an open-face filter holder about 6 feet (1.83 m) 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 (outside the hood) with disposable Millipore field monitors ("personal" samples). Sample air flow rates were approximately 1 cubic foot per minute (28.3 l/min) for all samples except the elutriator which were 50 l/min, and the personal, which were 3 l/min. Figures 1 and 2 show these locations.

During the scoring operation, only two sampling locations were utilised (room and personal samples) as shown in Figures 1 and 2. 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, another directed downward and the other directed horizontally. The data from these three samples are reported together as "room-B" in table 4. Sample air flow rates were again approximately 1 cubic foot per minute (28.3 l/min). These locations are shown in Figures 3 and 4.

All filters (except 37 mm personal sample filters) were weighed before and after use, each such weighing being preceded by desiccation for two hours to stabilise weights. From these weights, the gravimetric concentrations of total airborne dust were computed in mg/m^3 by dividing the change in weight in milligrammes by the total cubic metres of air which had passed through the filter. This was the sole analysis applied to the "bench" and "elutriator" samples.

The personal sample filters (and some "roof" and "room" filters) were analysed to determine the concentrations of mineral fibres. This analysis was by the standard method for the determination of asbestos fibres collected on membrane filters. 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 430 x magnification, with the microscopic field of examination limited to the area bounded by a Porton eyepiece reticle (0.0061 mm^2 per field). The mineral fibres seen in each field were recorded and placed into several length and diameter categories.

Results

The results of the air sampling for pipe-covering, tear-out and band sawing are shown in table 1 as milligrammes of total particulate material per cubic metre of air, and in table 2 as total mineral fibres per millilitre of air. Table 3 shows the results from the scoring and pounding operations, for total particulate; table 4 shows the concentrations of mineral fibres as fibres per millilitre.

Figures 5-9 graphically depict the ranges of the gravimetric concentrations for the several specific operations on each product tested. Figure 5 shows the ranges and means for the accumulated gravimetric data from the hand-sawing and application operations; Figure 6 the tear-out; Figure 7 the bandsawing) and Figures 8 and 9 show the scoring and pounding operations respectively. Figure 10 depicts the range of fibre counts from the personal samplers for all products for all operations.

In the tables, the numbers of air samples taken for each product are shown directly next to the name of the operation. For instance, in table 2, 24 filter samples were measured for the hand-sawing operation; table 3 shows that 18 filters were examined for fibre concentrations during the hand sawing. We emphasise that we took many air samples during the course of this investigation. The numbers of filters nominally exposed (a very few were lost due to sampling and handling mishaps) for each product were:

Hand sawing	30
Pipe covering	15
Tear-out	5
Band sawing	15
Scoring	6
Pounding	<u>12</u>
TOTAL	83

Since weight change and fibre count were measured on several categories of filters, the number of individual measurements on which the results were based are:

	Gravimetric	Fibre Count	Total
Hand sawing	24	18	36
Pipe covering	12	9	21
Tear-out	4	3	7
Band sawing	12	9	21
Scoring	6	6*	12
Pounding	12	9**	<u>21</u>
			118

* 3 for product B2.

** 0 for product B2.

The total number of filter samples taken and analysed for all products was thus 415, and the total number of analyses was 578.

Discussion

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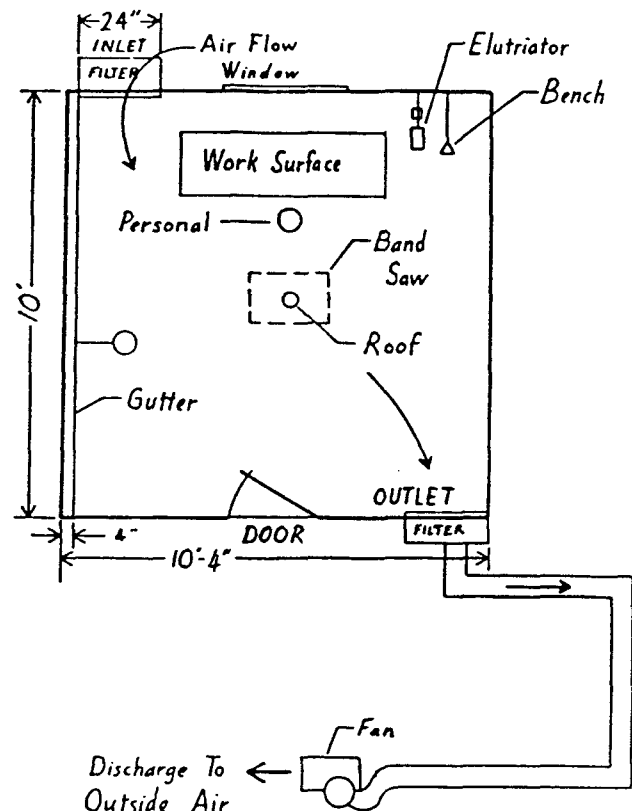


