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The Work Environment of Insulating Workers

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With the cooperation of the asbestos workers' union and insulating contractors, a study is being made of the environmental exposures and the health of insulating workers in the western United States. Surveys have been made in a number of work situations, including small commercial building, major industrial construction and marine operations. Major emphasis has been on exposures to asbestos-containing materials, fiber glass, cork, plastics, and adhesives. Trends in product usage are presented, as well as illustrative dust counts, based on membrane filter and impinger samples, for various components of the insulator's job, e.g., prefabrication, application, finishing, mixing and tearing out of old insulation.

Introduction

WORKERS IN THE insulating trade make up an occupational group known to have exposures to asbestos that are varied and difficult to control. In recent years, investigators have shown that the relationship between asbestos minerals and human disease extends beyond a disabling pneumoconiosis produced in some workers. Evidence has accumulated that asbestos workers have a higher incidence than average of malignancies of the lungs, pleura, and peritoneum.

Asbestosis in insulating workers has been reported in England by Ellman[1] in 1934 and by Leathart and Sanderson[2] in 1963; in the United States by Fleischer *et al.*[3] in 1946, Pendergrass[4] in 1958, Marr[5] in 1958, and by Selikoff *et al.*[6] in 1964; in Sweden by Ahlmark *et al.*[7] in 1960; and in Finland by Ahlman[8] in 1966. Selikoff[6] reported lung cancer deaths in insulating workers in New York-New Jersey to be over six times expected; Dunn and Weir[9] in 1965 reported a higher than expected incidence of lung cancer in California; and Keane and Zavon[10] in 1966 in their descriptive report of the insulating trade in Cincinnati also described an excess of lung cancer.

Because asbestos may be a widespread environmental contaminant and the established threshold limit may need re-examination, there is need for a thorough appraisal of the work environment of the insulating worker. We are now in the process of doing a study of San Francisco area insulating workers in order to determine the incidence of pneumoconiosis and malignancies and make observations and measurements on the work environment. This report summarizes our preliminary environmental findings on the materials used, methods of application, and dust and fiber concentrations.

Background Information on Union Membership

This study was made possible by the wholehearted cooperation of the International Association of Heat and Frost Insulators and Asbestos Workers (both from their national headquarters and from the officers of their various locals), and by insulating contractors, individually and through the Western Asso-

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ciation of Insulating Contractors. There are approximately 1,800 insulating workers in the Western States, but this report is limited to workers within the jurisdiction of the San Francisco Local (No. 16) which encompasses Northern California and Northern Nevada. This local at present has approximately 500 members, 70% of whom have been in the trade more than 10 years and 42% for more than 20 years. The union's health and welfare fund has sponsored a program of voluntary chest films for the past 10 years, and 80% of those eligible have participated. Review of these films has shown that about 25% of the members have roentgenographic changes strongly supporting a diagnosis of asbestosis with an equal percentage having suggestive changes.[11]

Most of the local union members work for one of the 20 or so insulating contractors in the area and travel from job to job with a specific firm. There is considerable shifting from contractor to contractor so that many men have worked for all of the major contractors at some time during the past 20 or 25 years. Nevertheless, the trade is a stable one, arising out of a high wage rate and a rigid apprentice testing and training program. Men who qualify and pass through the apprentice school program tend to stay in the trade for their working life.

Insulating workers learn to do all the major jobs in their trade and usually will work at any job assigned by their union dispatcher. Some prefer to work in heavy construction or on the waterfront. The major types of work in which men are engaged can be classified as: (1) commercial building, which involves the insulation of pipe and duct systems in office buildings, apartments, shopping centers, etc.; (2) heavy industrial building, which involves the insulation of turbines, boilers, pipes, duct systems, and processing equipment in power plants, factories, etc.; and (3) marine construction and repair, which involves insulating turbines, boilers, pipes, and duct systems in ships in both naval and private vessels. Local 16 does not have jurisdiction in U. S. Navy shipyards in the Bay Area, which have their own local unions; but many of the members have in the past been employed in the naval shipyards.