Fig. 1 - Plan of Enclosure - top view

Discussion of results

In considering the basic approach to be taken in this project, we were guided by several criteria. First, we wished to duplicate as closely as possible the actual conditions in which the material would be used. Second, we wished to develop a method which was reproducible, either by ourselves or others. Third, we wished to minimise the numbers of samples taken and analysed, since the microscopic method necessary for the enumeration of mineral fibres is time-consuming, tedious and expensive.

The first criterion, the need to duplicate the real world, was the most important in our view, and dictated our attempts to meet the other criteria. We thus began with the premise that we would have a skilled mechanic use customary trade methods in the handling of the products,

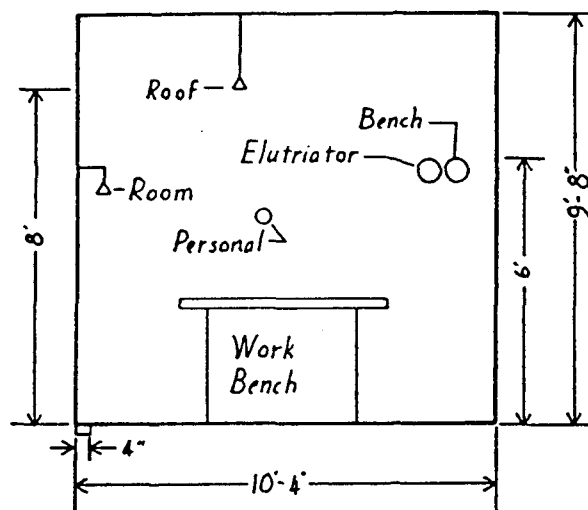
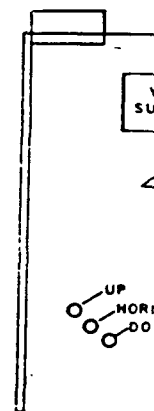


Fig. 2 - Plan of Enclosure - side view

and we would sample around him to measure the concentrations of airborne dust. Specific details of the application and handling of the insulation products were decided after detailed consultation with the mechanic.

We feel that our measurements were indeed representative of actual job conditions. Over the past several years we have been closely associated with the insulation trade in research and as medical and industrial hygiene consultants, and have visited many sites where materials similar to those examined in this study have been in use. The practices used by the mechanic might have been found on any of a number of construction or shipbuilding sites. The artificialities introduced in the band-sawing, scoring and pounding operations were necessary to regulate the internal (product to product) consistency of our measurements.

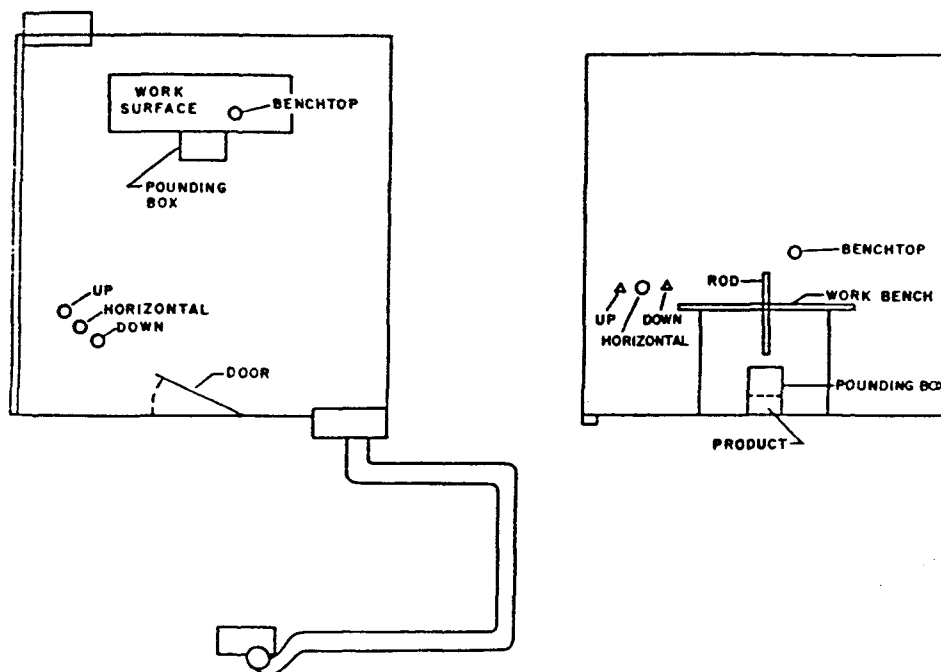
To meet the second criterion, we took several measures. The most important of these was the construction of the special room in which all operations were carried out. The space available for dilution of the generated dust was limited and constant; changing of the air



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Figs. 3 and 4 - Plan of test chamber during pounding
Top view and side view

between all operations and products permitted the return to a baseline concentration, which was measured at each discontinuity in the procedure; and the locations of sampling sites were clearly defined. Additionally, we attempted to define and hold constant all other variables in the experimental scheme, including tools used.

Our third criterion, the wish to minimise the number of samples taken, was reinforced by the sampling logistics. Many of the operations required a very short time for completion. Thus the time available for sampling was limited, and errors in the computation of the time intervals covered by the samples would have been relatively quite large, compared to the same errors in a longer sample. The number of pumps which can be turned on or off in a given time period is limited partly by the locations of the switches, and the number of people available. We grouped pumps as much as possible, but were limited by

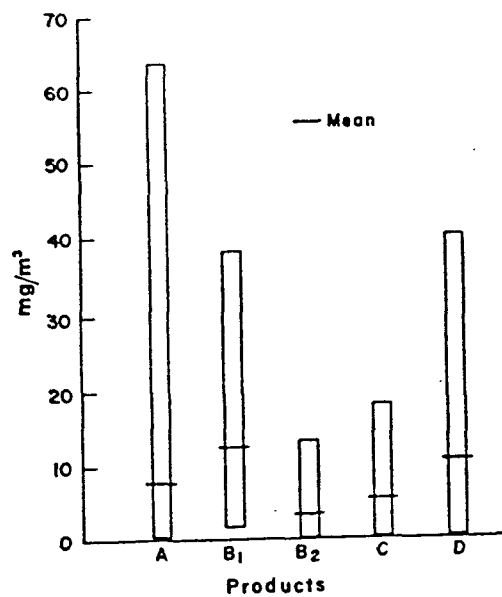


Fig. 5 - Pipe Covering and Hand Sawing - Gravimetric Concentration Ranges