The following is a breakdown of employment by types of construction of the 401 active members working as of March 31, 1967: 100 of the workers were employed in commercial building; 236 of the workers were employed in heavy industrial building; and 65 of the workers were employed in marine construction and repair. The majority are employed in the building trades. When there is an increased demand for ship construction and repair, there must be a shift of the union population. For example, during World War II, more than 1,800 insulating workers were employed in Bay Area shipyards, even though the local's membership was only 500 members. This was due to "travelers" from other locals and a large number of workers from other trades given temporary permits to do insulating work during this peak period. However, the general picture is that there are few travelers, and the Local 16 membership handles most of the jobs in this area. Rotation between employers tends to keep the local member working in this area for the duration of his working lifetime.

Insulating Materials Used

Our analysis of the insulating worker's environment indicates that they are predominantly working with calcium silicate and magnesium carbonate insulating material containing asbestos fibers, fibrous glass materials, plastics, foam glass, cork, and adhesives:

1. Materials Containing Asbestos—

100%	Amosite blankets
95%	Amosite—5% filler
10-15%	Mixed amosite and chrysotile —85% magnesia
10-15%	Amosite—85% calcium silicates
10-15%	Mixed amosite and chrysotile —85% calcium silicates
10-15%	Mixed amosite and chrysotile 85% calcined diatomaceous silica
100%	Chrysotile asbestos shorts for finishing (mud)
50%	Asbestos shorts and 50% cement for finishing (mud)

2. Materials Containing Fibrous Glass—
   Monoblock—compressed glass and resin binder
   Rolls
   Prefabricates—pipe and duct covering
   Mineral wool
   High temperature insulation
   Finishing materials (muds)
   Mineral wool and cement
3. Plastics—
   Polystyrenes—prefabricated product, powdered
   Polyurethanes—foam in places, prefabricated products
4. Cork
   100% cork blocks
5. Glass Flakes—
   Foam glass

TABLE I
Estimated Percentage of Volume and Application Time by Types of Insulation Material in Use in the San Francisco Bay Area

Type of Insulation Material	Volume % of total	Application % of time
Total:	100	100
Asbestos	45	55
Fibrous glass	45	40
Other (cork, rubber, foam glass, polystyrenes, polyurethanes)	10	5

TABLE II
Estimated Percentage of Current Use of Fibrous Glass and Asbestos Containing Materials by Major Types of Construction

Types of Construction	Fibrous Insulation Materials Used		
	Total	Fibrous Glass	Asbestos
Commercial building	100%	70%	30%
Heavy industrial building	100	30	70
Marine construction and repair	100	20	80

TABLE III
Characteristic Properties of Chrysotile and Amosite

Properties	Chrysotile	Amosite
Crystal structure	Sheet silicate	Chain silicate
Color	White	Ash-Grey
Approximate diameter of smallest fibers (μ)	0.006–0.015	0.05–0.1
Specific gravity	2.55	3.45
Index of refraction	1.567–1.639	1.639–1.708

6. Adhesives
   Epoxy and solvent; asphalt base and solvent
   Wheat paste
   Silicones
   Magnesia
   Portland Cement

Table I is an estimate of the products used by volume and the approximate times spent in applying them. This information was obtained from the contractors, men in the trade, and from personal observation during the past year. This table shows that fibrous asbestos and glass materials account for 90% of the materials applied.

Table II presents the percentage of fibrous insulation materials used by the contractors in our area by major types of work area. These fibrous materials were of paramount interest to us in reconstructing the work-a-day environment of insulating workers.

Physical and Chemical Properties of Fibrous Materials

Asbestos

Asbestos is a commercial term applied to a group of fibrous silicates. They include chrysotile and the amphibole minerals—crocidolite, amosite, anthophyllite, tremolite and actinolite. Chrysotile (hydrous magnesium silicates) is the most important commercial asbestos mineral, presently accounting for about 90% of the world's asbestos production. It occurs only in serpentine (hydrous magnesium silicate minerals) rock formations. Amphibole type asbestos is found in five commercially useful forms: crocidolite, amosite, anthophyllite, tremolite and actinolite. In the United States insulation industry, chrysotile (Canadian) and amosite (South African) are most often used in manufacturing insulation materials (Table III).

A unique physical characteristic of asbestos is its ability to longitudinally subdivide into fibrils of molecular diameter. The fibrils are too small to be counted with ordinary light microscopic techniques, making it difficult to assess the true fiber exposure.

From the literature and from manufacturers and their representatives, we ascertained the approximate amounts and types of asbestos fibers which are used locally in 14 different asbestos insulating products, manufactured by seven major producers of insulating materials in the United States. This information is summarized in Table IV. We confirmed the stated types of asbestos fibers in seven of the materials by x-ray diffraction analysis using a Norelco X-ray unit equipped with a copper target and x-ray diffraction tube.