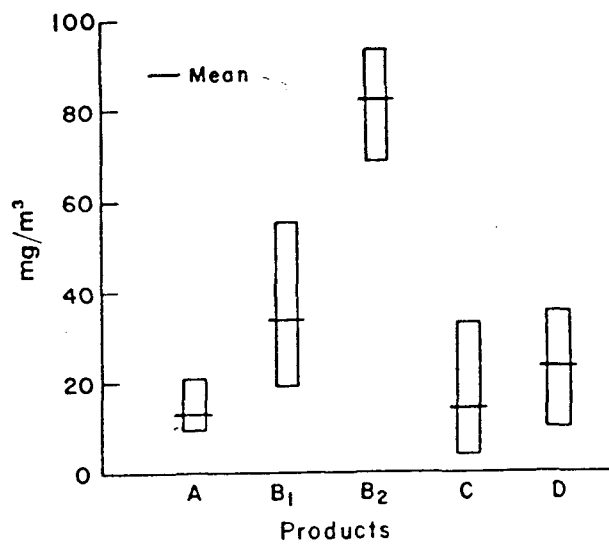


Fig. 6 - Tear-out - Gravimetric Concentration Ranges

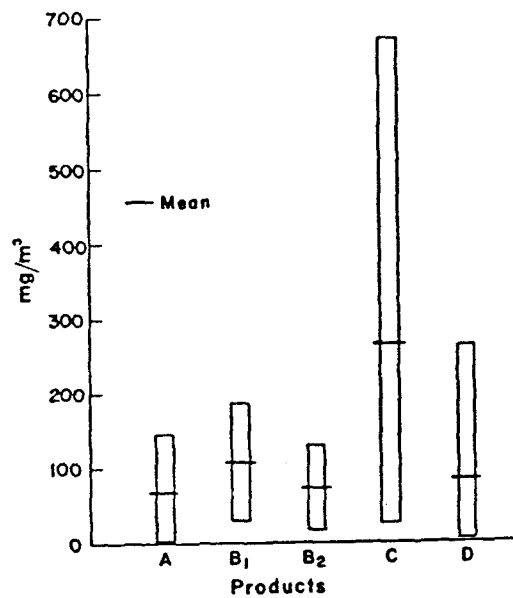


Fig. 7 - Band sawing - gravimetric concentration ranges

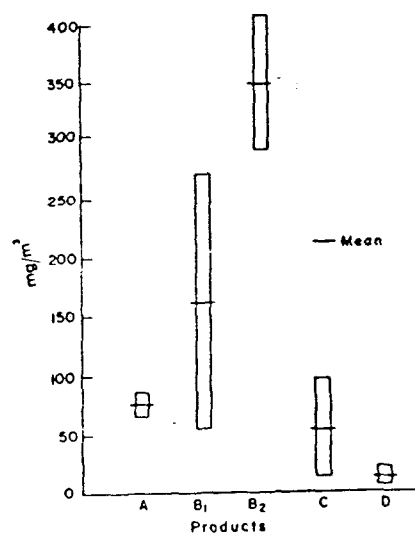


Fig. 8 - Scoring - gravimetric concentration ranges

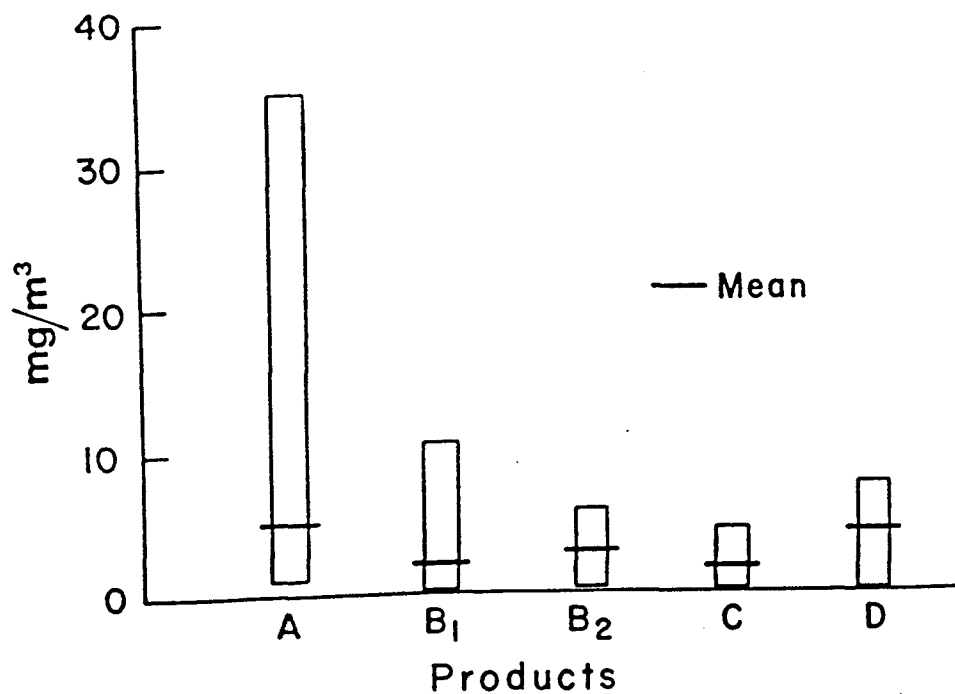


Fig. 9 - Pounding - gravimetric concentration ranges

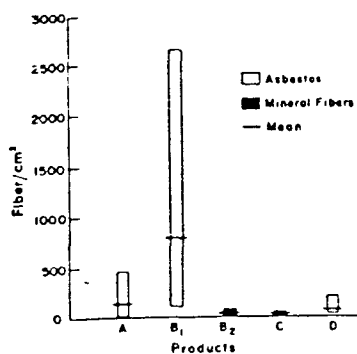


Fig. 10 - All operations - fibre concentration ranges

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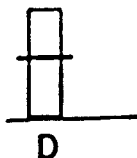
the need for switching pumps both inside and outside the test chamber, and the usual presence of no more than two investigators or technicians. Our practical upper limit to the number of pumps which could be turned on or off with sufficient rapidity to assure precision (± 10 seconds) in time measurement was five; for some operations it was less. Our experimental design was thus dictated by economics and the desire for precision in the measurements we did make, and not by the desirable goal of statistical reliability, for which a far greater number of samples would have been necessary.