The manufacturers of asbestos insulating materials use varying amounts and types of asbestos fibers in their products and may rebrand their product for distribution by another manufacturer. Contractors will also order specific types of asbestos insulation because of their thermal properties and not because of the type of asbestos fibers they contain. These practices on the part of manufacturers and contractors make it impossible to reconstruct a working population that has had a "pure" exposure to one type of asbestos fiber. It has been our practice, in environmental sampling, to record all the insulating materials being used in order to determine product acceptability by the insulators and to determine if any one type of insulation material produces more free fibers.

Fibrous Glass

Fibrous glass consists of a mixture of silicon dioxide, oxides of aluminum, calcium magnesium, boron and other additives. In general, the fibers of most commercial insulating products have a mean diameter of 4 microns or greater. Although this paper will not directly consider fibrous glass exposures, we have been obtaining environmental data and will analyze it later.

In our laboratory, we have optically determined the diameter in microns of various samples of fibrous glass insulating materials used in our area. The acoustical materials have the largest diameter: 11 to 14 microns; the building and duct insulation: 4 to 7 microns; pipe covering: 4 to 6 microns; and the special high temperature material: 1 to 2 microns.

It is evident from this data that it is not difficult to find glass fibers in the worker's environment that are of a respirable size. With the increased use of high temperature insulation and special fibrous glass insulation materials, we are likely to see more and more fibrous glass insulation materials with a mean diameter of respirable size.

Environmental Data

As was described in the previous section, the insulating worker works with and is exposed to a myriad of materials and conditions. Many times the materials he is exposed to result from the activities of other trades in the area. Obtaining a true time-weighted exposure under these conditions is impossible. It would require hours of observation and sampling of each worker in order to even attempt to estimate the integrated dose. Exposures in most other industries are fairly constant by comparison, in that workers continue at the same job in generally the same area. However, the insulating worker is always in a changing environment; the work locations, his position, materials, humidity, temperature, ventilation, and any number of other things are in a continual state of flux.

In an attempt to reduce this to some order, we have classified all the jobs performed by the insulation worker into six major categories: (1) Prefabrication: materials are precut and shaped using hand or power saws either on the job or at the contractor's shop (10% of his time). (2) Application: materials are fitted, hammered, or carved, and attached to the surface by wiring or gluing (40% of his time). (3) Finishing: materials are coated with asbestos containing cements, resins, asbestos or cotton cloth, or petroleum based sealers (30% of his time). (4) Tearing out: removal of old or unusable materials in the process of insulating or reinsulating (10% of his time). (5) Mix-

TABLE IV
Percentage and Type of Asbestos in Insulating Products in Current Use

Type of Asbestos	Percent by Weight	Number of Products
Amosite	10–15%	3
Amosite	95–100	3
Amosite-Chrysotile	10–15	3
Chrysotile	10–15	2
Chrysotile	85–100	3

TABLE V

Dust Concentrations Based on Impinger Samples by Job Classification

Job Classification	Number of Samples	mppcf Mean	Median	Range
Prefabrication	15	6.5	4.8	0.8–28.8
Application	17	3.5	2.5	0.8–8.2
Finishing	9	2.6	2.4	1.2–6.2
Tearing out	8	5.2	5.1	2.5–8.6
Mixing	6	9.1	8.4	2.8–16.0
General	9	1.4	1.4	0.6–1.8

TABLE VI

Fiber Concentration Based on Membrane Filter Samples by Job Classification

Job Classification	Number of Samples	Fibers/cc Mean	Median	Range
Prefabrication	22	8.5	8.4	0.1–24.3
Application	45	6.4	1.4	0.1–61.6
Finishing	31	2.7	0.8	0.1–24.4
Tearing out	17	8.9	4.9	0.2–26.3
Mixing	22	2.6	1.4	0.2–10.7
General	16	4.8	0.8	0.1–22.9

ing: mineral wool, asbestos, fibrous glass, and cements or glues are mixed separately or in combination in buckets or troughs (5% of his time). (6) General: cleaning up of old insulation, transporting of materials (5% of his time). The percentage figures indicating the amounts of time spent at each of the job classifications are, of course, variable and are only intended as rough guidelines.

For the purpose of this paper, we will limit our discussion to the environmental data obtained during insulating operations when only asbestos containing materials were used.

To compare our sampling data with the present threshold limit value (TLV) of 5 million particles per cubic foot, we have taken a number of midget impinger samples along with our other methods of sampling. The results of the impinger samples are summarized in Table V and are either breathing zone or general air samples of a particular insulation operation. All the samples were counted in accordance with the standard procedures prescribed by the American Conference of Governmental Industrial Hygienists and include both grains and fibers. It will be observed from Table V that we have three distinct areas—prefabrication, tearing out, and mixing—where the present TLV is exceeded.

Because of our interest in the role that fibers play in the pathogenesis of asbestosis, we placed the major emphasis of our environmental sampling on obtaining fiber concentrations under various working conditions. The personal and general samples were collected on Millipore Type AA Filters mounted in field monitor cases. Most of the samples were breathing zone samples worn by the workers for periods ranging from 30 minutes to 3 hours. Since it was easy to overload the filter with fibers during heavy dust periods and negate the countability of the sample, it was necessary to replace the field monitor cases several times during the sampling period. The fibers were counted by clearing a wedge-shaped segment of the filter using a modified technique of the United States Public Health Service[12] and sized by the length and diameter at 430x magnification using phase contrast illumination; we will only refer to the total fiber counts in this paper. A fiber is defined as having an aspect ratio of 3:1 length to diameter. If Timbrell's criteria[13] for respirable fibers (diameter smaller than 3.5 microns) was used, 98% ± 2% of the fibers we have counted would fall into this category. The fiber counts per cubic centimeter are given in Table VI by job classification.

Discussion

Our environmental observation in the insulation trade confirmed our initial impression that the varied job assignments, construction methods, and materials used in current work practices make it extremely difficult to reconstruct a time-weighted average exposure for the major hazardous dusts and chemicals. Reconstruction of past exposures is impossible.

Although materials in use have changed over the past 20 or 30 years, with an increasing use of fibrous glass and a decreasing use of cork, the construction industry continues to demand asbestos-containing insulation materials. The insulation worker's exposure to asbestos fibers is not disappearing. It is also evident that contrary to most other United

States industries where asbestos exposures occur, chrysotile asbestos has not yet supplanted the use of amosite asbestos in the manufacturing of insulation materials. Amosite exposures are the most significant in the insulating trade.

The breathing-zone dust levels found in the dustiest operations observed were not as high as the incidence of pneumoconiosis may have led us to expect. Some sample areas exceeded the present threshold limit value (TLV) recommended by the ACGIH; however, these samples were not for extended periods of time. Although we attempted to sample the dustiest operations, the time-weighted averages for dust samples containing asbestos would probably not exceed the TLV in most situations, even on ships. This conforms to findings by Fleischer *et al.*,[3] by Marr[5] and by Leathart and Sanderson[2] and to recently reported findings by Ferris[14] who last year reported studies in the same shipyards earlier appraised by Fleischer.[3]

The present TLV for asbestos was recommended by Dreessen *et al.*[15] in 1938, after epidemiologic studies in textile mills using chrysotile asbestos. It was not intended for extrapolation to all forms of asbestos use under all circumstances of exposure. The proven occurrence of pneumoconiosis in insulating workers exposed intermittently as described in this paper and by the authors previously cited suggests that the TLV for asbestos is too high. Our studies are, however, not yet complete enough to warrant a final conclusion. We cannot eliminate the possibility that other components of the insulating materials may be synergistic. The incidence of pneumoconiosis in these workers, the need for better environmental control measures, and medical surveillance will be the subjects of more detailed later reports.

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Errata

In the article "The Assessment of the Work Place—A Prerequisite to the Diagnosis of Occupational Chest Disease" by Kenneth M. Morse (*A.I.H.A. Journal 28:*135-143, March-April 1967) several errors unfortunately appeared on page 139. In the text table in right-hand column, the time percentage for item "3. Misc. (timbering, bit change, etc.)" should have read 4%. Immediately following this table the calculation for the time-weighted average concentration (TWAC) should have been:

$$\begin{aligned}\mathrm{TWAC} &= [(38.5 \times 4.68) + (6.5 \times 1.64) + (4.3 \times 0.32) \\ &\quad + (3.50 \times 0.48) + (4.5 \times 0.88)]/8 \\ &= 197.9/8 = 24.7 \text{ mppcf}\end{aligned}$$