Airborne dust exposures of workers in the actual application and manipulation of these products would often differ from 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, greater space available for dilution, or less use of power tools.

None of these data are representative of full working day exposures; they represent "peak" exposures. In some cases, the magnitude of the peak was dictated by the speed with which a given operation could be completed, since our sampling period only included the actual time necessary for completion. Nevertheless, the judgments of the relative hazard 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, and probably to a higher time-weighted average exposure.

As mentioned, we performed 578 analyses on 415 filter samples, a number which is greater than one might expect from several years of monitoring actual work situations. Still, an examination of the means and standard deviations given in tables 1-4 shows that we were far from precise definition of the over-all dust concentrations within our test chamber for some operations and products. This was particularly true of the band-sawing and scoring operations, which produced high, but variable, concentrations. A corollary of this finding was that we did not clearly define the single "best" product for all operations, particularly if the sole criterion of "best" is the lowest concentration of total airborne dust. Although we have not completed our statistical analysis of these data, which will be the subject of a later paper, the overlapping ranges shown in the figures, together with the standard deviations given in tables 1 and 3, are indicative of the problems associated with a definition of "best".

Taking the lowest airborne fibre concentration as the sole criterion of "best", which is more reasonable due to the demonstrated adverse health effects of inhaled asbestos fibres (and disregarding for the moment product B₂), our task is simplified. Product B₁ is clearly worst, and product C is less clearly best. Given a choice, then, it would be logical to choose product C in preference to all other products tested, and even more logical to reject product B₁. This would be true even if there were other incentives (ease of fabrication, low price, suitability for an intended use) for choosing



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B₁. The relative importance of these incentives would depend on the importance placed on maintaining a healthful working environment.

In examining the data, it must be remembered that comparison of product B₂ with the others on the basis of putative health effect (disease-causing potential) is unreasonable. B₂ contains no asbestos fibre, while the others contain significant amounts of asbestos fibre:

<u>Product</u>	<u>Composition</u>
A	Calcium silicate plus 10-15% asbestos
B ₁	Asbestos (65%) plus binder
B ₂	Mineral fibre (60-65%) plus binder
C	Calcium silicate plus 10-15% asbestos
D	Calcium silicate plus 10-15% asbestos

We would not have been able to predict the airborne dust concentration arising from use of these products if we had relied on our personal knowledge of their composition and structure. Indeed, after the tests we are still not certain as to the structural determinants of a high dust-producing potential. One must guess that it is related to the density and bonding within the product as much as to bulk composition. With further testing it is possible that these factors could be evaluated and that reduced production of airborne dust could be incorporated as a desirable factor in product design.

For all of these products, the application of machine-powered cutting processes generated much higher levels of total airborne dust, and much higher fibre concentrations, than did hand operations. In the case of the products containing asbestos, some of these concentrations were of a magnitude to cause justifiable concern for the health of workers exposed to them a very few times. Comparison of the bench and elutriator samples in table 2 for the pipe-covering and band-sawing operations shows that much of the increased mass of airborne dust associated with machine-powered sawing was probably caused by large particles which would be expected to settle out of the air relatively quickly and which would not be inhaled. Nevertheless, such large particles may be the cause of upper respiratory irritation, and will certainly cause the level of general cleanliness of the job site to be decreased. If strict attention is not given to immediate clean-up, the large particles which have fallen to the floor may be ground underfoot, to be later redispersed as small particles.

A 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/m³ for inert dusts. This indicates that, even if all of 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.

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

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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.

This has been a pilot study of a method of industrial hygiene control which, if not wholly new, has not been used widely. We compared the airborne dust production arising from the expected uses of several commercial insulation products with the objectives of developing a test method which might be applicable to other materials, and of applying that method to the materials at hand. The basic criteria were duplication of conditions of expected use, reproducibility and economical expenditure of effort. The specific conditions necessary to meet these criteria will vary with the materials to be tested and the methods needed to test them.

Our specific tests on the insulation products demonstrated some of the strengths and weaknesses of our attempts to meet our criteria. We failed partially in our goal of comparing the individual products. The variations in air concentrations were too great in some cases for adequate description by mean concentrations. This could be remedied by taking a greater number of samples, from which we would be able to decide if there were in fact statistically significant differences among the products.

From these tests, we are able to make some specific conclusions:

1. Comminution (by hand or mechanical means) of the products containing asbestos fibre within confined spaces may produce airborne asbestos fibre concentrations orders of magnitude above the ceiling limit value (10 fibres/ml) of the threshold limit value (as laid down by the American Conference of Governmental Industrial Hygienists).
2. Levels of total airborne dust produced from any of these products may exceed the "nuisance dust" limit.
3. Use of power tools on any of these products will probably produce levels of airborne dust significantly greater than the levels to be expected from hand-tool operations.
4. Industrial hygiene control of the concentrations of airborne dust is an essential part of any planned use of these products.

For any intended use, a consortium of hygienists, physicians, toxicologists, production specialists and materials scientists should (in our view) review the available literature and decide whether a proposed material can be defined as safe. When it cannot, tests to determine the degree of hazard in that use should be performed, much as is at present done for electrical and other equipment by Underwriters Laboratory in the United States.

We feel that this general approach to industrial hygiene, i.e. testing materials before use to decide upon the safest, is not different in kind from the approach that is taken to any other criterion of product desirability by a user. The difficulty which arises is that while such properties as colour, finish, size, heat resistance, etc. can be (and are) neatly tabulated for the prospective purchaser

TOTAL AIRBORNE DUST CONCENTRATIONS (mg/m^3) PIPE COVERING AND BANDSAWING

•• Std. Dev. = standard deviation.

AIRBORNE FIBRE CONCENTRATIONS (fibres/ml) PIPE COVERING AND BANDSAWING

[illegible]

Table 2

AIRBORNE FIBRE CONCENTRATIONS (fibres/ml) PIPE COVERING AND BANDSAWING

Sample Site		ROOF						ROOM						PERSONAL					
Project Code	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean
18	Hand Sawing	9.0	56.9	0.5	1.2	9.1	5.4	57.5	0.1	1.9	4.4	11.4	57.5	2.0	2.8	5.1	33.6	193.8	3.5
9	Appli- cation	18.7	42.1	0.8	4.7	21.3	9.0	32.1	0.6	4.8	12.2	16.8	113.9	1.3	6.5	24.0	16.8	113.9	1.3
3	Tear- out	2.7	7.5	0.2	1.9	2.7	4.4	7.1	0.4	2.7	5.5	2.7	51.6	0.2	1.1	4.2	2.7	51.6	0.2
9	Band Sawing	80.6	330.7	-	33.4	43.9	101.5	239.3	-	30.5	40.5	216.2	754.8	23.1	46.0	59.2	216.2	754.8	23.1
9	Band Sawing	66.1	46.3	-	5.0	44.2	9.1	87.6	-	2.6	16.4	32.7	376.2	8.4	5.2	28.4	32.7	376.2	8.4

** Total number samples per product.

to peruse, it is far more difficult to decide whether a given product is "safe", "safer than others", or "safest". This is particularly true when the criterion of safety (lack of adverse health effects) is a variable dependent upon many factors, including production of airborne dust.

Table 3

TOTAL AIRBORNE DUST (mg/m^3) CONCENTRATIONS, POUNDING AND SCORING

Operations		Pounding*				Scoring**	
Sample Site		Bench Top		Room B		Room	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
P R O D U C T S	A	3.2	1.0	6.6	11.7	73.6	14.2
	B ₁	3.6	1.7	1.1	3.7	159.8	152.0
	B ₂	4.0	1.6	2.9	1.2	345.8	81.5
	C	3.3	1.8	1.4	1.4	52.6	59.7
	D	2.0	1.5	4.8	2.7	12.8	9.4

* Twelve samples per product.

** Six samples per product.

Table 4

AIRBORNE FIBRE CONCENTRATIONS (fibres/ml) POUNDING AND SCORING

Operations		Pounding*		Scoring**			
Sample Site		Room B		Personal		Room	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
F R O D U C T S	A	5.7	3.0	442.3	263.4	126.7	92.3
	B ₁	37.1	8.9	2 629.7	444.8	761.7	55.9
	B ₂	-	-	63.2	43.1	-	-
	C	1.6	0.6	47.5	14.8	21.2	7.3
	D	3.3	1.6	185.7	29.1	71.2	34.1

* Nine samples per product.

** Six samples per product.

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